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Prospects for Electric Drive Vehicles

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Prospects for Electric Drive Vehicles

Daniel Sperling
Professor and Director
Institute of Transportation Studies (ITS-Davis)
University of California, Davis
and
Board Member, California Air Resources Board

APEC
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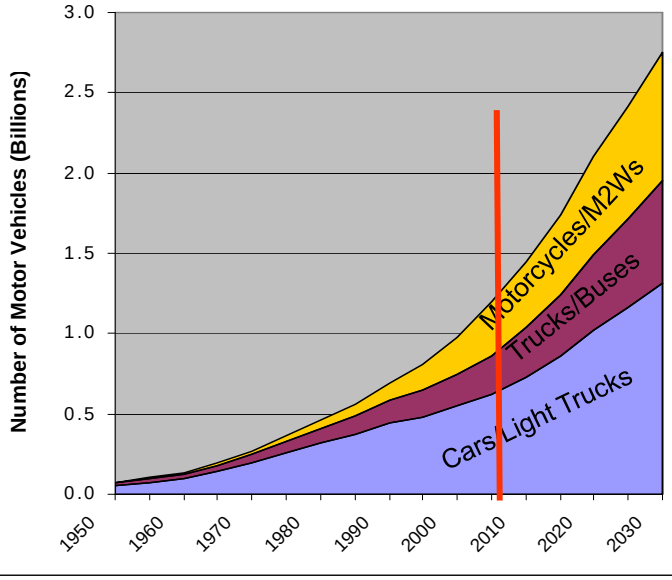
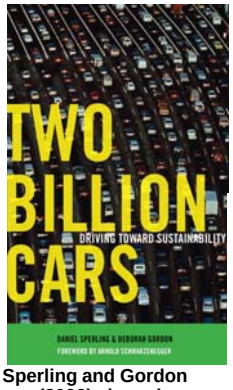
Good news and bad news

Soaring Global Demand for Vehicles (and Oil)





Sperling and Gordon (2009), based on DOE, JAMA, other

Fuel *du jour* Phenomenon

Disruptive and wasteful

- **30 years ago – Synfuels (oil shale, coal)**
- **20 years ago – Methanol**
- **15 years ago – Electricity (Battery EVs)**
- **5 years ago – Hydrogen (Fuel cells)**
- **2 years ago – Ethanol**
- **Today – Electricity (Plug-in hybrid vehicles)**
- ***What's next?***

GOVERNMENT POOR AT PICKING WINNERS …
NEED DURABLE POLICY SUCH AS LOW CARBON FUEL STANDARD

BEVs and PHEVs Entering the Market

MAJOR MANUFACTURERS

VEHICLE	MANUFACTURER	VEHICLE TYPE	ELECTRIC RANGE	BATTERY SIZE	MODEL YEAR
LEAF	Nissan	BEV	100 mi	24 kWh	2011
VOLT	GM	PHEV	40 mi	16 kWh	2011
ActiveE	BMW	BEV	120 mi	32 kWh	2011
Transit Connect Electric	Ford	BEV	80 mi	28 kWh	2011
Focus Electric	Ford	BEV	100 mi	24 kWh	2011
i-MiEV	Mitsubishi	BEV	75 mi	16 kWh	2011
Prius Plug-in Hybrid	Toyota	PHEV	14.5 mi	5.2 kWh	TBA
Smart ED	Daimler	BEV	70 mi	16 kWh	2012
RAV4-EV	Toyota	BEV	100 mi	~35 kWh	2012

NEW MARKET ENTRANTS

VEHICLE	MANUFACTURER	VEHICLE TYPE	ELECTRIC RANGE	BATTERY SIZE	MODEL YEAR
Roadster	Tesla	BEV	245 mi	53 kWh	2010
Karma	Fisker	PHEV	50 mi	20 kWh	2011
Coda Sedan	Coda	BEV	100 mi	37 kWh	2011
F3DM	BYD	PHEV	62 mi	13.2 kWh	2011
e6	BYD	BEV	250 mi	72 kWh	2011
Think City	Think!	BEV	120 mi	24 kWh	2012
Model S	Tesla	BEV	160–300 mi	42–95 kWh	2012

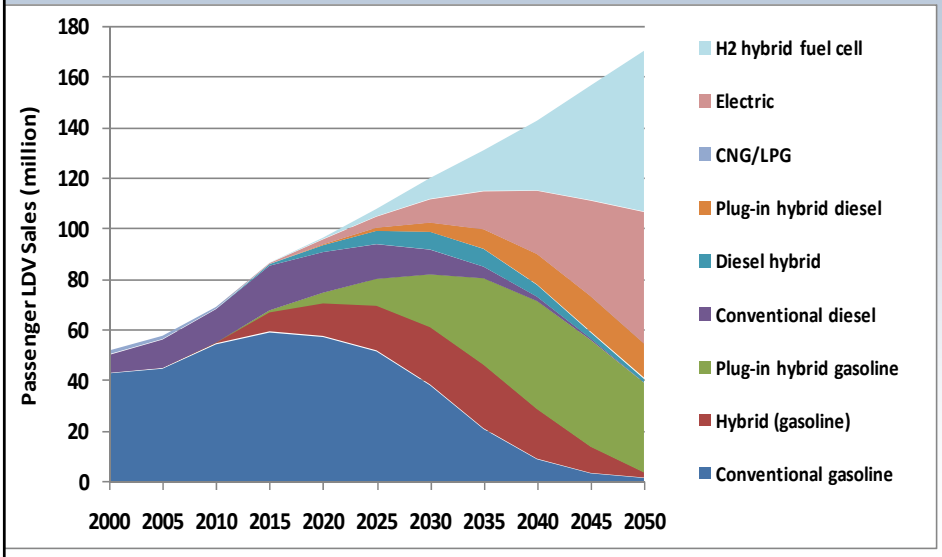

Prius Plug-in Hybrid


2011 Chevrolet VOLT


2011 Mitsubishi i-MiEV

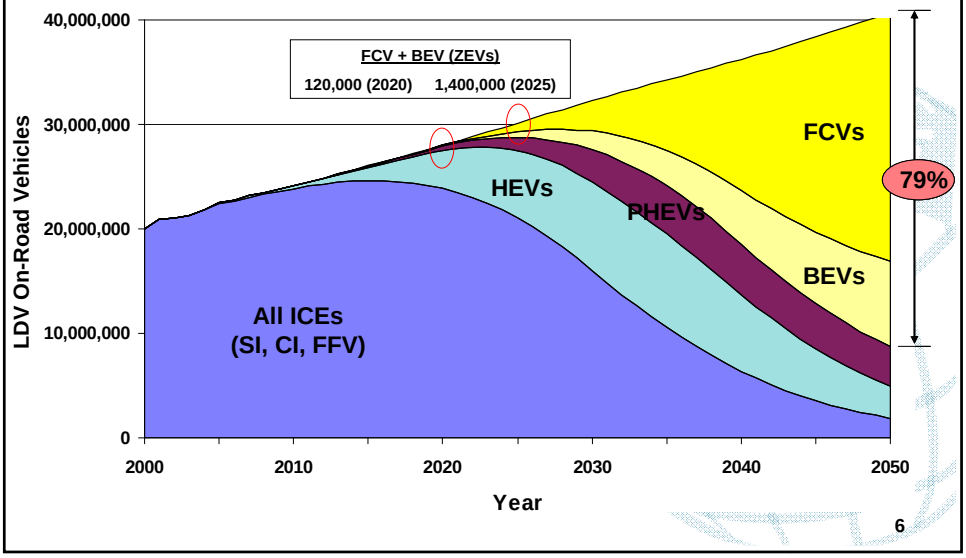

2011 Nissan LEAF

IEA Aggressive CO_2 Scenario… Almost All Cars are Electric-Drive in 2050



IEA, 2009 (blue map scenario: 50% reduction in CO2-e emissions by 2050)

California EV "Scenario" (for ZEV Mandate)



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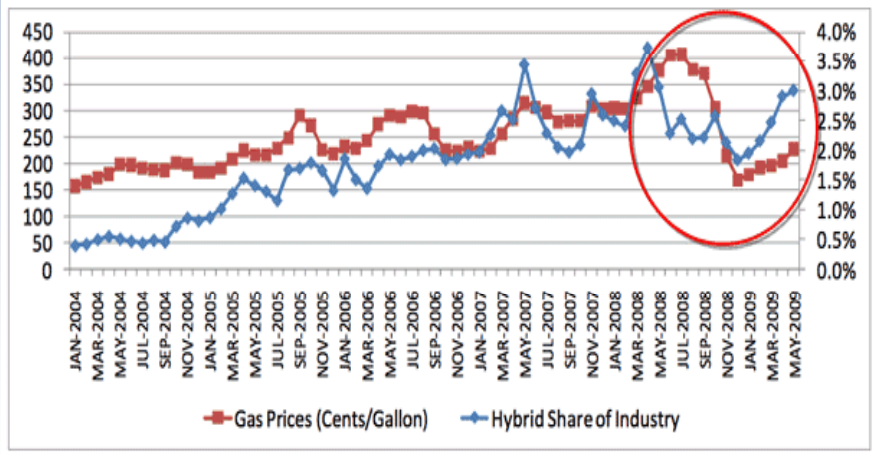
On the other hand … US National Academies Forecasts Low Market Shares for Electric-Drive Vehicles (USA)

	2020	2035
Diesels	8-12%	15-30%
Gasoline HEV	10-14%	15-40%
PHEV	**1-3%**	**7-15%**
BEV	**0-2%**	**3-10%**
FCV	**0-1%**	**3-6%**

Source: National Academies, 2009 (AEF energy efficiency chapter)

And what does slow HEV market growth say about PEVs?



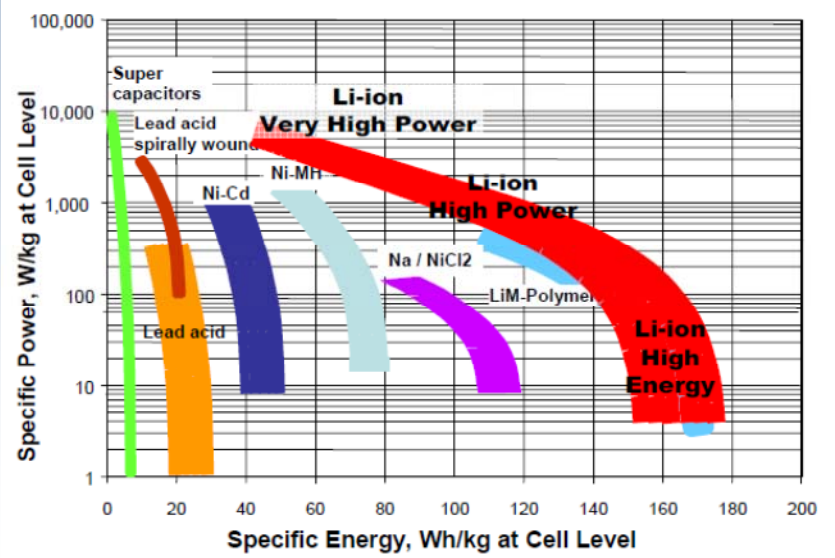
Q1: How much will battery costs come down (and when) …

Incremental Cost of Electric-Drive Vehicles Relative to Baseline 2005 Gasoline Vehicle over Next 25 years (2005$)

	Car
Current gasoline	0
Current diesel	+$1,500
Current HEV	+$4,400
Advanced gasoline	+$1,800
Advanced diesel	+$3,000
Future Gasoline HEV	+$2,500
PHEV	+$3,900
BEV	+$8,000
FCV	+$4,500

Source: Adapted from US National Academies, 2009; Bandivadekar et al., 2008; Kalhammer et al, 2007; Kromer and Heywood, 2007; NAS, 2008.

Batteries Getting Steadily Better, But Still Expensive (~8%/yr improvement)



Source: IEA (2009), from Johnson Control – SAFT, 2005 and 2007

Battery Cost Challenge

- Today's batteries cost ~$600-900/kW-hr
- Future batteries might cost ~$300/kW-hr

- Thus, today
  - Battery for Nissan Leaf (24 kW-hr) = ~$18,000
  - Battery for GM Volt (16 kW-hr) = ~$10,000

- Future:
  - Nissan Leaf battery = ~$7000
  - GM Volt battery = ~$5000

Batteries will be very expensive even in optimistic scenarios

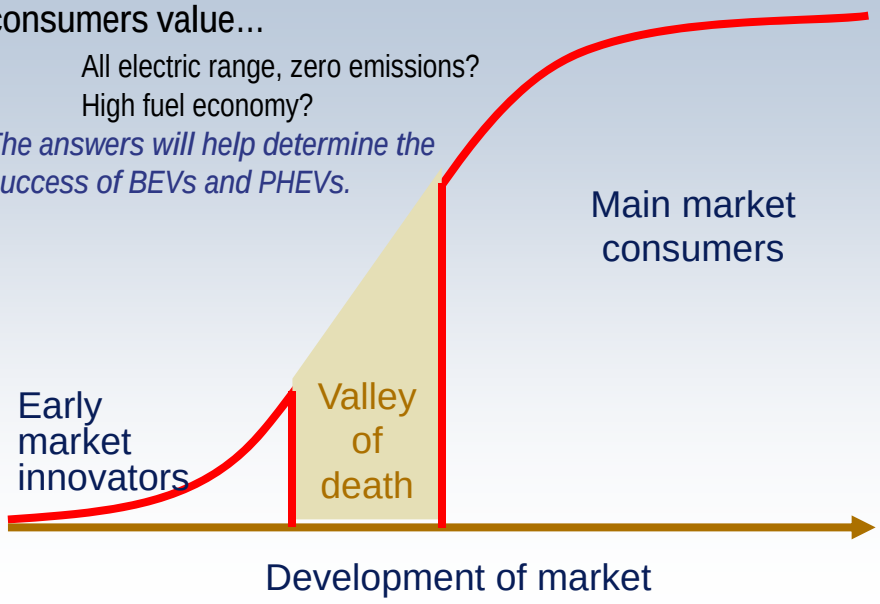
Q2: How will consumers respond?

Great uncertainty how market will evolve. How will consumers value…

All electric range, zero emissions?

High fuel economy?

The answers will help determine the success of BEVs and PHEVs.



Importance of Public Charging?

- Early evidence suggests EV buyers desire public charging as pre-condition to buy an EV, but rarely use it
  - Public charging important only for psychological reasons?!
- No business model for public charging?
- Big employers, big retail stores, and others likely to offer charging as “fringe benefit”

Q3: What should government do to help?

Financial Incentives from US Government

- Tax credits of $2500-$7500/vehicle (at least 4kWh batteries). Up to 200,000 PHEVs/BEVs per automaker
- Tax credits for refueling facilities: 50% (up to $50,000 for electricity stations and $2000 for residences, and $200,000 for H2 stations).
- ~$3 billion for advanced battery and electric-drive vehicle manufacturing (including $1 billion loans to startup EV companies: Fisker PHEV and Tesla BEV)
- Funds for thousands of charging stations

US Policy to Reduce GHGs With Electric-Drive Vehicles

Vehicles

- Fuel & GHG standards for light duty vehicles: 54 mpg by 2025, with EVs rated as 0 g/mile and double credit
- Fuel & GHG standards for trucks (2015)
- Market Instruments
  - Tax Credits for Low Carbon Vehicles ($2500-$7500/veh)
- ZEV requirements (California and 10 other states)
- R&D – batteries, H2 storage

Fuels

- Low Carbon Fuel Standard (California, 2011)
- Cap and Trade (California, 2011)
- Clean Fuels Outlet that requires H2 stations) (California, proposed)
- Renewable electricity requirements (Calif and many other states)
- R&D for low-carbon electricity, CCS, H2 production

Q4: Role of Electric Utilities

EV Electricity Demands Will Have Small Effect on Grid for Decades (US)

Vehicle	Energy use per vehicle (kWh/mi)	Total energy use per vehicle (kWh/yr)	1 million vehicles (GWh)	2 million vehicles (GWh)	5 million vehicles (GWh)	231 million vehicles (GWh)
PHEV10	0.045	534	534	1,068	2,671	123,405
			0.0%	0.0%	0.1%	3.1%
PHEV20	0.148	1,781	1,781	3,561	8,904	411,349
			0.0%	0.1%	0.2%	10.2%
PHEV40	0.223	2,671	2,671	5,342	13,356	617,024
			0.1%	0.1%	0.3%	15.3%
BEV	0.318	3,816	3,816	7,632	19,079	881,463
			0.1%	0.2%	0.5%	21.8%

Connect Vehicles to Buildings and Electricity Grid

- Reduces need for electricity peaking plants
- Generates revenue for car owner
- Emergency backup power for house/building

Q5: Who Will Lead?

Two Approaches to EV Development

1. **Top-down**. Build full-size, fully functional vehicles that compete with conventional vehicles.
   - Vehicles are expensive and market expansion is slow
   - Cutting-edge technology advances faster
2. **Bottom-up**. Build small, inexpensive electric vehicles, including e-bikes, neighborhood electric cars, and low speed vehicles
   - Many more vehicles are built and sold
   - Supplier base is broader and deeper
   - Experience gained with recharging infrastructure, government incentives and regulations, more engineers are trained, more experience with repairs

Who Will Lead?

- US is making substantial investments and adopting some supporting policies
- France has near zero carbon electricity (nuclear) and many incentives for EVs
- China has large e-bike industry and a determination to leap frog established auto industry
- Leader? All are faltering. To be determined

Market and Technology Vision for Electric-Drive Vehicles (US)

- BEVs for city cars and small vehicles with limited performance req'ts (10-30% of market)
- PHEVs and FCVs for larger cars and light trucks
- FCVs for large trucks

More ambitious vision:
Small "Connected" EVs from GM/China




Conclusions

- BEVs, PHEVs, and FCVs will all succeed, but at different times, in different places, in different ways
- BEVs will thrive in large cities (London, Paris), isolated markets (Israel, Hawaii), polluted regions (Kathmandu, Chinese cities), areas with abundant low-carbon electricity (France)
- PHEVs and FCVs have potential to fully replace petroleum-powered vehicles
  - Depends on progress of batteries, fuel cells, hydrogen supply, *and* policy
- Transition will likely be slow
- Many opportunities for collaboration (across universities, companies, governments)

It won't be easy …

"We stand at a crossroads. One path leads to despair, the other to destruction. Let's hope we choose wisely."
Woody Allen

I'm more optimistic…

Do we have a choice?