Lithium-Ion Batteries in Light-Duty On-Road Vehicles

NTSB Lithium Battery Forum

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Vehicle Market and Petroleum Consumption

>240M Vehicles on the Road

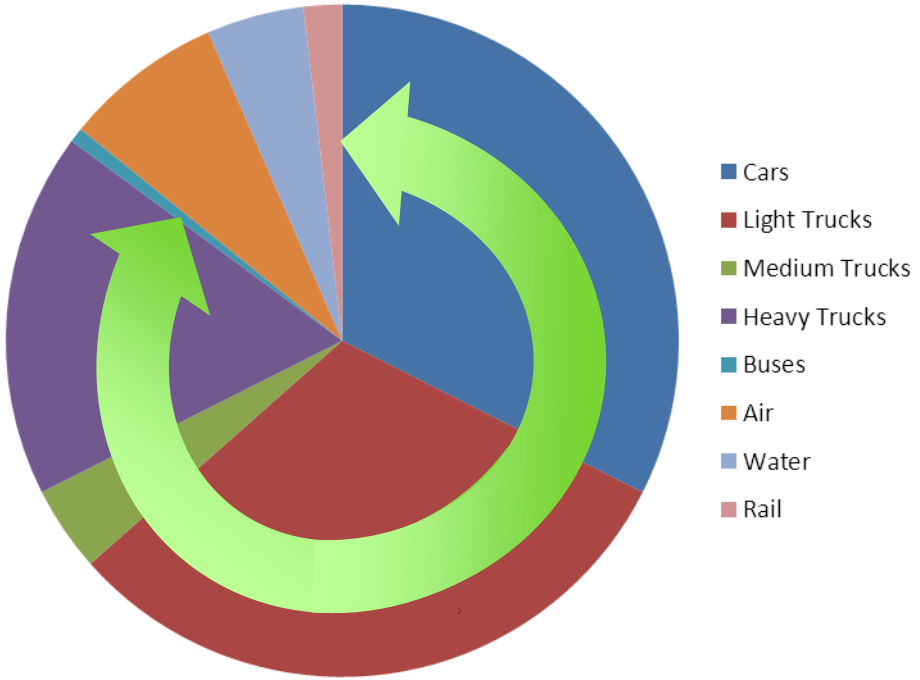
14.5M Light-Duty Vehicles Sold in 2012

94% dependent on petroleum

2012 Electric & Hybrid ~3% Sales

On-road Vehicles Account for 1/3 of Our Greenhouse Gas Emissions

On-road Vehicles Responsible for Over 2/3 of U.S. Petroleum Consumption



Importance of Vehicle Electrification

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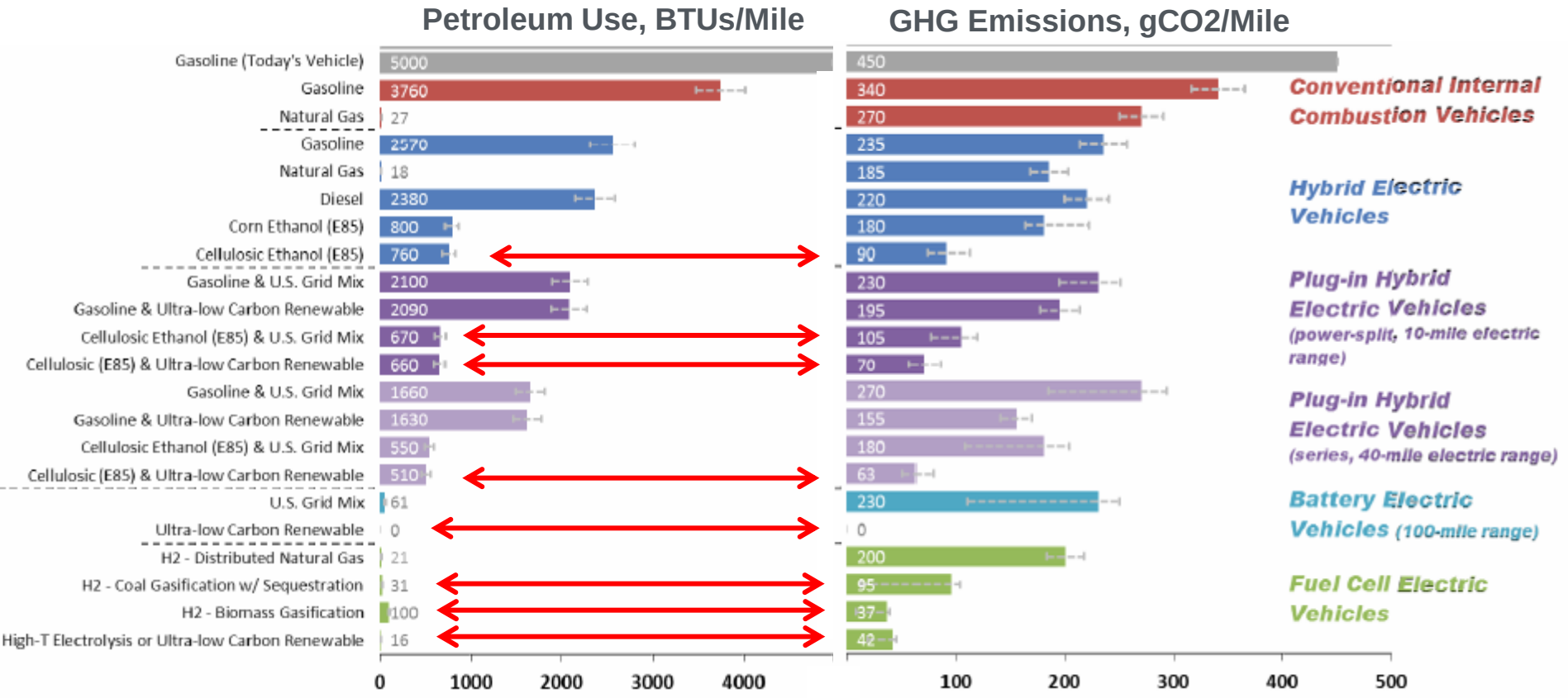
The Only Options That Achieve Very High Petroleum Reductions and Very Low Carbon Emissions Combine Electric Drive With Low Carbon Fuels



Electrification: What's Different This Time?

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Early 1900s

1970s

1990s

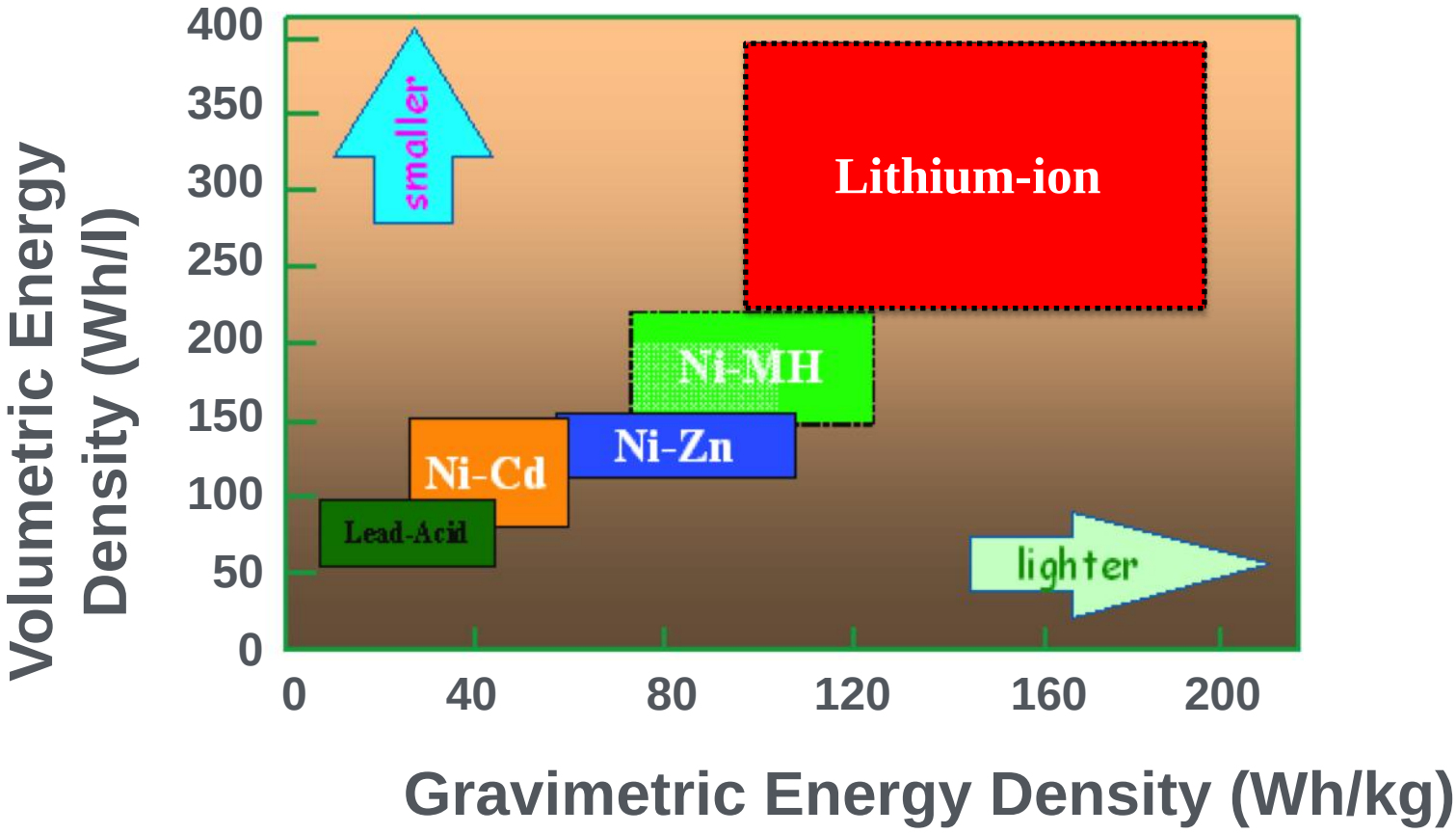
2013

Answer:

- Urgency of Energy and Environmental Challenges
- Battery Technology
- Federal, State, and Local Incentives
- 2025 CAFE

Why Li-Ion?

Superior Energy Density



Current Status of Lithium-ion Technologies

Chemistry	Anode / Cathode	Ah/kg (Practical)	Life	Power	Energy	Cost	Nominal Voltage
Cobalt Oxide	LiC_6/ $LiCoO_2$	~300/160+	☺	☺	😐	😐	3.9V
Nickelate	LiC_6 / $LiNi_xCo_yAl_z$	~300/180	☺	☺	☺	😐	3.6V
Manganese Spinel	LiC_6/ $LiMn_2O_4$	~300/~ 120	😐	☺	☺	😐	3.9V
Iron Phosphate	LiC_6/ $LiFePO_4$	~300/160	☺	☺	😐	😐	3.4V
Lithium-rich, Mn-rich	LiC_6 / xLi_2MnO_3-$(1-x)LiMO_2$	~300/250	?	😐	☺	😐	3.5V
Titanate	$Li_4Ti_5O_{12}$/ $LiMn_2O_4$	~ 170/~ 120	☺	☺	☹	😐	2.4V

- No consensus on chemistry – production vehicles using different Li-Ion types
- For **power** applications, the system limit is **60–65 Wh/kg** (100 Wh/kg at cell).
- For **energy** applications, the system limit is **100 Wh/kg** (170 Wh/kg at cell).

DOE Battery Innovation, Market Acceptance and Cost Reduction

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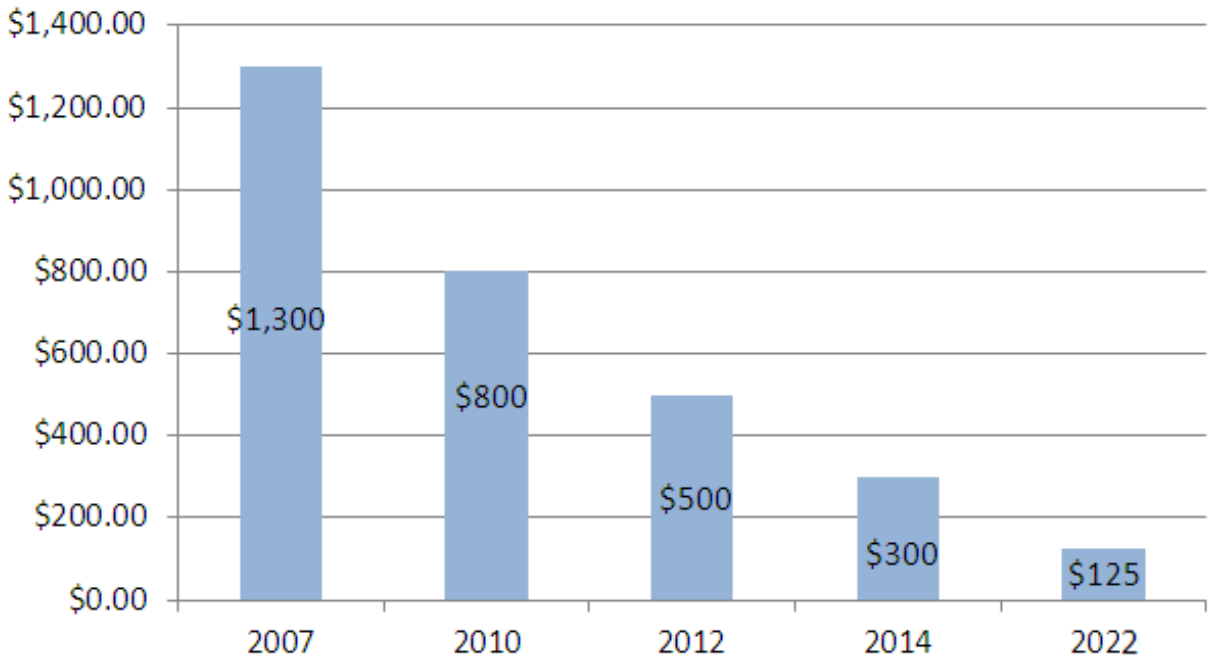
- 1990's → Nickel Metal Hydride (NiMH) batteries enable commercial introduction of HEVs
- 2000 - 2010's → Li-ion batteries enable next generation HEVs, PHEVs and EVs
- Future → Next Generation Chemistry with 3x energy density

Battery Cost on Track to Meet 2015 Goal of $300/kWhr



PEV Sales Growing

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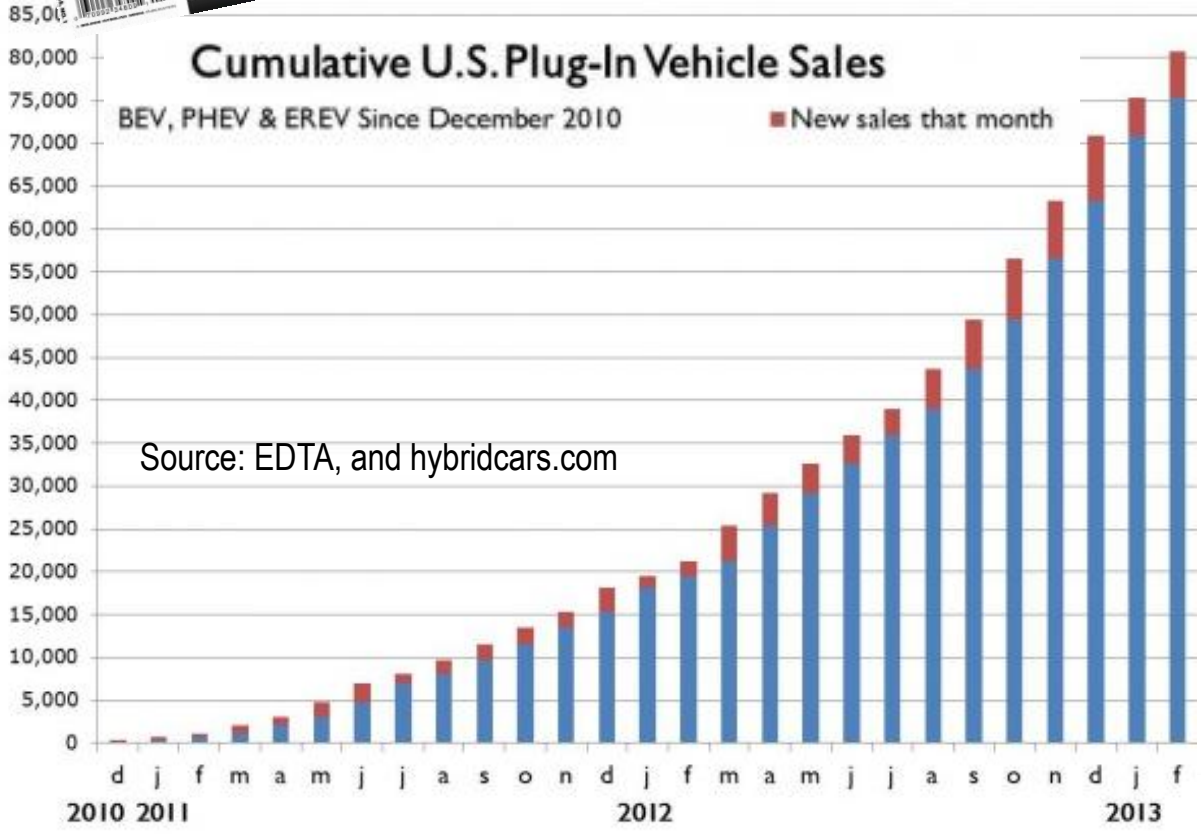
Ford C-Max Energi

GREEN CAR VISION™ AWARD



- PEV sales in the U.S. tripled in 2012
- Major awards
  - ✓ 2011 World Car of the Year (Nissan Leaf)
  - ✓ 2013 motor Trend Car of the Year (Tesla Model S)
  - ✓ 2012 Green Car Vision Award (Ford C-Max Energi)
- Hybrids share of the automotive market growing, currently over 3% of all sales for 2013

Plug-In Vehicles Available in 2013

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