Vehicle Choice Modeling and Projections for the *Annual Energy Outlook*

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Outline

- Overview of model structure and inputs
- Battery electric vehicles and current state of the market
- Projections of battery electric vehicles in the *Annual Energy Outlook 2013*
- High Battery Technology case in the *Annual Energy Outlook 2012*

Overview of model structure and inputs

Light duty vehicle technology market penetration

- Technologies affecting light-duty vehicle fuel economy are considered as either:
  - subsystem technologies
  - advanced/alternative fuel vehicles
- Manufacturers Technology Choice Component (MTCC)
  - adopts vehicle subsystem technologies for all vehicle types (conventional gasoline, hybrid, diesel, etc.) based on value of fuel economy and/or performance improvement
- Consumer Vehicle Choice Component (CVCC)
  - determines consumer acceptance (market share) by vehicle type (conventional gasoline, hybrid, diesel, etc.)

Manufacturers Technology Choice Component (MTCC)

- 9 vehicle manufacturers, 6 size classes, 16 vehicle types
- Technology adoption based on value of performance, fuel economics, CAFE standards and CAFE fines
  - reduced consumer demand for performance improvement as horsepower-to-weight ratio increases
  - minimum and maximum horsepower to weight ratios
- Fuel savings payback and value of performance based on economic relationship derived from historic data
- 86 vehicle subsystem technologies

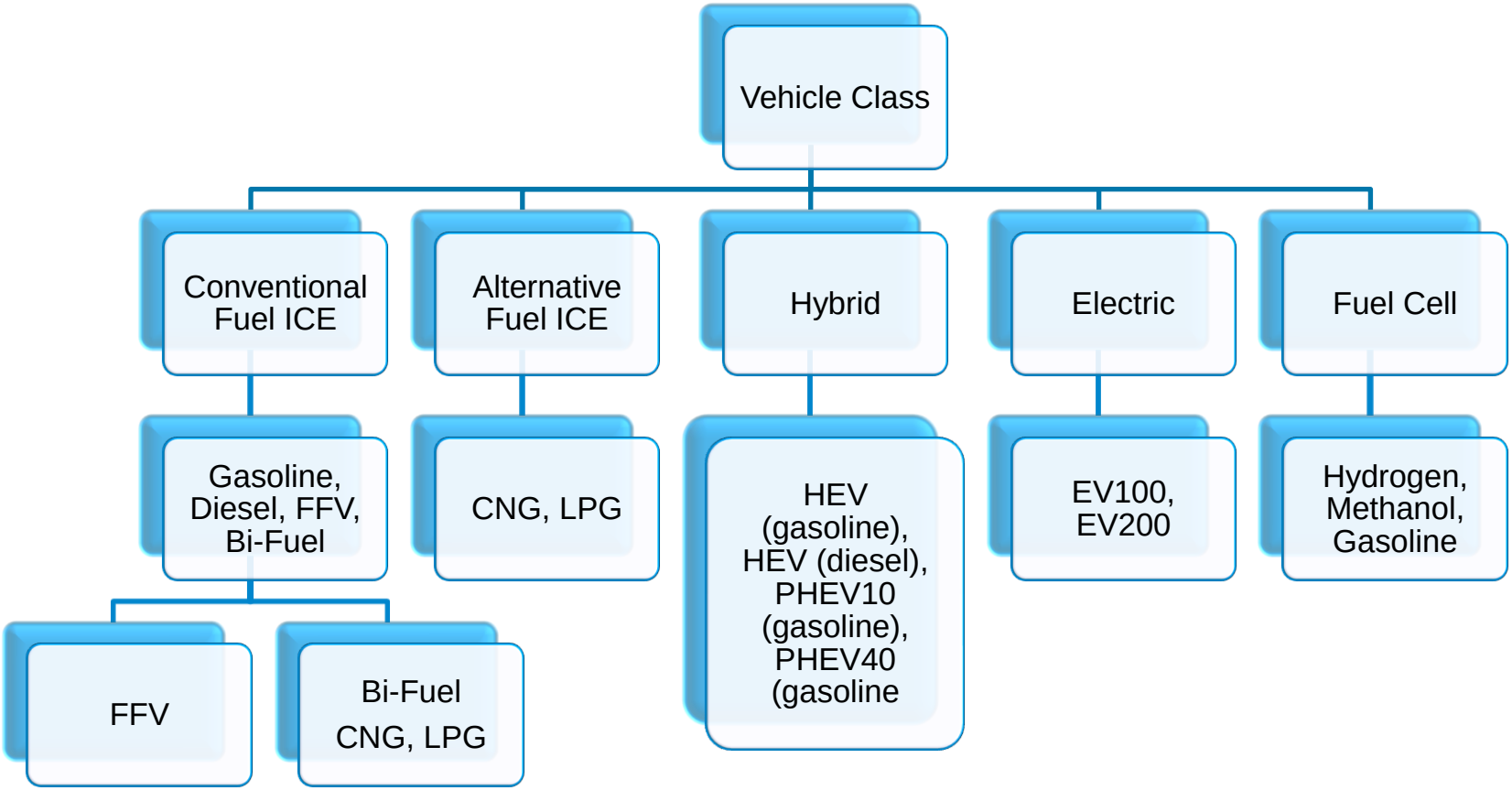
Subsystem technology parameters

- First year available
- Cost ($/unit or $/weight change)
- Efficiency improvement (percent)
- Impact on vehicle weight (percent or absolute)
- Horsepower improvement (percent)
- Technology application
- Cost parameters
- Engineering notes

Consumer Vehicle Choice Component (CVCC)

- Market penetration by vehicle type determined using a nested multinomial logit model
- Coefficients vary by vehicle size class
- Vehicle attributes
  - vehicle price, fuel cost, acceleration, range, luggage space, maintenance cost, fuel availability, model availability, and home refueling
- Mandated vehicle sales requirements
  - Low Emission Vehicle Program (LEVP) and EPAct Fleet
- CAFE optimization (Hybrid, Diesel, PHEV, and EV penetration)

Nesting structure



Battery electric vehicles and the current market

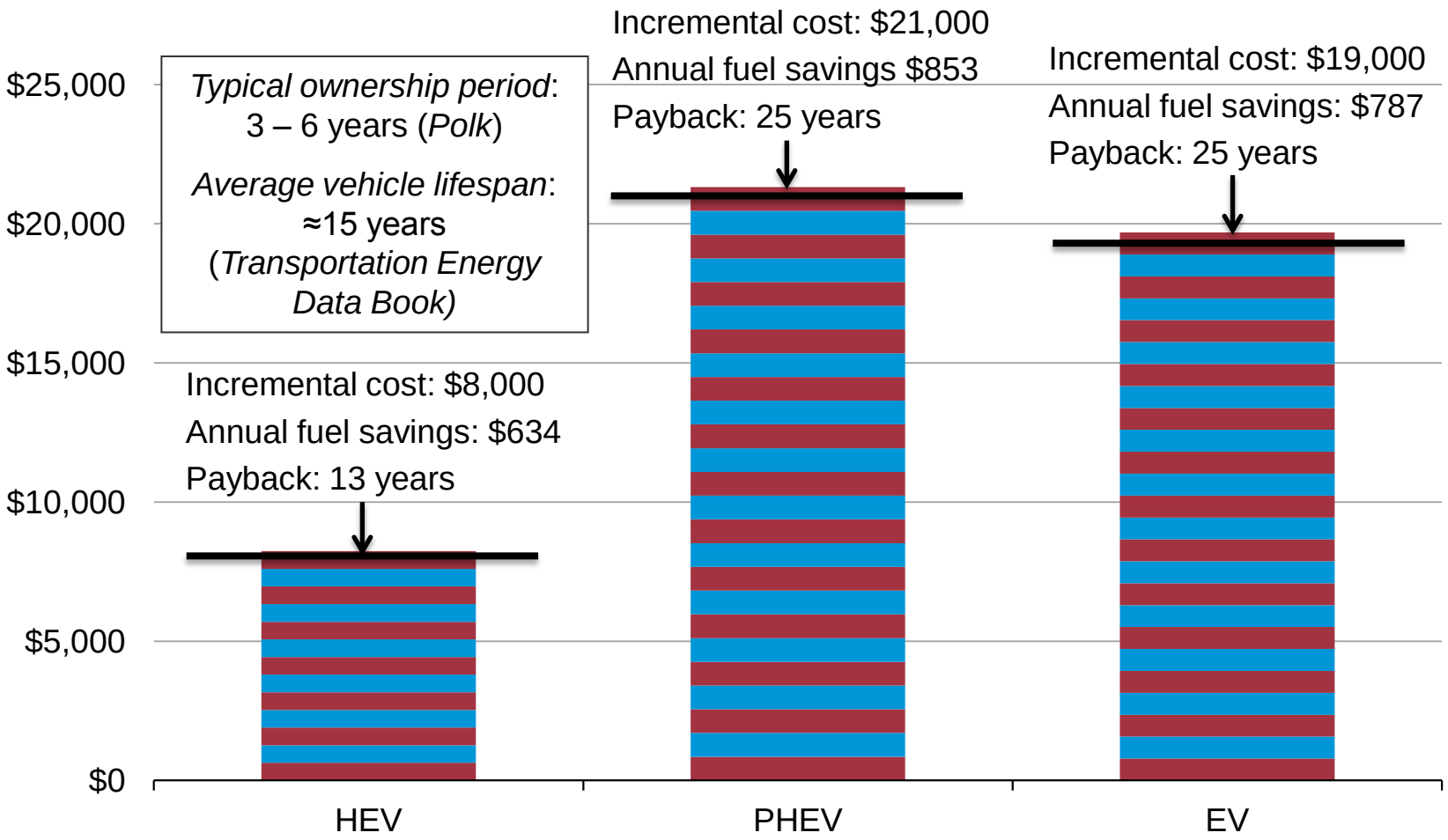
The degrees of electrification in light-duty vehicles

- Micro hybrids (start/stop)
  - electrically powered auxiliary systems that allow the internal combustion engine to be turned off when the vehicle is coasting or idle and then quickly restarted. Regenerative braking recharges the batteries but does not provide power to the wheels for traction; not connected to the electrical grid for recharging
- Mild hybrids
  - in addition to start/stop capability, provides some power assist to the wheels but no electric-only motive power; not connected to the electrical grid for recharging
- Full hybrid electric vehicles (HEVs)
  - in addition to start/stop and mild capabilities, operates the vehicle at slow speeds for limited distances on electric motor and assists the drivetrain throughout its drive cycle. Full HEV systems are configured in parallel, series, or power split systems, depending on how power is delivered to the drivetrain; not connected to the electric grid for recharging.

The degrees of electrification in light-duty vehicles—the plug-in vehicles

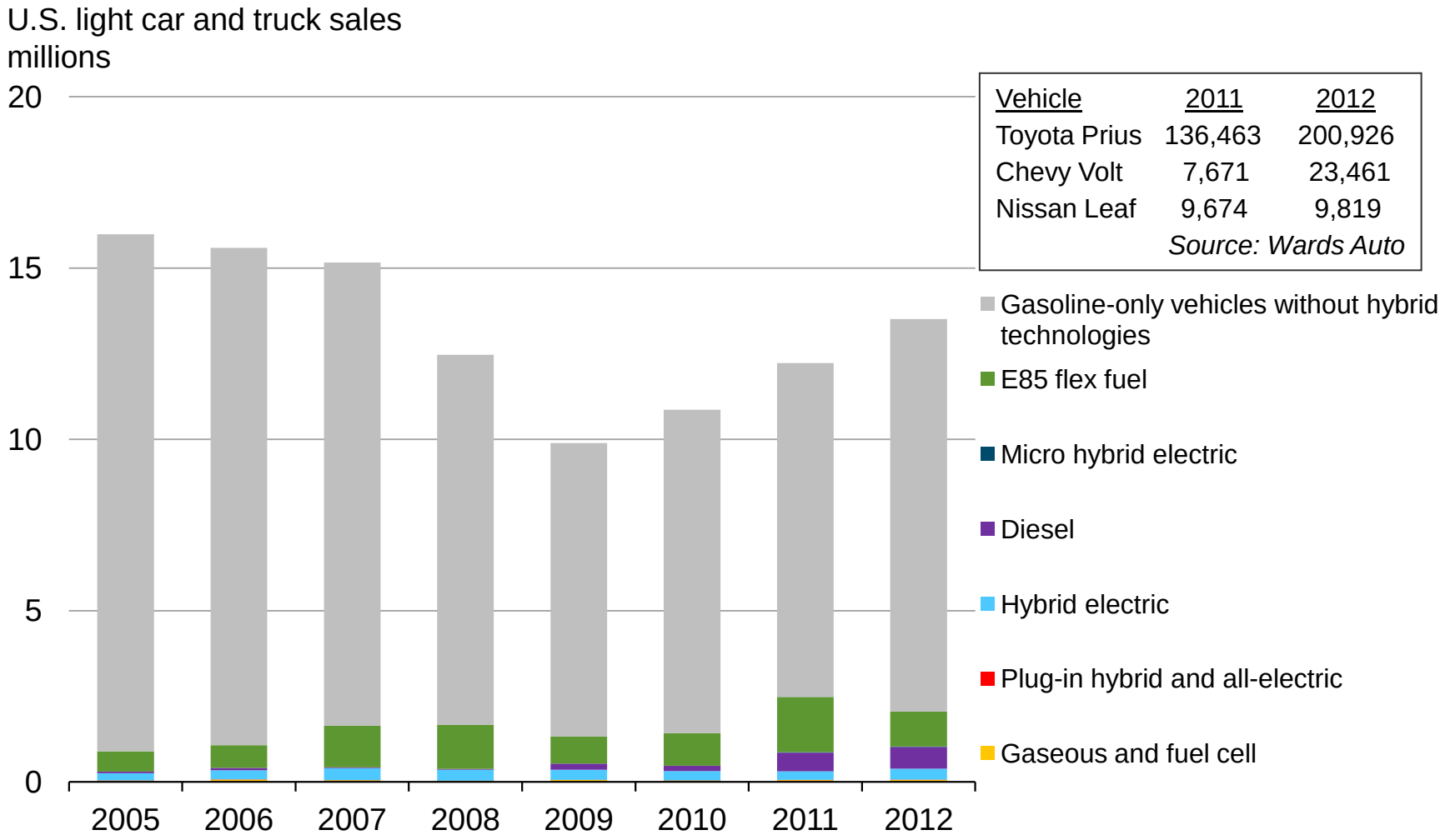
- Plug-in hybrid electric vehicle (PHEVs)
  - vehicles with larger batteries to provide power to drive the vehicle for some distance in charge-depleting mode, until a minimum level of battery power is reached (a "minimum state of charge"), at which point they operate on a mixture of battery and ICE power ("charge-sustaining mode"). PHEVs also can be engineered to run in a "blended mode," using an onboard computer to determine the most efficient use of battery and ICE power. The battery can be recharged either from the grid by plugging a power cord into an electrical outlet or by the ICE
- Plug-in battery electric vehicle (EVs)
  - vehicles that operate solely on an electric drivetrain with a large battery and electric motor and do not have an ICE to provide motive power. EVs are recharged primarily from the electrical grid by plugging into an electrical outlet, with some additional energy captured through regenerative braking

The payback from the fuel savings associated with battery electric vehicles is well beyond typical ownership period



Assumptions: 12,500 miles travelled per year, $3.50/gallon gasoline and $0.10/kWh electricity, PHEV 58% electric miles, ***0% discount rate***

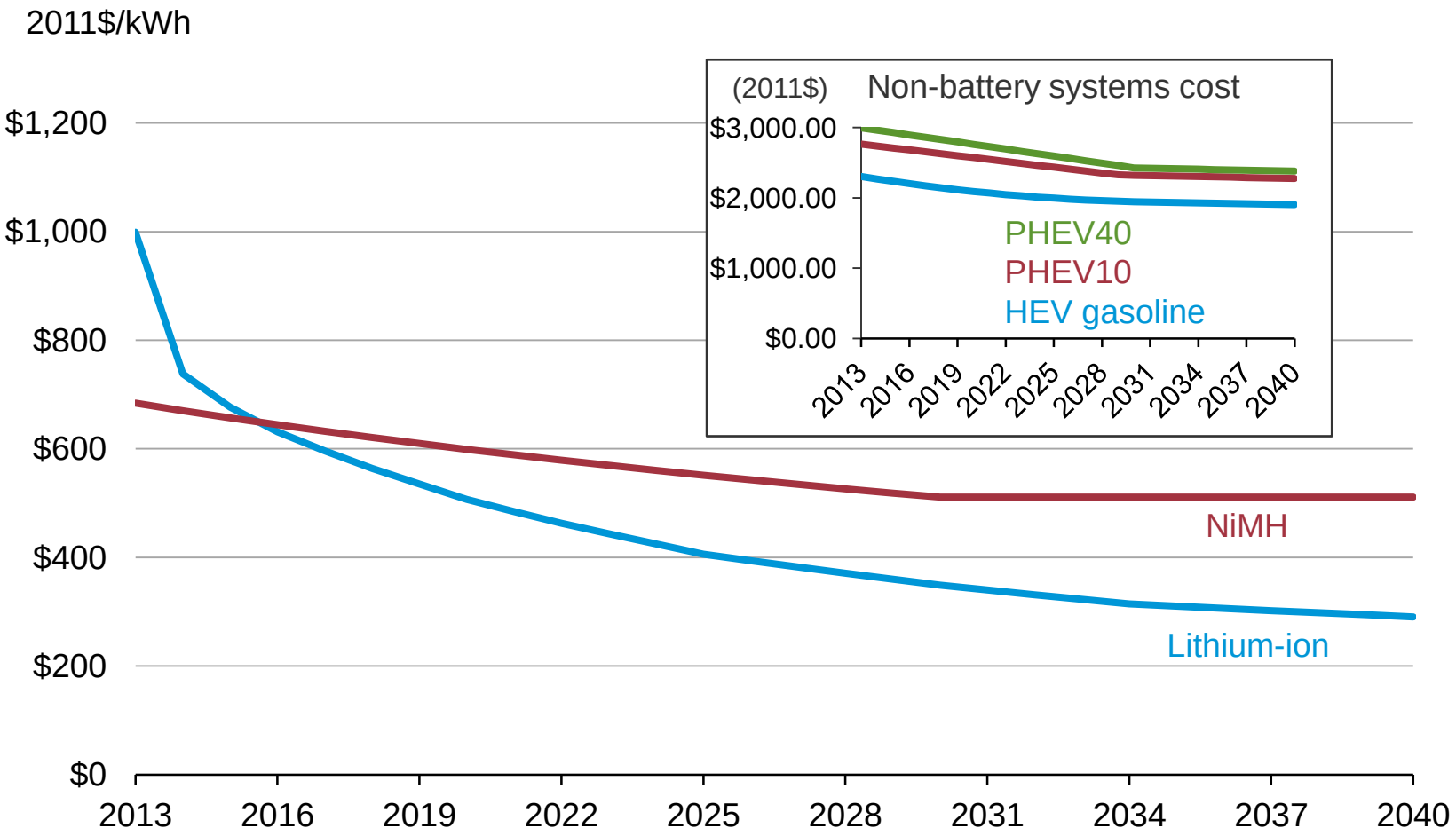
Light-duty vehicle sales are primarily gasoline, with some flex fuel, diesel, and HEVs



Source: EIA, Annual Energy Outlook 2013 Early Release Reference case

Projections of battery electric vehicles in the *Annual Energy Outlook 2013*

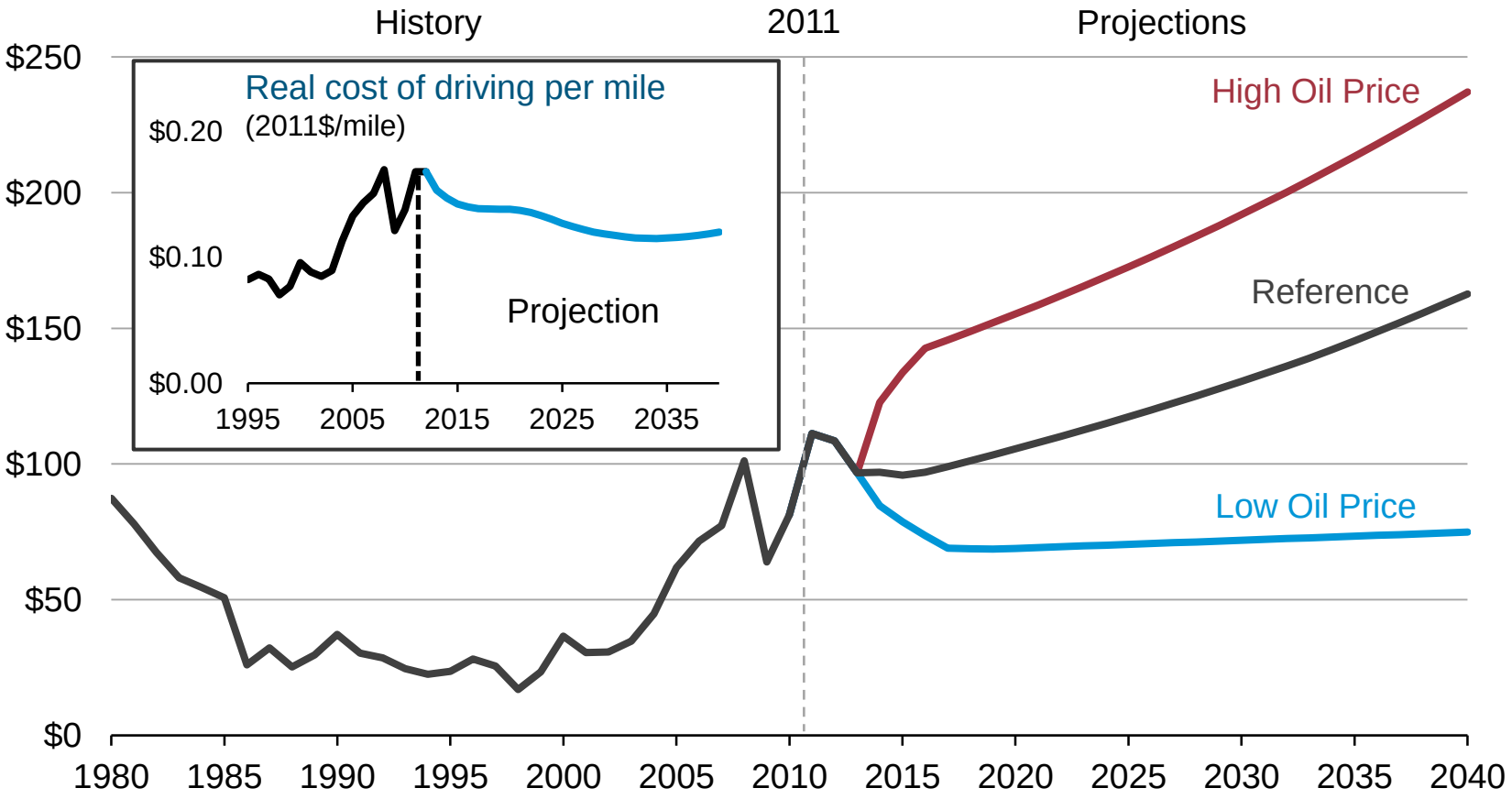
Battery cost and non-battery systems cost decline over time due to manufacturing learning and R&D



Source: EIA, Annual Energy Outlook 2013 Early Release Reference case

Reference case oil price initially drops and then rises steadily, but there is uncertainty about the future trajectory

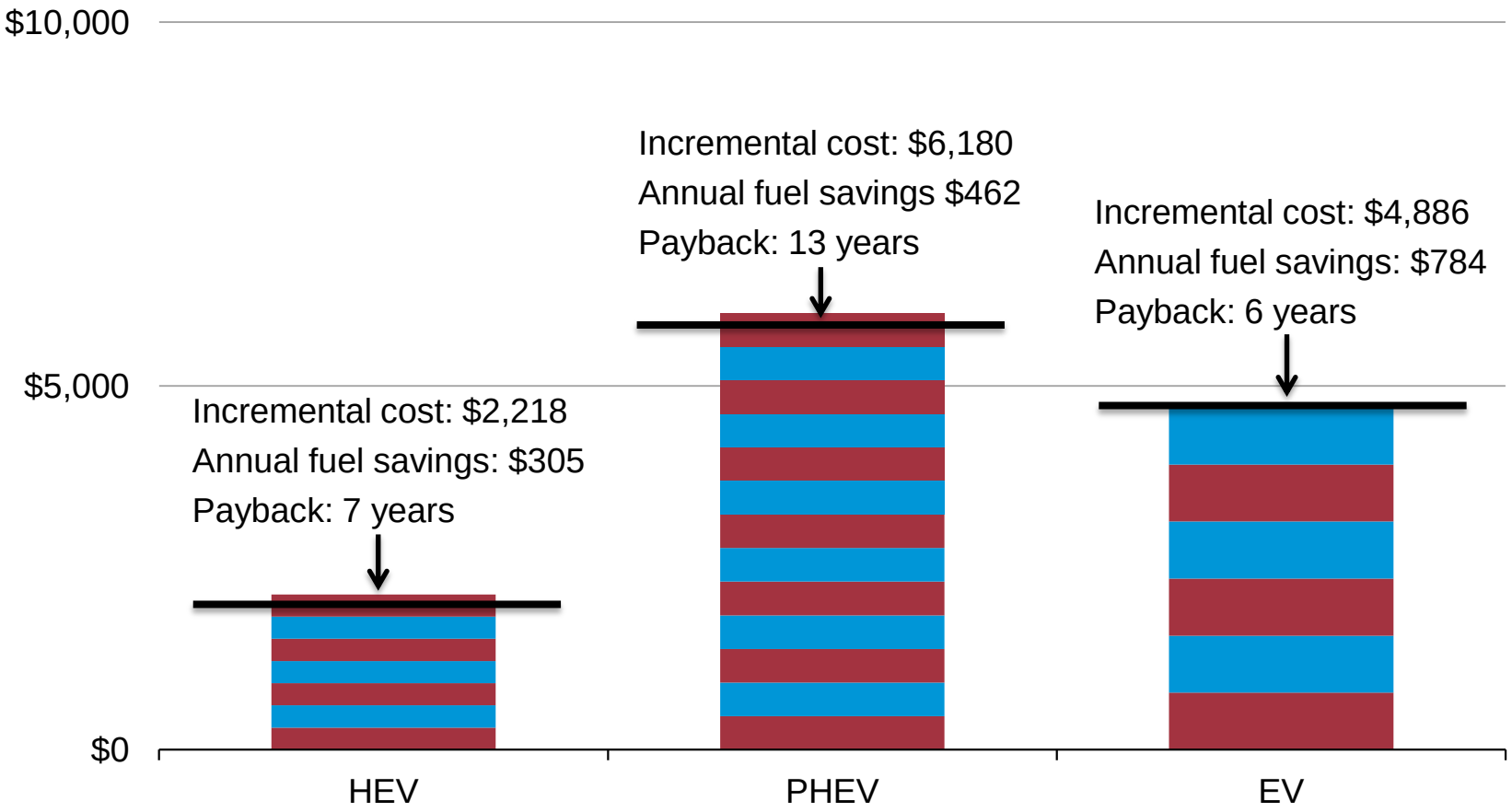
Annual average spot price of Brent crude oil
2011$/barrel



Source: EIA, Annual Energy Outlook 2013 Early Release Reference case

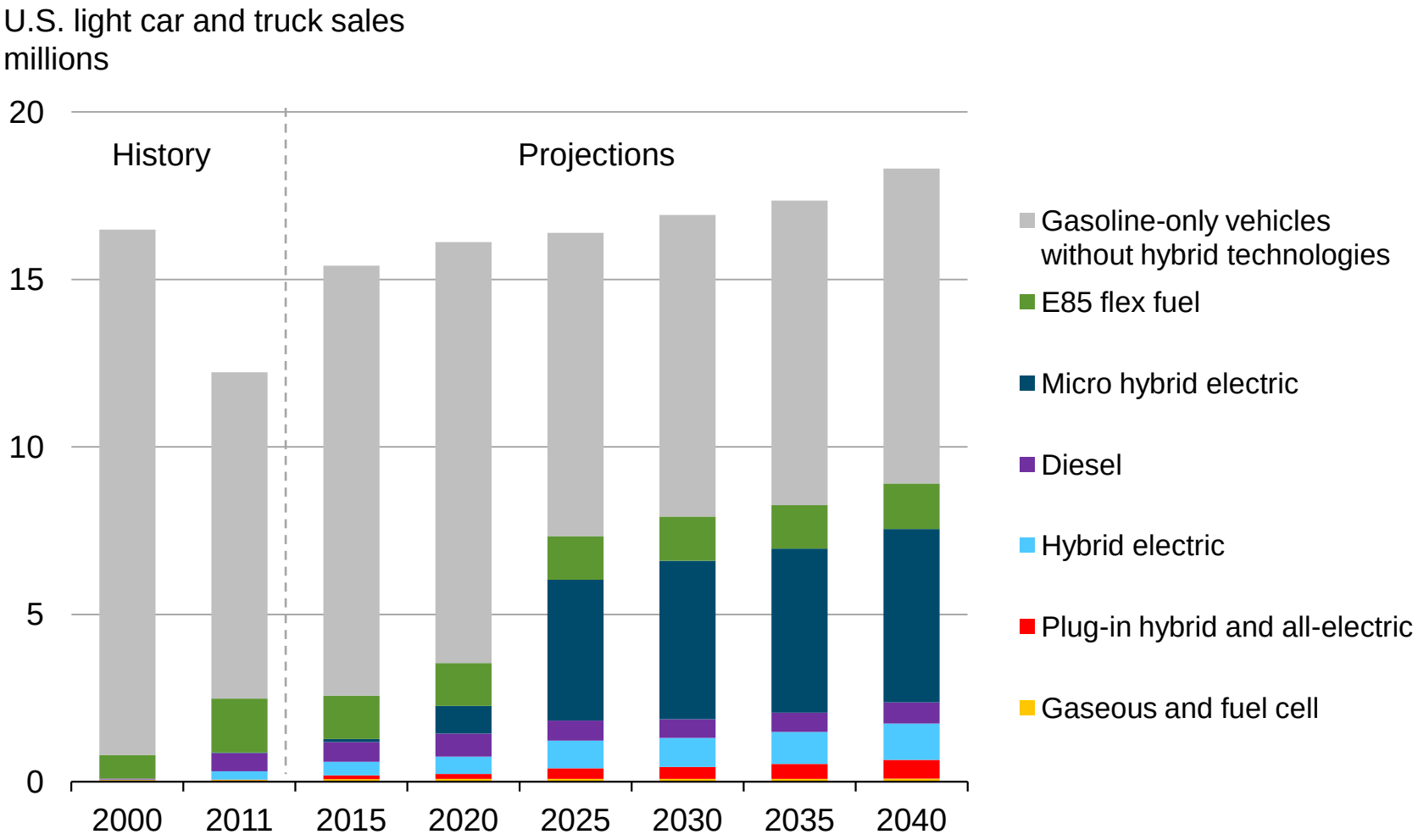
The fuel economics of battery electric vehicles in 2040—more favorable but still niche market and regulatory 'push'

13,300 miles travelled per year, $4.32/gallon gasoline and $0.11/kWh electricity, PHEV 58% electric miles, ***0% discount rate****; midsize HEV, compact PHEV40, midsize EV100*



Source: EIA, Annual Energy Outlook 2013 Early Release Reference case

Battery electric vehicles account for growing share (9%) of light-duty sales by 2040 (HEV 6%, PHEV and EV 3%)



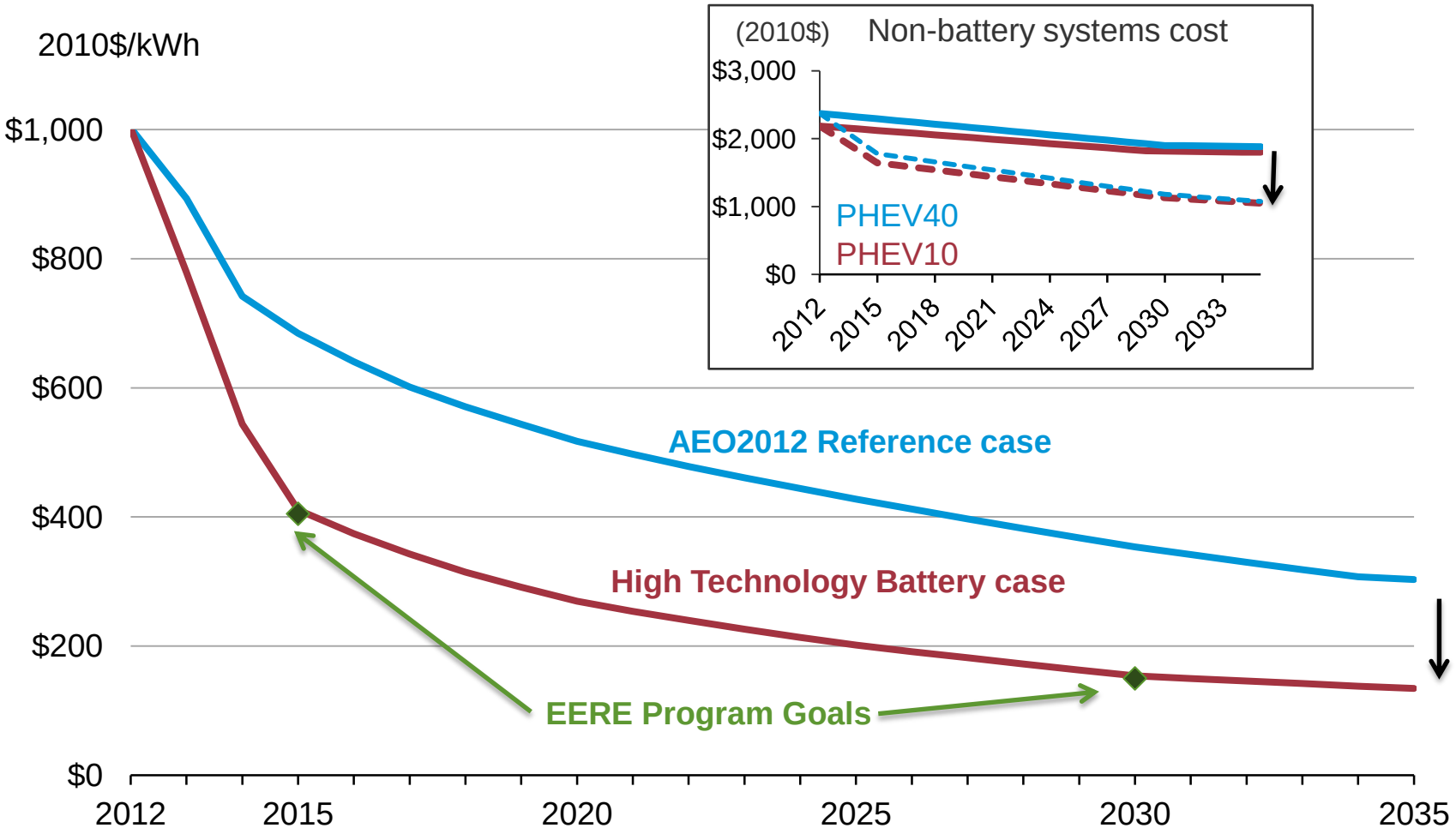
Source: EIA, Annual Energy Outlook 2013 Early Release Reference case

High Technology Battery case in the *Annual Energy Outlook 2012*

Battery and non-battery systems cost reduced to match EERE program goals

- Battery costs reduced to meet EERE program goal for 2015 and 2030
- Non-battery systems cost reduced to match EERE motor/converter program goals for 2015 and 2030
- More availability of EVs and PHEVs by size class

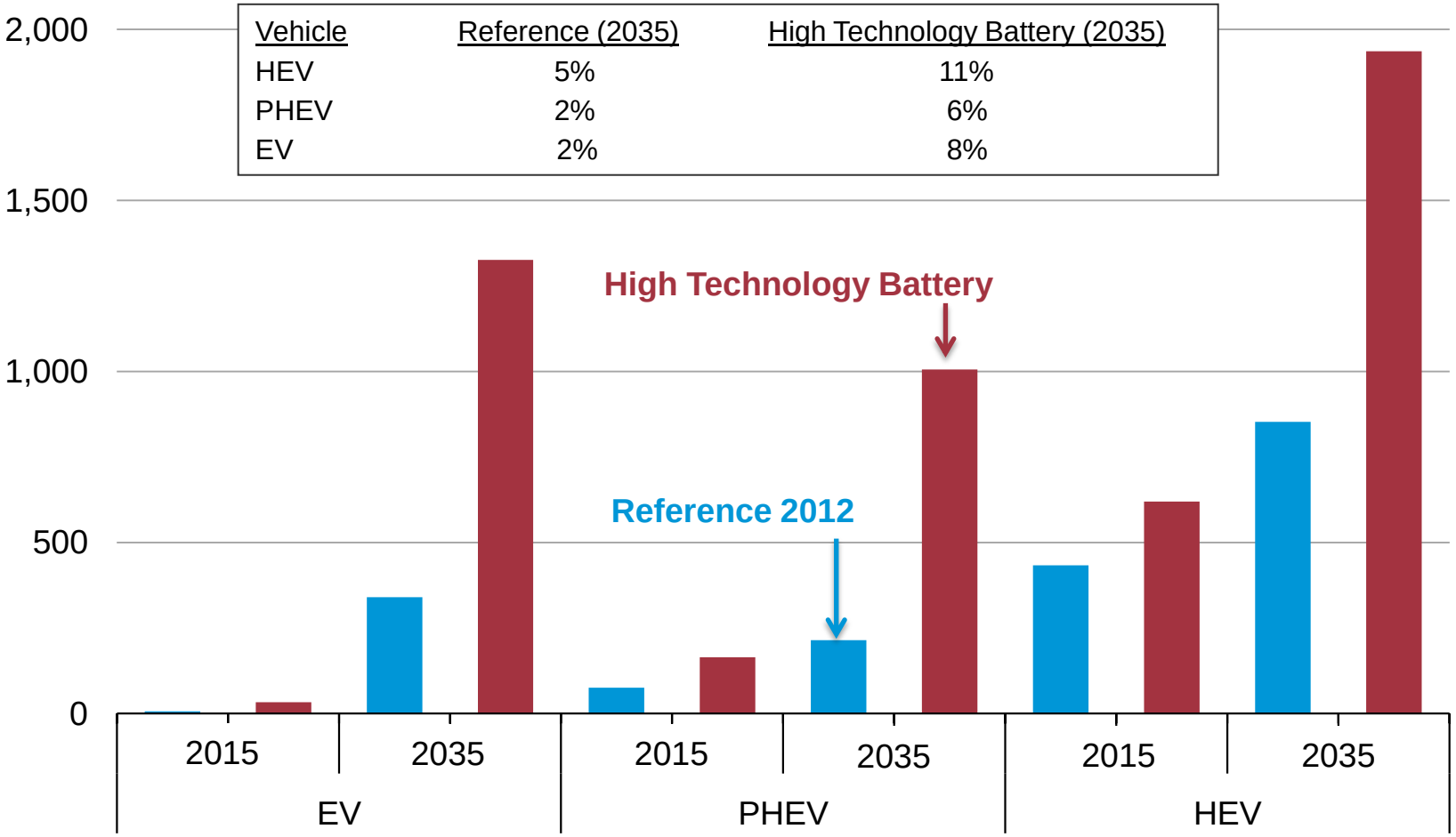
Lithium-ion battery ($/kWh) and non-battery systems cost decrease significantly in High Technology Battery case



Source: EIA, Annual Energy Outlook 2012 Reference case and High Technology Battery case

High Technology Battery case greatly expands battery electric vehicle sales, but still only about 25% of new vehicle sales

U.S. light car and truck sales
thousands



Vehicle	Reference (2035)	High Technology Battery (2035)
HEV	5%	11%
PHEV	2%	6%
EV	2%	8%

Source: EIA, Annual Energy Outlook 2012 Reference case and High Technology Battery case

For more information

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U.S. Energy Information Administration home page | www.eia.gov

Annual Energy Outlook | www.eia.gov/forecasts/aeo

Annual Energy Review | www.eia.gov/totalenergy/data/annual