Plug In Vehicle Technology
The Case for a Multi-Technology Approach

COMPETE Coalition

Washington DC

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Toyota Motor Sales, USA, INC

October 5, 2010

On One Hand: Growing Megacities (>10M)

Today – 2

New York, NY
18.65M

Los Angeles, CA
12.22M

4 Additional by 2050

Atlanta, GA

Chicago, IL

Dallas –
Fort Worth, TX

Miami, FL

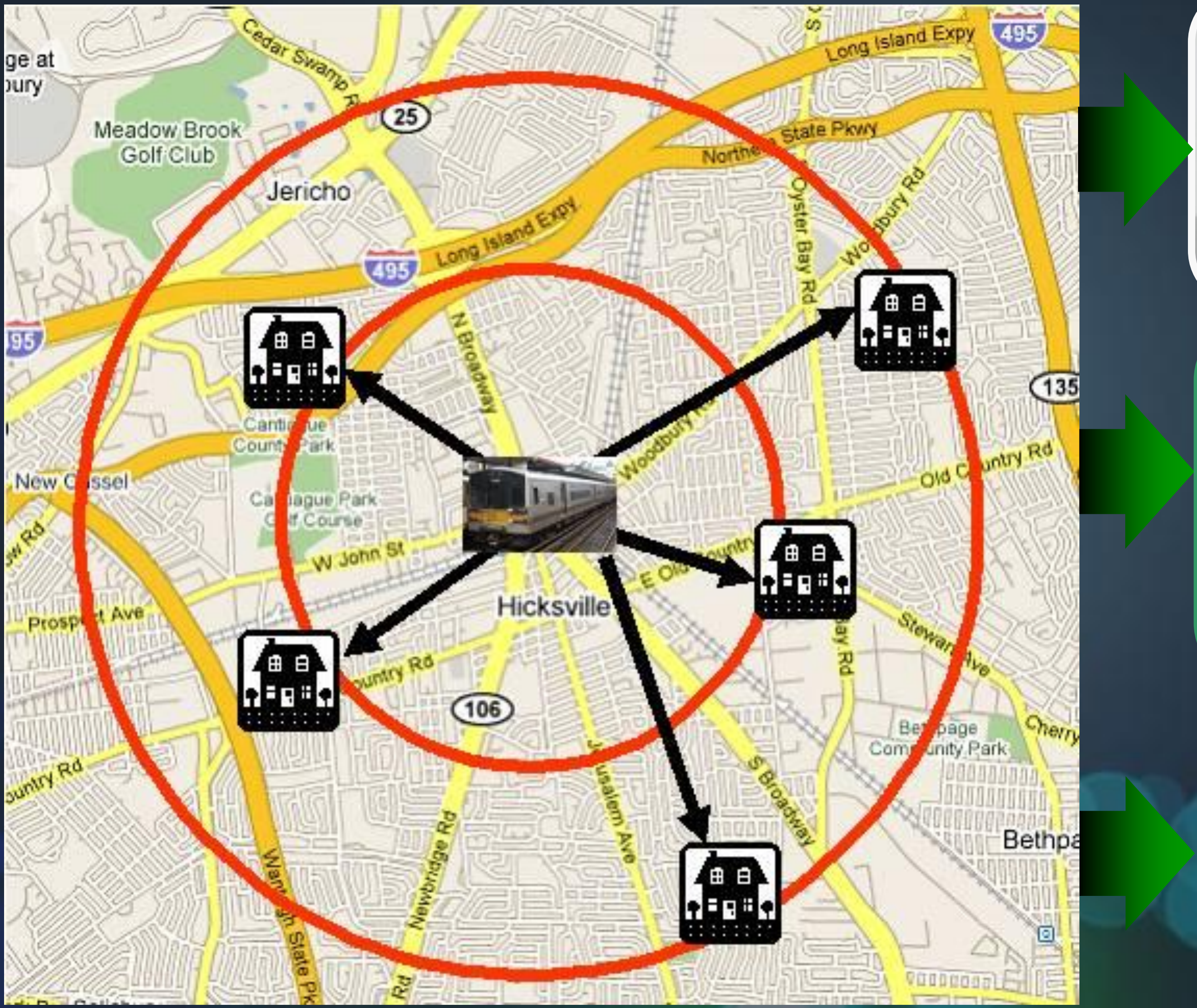
2006 citymayors.com

Urban Mass Transport Solutions

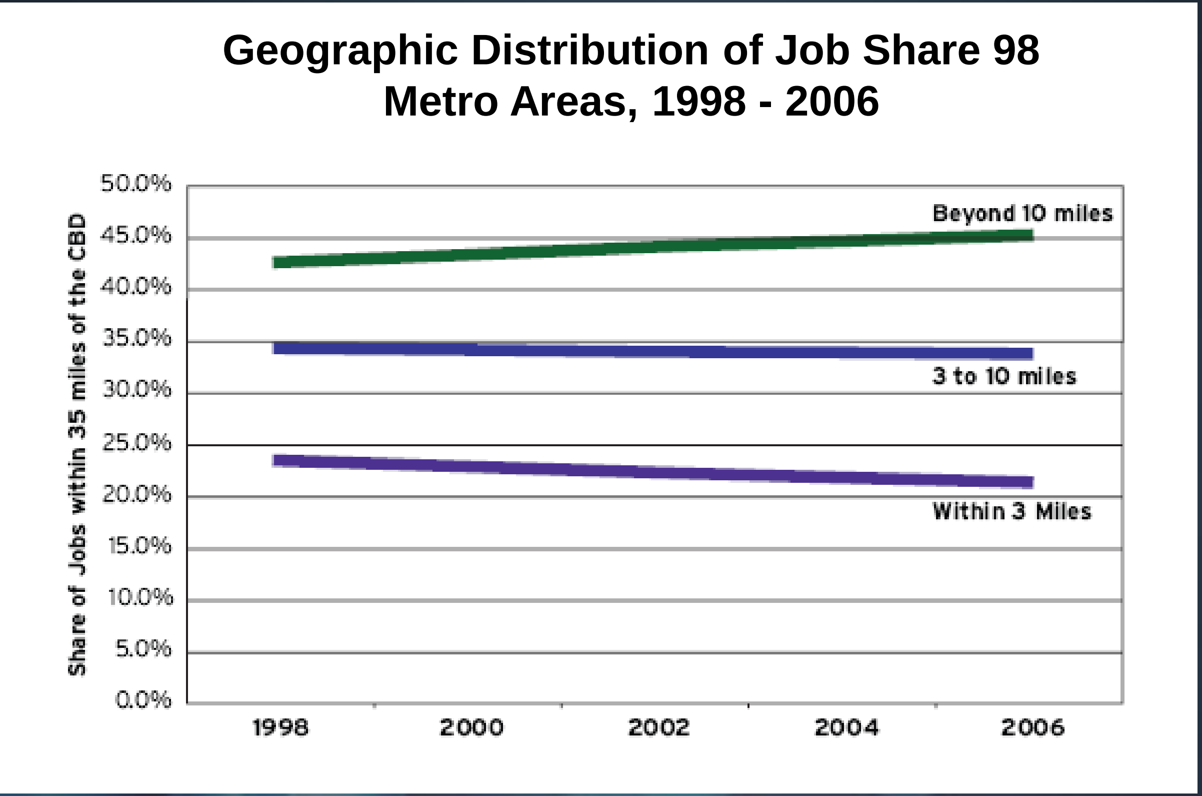
Light Rail

Personal Rapid Transit

Developing Solutions For The Last Mile Problem



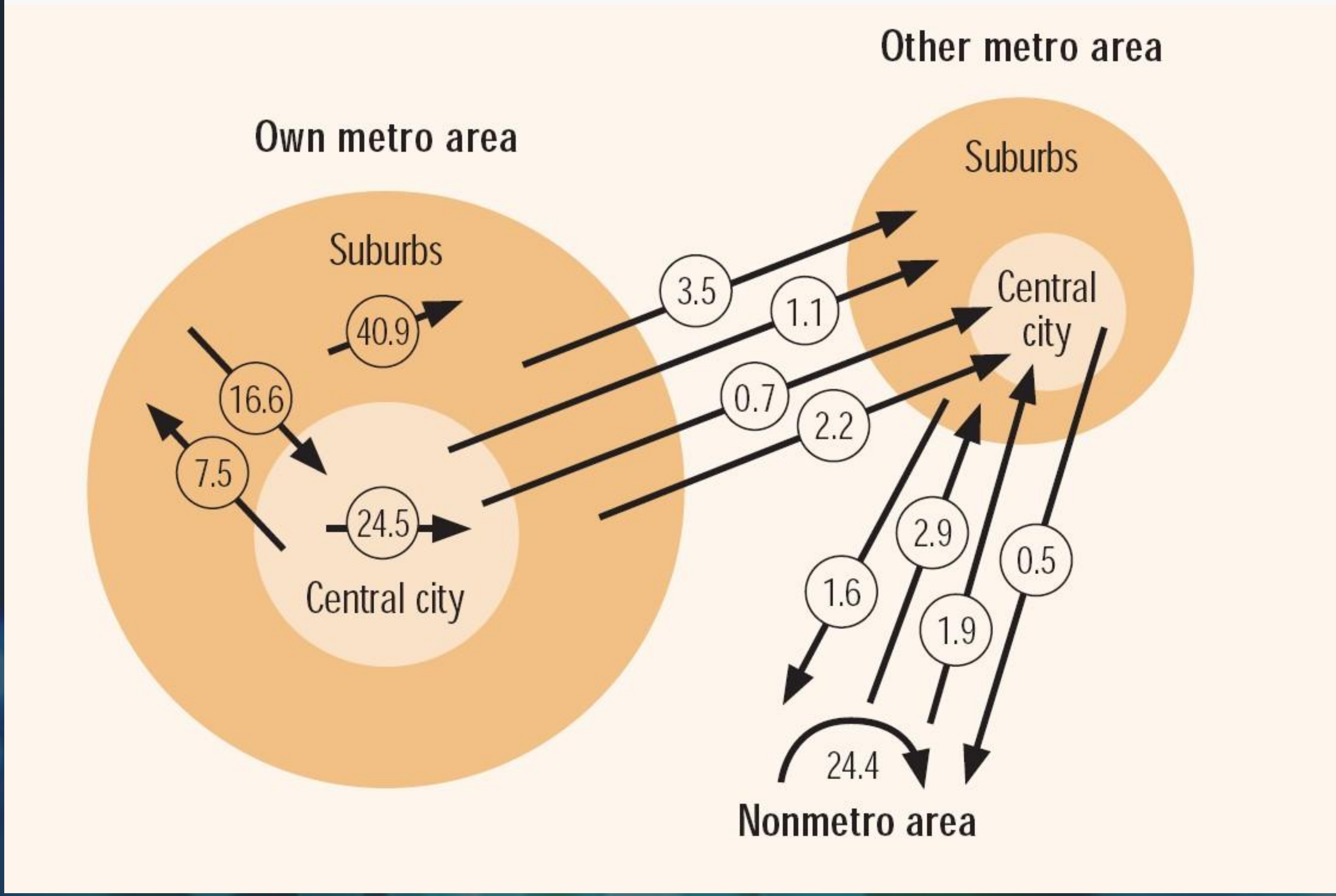
On the Other Hand: Populations are Spreading



2/3 of US jobs, 3/4 economic output, are within 35 mi of 98 largest central business districts (CBD). Increasingly, they are moving to a ring 10-35 mi from CBD. (Brookings Inst.)

Most Commutes Are Suburb to Suburb

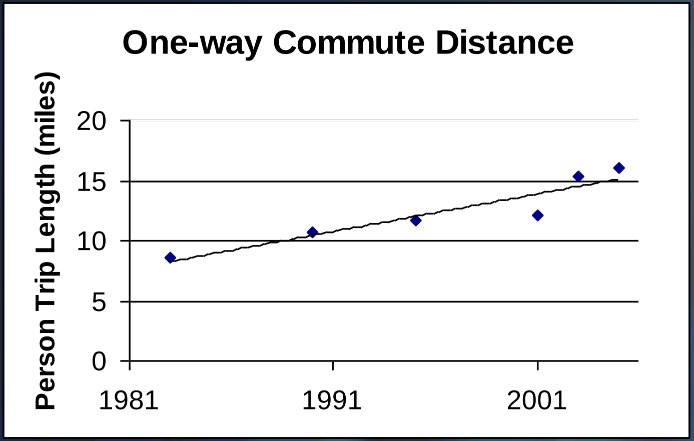
Metropolitan Flow Map (Millions of Commuters)



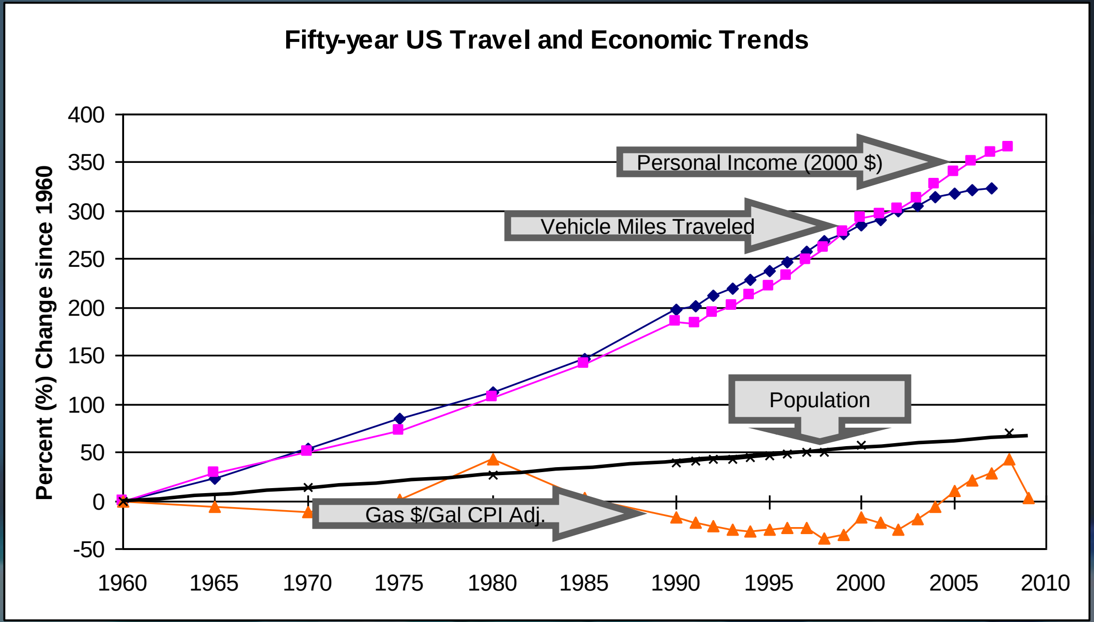
Source Brookings Inst.

Unique US Urbanization and Transportation Trends

- US Vehicle Miles Traveled grows with US economy
- Jobs and housing are decentralizing (despite efforts to do the opposite)
- Commute distance increasing (often between suburbs of metro area)
- Highway car remains critically important to US



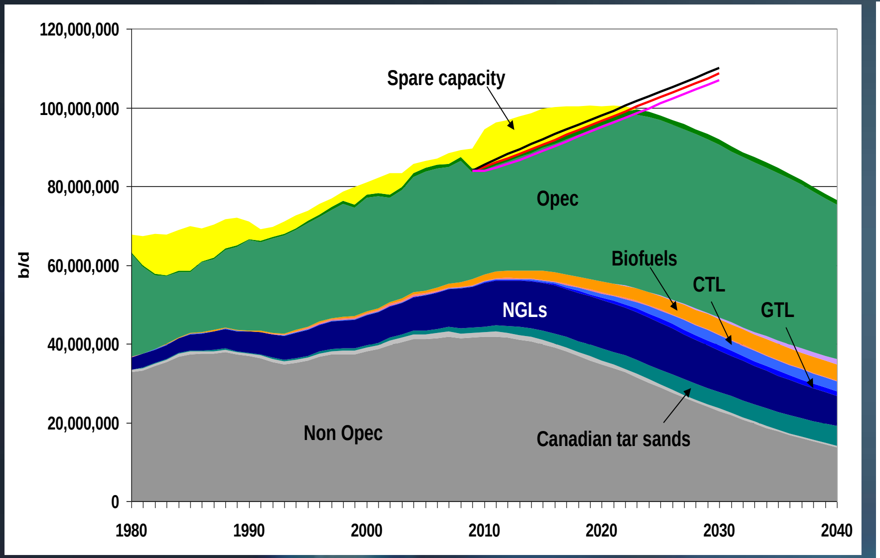
National Highway Travel Survey 2001, US Bureau of Transportation Statistics Omnibus Household Survey 2003, ABC News/Time magazine/Washington Post poll 2005



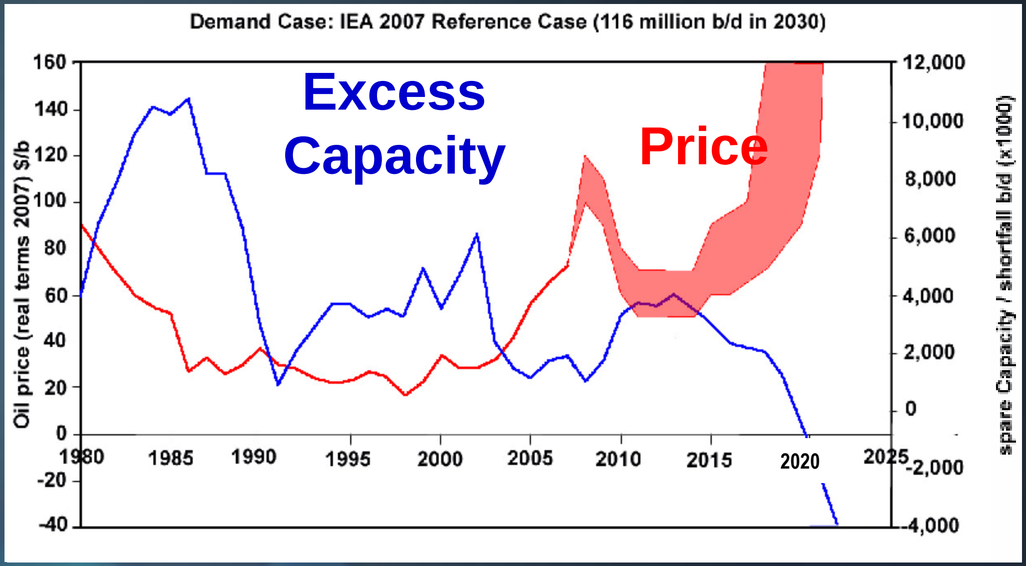
GDP: US Bureau of Economic Analysis, chained 2000 dollars; VMT: "Highway Statistics 2007" Table VMT-421, FHWA; Population: US Census; Gas Price: "Short Term Energy Outlook-October 2009" US Energy Information Administration, annual prices scaled by US CPI in 2008

Oil Prices Strongly Influenced by Excess Capacity

Oil Production Forecast



Oil Price Forecast



Platform Design

- Cheap Oil
- Expensive Oil
- Scarce Oil

Source: Neftex (Dr. Peter Wells)

Finding replacements part 1

		Land use				Water use (gallons)		Energy ratio	CO_2 emissions[a]
Fuel source	**Transportation energy displacement**	**Acres[b]**	**Fraction of U.S. cropland**	**gallons of fuel per acre**	**MMBTU[e] of fuel per acre**	**per gallon of fuel**	**per MMBTU of fuel**	**BTU input per BTU of fuel**	**lb per MMBTU of fuel**
Conventional gasoline	**0-100%**	a few thousand	very low	-	-	5	45	0.05	175
Conventional diesel	**0-100%**	a few thousand	very low	-	-	10	80	0.08	175
Coal-to-liquid	**10%**	4,100	very low	~4.4 M	~500,000	3	24	~0.5	~380
	25%	10,300							
	50%	20,600							
CNG	**0-100%**	a few thousand	very low	-	-	n/a	~10[d]	~0.1 [d]	~150
Heavy crude	**0-100%**	a few thousand	very low	-	-	~10	~80	~0.25	~200
***In situ* oil shale**	**10%**	7,500[c]	very low	~20 M	~65,000	~6	~45	~0.15	~240
	25%	19,000[c]							
	50%	37,000[c]							
Tar sands	**10%**	48,000[c]	low	~3 M	~350,000	~5	~38	~0.25	~180
	25%	120,000[c]							
	50%	240,000[c]							

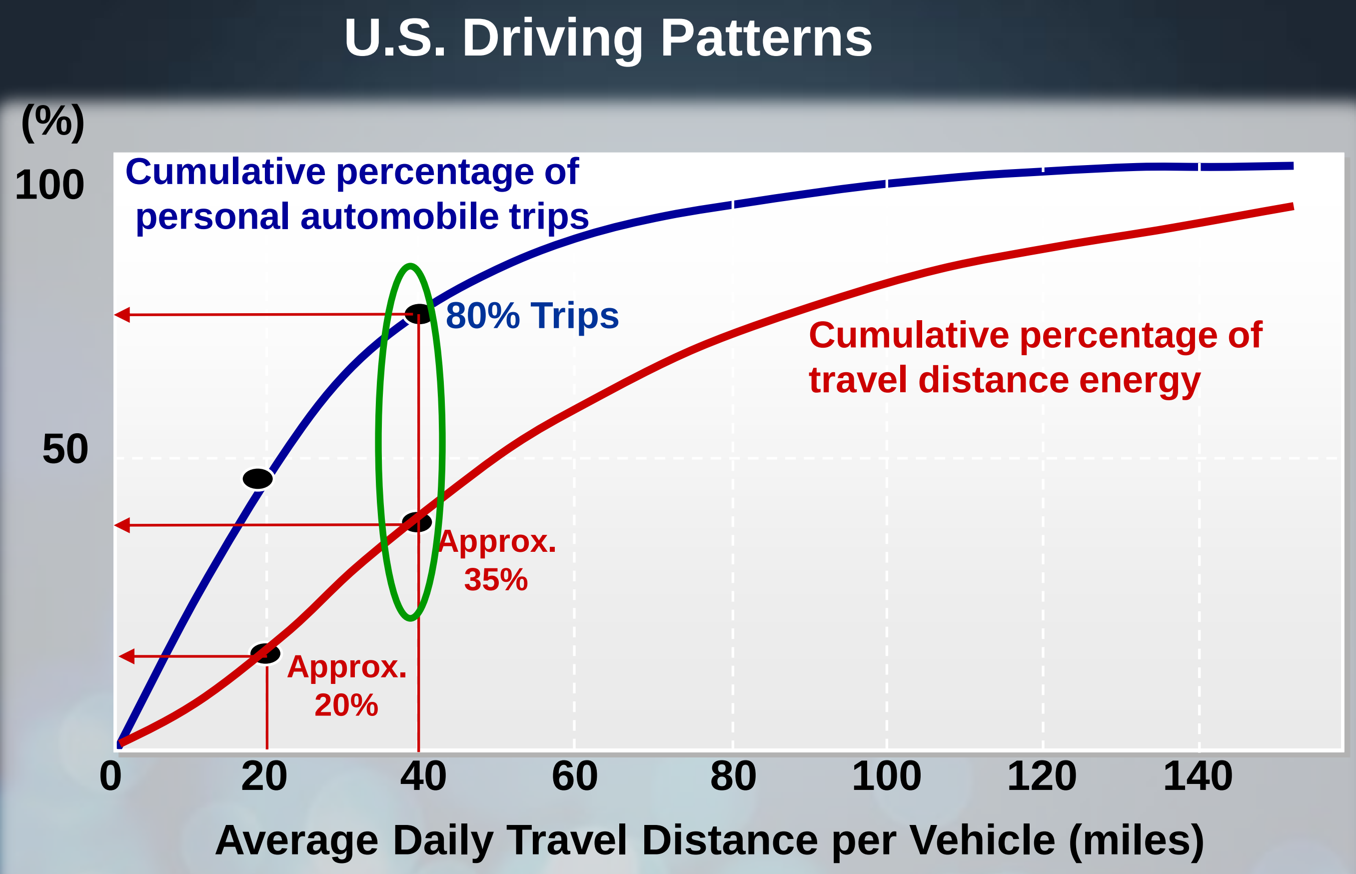
Source: Kreider and Associates

Finding replacements part 2

		Land use				Water use (gallons)		Energy ratio	CO_2 emissions[a]
Fuel source	Transportation energy displacement	Acres[b]	Fraction of U.S. cropland	gallons of fuel per acre	MMBTU[e] of fuel per acre	per gallon of fuel	per MMBTU of fuel	BTU input per BTU of fuel	lb per MMBTU of fuel
Conventional gasoline	**0-100%**	a few thousand	very low	-	-	5	45	0.05	175
Conventional diesel	**0-100%**	a few thousand	very low	-	-	10	80	0.08	175
Corn-based ethanol	**10%**	65 M	20%	370	28	170	2200	0.98	350
	25%	160 M	51%	370	28	180	2300	0.98	350
	50%	337 M	103%	360	28	220	2900	0.98	350
Cellulosic ethanol	**10%**	46 M	15%	515	39	146	1900	0.92	330
	25%	112 M	35%	515	39	146	1900	0.92	330
	50%	228 M	72%	510	39	149	1900	0.92	330
Soybean biodiesel fuel	**10%**	253 M	80%	57	7	900	6900	0.76	240
	25%	380 M	120%	57	7	900	6900	0.76	240
	50%	1.2 B	390%	57	7	900	6900	0.76	240
Algaculture	**10%**	2.5 M	< 1%	6000	800	50	400	0.2	absorbs CO_2 waste
	25%	6.5 M	2%	6000	800	50	400	0.2	
	50%	13 M	4 %	6000	800	50	400	0.2	
MSW-based ethanol	**0-100%**	tens of thousands	very low	-	-	5	65	0.6	~105

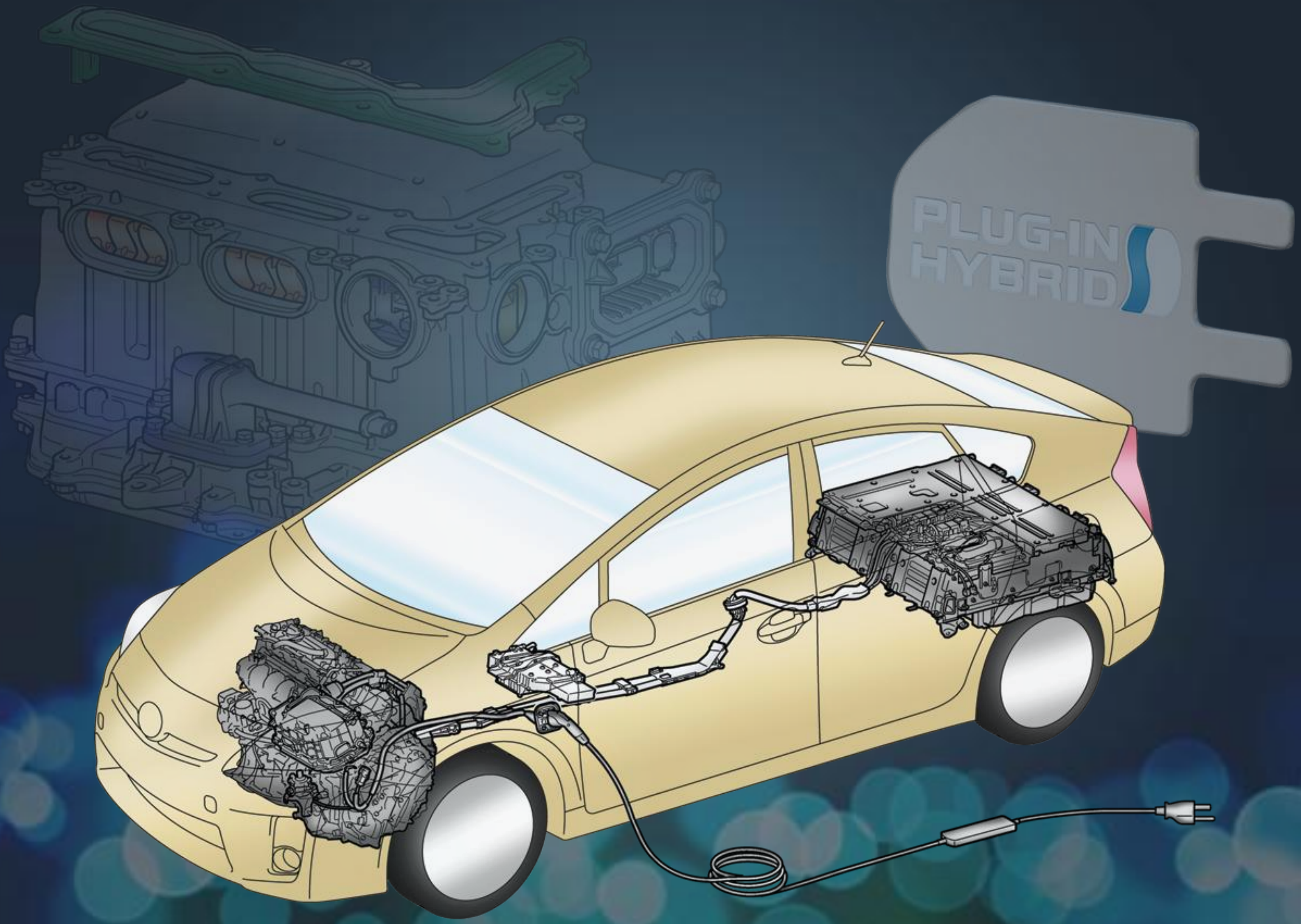
Source: Kreider and Associates

PHV Role: EV Mode For Short Distance HV Mode for Longer Trips

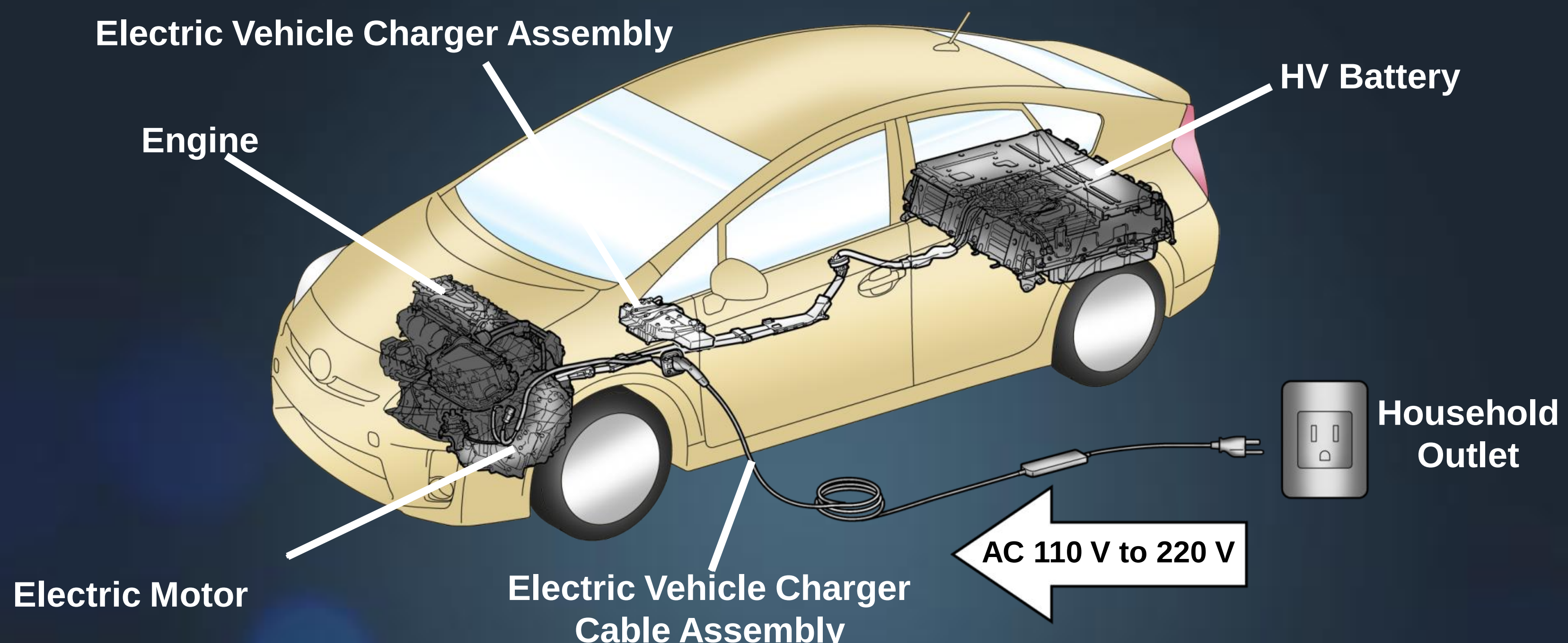


Source: 1990 Nationwide personal transportation survey

Toyota's PHV Development



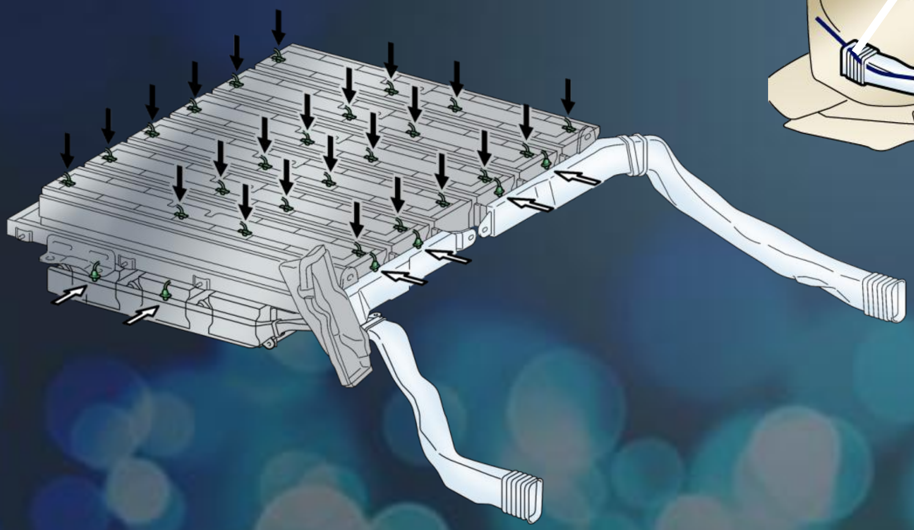
Operation Specifications

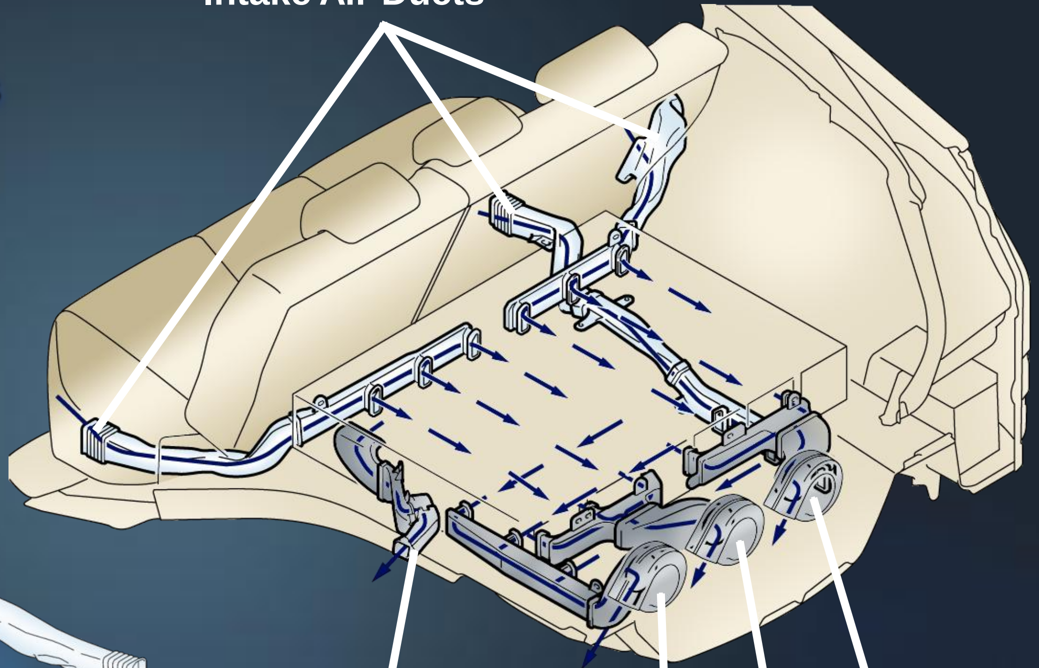


Max. Output	Engine	98 HP (73 kW)
	MG2	80 HP (60 kW)
In EV Driving Mode	Max. Speed	Approx. 62 mph (100 km/h)
	Range	Approx. 13 miles (21 km)
Power Source		Household Electrical Outlets
Charging Time		Approximately 3 hrs (110 V)

HV Battery Cooling

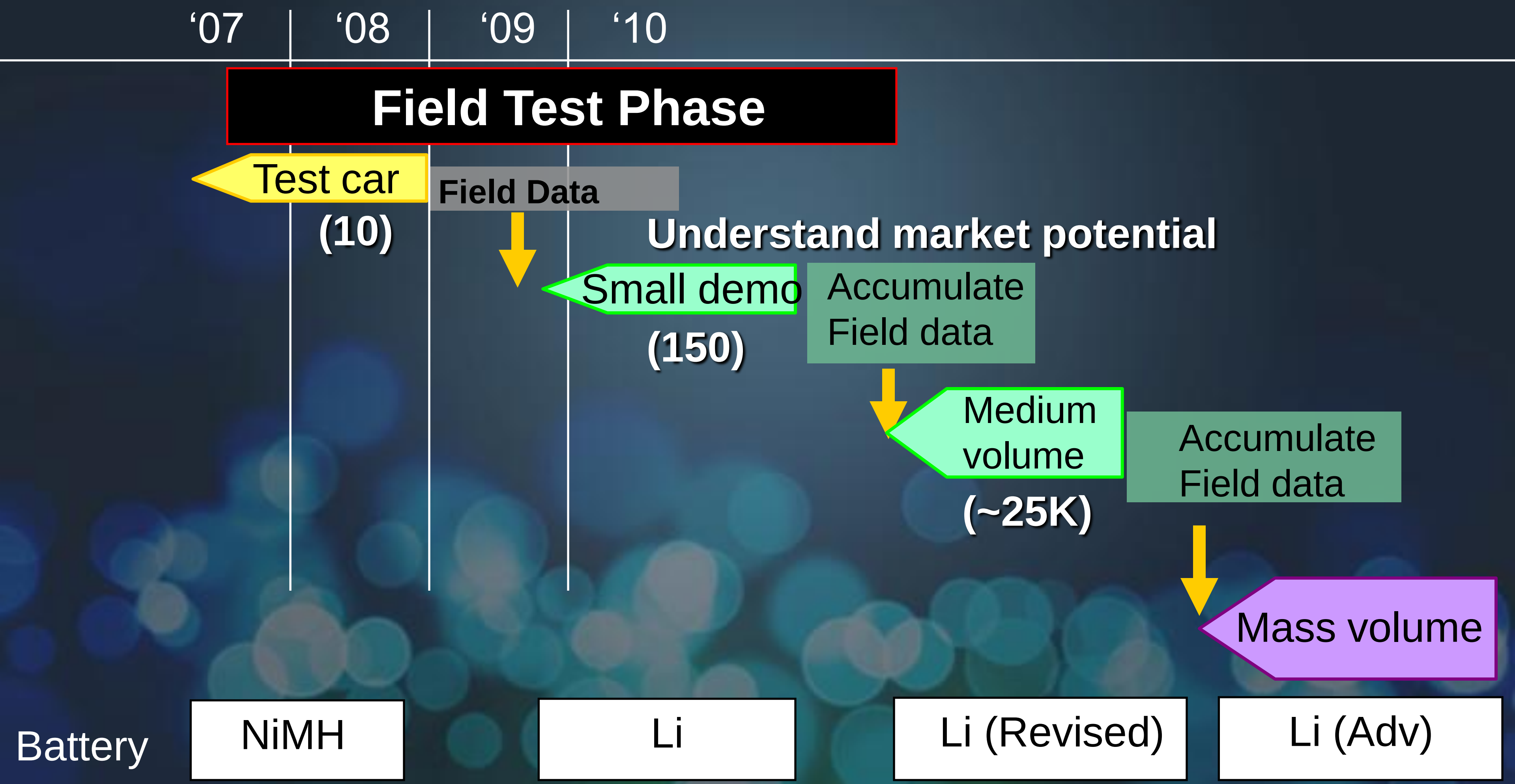
- Additional fans
- New ductwork
- 42 Temperature Sensors





Toyota's PHV Introduction Scenario

Step by Step approach, dependent on Battery Development



Last Century Urban Mobility Projects

Toyota e-Com
shared-use 'community' EVs
for employees

Crayon System
pay-as-you-go public EV
rentals

New Urban Mobility – EV Concept

- Range: 50 miles
- Charge Time:
  - ~ 2.5hr/7.5hr (220V/110V)
- 2012

Transition in Personal Mobility

Mobility based on Multiple Modes

- Car Sharing
- Personal Rapid Transit
- Mass Rapid Transit

Transition will require:

1. **Real-time Communication from Vehicle**
   a) to customer (web portal, Smart Phone)
   b) to utilities
2. **Shift to other modes of personal transportation**
3. **Partnerships**

Mobility based on Personal Automobile

Technology Enables New Possibilities

Wireless Technology Promotes Modal Diversity

Eco Technology Conserves Energy, Reduces CO_2

Locate Mass Transit

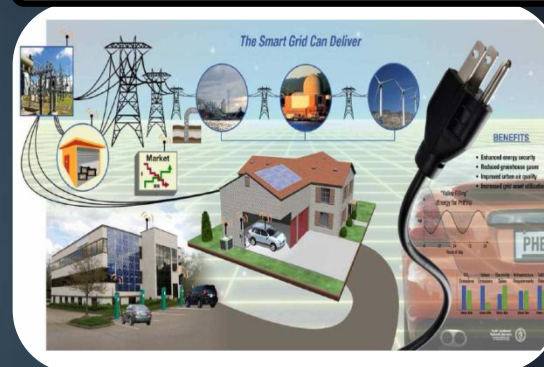
Zipcar Available?

Recommend optimal mode to **minimize price** & **travel time**

<u>Convergence</u> of:

- ***Wireless Computing***
- ***Consumer Electronics***
- ***Transportation***
- ***Energy Management***
- ***Eco-impact Metrics***

Smart Grid



Locate Charge Station

Smarter Charging Stations

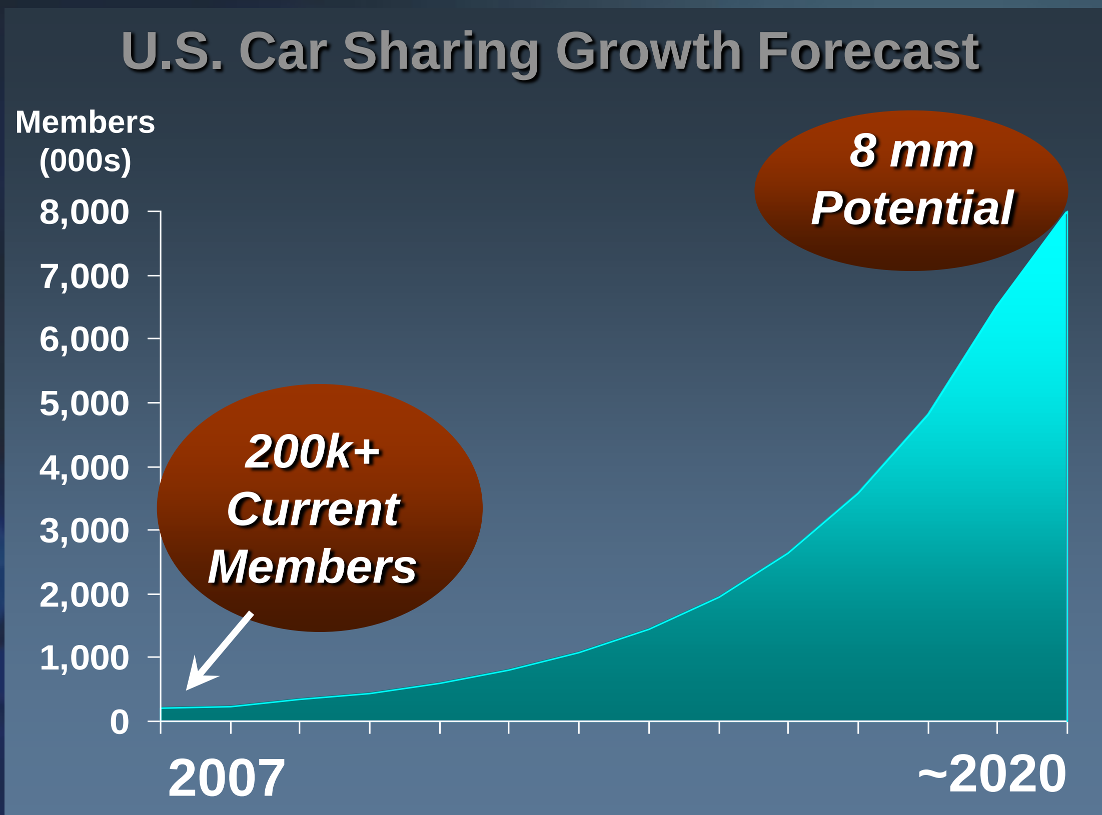
PEV ENABLERS

Monitor E F **Charge Status**

Vehicle to Grid

Car Sharing is Growing

- Currently at 70+ U.S. college campuses



Fox Business 2008 (70 Campuses); Innovative Mobility Research 2007 (current members), CNW Research 2008 (8 million forecast)

Car Sharing Opens New Market Opportunities

Two Basic Models, OEM Owner and Independent

- **OEM Owned Example: Mercedes Smart Car To Go**
  - Two Locations, Austin, Texas and Ulm Germany
  - Charge $.35/minute or $70 for all day
  - Insurance (and future charging) Provided
  - Mercedes Retains Control of Vehicle
  - Municipality Provides Free Parking
  - Income Stream From Services not From Sales
  - Enabled by Smart Phone Applications
- **Independent Owner Example: Zip Car**
  - 350,000 Subscribers and Climbing
  - 49 US Cities, Plus Toronto, Vancouver and London
  - 6000 Vehicles, 70 Different Models
  - Largest Car Sharing Operation in the World
  - Estimated to be $1 Billion Company in 5 years (Fortune Magazine)
  - iPhone App Finds the Car, Reserves the Car and Unlocks the Car
  - Municipalities Provide Dedicated Parking and Charging

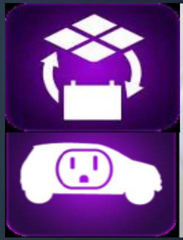
Key Infrastructure Issues Remain

Vehicle to Grid Communications

- Electric Utilities have excess electricity *generation* capacity during off-peak hours – typically at night
- Even during off-peak times, however, there is insufficient electricity *distribution* capacity for many PEVs to charge at the same time

→ **Communication between vehicle and "grid" is necessary to avoid negative impacts to distribution system (such as local outages)**

Level 2 Charging Equipment



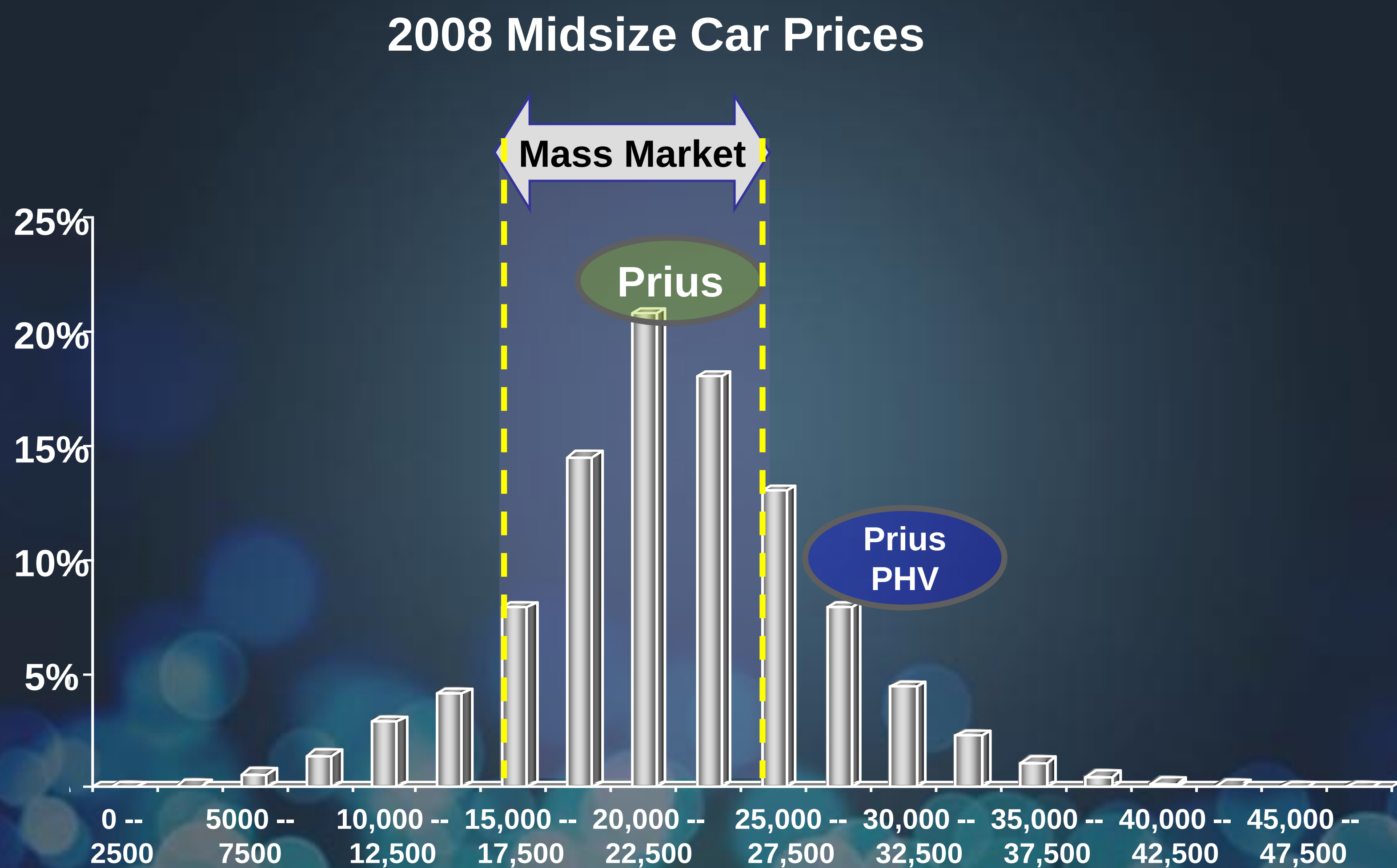
- The majority of customers, particularly larger-capacity BEVs (50+ miles), will need/want L2 (220V) charging at home and business
- The installation of L2 charging equipment is extremely challenging: high cost, lengthy time period, complex interactions among City, Utilities, Contractor, Customer, OEM and Dealer

→ **Resolving L2 installation issues will be critical for EV market adoption**

Last Mile Grid System not Developed

- Old Transformers Cannot Accommodate Multiple EVs Charging in One Neighborhood
- Night Time Charging Limits Charging Hours
- Public Charging Not Assured

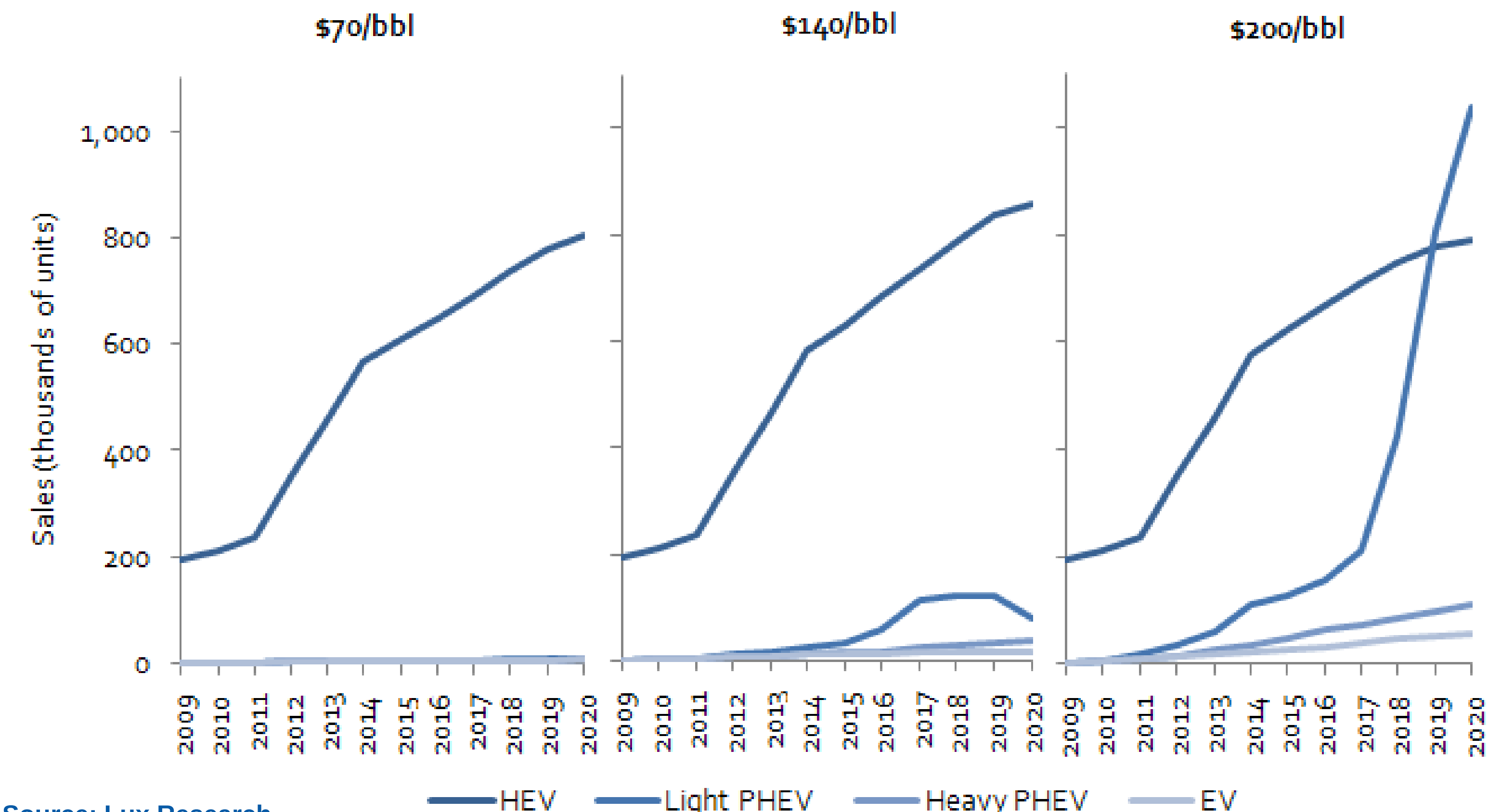
"What the Market will Bear"



Source: PIN

The U.S. market is primed for light PHVs . . . . .

if oil prices play along



Source: Lux Research

The Obama administration has made EVs an agenda item…

Energy Plan from Campaign - Key Points

- Put 1 million plug-in hybrid and/or electric vehicles on the road by 2015
- Ensure 10% of energy comes from renewable sources by 2012 and 25% by 2025
- Implement economy-wide cap-and-trade program to reduce greenhouse gas emissions 80% from 1990 levels by 2050

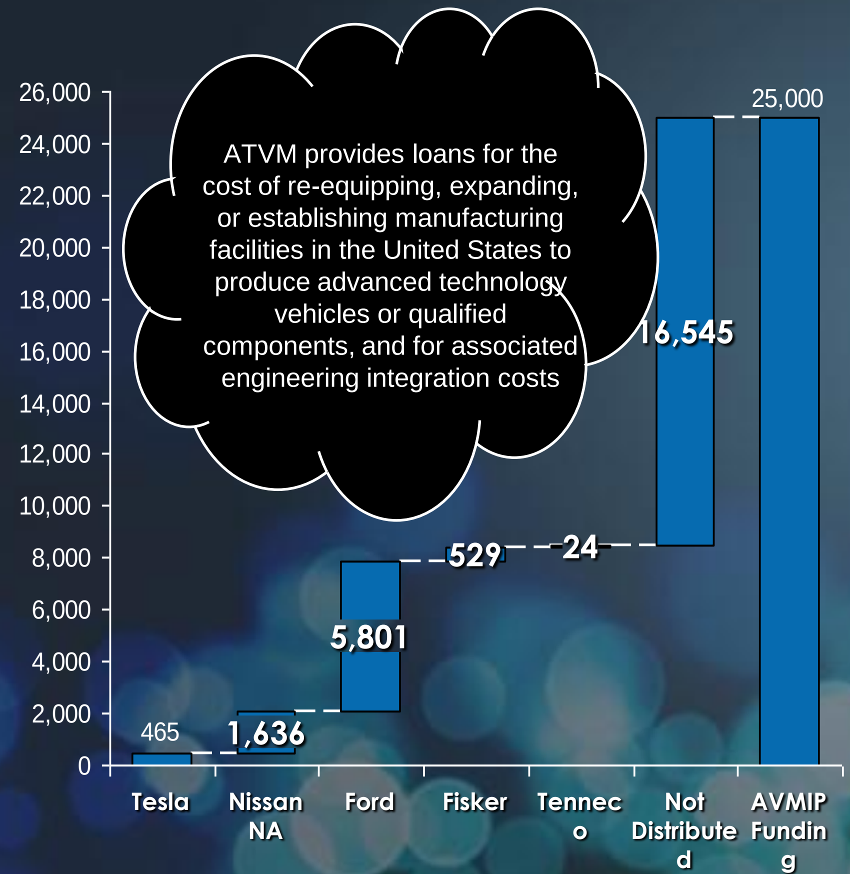
Progress vs. Campaign Promises

- Congress passed energy legislation in 2009 to reduce U.S. emissions below 2005 levels (Senate has not voted on legislation)
  - 17% reduction by 2020
  - 83% reduction by 2050
- American Recovery and Reinvestment Act included $2.4 billion in funding for battery development and electric vehicle component

…backed by significant financial commitments

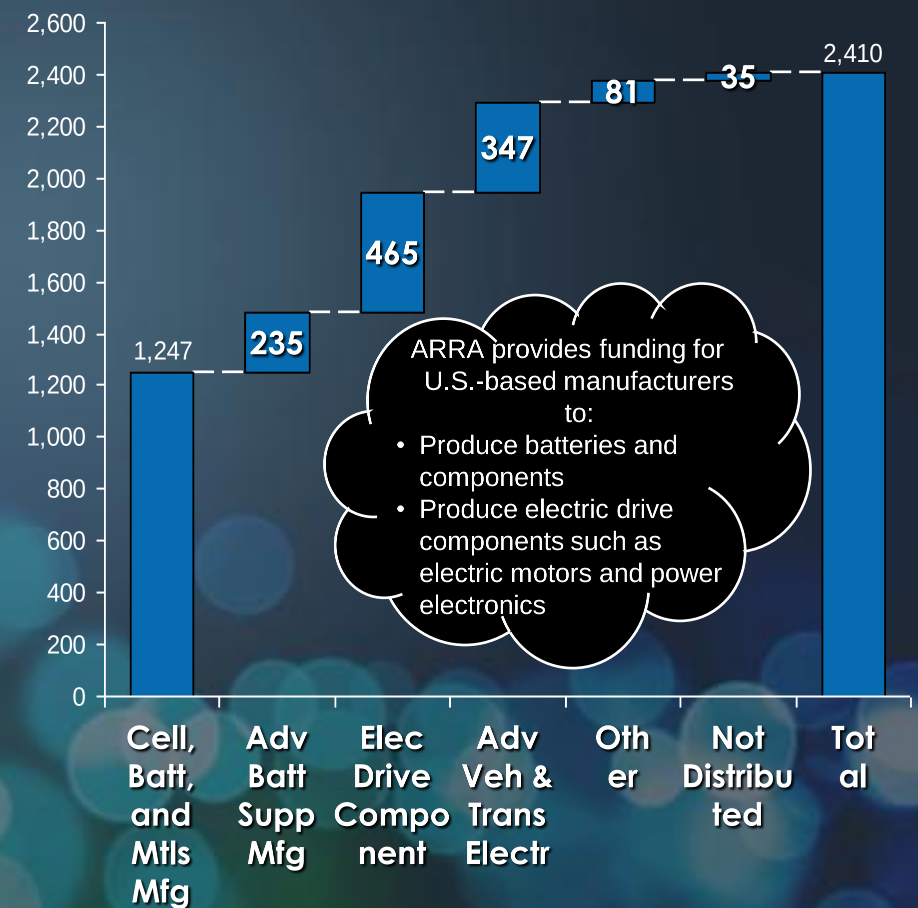
Advanced Tech Vehicles Manufacturing Loan Program

Measured in USD Millions



American Reinvestment & Recovery Act Awards

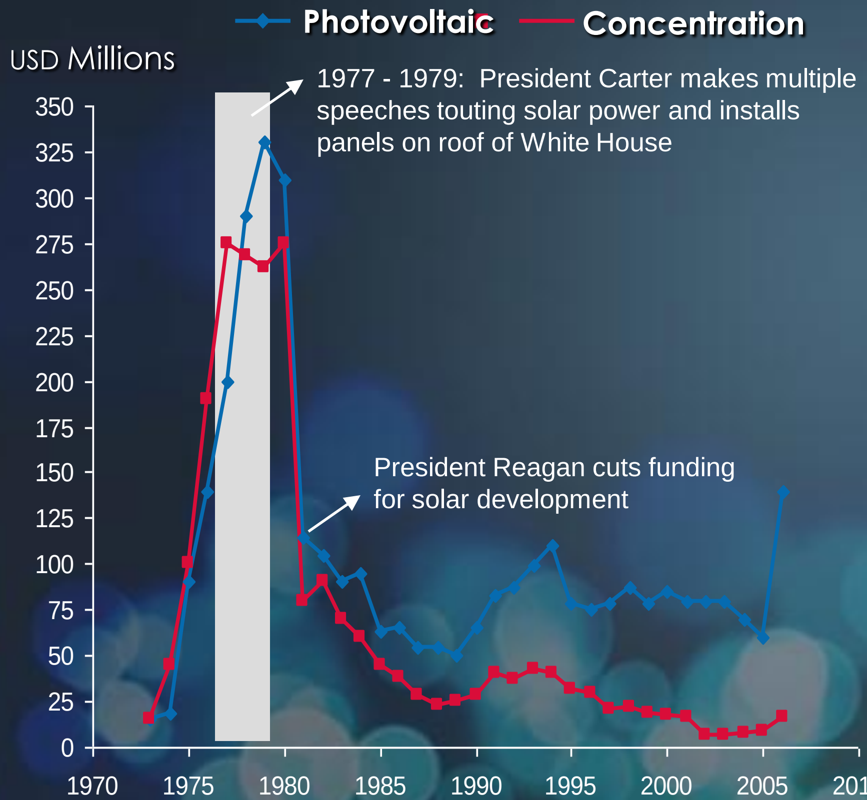
Measured in USD Millions



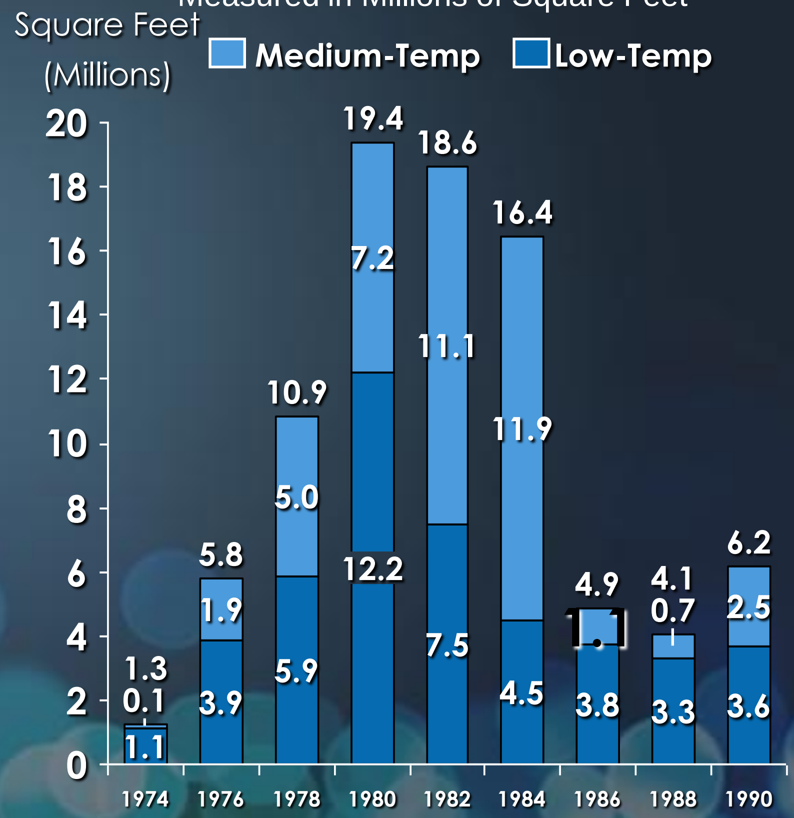
Source: U.S. Department of Energy

However, past presidential agenda items such as solar power
have struggled once funding was cut

Estimated Department of Energy Solar Funding
Measured in 2007 Dollars



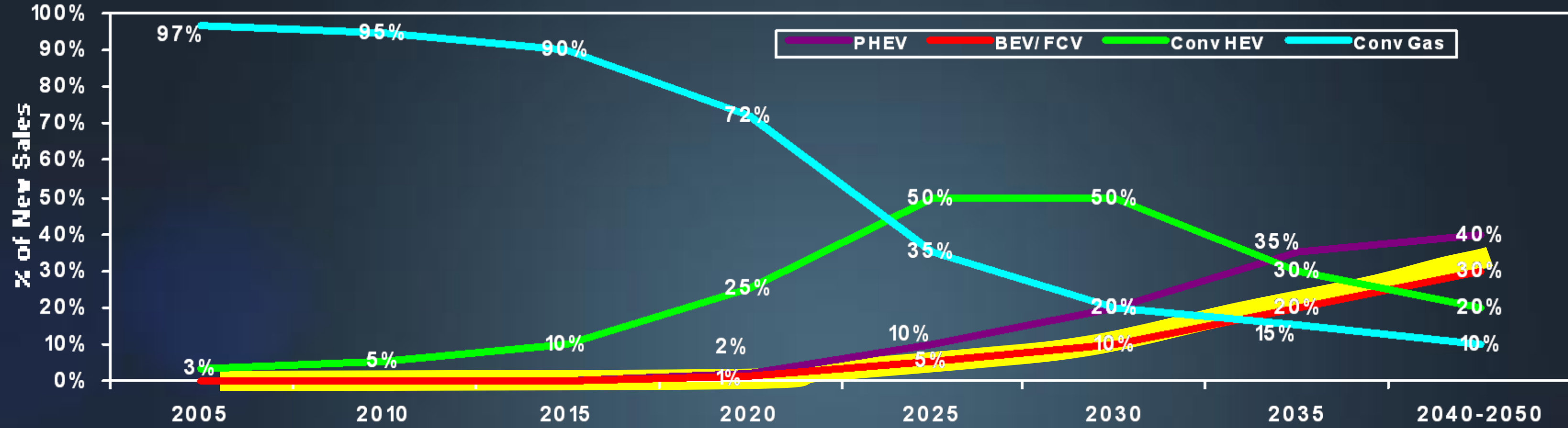
Shipments of Solar Thermal Collectors
Measured in Millions of Square Feet



Source: Sissine, “Federal Spending for Solar Energy”, Congressional Research Service July 11, 2008; EIA “Solar Thermal Collector Shipments by Type, Price, and Trade 1974 - 2007

Strong Regulatory Push: Reduce CO_2

CARB 2050 Vision

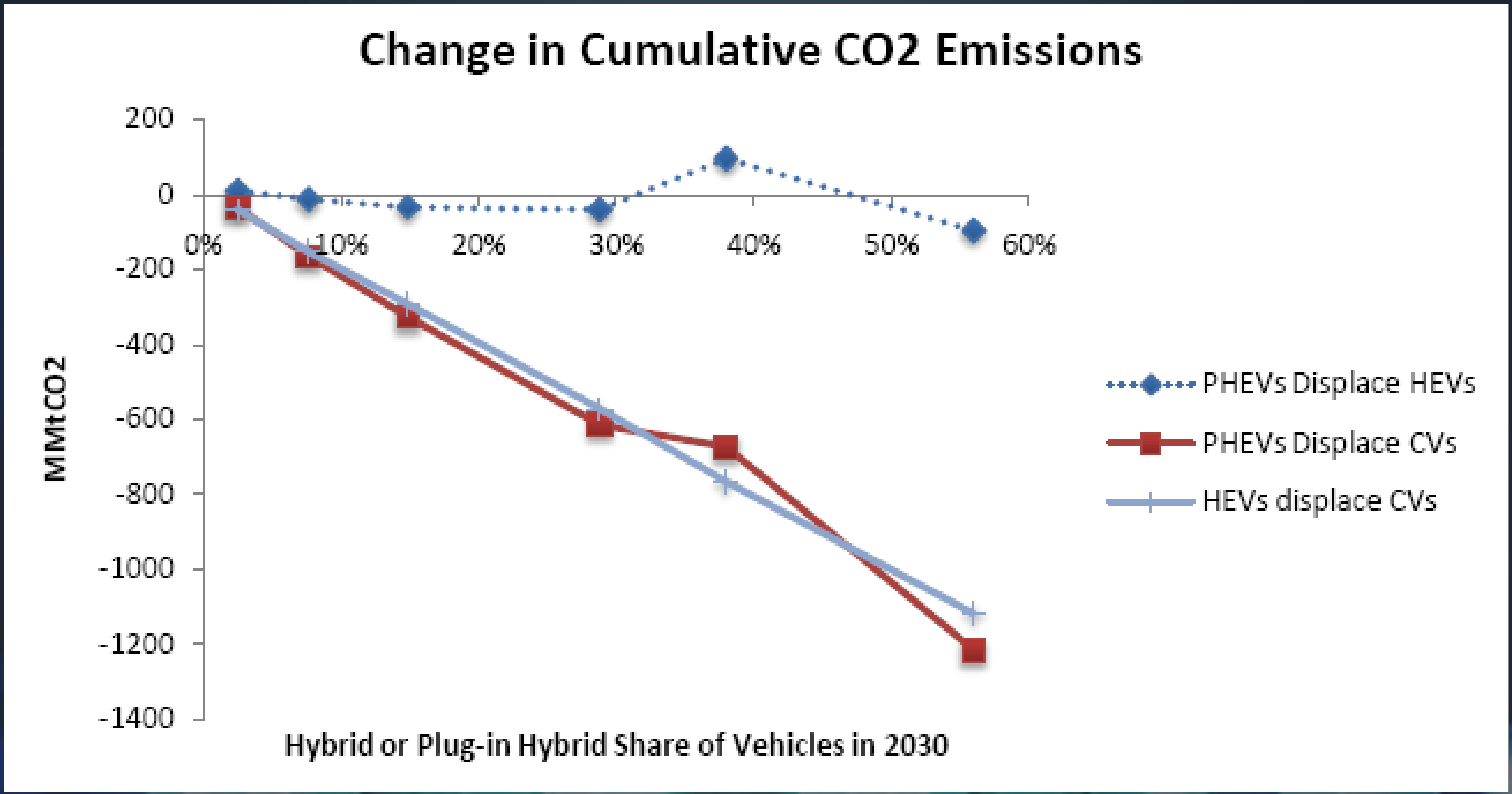


CARB Assumptions: Retail Price Increase Versus 2035 Hybrid	
2035 Plug-in Hybrid (30 mile AER)	$3,400
2035 Battery Electric (100 mile range)	$5,500
2035 Fuel Cell	$2,800

Sources: California Air Resources Board; "[ZEV] White Paper"

- CARB expects **BEV/FCV sales volume to surpass conventional gas** by 2035 and reach **30% of mix** by 2040
- However, the above vision does not achieve the 80% reduction in GHG emissions from 1990 levels by 2050; **ZEVs will need to reach 100%** of vehicle sales **by 2040, to meet the 80% goal**

Outside Voices: Evaluation of PHVs, Duke University



Duke University, *Plug-in and regular hybrids: A national and regional comparison of costs and CO_2 emissions*.

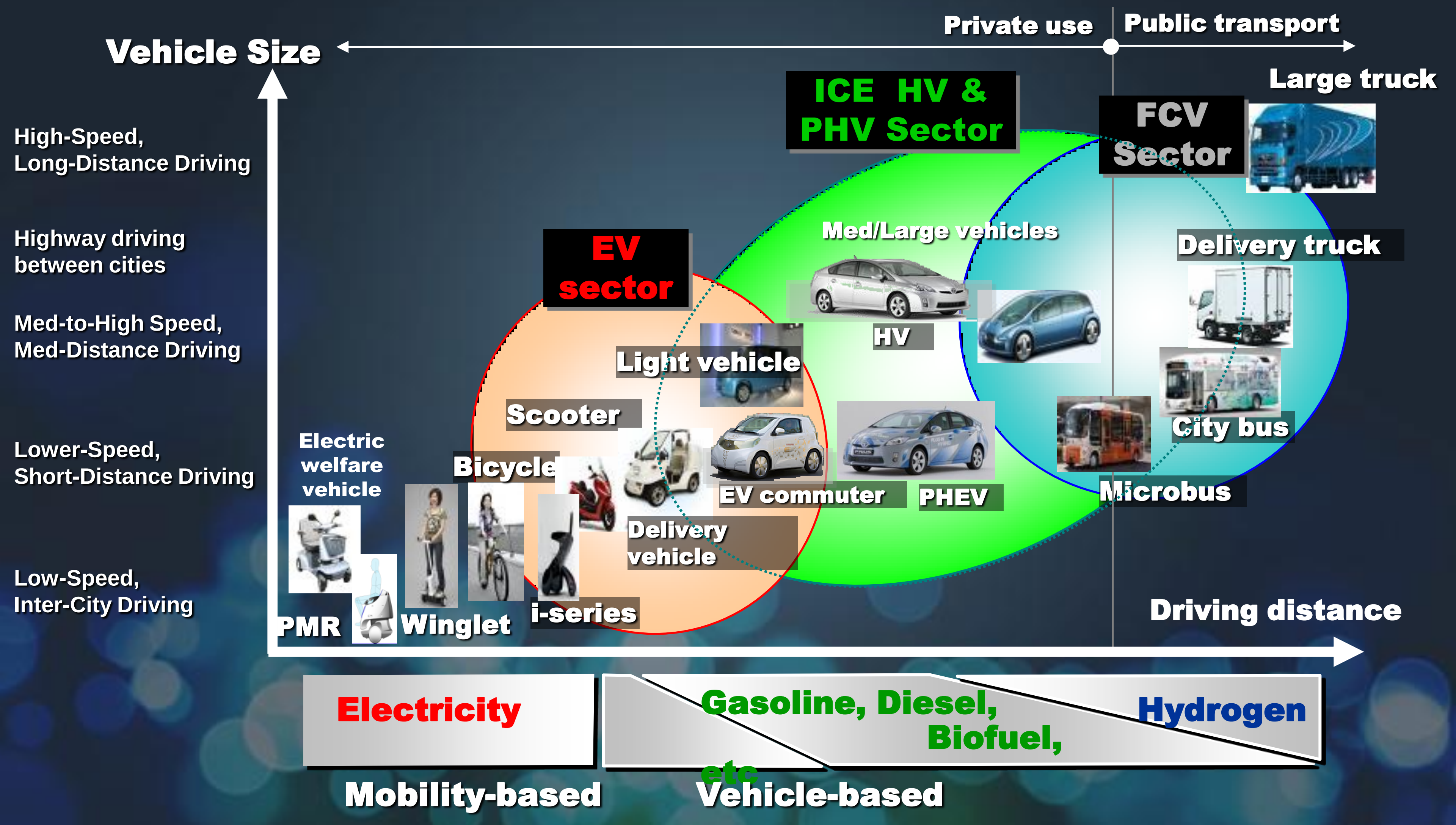
Comparison of Vehicle Powertrain Technologies

	Lifetime emissions				Lifetime energy use
	CO2 equiv	**SOx**	**NOx**	**Hg**	
	lb	***lb***	***lb***	***lb***	***MMBTU***
Gasoline (30mpg Sentra)	140,000	150	160	0.00084	721
EV-40 (Current US Grid)	110,000	430	210	0.00190	339
PHEV-20 (Reduced Volt)	100,000	270	160	0.00120	409
HEV (2010 Prius)	97,000	140	120	0.00071	472
Fuel Cell (70mi/kg)	76,000	4,100	53	0.00047	626

Comparison of Vehicle Powertrain Technologies

	Lifetime energy use breakdown				
	FC	**HEV**	**PHEV-20**	**EV-40**	**Gas**
Material production	**17%**	**17%**	**20%**	**25%**	**11%**
Vehicle assembly	**3%**	**3%**	**4%**	**5%**	**2%**
Fuel production / transport	**10%**	**10%**	**9%**	**5%**	**12%**
Vehicle operation	**63%**	**63%**	**59%**	**54%**	**71%**
Vehicle maintenance	**3%**	**3%**	**3%**	**4%**	**2%**
Vehicle disposal	**4%**	**4%**	**5%**	**7%**	**3%**
Total	100%	100%	100%	100%	100%

Roles of EV/PHEV/FCV



Summary

- Apply existing technologies in new ways
  - Most of the technologies mentioned already exist, just not yet in the mobility space
- For now smaller battery approaches are more cost effective
  - Implies multiple charge periods throughout the day
- At the end of the day, customer is king
  - All solutions must solve customers problems without creating new ones
  - Charging solutions to manage the grid may be at odds with customer expectations.