

# The ZEV Technology Objective: Transportation Without Petroleum

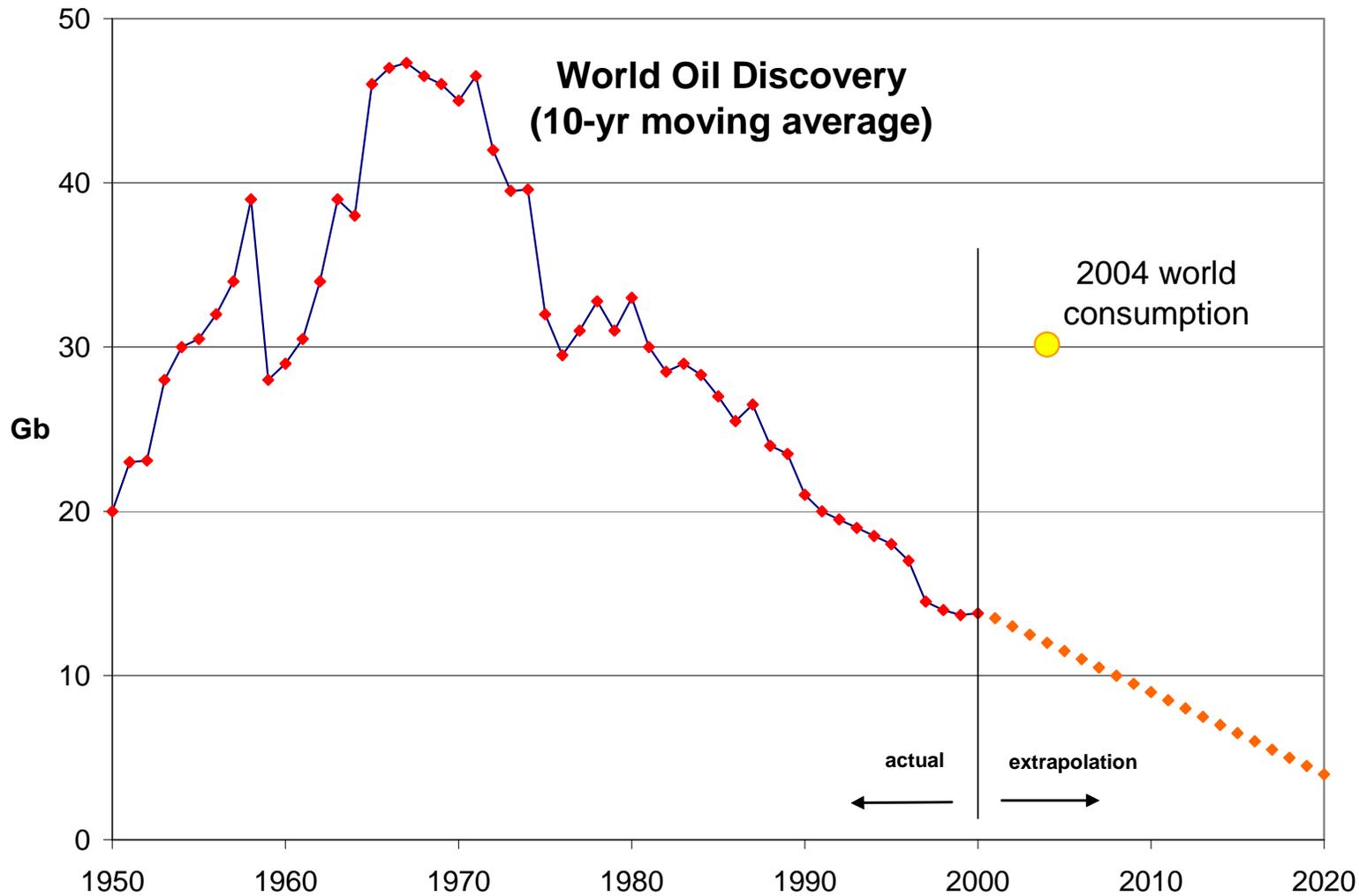
CARB ZEV Technology Symposium  
Sacramento, CA  
September 26, 2006

Tom Gage  
AC Propulsion, Inc.

<http://www.acpropulsion.com>



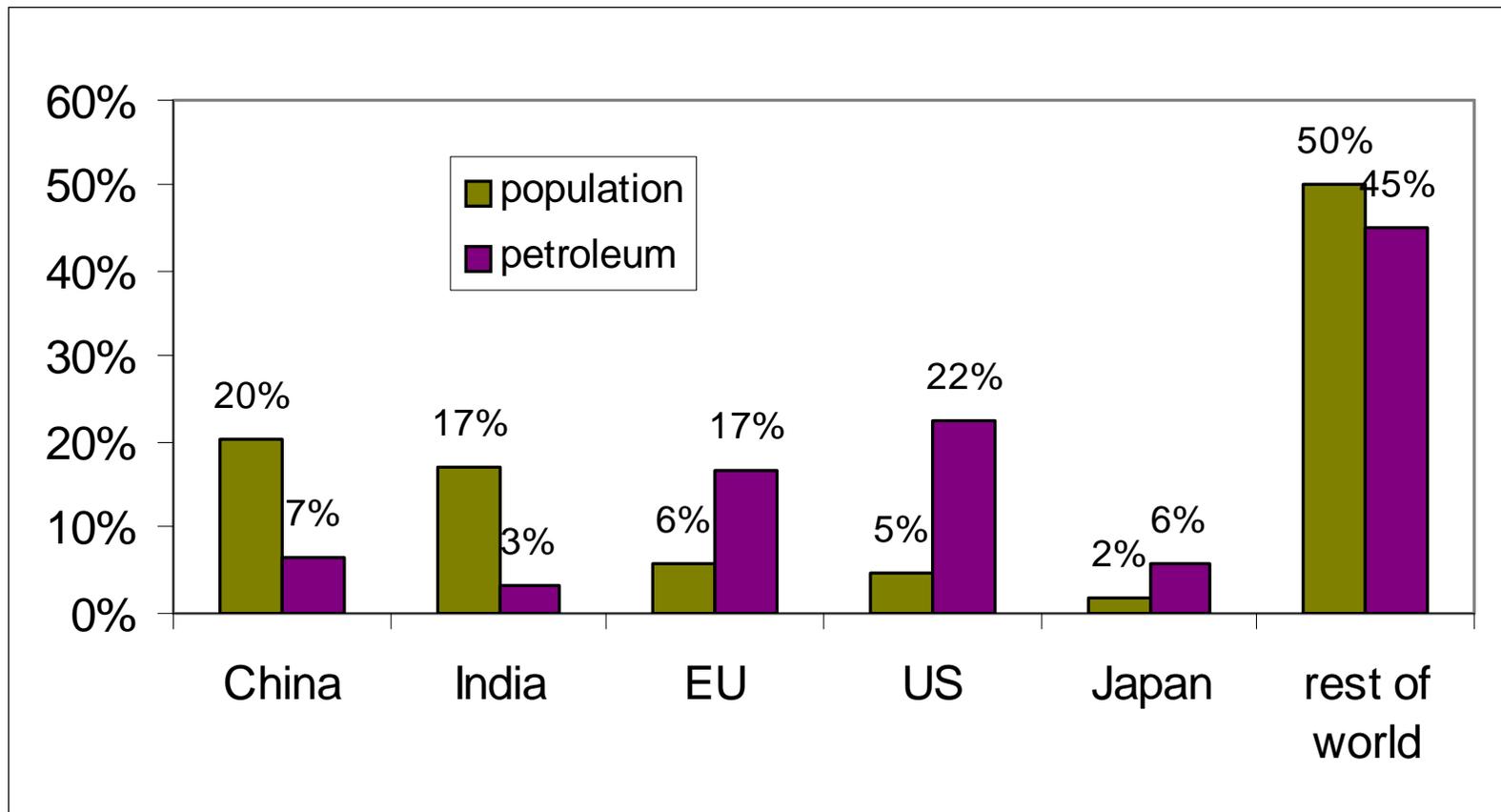
# World Oil Discovery In Decline Since 1970



Source: Peak Oil, C.J. Campbell

# World Population and Petroleum Consumption

---



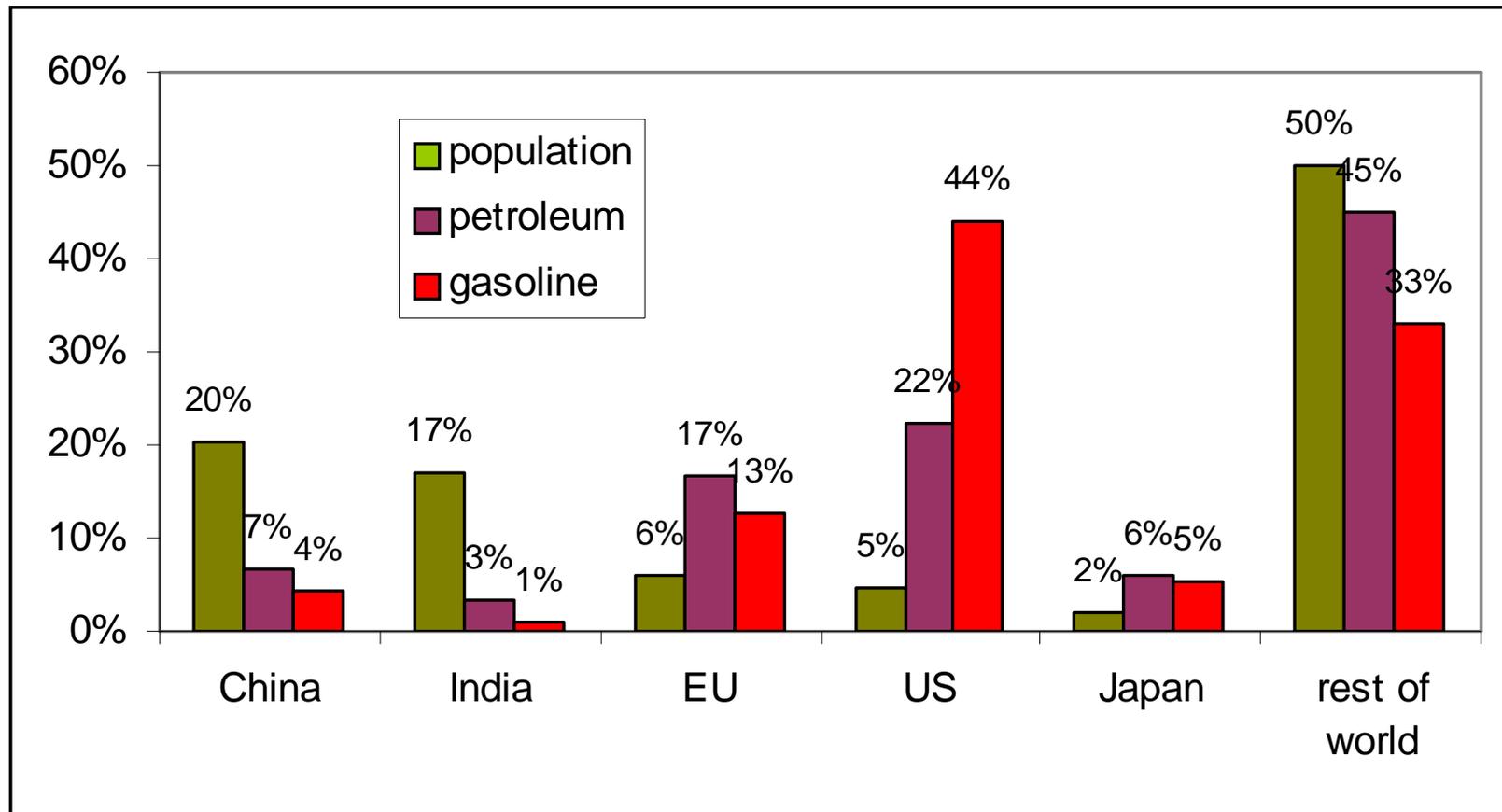
source: Population Reference Bureau  
Energy Information Administration

# Petroleum: A Hierarchy of Value

---

1. Aviation
2. Petrochemicals
3. Maritime shipping
4. Long haul trucks
5. Rail transport
6. Long trips by car
7. Commuting
8. Picking up the kids
9. Driving a Hummer

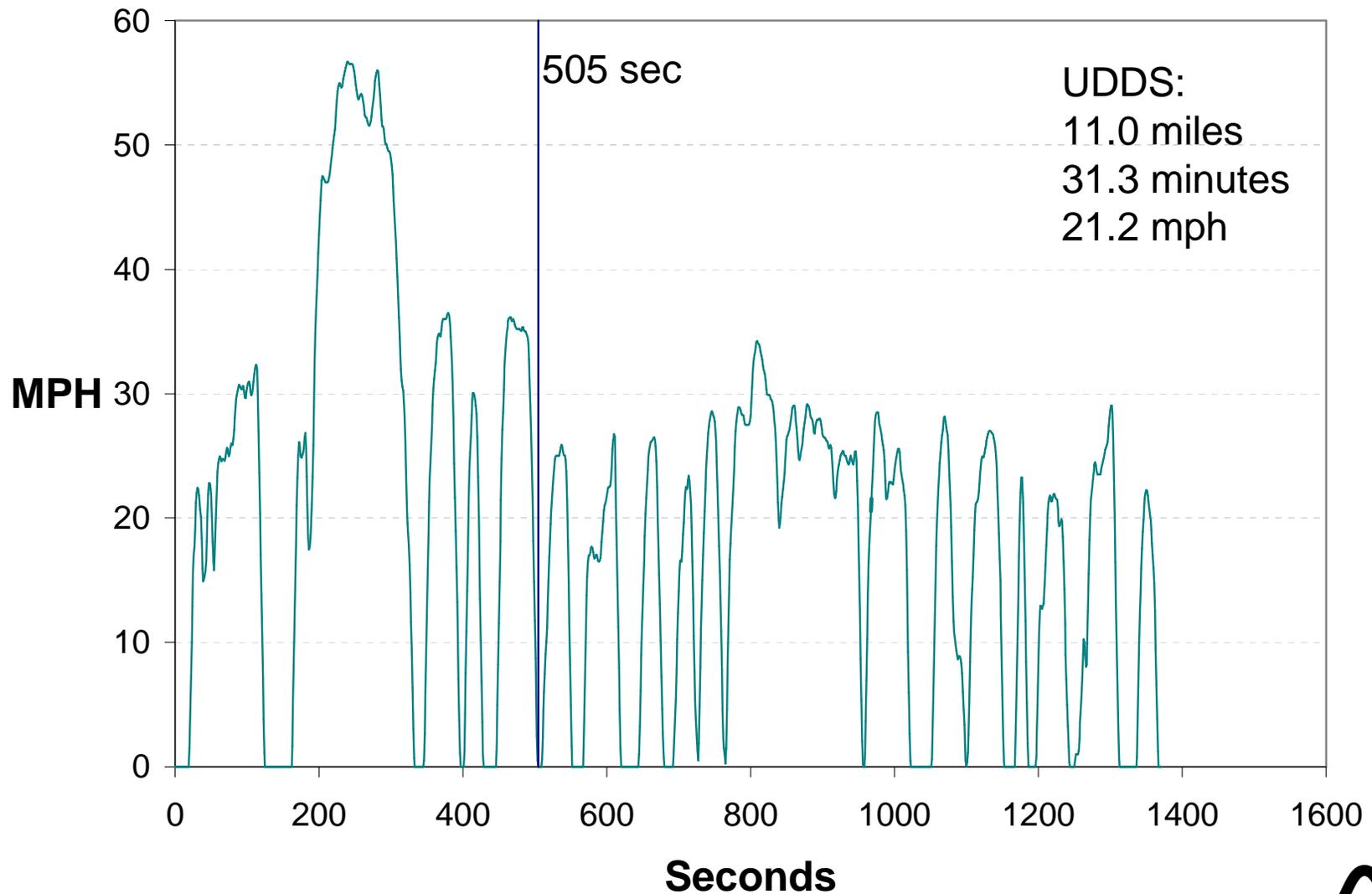
# World Population and Gasoline Consumption



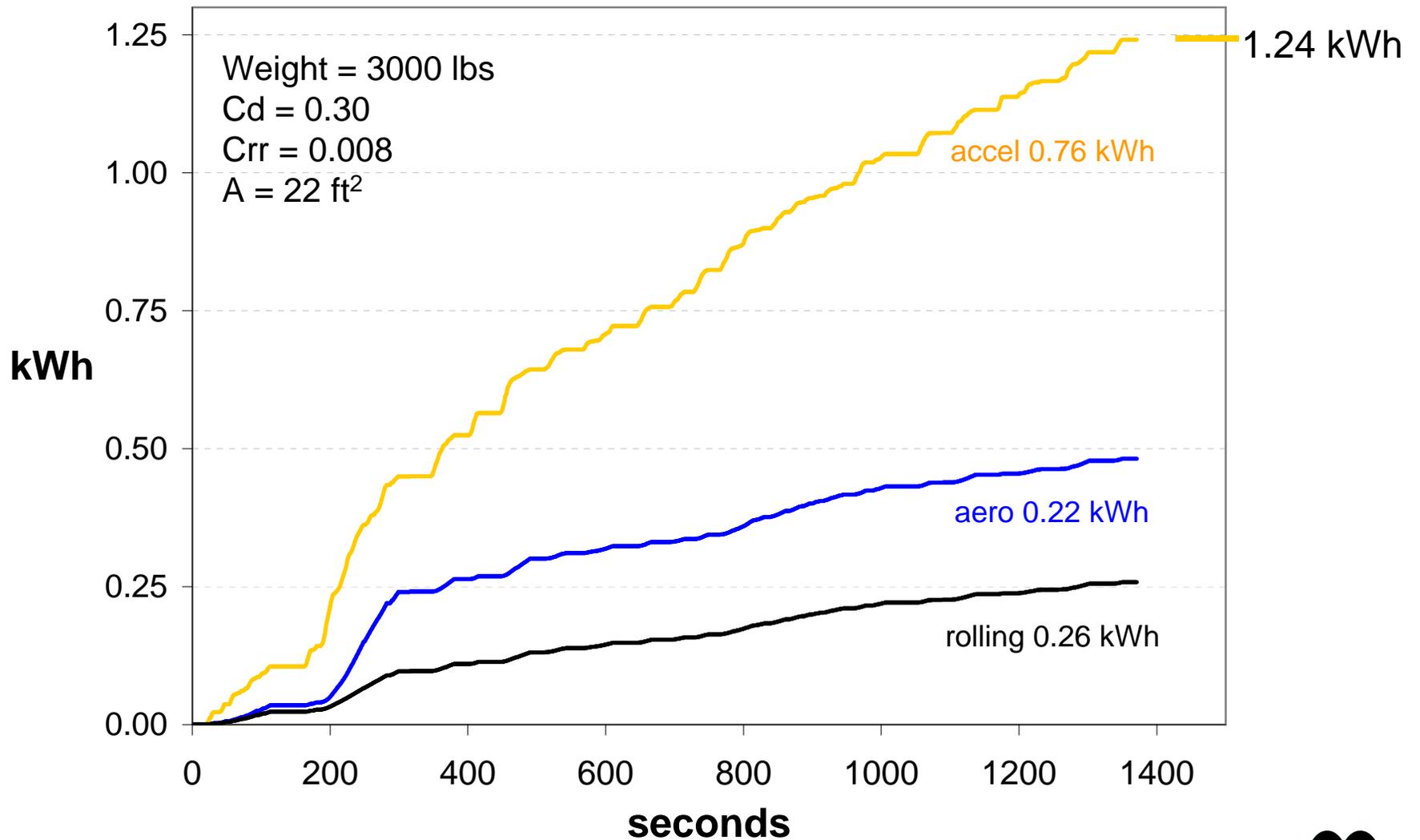
source: Population Reference Bureau  
Energy Information Administration



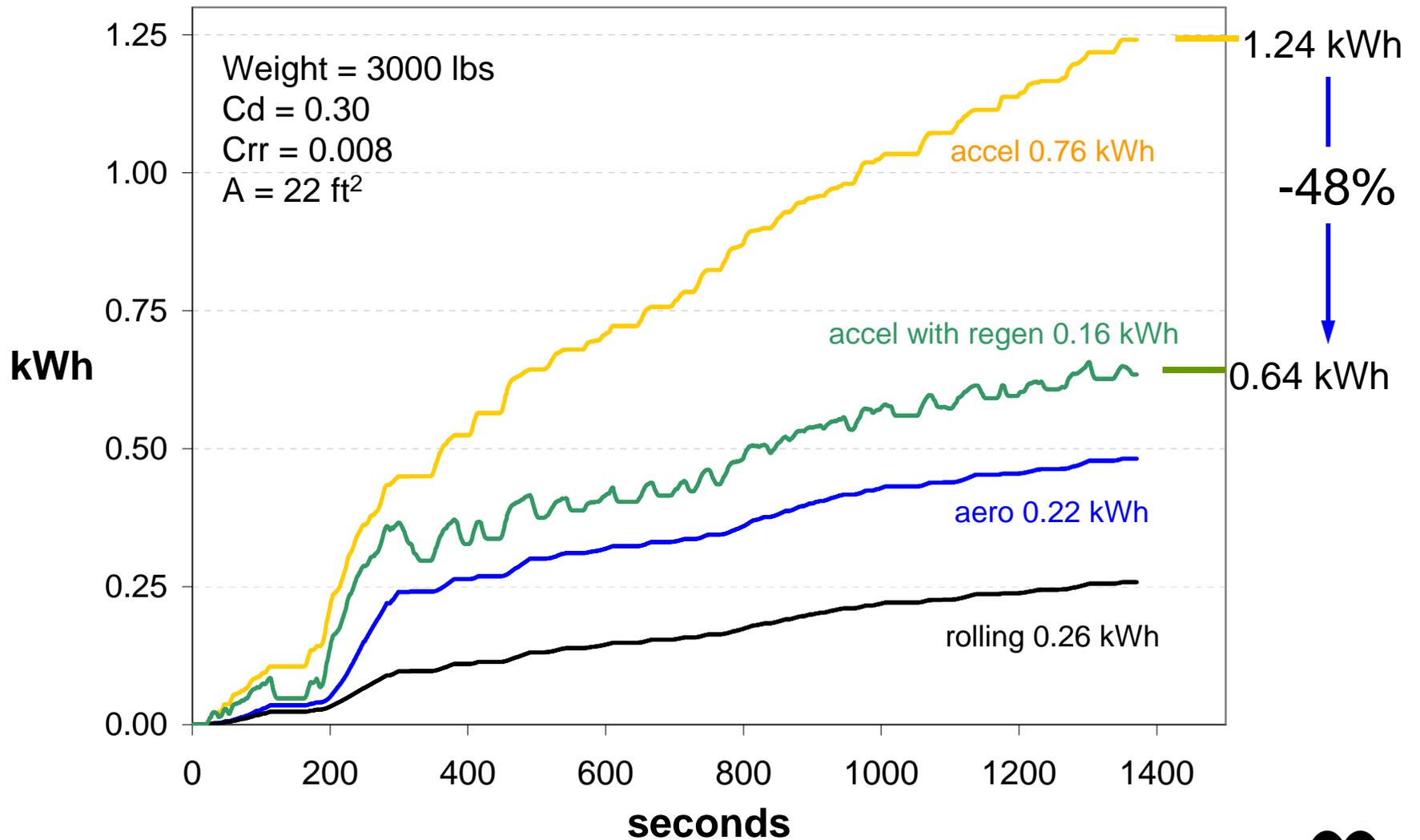
# Urban Dynamometer Driving Schedule (UDDS)



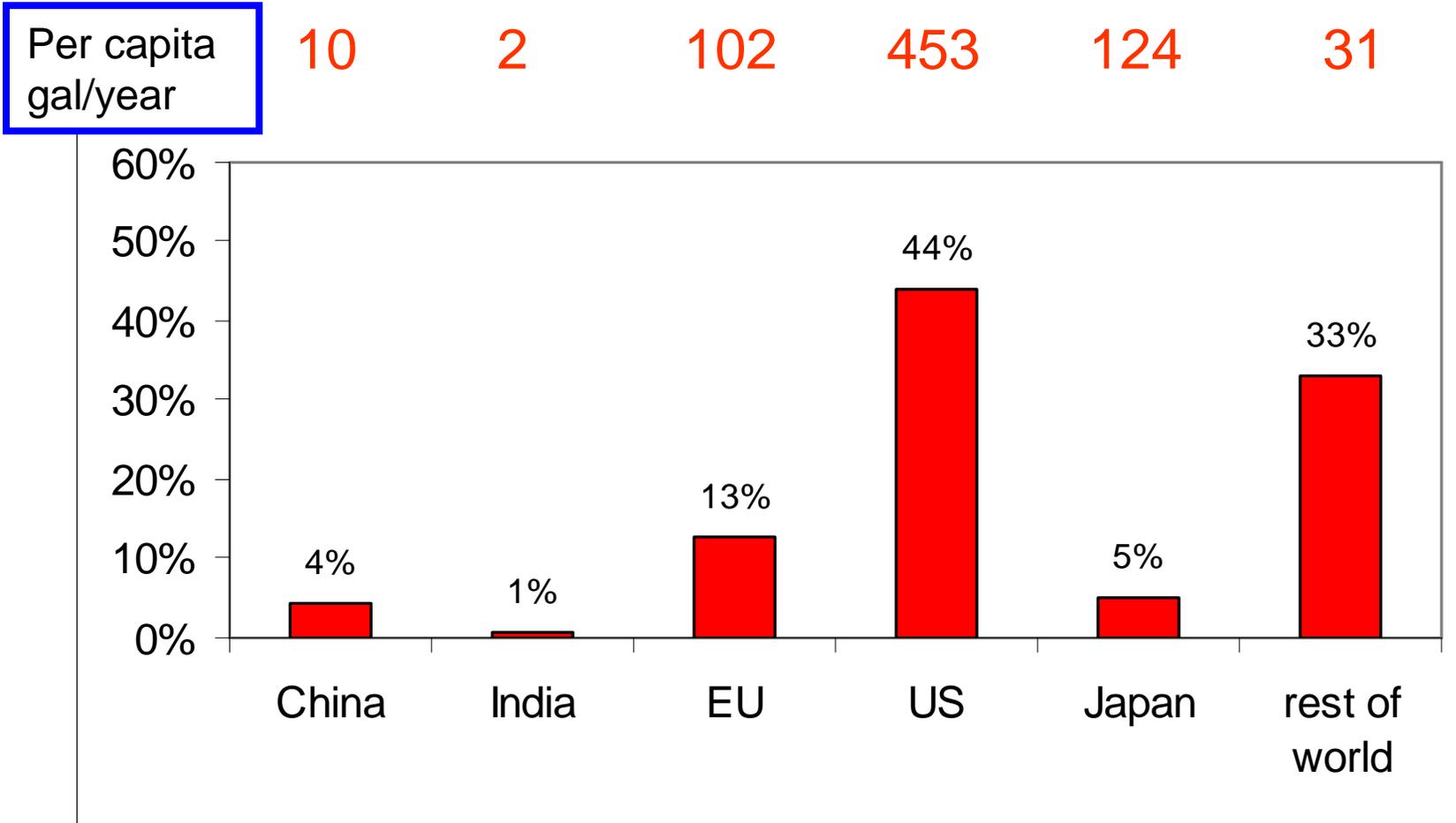
# Acceleration Consumes Energy



# Regenerative Braking Recovers Energy



# World Gasoline Consumption



source: Population Reference Bureau  
Energy Information Administration



# Fuel Substitution in Addition to Conservation

---

- ★ Electricity
- ✓ Natural gas
- ✓ Ethanol
- ✓ Methanol
- ✓ Bio-diesel
- ✗ Hydrogen

# Hydrogen Hype

---

“...While oil is a finite resource, hydrogen is infinite, it’s in water, it’s everywhere, the most abundant element in the universe ...”

- CBS Evening News, September 12, 2006

# Electric Reality

---

- Established and available infrastructure
- Off-peak capacity
- Diverse, secure, efficient resources, including renewables
- Low emissions
- Suitable for most driving
- Proven vehicle technology

# Electric Power Mix

---

	2003	
	CA	US
Natural Gas	37%	17%
Large Hydro	16%	7%
Coal	21%	51%
Nuclear	15%	20%
Eligible Renewables	11%	2%
Petroleum	0%	3%
	<hr/> <hr/> 100%	<hr/> <hr/> 100%

source: CEC, EIA

**Grid-Connected Vehicles:  
Transportation Without Petroleum**

# 8,000,000 Plug-in Vehicles In US

---

Recreational vehicles access grid power at over 16,000 RV parks nationwide



- Safe, simple, reliable hookups
- Up to 12 kW at each hookup
- More RVs than FFVs + NGVs
- Over 30 million people with RV experience

source: RVIA

# EVs, PHEVs Can Use the Same Simple Hookups

Charging at RV park, Coalinga, CA



12 charging pedestals, Pasadena, CA



# GM Impact - 1989

---

- Alan Cocconi developed the drive system for the General Motors Impact EV prototype.



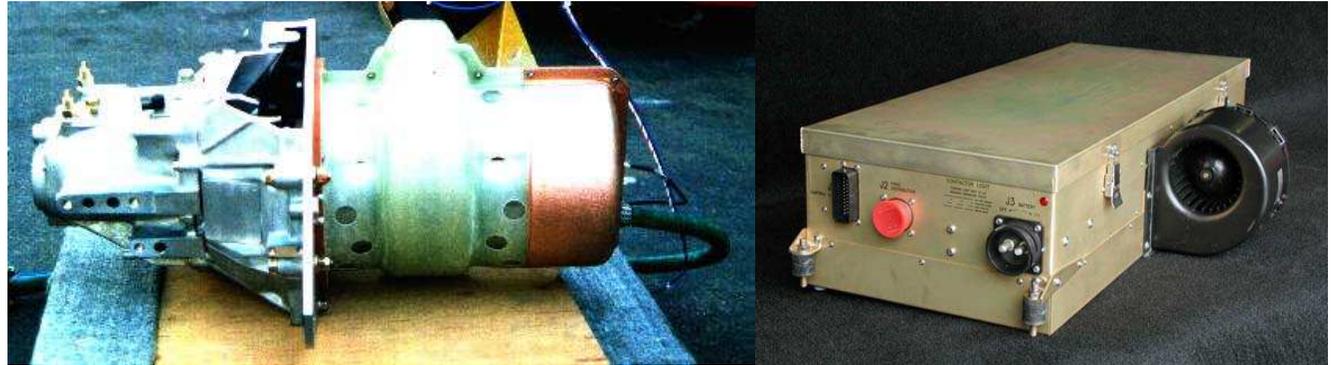
Two design objectives:

- high efficiency
- high performance

# AC150 Drive System - 1994

---

**150 kW drive**  
**20 kW charge**  
**88%-92% eff**



**Civic EV with AC150**  
**0-60 in 6.2 secs**  
**0-135,000 miles in 12 yrs**  
**0 emissions**

# tzero - 1997

---



tzero vs:  
Ferrari  
Porsche  
Lamborghini



# FIA Electric Land Speed Record - 1999

---

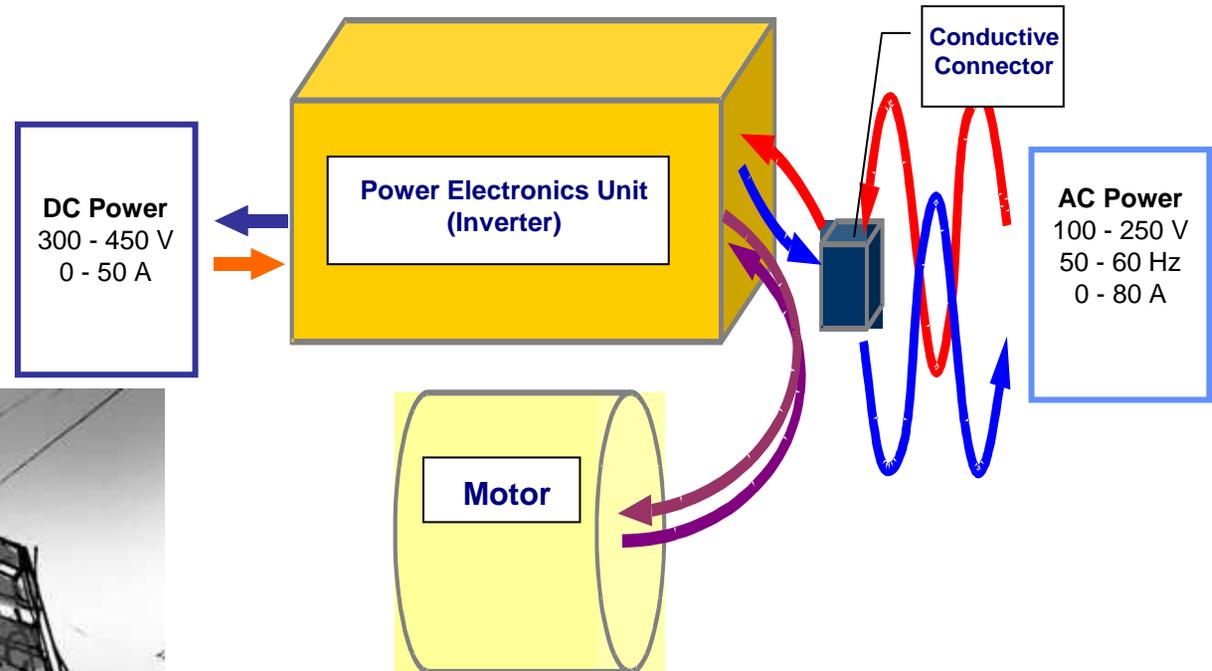
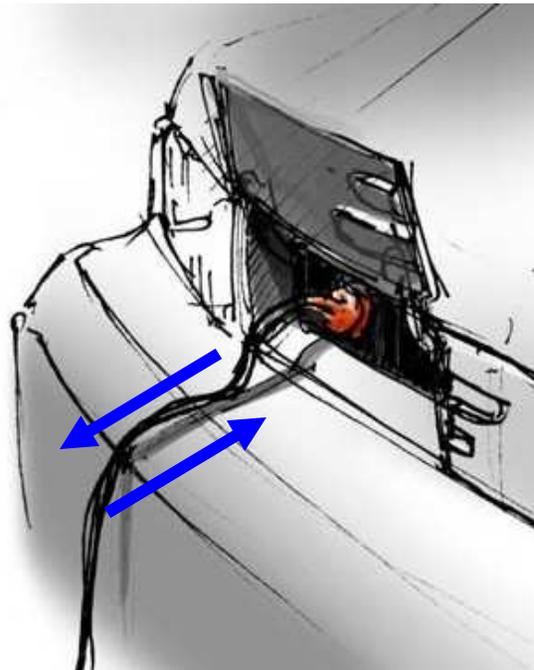


Two AC-150s  
6,000 sub-C NiMH cells  
400 hp, 254 mph



# AC150 Gen2 Bidirectional Charger – 2000

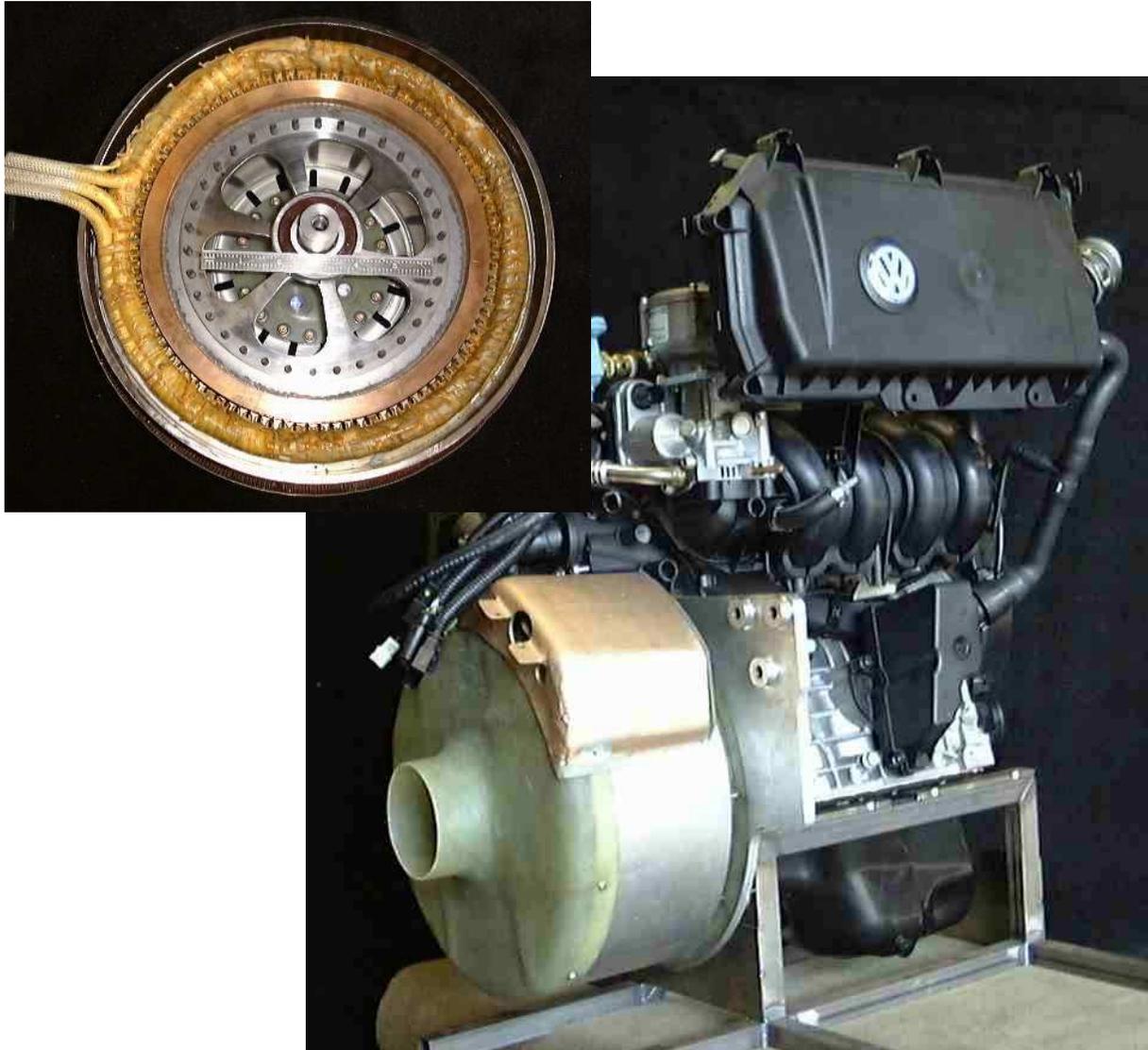
Power can flow to or from vehicle



- Grid-tied
- Stand-alone

# Plug-in Hybrid Power Unit - 2001

---



- 35kW, 350V, 3500 rpm
- Full emission controls
- Adaptable to other engines, power levels, applications

# CARB-Sponsored PHEV - 2002

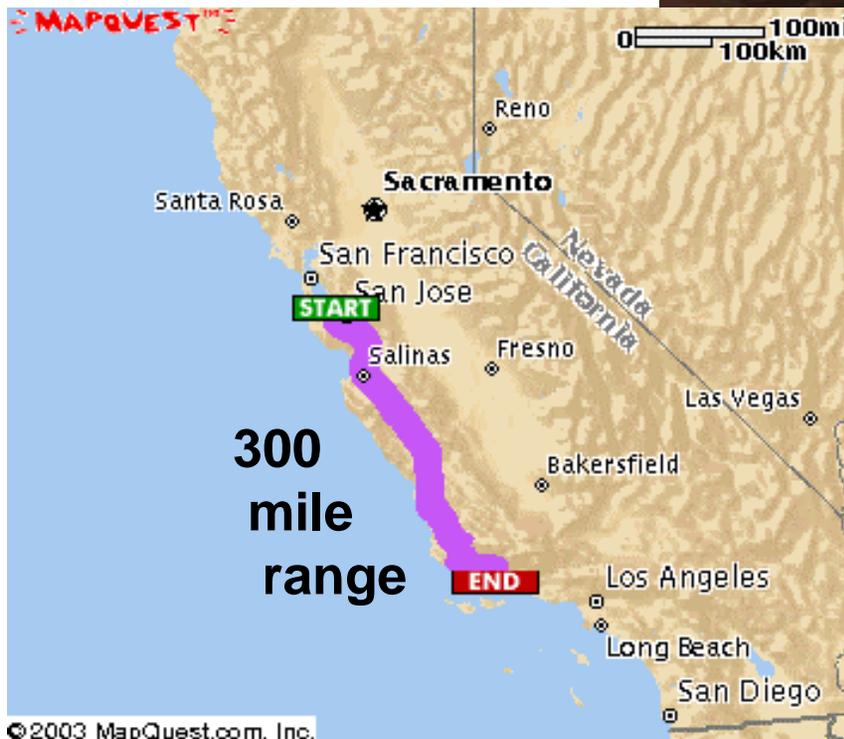
---

- 2003 Michelin Challenge Bibendum - San Francisco



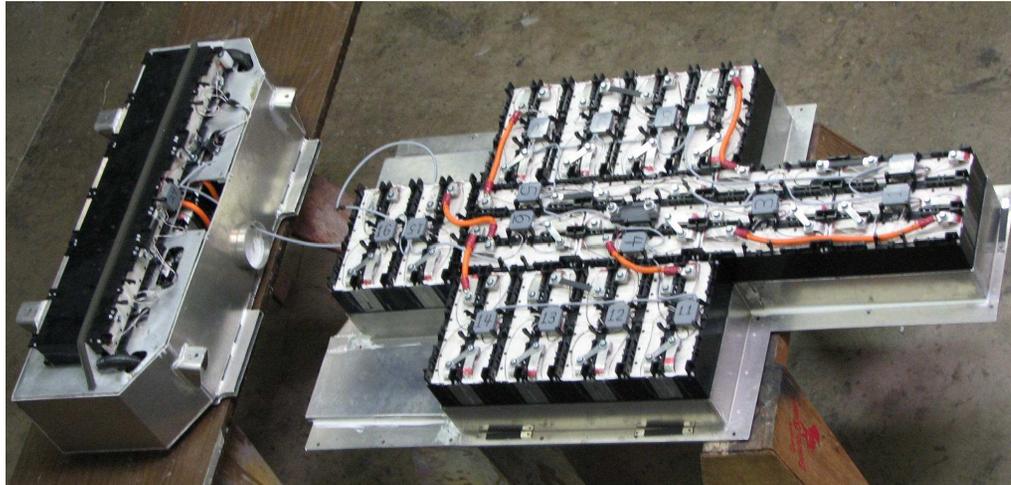
# Li ion tzero - 2003

6,800 18650 Li Ion cells  
50 kWh, 165 kW  
350 kg



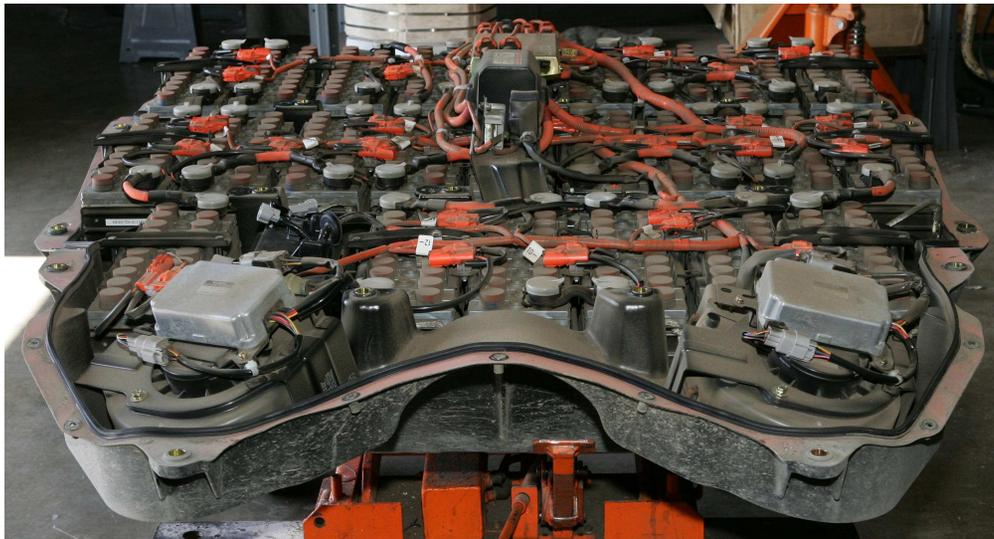
# Li Ion Battery Allows Practical EV Conversions

---



## Li Ion

- 35 kWh
- 320 kg
- 265 liter



## NiMH

- 25 kWh
- 380 kg
- 270 liter (est)

# The AC Propulsion eBox

---



## Features

- AC Propulsion drive system
- 35 kWh Li Ion battery
- Fast charging
- V2G capable
- Regenerative braking
- Onboard battery diagnostics
- A/C, full power

## Performance

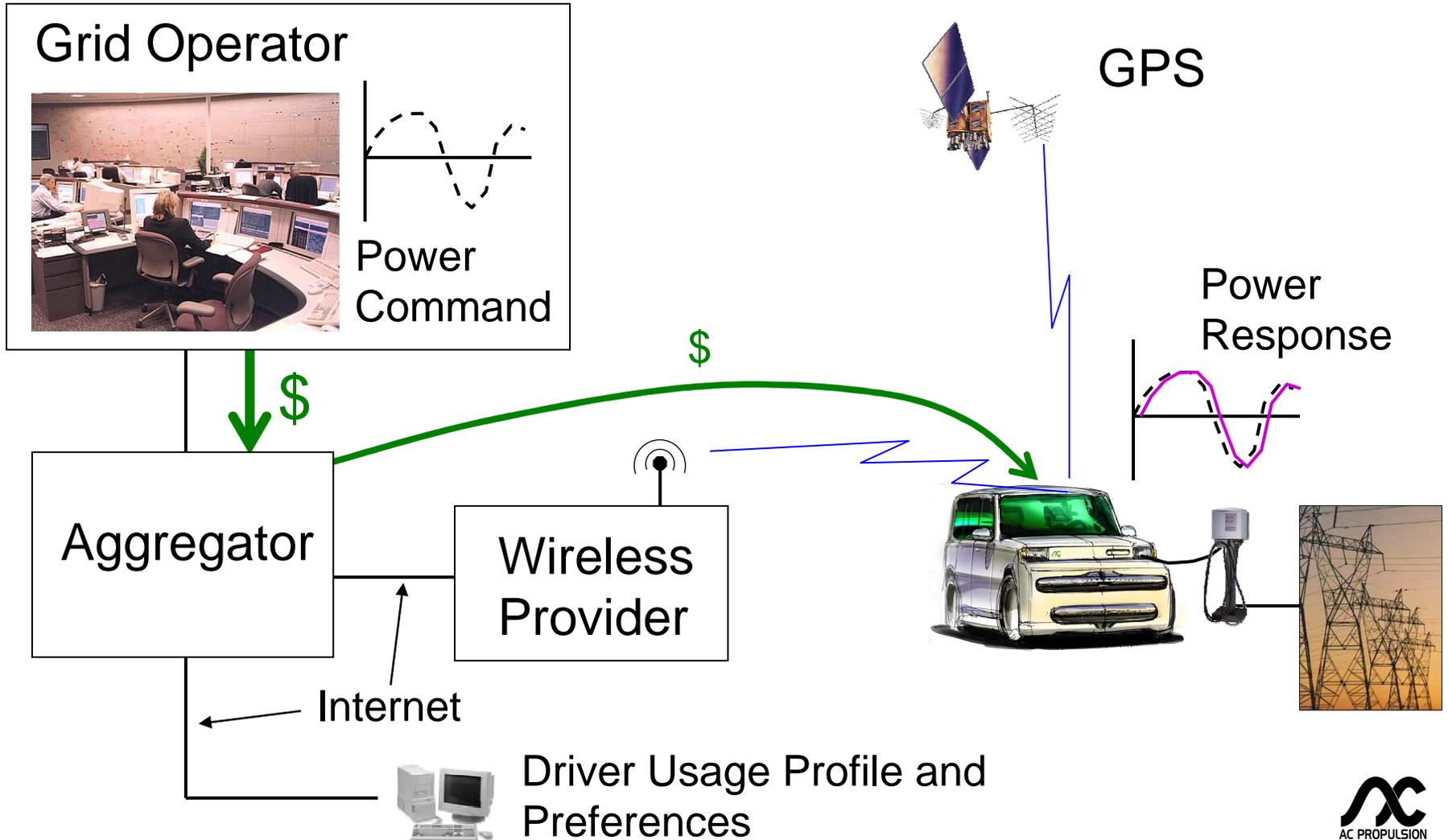
- 150 mile range
- 0-60 ~7 sec
- 95 mph
- 1 mile/min charging

## Economy

- 250 Wh/mi (AC)
- 3¢/mi electricity cost
- 20¢ - 40¢/mi battery cost

# eBox is Ready for V2G

Connected vehicles serve as distributed energy resource (DER)



# A Small Fleet of eBoxes Buffers Renewables

---

100 kW peak power, intermittent



10 to 15 kW dispatchable power from each car

+



=

Higher reliability from intermittent renewables

# Efficient Package

---



	<u>Curb weight</u>	
2750 lbs	Gasoline	2400 lbs
3550 lbs	Electric	3050 lbs

# Roomy Interior

---



3 happy six-footers  
in eBox's back seat

# People Like Electric Vehicles

---

Driver quotes from AC Propulsion prototype demo,  
Long Beach, November 2003

- “very good acceleration, quite good, actually better than my car”
- “I do like the strong regen(enerative braking). I didn’t think I would. You really have much more control”
- “I like this one, you have full accel and decel on one pedal”
- “really amazing power, no shifting”
- “wow, wow, wow-wow-wow, it really goes. I’m amazed, wow, like a race car, unbelievable”
- “It’s definitely the strongest EV I’ve ever driven”
- “it just drives beautifully”

# The Ultimate ZEV Technology Objective

---



# The Ultimate ZEV Technology Objective

---



<http://www.stefanoparis.com>

