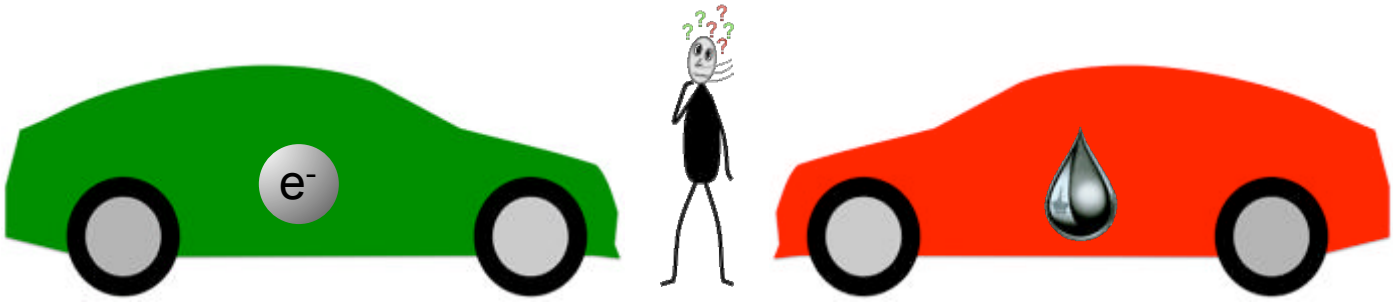
Electric Mobility

Unanswered Questions Regarding the Future of the Automobile

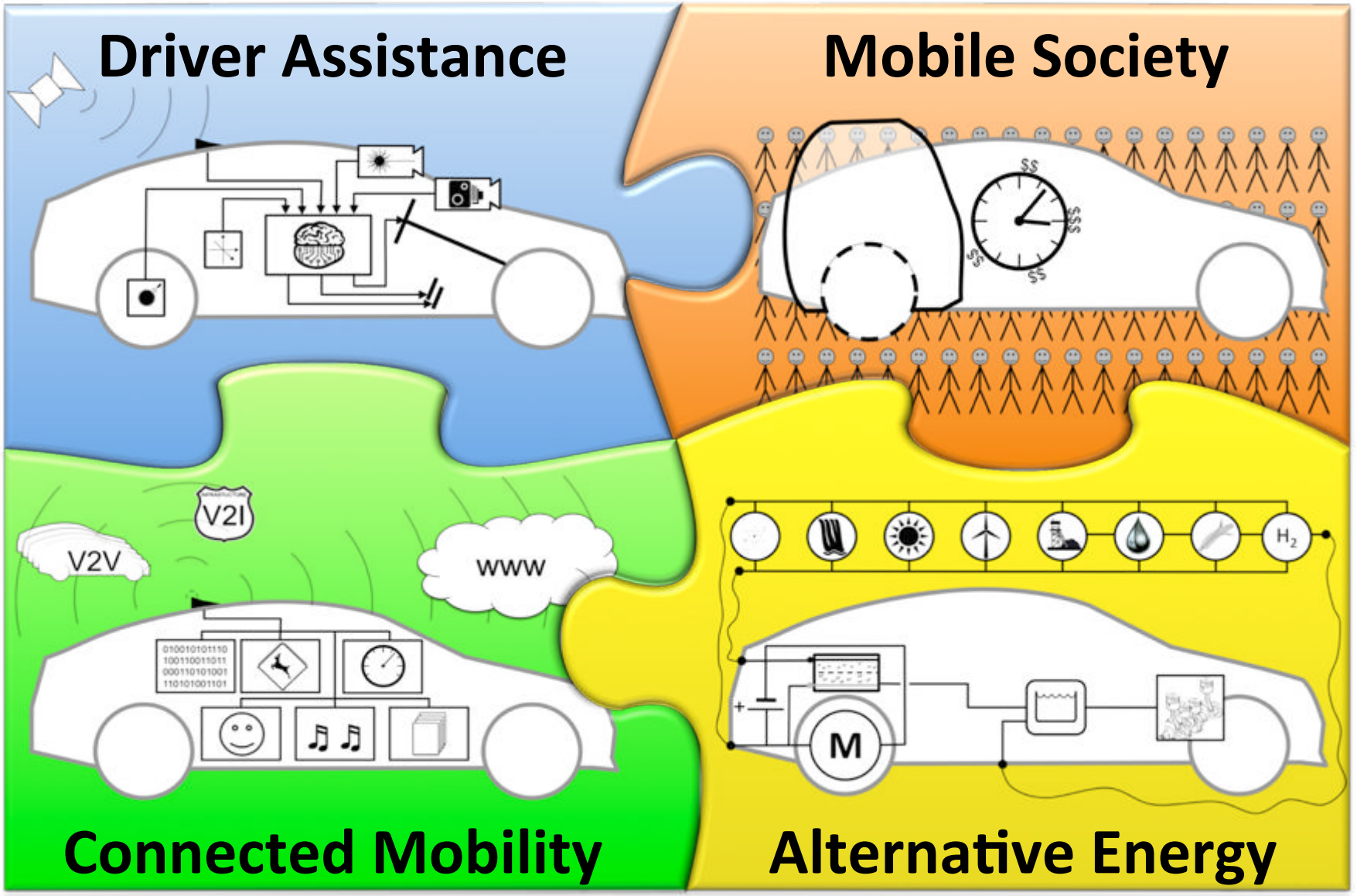
Stanford University – December, 2010



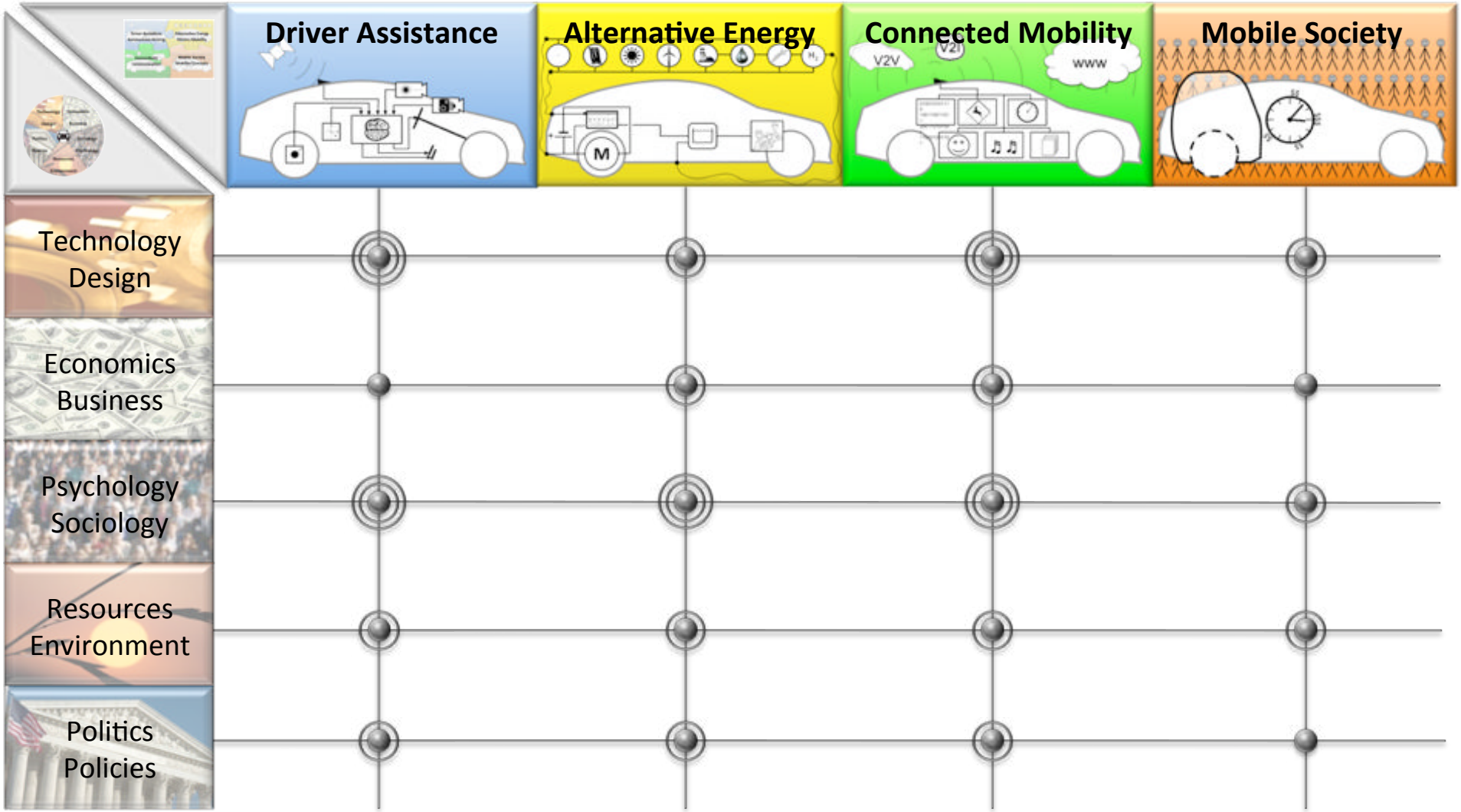
Sven A. Beiker, Executive Director CARS, December 2010

Automotive Research with a Flavor of Silicon Valley

Individual Mobility in the 21st Century



Automotive Competences at Stanford University



competence of CARS core labs competence of other labs competence w/ limited applicability

Would you Like / Drive / Buy an Electric Car?

A recent U.S. survey [1] shows:

70% think expanded use of EVs is vital part to reduce use of fossil fuels
66 % support EV recharging infrastructure investment by electric utilities
54 % believe EVs will account for about 20 % of new vehicles sold in 15-20 years
52 % would like to see utilities taking leadership to encourage shift to EVs
43% could see themselves driving EV in 10 years
13% "very likely" to buy EV in 10 years

Challenges consumers see regarding electric vehicles
28% range and battery life
20% availability of charging stations
17 % total cost/affordability
9% high [purchase] cost of vehicles

Analysts expect EVs to have 2% to 3% share of the new-car market by 2020 [2]

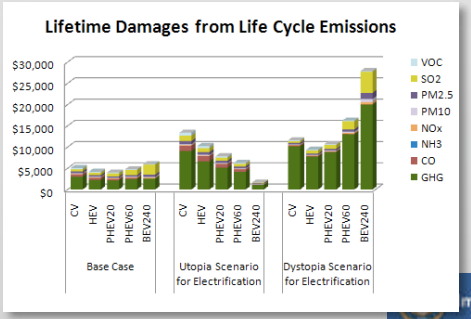
[1] "Energy + Environment Study", Market Strategies International, Nov 2010
1,168 interviews U.S. nationwide, October 14-25, 2010
[2] "Are Americans Willing to Try Electric Cars?", The Wall Street Journal, Dec 1, 2010

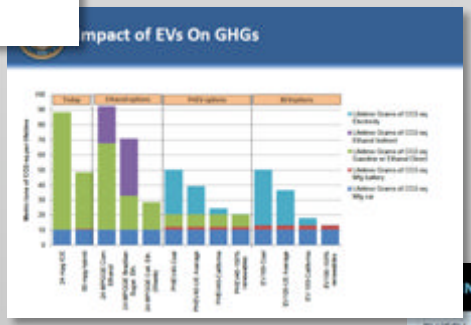
Public Discussion and Research Facts

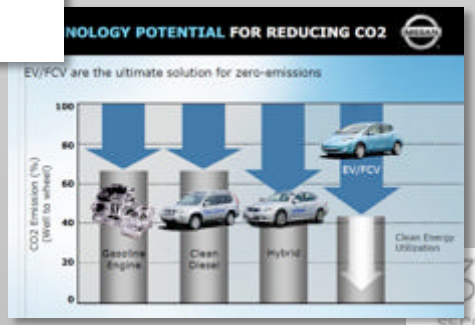
EVs are the solution, because…	But did you consider that…
EVs don't generate tailpipe emissions	
	EVs simply move the emissions from tailpipe to smokestack
With the present electricity mix, EVs still leads to less GHG	
	With particles, SO_2, NO_x from power plants, EVs are not cleaner
EVs help gaining independence from foreign oil	
	EVs will create new dependence on lithium producers, resources
Li: Chile world's largest producer, batteries don't need that much	
	Considering the battery mass, EVs are inefficient
EVs are modular, simpler, cheaper than conventional vehicles	
	The range of EVs does not meet consumer demands
50% of people drive less than 25mls a day (80% less than 50mls)	
	Charging takes too much time and requires behavioral change
Most consumers will never need to go to filling station again	
	The electricity infrastructure is not ready for electric vehicles
The transformation of mobility sector will take time	
	EVs cost more than conventional vehicles
Tax breaks offset the higher purchase price of an EV	
	Once the tax breaks are used up the real cost of EVs will surprise
Energy cost of EVs is lower than conventional vehicle	
	Operating cost of EVs will increase with more renewable energy
Oil price will increase operating cost of conventional vehicle	
	Batteries from EVs will create a new waste problem
Recycling lithium batteries is well understood	
	EVs are too quiet and will lead to new accident pattern
EVs will improve significantly over time	

Electric Vehicles – Facts and Hopes

‘Published’ Level of Detail

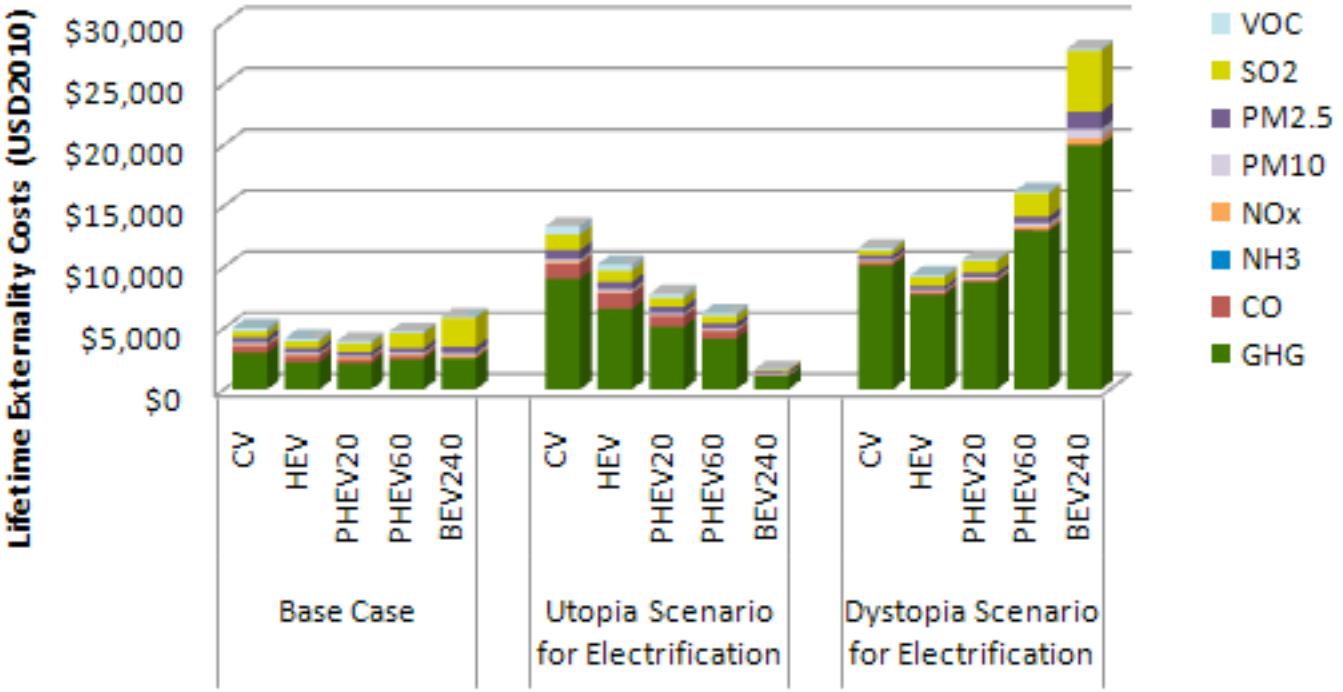




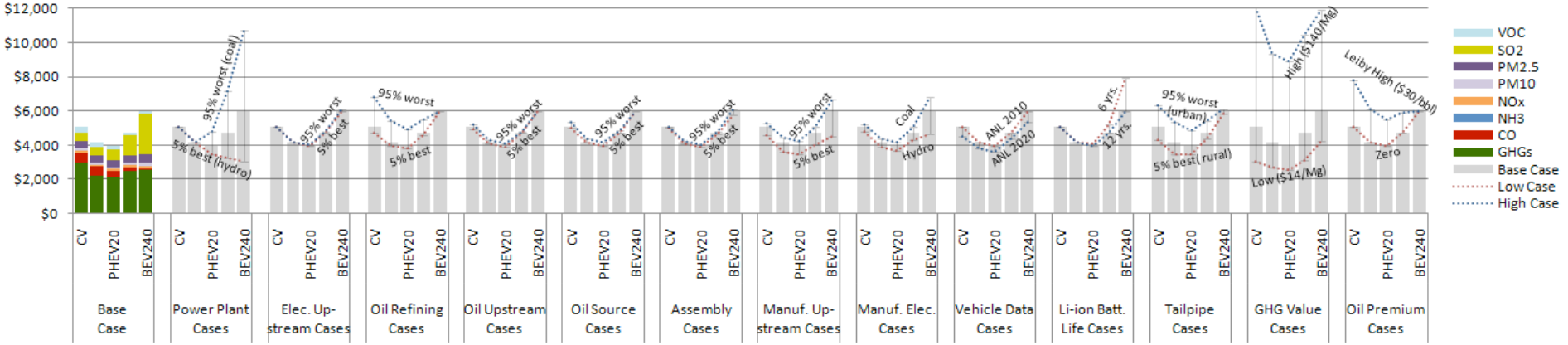


‘Perceived’ Sustainability of EVs

Lifetime Damages from Life Cycle Emissions

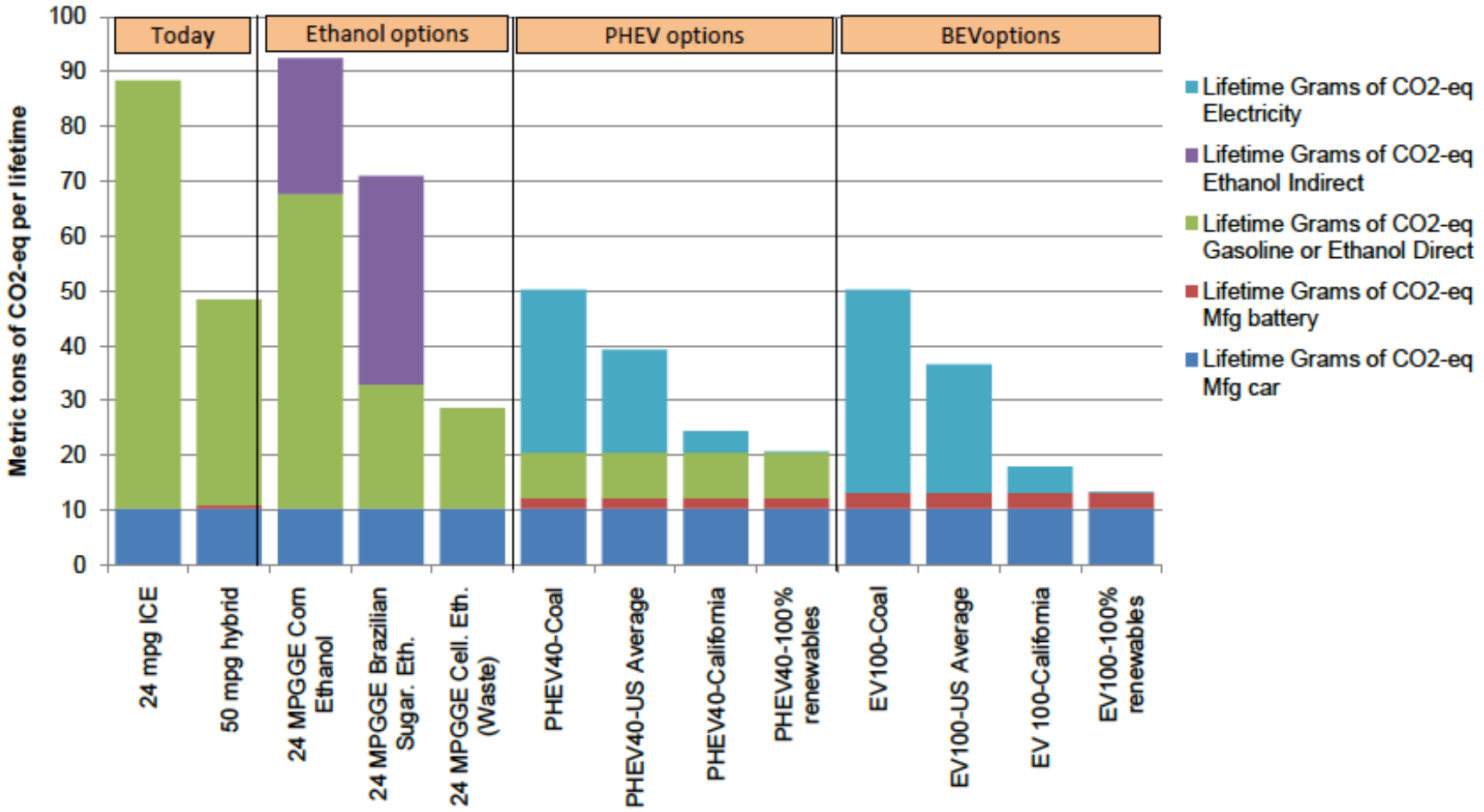


Lifetime Emissions Damages w/ Sensitivity Analysis



Source: J. Michalek et al, CMU, 2010

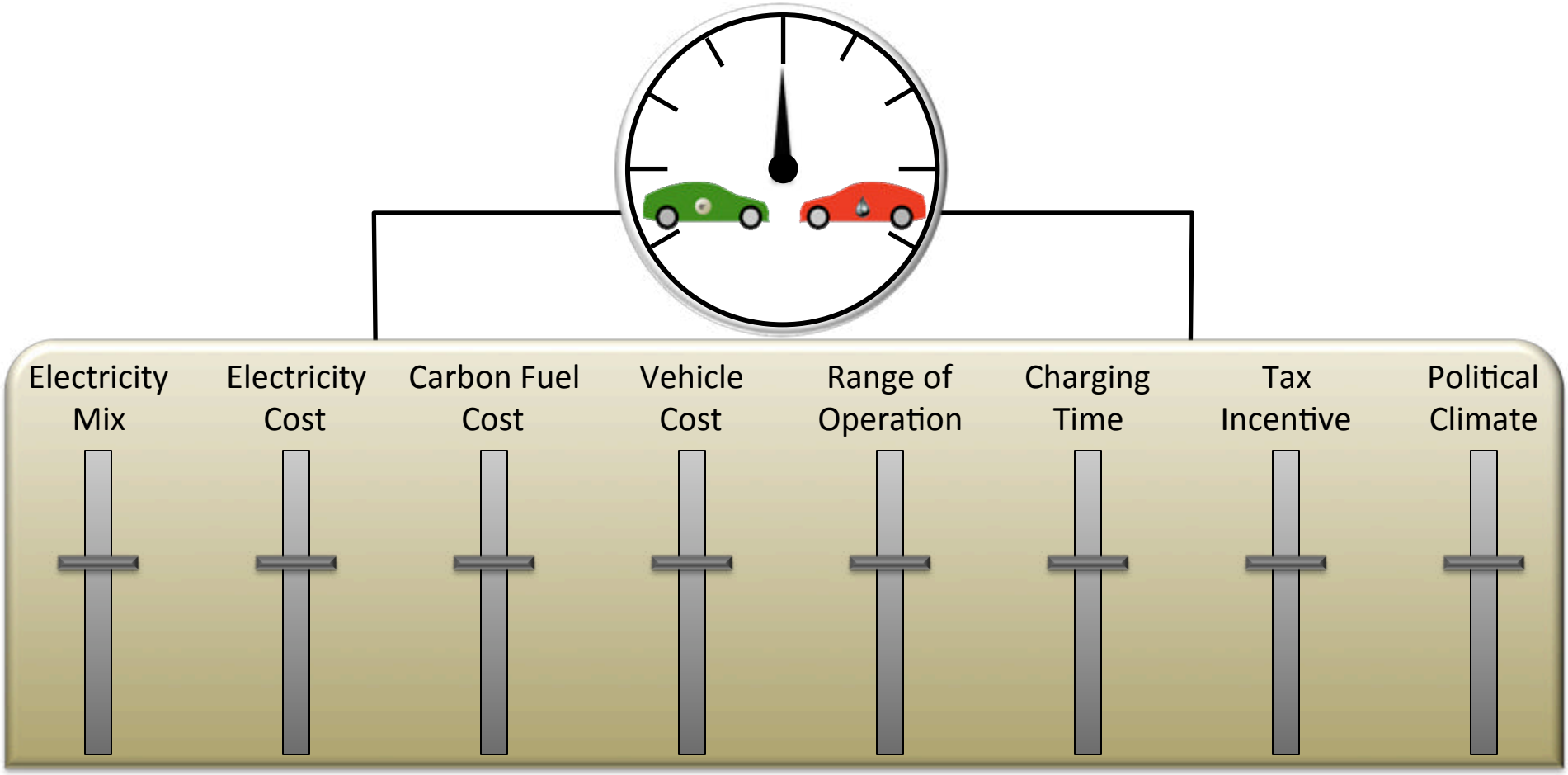
Impact of EVs On GHGs



Source: L. Schewel et al, UC Berkeley, 2010

Stanford Proposal to Research Electric Mobility

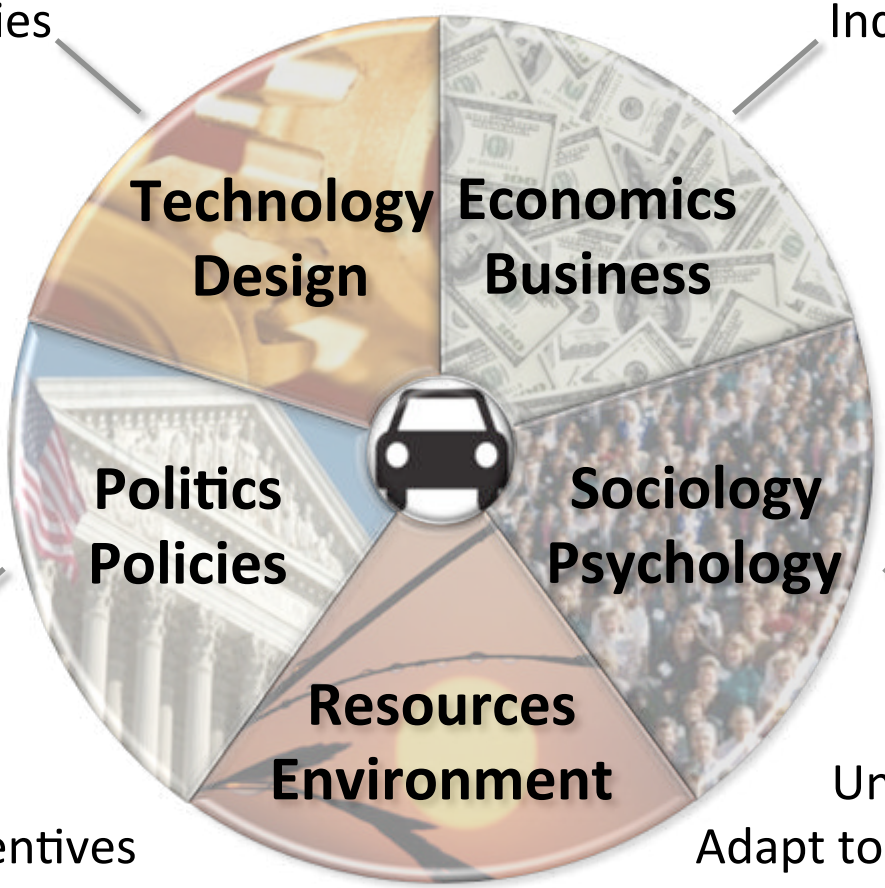
- Integrate existing studies, assessments, forecasts
- Create concise scenarios for the transition of the mobility sector
- Understand sensitivities of different influences, boundary conditions
- Provide background for more educated assessments and decisions



Electric Mobility Touching all Disciplines

Development of charging infrastructure
Improvement of batteries
…

Cost of ownership and operation
Industry business models
…



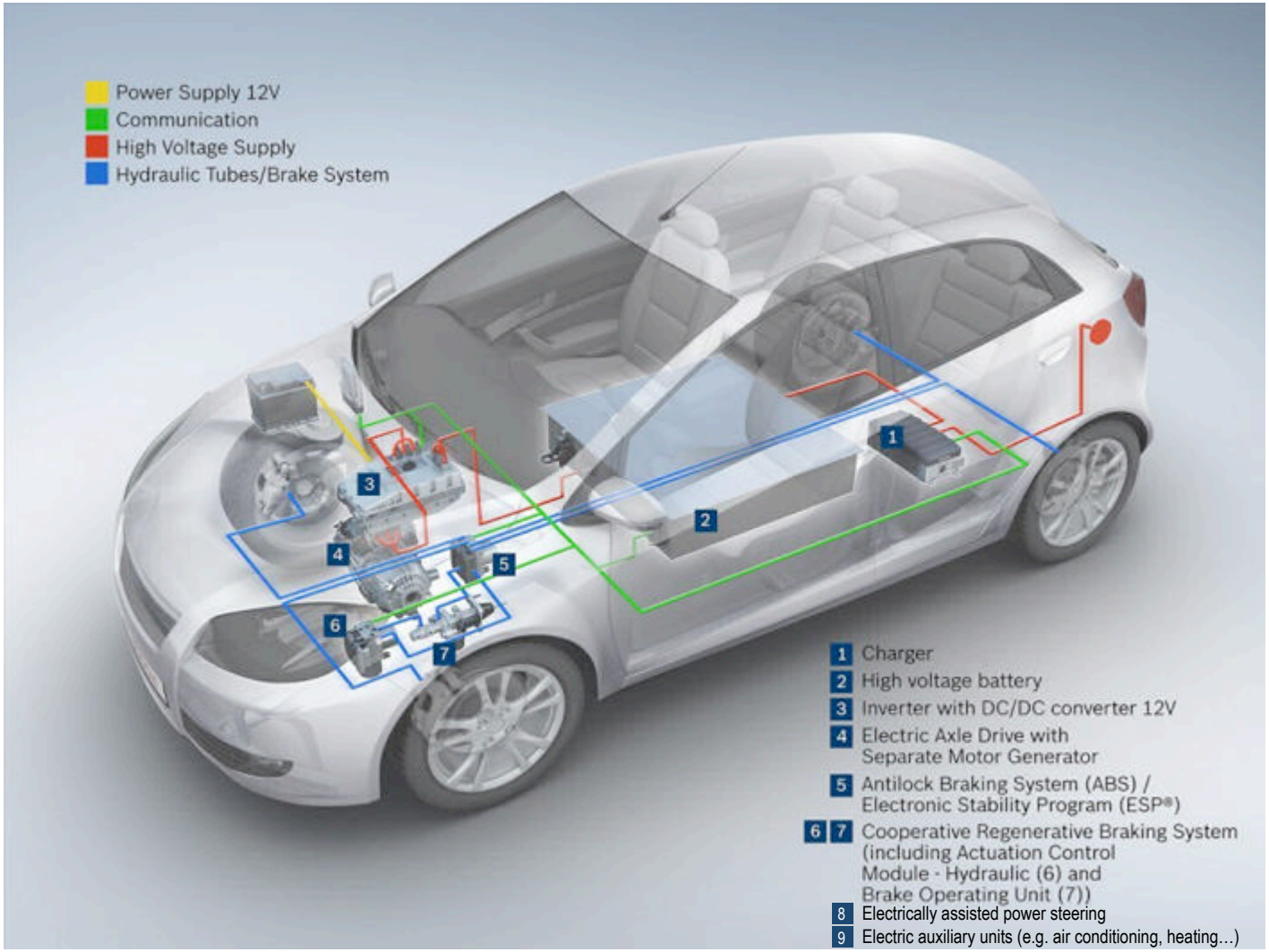
Connections to politics
Appropriateness of incentives
…

Unlimited mobility needs
Adapt to new vehicle operation
…

Assessment of environmental impact
Availability of resources
…

A Closer Look at the Car

EV – Just a Car with a Motor instead of an Engine?



Source: http://www.allcarselectric.com/image/100318171_bosch-ev-powertrain

EV – Just a Car with a Motor instead of an Engine?

1 MOTOR CONTROLLER
Monitors the motor's position, speed, power consumption and temperature. It uses these inputs along with driver throttle input to enable an inverter to convert DC voltage from the battery into three precisely timed signals that drive the motor.

2 HIGH-VOLTAGE ELECTRIC HVAC COMPRESSOR
Is specifically designed for electric vehicle applications, drawing energy directly from the main battery pack.

3 ELECTRIC WATER PUMPS
Circulates coolant for the traction motor, inverters, battery and heater.

4 TRACTION MOTOR
Performs the conversion between electrical and mechanical power. Electric motors have efficiencies three times higher than that of a standard gasoline engine, minimizing energy loss and heat generation.

5 ELECTRIC POWER STEERING
Is tuned to deliver the same driving dynamics as the gasoline-powered Focus.

6 TRANSMISSION
Has the identical role as in a gasoline vehicle; however, it has different design considerations due to the higher rpm range available from the electric motor and increased emphasis on efficient and silent operation. The transmission is a single-speed unit.

7 MODULAR POWERTRAIN CRADLE
Enables the entire propulsion system to be inserted as one piece within the engine compartment and isolated from the vehicle body.

8 ELECTRIC VACUUM PUMP
Supplies vacuum to the brake system for power assist.

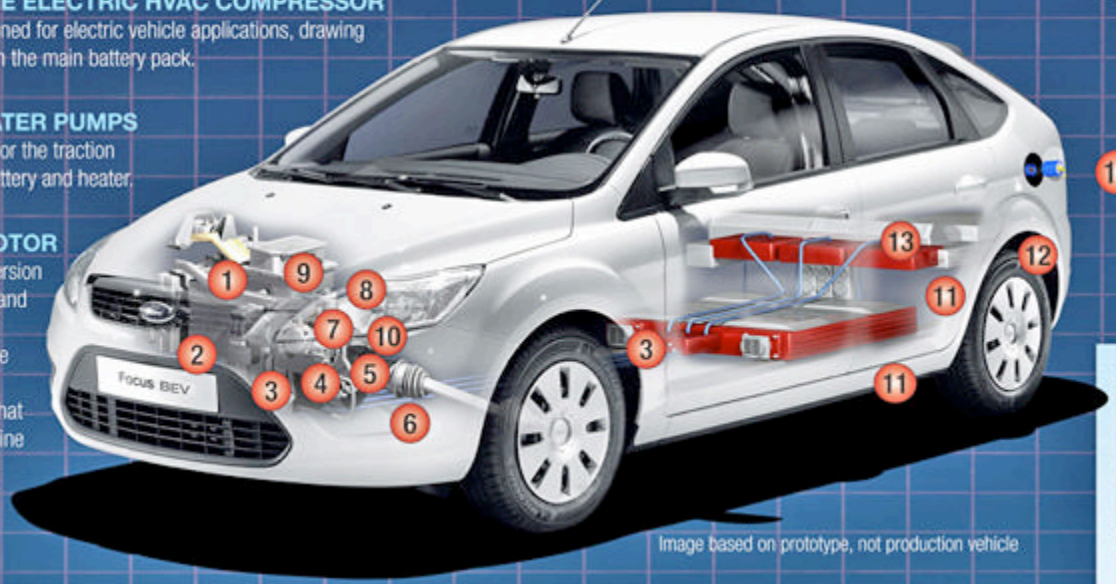


Image based on prototype, not production vehicle

9 HIGH-VOLTAGE ELECTRIC COOLANT HEATER AND CONTROLLER
Specifically designed for electric vehicle applications, using energy-efficient technology to heat and circulate coolant. Heat also may be circulated to the battery to optimize performance.

10 VEHICLE CONTROL UNIT
Monitors and controls each vehicle system, and manages energy and mechanical power being delivered to the wheels to maximize range.

11 BATTERY PACK
Uses total of 23 kWh of power and liquid coolant for thermal management, and includes an electronic monitoring system that manages temperature and state of charge.

12 AC CHARGER
Converts the AC electricity from the power grid to DC voltage required by the battery, enabling full state of charge in a matter of hours when plugged in. The vehicle will accommodate both 120V and 240V power sources.

13 DC-DC CONVERTER
Allows the vehicle's main battery pack to charge the on-board 12V battery to power various vehicle accessories (headlights, etc.).

FOCUS ELECTRIC FACTS

- **Final assembly location:** Michigan Assembly Plant
- **Battery cell manufacturer:** Compact Power Inc., Holland, Mich.
- **Battery system:** Lithium-ion, liquid-cooled/heated, recyclable
- **Total battery capacity:** 23kwh
- **Estimated cost to fully charge vehicle:** $2 to $3 (based on nationwide average cost of $0.10 per kWh)
- **Cost of 240v charging station:** TBD
- **Tire size:** 17-inch
- **0-60 acceleration:** TBD, similar to gas-powered base model
- **Braking distance:** TBD, similar to gas-powered base model
- **Passenger room and cargo room:** TBD
- **Price range:** TBD

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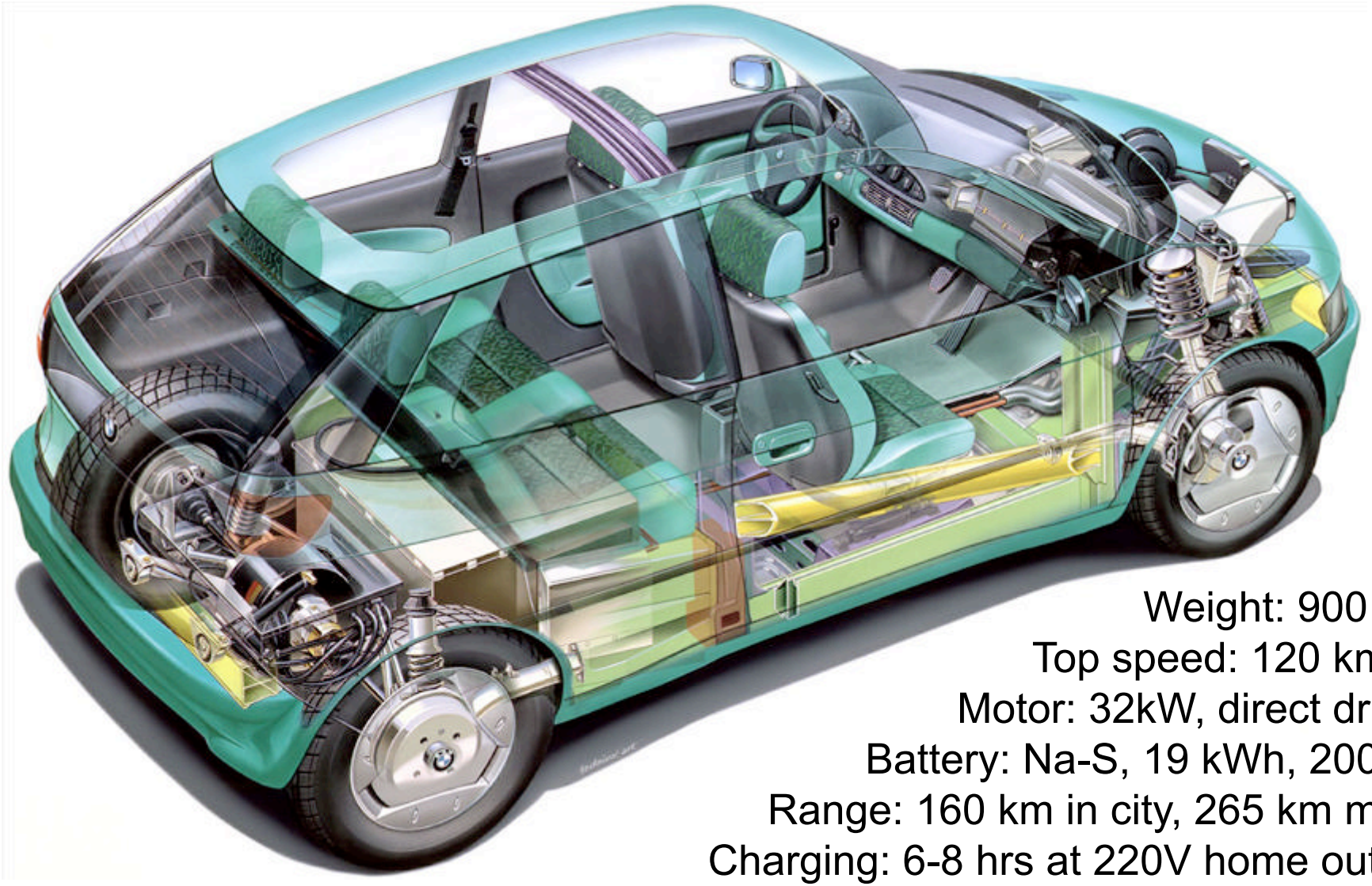
http://fordfocuselectric.com/2010/10/23/ford-confirms-focus-electric-production-for-2011-but-stresses-real-volume-in-2012/

Many of the Current Electric Vehicles are Conversion

Vehicle layout optimized for conventional powertrain
Breaking, steering, air-condition systems need to be adapted
Manufacturing, distribution, service not scaled to large volume

http://theage.drive.com.au/motor-news/mini-plans-electric-vehicle-trial-for-australia-20091027-hhj8.html

A Completely New Vehicle Concept not a Conversion



Weight: 900 kg
Top speed: 120 km/h
Motor: 32kW, direct drive
Battery: Na-S, 19 kWh, 200kg
Range: 160 km in city, 265 km max
Charging: 6-8 hrs at 220V home outlet
BMW E1, 1991 Frankfurt Automobile Show

http://www.carbodydesign.com/gallery/2010/04/bmw-technik-gmbh-25th-anniversary/13/, http://de.wikipedia.org/wiki/BMW_E1

Why We Drive What We Drive – A Case Study

	1990's	2000's
Technology Design	Super Computing ➔ Engine / Chassis Control	Mobile Computing ➔ High Performance Batteries
Economics Business	Booming Economies, Pre-Burst ➔ Consumer spending high	Economic Crisis, High Oil Price ➔ Consumer spending low
Resources Environment	Andrew '92, El Niño, Cheap Oil ➔ …	Katrina / Rita '05, Glaciers, Peak Oil? ➔ Oil Usage more considerate
Psychology Sociology	Individualism, Counter-Culture ➔ Individual freedom essential	Grass Root Movements, CO2 Movies ➔ Green becomes mainstream
Politics Policies	Gulf War, ZEV Mandate ➔ …	Iraq / Afghanistan, HOV for HEV ➔ "Dependence on Foreign Oil"
Automobiles Defining the Decade		

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