Light Duty Vehicle Attributes: PEVs

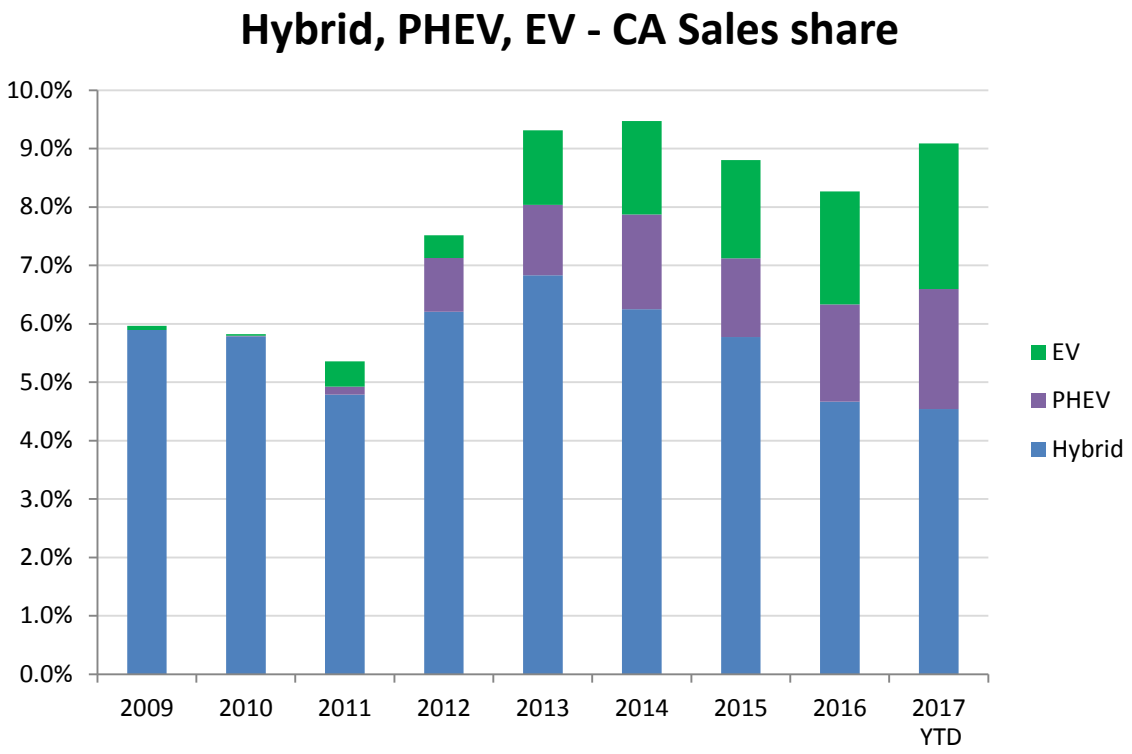
DAWG Transportation Meeting

August 23, 2017

Historical California Vehicle Trends

EV and PHEV sales continue to grow

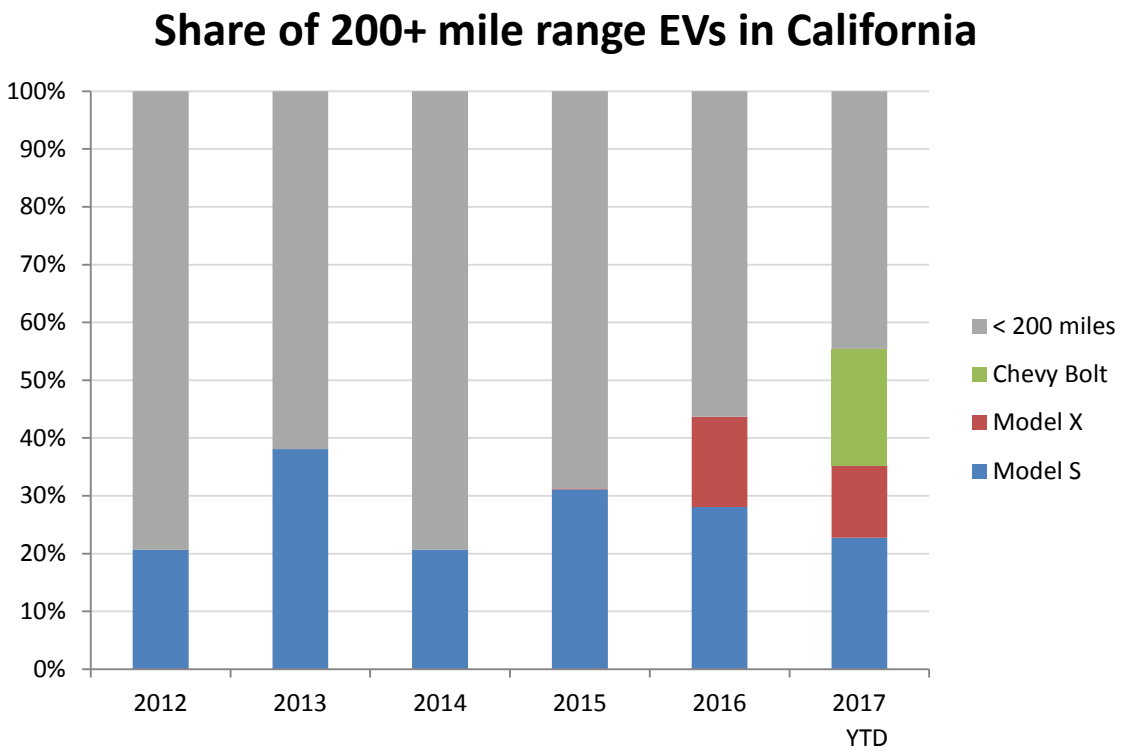
Decreasing gasoline prices effect hybrid sales



Source: California Energy Commission analysis of CNCDA / Polk / IHS Markit Data

Historical California Vehicle Trends

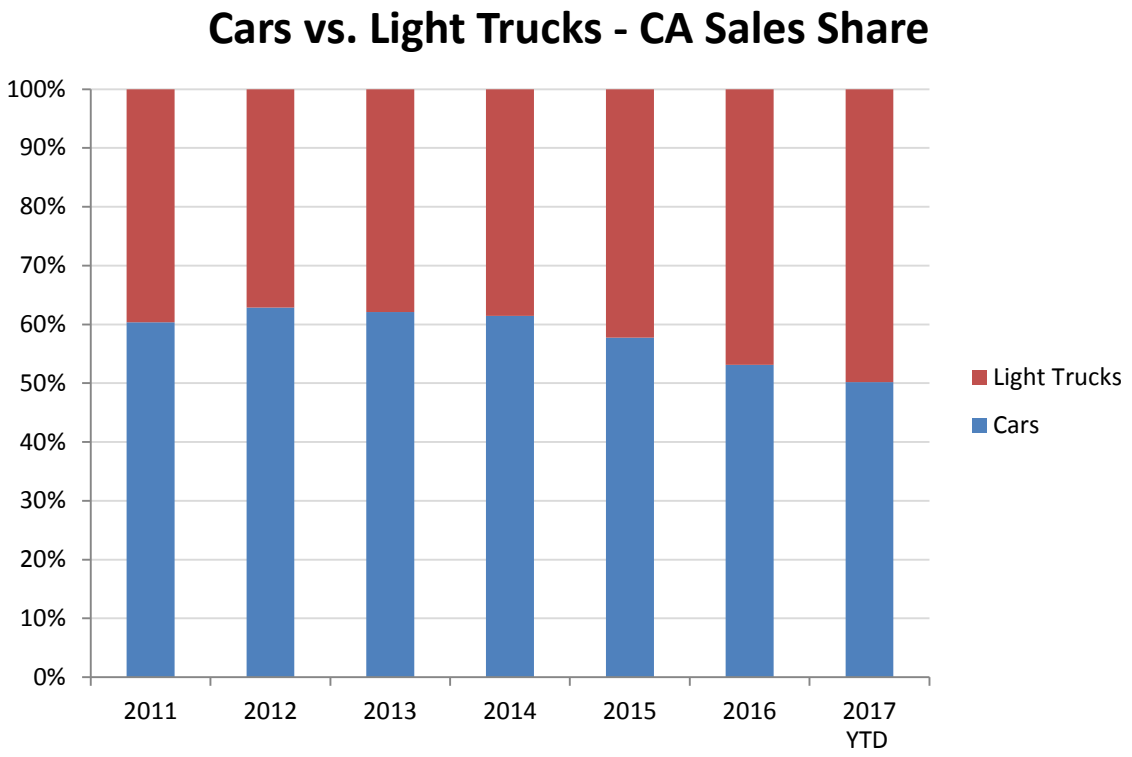
Higher range electric vehicles now make up half of all EV sales



Source: California Energy Commission analysis of CNCDA / Polk / IHS Markit Data

Historical California Vehicle Trends

Popularity of light-duty trucks continues to grow



Source: California Energy Commission analysis of CNCDA / Polk / IHS Markit Data

PEV Makes and Models

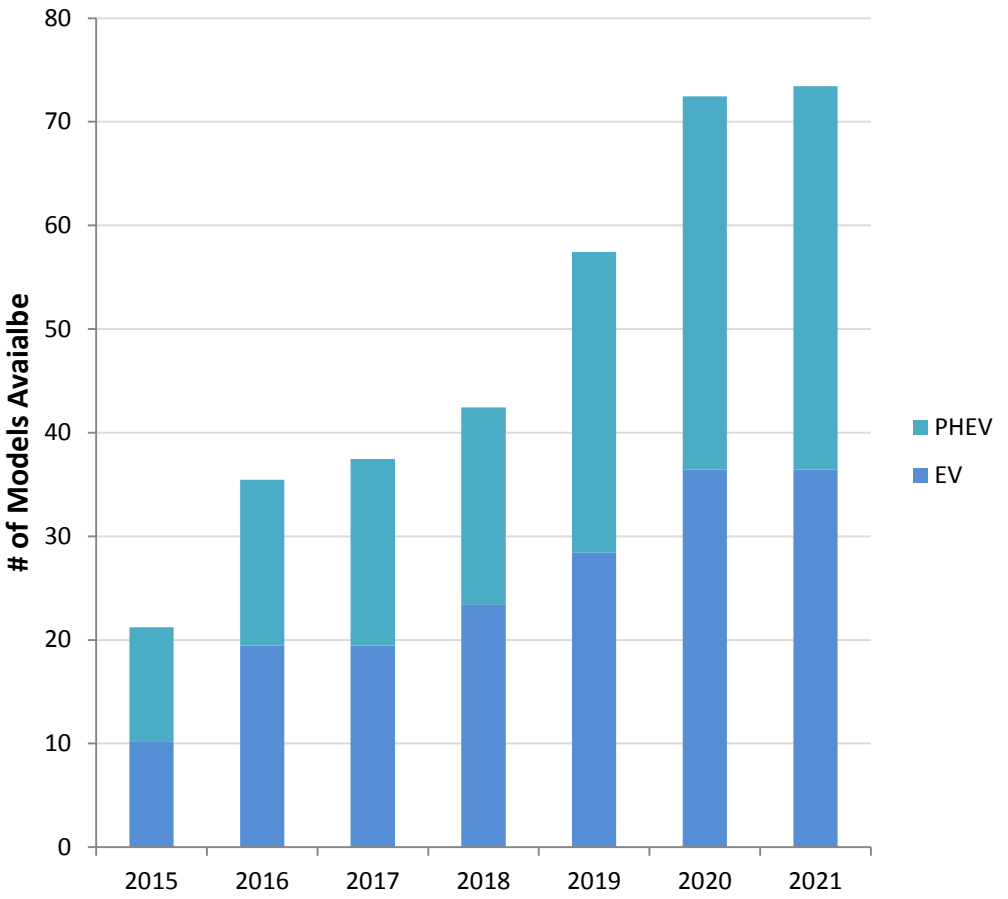
Current PEV Offerings

Plug-in Hybrid	EV
Audi A3 e-tron	BMW i3 BEV
BMW 330e	Chevrolet Bolt EV
BMW 530e xDrive	Fiat 500e
BMW 740e xDrive	Ford Focus Electric
BMW i3 REX	Hyundai Ioniq Electric
BMW i8	Kia Soul Electric
BMW X5 xDrive40e	Mercedes-Benz B250e
Cadillac CT6 Plug-In	Mitsubishi i-MiEV
Chevrolet Volt	Nissan Leaf
Chrysler Pacifica	Tesla Model S 100D
Ford C-MAX Energi	Tesla Model S 75D
Ford Fusion Energi	Tesla Model S P100D
Hyundai Sonata	Tesla Model X 100D
Kia Optima	Tesla Model X 75D
Mercedes-Benz C350e	Tesla Model X P100D
Mercedes-Benz GLE550e	Volkswagen e-Golf
Mercedes-Benz S550e	
MINI Cooper SE Countryman	
Porsche Cayenne S	
Toyota Prius Prime	
Volvo XC90 AWD PHEV	

Announced / Expected PEVs

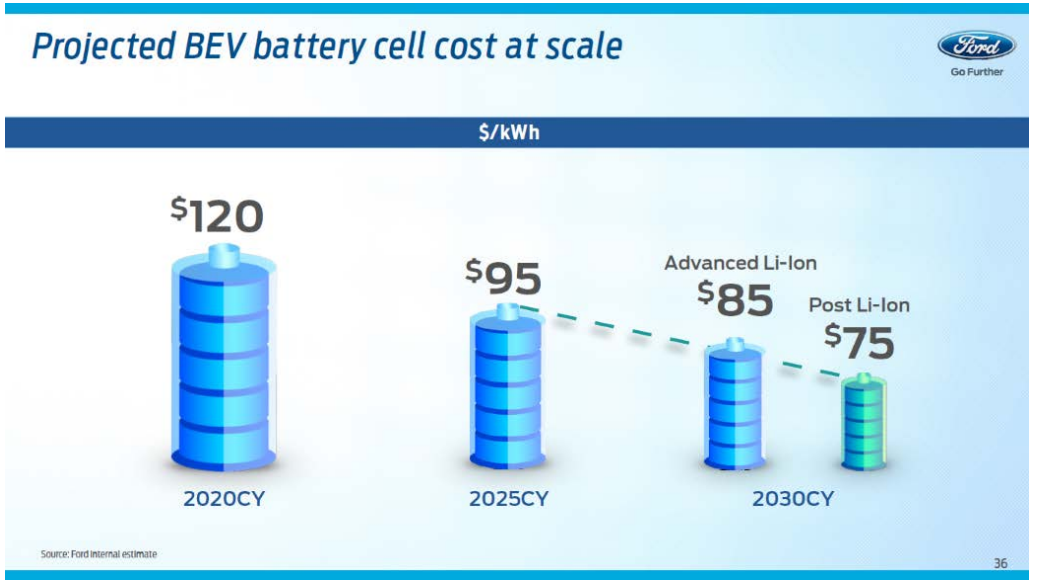
Year	Make & Model	Powertrain
2017	Tesla Model 3	EV
2018	Hyundai Kona	EV
2018	Hyundai Niro	EV
2018	Honda Clarity	EV
2018	Honda Clarity	PHEV
2018	Jaguar I-Pace	EV
2018	Mercedes Generation EQ	EV
2018	Nissan Leaf 2.0	EV
2018	BMW i8 roadster	PHEV
2018	Volkswagen Golf	PHEV
2019	Audi (Q6) e-tron sportback	EV
2019	Audi A8 e-tron	PHEV
2019	Porsche Mission e	EV
2019	Tesla Model Y	EV
2019	Kia Stonic	EV
2019	Electric Mini	EV
2019	Volvo Crossover	EV
2019	Volkswagen e-golf 2.0	EV
2020	Audi A9 e-tron	EV
2020	Tesla Roadster	EV
2020	BMW X3	EV
2020	Ford Electric Crossover	EV

Expected PEV Models



Battery Pack Cost Methodology

- CEC projections based on estimates provided by automakers
  - Ford and General Motors published internal estimates of battery cell costs.
- Converted battery cell cost to battery pack cost.
  - Literature review found battery cells typically compose 70-73% of battery pack costs



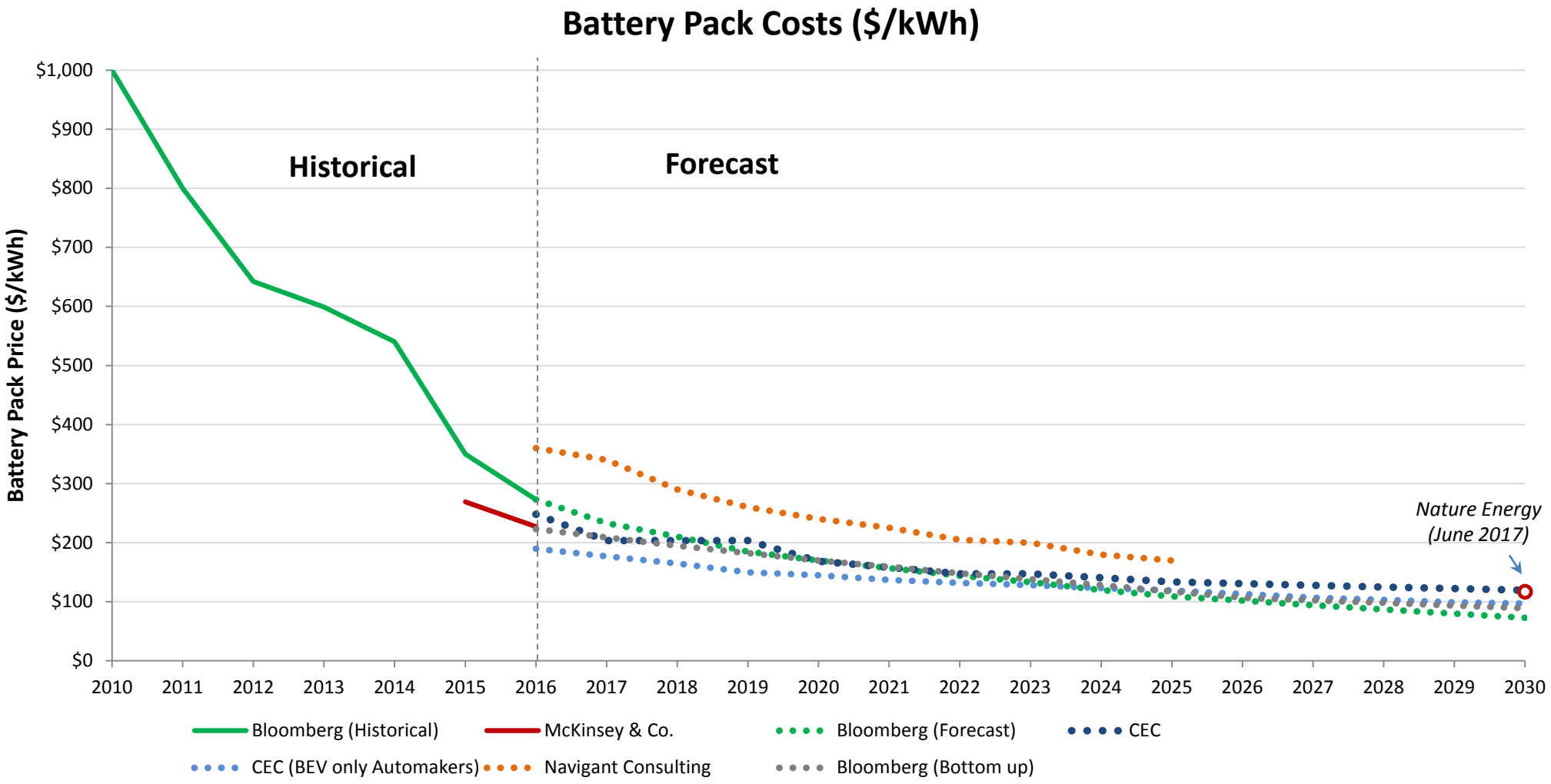
Battery Pack Cost = Battery Cell Cost + other components (wiring, cooling, etc.)

Sources:

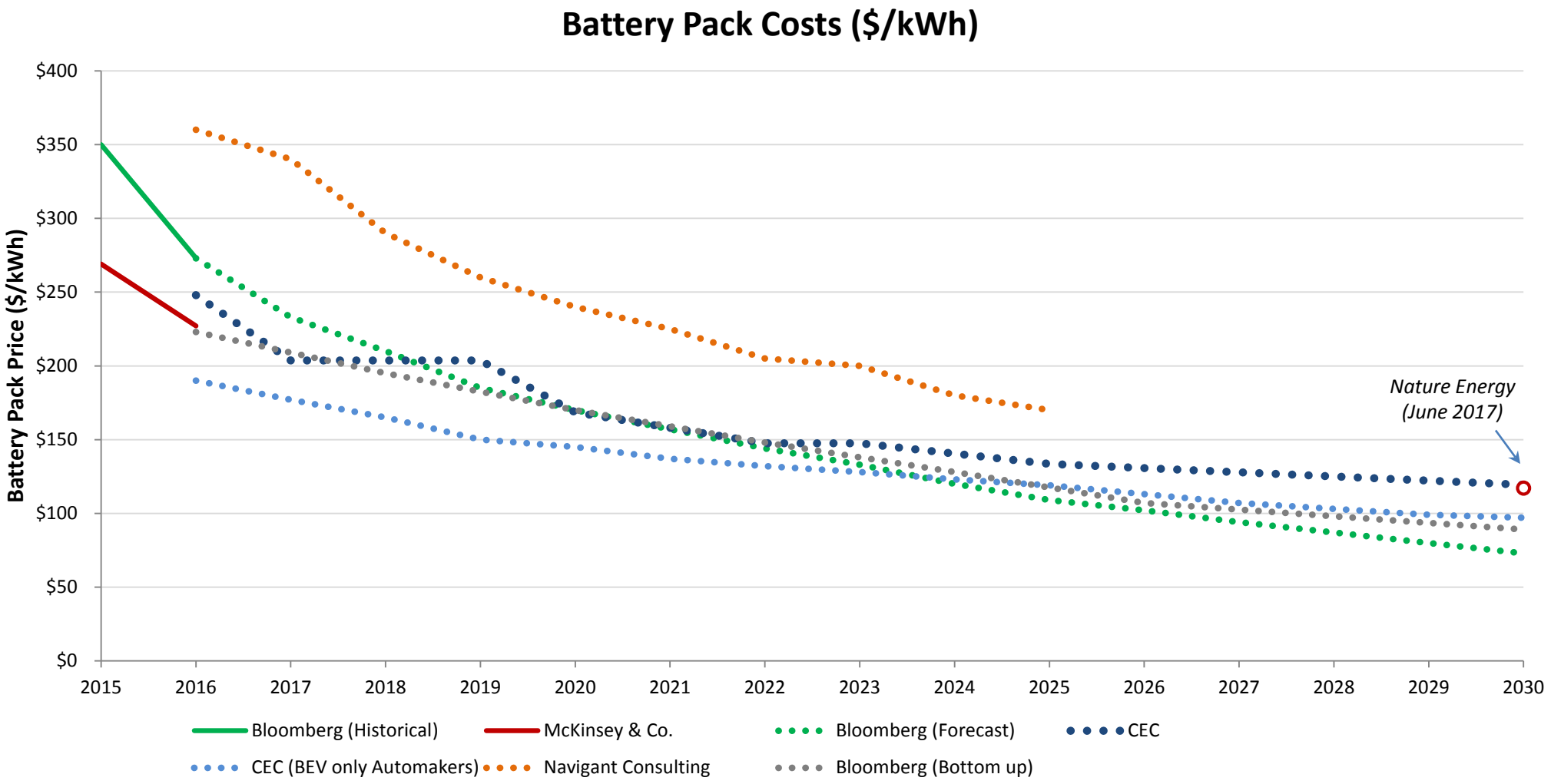
Ford (September 14th, 2016) <http://shareholder.ford.com/~/media/Files/F/Ford-IR/events-and-presentations/2016/09-14-2016/investor-day-final.pdf>

General Motors Company 2015 Global Business Conference Call <http://edge.media-server.com/m/p/6pz5fwmg/lan/en>

Forecasts of Battery Costs

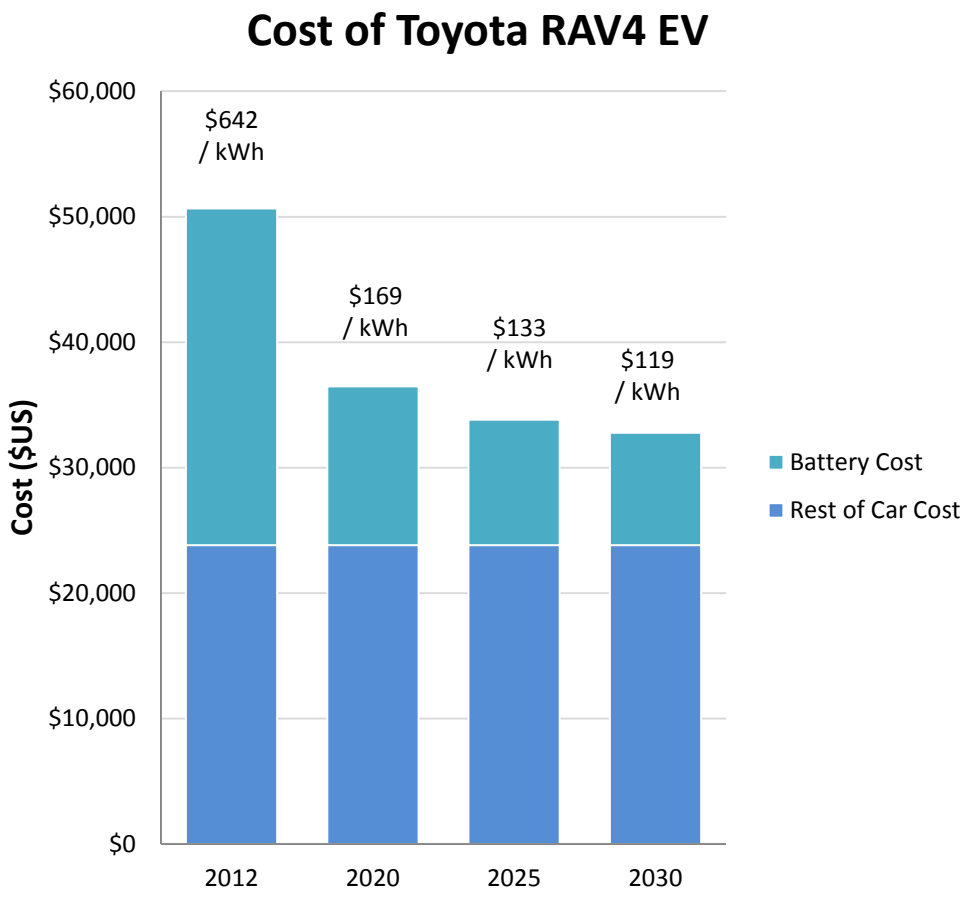


Forecasts of Battery Costs



Calculating EV Prices

- Analyzing battery cost reduction on total EV price
- Example: Toyota RAV4 EV
  - Introduced in 2012
    - $50,600, 103 mile range, 41.8 kWh battery pack
  - Discontinued in 2014
- If RAV4 EV were reintroduced, how much would it cost?
  - Assume its reintroduced in 2020
    - With 75 kWh battery pack
    - Battery size held **constant** through 2030
      - Observe effect of declining battery prices on vehicle price

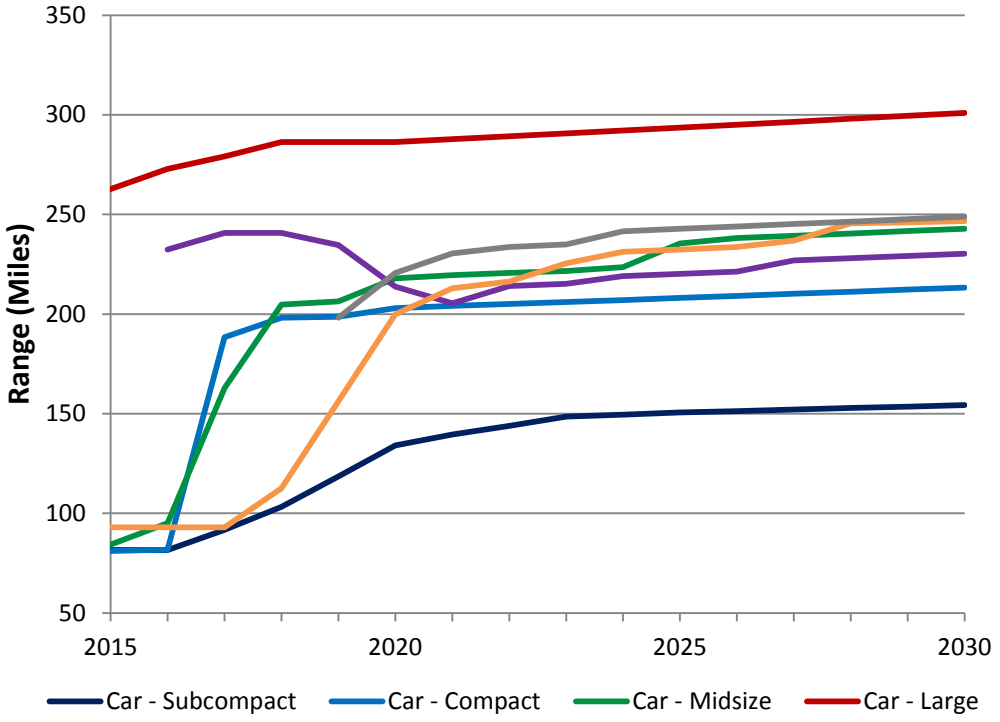


Forecast BEV Range and Price

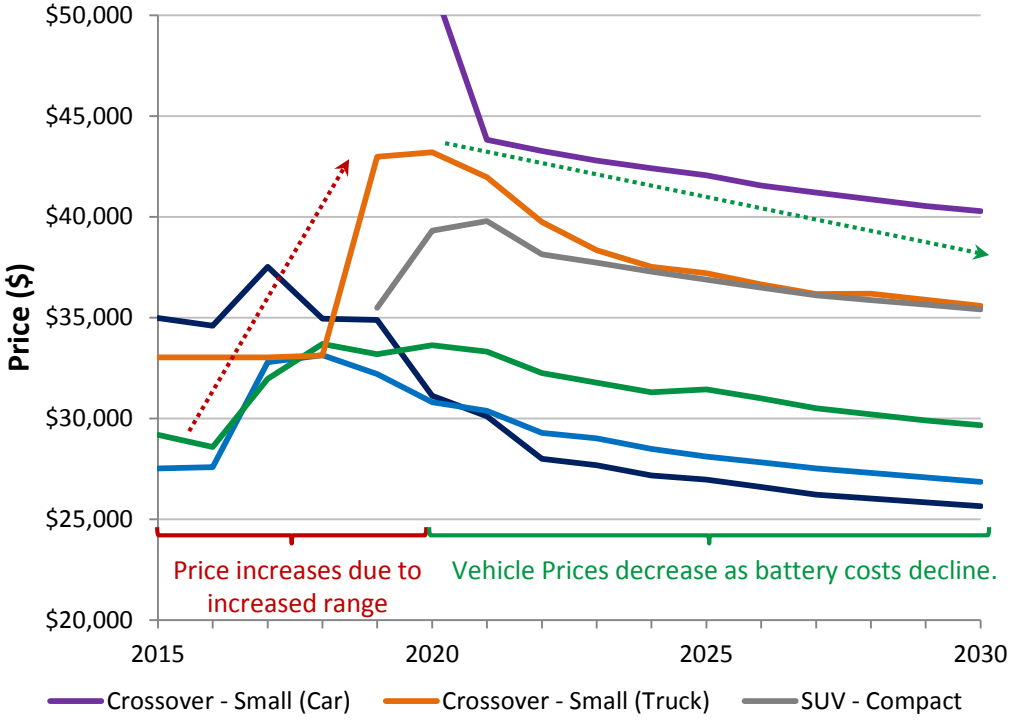
Mid case (same as preliminary)

- Most likely EV range
- CEC (most likely) battery pack cost estimates used

Projected Average EV Range



Projected Average EV Price

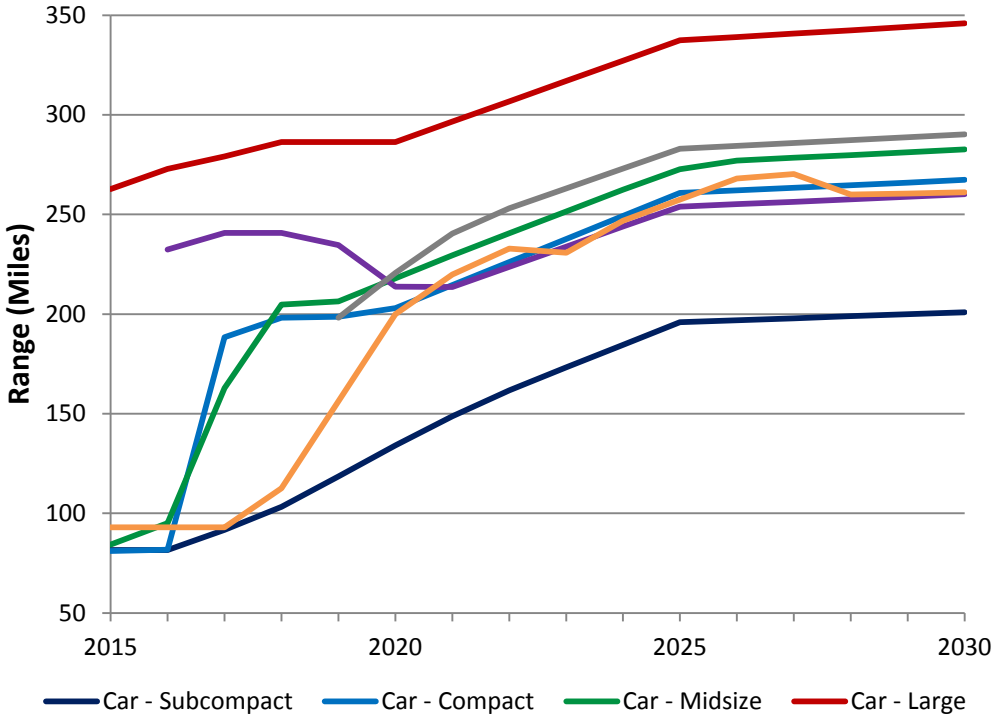


Forecast BEV Range and Price

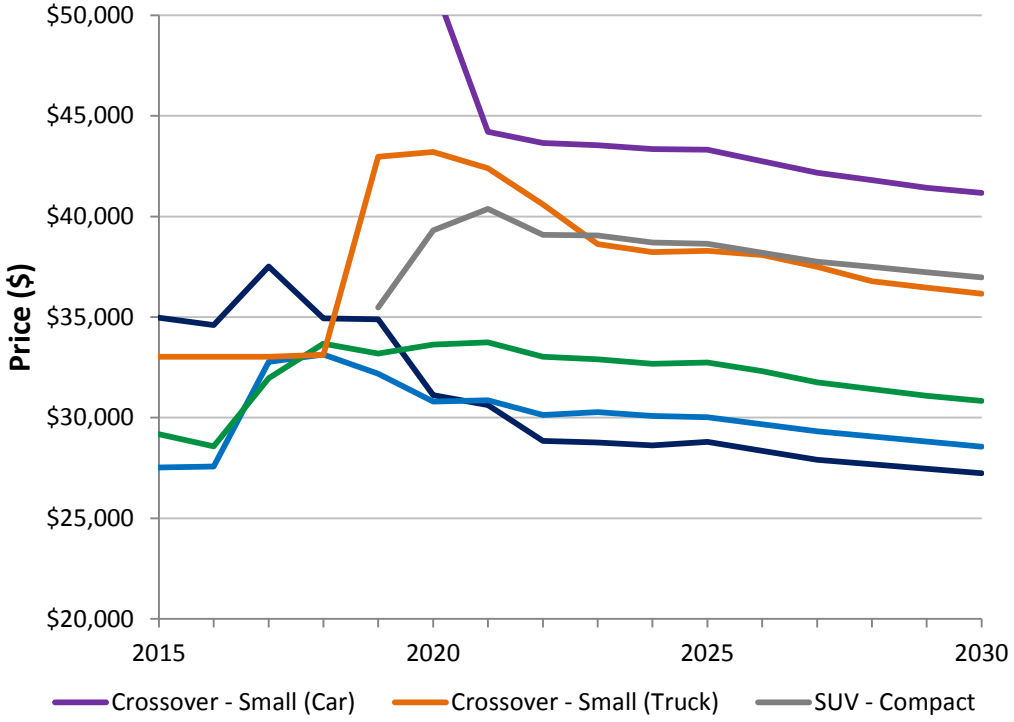
High Case

- Longer EV range corresponding to ARB High Tech Scenario
- CEC (most likely) battery pack cost estimates used

Projected Average EV Range



Projected Average EV Price

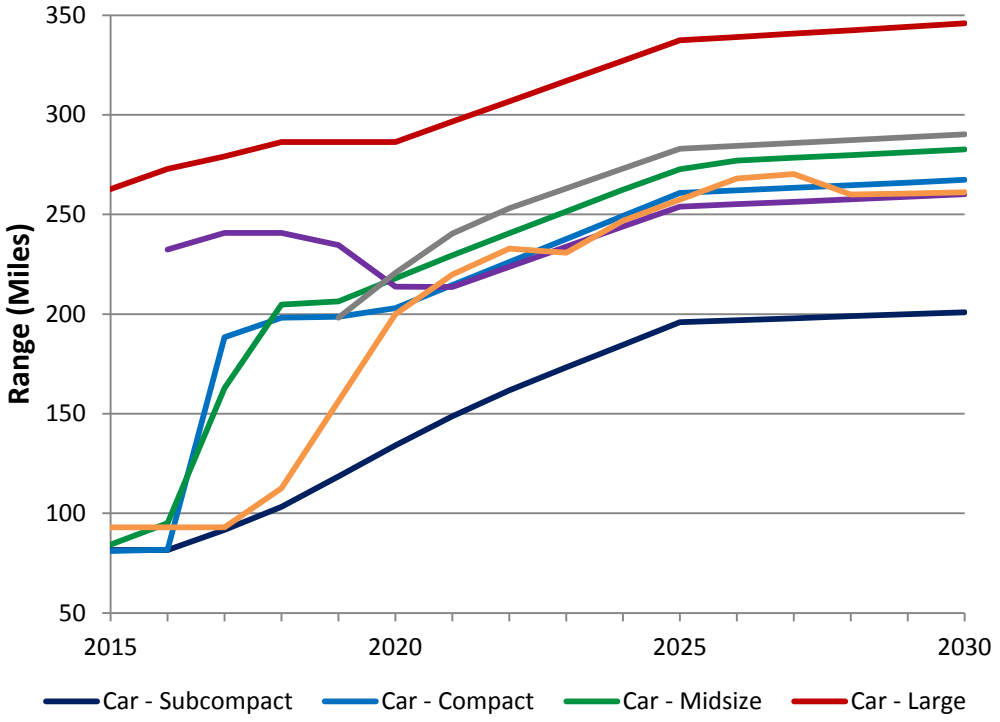


Forecast BEV Range and Price

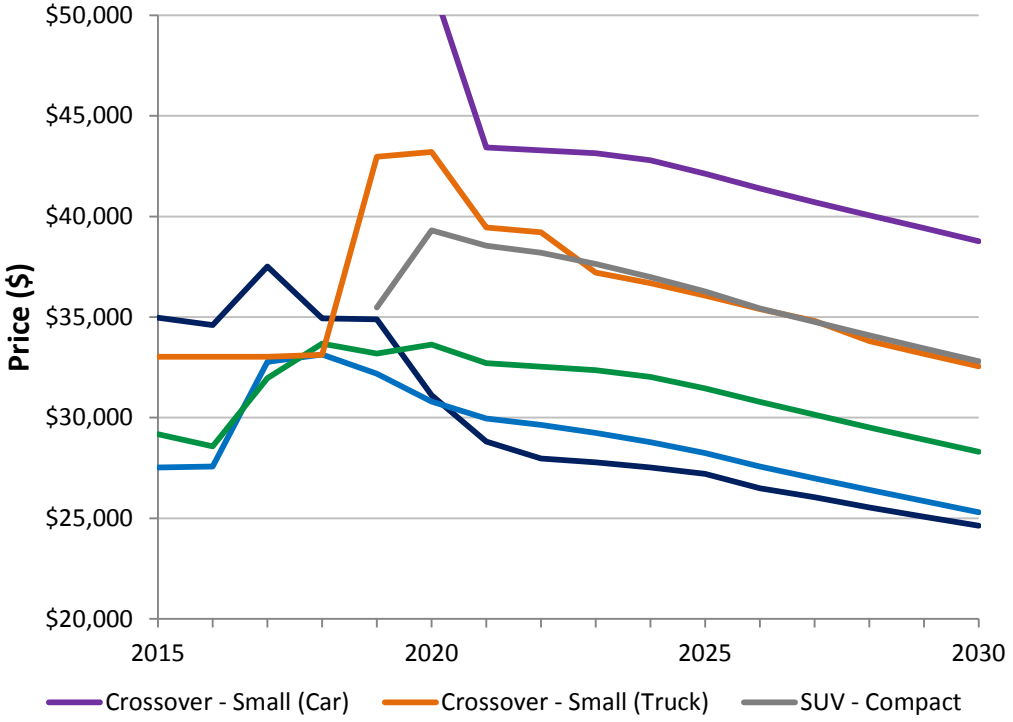
Aggressive Case

- Longer EV range corresponding to ARB High Tech Scenario
- Bloomberg battery pack cost estimates used

Projected Average EV Range



Projected Average EV Price



Forecast of BEV Range

- Compares mid case, high case, and aggressive case
- Mid and high case use same per kWh battery prices
  - Aggressive case uses lower per kWh battery prices (aligned with Bloomberg projections)
- High and aggressive cases use same range.

AVERAGE BEV RANGE (Case: Mid / High & Aggressive)				
Vehicle Class	2015	2020	2025	2030
Car - Subcompact	82	134	151 / 196	154 / 201
Car - Compact	81	203	208 / 261	213 / 267
Car - Midsize	84	218	235 / 273	243 / 283
Car - Large	263	286	294 / 337	301 / 346
Car - Sports		308	308 / 355	308 / 355
Crossover - Small (Car)		214	220 / 254	230 / 260
Crossover - Small (Truck)	93	200	232 / 257	247 / 261
SUV Compact		221	243 / 283	249 / 290

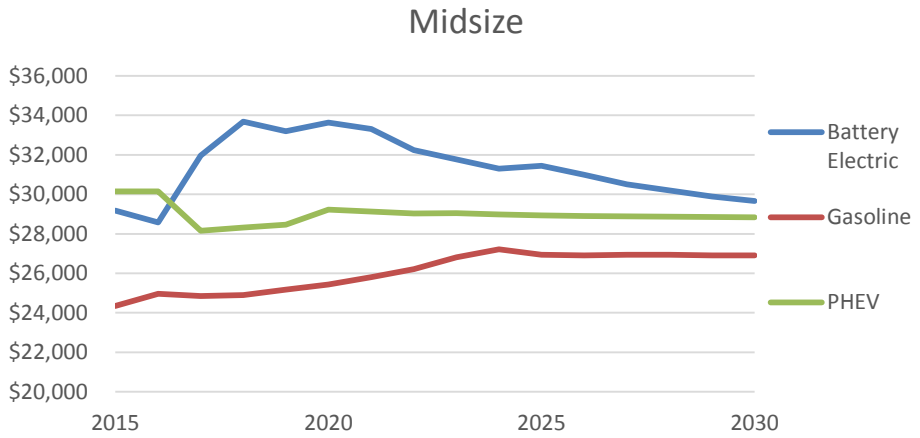
Mid High & Aggressive

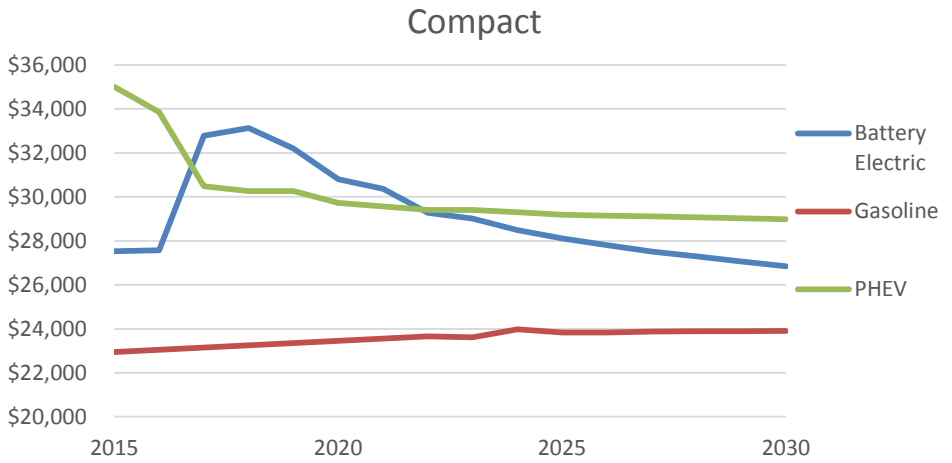
NOTE: Values may change in revised forecast.

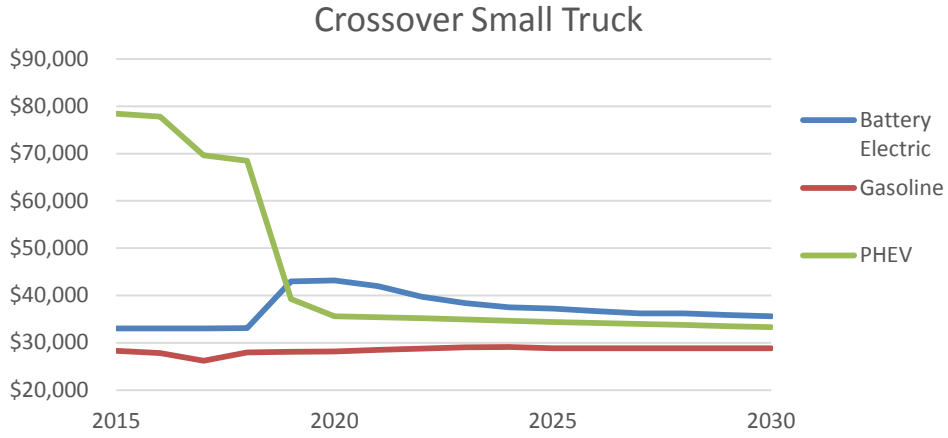
Comparison of PEV and Gasoline Vehicle Prices

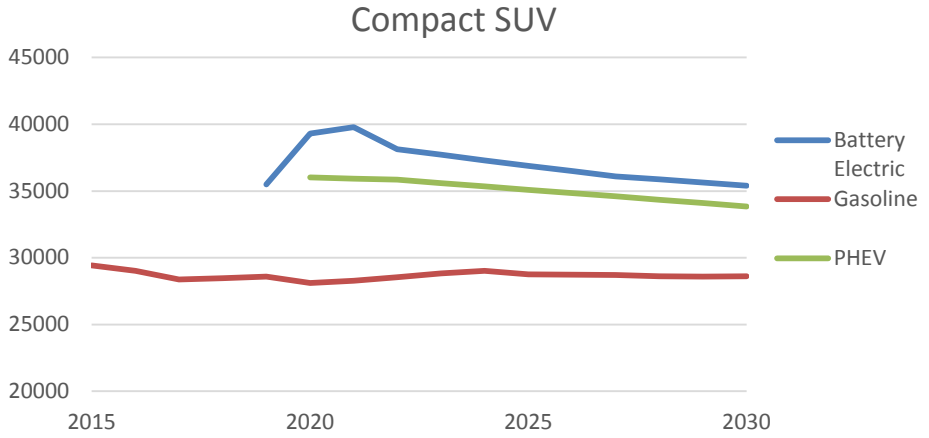
High Case

- Comparison of prices throughout forecast using preliminary prices









PEV Prices vs Gasoline Vehicles: % Difference

- BEV and PHEV prices shown in terms of percentage difference in relation to gasoline vehicle prices
  - Prices are average for entire vehicle class
  - "Compact car", "mid-size car", " small crossover (truck)" are best-selling
    - Higher share of luxury vehicles for large and sports car classes for BEVs and PHEVs → higher BEV and PHEV prices

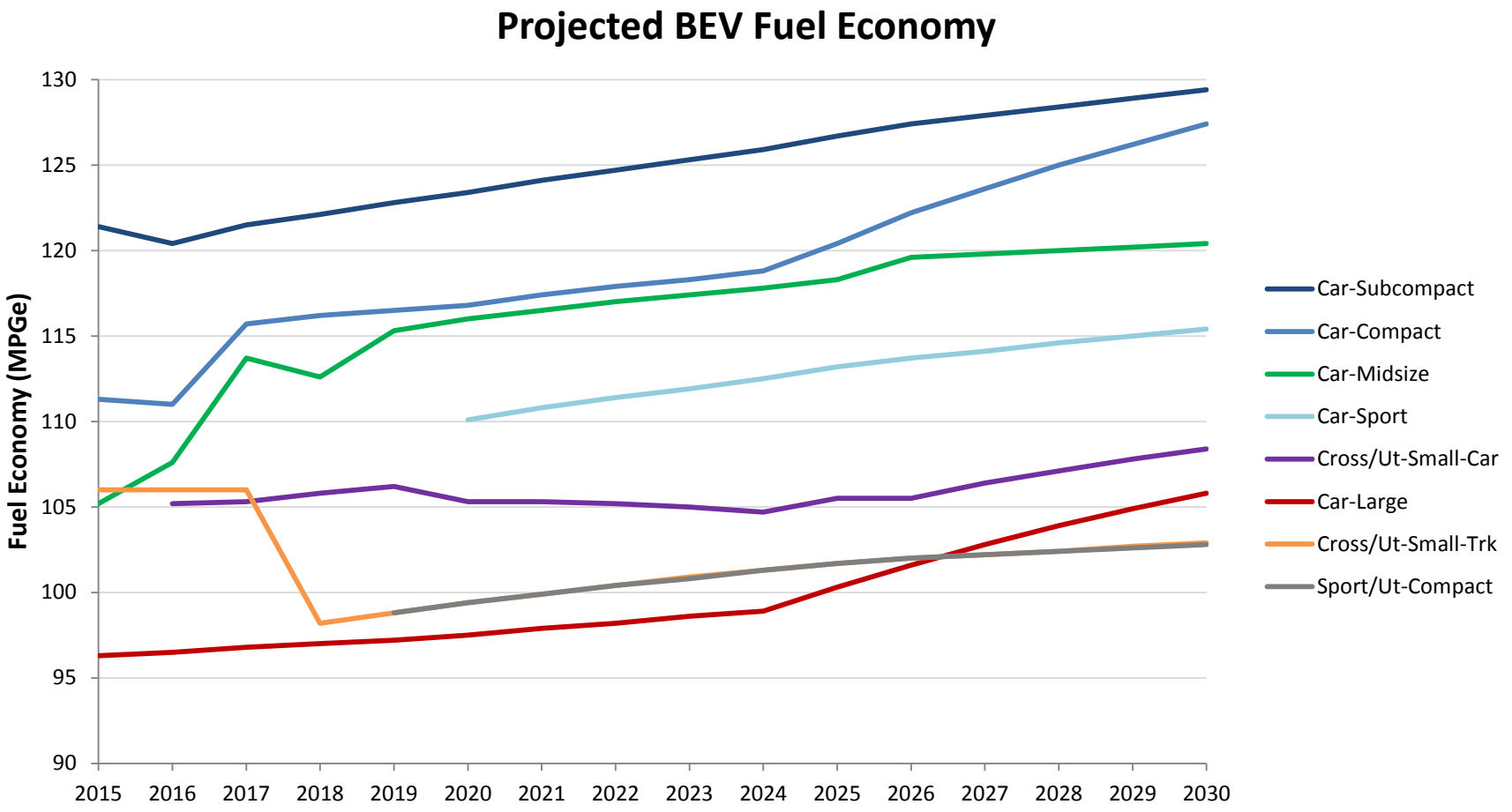
Vehicle Class	2017			2030			
SCENARIO	ALL			MID	HIGH	AGR	MID
Powertrain	BEV	PHEV	Gas	BEV	BEV	BEV	PHEV
Car-Compact	42%	32%	23,000	12%	20%	6%	21%
Car-Large	141%	115%	34,250	76%	79%	73%	72%
Car-Midsize	29%	13%	24,800	10%	15%	5%	7%
Car-Sport		231%	39,750	133%	136%	131%	150%
Car-Subcompact	94%	138%	19,500	6%	12%	1%	62%
Cross/Ut-Midsize			32,750				-11%
Cross/Ut-Small-Car	84%		40,200	59%	63%	54%	7%
Cross/Ut-Small-Trk	26%	165%	26,200	23%	25%	13%	15%
Sport/Ut-Compact			28,400	24%	29%	15%	18%
Van-Compact		35%	32,000				15%

NOTES:
(1) Mid and high case share same $/kWh battery price.

(2) High & aggressive cases have longer BEV range.

NOTE: Values may change in revised forecast.

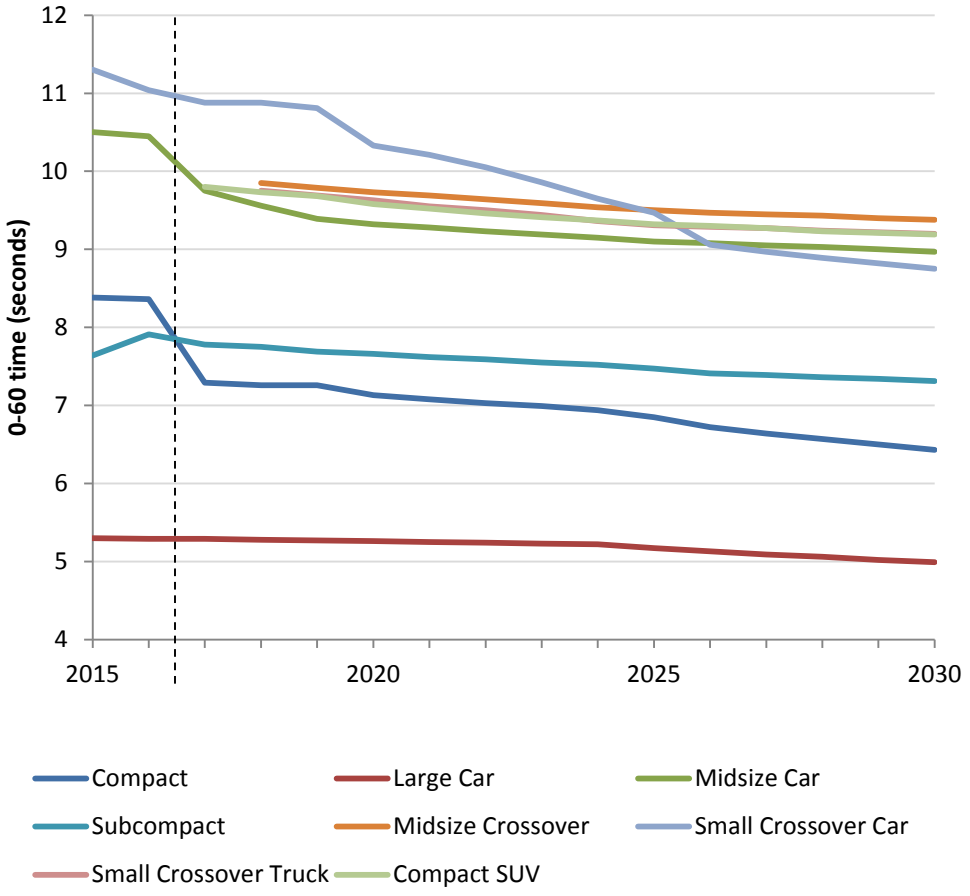
Forecast of BEV Fuel Economy



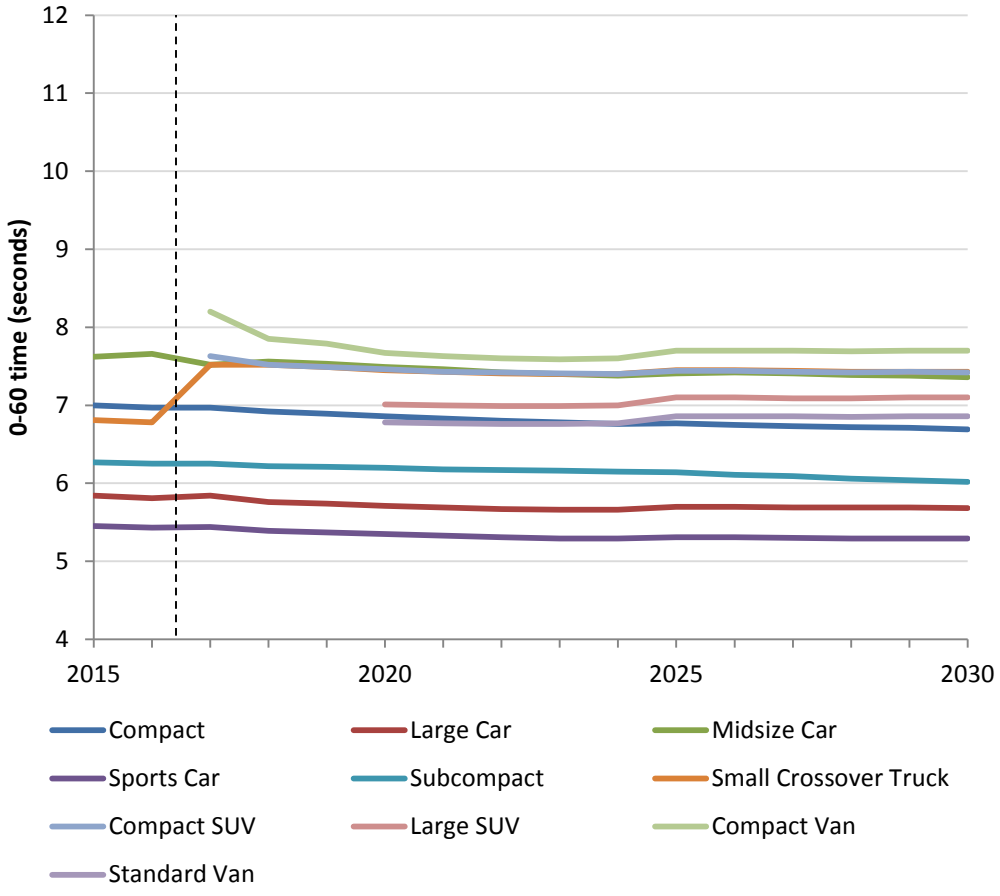
Source: National Renewable Energy Laboratory

Forecast of PEV Acceleration

Battery Electric Vehicles



Plug-in Hybrid Electric Vehicles

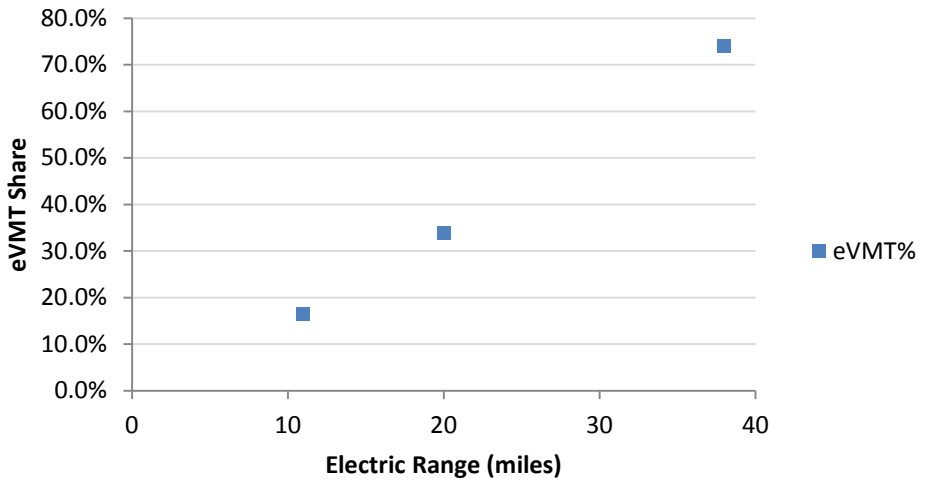


Source: National Renewable Energy Laboratory (NREL)

PHEV eVMT Percent of AVMT

- ARB ZEV Midterm review supplied INL and UC Davis study data on eVMT and AVMT of PHEVs
- Analyzed results, and used to generate estimates based on range.

PHEV eVMT% - All Sources (n=77,000)



Source: ARB ZEV Midterm Review - Appendix G

Percent of AVMT by Fuel Type

Year	Gas	Electricity
2015	55%	45%
2016 - 20	40%	60%
2021	39%	61%
2022	38%	62%
2023	37%	63%
2024	36%	64%
2025	35%	65%
2026	34%	66%
2027	33%	67%
2028	32%	68%
2029	31%	69%
2030	30%	70%

LDV Introduction Matrix

Preliminary – All Cases

	Class	Gasoline	Hybrid	PHEV	EV	FCV	Diesel	FFV
1	Subcompact						2017	
2	Compact					Mirai		
3	Midsize					Clarity (2017)		
4	Large						2017	
5	Sport		2017		2020		2015	2015
6	Crossover - Small Car			2019	2016			
7	Crossover - Small Truck						2015	
8	Crossover - Mid			2019			2016	
9	Sports Utility - Compact			2020	2019		2017	
10	Sports Utility - Midsize							
11A	Sports Utility - Large							
12	Van Compact		2019	2017				
13A	Van - Large							
14	Pickup - Compact		2020			2023	2016	
15A	Pickup - Standard		2017					

Exists 2015 - 2030	
Introduced	YEAR
Eliminated	YEAR
Never Introduced	
Introduced in Revised Forecast	YEAR

NOTE: Combinations may change further for revised forecast.

LDV Introduction Matrix

Updated Mid Case

	Class	Gasoline	Hybrid	PHEV	EV	FCV	Diesel	FFV
1	Subcompact						2017	
2	Compact					Mirai		
3	Midsize					Clarity (2017)		
4	Large						2017	
5	Sport		2017		2020		2015	2015
6	Crossover - Small Car			2019	2016			
7	Crossover - Small Truck						2015	
8	Crossover - Mid			2019	2020		2016	
9	Sports Utility - Compact			2020	2019		2017	
10	Sports Utility - Midsize			2020				
11A	Sports Utility - Large							
12	Van Compact		2019	2017				
13A	Van - Large			2020				
14	Pickup - Compact		2020			2023	2016	
15A	Pickup - Standard		2017	2020	2021			

Exists 2015 - 2030	
Introduced	YEAR
Eliminated	YEAR
Never Introduced	
Introduced in Revised Forecast	YEAR

NOTE: Combinations may change further for revised forecast.

LDV Introduction Matrix

Updated High Case & Aggressive Case

	Class	Gasoline	Hybrid	PHEV	EV	FCV	Diesel	FFV	PHFCV
1	Subcompact						2017		
2	Compact					Mirai			
3	Midsize					Clarity (2017)			
4	Large						2017		2024
5	Sport		2017		2020		2015	2015	
6	Crossover - Small Car			2019	2016				
7	Crossover - Small Truck						2015		2021
8	Crossover - Mid			2019	2020	2027	2016		
9	Sports Utility - Compact			2020	2019	2020	2017		2022
10	Sports Utility - Midsize			2020		2023			2023
11A	Sports Utility - Large								2025
12	Van Compact		2019	2017					
13A	Van - Large			2020					
14	Pickup - Compact		2020			2023	2016		
15A	Pickup - Standard		2017	2020	2021				

Exists 2015 - 2030	
Introduced	YEAR
Eliminated	YEAR
Never Introduced	
Introduced in Revised Forecast	YEAR

NOTE: Combinations may change further for revised forecast.