The EV Business:
A Post-Mandate Perspective

Electric Auto Association - Silicon Valley
October 18, 2003

AC Propulsion, Inc.
San Dimas, California

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EVs Available 1998 - 2002

Toyota RAV4 EV

Chevy S10 EV

Honda EV Plus

GM EV1

Ford Ranger EV

Chrysler EPIC EV

But things change...

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2003: OEMs leave the EV business

Toyota RAV4 EV
out of production

Chevy S10 EV
out of production

Honda EV Plus
out of production

GM EV1
out of production

Ford Ranger EV
out of production

Chrysler EPIC EV
out of production

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EVs Available Now

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People Still Like Their EVs

Many of these EVs will be gone within three years

Source: Myron Ahn

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Things Change

- **Market forces commercialize small Li Ion cells**

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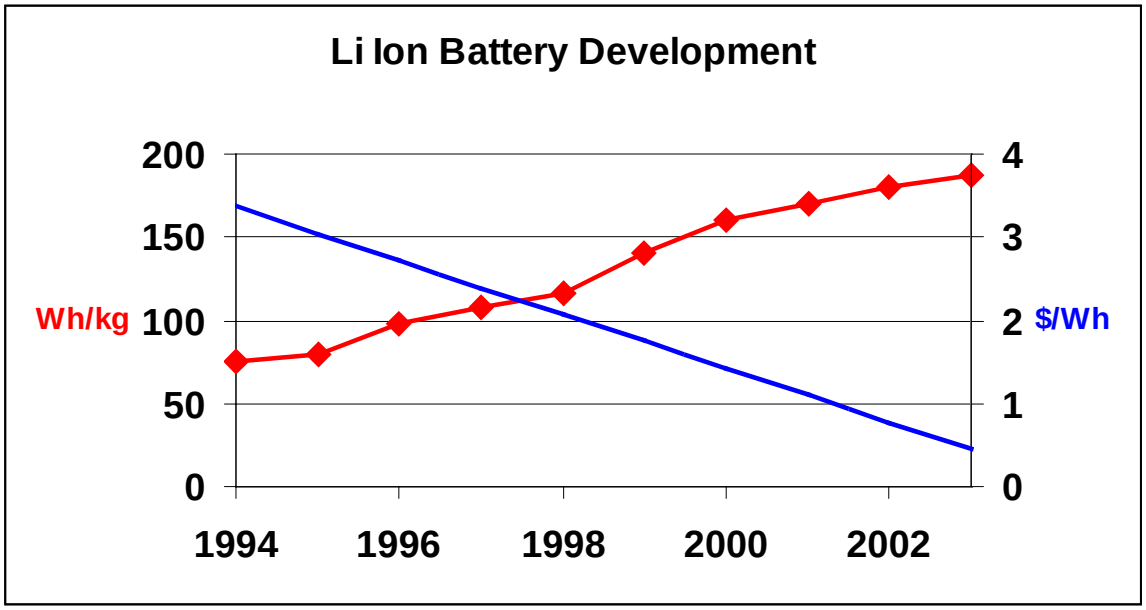
LiIon Battery Progress

- Li Ion cells now in mass production
  - 18650 cells used for laptops
  - Many producers, millions per month
  - High durability, reliability, uniformity
  - 170 Wh/kg now and increasing
  - $500/kwh now and decreasing



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1999 - Successful Assembly of Small Cells

Electric Land Speed Record - 245 mph

6000 NiCad“sub-C” cells

Dual AC Propulsion drive systems

400 hp

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Li Ion 18650s In Battery-Powered Airplanes

Requirements: Energy, power, lightness

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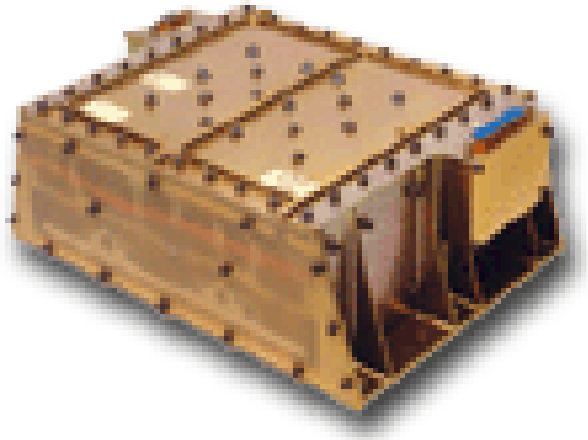
18650s in Space

COM DEV



- **COTS - commercial off-the-shelf**
- **Up-screened commercial 18650 cells**
- **Tested for**
  - vacuum
  - conduction-only cooling
  - micro-meteorite impact

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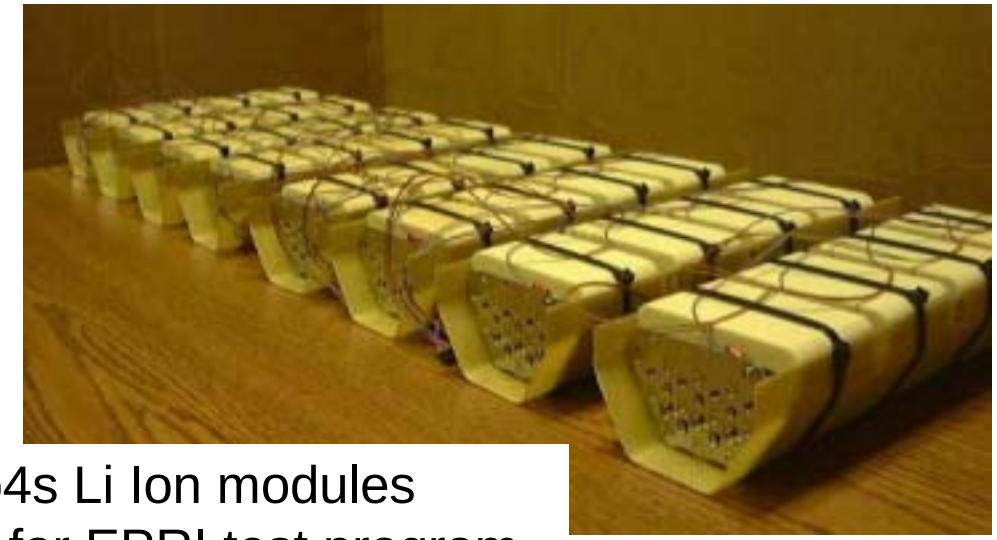
Automobile Application Methods

- Small cell assembly and management techniques for vehicle applications
  - Vehicle packs made from 3000 to 7000 cells
  - 30 to 70 cells in parallel-connected blocks
  - 100 blocks in series
  - Robust and efficient assembly
  - Block-level battery management system



Eight 12p4s Li Ion modules delivered for EPRI test program

Voltage/temperature monitor

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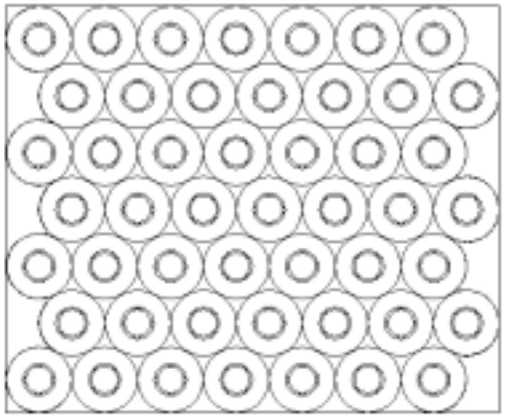
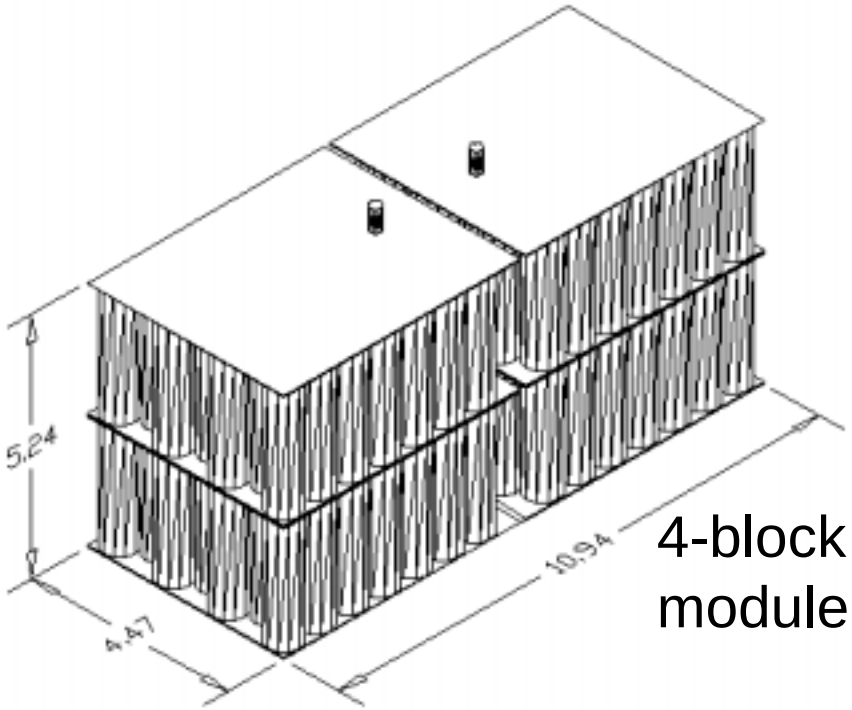
Configurable Blocks and Modules

Typical design:



7 x 7 cell block



4-block module

- 49P100S configuration, 370V nominal
- 25 14.8V modules of 4 cell blocks each
- 33 kWh
- 250 kg

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Lead-acid tzero accelerates faster than Corvette

Lead-acid tzero accelerates faster than Porsche

tzero

Lead-acid tzero accelerates faster than Ferrari

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tzero

Lead-acid tzero accelerates faster than Lamborghini

Lead-acid tzero - 0-60 in 4.1 secs, 80 mile range

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Proof of Concept - Lilon tzero

Concept: convert the original tzero from
a lead acid battery to an assembled Lilon battery

- 6,800 18650 cells
- 68P100S configuration
- 370V
- 50 kWh
- 165 kW
- 350 kg

Lilon tzero:
Same power, 500 pounds lighter, 4 times the energy

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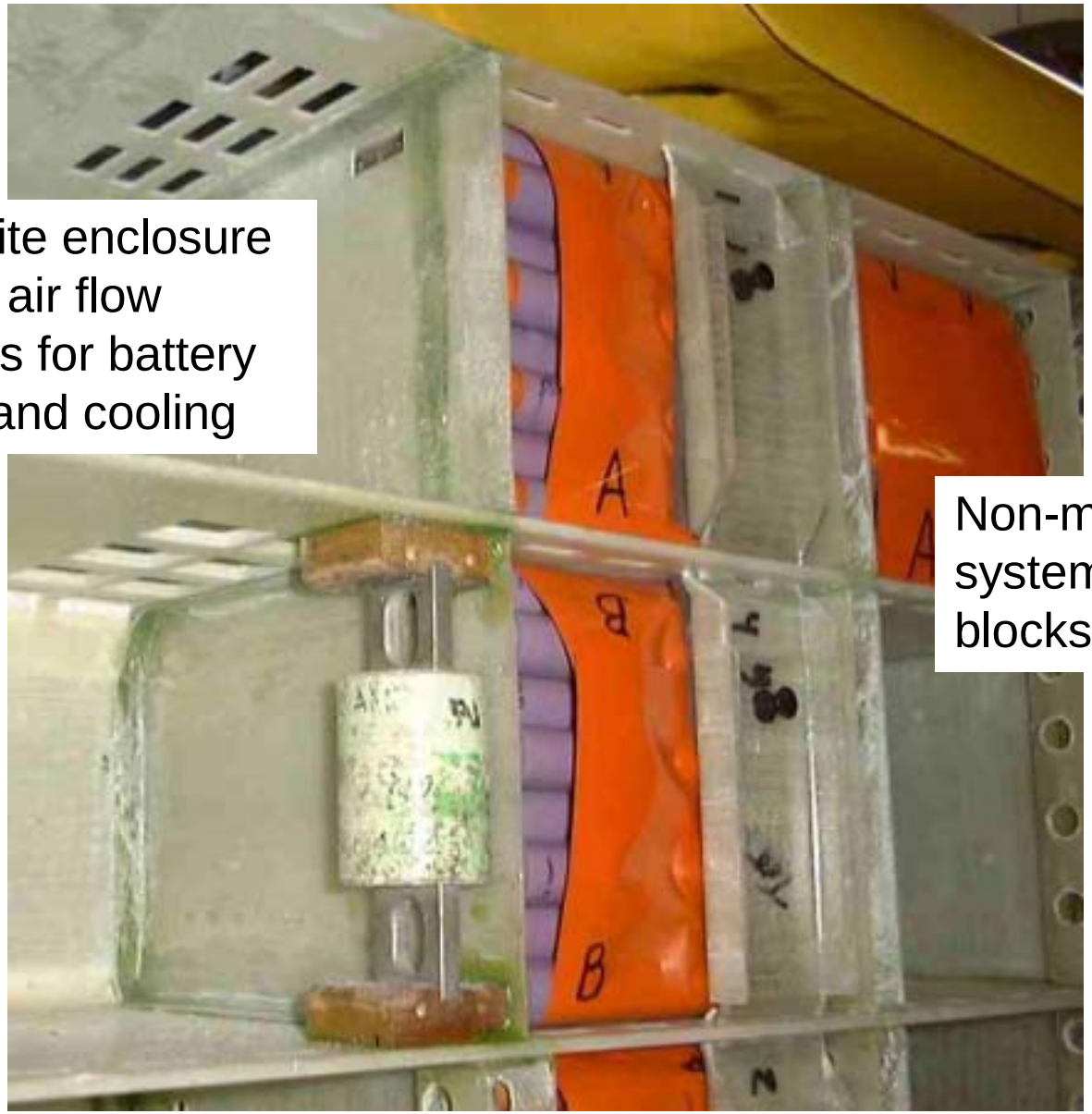
Proof of Concept - Lilon tZero

Composite enclosure includes air flow passages for battery heating and cooling



Non-metallic clamping system holds battery blocks in place.

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Proof of Concept - Lilon tZero

Enclosure supports, insulates, and protects Li Ion cell blocks

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Proof of Concept - Lilon tzero

Sealed battery enclosure mounts to tzero frame

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Lilon tzero 0-60 mph in 3.6 sec

On Tuesday September 9, in a series of acceleration tests, the tzero repeatedly achieved 0-60 in under 4 secs. Alan Cocconi achieved the best time - 3.6 secs. Writer Chris Dixon got 3.7 secs and reported it in the *New York Times*.

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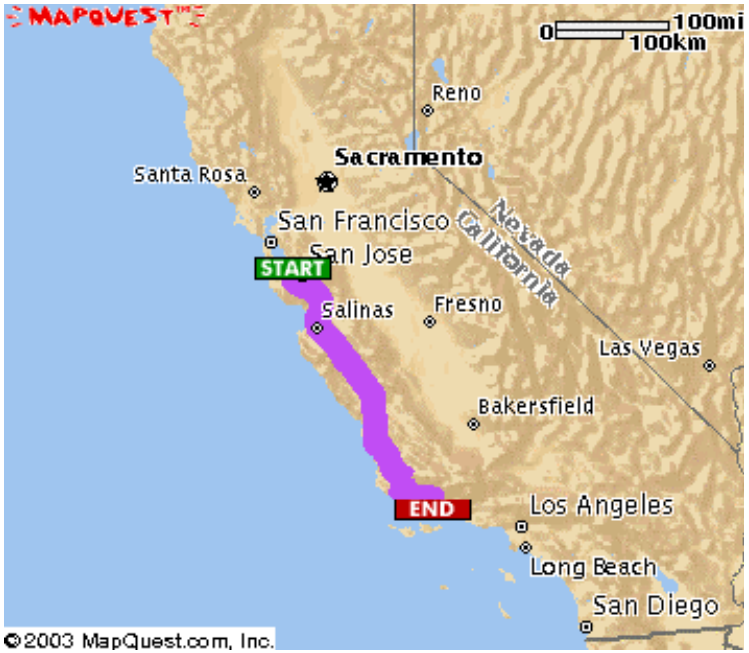
Lilon tzero 300 mile range



On Thursday October, 3, 2003, the tzero drives from Sunnyvale to Santa Barbara on US 101, with the cruise control set at 60 mph - 302 miles - without charging.

130 net Ah, 3.4 Ah regen
57.1 mph avg, 160 Wh/mi, 302 miles

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Lilon tzero All-Around Performance

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FOR IMMEDIATE RELEASE
September 29, 2003
San Francisco

tzero Earns Highest Grade at 2003 Michelin Challenge Bibendum

Things Change

- **Electric vehicles - now we need them for energy security, not just clean air.**

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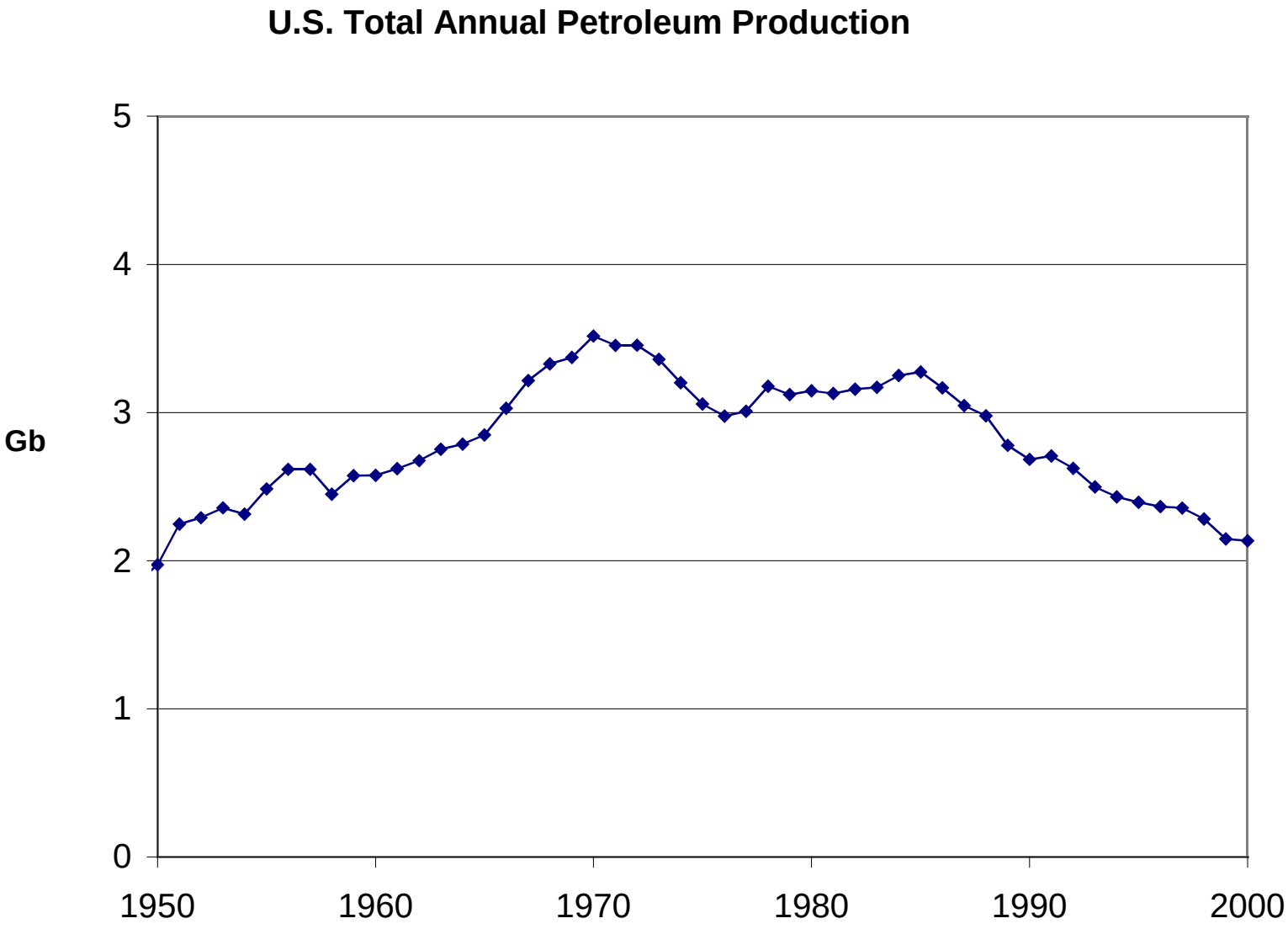
The Decline of US Petroleum



Source: U.S. Energy Information Administration

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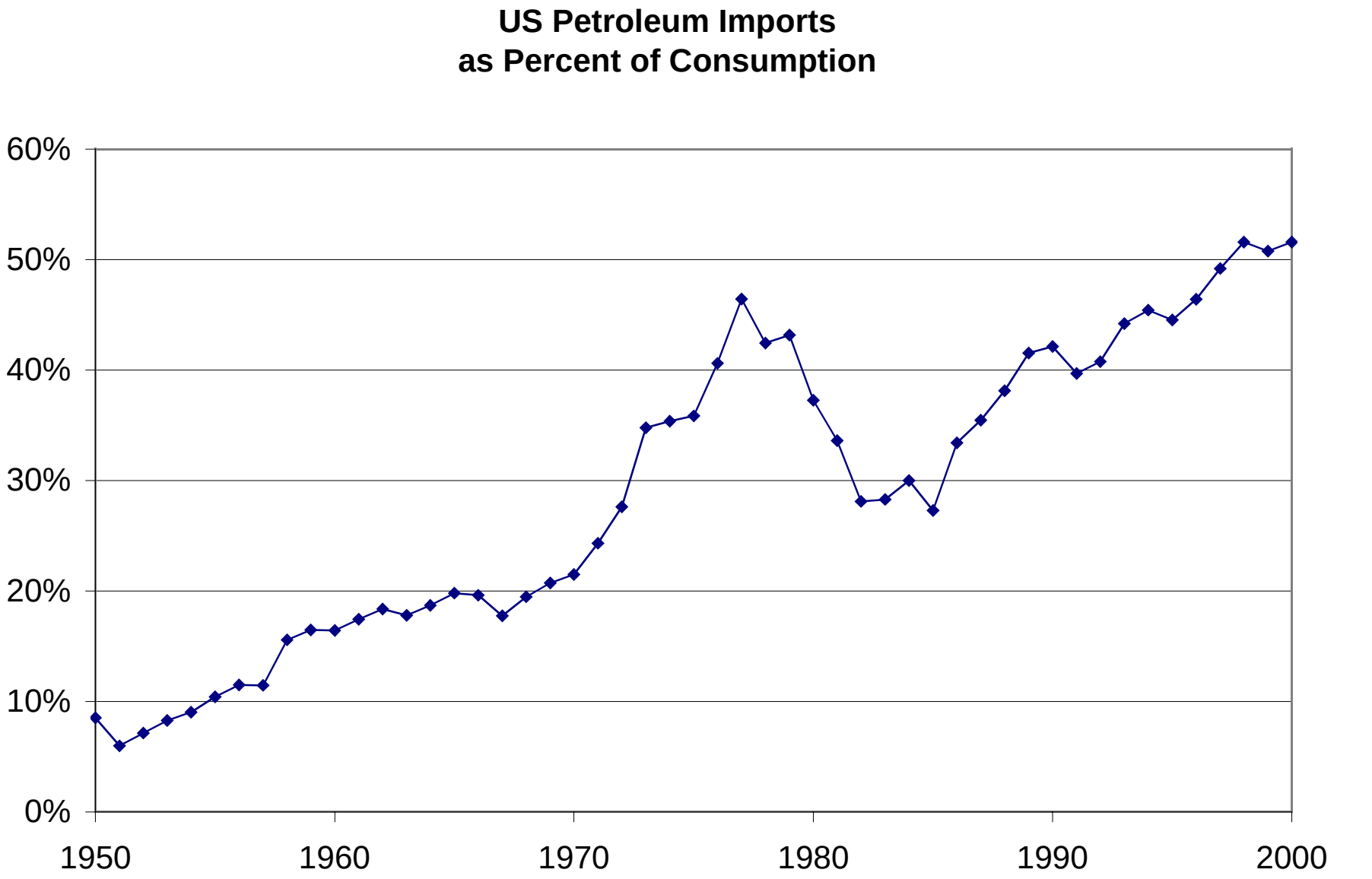
The US Response - Oil Imports



Source: U.S. Energy Information Administration

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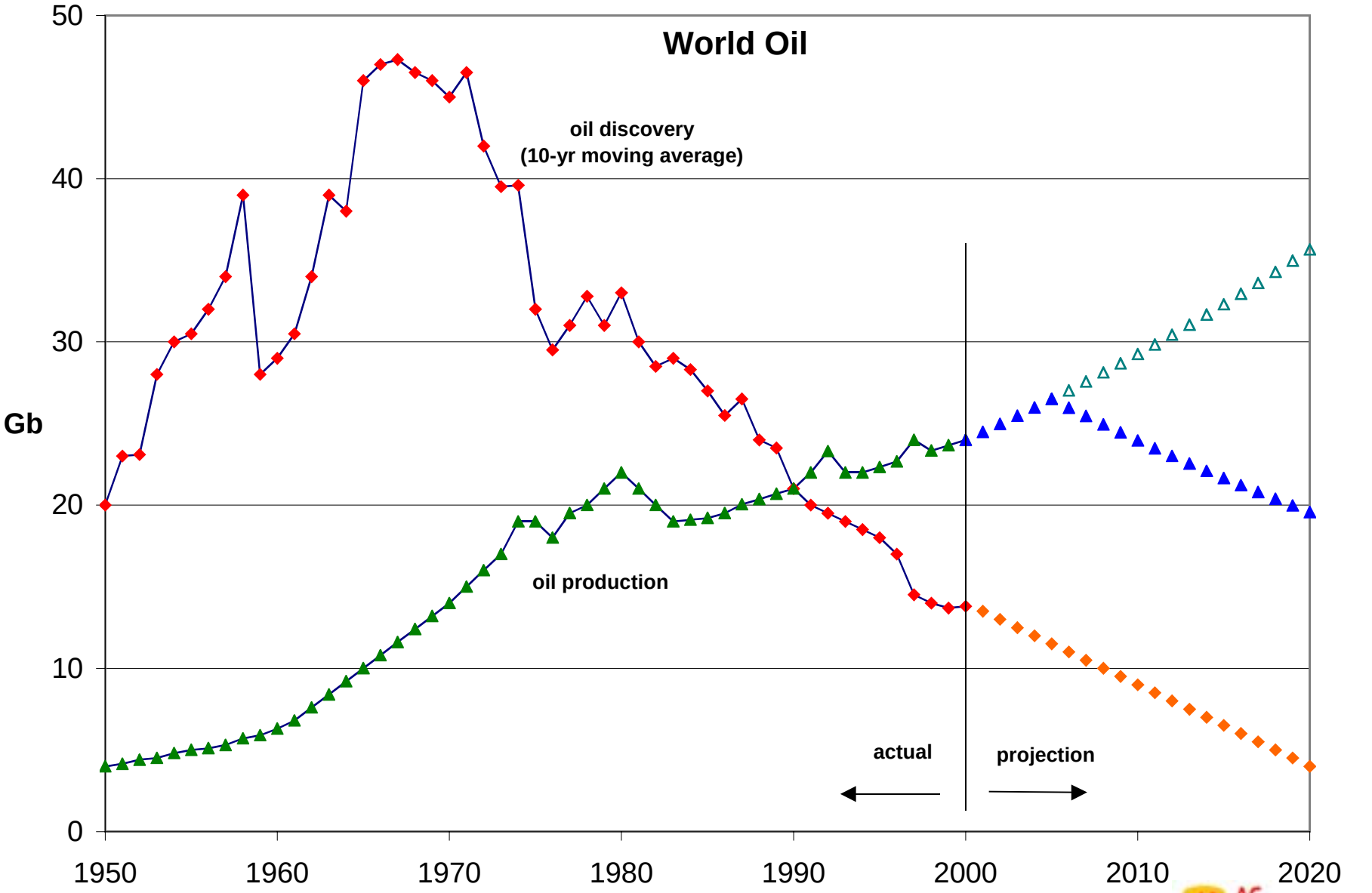
The Impending Decline of Global Petroleum



Source: Peak Oil, C.J. Campbell

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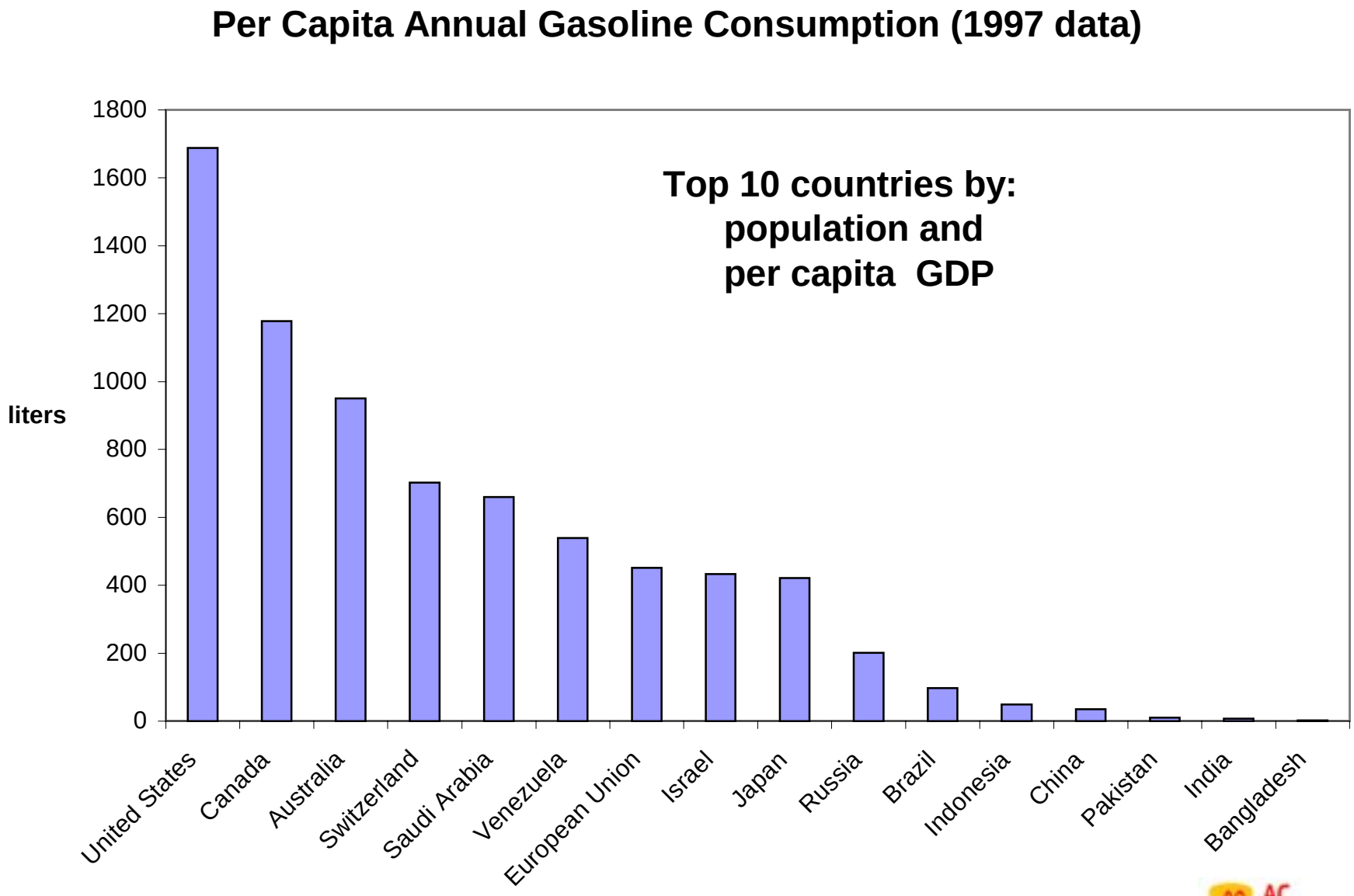
Unsustainable Gasoline Consumption



Source: World Resources Institute

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The Energy Imperative

Energetics more than emissions
must inform automobile design
over the coming decades.

Electricity must substitute for petroleum
as an energy source for automobiles

Use less gas or fight more wars

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U.S. Energy Policy

- **The Right Problem**

  "The Federal government recognizes that the steady growth of imported oil to meet U.S. requirements cannot continue..."

  U.S. Secretary of Energy Spencer Abraham

  January 9, 2002

- **The Wrong Solution**

  "The government and the private sector will fund research into advanced, efficient fuel cell technology which uses hydrogen to power automobiles..."

  U.S. Secretary of Energy Spencer Abraham

  January 9, 2002

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Fuel Cell Vehicles Use More Energy than EVs

	EPA Rating	Well-to-Wheels (mpg equivalent)
• RAV4 electric	301 Wh/mi	49 mpg
• FCX fuel cell	50 mi/kg H2	
	H2 from natural gas	30 mpg
	H2 from renewables	12 mpg

Source: USEPA, AC Propulsion estimates

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Hydrogen - A Poor Automotive Fuel

- Hydrogen production requires natural gas or electricity.
- Natural gas and electricity are both secure, domestic, non-petroleum energy sources.
- Using natural gas to fuel conventional engines directly is much less costly, more efficient, and cleaner than hydrogen over the fuel cycle.
- Using electricity to fuel battery electric vehicles directly is much less costly, much more efficient, and much cleaner than hydrogen over the entire fuel cycle.

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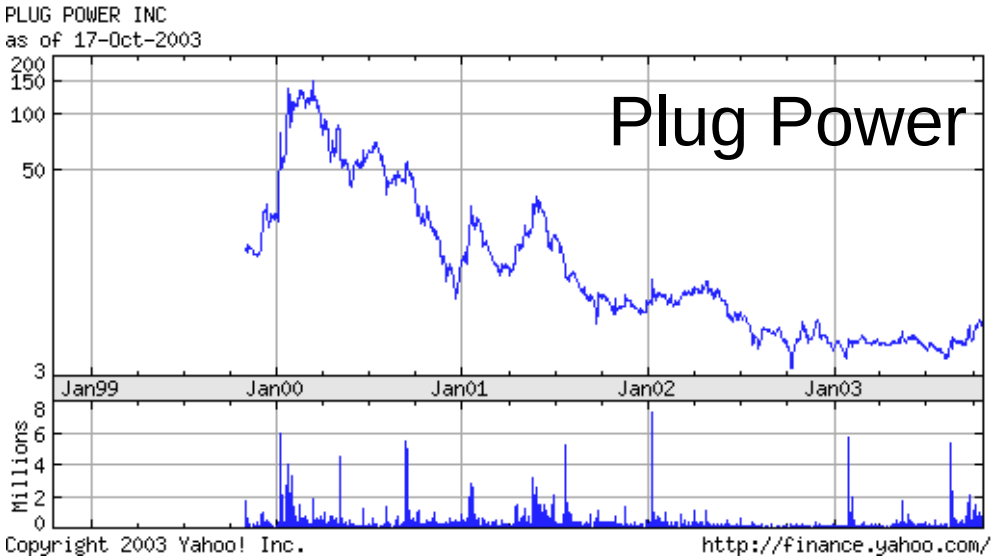
Fuel Cell Stocks Are Down



The smart money got out of fuel cells three years ago. Why are politicians getting in now?

Source: Yahoo!l.com

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Two Problems with Fuel Cells

1. The fuel
2. The cell

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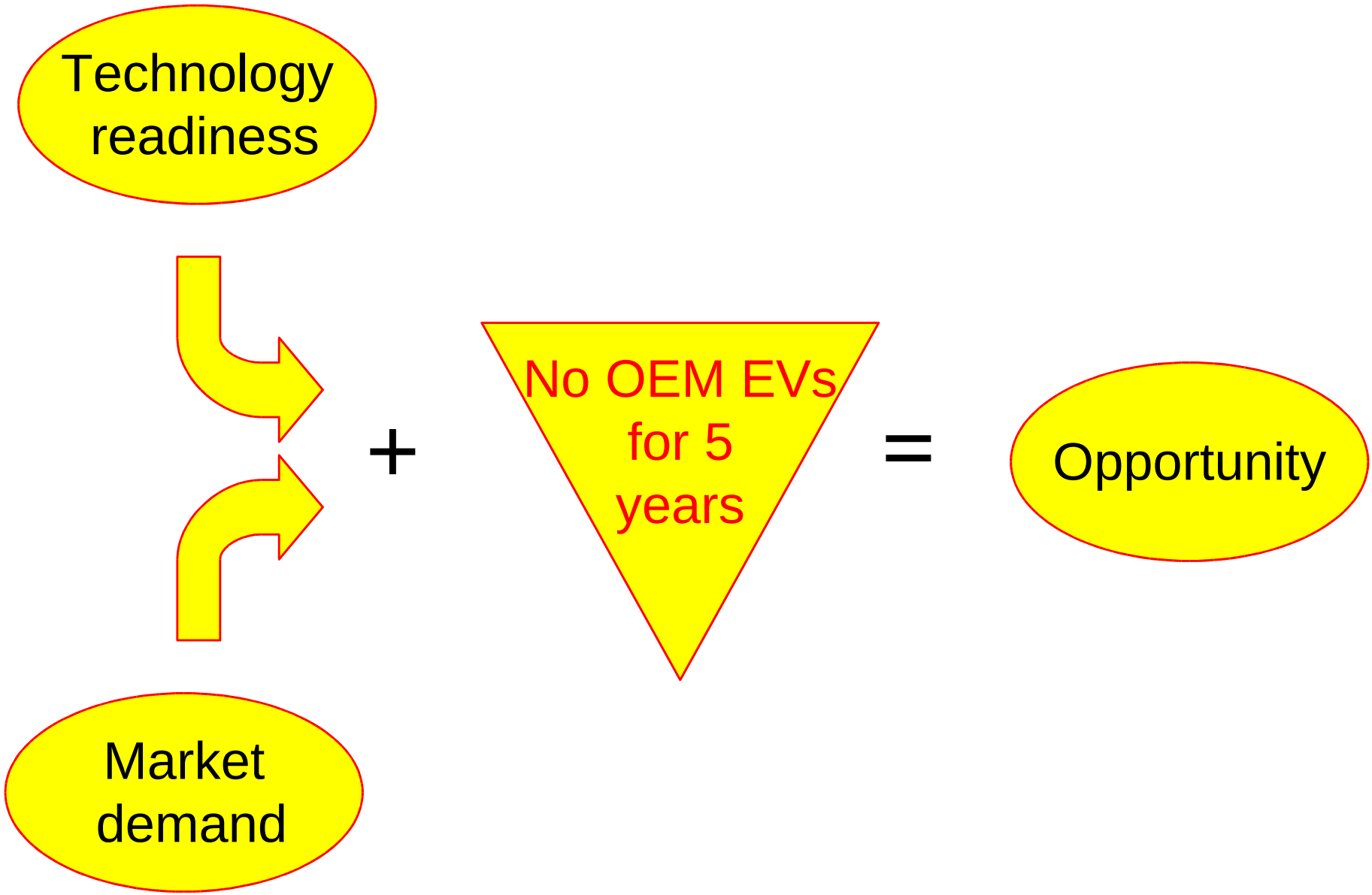
Why Not Build EVs?



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Vehicle Installation Benefits with Li Ion Cells

- Reduced weight simplifies FMVSS compliance
- Smaller size reduces vehicle tear-up
- Lower battery cost for greater range

VW Golf platform	PbA observed	NiMH observed	Li Ion estimated
battery modules	30 x 12V	30 x 12V	25 x 14.8V
nominal voltage	360V	360V	370V
rated capacity	55 Ah	90 Ah	98 Ah
delivered capacity	50 Ah	80 Ah	90 Ah
delivered energy	18 kWh	29 kWh	33 kWh
weight of modules	1440 lbs	1307 lbs	540 lbs
vehicle weight	3920 lbs	3700 lbs	3020 lbs
energy consumption	212 Wh/mi	223 Wh/mi	200 Wh/mi
range	85 mi	130 mi	165 mi
cost of modules	$10,000	$37,500*	$24,500

* Based on Toyota quote. Cost to purchase in 1998 was $90,000

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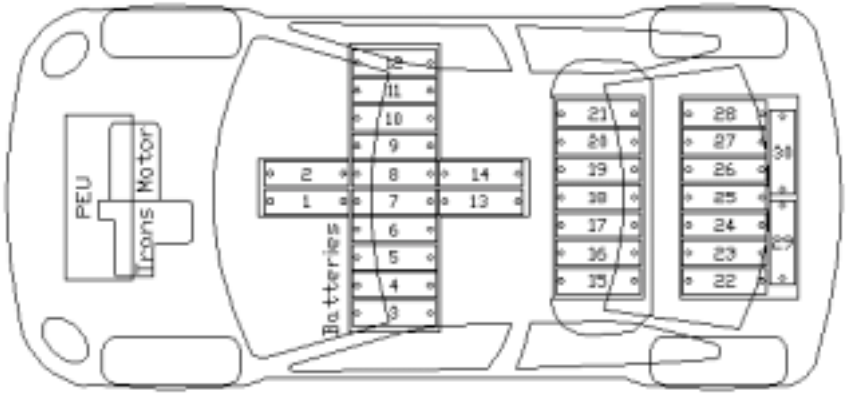
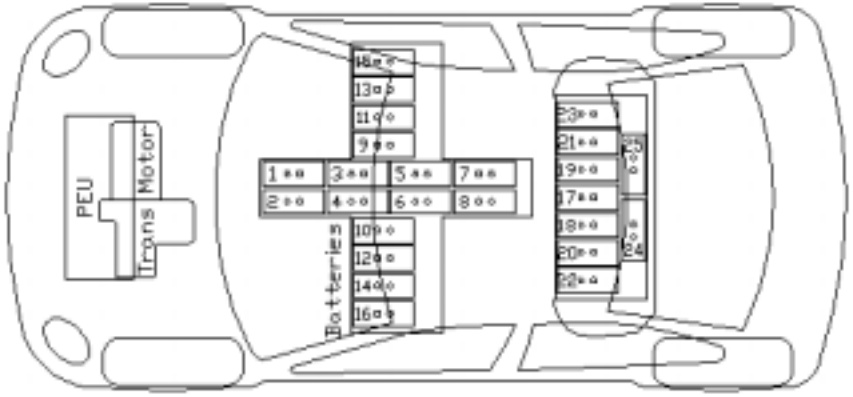
EV Conversion Comparison





PbA EV

- 3920 lbs, 49%F / 51%R
- 18 kWh
- 220 Wh/mi
- 80 mile range
- 77 kW/ton

Li Ion EV

- 3070 lbs, 58%F / 42%R
- 33 kWh
- 200 Wh/mi
- 165 mile range
- 80 kW/ton

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EV Conversion Possibilities

Scion xB

- “advanced” styling
- light weight
- comfortable
- versatile
- fleet market

Mini Cooper

- “fun” styling
- small and light
- sporty
- 4-passenger
- good demographics

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EV Conversion Specifications*

Base Model

- 2700 pounds
- 21 kWh battery
- 100 mile range
- 0-60 < 10 sec, 85 mph
- 2-hour charge (240V/50A)

Premium Model

- 3000 pounds
- 35 kWh battery
- 180 mile range
- 0-60 < 7 sec, 90 mph
- 3.5 hour charge (240V/50A)

Standard Equipment:

- Bi-directional power
- Cruise control
- Level 3 AC charging (20kW)
- Onboard battery diagnostics
- Full power
- Regen braking
- Traction control

* subject to change

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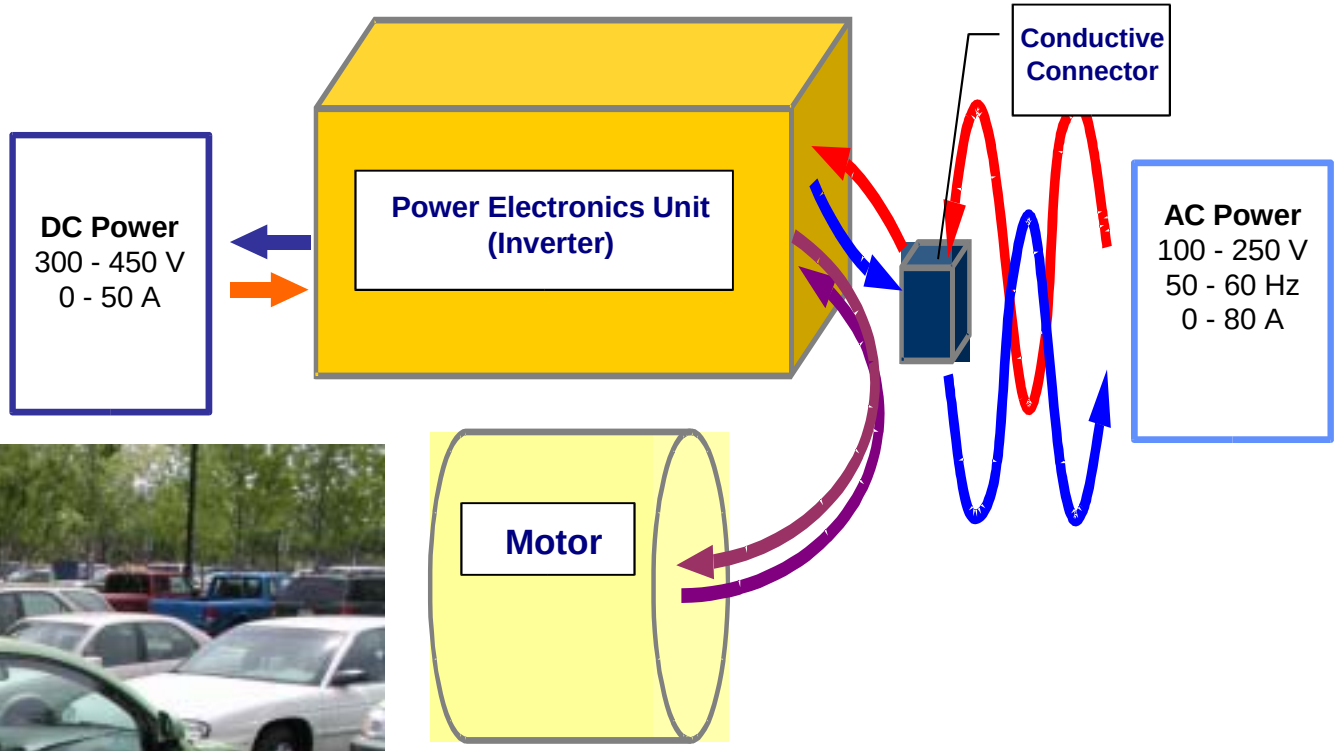
Vehicle to Grid – V2G

The charger is bi-directional



Power can flow both ways

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V2G – The Market Pull

- Discharge battery into grid for diagnostics and capacity measurement
- AC power in remote locations - emergencies, EV-to-EV charging, service vehicles, camping, tailgate parties
- UPS for house or business during blackouts or brownouts
- Grid support functions - supply and demand buffers, grid regulation, local and large area distributed generation

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AC Propulsion Goal

- Make things change in the right direction

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