



Electric Vehicle Technology Issues

briefing for:

NAS Committee

Assessment of Technologies for Improving Fuel Economy of Light-Duty Vehicles—Phase 3

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Outline

- Industry engagement and publications on EV technology
- EV technology assessment and areas of interest
 - Battery costs
 - Battery materials demand and availability
 - Non-battery cost and efficiency trends
 - Charging technologies, costs, and efficiencies
 - Technology developments and BEV cost parity



Ongoing industry engagement

Conferences

* = as presenter or co-organizer

- Advanced Automotive Battery Conference (AABC)
- Electric Vehicle Symposium and Exhibition (EVS)*
- The Battery Show*
- SAE Electric & Hybrid Vehicle Technologies Symposium
- SAE Government-Industry Meeting*
- SAE World Congress and Exhibition*
- SAE Thermal Management Systems Symposium*
- UC-Davis STEPS Symposium
- DOE Annual Merit Review

Collaborations

- Argonne National Laboratory
 - BatPac Battery Cost Model
- European Joint Research Centre and Environment Canada
 - Test procedure for system power of hybrid vehicles for use with WLTP
- United Nations Economic Commission for Europe
 - Global Technical Regulation (GTR) development
- SAE Government-Industry Meeting
 - Organizer, Electric Drive sessions
- The Battery Show
 - Advisory and Reviewer Board



Selected EPA publications on H/EV technology

1. "The Upcoming Global Test Procedure for Rating the Power of Electric and Hybrid Vehicles," EVS-33 (Portland), June 2020.
2. "Development and Validation of a Test Procedure for Determining the System Power of Hybrid and Plug-In Hybrid Electric Vehicles," EVS-32 (Lyon), May 2019.
3. "Modeling and Validation of 48 V Mild Hybrid Lithium-Ion Battery Pack," SAE Journal of Alternative Powertrains, October 2018.
4. "Predicting the Future Manufacturing Cost of Batteries for Plug-In Vehicles for the U.S. EPA 2017-2025 Light-Duty Greenhouse Gas Standards," World Electric Vehicle Journal, v.9 n. 42, October 2018.
5. "Predicting Powertrain Costs for Battery Electric Vehicles Based on Industry Trends and Component Teardowns," EVS-31 (Kobe), October 2018.
6. "Impacts of Mileage Accumulation and Fast Charging on EV Range and Energy Usage – Part 3," EVS-31 (Kobe), October 2018.
7. "Modeling and Controls Development of 48V Mild Hybrid Electric Vehicles," SAE Technical Paper 2018-01-0413, 2018.
8. "Modeling and Validation of 48 V Mild Hybrid Lithium-Ion Battery Pack," SAE Technical Paper 2018-01-0433, 2018.
9. "Predicting the Future Manufacturing Cost of Batteries for Plug-In Vehicles for the U.S. EPA 2017-2025 Light-Duty Greenhouse Gas Standards," EVS-30 (Stuttgart), October 2017.
10. "Modeling and Validation of 12V Lead-acid Battery for Stop-Start Technology," SAE World Congress, 2017.
11. "EPA Battery Sizing and Cost Analysis for Future Plug-In Vehicles for the Midterm Evaluation of the 2022-2025 Light-Duty GHG Standards," The Battery Show, Novi, MI, September 15, 2016.
12. "Effect of Current and SOC on Energy Efficiency of a Li-FePO₄ Battery Pack", Society of Automotive Engineers Paper No. 2015-01-1186, April 2015.



Battery costs

- EPA uses Argonne National Lab's *BatPaC* to estimate battery costs
 - A detailed, rigorous, ground-up model
 - Fully transparent spreadsheet-based model
- Since 2009, EPA has worked closely with ANL on its development
- BatPaC underwent a formal peer review
 - Managed by EPA and conducted independently following EPA and OMB guidelines
 - Peer review panel drawn from auto industry, academia, and battery suppliers
- ANL has regularly updated BatPaC to incorporate capabilities requested by EPA
- We continue to assess how BatPaC can support the need for battery cost estimates across our technical, policy and rulemaking efforts
- We continue to evaluate updates to the model and recommend new features



Battery costs

- Current and future applications of BatPaC
 - Estimate of light-duty electrified vehicle battery costs
 - “Reality checking” of cost estimates reported in the literature
 - Supplying battery cost inputs for EPA technical assessments/models
 - Supplying year-over-year battery cost estimates for study of BEV cost parity
 - Estimating battery costs for heavy-duty hybridized and electrified trucks in support of Cleaner Trucks Initiative (CTI)
- Opportunities for continued collaboration with ANL
 - Ongoing use and testing of new versions of the model
 - Potential for continued collaboration to further expand the model’s capabilities
 - Refinement of material cost inputs
 - Improvement of model application to stationary and heavy-duty battery designs
 - Improvement of life-cycle manufacturing-stage GHG estimation capabilities



Materials demand and availability

- Many sources cite the potential for scarcity of battery raw materials
- Scarcity could introduce uncertainty and instability and have a strong influence on future price trends
- Issues we are tracking:
 - Which materials pose the greatest risk of scarcity? E.g. cobalt, nickel, lithium
 - What are the causes of potential scarcity?
 - Resource: e.g. availability of preferred nickel ore types
 - Geopolitical: e.g. ethical sourcing, export limitations
 - Economic: e.g. lagging production capacity, capital recovery, profitability of recycling
 - How sensitive are battery pack costs to changes in the cost of specific materials?
 - Which emerging chemistries reduce or eliminate the riskiest materials?
 - What do future estimates of battery production volumes say about material scarcity?
 - Will material costs fall (due to increased capacity) or increase (due to demand)?
 - Does material cost establish a floor on future battery costs?



Non-battery cost and efficiency trends

- In 2011-2012, EPA commissioned teardown studies
 - FEV performed teardowns of electrified components available at the time
 - Supported development of scaled cost estimates on a relative cost basis
 - Reports were made publicly available for transparency
- Since then, various other sources have become available. Examples:
 - Munro teardowns of Chevy Bolt, Model 3
 - UBS report on Chevy Bolt based on Munro teardown
 - CARB published teardown of power electronics and thermal management
- In 2018, EPA collected and aggregated these and other new data sources to evaluate directional cost trends and revise non-battery cost estimates that had been used previously
 - See “Predicting Powertrain Costs for Battery Electric Vehicles Based on Industry Trends and Component Teardowns,” EVS-31 (Kobe, Japan), October 2018
- We continue to monitor new data sources through ongoing industry engagement
- We are considering options for developing component cost estimates on an absolute basis
 - To provide inputs for EPA technical assessments, such as the OMEGA model
 - To provide inputs for cost parity study and future analyses



Non-powertrain BEV-specific costs

- BEVs have fewer moving parts than ICEVs
- BEVs have no emissions
- Implications:
 - Lower design cost?
 - Lower assembly cost?
 - Lower overhead cost for both?
 - Lower calibration cost?
 - Lower certification cost?
- Manufacturing cost differences are therefore likely to extend into indirect costs and non-powertrain components
- This may require costing on an absolute basis, and for a wider range of component types



Charging technologies, costs, and efficiencies

- In past EPA analysis from 2012-2016, home charging equipment and installation was part of BEV and PHEV cost. Assumptions:
 - Cost of EVSE equipment
 - Average cost of installation, including service or wiring upgrade
 - Percentage of homes opting for Level 2, Level 1, and percent needing upgrade
- Issues we continue to track:
 - EVSE technologies and their costs / reliance on Level 1 or 2 / service upgrades
 - Efficiencies of onboard charging equipment at Level 1 and Level 2
 - Efficiencies, costs, and demand for DC fast charging and extreme fast charging
 - Developments in wireless charging (technologies, efficiency, potential adoption)
 - Developments in charging options affecting multi-unit dwellings and workplaces
 - Developments in public charging (availability, interoperability, infrastructure needs)



Technology developments and BEV cost parity

What is cost parity?

- It is a quantitative construct:
 - Captures a key market-related factor in BEV adoption: relative cost
 - May be focused on either purchase price, or total cost of ownership (TCO)
 - **“A time when cost no longer poses an argument regarding BEV adoption”**
- Often used to support various positions or predictions:
 - “Cost parity will eliminate the need for incentives”
 - “Cost parity will be the tipping point, then BEVs will dominate”
 - “EV infrastructure is not prepared for when we reach cost parity”
 - “There will be battery shortages when we reach cost parity”
- *EV technology cost is a primary input for predicting cost parity*



Technology developments and BEV cost parity

Other kinds of parity

- Convenience parity
 - “It is no less convenient for me to own and operate a BEV”
- Value parity
 - “I get just as much for my money when I buy a BEV”
- Utility parity
 - “I get no less usefulness from a BEV than an ICEV”
- Choice parity
 - “Buying a BEV does not limit my choice of vehicle style, size, manufacturer, etc”
- Consumer acceptance parity
 - All of these things together, AND cost

What is commonly called “cost parity” may have elements of these other factors.



Assessing the prospect of BEV cost parity

- Technical needs:
 - Keeping up with technology costs (primary inputs to cost parity projections)
 - Ability to evaluate studies of cost parity in the literature
 - There are many – and all have different inputs, and reach different conclusions
 - Having our own model would allow us to compare, contrast, critique
 - Policy implications:
 - Predictions of cost parity are often used to support specific positions or arguments
 - Policymakers should be prepared to evaluate and respond
- What do we think about the timing and importance of cost parity?
- How can we build upon or add value to existing knowledge?



Some cost parity date projections

Source	\$100/kWh date	Parity date	Basis	2025 sales		2030 sales	
				US	World	US	World
Bloomberg	2023-2024	2023-2024	Purchase	10.5%	10.5%	32.5%	30%
JP Morgan		"Mid 2020s or earlier"	Purchase?	~11%	12%		20%
Boston Consulting	2030	2022-2023	TCO		11%		24%
Wood Mackenzie	2027	2027	Purchase?	~7%		~17%	
Deloitte		2022 (UK?)	TCO		11.5%		20%
Morgan Stanley	"early 2020s"	~2025	Purchase?		12%		16%
DNV GL	2021-2022	2024	TCO	11%		35%	
McKinsey	2025	~2024	TCO				
		2025	Purchase				
OPEC		Mid-late 2030s?	Purchase				~15%
ICCT	2026	2024-2028	Purchase				
		2022-2026	TCO				
Rocky Mountain Institute	2024-2025	2029-2030	Purchase				
MIT	Well after 2030	never	Purchase	6%		9%	
		~2029	TCO				



Future EPA work on BEV parity

*Add value to
existing knowledge*

*What do we think
about the timing and
importance of
cost parity?*

- Technical work:
 - Continue battery and component cost assessment work
 - Engaging with technical experts at ANL, DOE, CARB, ICCT, MIT, and others
 - Develop a BEV cost parity model
 - Implement and track the relevant scientific inputs
 - Commission studies/teardowns to further inform component cost trends
 - Evaluate, compare, and contrast external cost parity projections
- Develop insight to inform policy. Examples:
 - Is cost parity necessary for wider BEV adoption? Why or why not?
 - Is cost parity sufficient for a tipping point? Why or why not?
 - Would cost parity affect the need for policy measures or incentives?
 - Is parity already here in some markets? (e.g. luxury, delivery, MaaS)



Questions ?