AC Propulsion History

- Alan Cocconi developed the drive system for the General Motors Impact EV prototype in 1989, setting a new standard for EV performance.

- Cocconi founded AC Propulsion in 1992 to develop electric vehicle technology.
AC Propulsion Today

• A full-function R&D facility located in San Dimas, California, dedicated to building electric vehicles that people want to buy

• Power electronics lab
• Battery test lab
• 200-hp electric dynamometer
• Electronics assembly
• Machine shop
• Fabrication shop
• Composite shop
• Automotive service bays
Honda Civic EV Conversion - 1994

200 hp
0-60 mph in 6.2 seconds
0-125,000 miles in 10 years
0 emissions
Electric Sports Car - 1996

- 220 hp
- 2500 pounds
- 0-60 in 4.9 secs
- 0 emissions
Proven in Battle

Ferrari F355
375 hp V8

Porsche Carrera 4
282 hp F6, 4WD

Chevrolet Corvette
345 hp V8
tZero vs Lamborghini Diablo VT

543 hp V12 4WD vs 220 hp electric RWD
Launch
Pulling Away
Hasta la Vista
Electric Land Speed Record - 1999

Two AC-150 drive systems
6000 sub-C NiMH cells
400 hp
254 mph
VW Golf EV Conversion – 2001

NiMH Battery
3100 pounds
100 miles range
VW Beetle “The Plug Bug” - 2002

Bi-directional charger.
Power can flow to or from vehicle

DC Power
300 - 450 V
0 - 50 A

AC Power
100 - 250 V
50 - 60 Hz
0 - 80 A

Power Electronics Unit
(Inverter)

Conductive Connector

Motor

- Stand alone
- Grid-tied
- V2G
The Vehicle-to-Grid Concept - V2G

Connected vehicles serve as distributed energy resource (DER)

Grid Operator

<table>
<thead>
<tr>
<th>Wireless Provider</th>
</tr>
</thead>
</table>

Driver Usage Profile and Preferences

Internet

Power Command

GPS

Power Response

Aggregator

$
Los Angeles City Hall Shuttle - 2002

AC Propulsion upgrades two buses for LADWP to improve reliability and driveability, and to increase range.

On Thursday October, 3, 2003, Tom Gage drove the tzero 302 miles, from Sunnyvale to Santa Barbara, without charging. Average speed was 58 mph.
Challenge Bibendum San Francisco - 2003

tzero - 1st overall
tZero vs VIPER
tZero vs VIPER
tZero vs VIPER
tZero vs VIPER
Challenge Bibendum, Shanghai - 2004

• 3rd Overall
• Volvo 3CC Concept
• AC Propulsion Power
• Made in Los Angeles

• 2nd Overall
• Courrèges Design EXE
• AC Propulsion Power
• Made in Paris
Courrèges Design EXE

EXE
Volvo 3CC EV Concept

- Front-wheel drive
- Battery in floor
- Two-plus-one seating

- 2004 Challenge Bibendum, Shanghai
- 2005 NAIAS, Detroit
- 2005 Geneva Auto Show
Venturi Fétish EV Prototype - 2004

- Mid-motor, rear wheel drive, $500,000
- AC Propulsion Power
- Made in Monaco
- World Debut, Paris 2004
- US Debut, Los Angeles 2005
Fétish Battery: T-Pack for Good Balance

AC Propulsion battery assembly and management system

- 7,200 cells
- 72P100S
- 370 V
- 58 kWh
- 165 kW
- 350 kg
Wrightspeed X1 - 2005

- Mid-motor, rear wheel drive
- AC Propulsion Power
- Made in California

November 8, 2005, Infineon Raceway

Wrightspeed X1 vs Porsche Carrera GT, 605 hp V10
Automakers Say:

Use Gasoline Only and Be Proud of It

• “Remember, Prius never needs to be plugged in.”
  – 2004 Toyota Prius Product Reference Guide

• “The Civic Hybrid’s gas-electric powertrain works seamlessly and automatically as you drive.
  So you never plug it in. (emphasis in original)
  – 2004 Honda Car & Truck product brochure

• “Do I have to plug it in?”
  “No. Not once. Not Ever. Plug-in vehicles are strictly electric, not hybrids.”
  – Lexus brochure for 2005 RX 400h
<table>
<thead>
<tr>
<th>Region</th>
<th>population millions</th>
<th>% of world population</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>6,396</td>
<td>100%</td>
</tr>
<tr>
<td>China</td>
<td>1,307</td>
<td>20%</td>
</tr>
<tr>
<td>India</td>
<td>1,087</td>
<td>17%</td>
</tr>
<tr>
<td><strong>US</strong></td>
<td><strong>294</strong></td>
<td><strong>5%</strong></td>
</tr>
<tr>
<td>EU</td>
<td>381</td>
<td>6%</td>
</tr>
<tr>
<td>Japan</td>
<td>128</td>
<td>2%</td>
</tr>
<tr>
<td>ROW</td>
<td>3,200</td>
<td>50%</td>
</tr>
</tbody>
</table>

source: Population Reference Bureau
## Crude Oil Consumption

<table>
<thead>
<tr>
<th>Region</th>
<th>population millions</th>
<th>% of world population</th>
<th>Crude Oil Use, Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>million tonnes</td>
</tr>
<tr>
<td>World</td>
<td>6,396</td>
<td>100%</td>
<td>3,413</td>
</tr>
<tr>
<td>China</td>
<td>1,307</td>
<td>20%</td>
<td>228</td>
</tr>
<tr>
<td>India</td>
<td>1,087</td>
<td>17%</td>
<td>115</td>
</tr>
<tr>
<td>US</td>
<td>294</td>
<td>5%</td>
<td>764</td>
</tr>
<tr>
<td>EU</td>
<td>381</td>
<td>6%</td>
<td>571</td>
</tr>
<tr>
<td>Japan</td>
<td>128</td>
<td>2%</td>
<td>200</td>
</tr>
<tr>
<td>ROW</td>
<td>3,200</td>
<td>50%</td>
<td>1,535</td>
</tr>
</tbody>
</table>

source: International Energy Agency
Gasoline Consumption

Annual Gasoline Consumption - Gallons per Person

<table>
<thead>
<tr>
<th>Country</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>2</td>
</tr>
<tr>
<td>China</td>
<td>10</td>
</tr>
<tr>
<td>World w/o US</td>
<td>28</td>
</tr>
<tr>
<td>World</td>
<td>47</td>
</tr>
<tr>
<td>EU</td>
<td>102</td>
</tr>
<tr>
<td>Japan</td>
<td>124</td>
</tr>
<tr>
<td>US</td>
<td>453</td>
</tr>
</tbody>
</table>

source: International Energy Agency
Plug-In Hybrids Use Gas and Electricity

- Have enough EV range for daily driving
- Plug in at home
- Charge while you sleep
- Go on trips - 450 miles per tank

Plug-In Hybrids Use Gas and Electricity

- Reduce petroleum imports
- Get better mpg
- Use domestic energy
- Use renewable electricity
- Reduce cold start emissions
- Kick the gasoline habit
AC Propulsion Plug-in Hybrid Prototype - 2003

100 kW drive system with bi-directional AC power interface

- 8 kWh lead-acid hybrid battery
- 15 kW on natural gas for stationary generation
- 35 kW APU output on gasoline for driving

- 4-passenger
- 35 mile battery range
- 0-60 in 8.5 sec
- 87 mph top speed
- 3750 pounds

Project Sponsors:
SCAQMD
CARB
VW
NREL
EPRI

Auxiliary power unit
1.4L engine, inverter-controlled alternator
EV Conversion and Upgrade

- Installation of 110 kW electric drivetrain
- Replace Gen 1 power electronics with Gen 2
Battery Pack

- Panasonic HV1225, 25Ah
- Pack weight: 310 kg
- Capacity: 8.7 kWh (rated)
APU Installation

- Rear-mounted APU
- Packaging, cooling, NVH
APU Development

- Stand-alone, self-contained unit
- Adaptable to other engines, power levels, applications
Alternator Design

- New design with 8” diameter rotor
- Mounts directly to engine crankshaft
- Inverter control allows engine stop/start
On-track

- Michelin Challenge Bibendum - September, 2003
# Jetta: Hybrid vs Conventional

<table>
<thead>
<tr>
<th></th>
<th>Project Vehicle</th>
<th>VW Jetta 2.0L auto.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-60 mph acceleration</td>
<td>8.7 secs ¹</td>
<td>12.0 secs ²</td>
</tr>
<tr>
<td>Top Speed</td>
<td>87 mph ³</td>
<td>&gt;100 mph</td>
</tr>
<tr>
<td>City fuel economy</td>
<td>27 mpg ⁴</td>
<td>23 mpg ⁵</td>
</tr>
<tr>
<td>Highway fuel economy</td>
<td>34 mpg ¹</td>
<td>29 mpg ⁵</td>
</tr>
<tr>
<td>EV range</td>
<td>30 miles</td>
<td>0 miles</td>
</tr>
<tr>
<td>Max Range</td>
<td>540 miles</td>
<td>435 miles</td>
</tr>
</tbody>
</table>

¹ measured
² Consumers Reports test data
³ Governed by control system
⁴ CARB test result depreciated 10%
⁵ EPA label value
## Plug-in Jetta vs Plugless Prius

<table>
<thead>
<tr>
<th>Component</th>
<th>Plug-in Jetta</th>
<th>Plugless Prius</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine</td>
<td>1.4 liter</td>
<td>1.5 liter</td>
</tr>
<tr>
<td></td>
<td>35 kW</td>
<td>56 kW</td>
</tr>
<tr>
<td>Generator</td>
<td>30 kW</td>
<td>20 kW (est)</td>
</tr>
<tr>
<td>Traction Motor</td>
<td>110 kW</td>
<td>50 kW</td>
</tr>
<tr>
<td>Transmission</td>
<td>Fixed ratio</td>
<td>Planetary</td>
</tr>
<tr>
<td>Battery</td>
<td>PbA</td>
<td>NiMH</td>
</tr>
<tr>
<td></td>
<td>8 kWh</td>
<td>2 kWh</td>
</tr>
<tr>
<td></td>
<td>650 lb</td>
<td>100 lb (est)</td>
</tr>
<tr>
<td>Charger</td>
<td>20 kW (V2G)</td>
<td>none</td>
</tr>
<tr>
<td>Charge port</td>
<td>conductive</td>
<td>none</td>
</tr>
</tbody>
</table>
Plug-in Hybrids 2005 and Beyond

Li batteries for plug-in hybrids

<table>
<thead>
<tr>
<th>Battery</th>
<th>Li Polymer</th>
<th>Li Ion</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 kWh</td>
<td>9 kWh</td>
<td></td>
</tr>
<tr>
<td>275 lb</td>
<td>135 lb</td>
<td></td>
</tr>
</tbody>
</table>

| Charger         | 20 kW w/V2G onboard | 1.5 kW offboard |

| MPG: 1st 50 mi  | 30-40             | 125             |
| rest of tank    |                   | 40-50           |
The Impending Decline of Global Petroleum

Source: Peak Oil, C.J. Campbell
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
## Electric Power Mix

<table>
<thead>
<tr>
<th>Source</th>
<th>CA</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>37%</td>
<td>17%</td>
</tr>
<tr>
<td>Large Hydro</td>
<td>16%</td>
<td>7%</td>
</tr>
<tr>
<td>Coal</td>
<td>21%</td>
<td>51%</td>
</tr>
<tr>
<td>Nuclear</td>
<td>15%</td>
<td>20%</td>
</tr>
<tr>
<td>Eligible Renewables</td>
<td>11%</td>
<td>2%</td>
</tr>
<tr>
<td>Petroleum</td>
<td>0%</td>
<td>3%</td>
</tr>
</tbody>
</table>

100% 100%

Source: CEC, EIA

Plug-in Vehicles: Transportation Without Petroleum
Electricity: Already a Great Fuel for Cars

- Low Pollution
- Low Greenhouse Gas Emissions
- Available and sustainable
- Diverse domestic resources
- Efficient in generation and use
- Established infrastructure
- Off-peak load
- Synergistic with solar and wind resources
Other Fuels Can Substitute Too

- Natural gas
- Bio-fuels
- Ethanol
- Methanol
- Hydrogen
Hydrogen Production Wastes Energy

- Hydrogen is made from natural gas or electricity
- Conversion process reduces energy content

Natural gas $\Rightarrow$ hydrogen: 20% loss
Electricity $\Rightarrow$ hydrogen: 48% loss
Fuel Cell EVs Use More Energy Than EVs

- **EV**: Toyota RAV4EV, 33 Miles, 10 kWh
- **FCEV**: Honda FCX, 33 Miles, 40 kWh

Source: US EPA fuel economy ratings
Hydrogen Increases CO2 Emissions

CO2 Emissions Well-to-Wheel

<table>
<thead>
<tr>
<th>Car Model</th>
<th>CO2 Emissions (gm CO2 per mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAV4 EV</td>
<td>133</td>
</tr>
<tr>
<td>Prius</td>
<td>198</td>
</tr>
<tr>
<td>Civic (gasoline)</td>
<td>321</td>
</tr>
<tr>
<td>FCX</td>
<td>508</td>
</tr>
</tbody>
</table>
Plan for Production of Electric Vehicles

- Sell systems and technology licenses to EV manufacturers
- **Build EV conversions, low volume**
- Support V2G development and demonstration
- Develop one or more suppliers of EV batteries
- Reduce cost of drive system
- JV with automakers, medium to high volume
People Like Electric Vehicles

Quotes from drivers who tested an AC Propulsion conversion at EVS-20, Long Beach, November 2003

• “very good acceleration, quite good, actually better than my car”
• “I do like the strong regenerative 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”
Electric Vehicle Survey

• Survey Objective:
  – To understand what people want and need in a modern Electric Vehicle

• Online Survey Launched on January 1, 2005

• 635 Respondents as of January 19, 2005

• Response Rate exceeds 100%

• Survey conducted by Nadine Weil
64% of all car trips are 30 miles or less

Q: How long is your typical trip in your car?

- Under 10 miles: 18%
- 10 – 30 miles: 46%
- 31-60 miles: 25%
- 61+ miles: 8%
- No car: 3%

Source: EV Survey. 625 Respondents
45% either own a hybrid now or want to buy one, while 47% also prefer EVs

Q: What do you think of hybrid cars?

- I’d rather have a cool EV: 47.2%
- Want to buy hybrid in 1-2 years: 18.1%
- Want to buy hybrid in 3-5+ years: 14.7%
- I own a hybrid now: 12.5%
- No hybrids in future: 6.7%
- Used to have hybrid: 0.4%
- What’s a hybrid?: 0.3%
- I prefer my Hummer: 0.3%

Source: EV Survey. 778 Total Responses
59% would pay up to $20K more for EV

Q: Would you consider paying a small price premium to have an Electric version of your favorite car?

Source: EV Survey. 607 Respondents
## The Car Candidates

<table>
<thead>
<tr>
<th>Acura RSX EV</th>
<th>Chevy Aveo EV</th>
<th>Honda Civic EV</th>
<th>Mazda 3 EV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini Cooper EV</td>
<td>Pontiac Vibe EV</td>
<td>Scion xA EV</td>
<td>Scion xB EV</td>
</tr>
<tr>
<td>Suzuki Forenza EV</td>
<td>Toyota Corolla EV</td>
<td>Volvo S40 EV</td>
<td>Venturi Fetish EV</td>
</tr>
</tbody>
</table>
Rankings of EV Car Candidates

Q: What do you think of the following EVs?

Average Score of All Segments

<table>
<thead>
<tr>
<th>EV Model</th>
<th>Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mazda 3 + Volvo</td>
<td>2.25</td>
</tr>
<tr>
<td>Vibe/Matrix + Corolla</td>
<td>2.60</td>
</tr>
<tr>
<td>Scion xA + xB</td>
<td>2.94</td>
</tr>
<tr>
<td>Volvo S40 EV</td>
<td>2.15</td>
</tr>
<tr>
<td>Mini Cooper EV</td>
<td>2.17</td>
</tr>
<tr>
<td>Mazda 3 EV</td>
<td>2.36</td>
</tr>
<tr>
<td>Acura RSX EV</td>
<td>2.37</td>
</tr>
<tr>
<td>Honda Civic EV</td>
<td>2.38</td>
</tr>
<tr>
<td>Toyota Corolla EV</td>
<td>2.47</td>
</tr>
<tr>
<td>Scion xA EV</td>
<td>2.69</td>
</tr>
<tr>
<td>Pontiac Vibe EV</td>
<td>2.74</td>
</tr>
<tr>
<td>Suzuki Forenza EV</td>
<td>2.86</td>
</tr>
<tr>
<td>Scion xB EV</td>
<td>3.18</td>
</tr>
<tr>
<td>Chevy Aveo EV</td>
<td>3.22</td>
</tr>
</tbody>
</table>

Source: EV Survey. 591 Respondents
Rankings of EV Car Candidates

Q: What do you think of the following EVs?
“Love It” Plus “Like It” for Price Segment $30K+

- Scion xA + xB: 52%
- Mazda 3 + Volvo: 51%
- Vibe/Matrix/Corolla: 39%
- Mini Cooper EV: 66%
- Volvo S40 EV: 58%
- Scion xA EV: 56%
- Scion xB EV: 48%
- Mazda 3 EV: 44%
- Acura RSX EV: 44%
- Pontiac Vibe EV: 41%
- Honda Civic EV: 41%
- Toyota Corolla EV: 37%
- Suzuki Forenza EV: 22%
- Chevy Aveo EV: 20%

Source: EV Survey. 59 Respondents
The AC Propulsion EV

FMVSS-certified EV conversion of Scion xA and xB

**Features**
- AC Propulsion drive system
- Li Ion battery
- Fast charging
- Regenerative braking
- Onboard battery diagnostics
- A/C, full power

**Performance**
- 100 mile range (180 mi option)
- 0-60 <10 sec (<7 sec option)
- 90 mph
- 1 mile per minute charging
Two Prototypes Under Construction

Check http://www.acpropulsion.com for updates