Electric, Hybrid and Fuel cell Vehicles and Technology Trends

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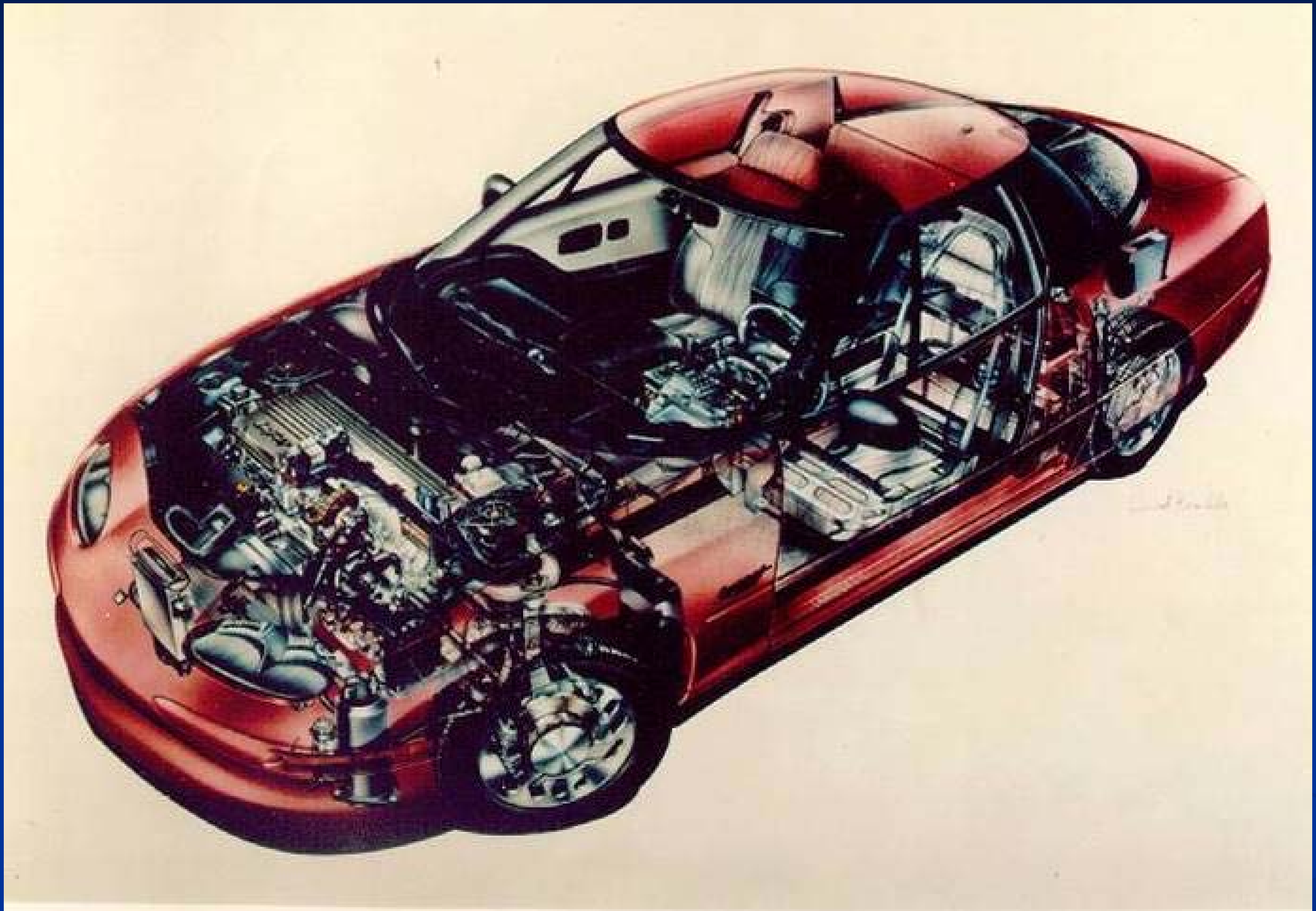
Biography

- 1990-2000 R&D engineer at GM
  - Production and R&D for GM EV1 and electric buses
  - R&D for standard and rapid charging
  - Technical lead for joint R&D with Toyota Motor Co for EV charging standardization
- 2000-present:
  - Power lecturer at UCC
  - PI for automotive R&D
- Purchased one of first Prius in Ireland, Feb. 2001
  - Just replaced battery after 8 years!
- July-Dec, 2008 – Automotive sabbatical in Detroit

Objectives

- Discuss cars with electrical propulsion from the major global manufacturers.
  - EV
  - Hybrid
  - Fuel cell
- Review technology trends.
- Provide perspective on earlier EV activity

1996 GM EV1



- 2 seater
- T-shaped Lead Acid BP
- 1200 lb BP, ½ g.
- Induction motor
- 100 kW
- 600 V IGBT
- 6 kW off-vehicle charger
- CD = 0.19
- High-pressure tires
- Aluminum frame

Electric Bus

- 5 miles/hour airport routes, 8 hours of operation
- Swappable battery pack on rear axle

Rapid Charging I

Rapid Charging II

Who killed the electric car?

- Hollywood Documentary – big bad automotive companies!

Vs.

- Reality –
  - $10-15 per barrel gasoline (< $1/US gallon)
  - Limited advances in battery technology
  - Limited range – "range anxiety"
  - Lack of market interest in green technologies
  - Limited customer base
  - High cost base

Who killed the electric car?
The Battery!

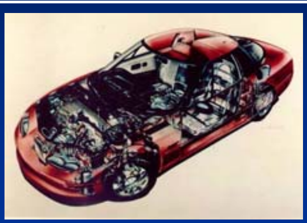
Battery Type	Pack Energy Density Wh/kg	Cost $/kWh	Cycle life	Self Discharge	Toxic
Lead Acid	30+ (EV1)	$	Low	Low	High
Nickel-Metal Hydride	40+ (Prius)	$$$	High	High	Low
Lithium Ion	90+ (MiEV)	$$$$	High	Low	Low
Sodium Nickel Chloride	< Li Ion	$$$	High	?	?

- **All values approximate or educated guesses!**
- **Lead acid has improved in energy density 20-30 % in 100 years!**
- **NiMH problems: deep cycling for hybrids, self discharge, nickel cost**
- **Li Ion Problems: overvoltage & safety, cost**

Who killed the electric car? Hindsight

- Visionary concept:- zero emissions, high performance
- 15 years too early, Li Ion an enabling technology?
- EV an important marketing tool
- Continue diverse R&D for EV, hybrid and fuelcell and petrol\diesel powertrains.
- CARB mandates not practical (vs. earlier catalytic converter)

EV1-iMiEV-Volt-Tesla Comparison



	1996 EV1	iMiEV	2010 Volt	Tesla
Batteries	Lead Acid	Li Ion	Li Ion	Li Ion
EV Range	50-80 miles	60-100 miles	40 miles	? -220 miles
Storage	17 kWh	16 kWh	16 kWh	53 kWh
Generator	None	None	53 kW/1.4 l	None
BP Weight	1200 lb	375 lb	375 lb	990 lb
Curb weight	2970 lb	2400 lb	3520 lb	2690 lb
Horse power	130	64	150	248
0 – 60 mph	8.5 s	?	9 s	3.9 s
Charging	230 V, 30 A	200 V, 15 A	230 V, 16 A	Integrated

iMiEV-Reva-Verde-ZEV Comparison

	iMiEV	2009 Reva	Verde Van	ZEV Tepee
				
Batteries	Li Ion	Li Ion	Lead Acid	LiIon
EV Range	60-100 miles	? -75 miles	? -63 miles	? -100 miles
Storage	16 kWh	10 kWh	?	43 kWh
Generator	None	None	None	None
BP Weight	375 lb	260 lb	?	?
Curb weight	2400 lb	1400 lb	2730 lb	?
Horse power	64 hp	?	?	80
0 – 60 mph	?	?	?	?
Max. speed	80 mph	50mph	53 mph	60 mph
Charging	200 V, 15 A	230V,15A/Fast	230 V, 15 A	?

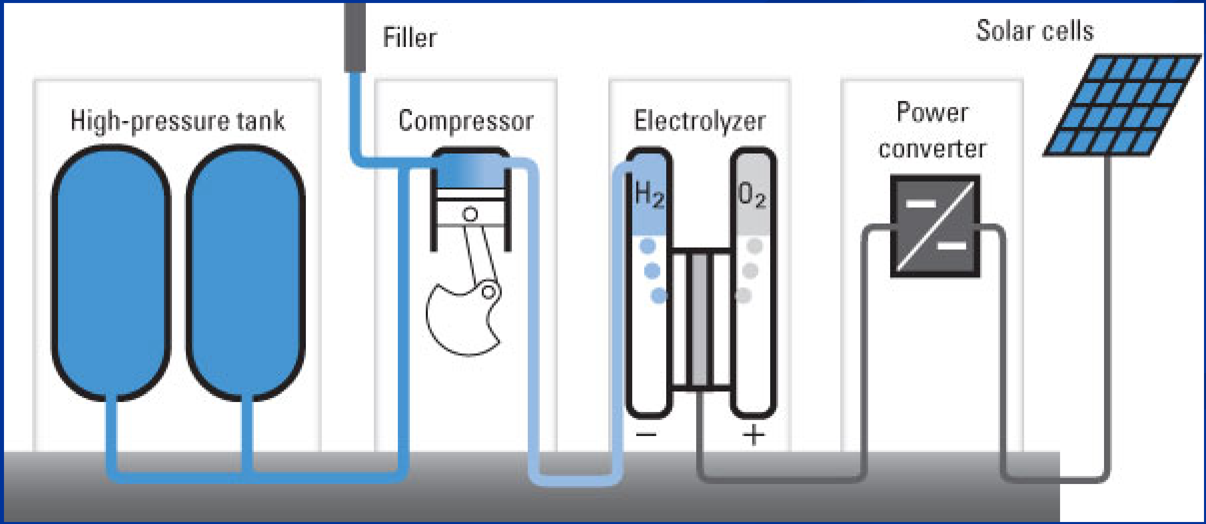
Volt-Prius-Insight Comparison

	2010 Volt	2010 Prius	2009 Insight
			
Batteries	Li Ion	Li Ion	NiMH
EV-only Range	40 miles	7 miles	0 miles
SOC	16 kWh	4 kWh	0.6 kWh
Generator	1.4 l	1.8 l	1.3 l
BP Weight	375 lb	?	?
Curb weight	3520 lb	2975 lb	2723 lb
Horse power	150	134	98
0 – 60 mph	9 s	?	11-12 s
Mpg	?	65	?
Charging	230 V, 16 A	?	NA

EV alternatives: Fuel cell vehicles

- "For the long term, we believe fuel-cell electric vehicle technology is the ultimate environmental solution. But to reduce CO_2 emissions in the near term, Honda believes the best approach is to advance hybrid technology to mainstream customers." - **Takeo Fukui, President and CEO of Honda Motors at 2008 Paris Auto Show**

Fuel Cell Vehicles – Honda Solar Station



Electric Vehicle Map

Plug-in

Fuelcell electric

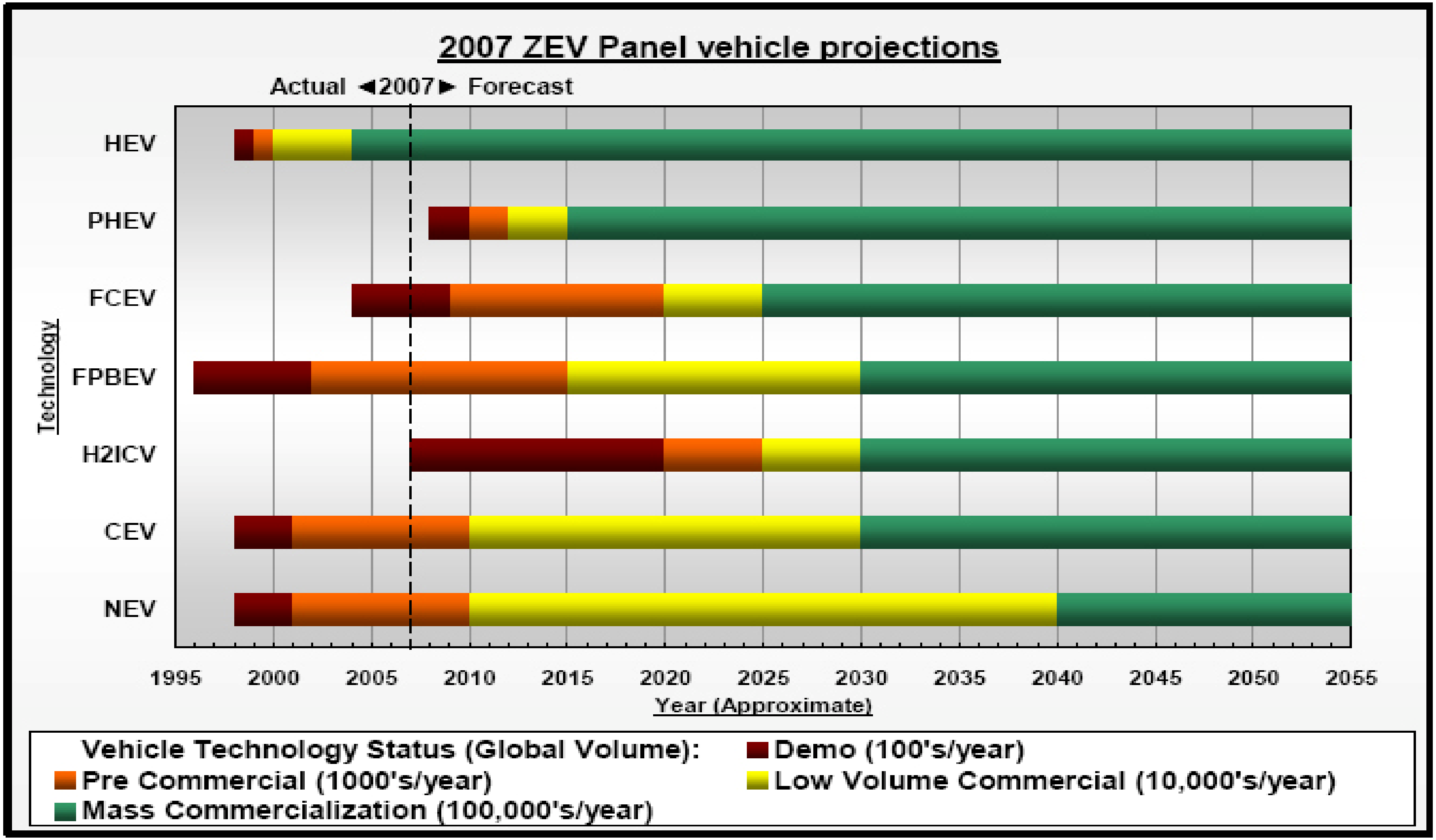
Electric

EREV-Hybrid

FCX	Tesla	iMiEV	Volt	Prius	Insight
					

Less Battery → **More Battery** ← Less Battery

Figure 3.1
Projected Achievement of Global Volumes



Source: Status Report on the California Air Resources Board's Zero Emission Vehicle Program, April 2007

Technological Challenges for Future EVs Batteries

- LiIon:
  - Cost
  - Option of leasing?
  - -40 to -20 C cold start
  - Next frontier: advanced batteries beyond LiIon
    - Revolution required but not in sight?
    - Toyota 2030 strategy:- solid-state and metal-air batteries
    - Prius NiMH 40-60 % SOC, i.e. 20 % usage for 10 yr life

- Better Place:
  - It this a consumer-oriented solution?
  - Low-population density in Ireland a negative

- Plug-in hybrids and domestic photovoltaics?

Technological Challenges for Future EVs Fuel cells and Grid

- Fuel cells
  - Cost of system and components
  - Membrane materials, cold start
  - Hydrogen production, storage and infrastructure
- Battery Charging and Grid Interface
  - Standardize infrastructure
  - Simplest = 230 V, 16 A on-vehicle plug-in chargers
  - Quantify impact on Electrical Grid
  - Optimize Energy Sources e.g. wind, solar, etc.
    - Satisfy driver “range anxiety”
  - Rapid charging for heavy-duty, fleet vehicles
  - All chargers unity power factor

WHERE FINBARR TAUGHT LET MUNSTER LEARN

Technological Challenges for Future EVs

Advanced Engine Technology

- Diesel hybrids
- Advanced engine technologies, e.g. latest Daimler concept

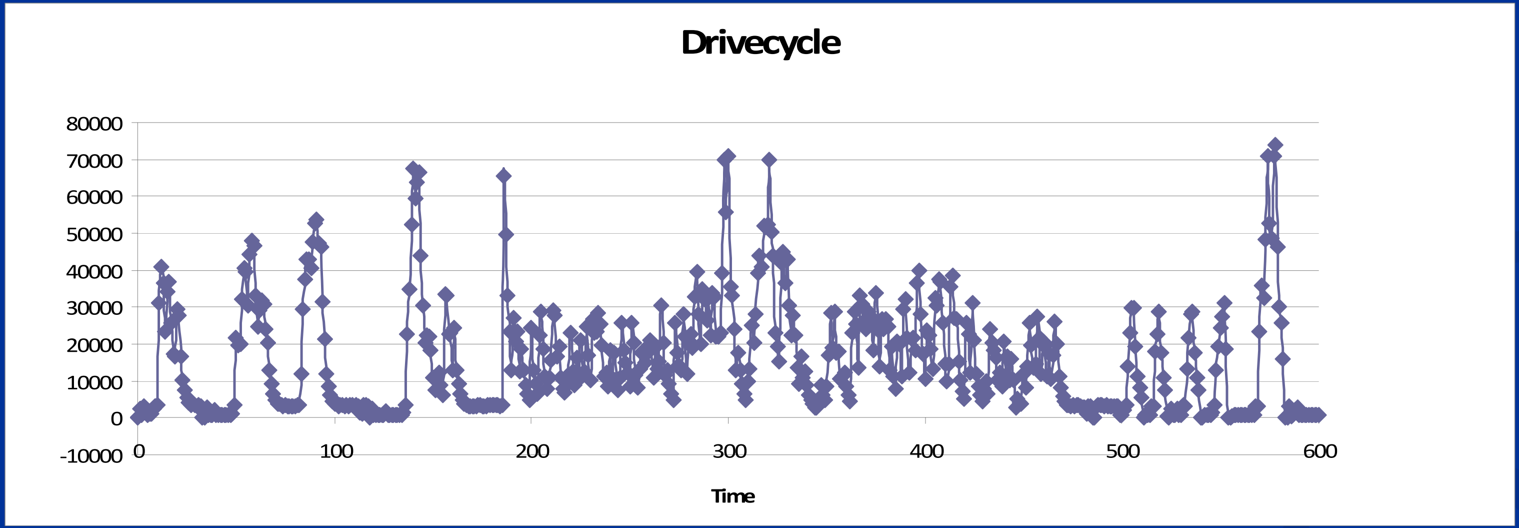
Advanced Power Electronics and Electric Drives

- Advanced Power Semiconductors:
  - Si, SiC, etc
- Passives – e.g. nanocrystalline
- Thermal management
- Machines
  - higher performance PMAC, SCIM, in-wheel motors

EV R&D at UCC

Power Electronics and Electric Drives

- Electric propulsion\charging architectures
- Power converters
- Vehicle Performance: cost, range, efficiency



- Transportation Policy (biofuels, carbon emissions)
- Grid impact

Industrial Policy – Michigan & USA

- US DOE Freedom CAR Partnership
- Detroit, Michigan investing heavily in LiIon startups
  - E.g. Sakti3 at the University of Michigan, Ann Arbor
- **<u>MI to produce lithium-ion car batteries</u>** Jan. 2009.

  "A123 Systems applying for $1.84 billion in federal loans to build the nation's first commercial-scale lithium-ion advanced storage systems manufacturing plant in Michigan."

Summary

- Presented on vehicles with electrical propulsion
- Provided a historical perspective on GM EV1
- Diverse solution set from major manufacturers.
  - 2010-2015: Urban BEV, EREV, PHEV
  - 2015-2025: FCEV, FPEV
- Identified key technical challenges

Conclusion

- A rapidly-moving automotive revolution
- Global resourced
- Significant spinoff technologies in storage and energy conversion

Thank you

Questions?