

AC Propulsion Past, Present, and Future

AC Propulsion, Inc.

San Dimas, CA

November, 2005

<http://www.acpropulsion.com>

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

tZero

Electric Sports Car - 1996



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

tZero

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

220 hp electric RWD

Launch



Acceleration



Pulling Away



Hasta la Vista



Electric Land Speed Record - 1999



**Two AC-150 drive systems
6000 sub-C NiMH cells
400 hp
254 mph**



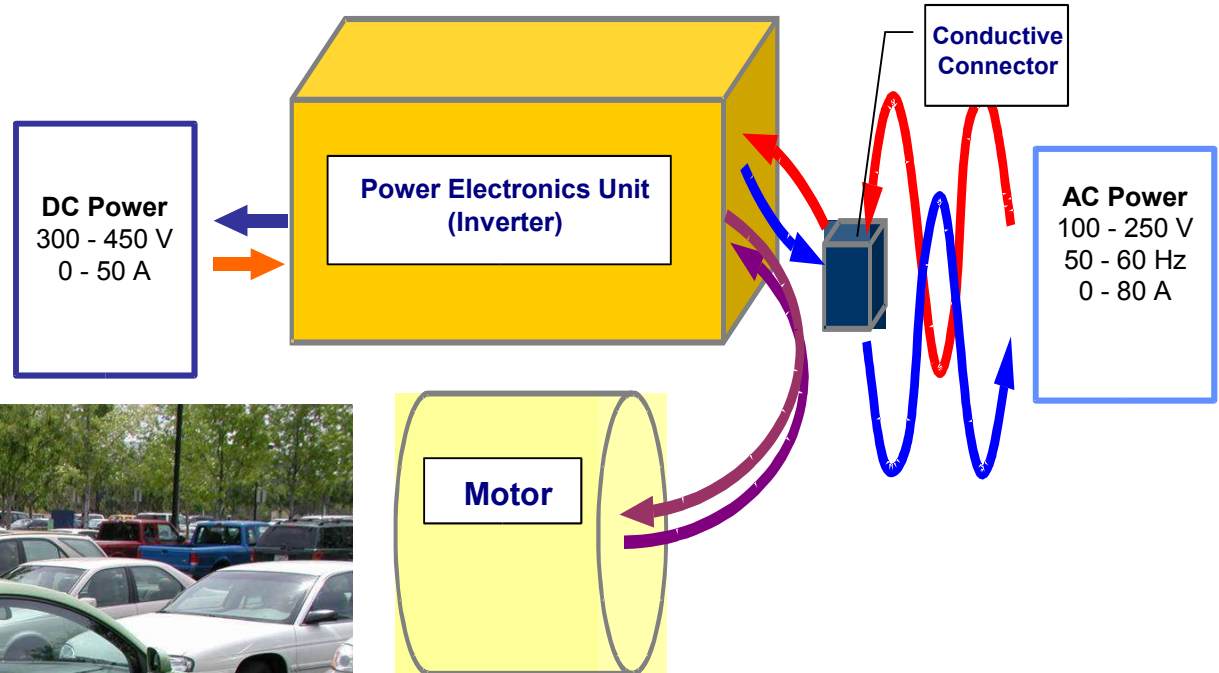
VW Golf EV Conversion – 2001



NiMH Battery
3100 pounds
100 miles range

VW Beetle “The Plug Bug” - 2002

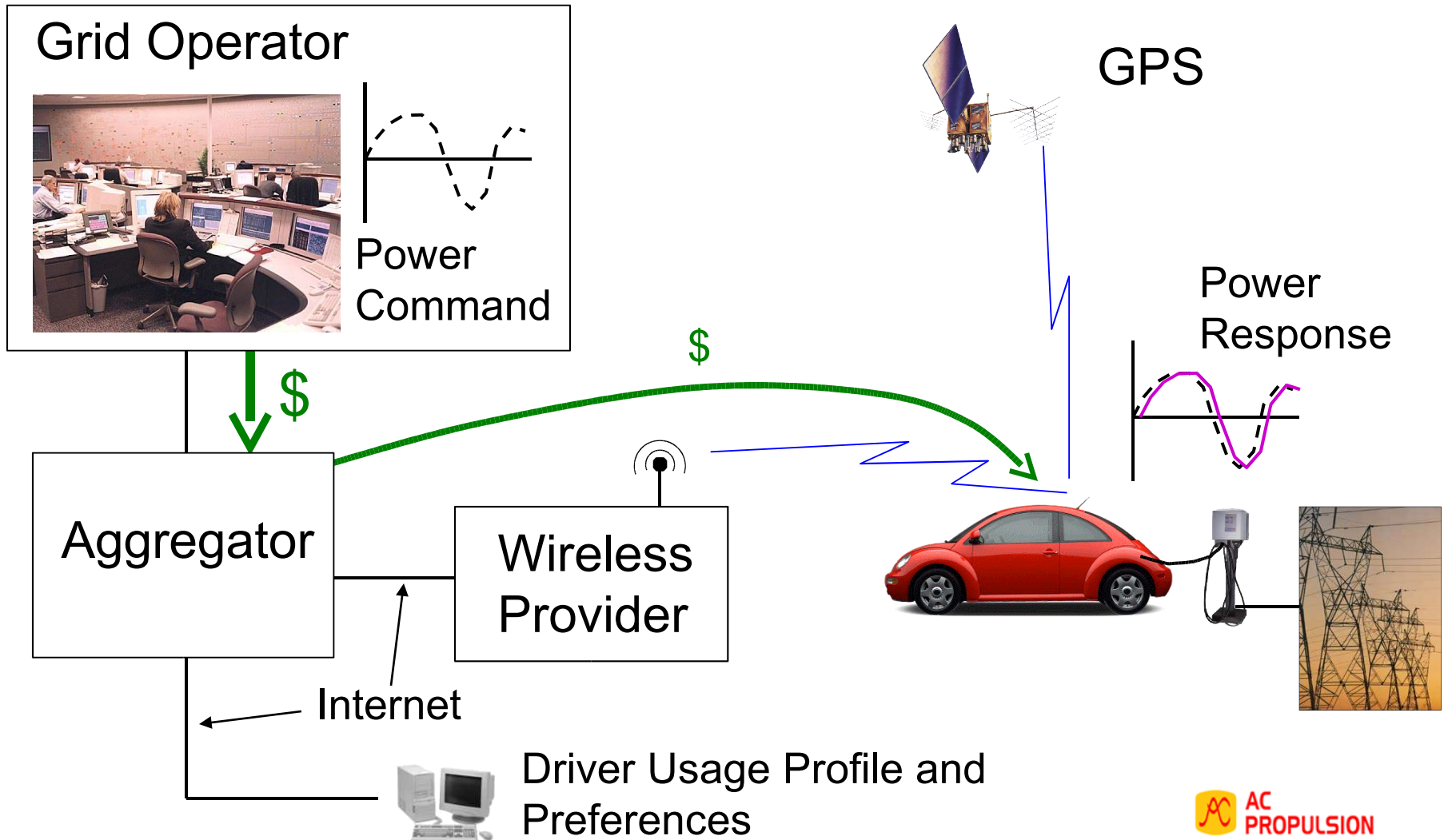
Bi-directional
charger.
Power can flow
to or from
vehicle



- Stand alone
- Grid-tied
- V2G

The Vehicle-to-Grid Concept - V2G

Connected vehicles serve as distributed energy resource (DER)



Los Angeles City Hall Shuttle - 2002

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



Lilon *tzero* - 2003

0-60 mph in 3.6 sec



On Tuesday September 9, 2003 in a series of acceleration tests, the tzero repeatedly accelerated 0-60 in under 4 secs. Alan Cocconi achieves the best time - 3.6 secs. Writer Chris Dixon gets 3.7 secs and reports it in the *New York Times*.

300 mile 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



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

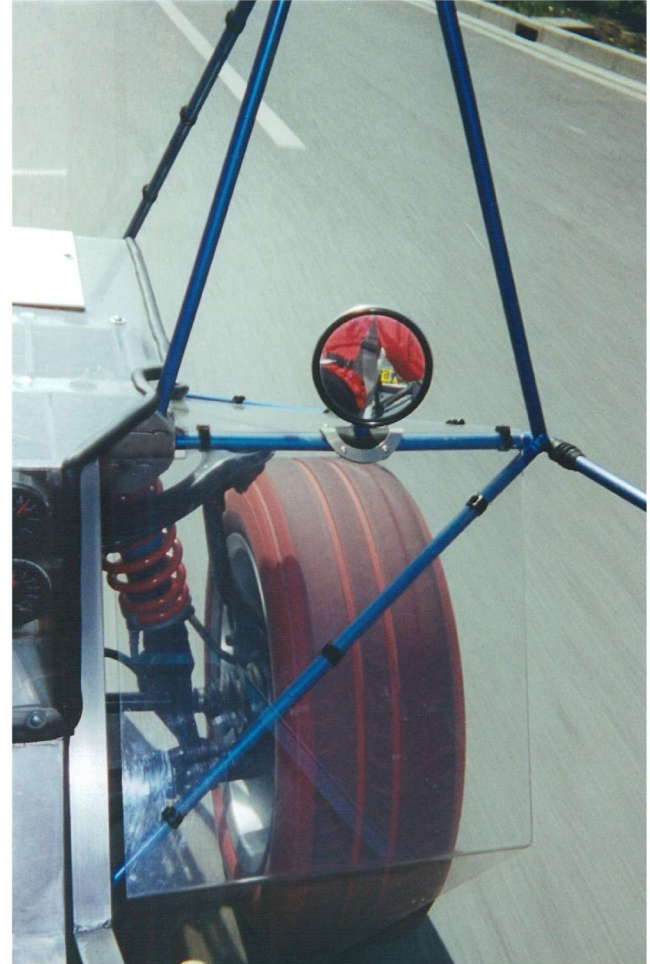
- 3rd Overall
- Volvo 3CC Concept
- AC Propulsion Power
- Made in Los Angeles



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

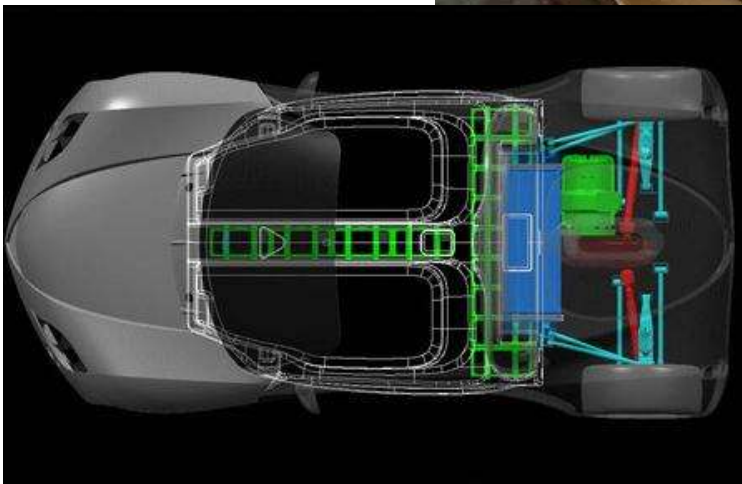
- Mid-motor, rear wheel drive, \$500,000
- AC Propulsion Power
- Made in Monaco
- World Debut, Paris 2004
- US Debut, Los Angeles 2005



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

World Population

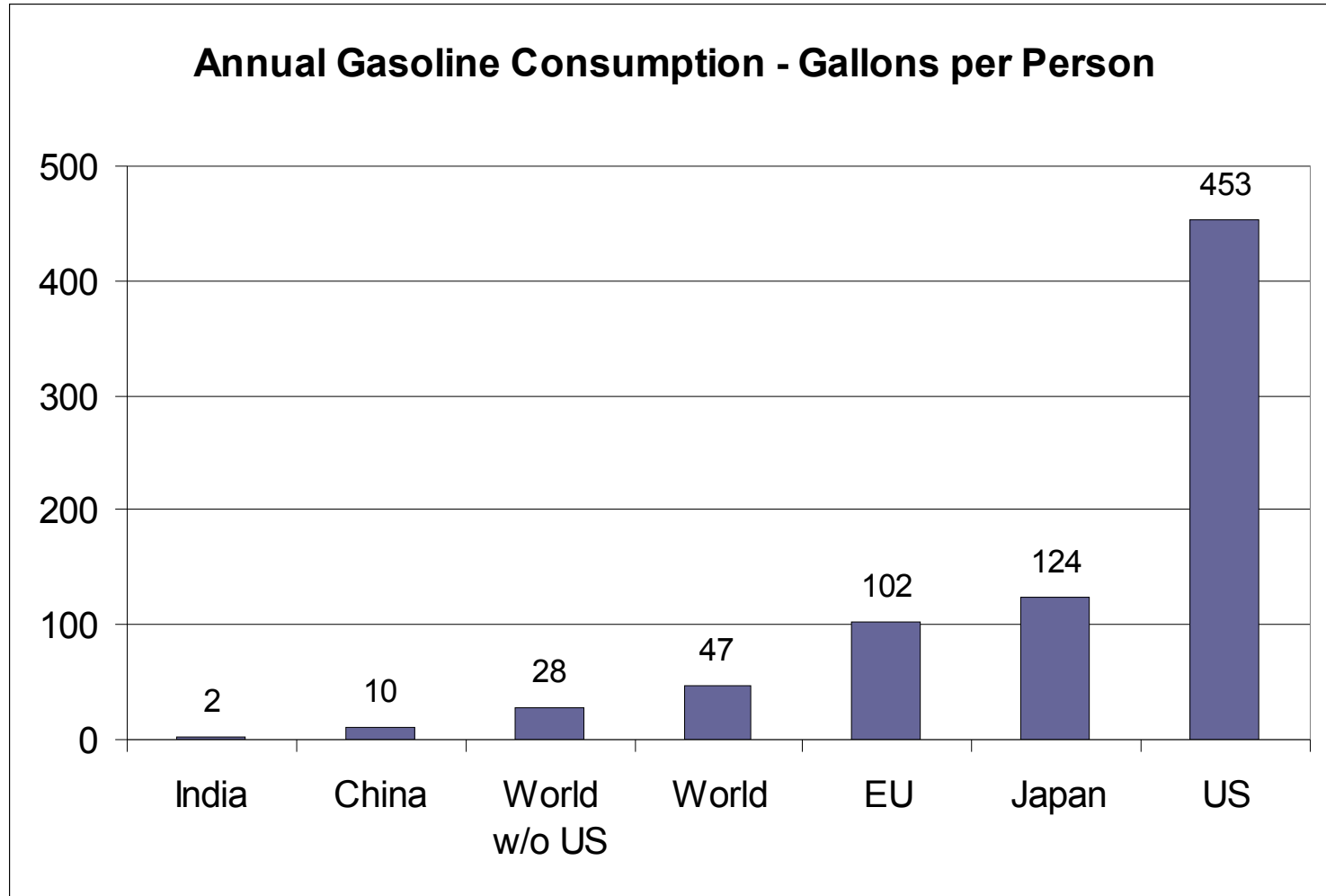
Region	population millions	% of world population
World	6,396	100%
China	1,307	20%
India	1,087	17%
US	294	5%
EU	381	6%
Japan	128	2%
ROW	3,200	50%

source: Population Reference Bureau

Crude Oil Consumption

Region	population millions	% of world population	Crude Oil Use, Total		
			million tonnes	% of world	per cap vs world
World	6,396	100%	3,413	100%	1.0
China	1,307	20%	228	7%	0.3
India	1,087	17%	115	3%	0.2
US	294	5%	764	22%	4.9
EU	381	6%	571	17%	2.8
Japan	128	2%	200	6%	2.9
ROW	3,200	50%	1,535	45%	0.9

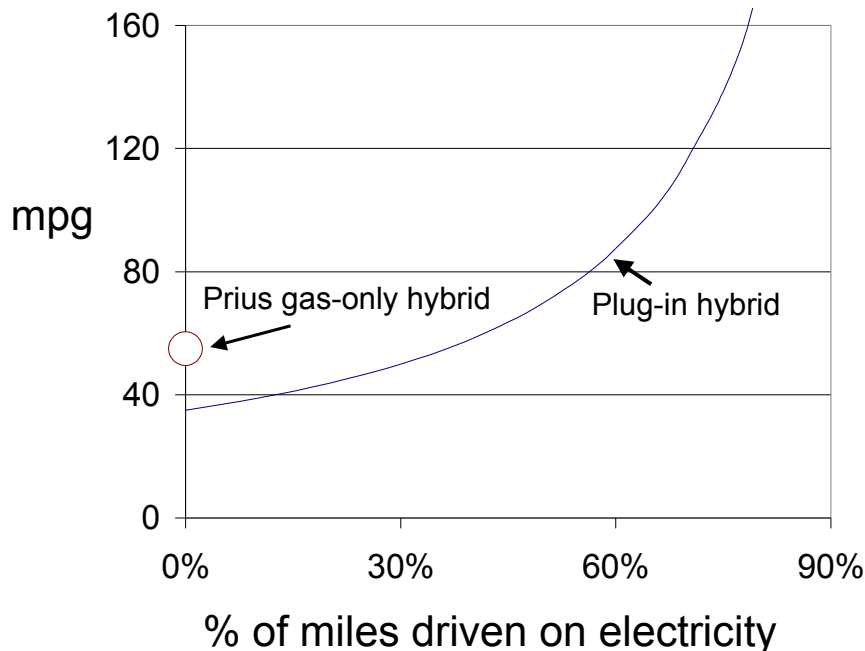
Gasoline Consumption



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



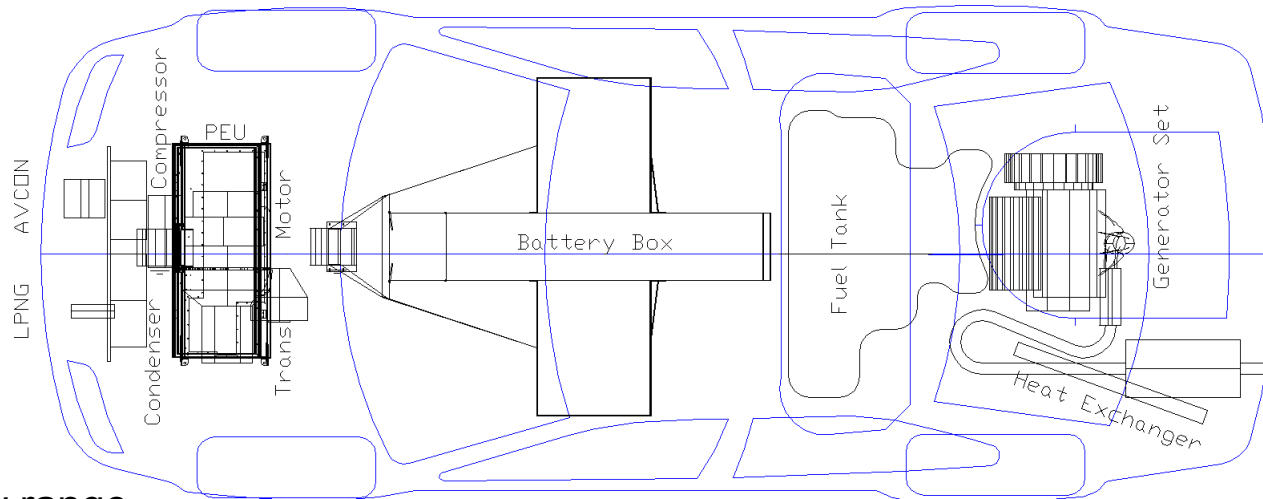
- Reduce petroleum imports
- Get better mpg
- Use domestic energy
- Use renewable electricity
- Reduce cold start emissions
- Kick the gasoline habit

AC Propulsion Plug-in Hybrid Prototype - 2003

100 kW drive system with bi-directional AC power interface

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

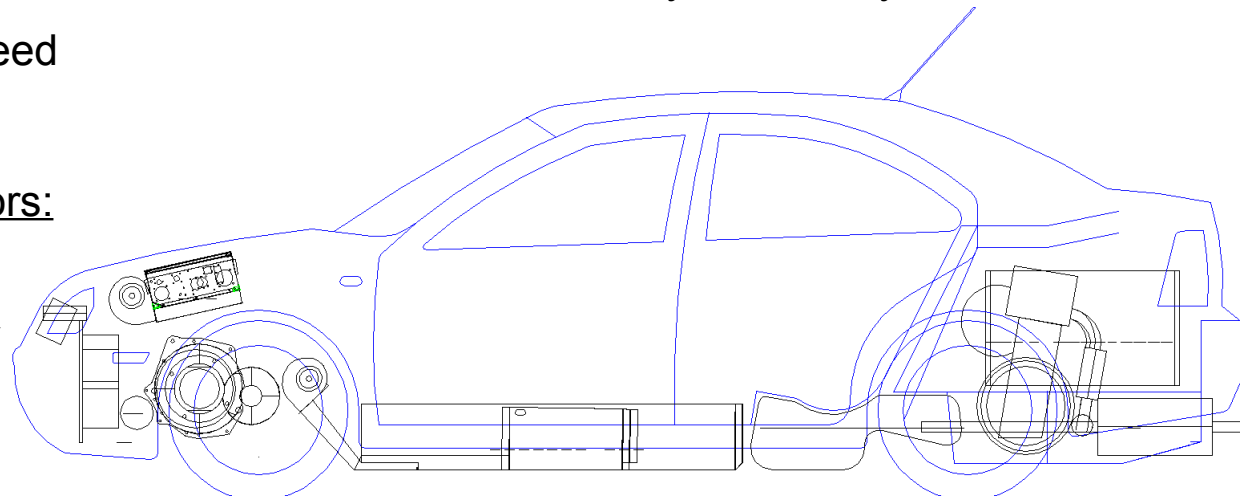


8 kWh lead-acid hybrid battery

Auxiliary power unit
1.4L engine,
inverter-controlled alternator

35 kW
APU output
on gasoline
for driving

15 kW on
natural
gas for
stationary
generation



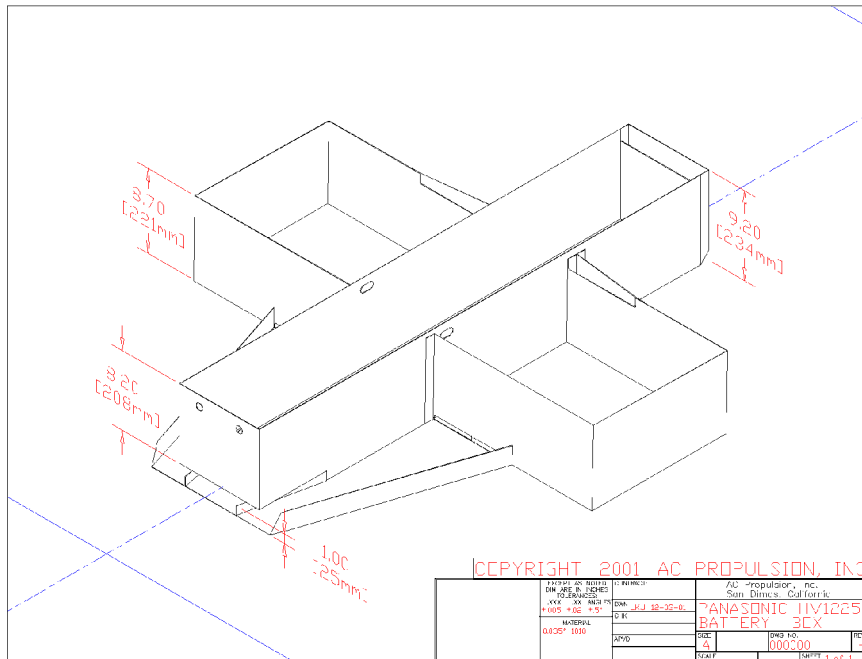
EV Conversion and Upgrade

- 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

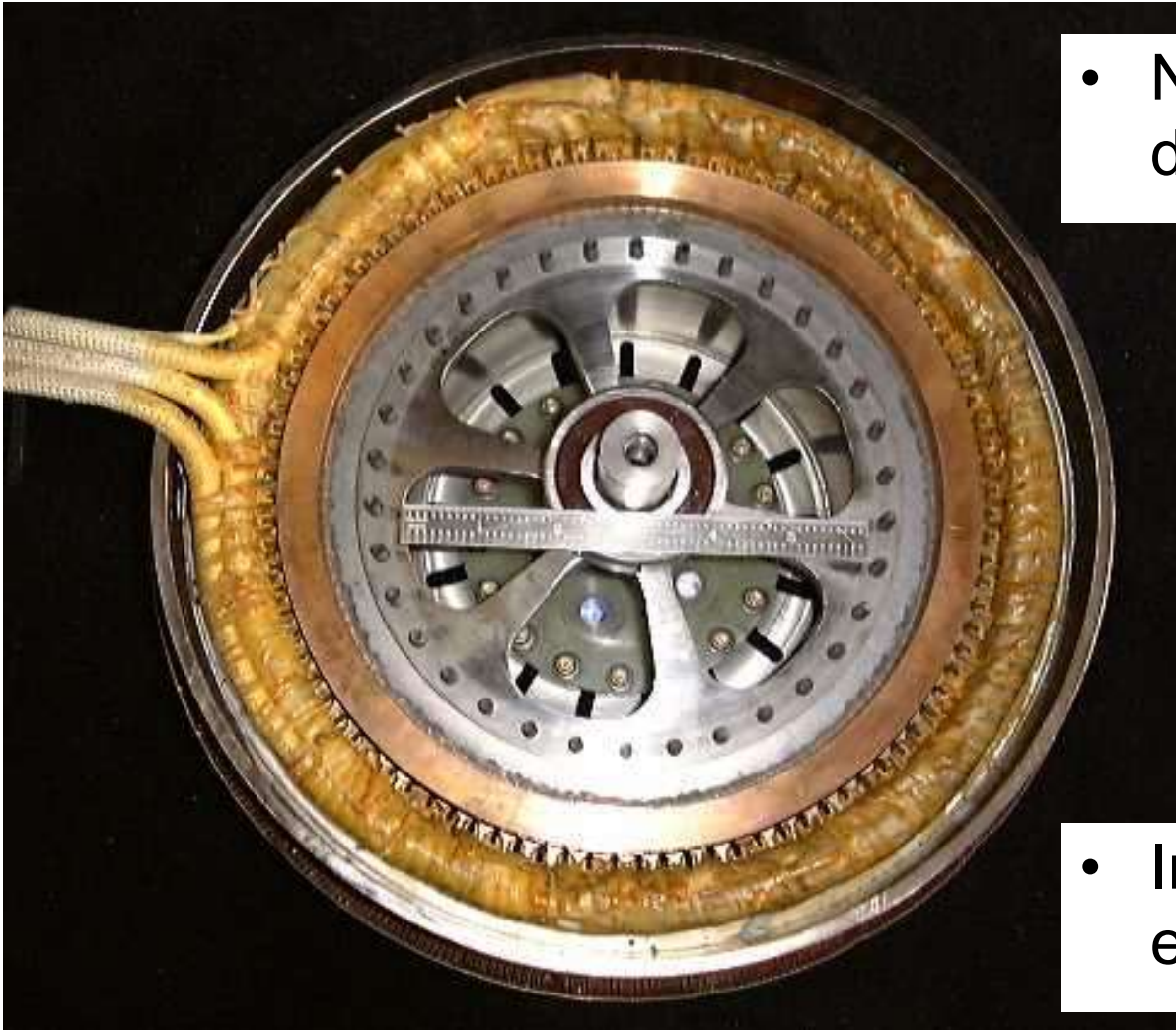


APU Development



- 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

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

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



Engine	1.4 liter 35 kW	1.5 liter 56 kW
Generator	30 kW	20 kW (est)
Traction Motor	110 kW	50 kW
Transmission	Fixed ratio	Planetary
Battery	PbA 8 kWh 650 lb	NiMH 2 kWh 100 lb (est)
Charger	20 kW (V2G)	none
Charge port	conductive	none

Plug-in Hybrids 2005 and Beyond

Li batteries for
plug-in hybrids



Battery

Li Polymer

Li Ion

14 kWh

9 kWh

275 lb

135 lb

Charger

20 kW w/V2G
onboard

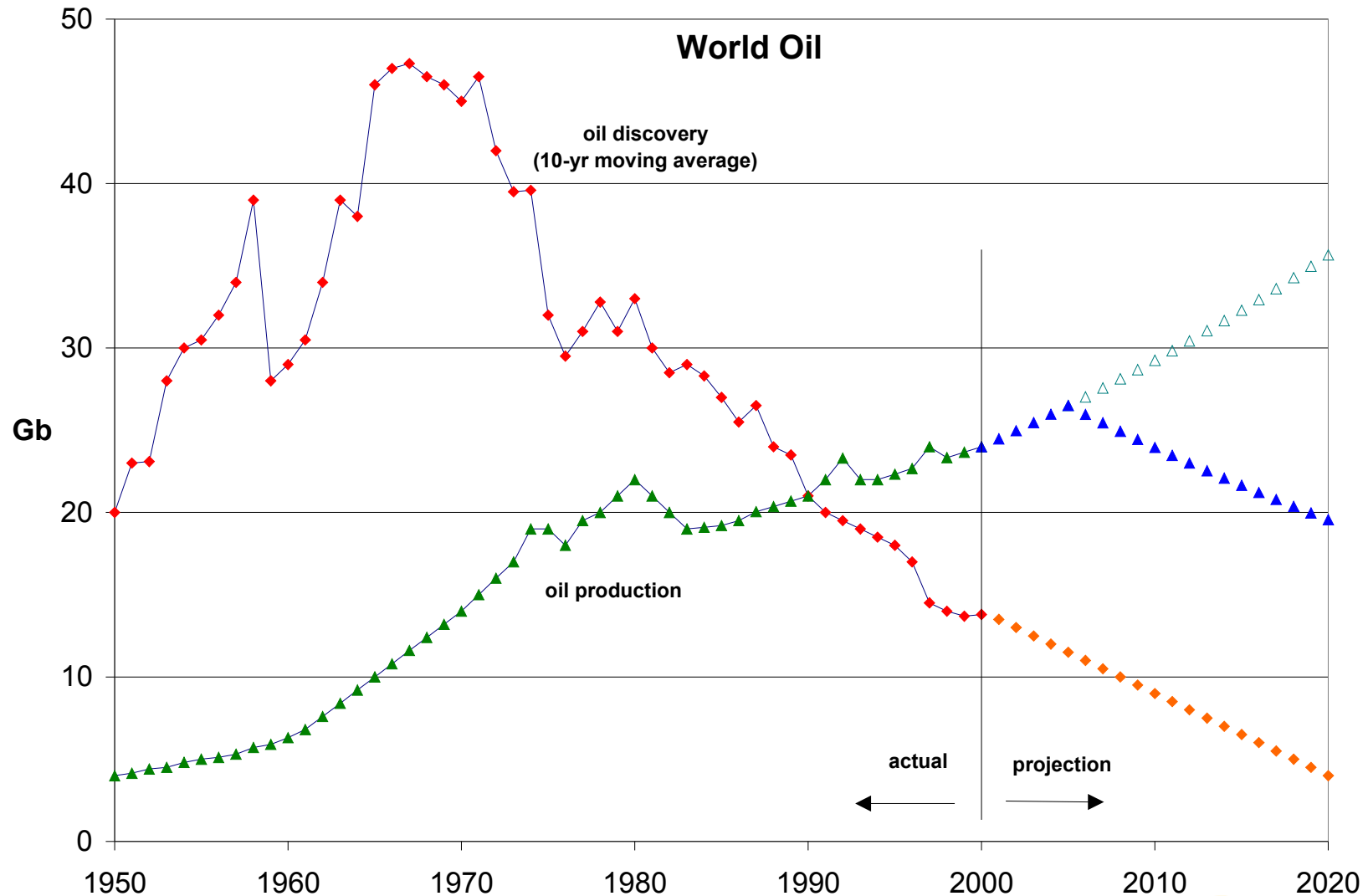
1.5 kW
offboard

MPG: 1st 50 mi
rest of tank

30-40

125
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

	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

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

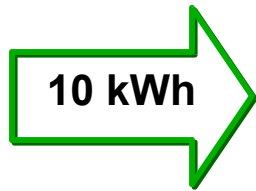
Hydrogen Production Wastes Energy

- 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

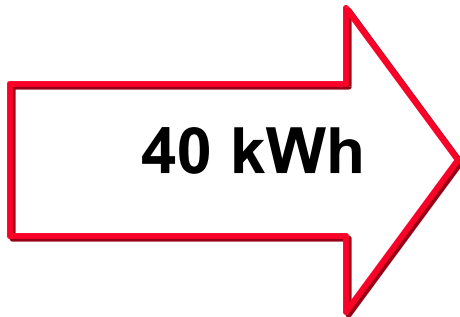
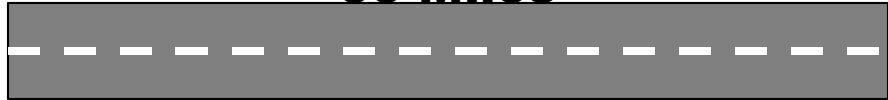


EV



Toyota RAV4EV

33 Miles



FCEV

Fuel Cell



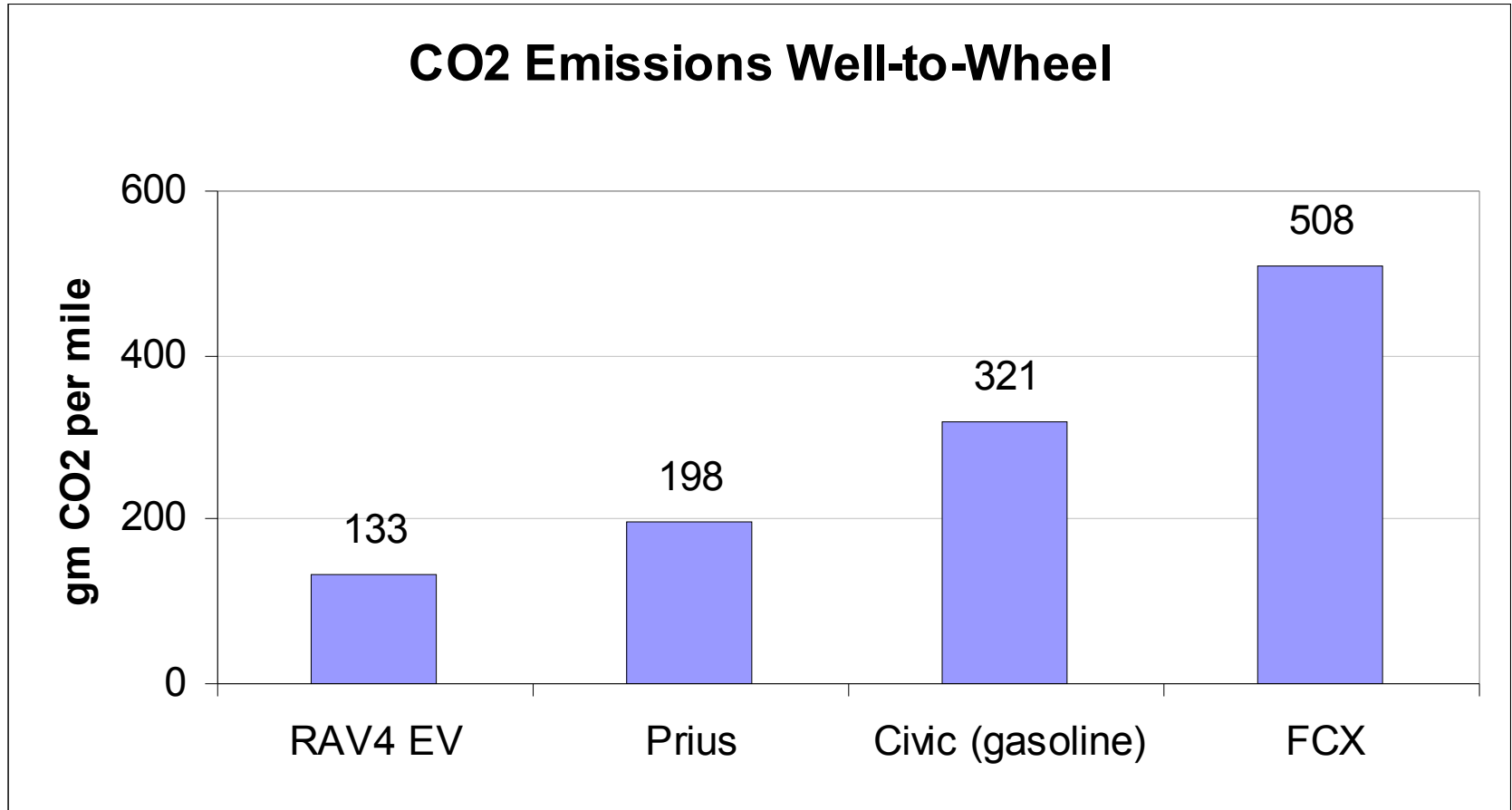
Honda FCX

33 Miles



Source: US EPA fuel economy ratings

Hydrogen Increases CO2 Emissions



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

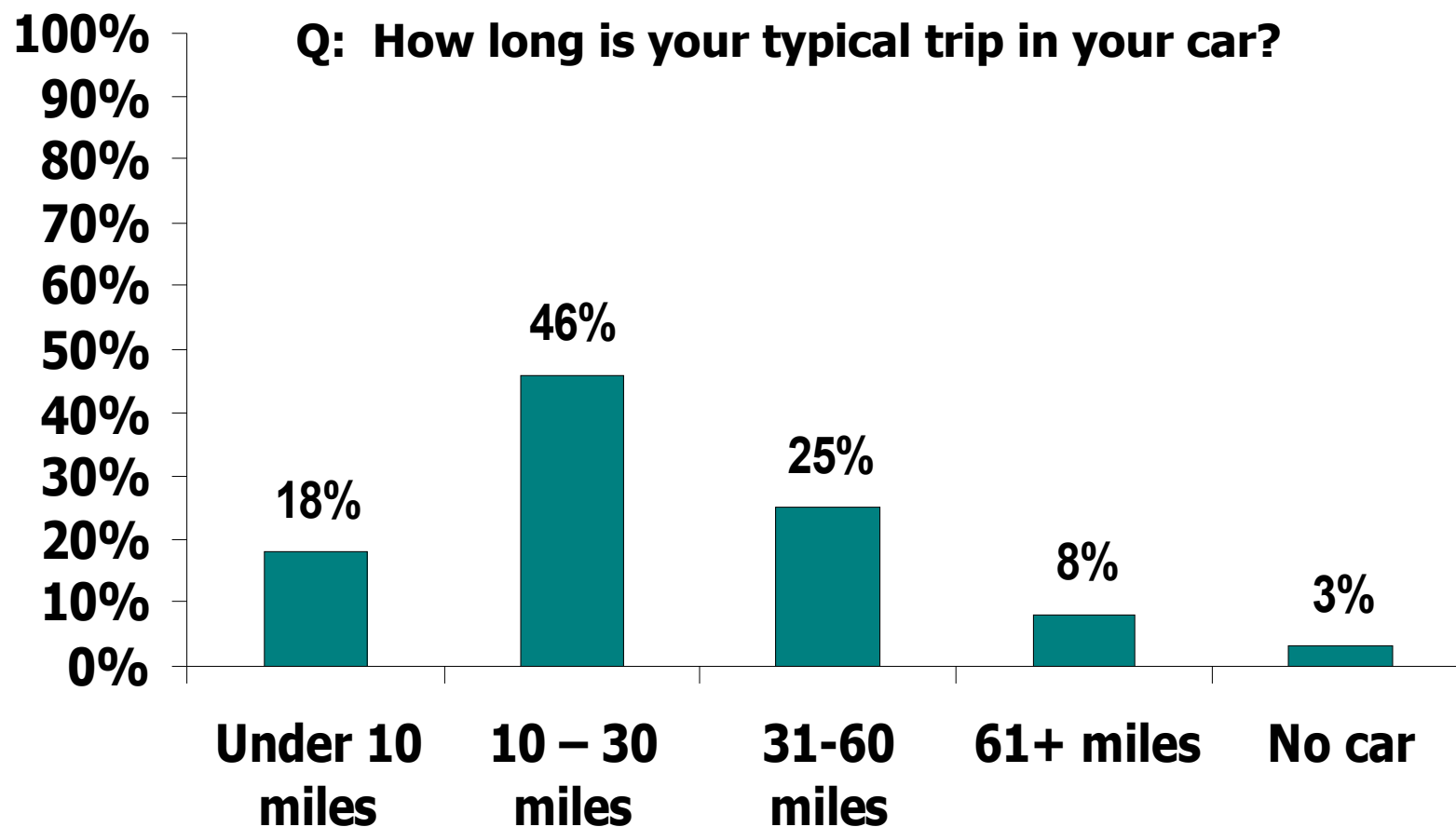
Quotes from drivers who tested an AC Propulsion conversion at EVS-20, Long Beach, November 2003

- “very good acceleration, quite good, actually better than my car”
- “I do like the strong 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”

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

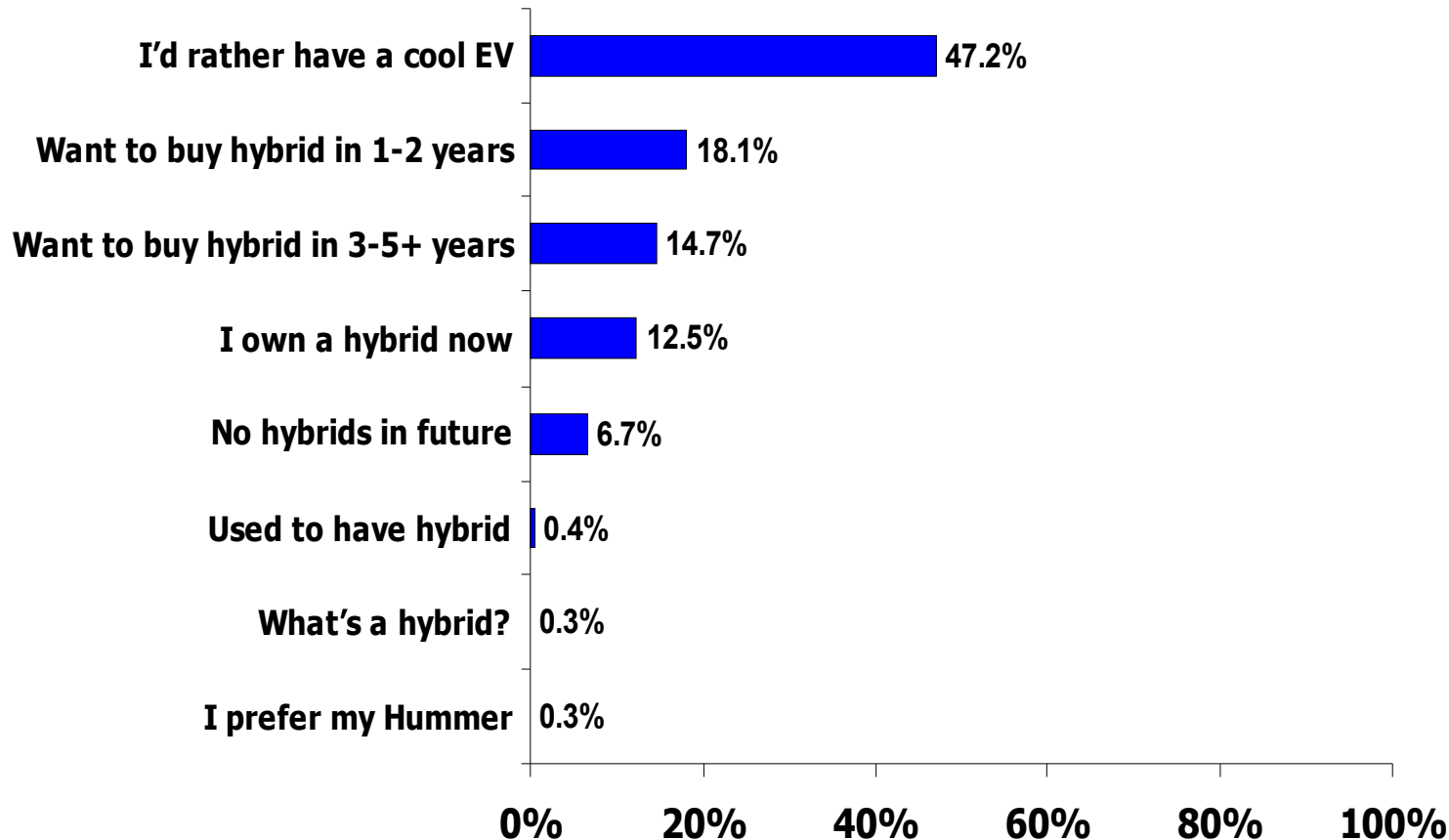
64% of all car trips are 30 miles or less



Source: EV Survey. 625 Respondents

45% either own a hybrid now or want to buy one, while 47% also prefer EVs

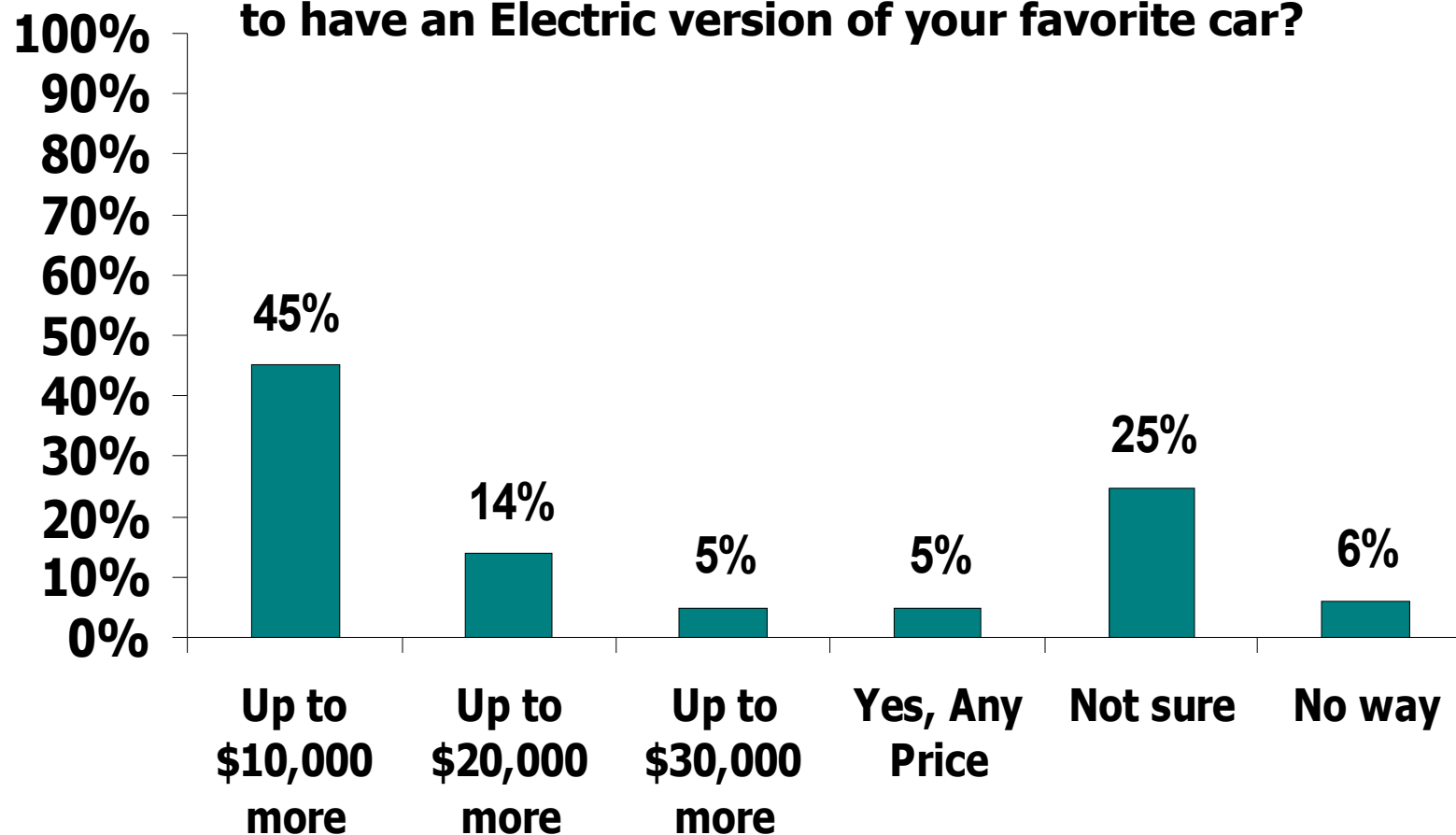
Q: What do you think of hybrid cars?



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

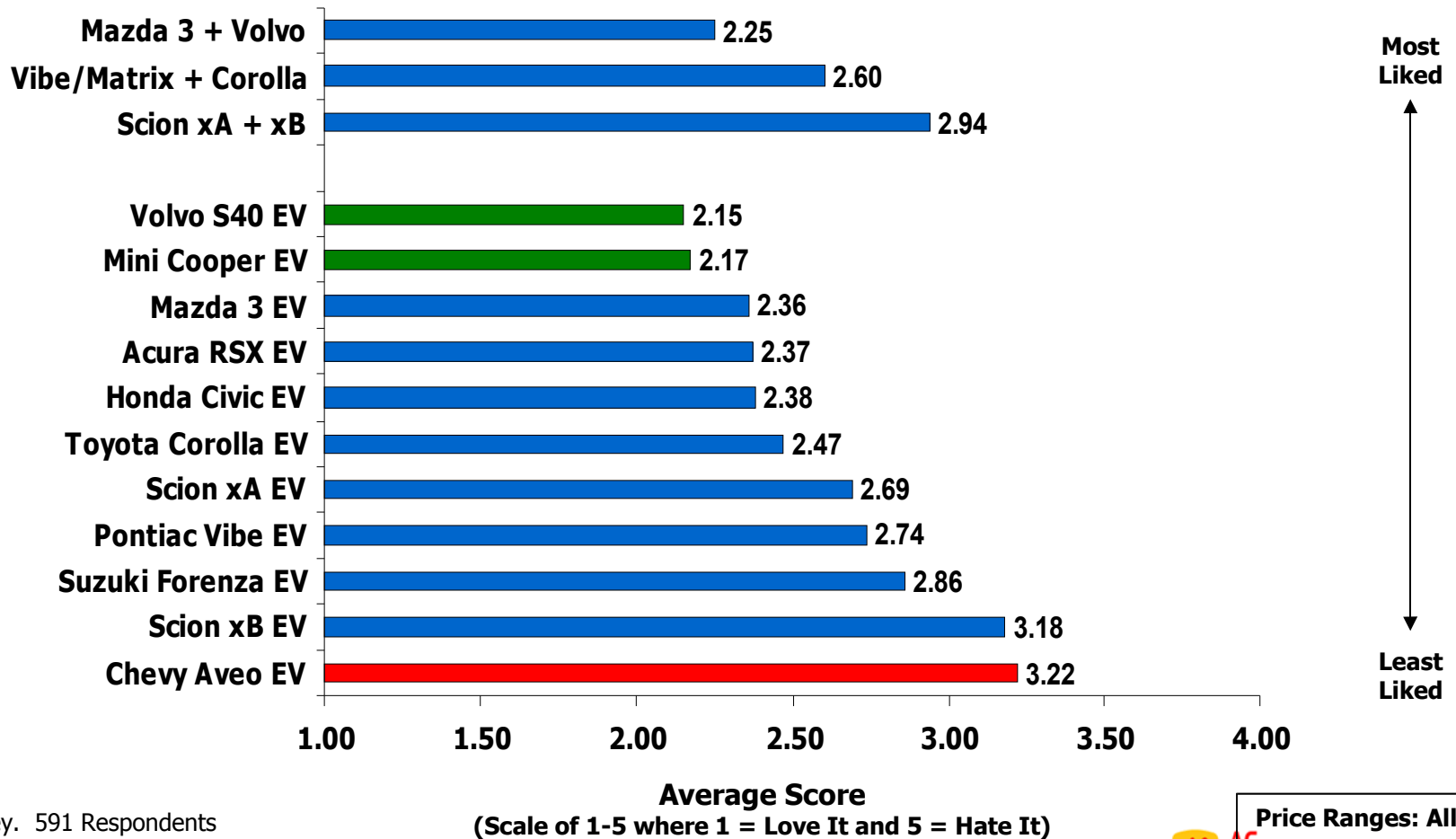
The Car Candidates

			
Acura RSX EV	Chevy Aveo EV	Honda Civic EV	Mazda 3 EV
			
Mini Cooper EV	Pontiac Vibe EV	Scion xA EV	Scion xB EV
			
Suzuki Forenza EV	Toyota Corolla EV	Volvo S40 EV	Venturi Fetish EV

Rankings of EV Car Candidates

Q: What do you think of the following EVs?

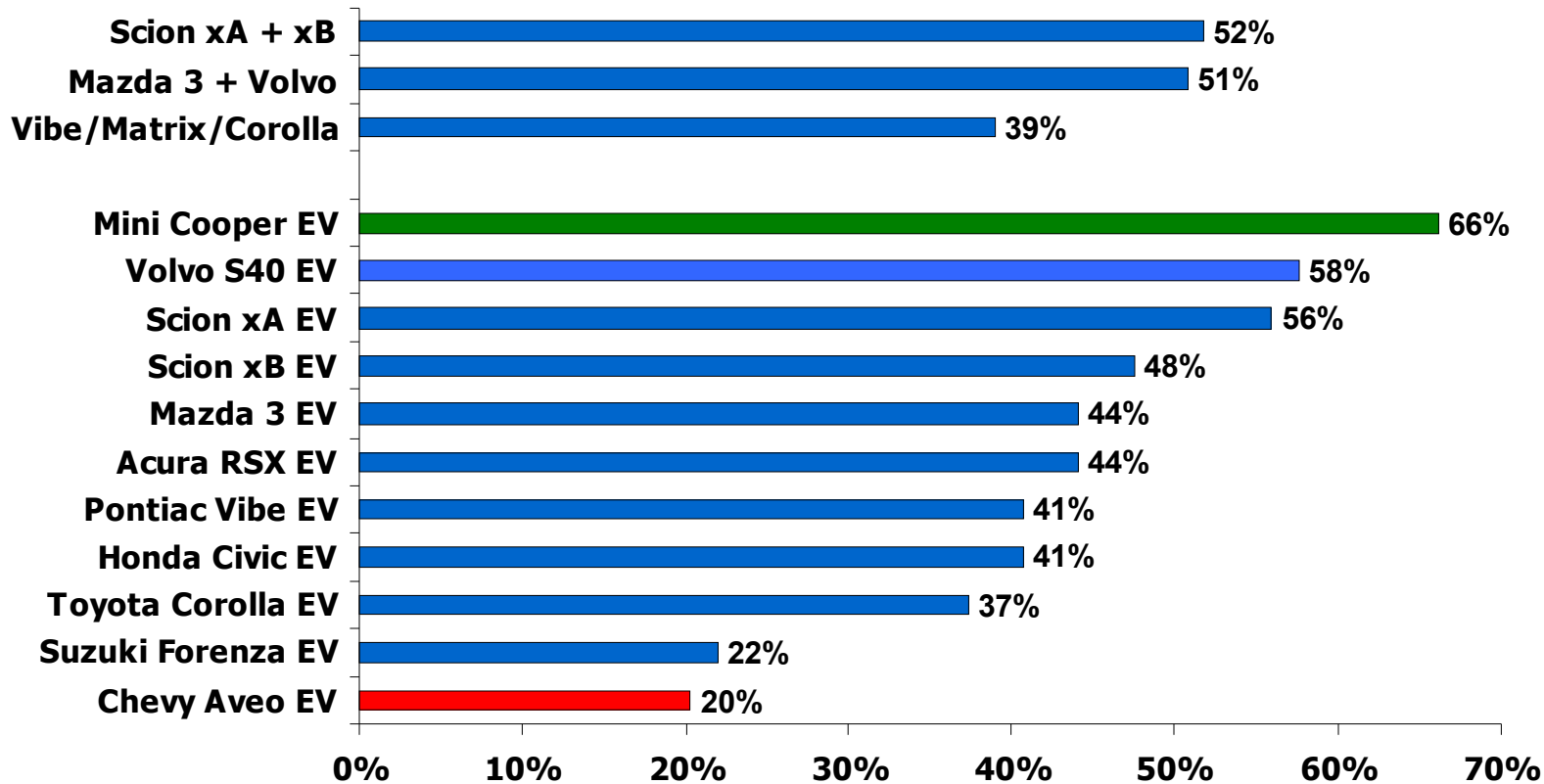
Average Score of All Segments



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+**



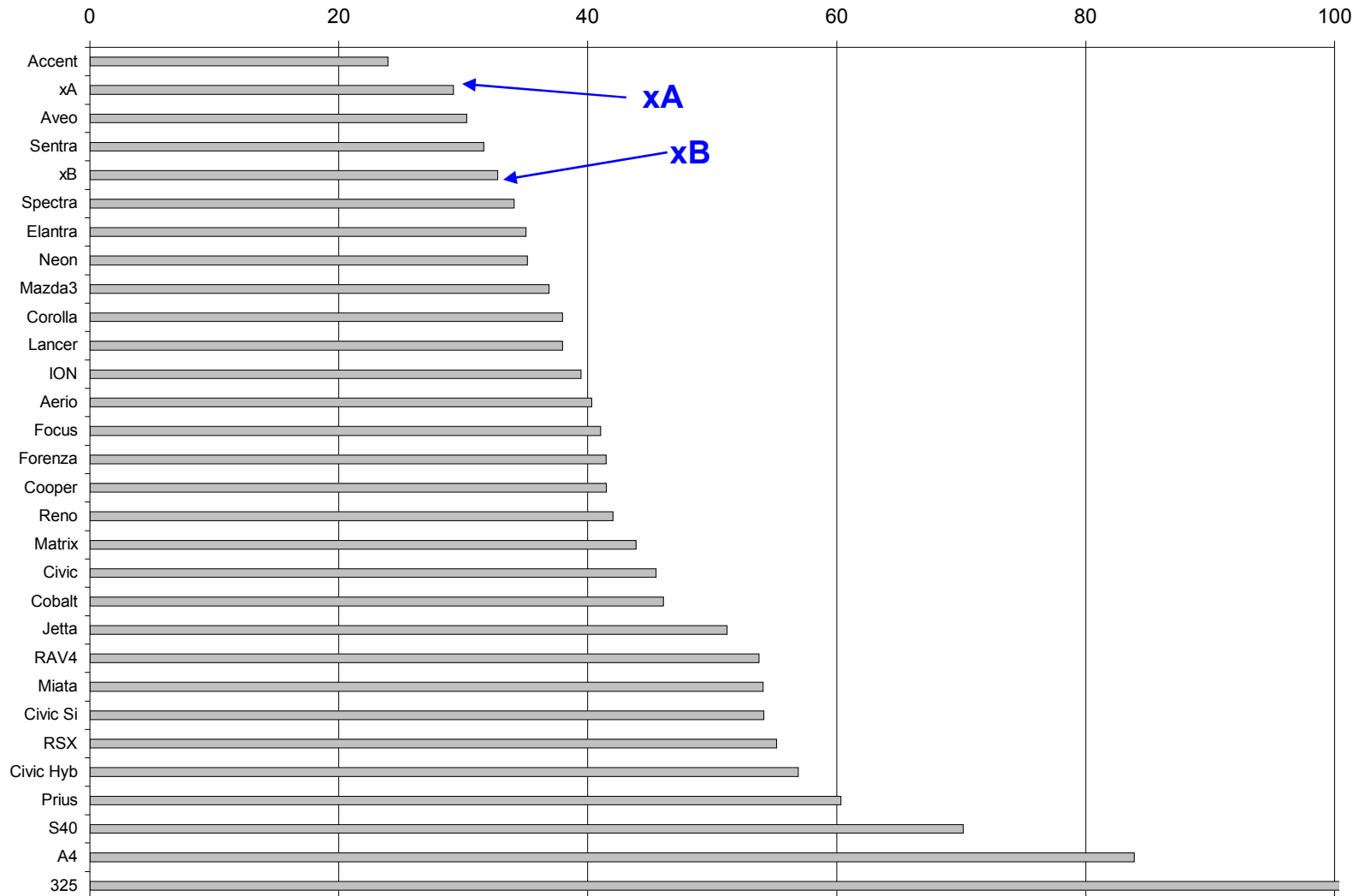
Source: EV Survey. 59 Respondents

Percent of Respondents: Love + Like

Price Ranges: \$30K+



Car Comparison: Price x Weight



The AC Propulsion EV

FMVSS-certified EV conversion of Scion xA and xB



Scion xB

Features

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



Scion xA

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

