Electric Vehicles: Transportation Without Petroleum

Symposium on Electric Vehicles

Center for Information Technology

Research in the Interest of Society

University of California, Santa Cruz

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http://www.acpropulsion.com

AC PROPULSION

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

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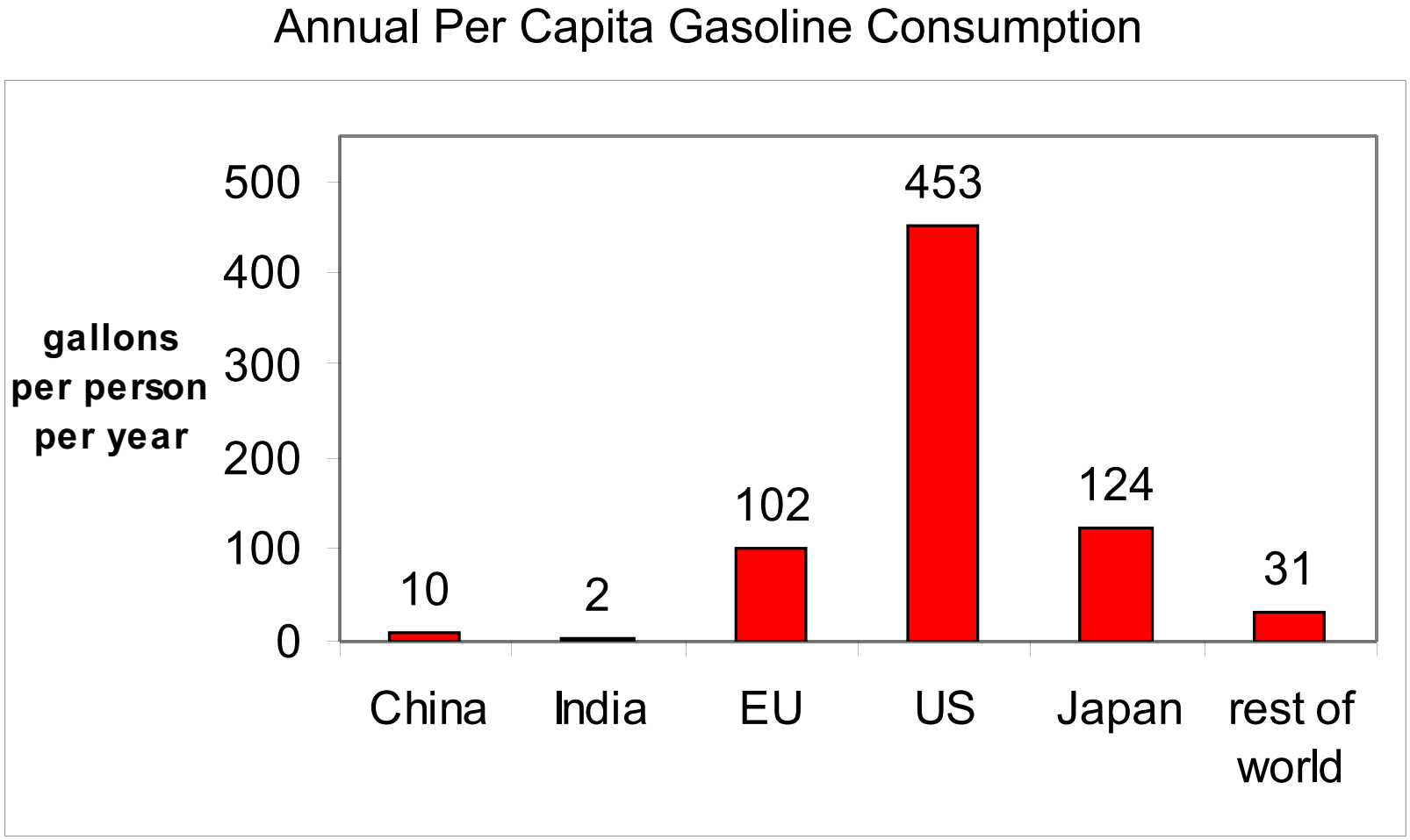
US Gasoline Addiction: Undeniable



source: Population Reference Bureau

Energy Information Administration

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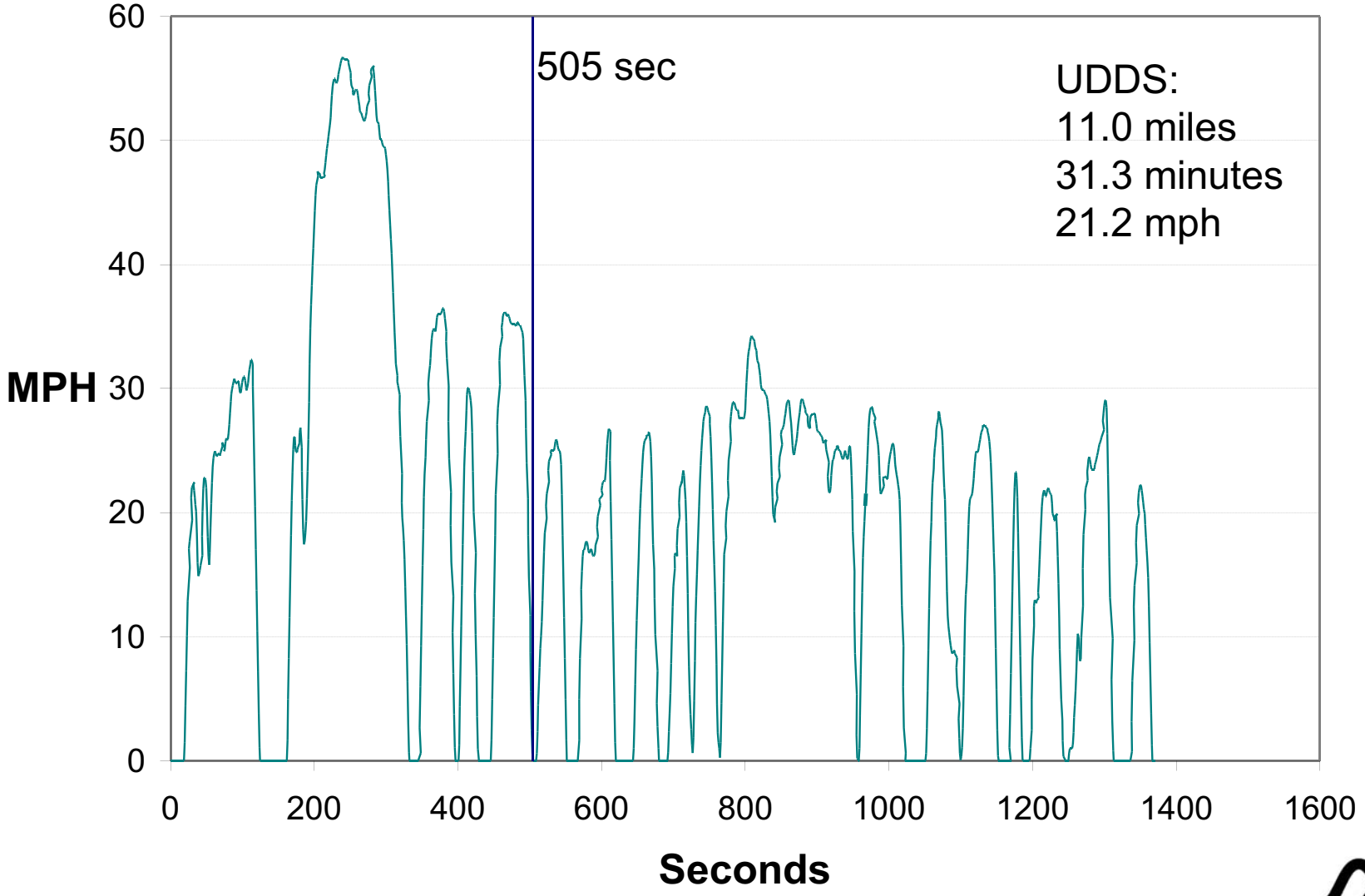
Urban Dynamometer Driving Schedule (UDDS)



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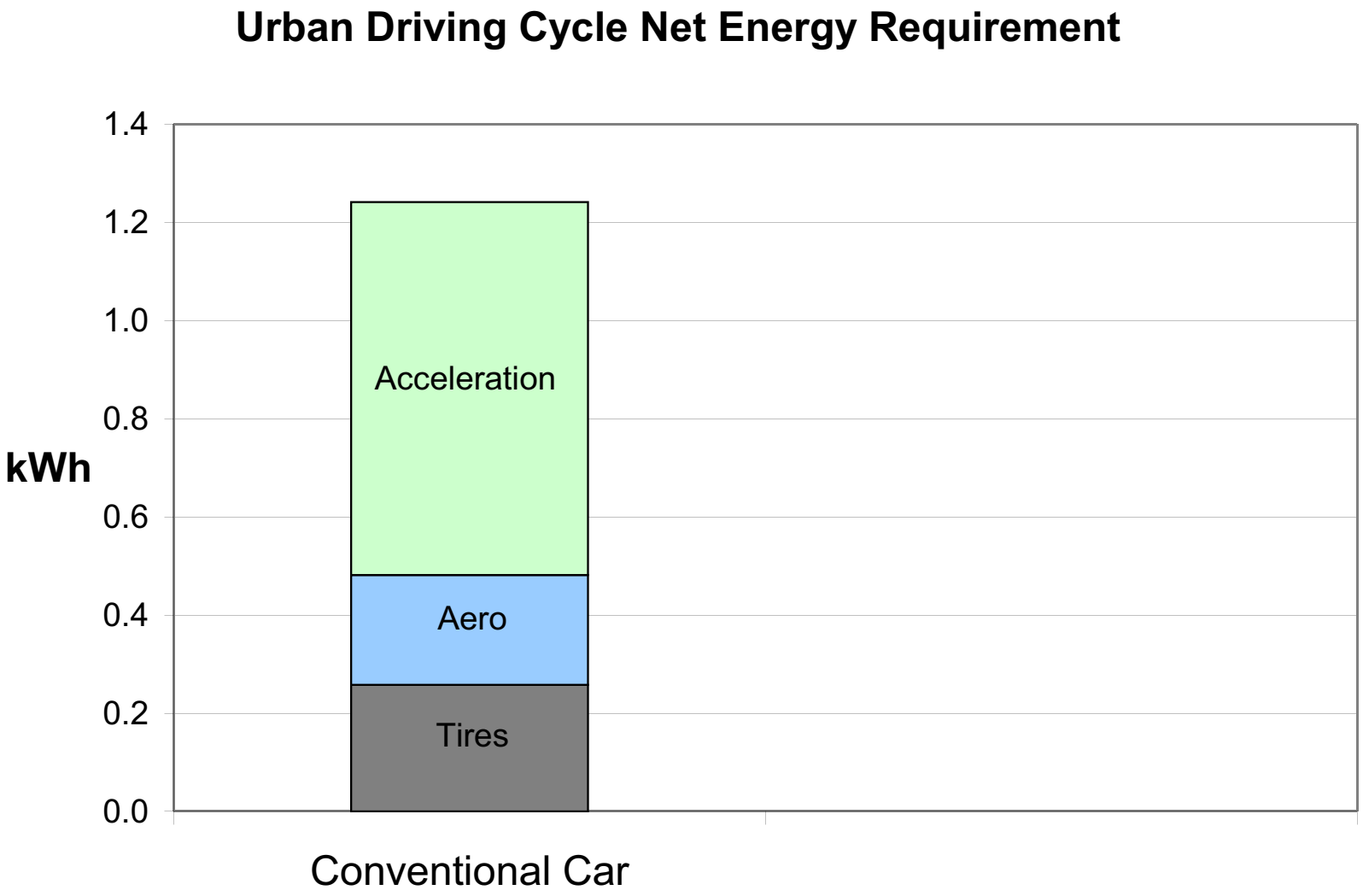
Acceleration Consumes Most Energy



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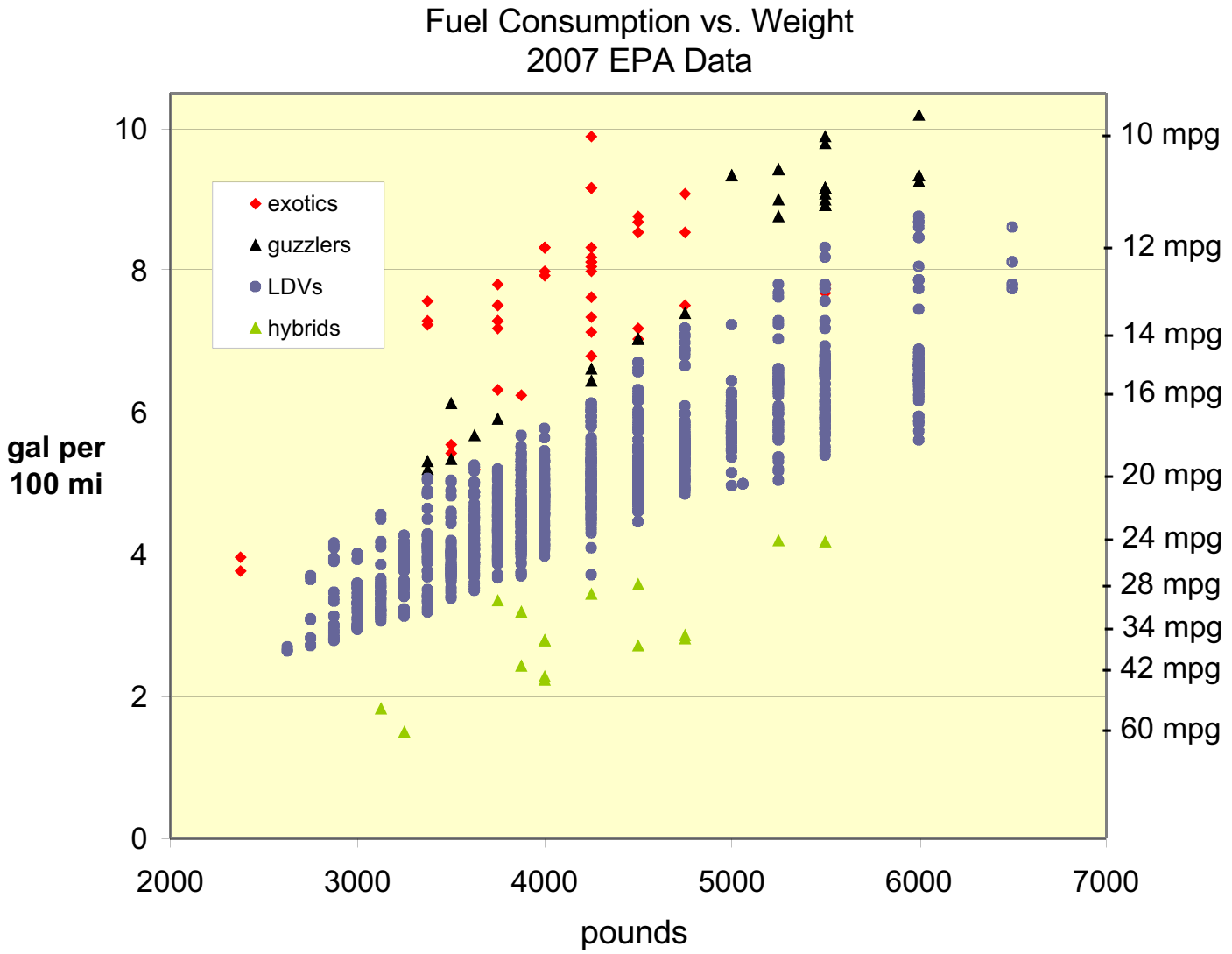
Vehicle Weight Determines MPG



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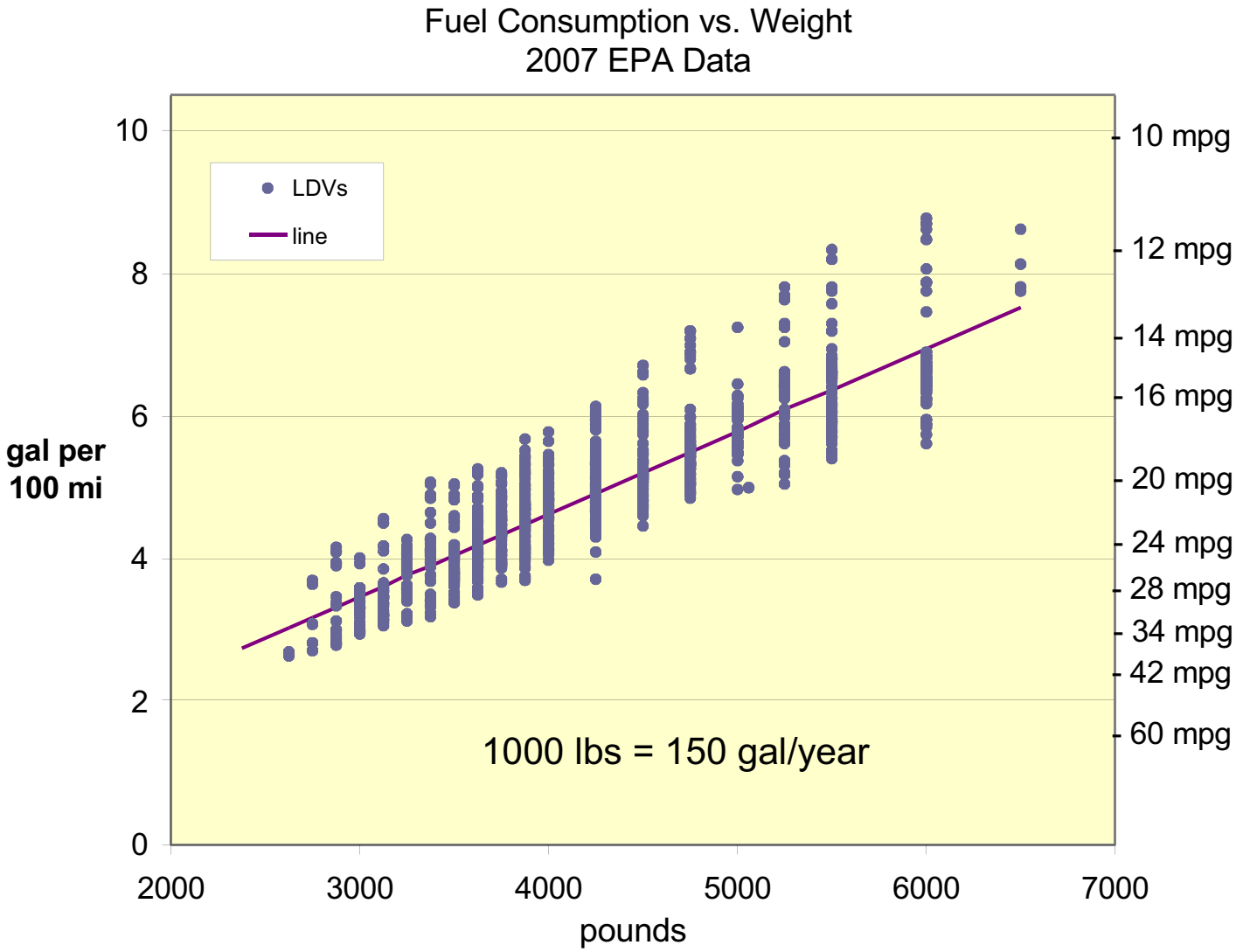

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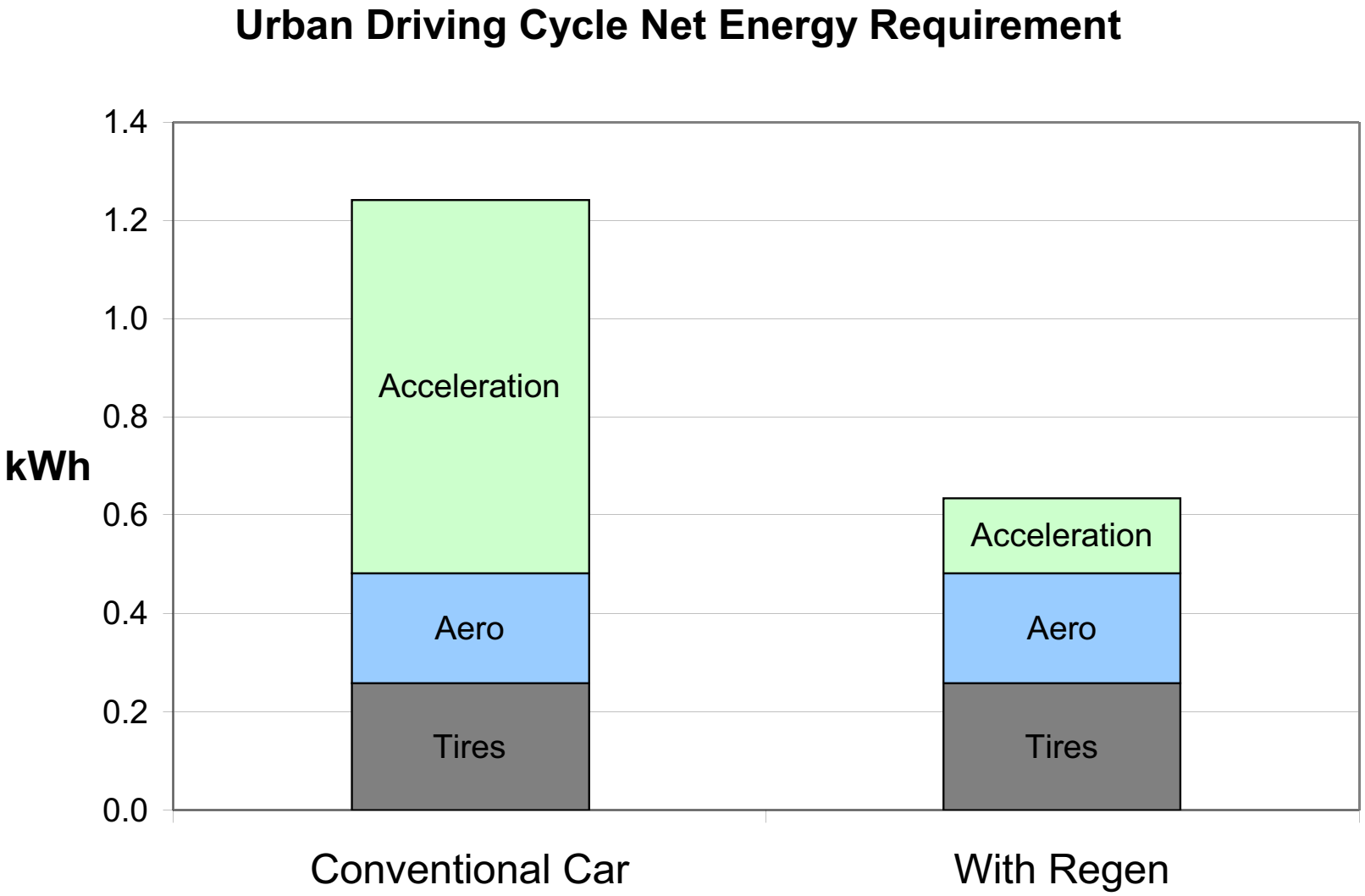
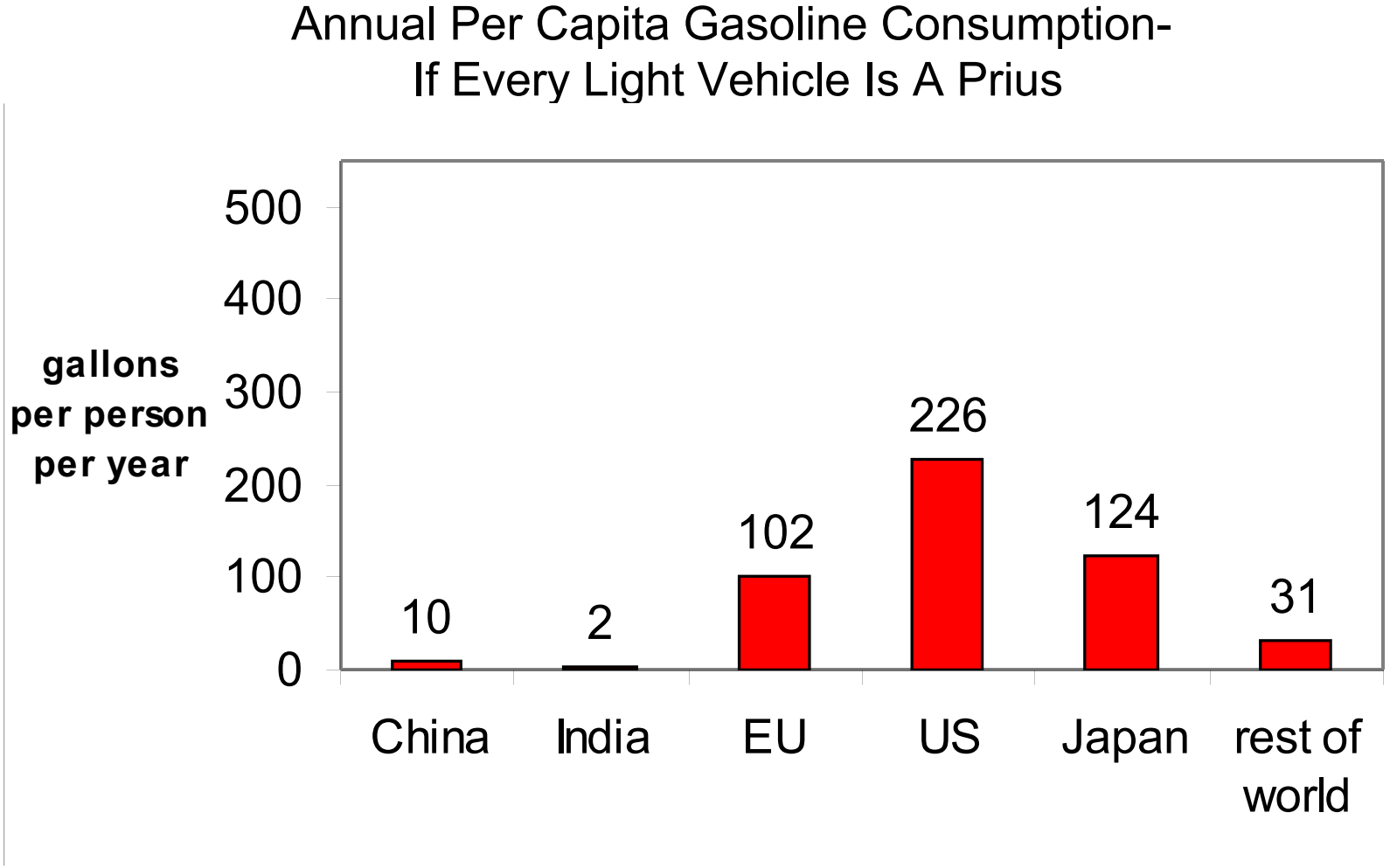
Regenerative Braking Recovers Energy



AC PROPULSION

US Gasoline Addiction: Unsustainable



source: Population Reference Bureau

Energy Information Administration

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Fuel Substitution in Addition to Conservation

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

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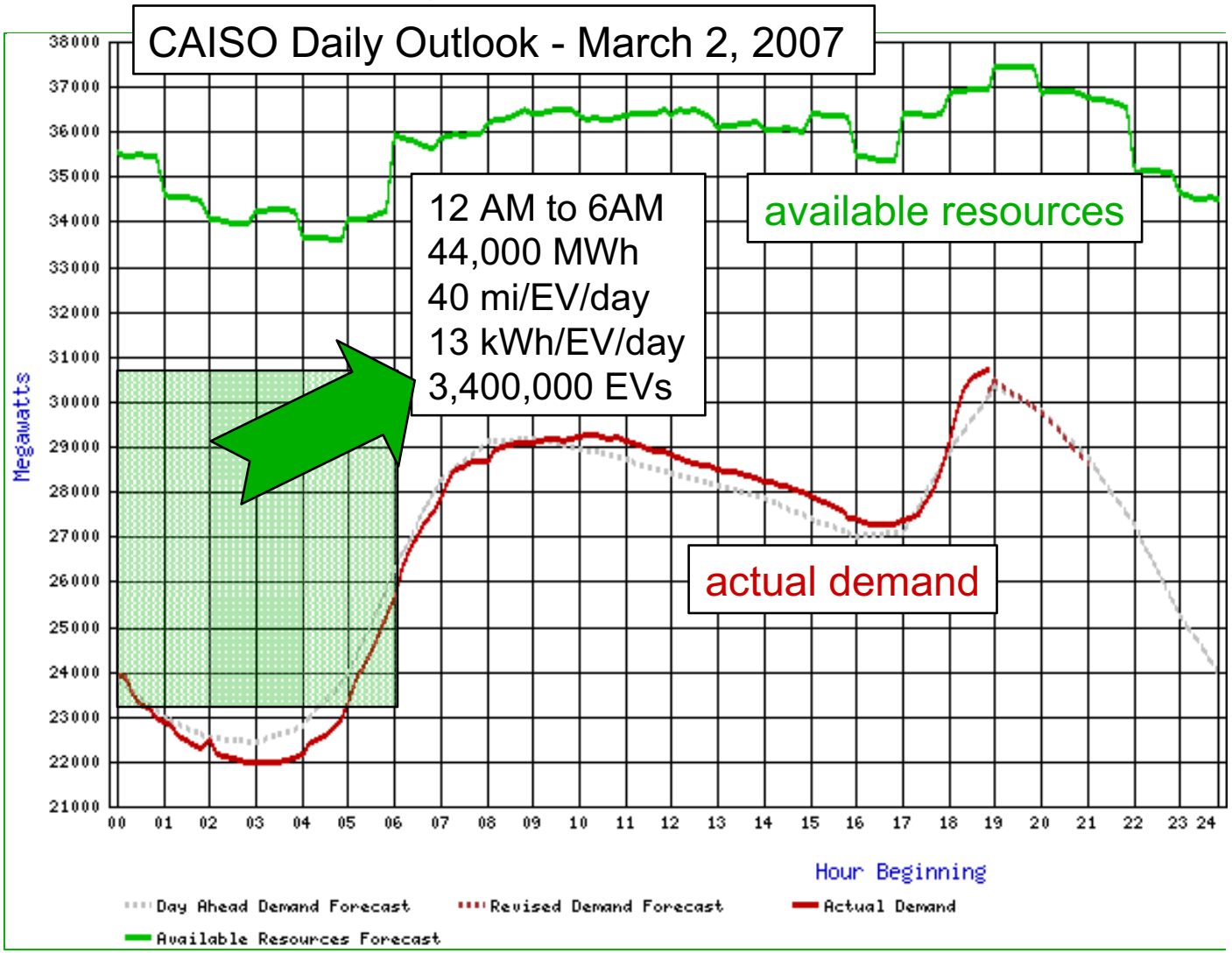
Electricity: The Best Alternative to Gasoline

- Off-peak capacity
- Diverse energy resources – without oil
- Low emissions
- Suitable for most driving
- Proven vehicle technology
- Established and available infrastructure

AC PROPULSION

Off-Peak Capacity



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Electricity

Diverse Energy Resources – Without Oil

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

source: CEC, EIA

Plug-In Vehicles:
Transportation Without Petroleum

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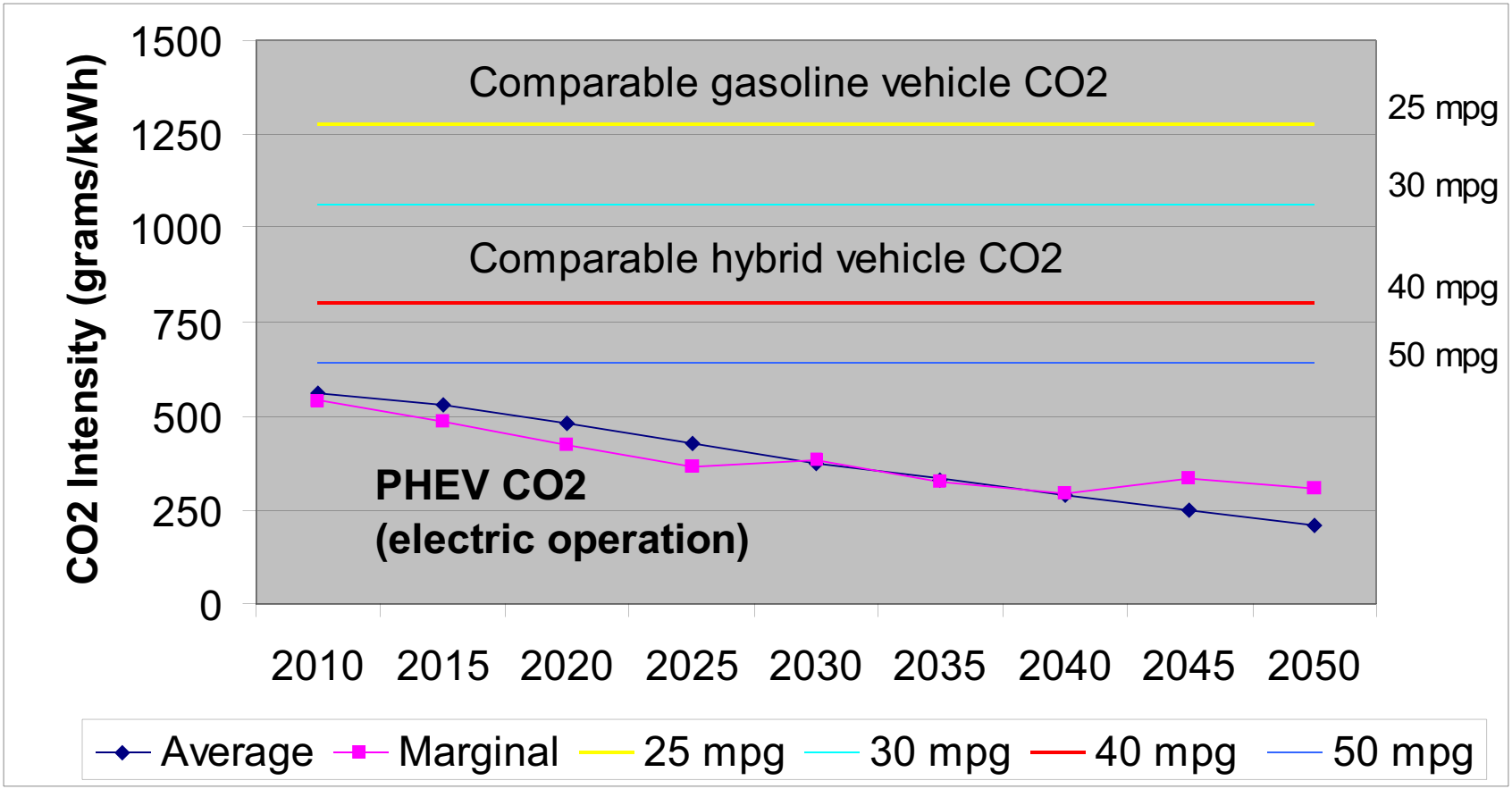
Electricity

Low Emissions

Joint NRDC/EPRI Environmental Analysis
Preliminary National CO2 Results



Source: NRDC, EPRI

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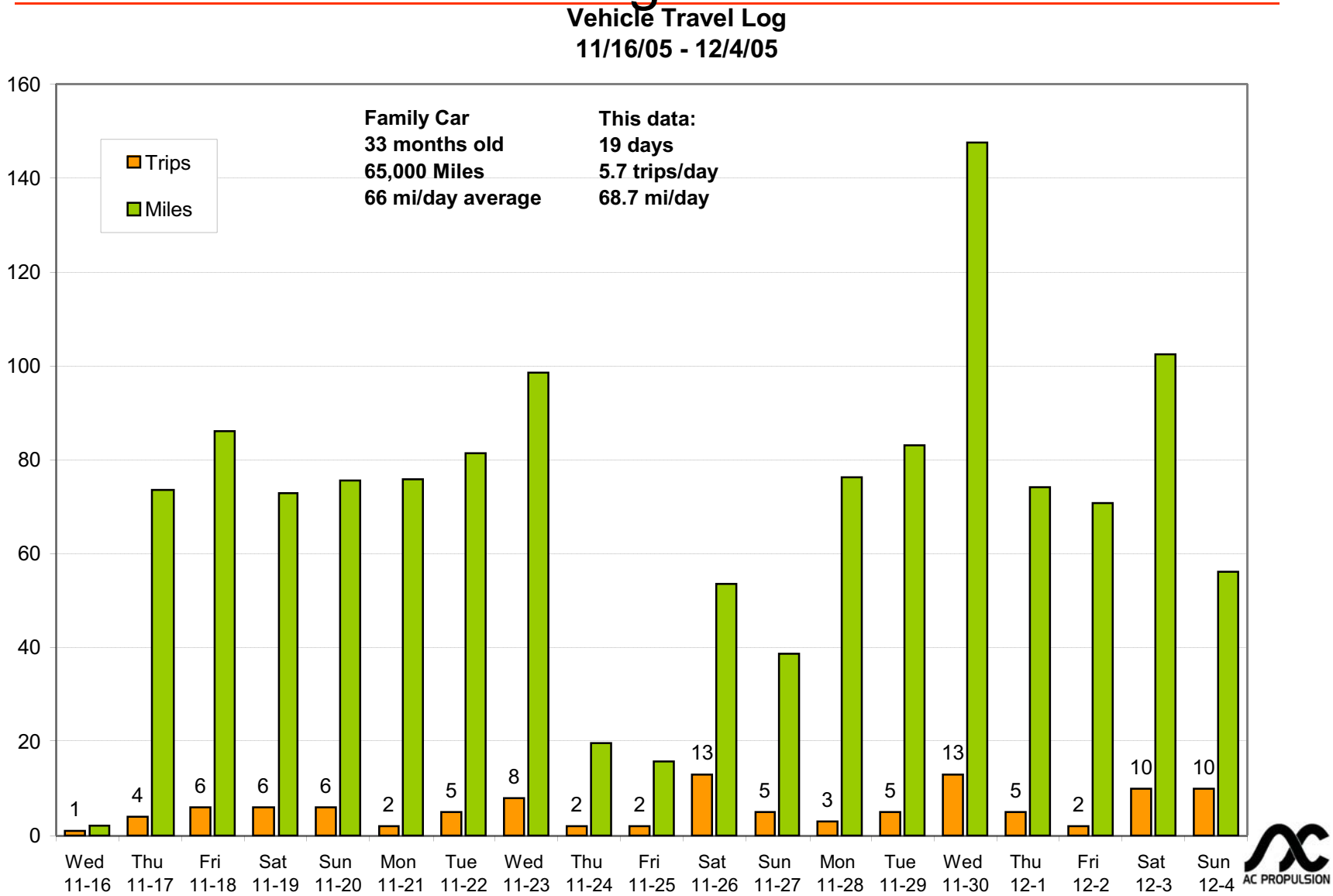
Electricity

Suitable for Most Driving



Electricity

Proven Vehicle Technology

ACP Civic EV

- First AC150
- Still in use
- Brake pads ½ worn

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Electricity

Established and Available Infrastructure

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 + HEVs
- Over 30 million people with RV experience

source: RVIA

AC PROPULSION

Electricity: The Best Alternative to Gasoline

- Off-peak capacity
- Diverse energy resources – without oil
- Low emissions
- Suitable for most driving
- Proven vehicle technology
- Established and available infrastructure

All we need is electric cars

AC PROPULSION

eBox by AC Propulsion

Urban Utility Vehicle

Spacious, efficient, comfortable, unique, sporty, versatile, zero emission.

Electric.

Performance

Range	120 – 150 miles
Acceleration	0-60 mph < 7 sec
Top speed	95 mph
Charge rate	30 minutes for 20 to 50 miles
Charge time	2 hours (fast), 5 hours (normal)
Grid connection	Bi-directional, V2G-capable

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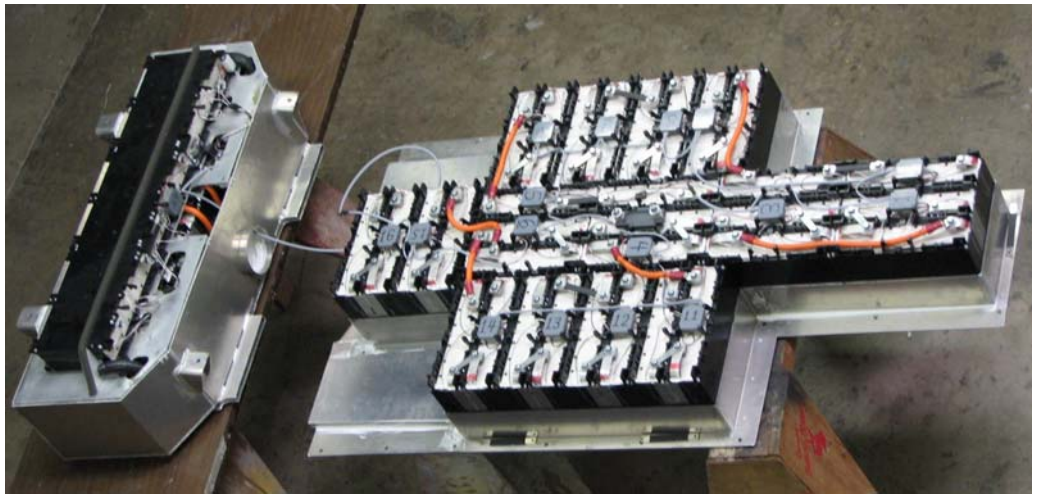
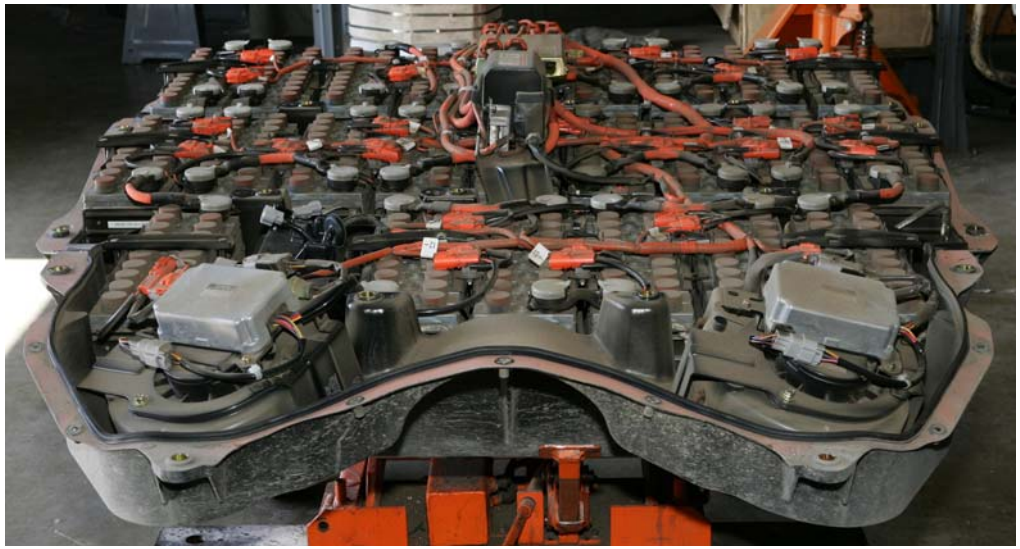
Li Ion Battery Allows Practical EV Conversions



Li Ion (eBox)

- 35 kWh
- 270 kg
- 130 Wh/kg



NiMH (RAV4 EV)

- 25 kWh
- 475 kg
- 52 Wh/kg

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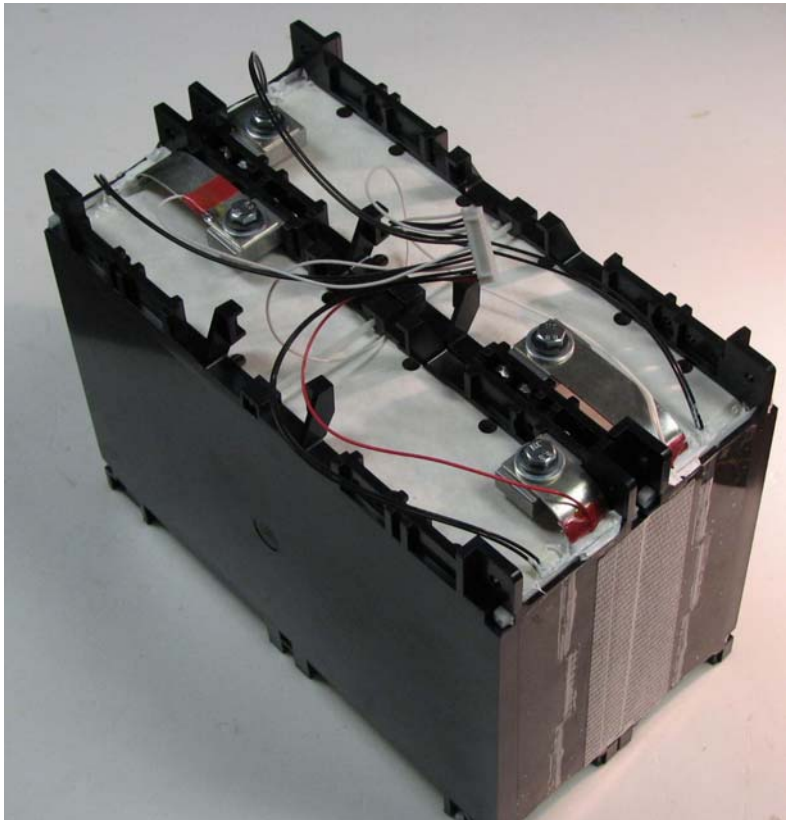
Commodity Cells Offer Price and Performance

Li Ion 18650 cell

2.0 Ahr, 3.7 V, 45 g



53P2S modules

106 Ahr, 7.4 V, 5.7 kg

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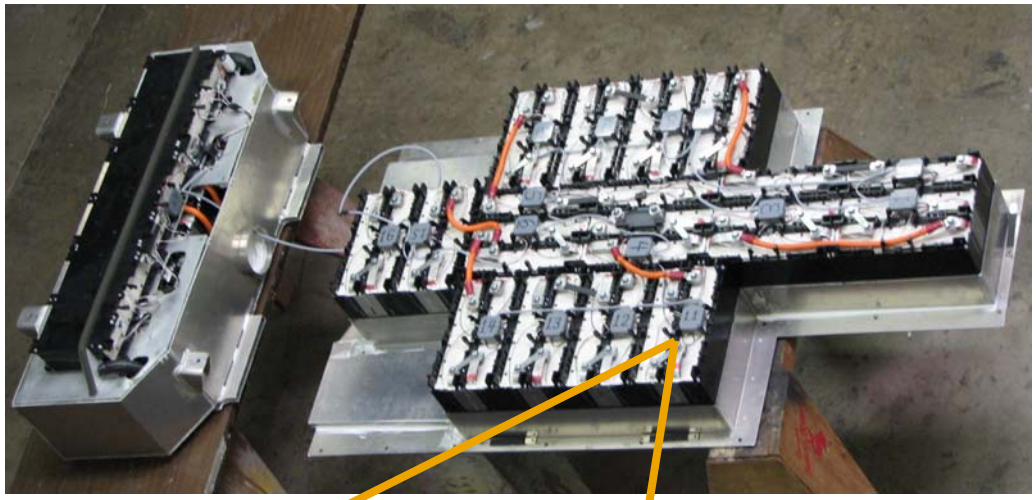
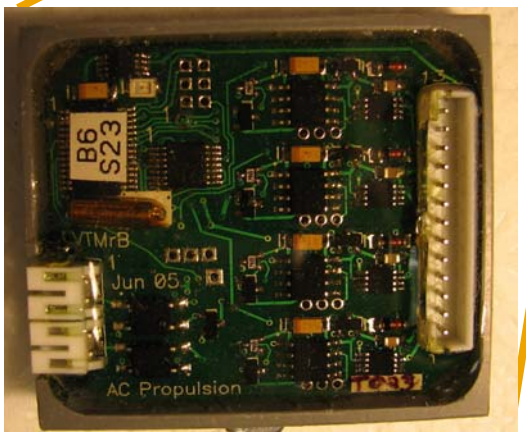
BMS - Maintains Critical Battery Parameters



eBox Pack

- 5088 cells
- 96 blocks in series
- 96 volt and temp measurements
- 24 LVTMs



LVTM

- 4 volts and temps
- Synchronized sampling
- Optically isolated
- Serial communication

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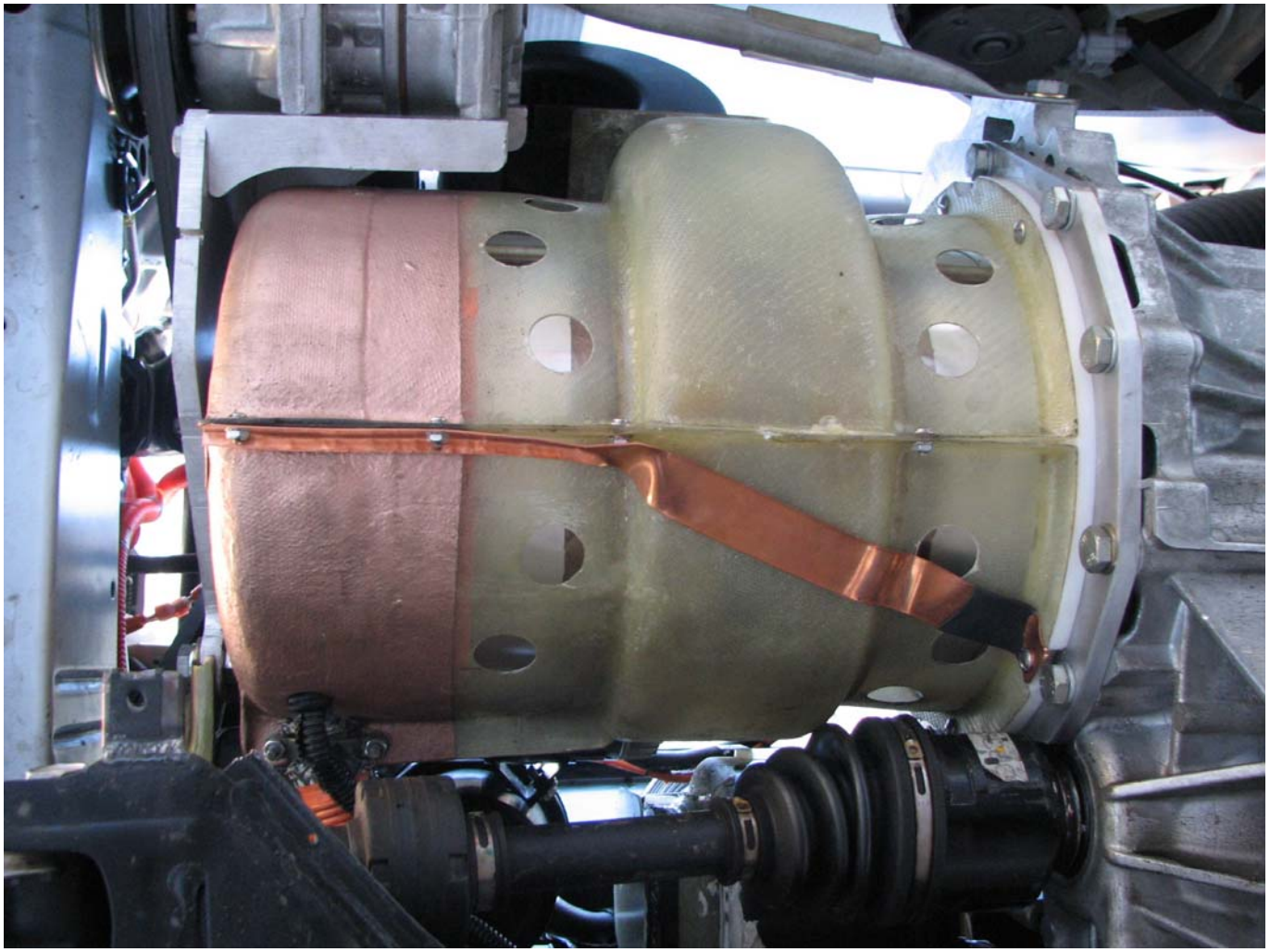
Motor Moves Car, and Stops It



AC150 Motor

- AC Induction
- 120 kW
  (160 hp)
- 200 Nm
  (165 ft-lbs)
- 13,000 rpm
- 3-phase
- 4-Pole
- 50 kg
  (110 lbs)
- Air-cooled

AC PROPULSION

Inverter Smooths Torque Response Efficiently

AC150 Inverter

- Up to 180 kW
- 350V to 440V
- Smooth
- Quiet
- Efficient
- Air-cooled

AC PROPULSION

Charger Saves Time, Increases Convenience

AC150 Charger

- Up to 20 kW
- 110V or 220V
- Quiet
- Efficient
- Fast -

  Charge rate in mi/hr:

  - 30A – 25 mi/hr
  - 50A – 40 mi/hr
  - 80A – 65 mi/hr

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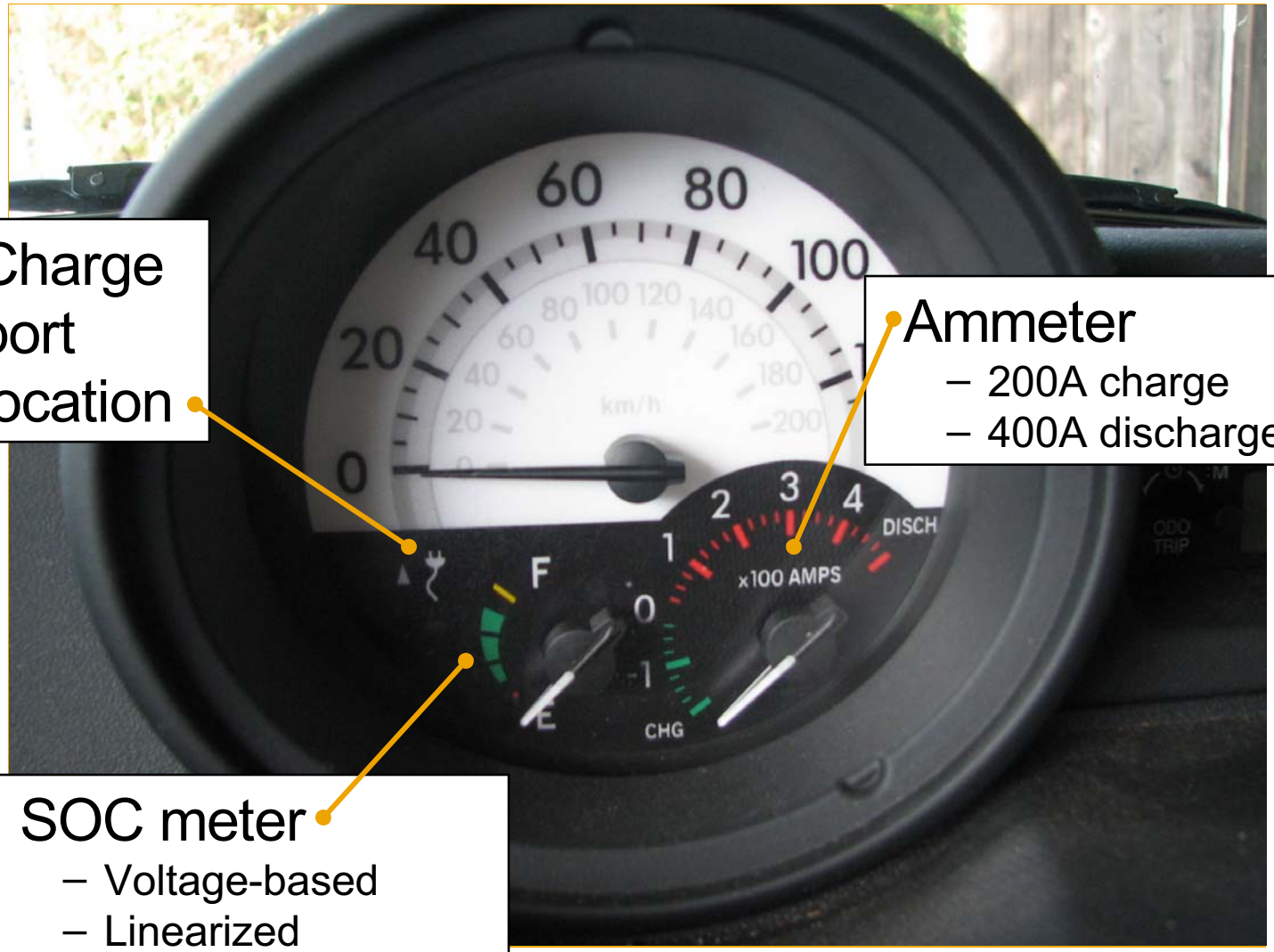
New Instruments and Controls Aid Driver

- Modified cluster
- Drive selector
- Multi-function display
- Regen control
- Cruise Control
- MFD control

AC PROPULSION

Modified Instrument Cluster



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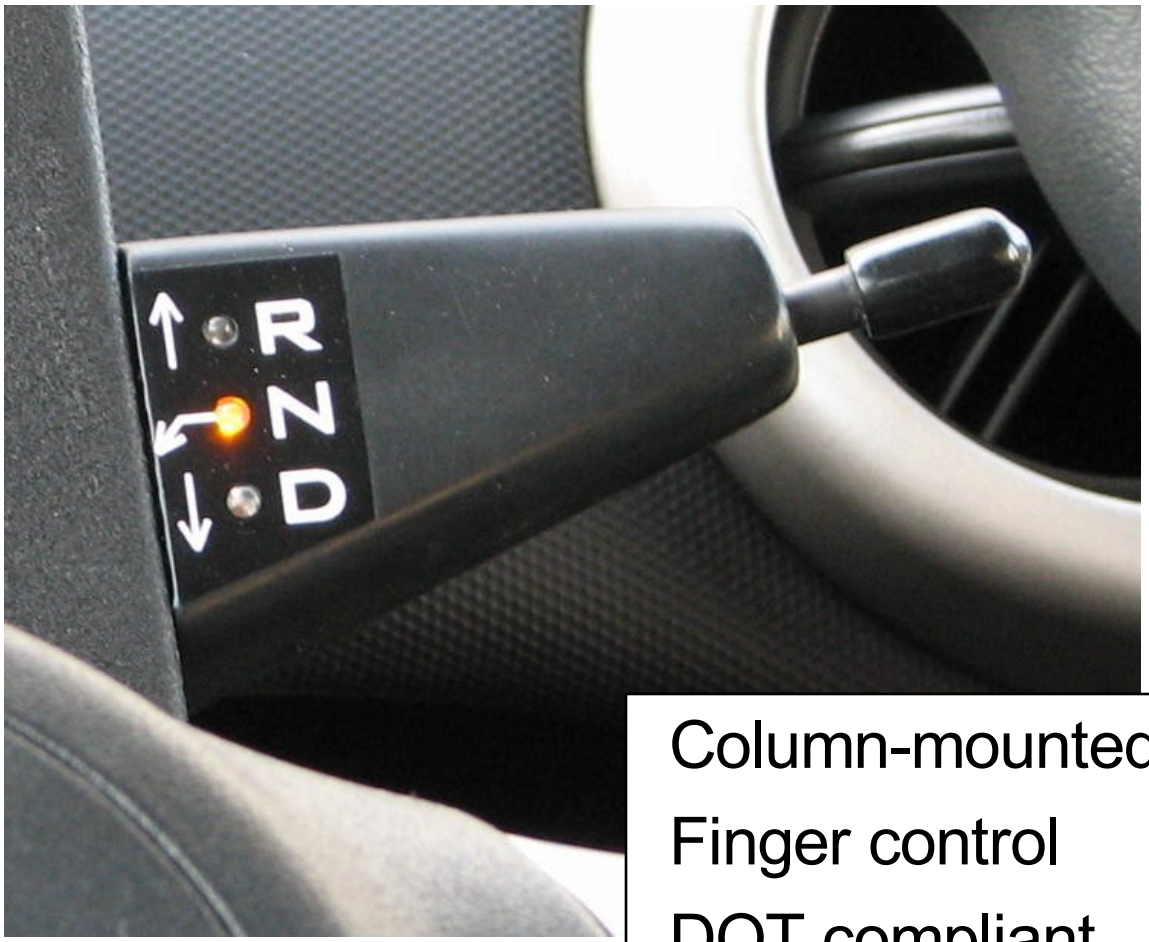
Electronic Drive Selector Saves Weight



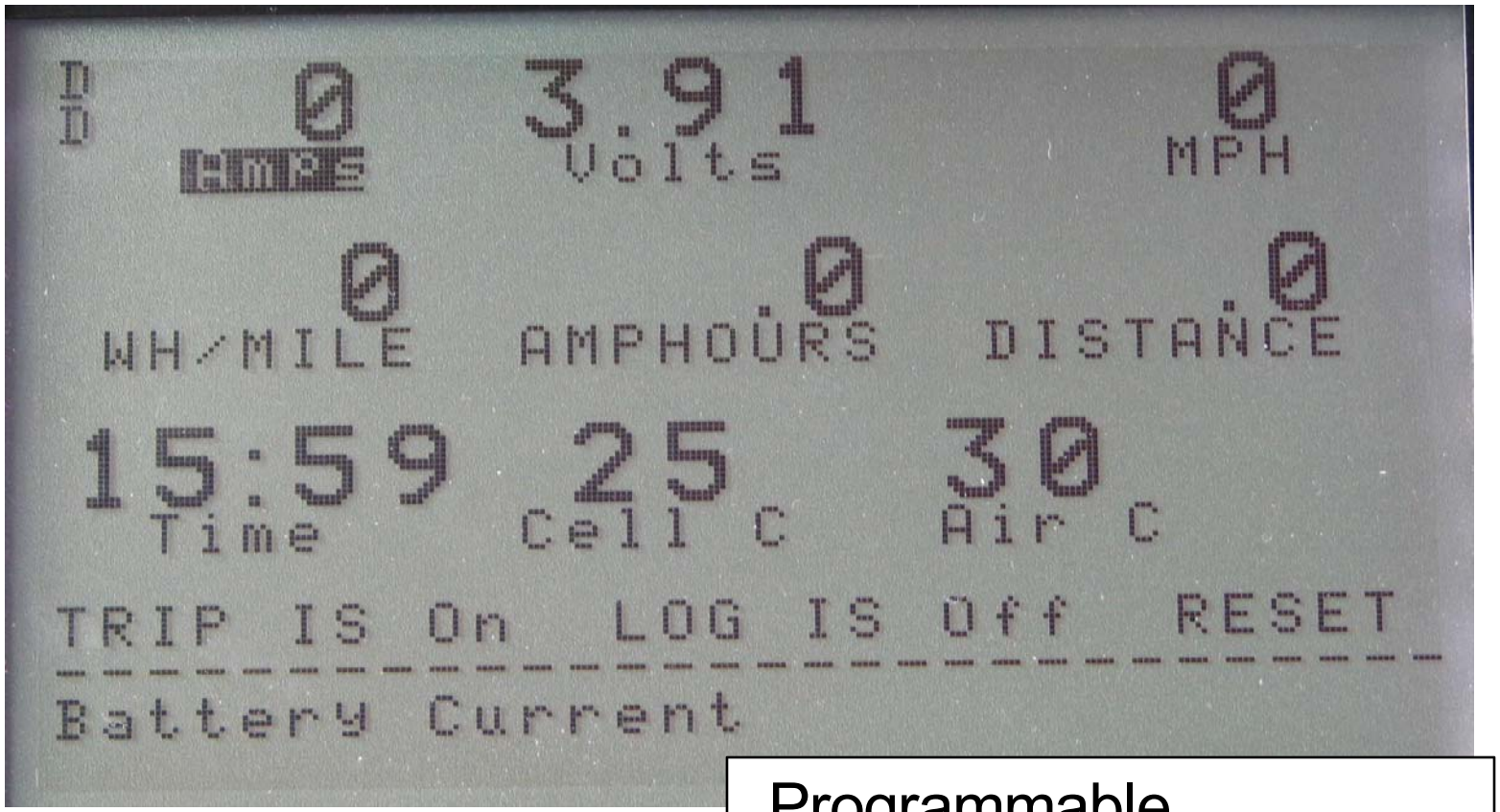
Column-mounted

Finger control

DOT compliant

AC PROPULSION

Multi-Function Display



- Programmable
- Digital or analog presentation

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Regen Control

Regen on accel pedal

Adjustable on the fly

Brake light indicator

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Cruise Control

- Accurate
- Stable
- Easy to use

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MFD Control

Controls screens and menu selections on MFD

Easy to reach

Push to select

Turn to scroll

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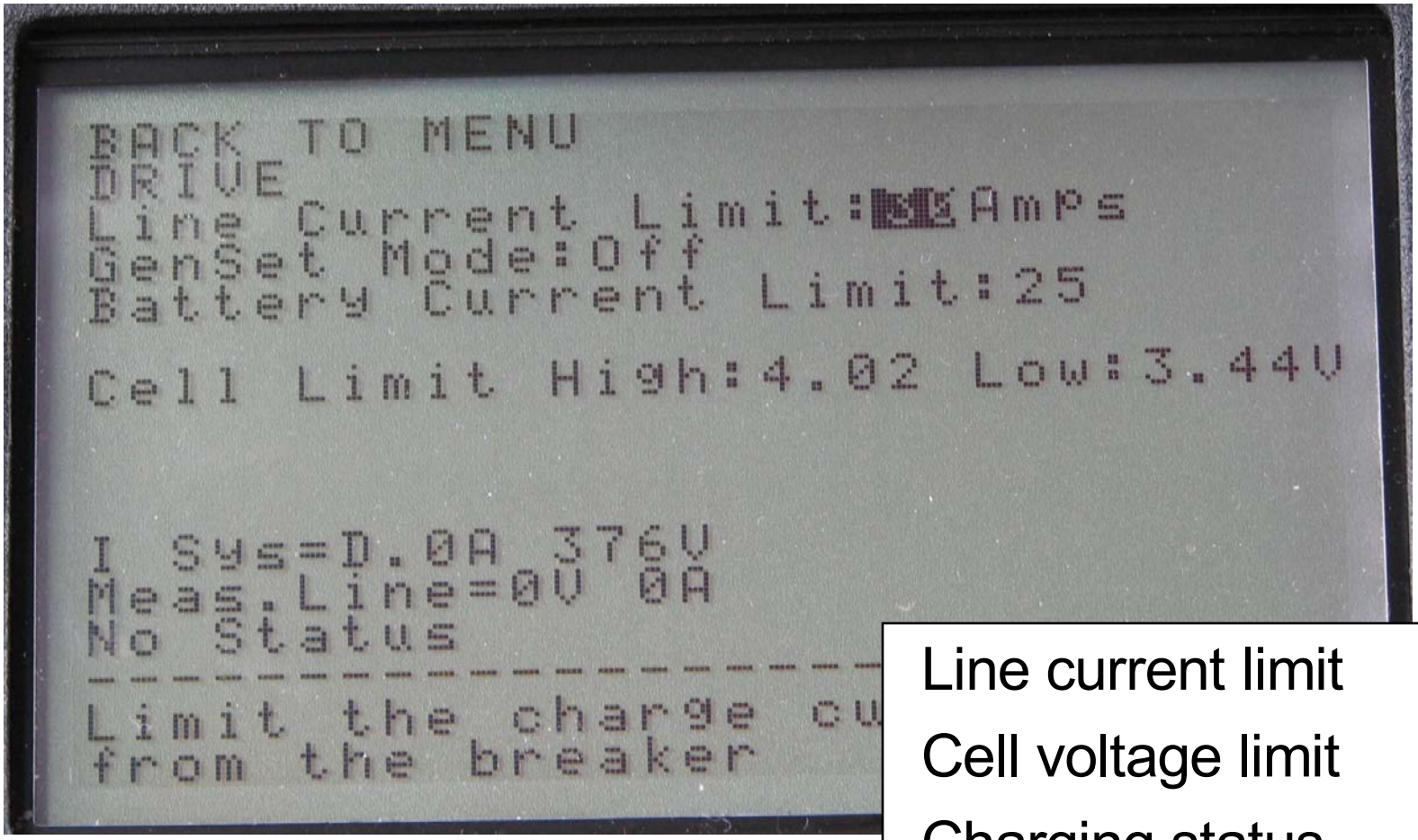
Charge Control Screen



- Line current limit
- Cell voltage limit
- Charging status

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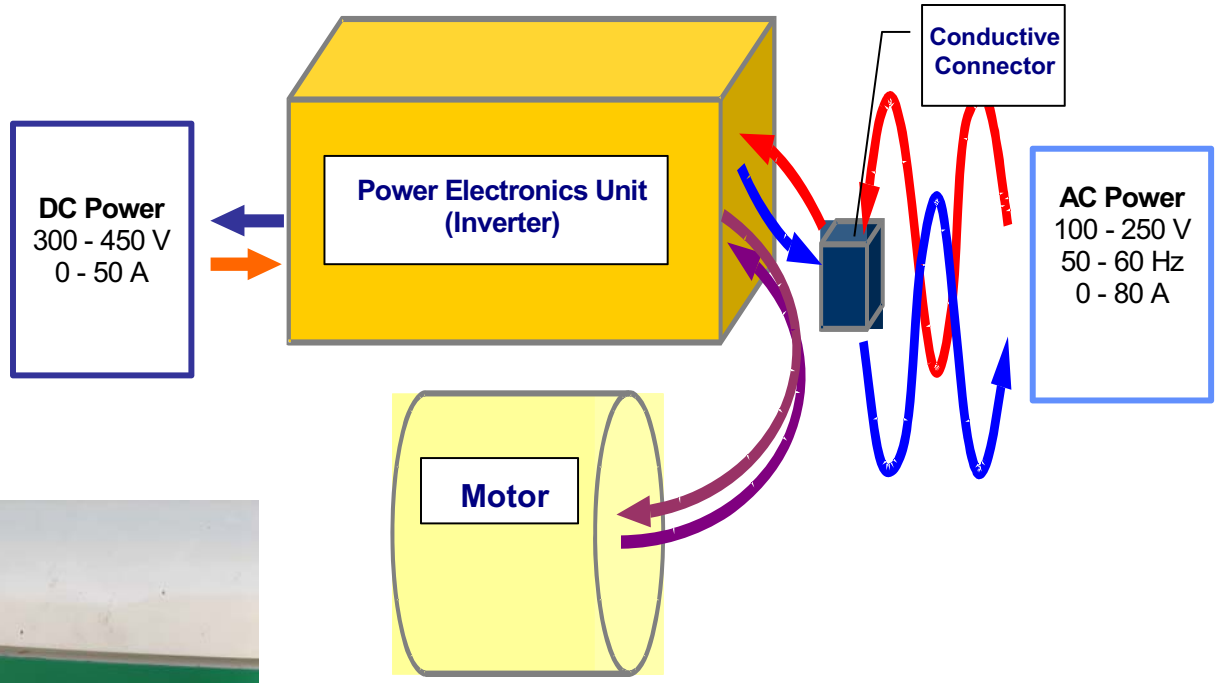
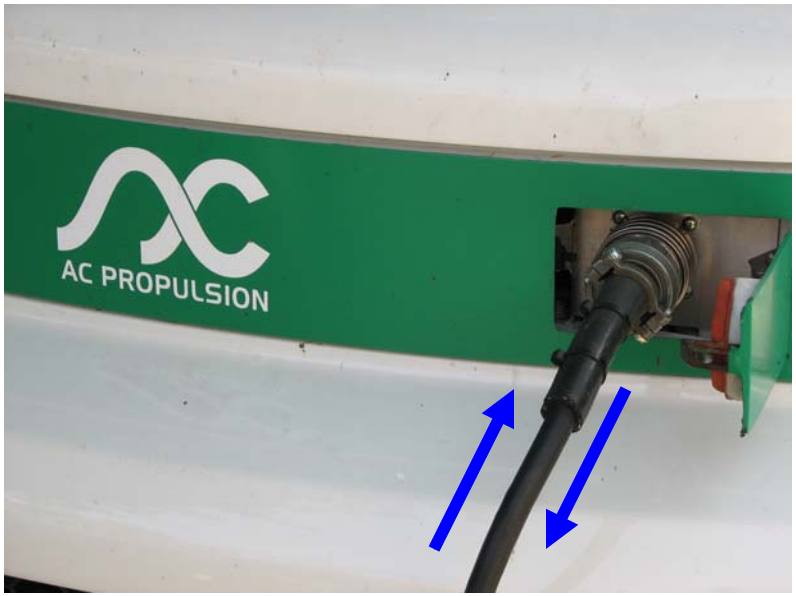
Onboard Charger Is Bidirectional

Power can flow to or from vehicle





- Stand-alone or grid-tied
- Unity power factor
- Sine wave current draw
- GFI compatible
- Discharge to grid for batt test

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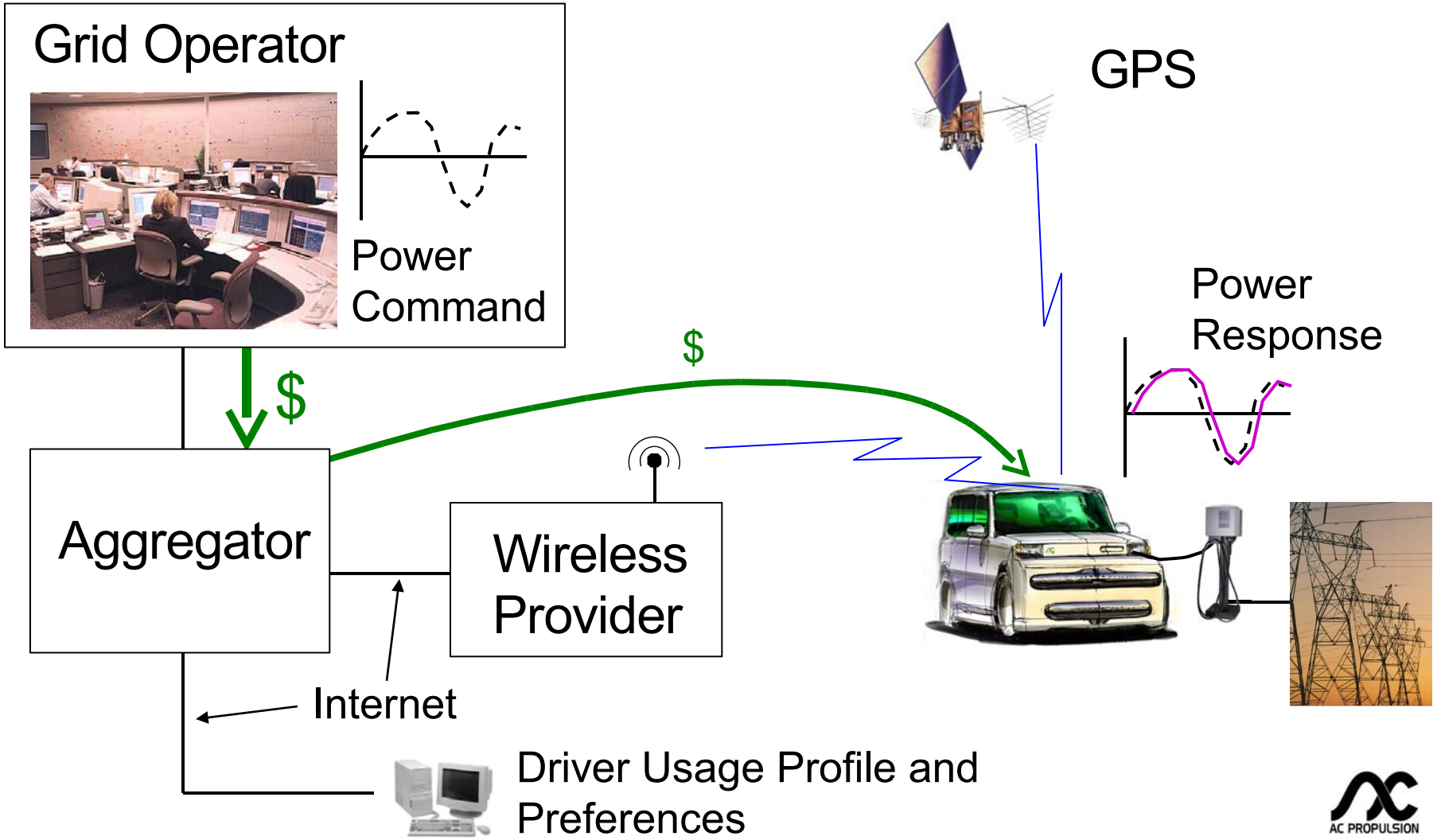
Vehicle ⟵ to ⟶ Grid

Plug-in vehicles serve as distributed energy resource (DER)



Plug-In Vehicles = “A Battery on the Grid”

AC Propulsion Demonstration Projects

- ☑ Grid regulation (automatic generation control - AGC)
- ☑ Extra power during demand peaks

Other Possible V2G Functions

- ★ Energy buffer for variable renewables
- – Spinning reserves
- – Uninterruptible power source for businesses and homes
- – Active stability control of transmission lines
- – Standby power for interruptible customers

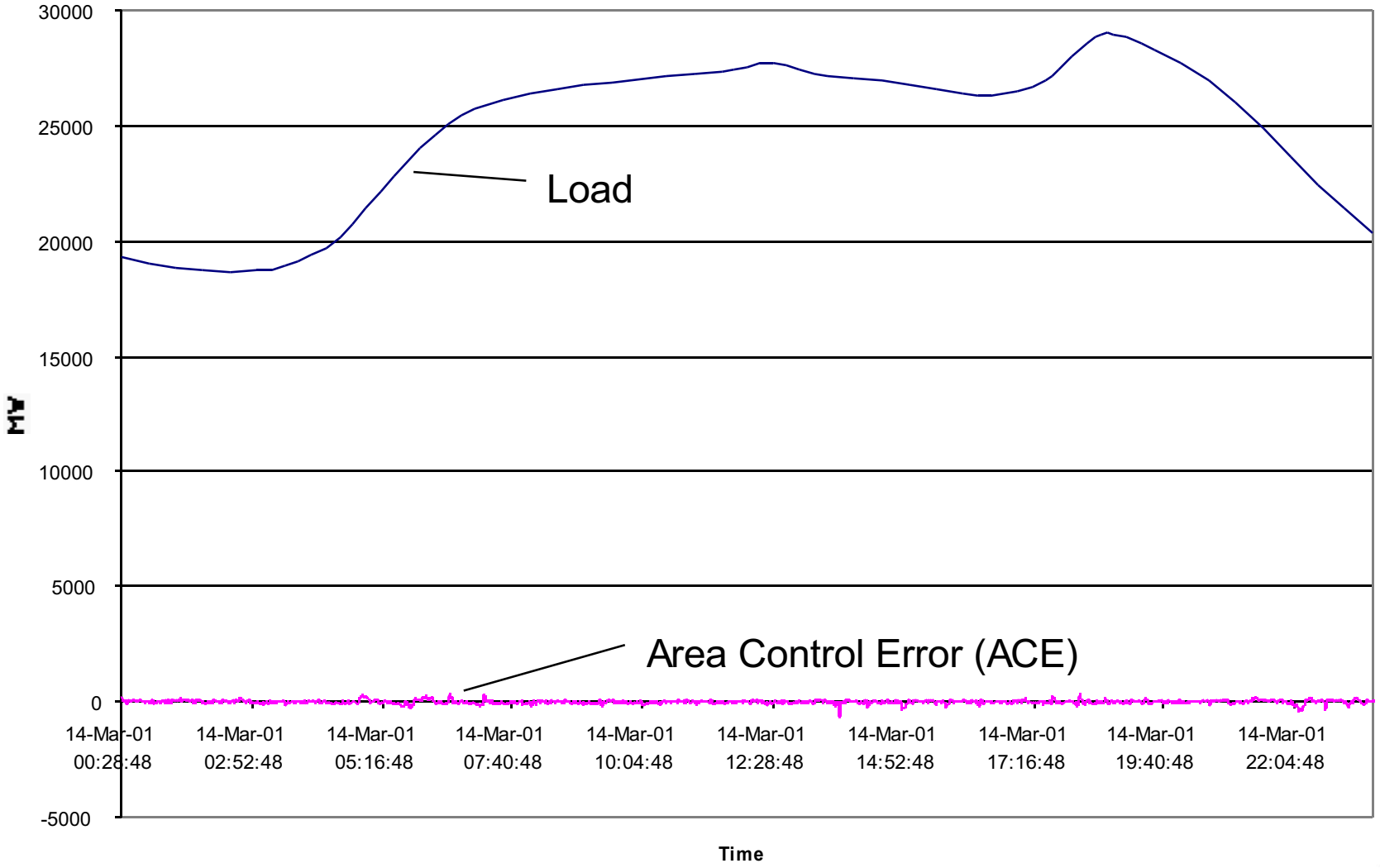
AC PROPULSION

Grid Regulation With an EV

- Project Sponsors – CARB, CAISO
- Contractor – AC Propulsion
- Vehicle – “Plug Bug” VW Beetle EV conversion
- Duration – October 2001 to December 2002
- Results
  - Vehicle driven normally, plugged in when parked
  - Vehicle automatically maintains battery state of charge to comply with driver usage requirements
  - Vehicle dispatches +/- power to grid upon remote command
  - Value of service provided estimated at $100 - $500/mo

AC PROPULSION

Vehicles Regulate Area Control Error



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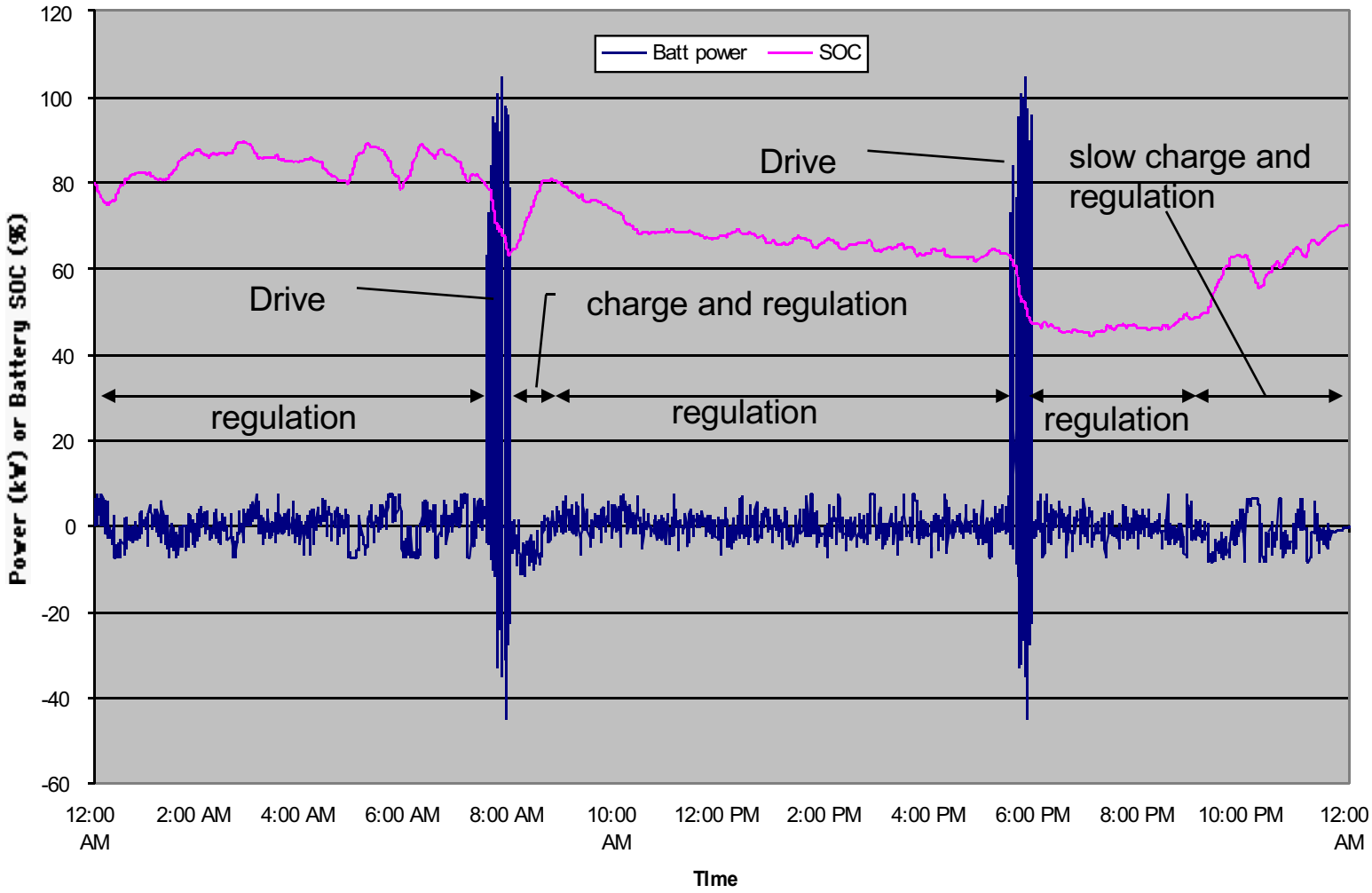
24 Hour Cycle - Driving, Charging, Regulation



AC PROPULSION

A Small Fleet of V2G Cars Buffers Renewables

100 kW peak power, variable output

10 to 15 kW dispatchable power from each car

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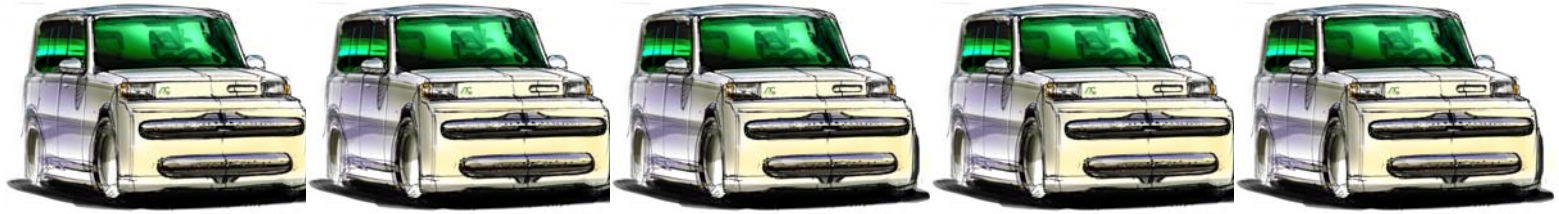

= **Higher reliability from renewable resources**

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Plug-in Cars for V2G

Battery	Li Ion 35 kWh 600 lb	Li Ion 9 kWh 145 lb
Charger	20 kW onboard bi-directional	1.5 kW onboard charge only

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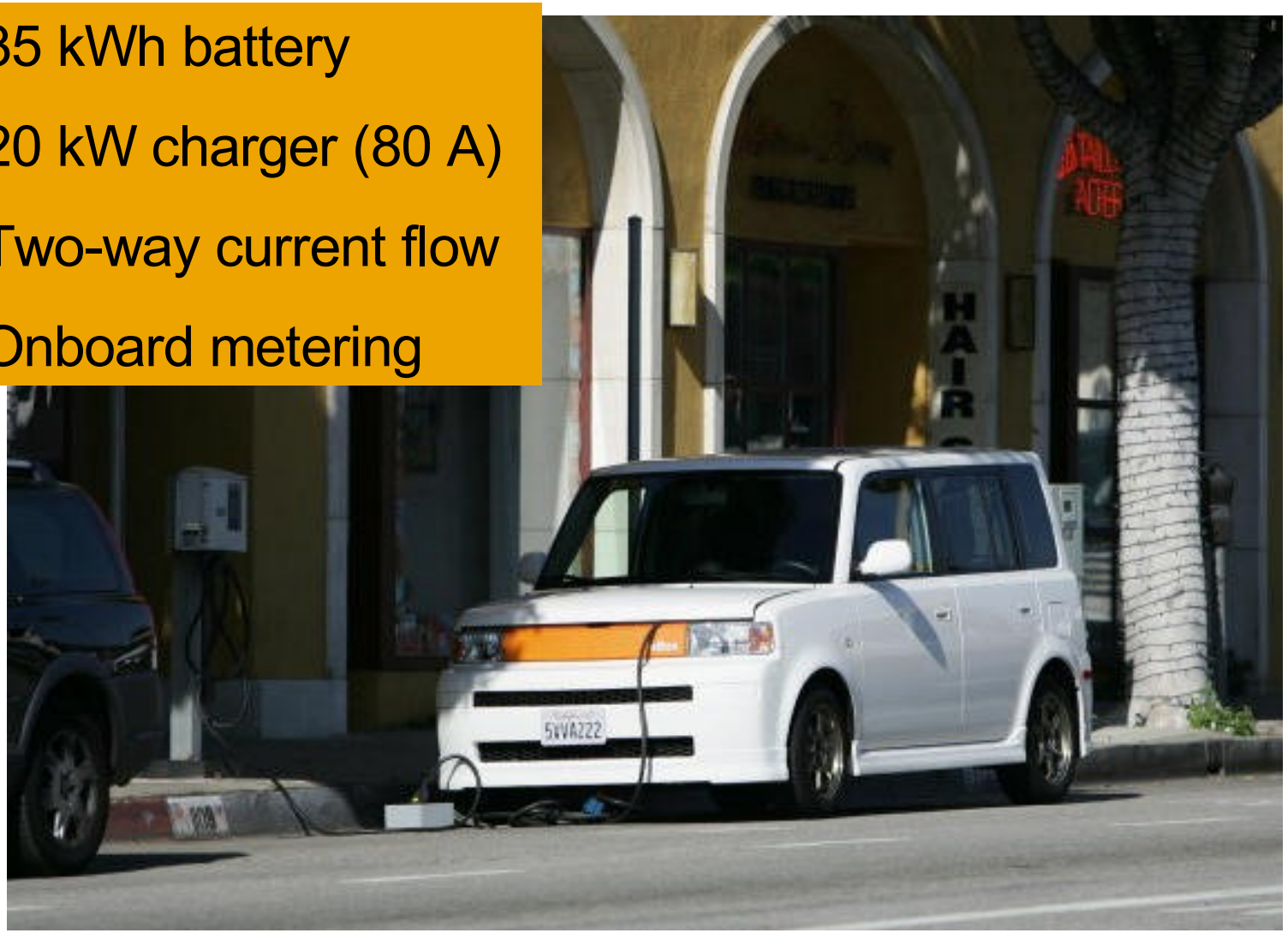
eBox : V2G-Ready

- 35 kWh battery
- 20 kW charger (80 A)
- Two-way current flow
- Onboard metering



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eBox : Efficient Package

	Curb weight	
2400lbs	Gasoline	2750 lbs
3050 lbs	Electric	3550 lbs

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eBox : Available Now

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eBox: How to Get One

- Have $70,000 to $80,000 to spend
- Place deposit with AC Propulsion - $10,000 per car
- Buy Scion xB 5spd - $17,000 new, $15,000 used
- Deliver Scion to AC Propulsion
- Wait while AC Propulsion converts your car
  - Current backlog is three to four months
  - Conversion takes about one month
- Pay balance due - $45,000 plus options and tax
- Drive away in your eBox electric

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AC Propulsion Next Steps

- Continue eBox conversions to end of 2007 at least
- Plan to replace xB with new platform
  - Another conversion
  - Fully-certified vehicle
  - Joint venture with an OEM
- Cost reduction
  - Drive system manufacture in Shanghai
  - Joint effort with battery supplier
  - Higher production volume
- Sales to other manufacturers

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