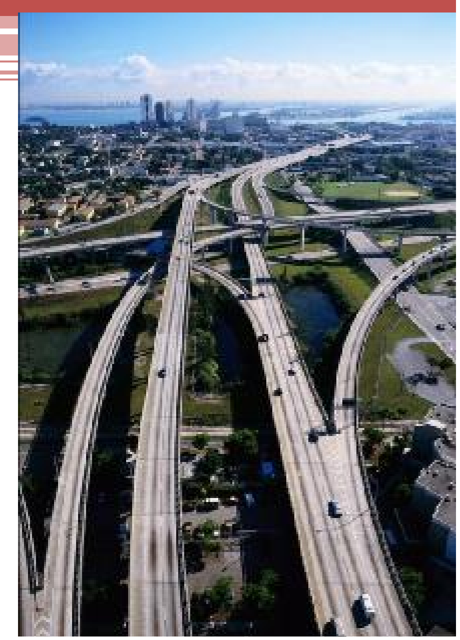
URBAN PLANNING, LAND USE POLICY , & VEHICLE TECHNOLOGIES TO REDUCE GHG EMISSIONS IN CITIES

Kara Kockelman

Professor of Transportation Engineering

Department of Civil Engineering

The University of Texas at Austin



Key, Connected Topics

Land Use Policies

Example: Parking policies

Transportation Policies

Example: Plug-in vehicles

Transportation Technologies

I. Land Use Policies

Denser Development (more persons & jobs per acre)

More ***Accessible*** Regions & Neighborhoods

More ***Mix & Balance*** of Complementary Use Types

Transit-Oriented Designs

More ***Connected*** Networks

Urban Growth ***Boundaries***

Parking Maxima (per dwelling unit, job, m^2)

→ Various co-benefits, but driving distances & GHGs do not fall as much as we would like.

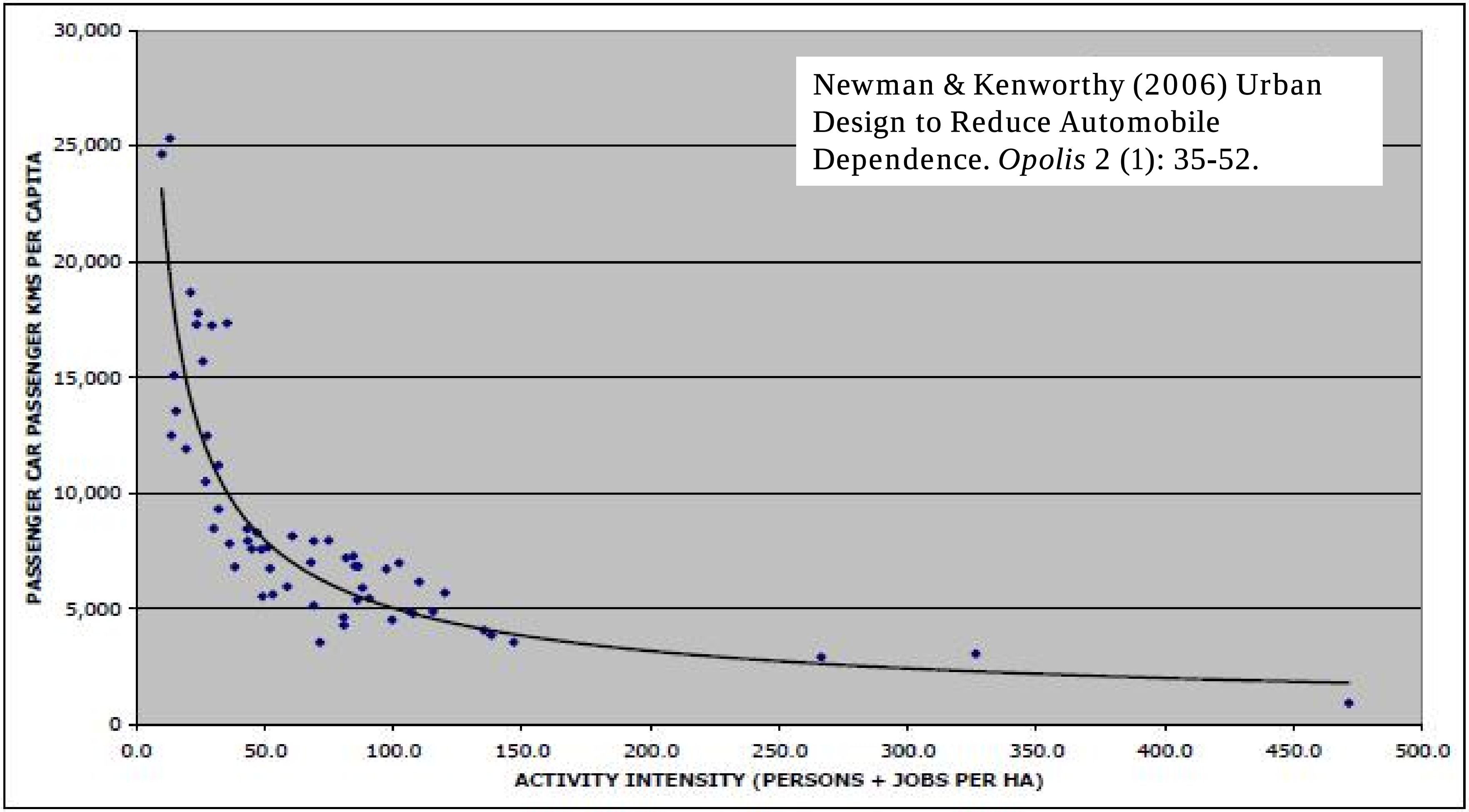
How helpful are these?

10% increase in the following values, with 1% of U.S. households affected ...

- % of 4-way intersections: 0.40 M tons/yr
- Net (jobs + population) density: 0.32
- Population density: 0.07 to 0.30
- Accessibility: 0.27
- Land use mixing: 0.18
- Walking quality: 0.14
- Vertical mixing: 0.095
- Population centrality: 0.030

Note: Values assume no vehicle type/fuel economy changes.

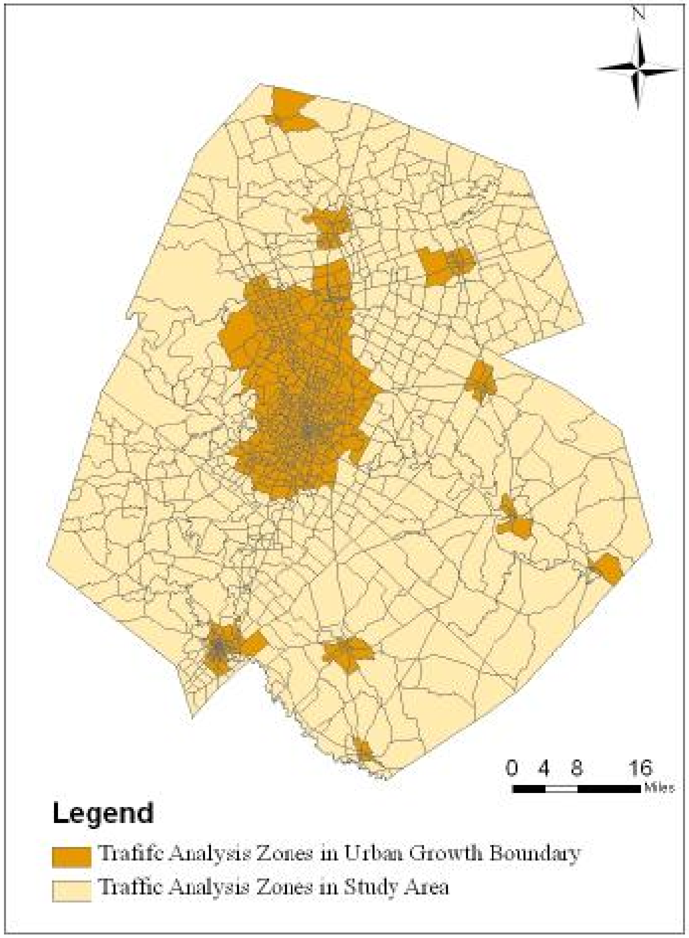
Car Distances vs. Density



Example: Modeling Land Use-Transportation Futures

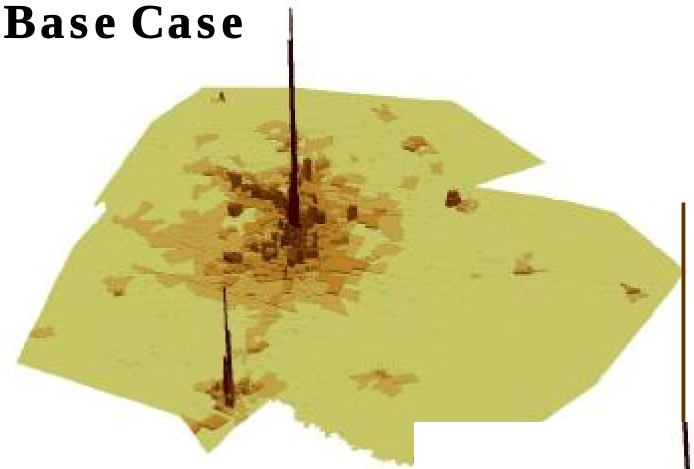
3 Austin, Texas Scenarios

- **Base Scenario:** Business as usual/Trend
- **Road Pricing:** Congestion pricing (on freeways) + Carbon tax (4.5¢ per mile)
- **Urban Growth Boundary:** Zones with 3+ person-equivalents per developable acre, plus adjacent zones



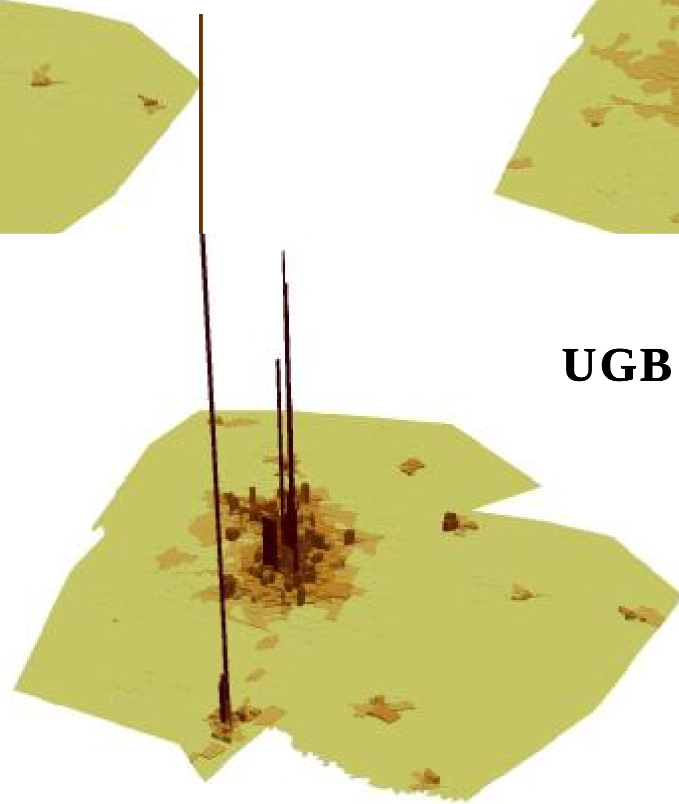
Forecast Comparisons
Job Densities in 2030

Base Case



Road Pricing

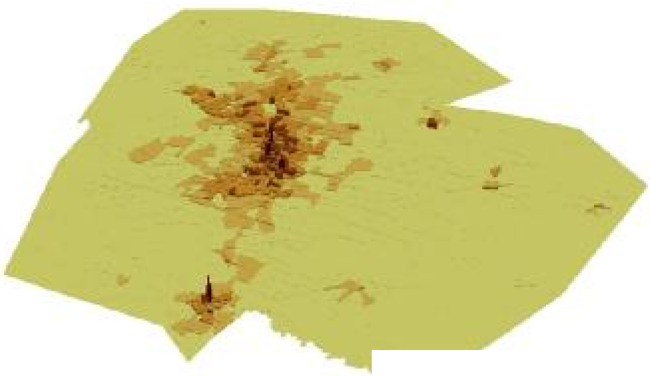
UGB



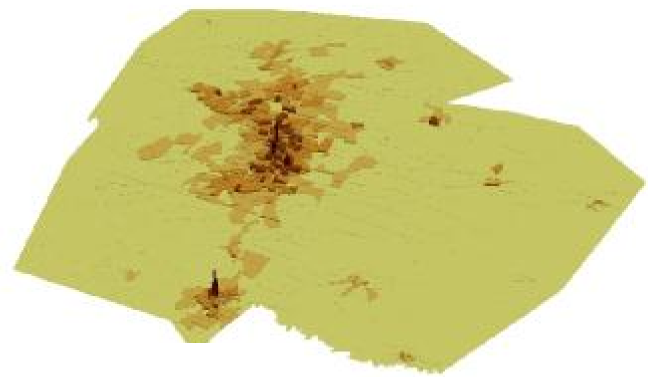
Forecast Comparisons

Population Densities in 2030

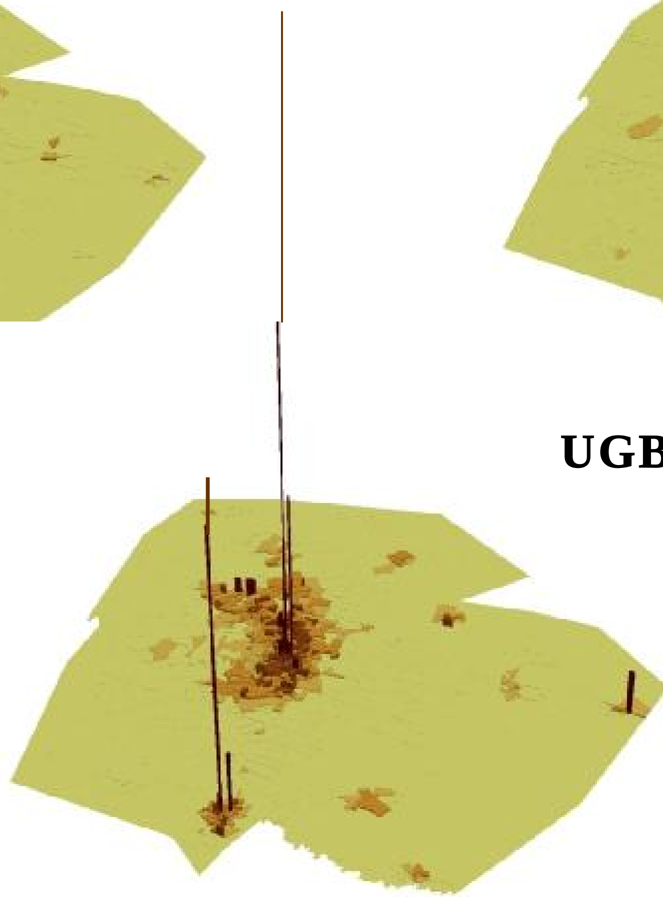
Base Case



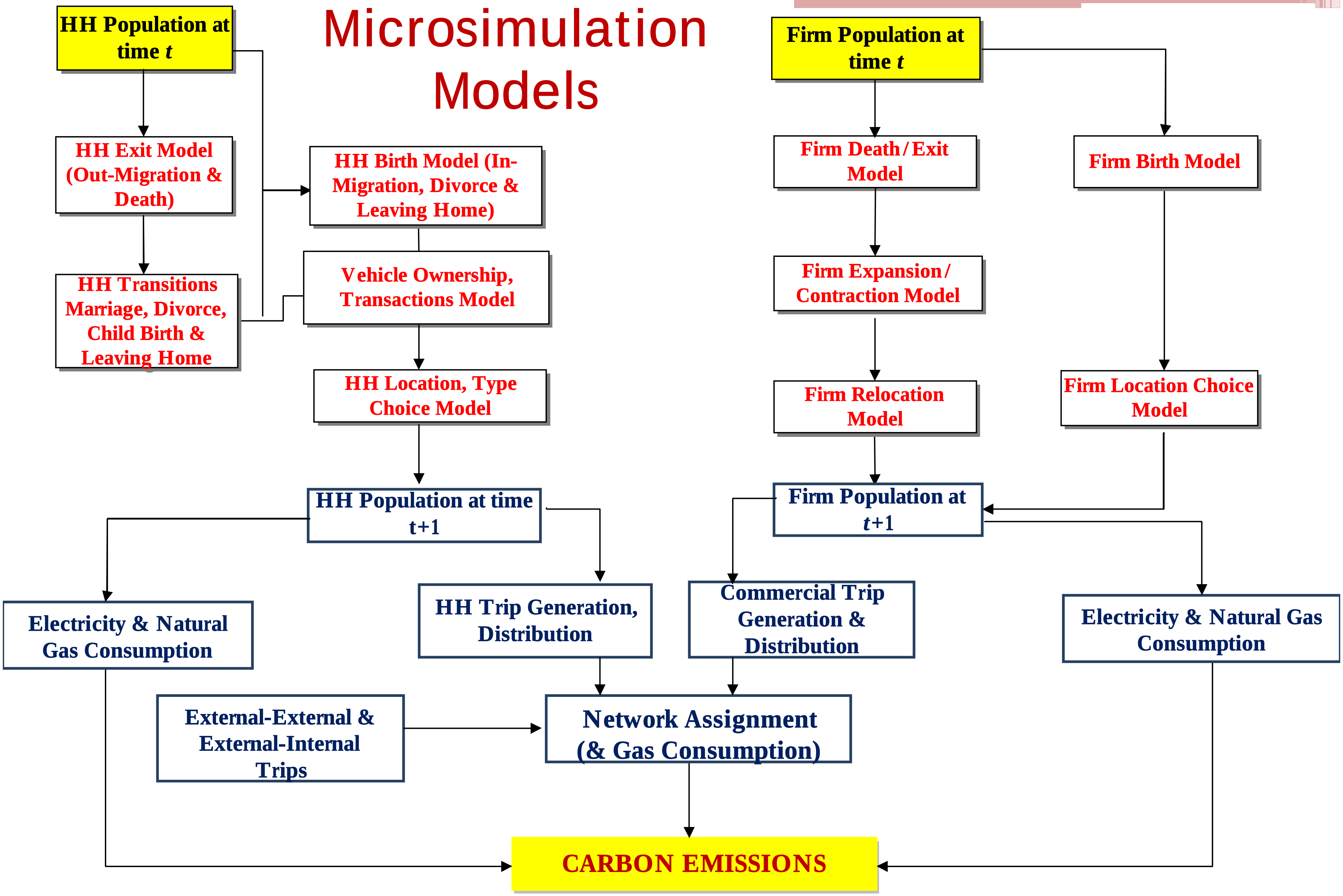
Road Pricing



UGB



Microsimulation Models



Scenario Comparisons

- Jobs, Households, & Traffic Patterns

	Accessibility (of CBD)		Reg. Density (per sq.mi.)		Avg. Speed (mph)		VMT
	HHs (10^6/day)	Jobs (10^6/day)	HHs	Jobs	AMPK	PMPK	(10^6/day)
Base Case	1.81	6.29	1483	7995	43.4	45.5	84.8
Road Pricing	1.53	6.32	1477	8047	44.0	46.2	**71.2**
UGB	**3.74**	6.93	**29,696**	**22,581**	44.0	45.5	**70.2**

$$Accessibility = \sum_i \frac{Count_i}{DistToCBD_i}$$

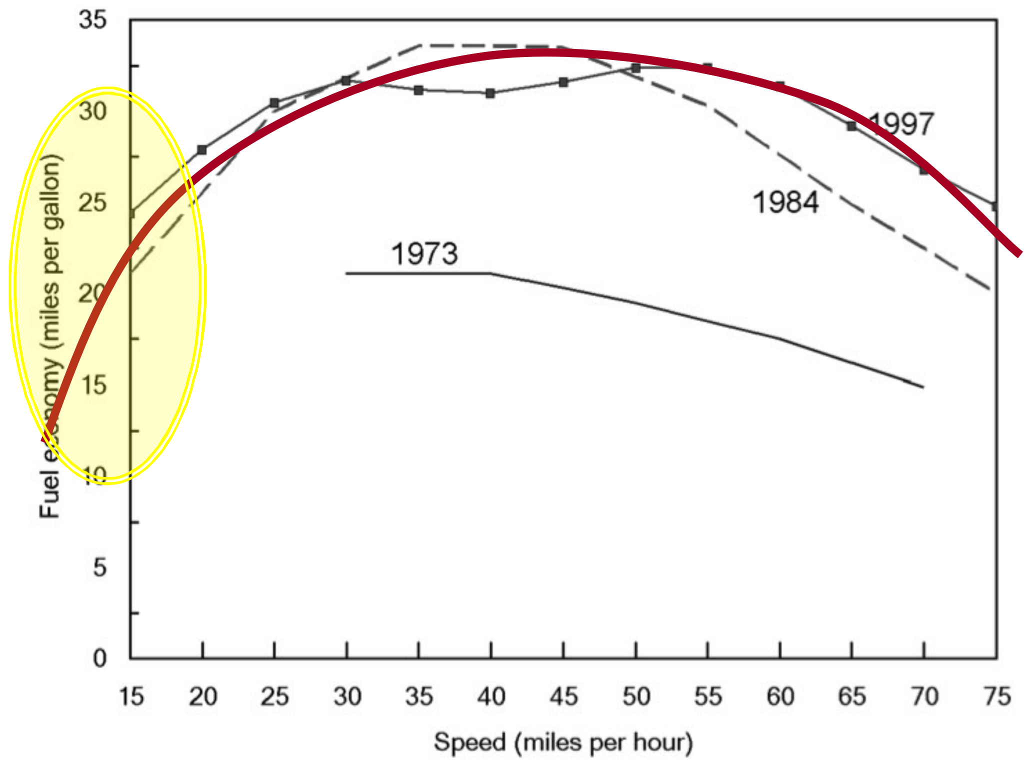
More Traffic Comparisons

	Average Speed		Average Max. VOC		Total Flow (x 10^6)	
	AM	PM	AM	PM	AM	PM
Base Scenario	43.4	45.5	0.556	0.443	35.0	58.3
Congestion Pricing	44.0	46.2	0.491	0.376	29.4	46.9
Density Floor	43.3	45.3	0.554	0.448	35.5	59.6
Urban Growth Boundary	44.0	45.5	0.495	0.401	32.1	53.7

	Vehicle Miles Traveled				
	AM	OP	PM	MID	Total
Base Scenario	17,010	6,463	27,176	34,146	84,795
Congestion Pricing	14,636	5,468	22,821	28,326	71,252
Density Floor	16,913	6,465	27,261	34,321	84,960
Urban Growth Boundary	14,205	5,336	22,488	28,187	70,216

A Word of Caution: Low Speeds from Higher Densities ?

- Maximum fuel economy at higher speeds (30 to 60 mph).
- Reduce/enforce freeway speed limits.
- Increase urban speeds (via road pricing & design).



Source: ORNL (1997)
Based on 8 vehicles (5 PCs & 3 LDTs)

II. Transportation Policies

Pricing (by vehicle type, location & time of day)...

- ... of Parking & Road Use
- ... of Vehicles & Fuels (via Feebates, Fees & Taxes)

Fuel Economy Standards

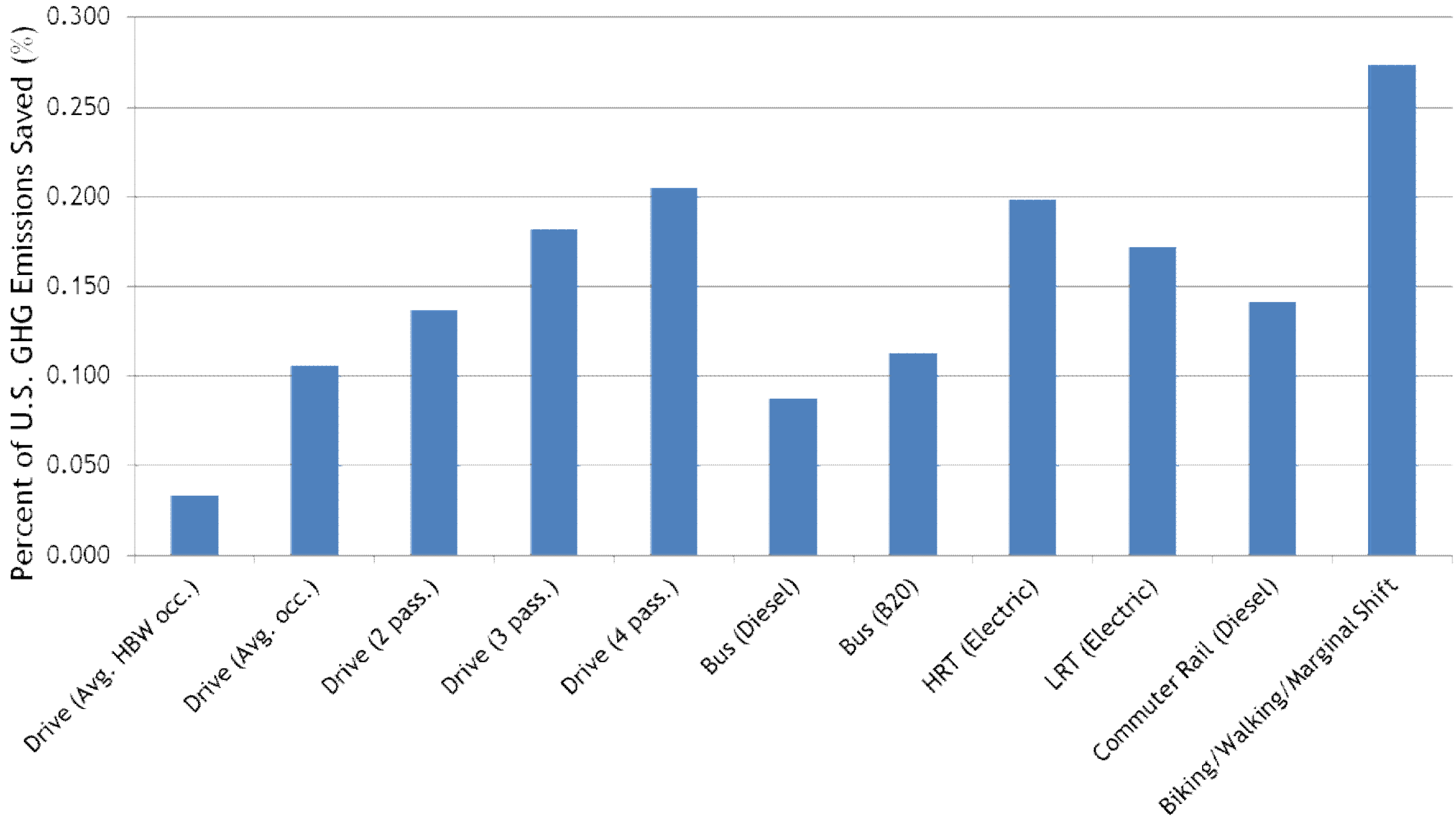
Resource Sharing (carsharing, bikesharing, dynamic ride-sharing, transit provision, mixed parking lot uses)

Information Provision (to car buyers, drivers, transit users, sluggers, via Smartphones & Smartmeters, ...)

Fuel Economy & Pricing Policies

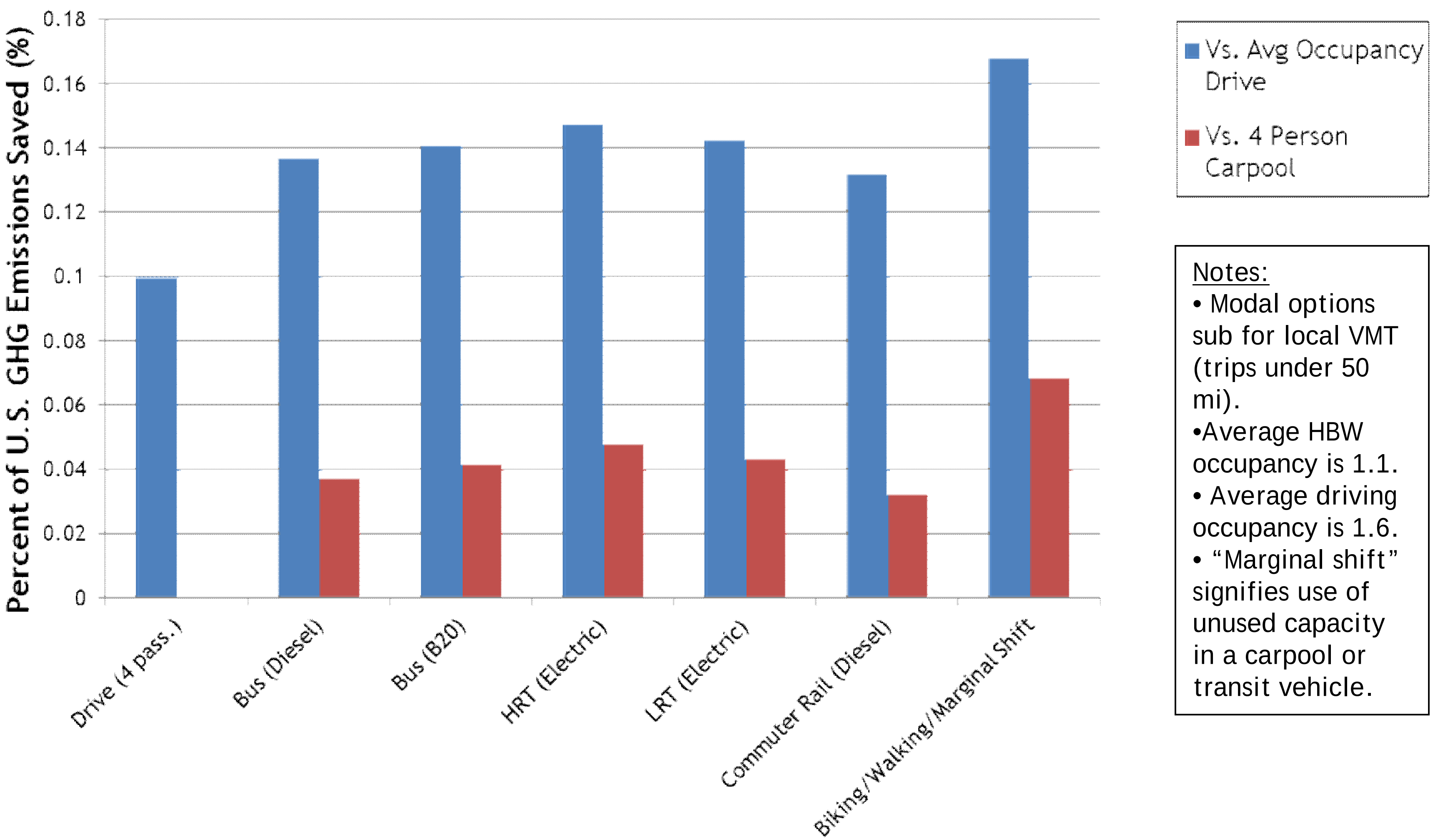
- Gas Taxes (relatively low impact)
- Vehicle Registration Fees (significant in Asia)
- Fuel Economy Standards (common & meaningful)
- Feebates (may emerge in US)
- GHG Emissions Standards (present in EU)
- Road Pricing (controversial & targets congestion)
- Paying More for Parking (effective & underutilized in many locations)
- Subsidy of Alternative Modes (negative benefit-cost ratios in many contexts)

What does a 1% Mode Shift buy us, vs. Drive Alone? (At ***Average Occupancies***, Trips <50 miles)



1% Local Travel Mode Shift

(Alternative Modes at ***Full Occupancy***)

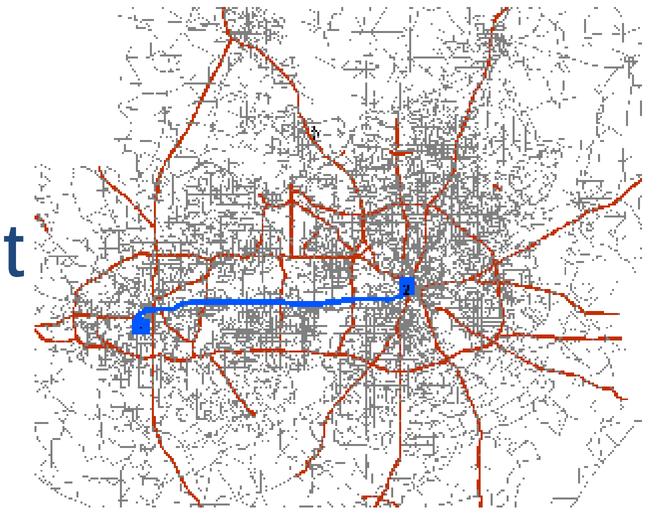


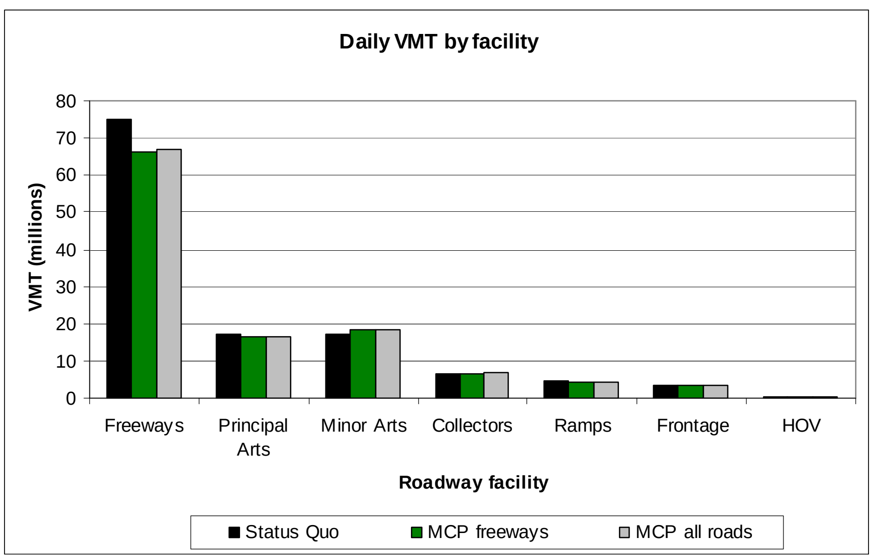
Notes:
- Modal options sub for local VMT (trips under 50 mi).
- Average HBW occupancy is 1.1.
- Average driving occupancy is 1.6.
- "Marginal shift" signifies use of unused capacity in a carpool or transit vehicle.

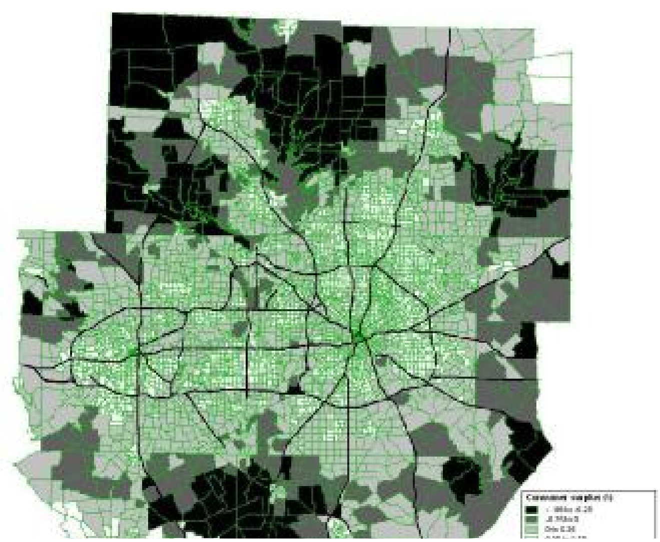
Example:
Credit-Based Congestion Pricing

Speeds rise & most travelers benefit.

Miles-driven & emissions fall just 7% if charge marginal delay cost.







III. Transportation *Technologies*

Plug-in Electric Vehicles (PEVs)

- BEVs (ex. Leaf & Roadster) + PHEVs (ex. Volt)
- Tax credits → Owner savings under moderate energy prices (offset by uncertainty & myopia?)
- Battery advances
- Cleaner power (offshore wind fields, solar films, algae-based fuels, carbon sequestration, & more affordable energy storage)
- Smart Charging & V2G Opportunities

Vehicle Safety (stronger , lighter-weight materials; electronic stability control; obstacle detection & lane-departure warnings; GPS navigation)

PEVs: Plug-in Hybrids & BEVs

Electrification of miles…

- Maximizes efficiency of electric motors.
- Allows substitution of lower GHG “fuels”.
- Centralizes emissions (opportunity for CCS).
- Charging schedules can exploit excess off-peak capacity & wind’s peak generation times.
- Does best for those with stable driving patterns (e.g., suburban commuters).
- Key markets: High gas prices, 220 V outlets, & reasonable alternatives for long-distance trip-making.

Issues

- Battery cost, weight, range, durability & supply.
- Emissions of power grid (GHGs & other pollutants).
- Possibly no improvement over improved HEVs (given cost).

Some PEV Examples

BEVs eREVs PHEVs

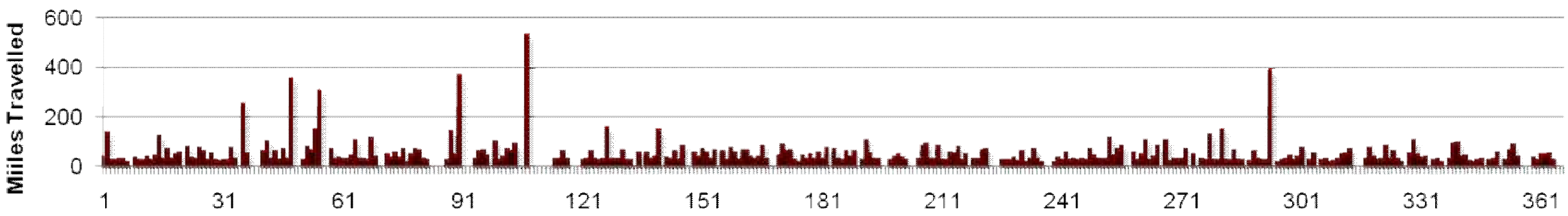
	BEVs	eREVs	PHEVs
Battery size	24-85 kWh	14-16 kWh	4-6 kWh
AER	60-300 miles	25-50 miles	10-15 miles
Price	~$30,000 – $100,000	~$40,000	~$40,000
Gasoline	None	Conventional	Conventional
Advantages	No internal combustion engine. No Tailpipe emissions.	No range limitation. Reduced tailpipe emissions. Acts as a BEV for shorter trips.	No range limitation. Fast charging. Reduced tailpipe emission.

Slide Contents: Dave Tuttle

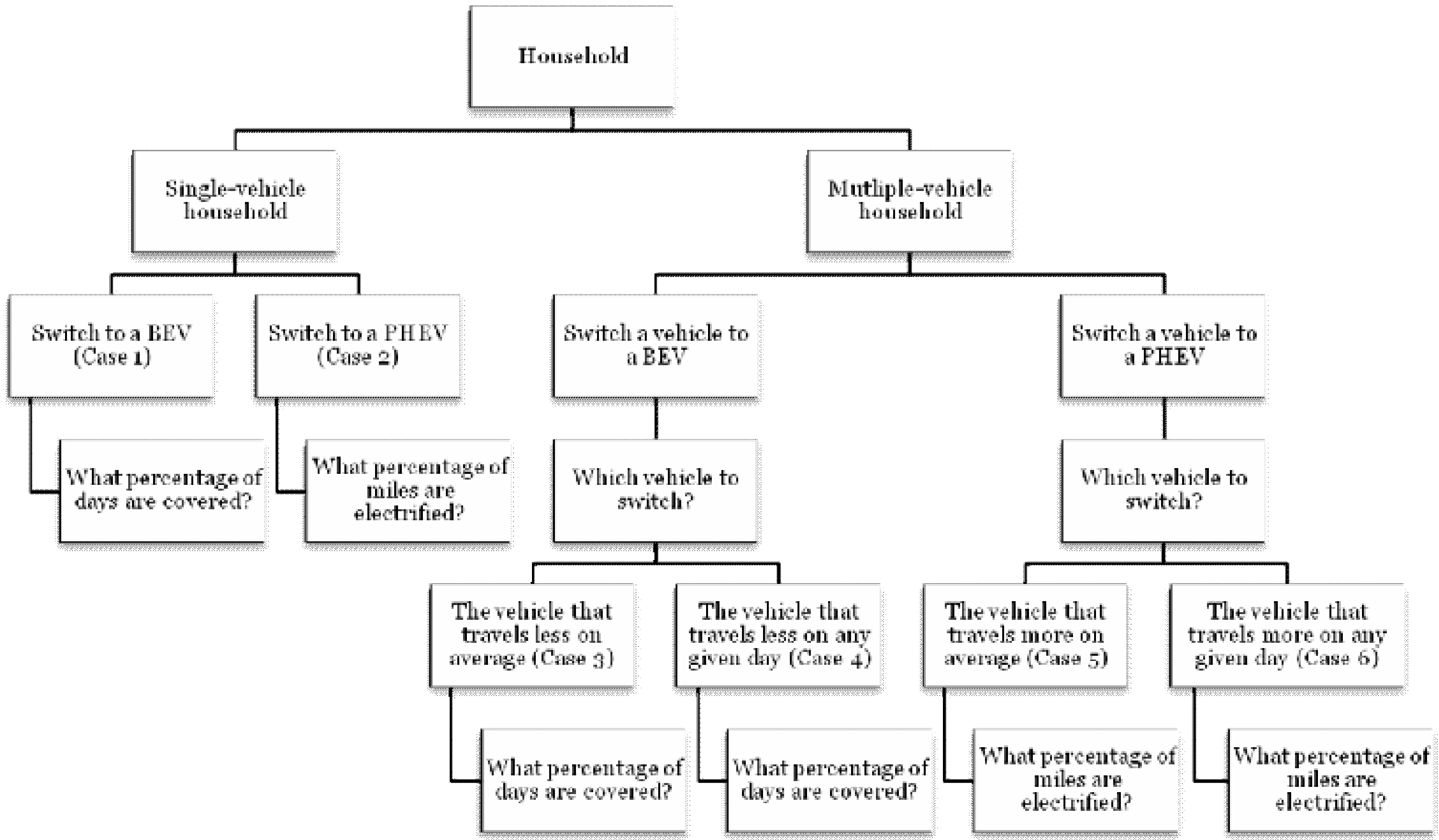
Make & Model	**Release Date**	**Estimated Retail Price** (after rebate)	**Body Type**	**Battery Size (kWh)**	**Estimated State of Charge Window**	**All Electric Range (miles)**
Range-Extended PEVs						
Chevy Volt eREV	2010	$33,500	4-door sedan	16	65%	25-50
Ford CMAX Energi PHEV	2012	TBA	4-door CUV	10	TBA	TBA
Toyota Prius PHEV	2012	TBA	4-door sedan	5.3	Est 50%	13 (at limited speeds)
Non-Range-Extended (BEVs)						
Tesla Roadster	2009	$101,500	2-door sports car	53	80%+	240
Nissan Leaf	2010	$25,250	4-door sedan	24	90%+	100
Ford Focus	2012	TBA	4-door sedan	23	TBA	100
Tesla Model S	2012	$49,900 base	4-door sedan	42 (also 65 & 85kWh options)	80%+	160 (also 230 & 300 options)
Mitsubishi iMiEV	2011	TBA	4-door sedan	16	TBA	100
Mercedes Smart Car	2012	TBA	2-door sedan	TBA	TBA	90

Example:
Long-term Driving Patterns

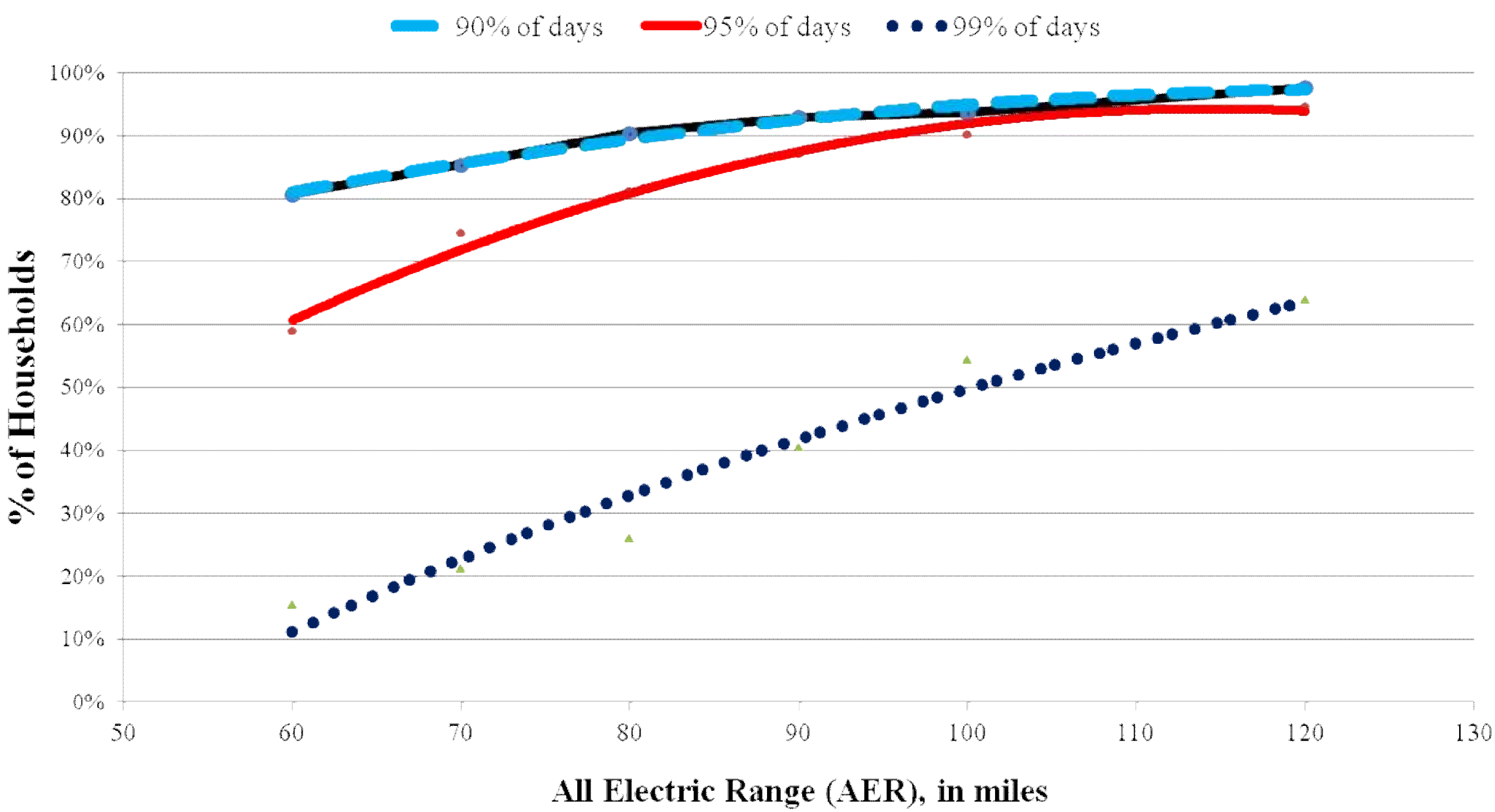
- Data Set: 1-year of GPS data from **445 vehicles** (264 households) in Seattle area (2004 through 2006).
- How might **day-to-day variability** in driving affect PEV **adoption & use** opportunities?
- We find that the market offers **great potential for heavy adoption**, with very moderate household adjustment.



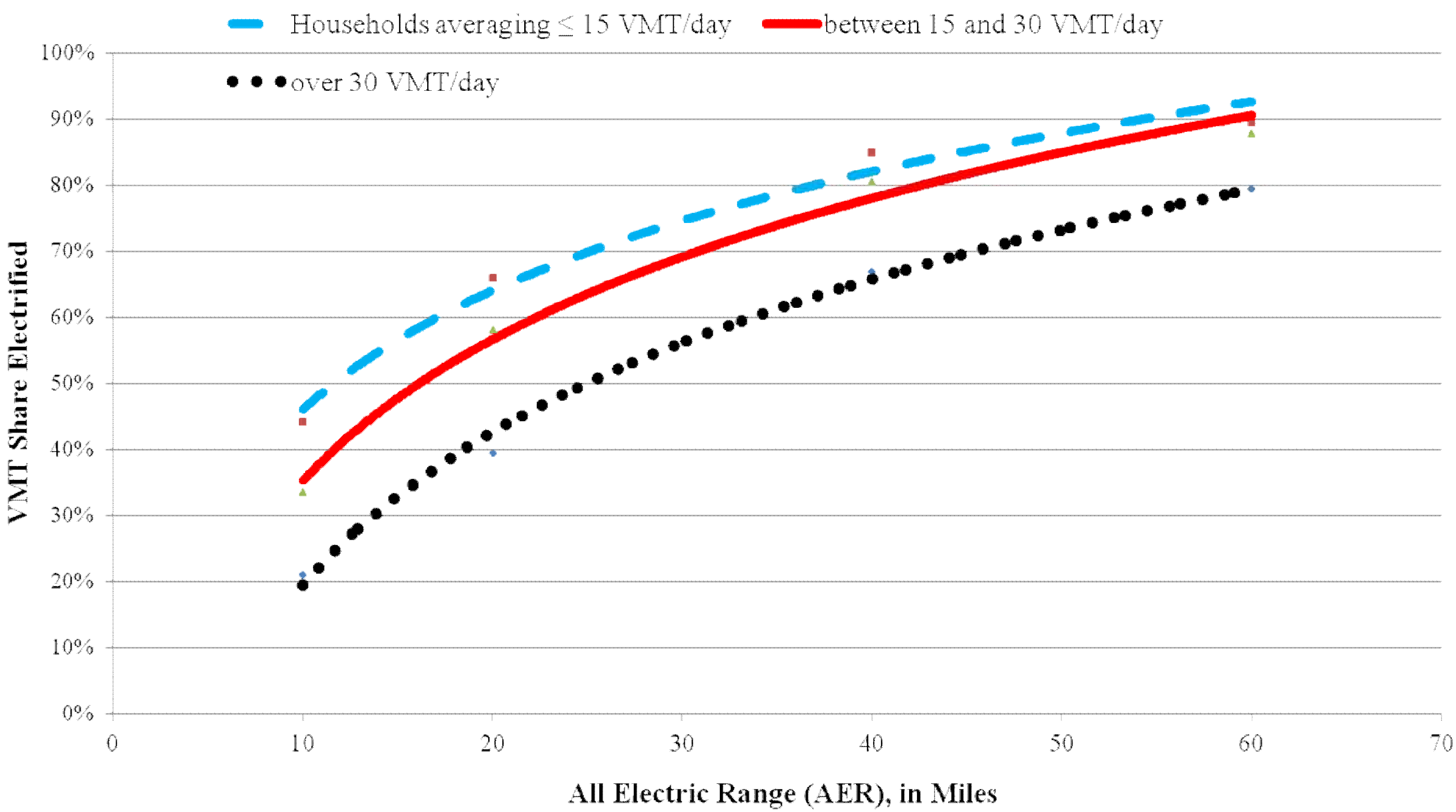
Analysis Framework



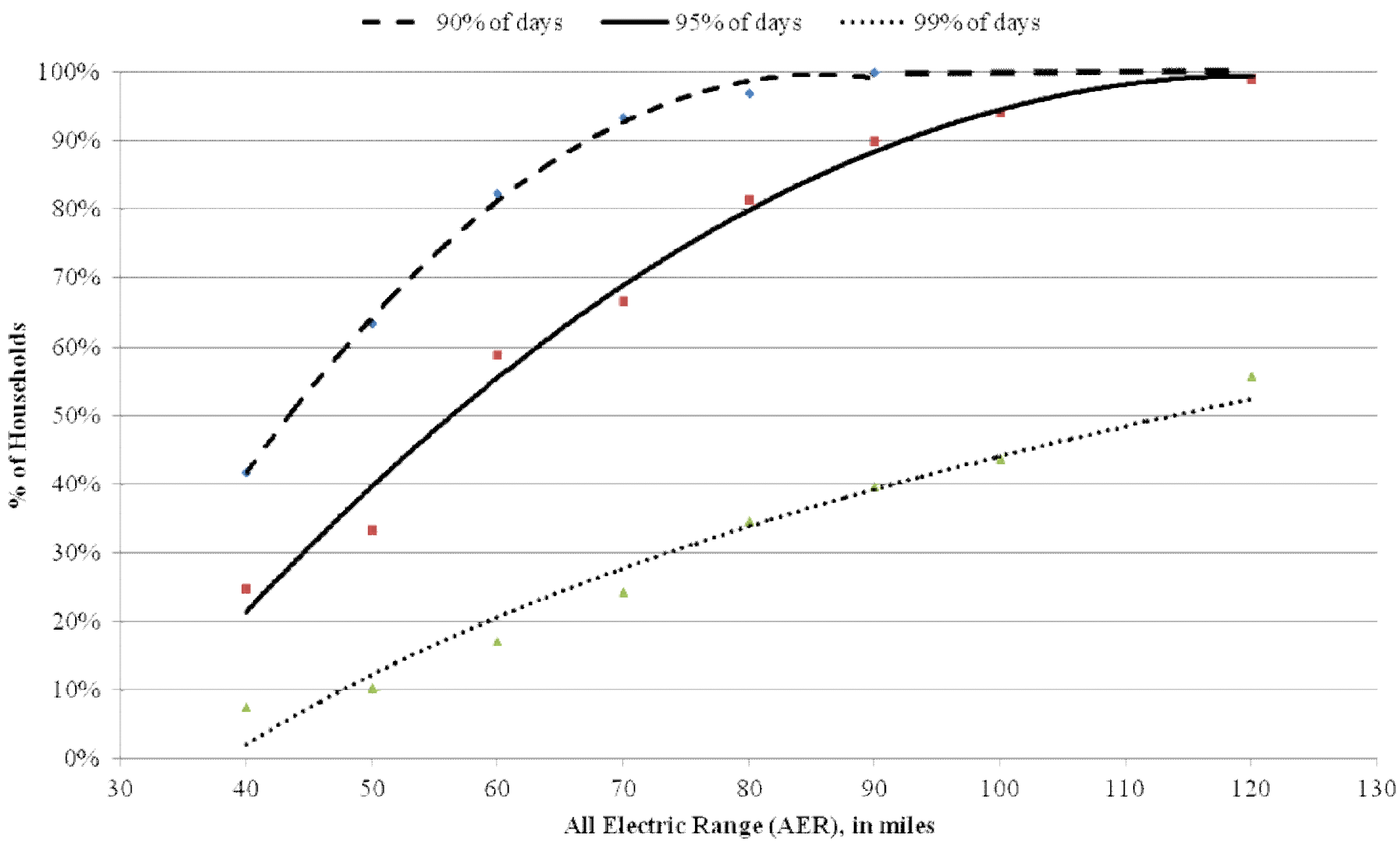
Adoption Rates: 1-BEV Households



Electrified Miles: 1-PHEV Households

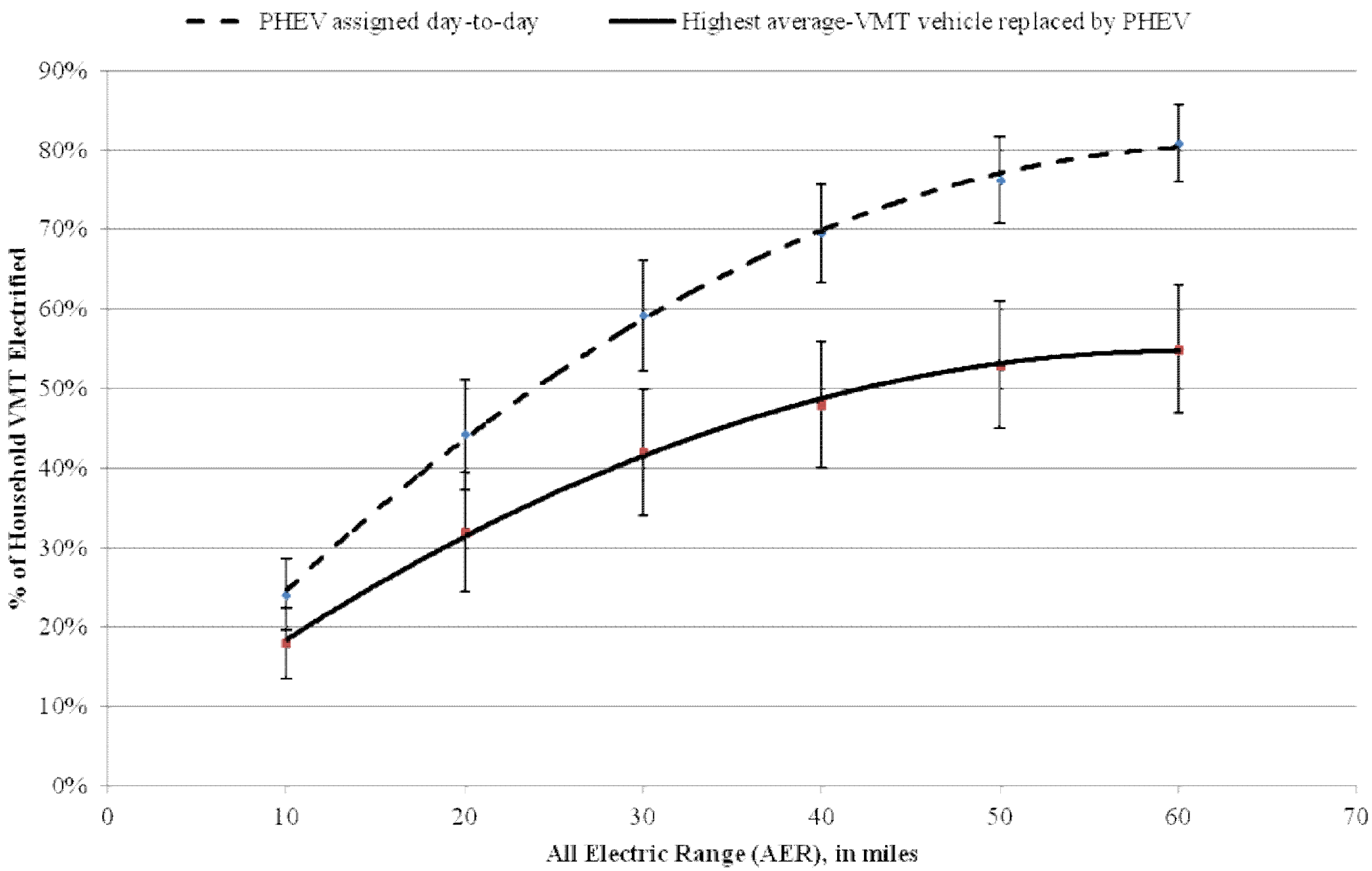


BEV Adoption Rates: 2+ vehicle HHs



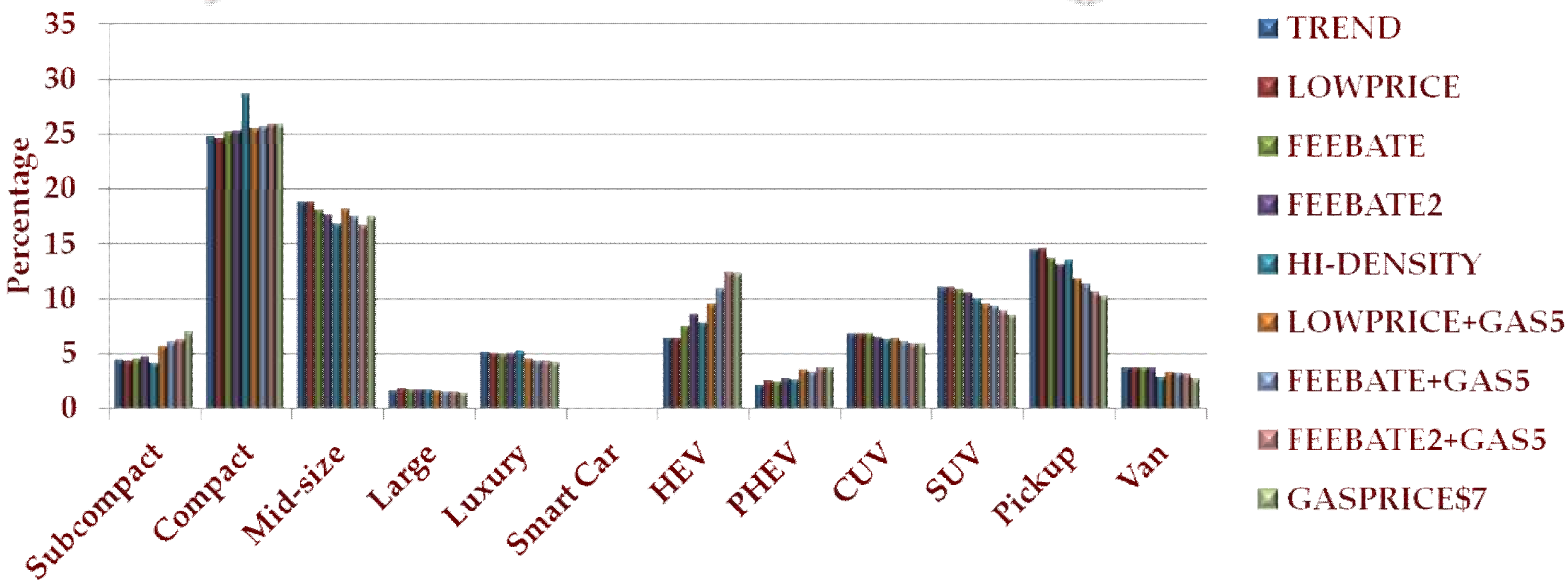
Maximum Possible Multiple-vehicle Household BEV Adoption Rates in Seattle, with BEV Replacing the Lower Overall-VMT Vehicle (Case 3)

Electrified VMT: Multi-vehicle HHs



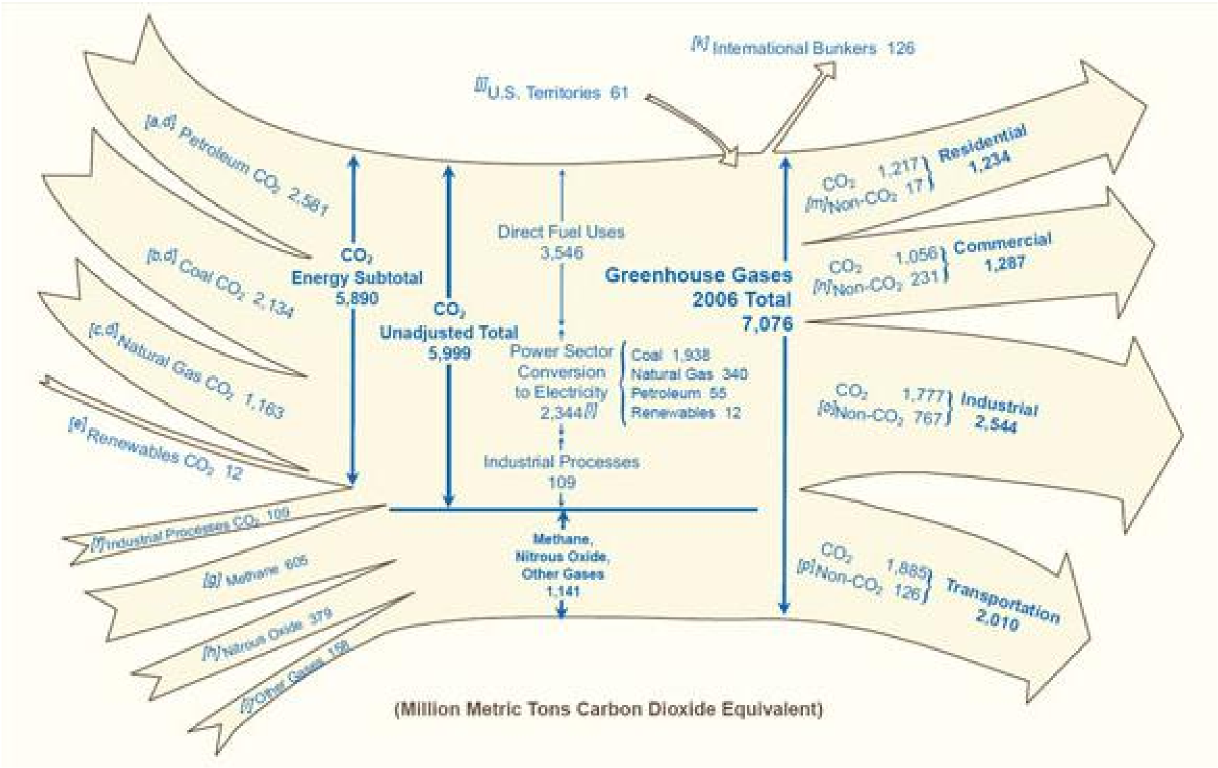
Average Shares of Household Miles Electrified (with Standard Deviations) using PHEVs in Multiple-vehicle Seattle Households

Example:
25-year Fleet Forecasting



- PHEV , HEV & SmartCar shares peak under **FEEBATE2+GAS$5** scenarios (16.4% of fleet) & GASPRICE$7 scenario (16.3% market share), while total miles-traveled fall about 30%.
- HI-DENSITY scenario shows average vehicle ownership falling 7% (to 1.72 veh per household, vs. 1.85 under TREND).

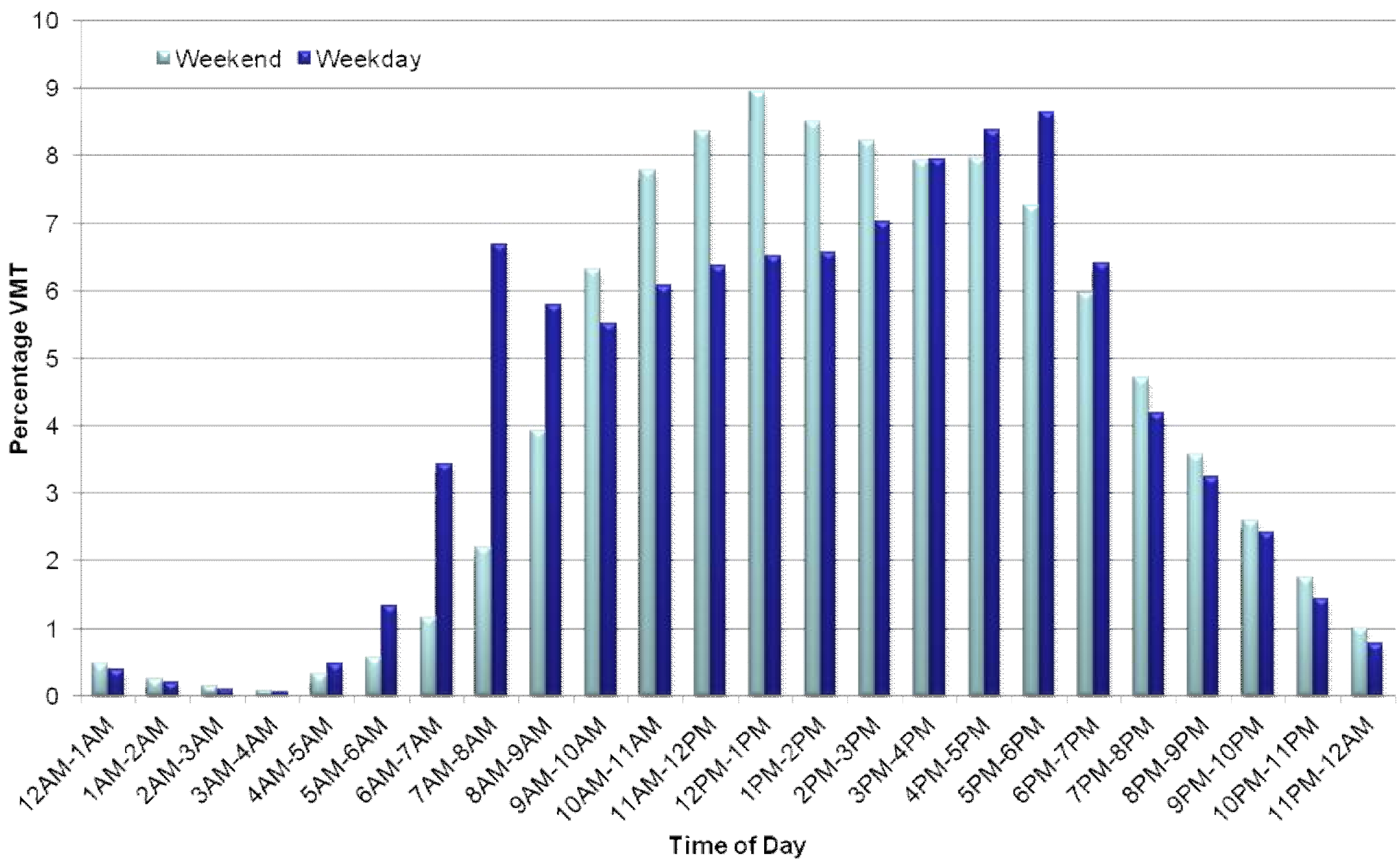
Power + Transport ≈ 62% of U.S. GHGs → Key to Emissions Abatement



Source: EIA (2008)

Timing of Travel

- VMT by time of day (using NHTS 2009 data).



Best Options for Sustainable Cities

- PHEVs with Clean Grid (renewables, nuke & CCS)
- Non-motorized Modes (biking & walking)
- Shared Cars & Buses running Full (via real-time carpooling?)
- Parking Charges + Fuel Pricing
- Urban Growth Boundaries (controlled release of land to development)

Other Findings

- HEVs are a very cost-effective technology. (We need more HEV vehicle-body options, & U.S. needs smaller vehicles.)
- Reducing Coal-fired Power Generation is Key. (offering greater savings than *any* single transportation or land use option)
- Advertising Societal Benefits of New Technologies & Lifetime Fuel Savings (via vehicle stickering & online) is cheap yet powerful!
- And how about tradable carbon credits at level of households? (for home energy + vehicle odometer readings + air travel)

The Rankings of 1% Adoption Strategies…

Reduction Strategy (1% Adoption)	% U.S. Total GHG Emissions	Reduction Strategy (1% Adoptions)	% U.S. Total GHG Emissions
1% Shift to Renewables – 2050	0.450	1% HHs Switch to Heat Pump	0.031
1% Shift to Renewables – 2030	0.380	Downsize Home: 2400 to 2000 sq ft	0.005 - 0.026
1% Shift to Renewables - 2006	0.330	Parking to Rear Lot	0.021
Conv. Improv. + 10% Lightweighting + Cellulosic Ethanol Fuel	0.208	Warmest Climates Reduce A/C Operation by 1 hour/day	0.018
Cellulosic Ethanol	0.161	Clothes Washing in Cold Water (versus hot)	0.016
Conv. Improv. + 10% Lightweighting + Biodiesel Fuel	0.160	HHs Reduce Water Heater Temp from 140 to 120°F	0.013
PHEV 30 (2030, renewable energy)	0.160	Insulation: from 90 to 500 mm	0.013
PHEV 30 (2030, projected ave grid)	0.134	10% Lightweighting	0.012
Biodiesel	0.119	Front & Side Parking	0.010
Subway/Rapid Rail - avg occupancy	0.096	Paid employee parking	0.002 – 0.010
SFDU to MFDU	0.026 – 0.078	Four-way Intersections	0.005
Conventional Improvements	0.045	HDT Idle Reduction (APU)	0.005
$50/month Residential Parking	0.041	Increase Population Density 10%	0.001 – 0.003
Rail Mode Shift	0.039	Bus Mode Shift - full occupancy (average occupancy)	0.137 (-0.060)

HHs = Households

Important Tools & Challenges

Simulation (of human behavior , for uncertainty in inputs & parameters, & for model estimation)

… yet **land use** change remains *very* **difficult to mimic.**

Discrete choice models (to forecast land use types, buy/sell decisions, vehicle choices, destinations & modes & routes, vehicle allocation to household members, …)

Spatial relationships (heavy use of GIS databases, spatial econometrics for autocorrelation in location factors & behavioral processes)

Thank you for your time!

Papers available at
www.ce.utexas.edu/prof/kockelman.

Air Travel (Passenger)

- 6.5% U.S. transp. GHG emissions come from commercial air travel.
- Emissions per passenger-mile depend on aircraft occupancy, trip length, & design:
  - Short trip (200 mi): 0.53 lb/pax-mi (WRI 2006)
  - Med. trip (700 mi): 0.42
  - Long trip (1500 mi): 0.40

vs. 20 mpg LDV…

  - Solo driver: 1.3 lb/paxmi
  - 4-persons Carpool: 0.32

Home Design: CO_2 Savings

- Double vs. Single Pane: 1,000-7,000 lbs/year/home (0.30-2.5 million tons for 1% of homes)
- Triple vs. Double Pane: 6,000-10,000 lbs (3.2-5.4)
- Update the A/C unit: 1,000 lbs (0.54)
- Upgrade R21 insulation to R60: 1,000-34k lbs (0.54-3.65)
- Replace incandescent bulbs with CFLs: 1,550 lbs (0.84)

(X)= Millions of Tons CO_2e per year for 1% of households (vs. 6 B = U.S. total)

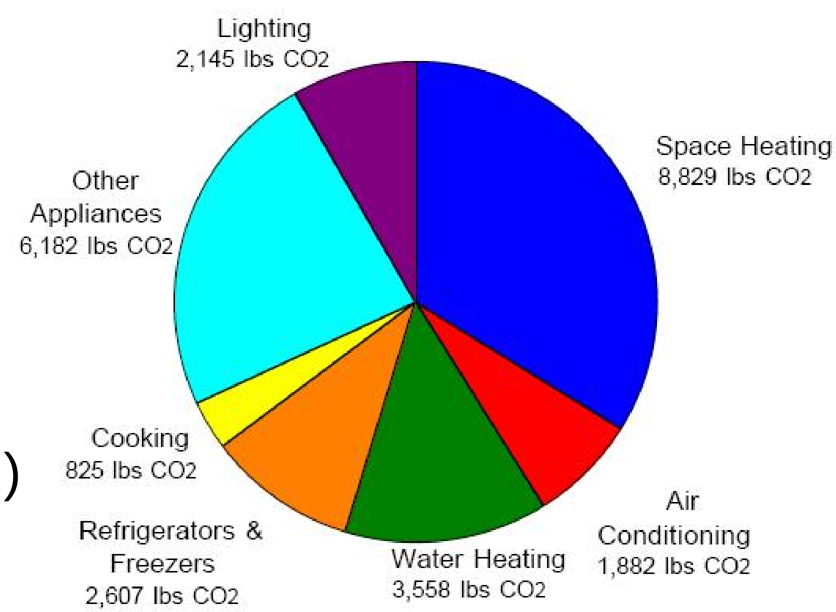
Estimates of CO_2 Savings from Home Design Changes

- Install double-pane windows: 2,240 lbs/year/home
- Replace incandescent bulbs with CFLS: 1,550 lbs
- Update the A/C unit: 1,000 lbs
- Upgrade R15 insulation to R21: 750-1450 lbs
- A/C savings from downsizing home 250 sf: 450 lbs

- All together: > 6,000 lbs/yr/home (>20% average home energy demand)

Still to come: More calculations on building materials & insulation, & commercial heating loads.

CO_2 Emissions per Household, 1997



Rocky Mountain Institute, Snowmass, CO, www.rmi.org

Home Design (2)

- Downsize home ~20% (2400 to 2000 sf):

  450 lbs/year/average home from A/C (.25)

  plus 1,000-2,000 lbs from heating (0.54-1.1)

- Move from 2400 sf SFDU to MFDU:

  3,000-20,000 lbs (1.6-12)

(X)= Millions of Tons CO_2e per year for 1% of households

Parking Policies

- **$50/month** for **Residential** parking: **5,560 lbs** per household per year (stemming from reduced vehicle ownership) (3.5 M tons/yr)
- **Downtown Employees Pay** market rates for parking: 300-1400 lbs per worker (due to reduced SOV mode share) (.18-0.85)
- **Market-priced Curb Parking**: 230 lbs per year per parking space (.15) (from reduced cruising)

(X)= Millions of Tons CO_2e per year for 1% of households or 1% of workers or 1% of CBD parking spaces.

Ranking of Home Design Changes & Parking Policies

If applied to 1% US households:

- Double to triple pane glass: 3.2-5.4 M tons/yr
- Residential parking at $50/month: 3.5
- Move from 2400 sq ft SFDU to MFDU: 1.6 to 12
- Replace R15 Insulation with R60: 0.54 to 3.6
- Single to double pane glass: 0.3 to 2.5
- Reduce average home size to 2000 sf: 0.25 cooling & 0.54 to 1.05 heating
- Move to CFLighting: 0.84
- Reduce A/C oper. 1 hr/day during hot months: 0.64
- Update A/C unit: 0.54
- Paid employee parking: 0.18 to 0.54

Land Use: *Design*

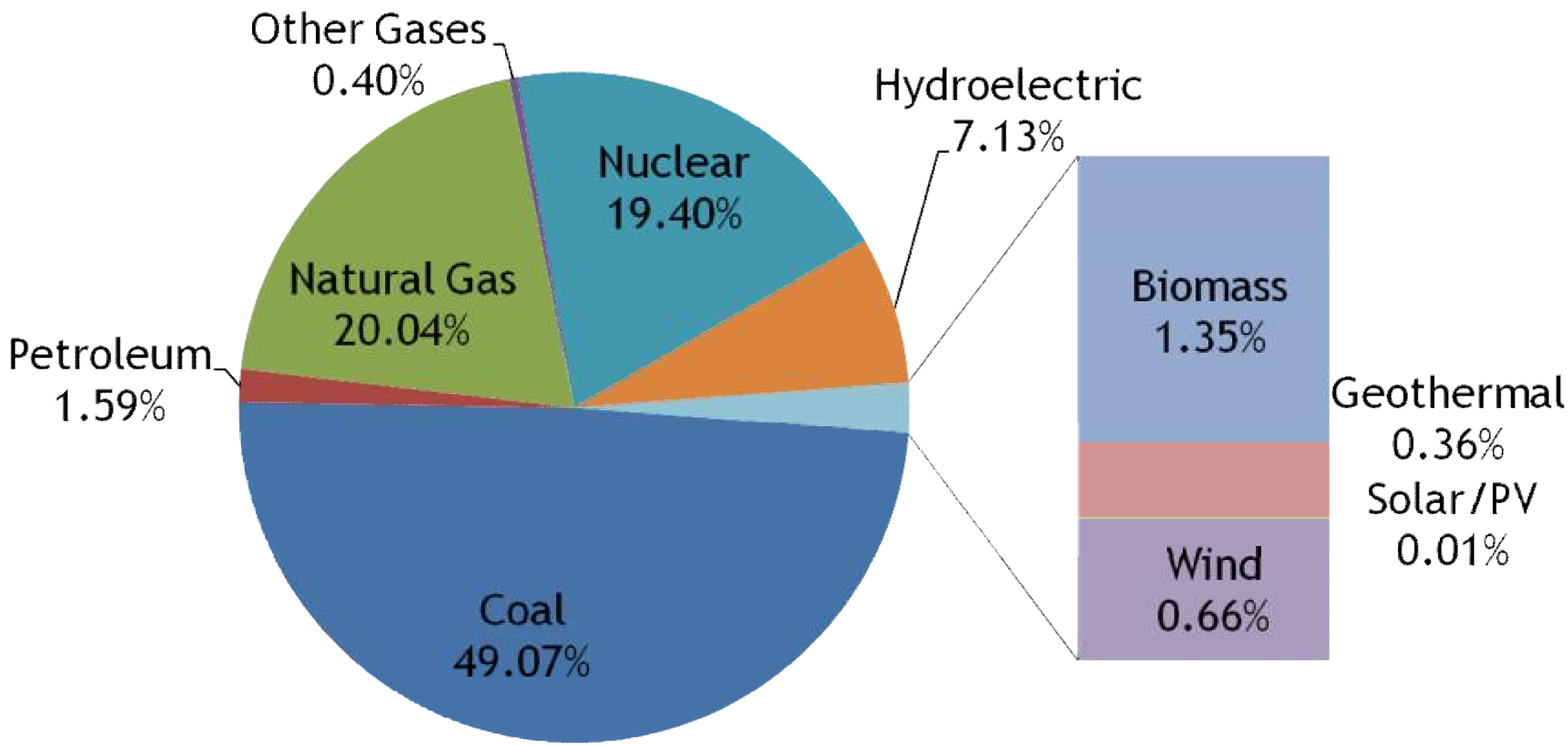
- SOV mode reduction due to 10% change in:
  - Increase Walking Quality: 267 lbs/HH (.286 B/yr)
  - Increase Land use mixing: 350 lbs/HH (.371)
- CO_2 reduction due to 10% increase:
  - Vertical Mixing: 178 lbs/HH (.190)
  - Four-way intersections: 750 lbs/HH (.800)

Reducing Braking & Inertial Forces

Reduce Vehicle Weights

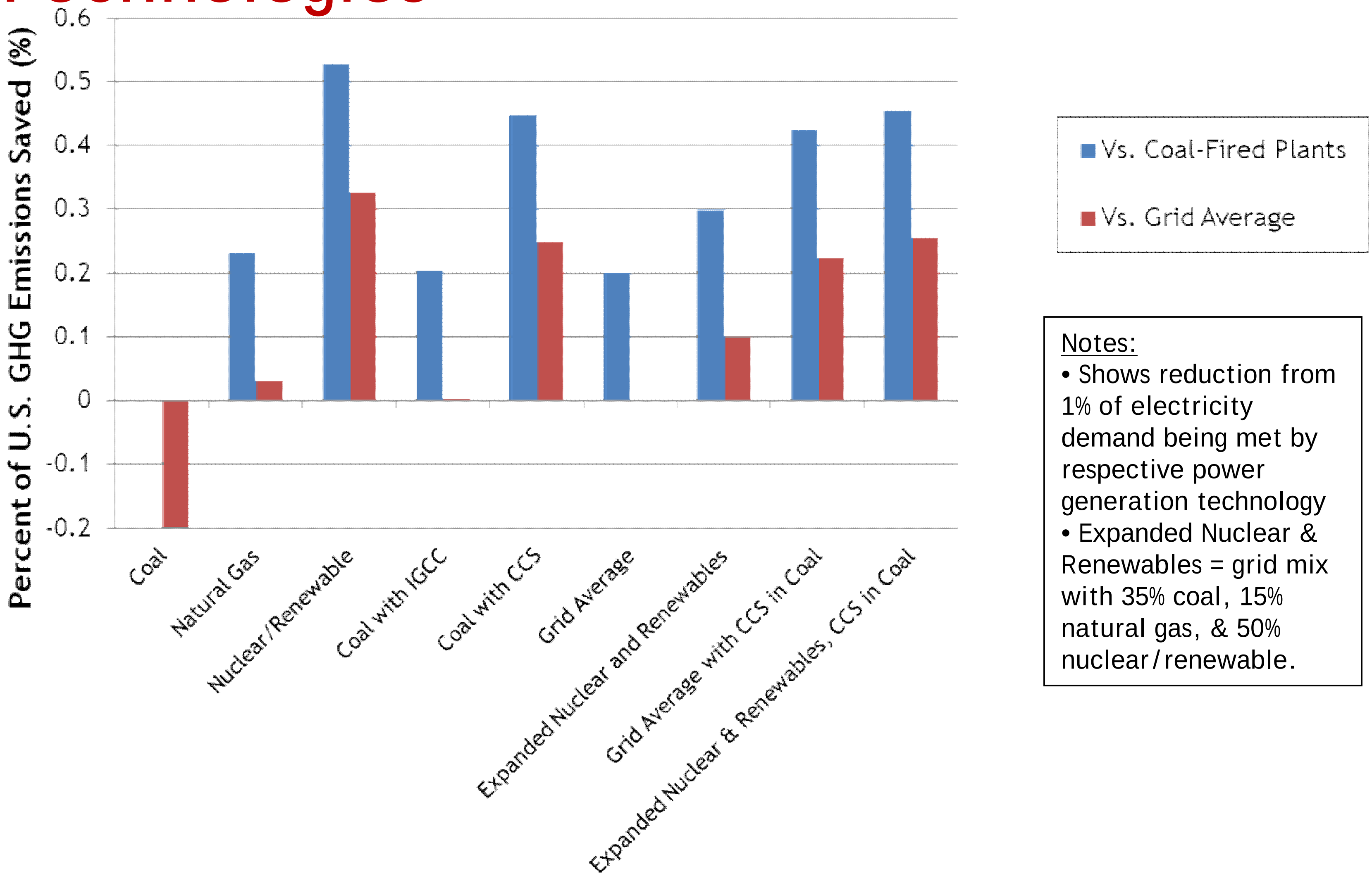
- *10% Mass reduction* à 6% FE improvement (IEA 2007)
  - FE improvement can reach 10% if engine downsized to match lighter vehicle body.
- Ways to lightweight:
  - Replace heavy materials with lighter weight materials – already being done
  - Downsize vehicle – decreases utility of vehicle
  - Improved packaging, unit body construction (body panels are load bearing), parts consolidation, ...
- Most alternative materials are cost effective, based on lifetime fuel savings.
- Safety: Design is more important than mass.

Current U.S. Power Generation Sources



Source: EIA (2008)

1% Adoption of Various Power Technologies



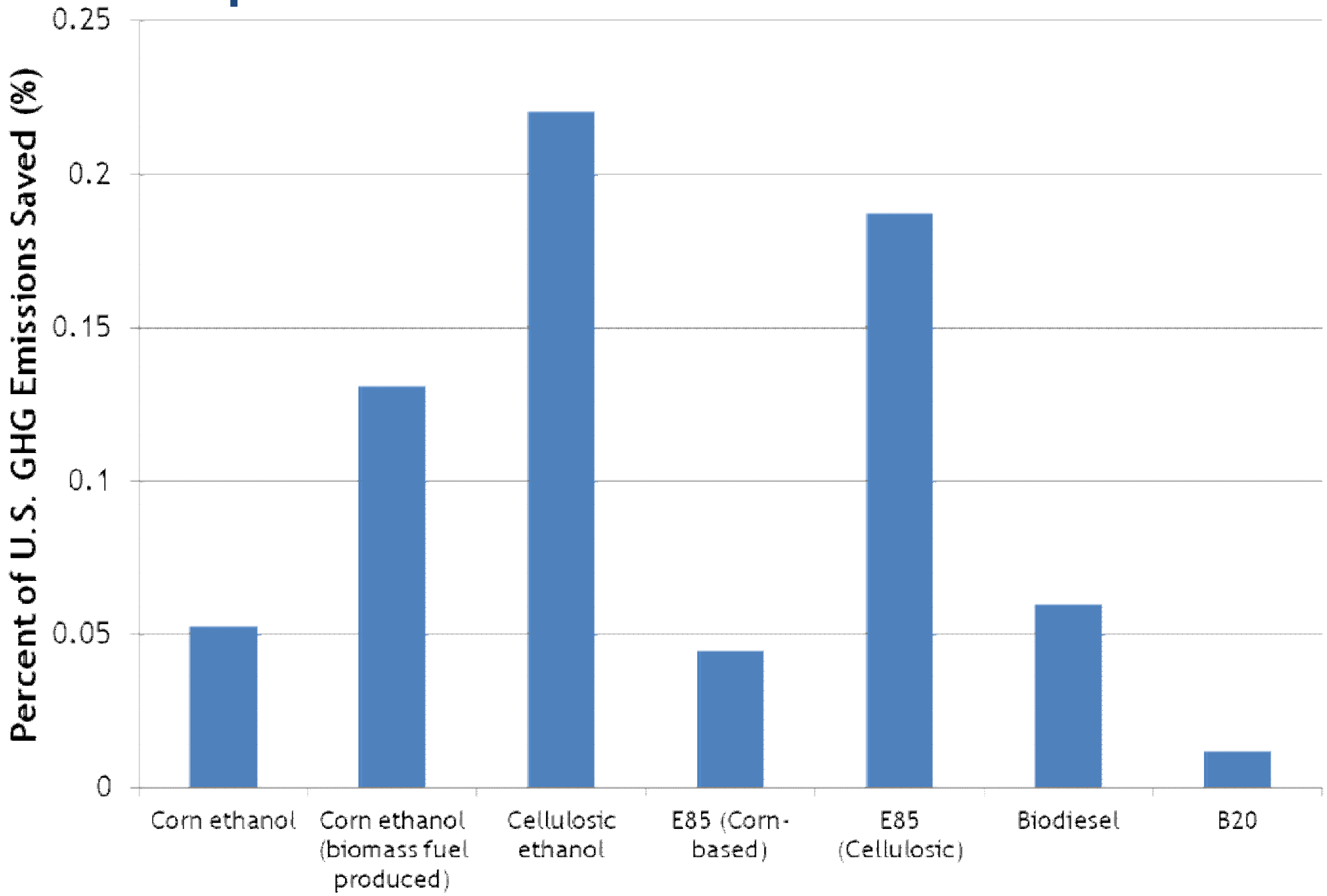
Notes:
- Shows reduction from 1% of electricity demand being met by respective power generation technology
- Expanded Nuclear & Renewables = grid mix with 35% coal, 15% natural gas, & 50% nuclear/renewable.

Power Generation Policy Barriers

Technology	Transmission & Distribution	Intermittence	Supply Uncertainty	Other Barriers
Natural Gas			X	
Wind	X	X		
Nuclear				Security & waste storage
Geothermal	X			Advanced tech. undemonstrated
Solar: Photovoltaics		X		Grid not designed for distributed generation
Solar: Concentrated Solar Power	X	X		
Biomass			X	
Coal w/CCS				Undemonstrated

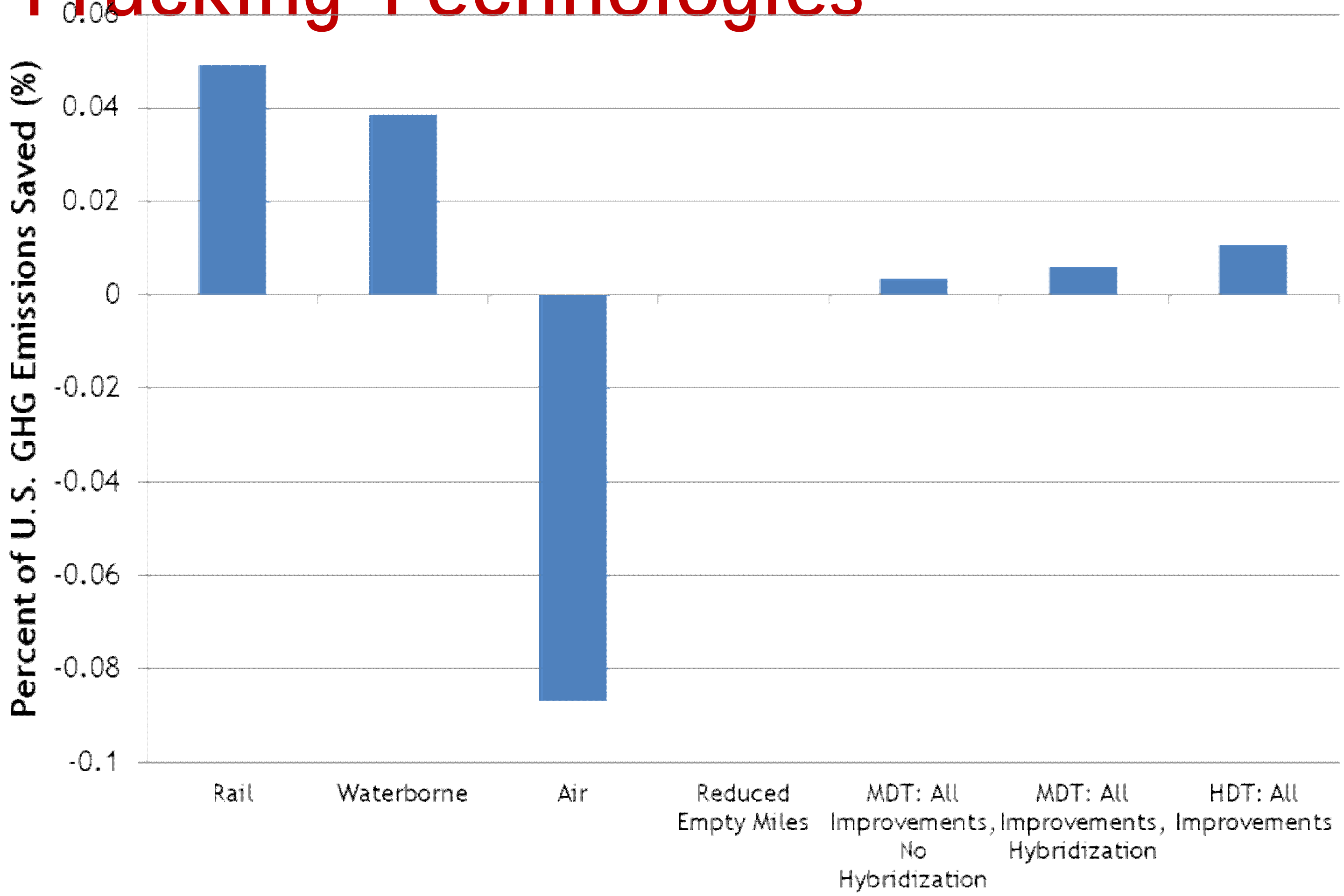
Note: Hydroelectric excluded due to limited new sites/capacity.

1% Adoption of Alternative Fuels



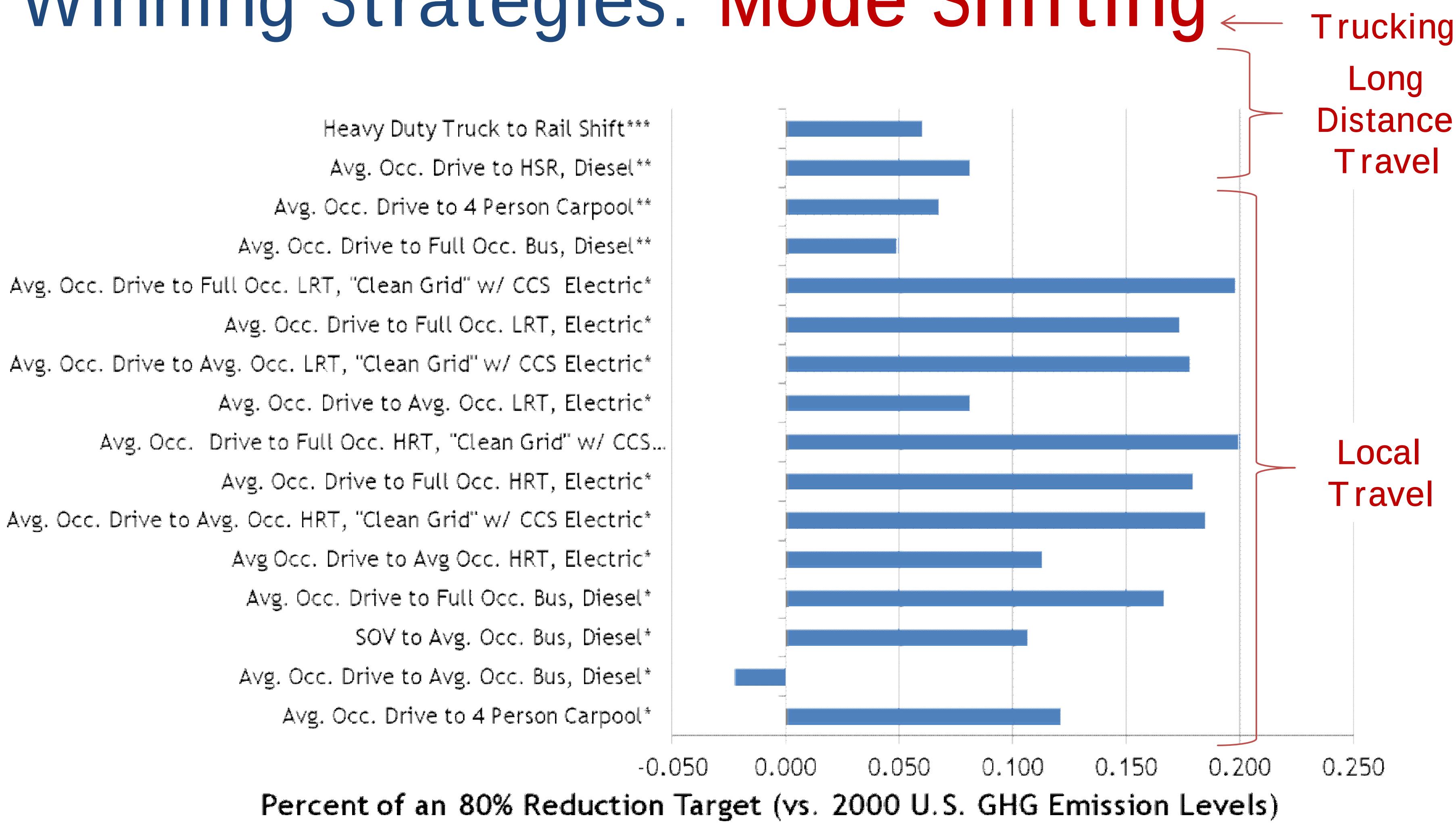
Notes:
- Ethanols sub for gasoline.
- Biodiesels sub for diesel.
- Chart based on total annual fuel consumption by transportation.

1% Adoption of Freight Mode Shifts & Trucking Technologies



Notes:
- Options sub for 1% of truck ton-miles.
- Reduced Empty Miles is a 1% reduction in the estimated 15,000 miles driven empty per year per truck. Has negligible impact.

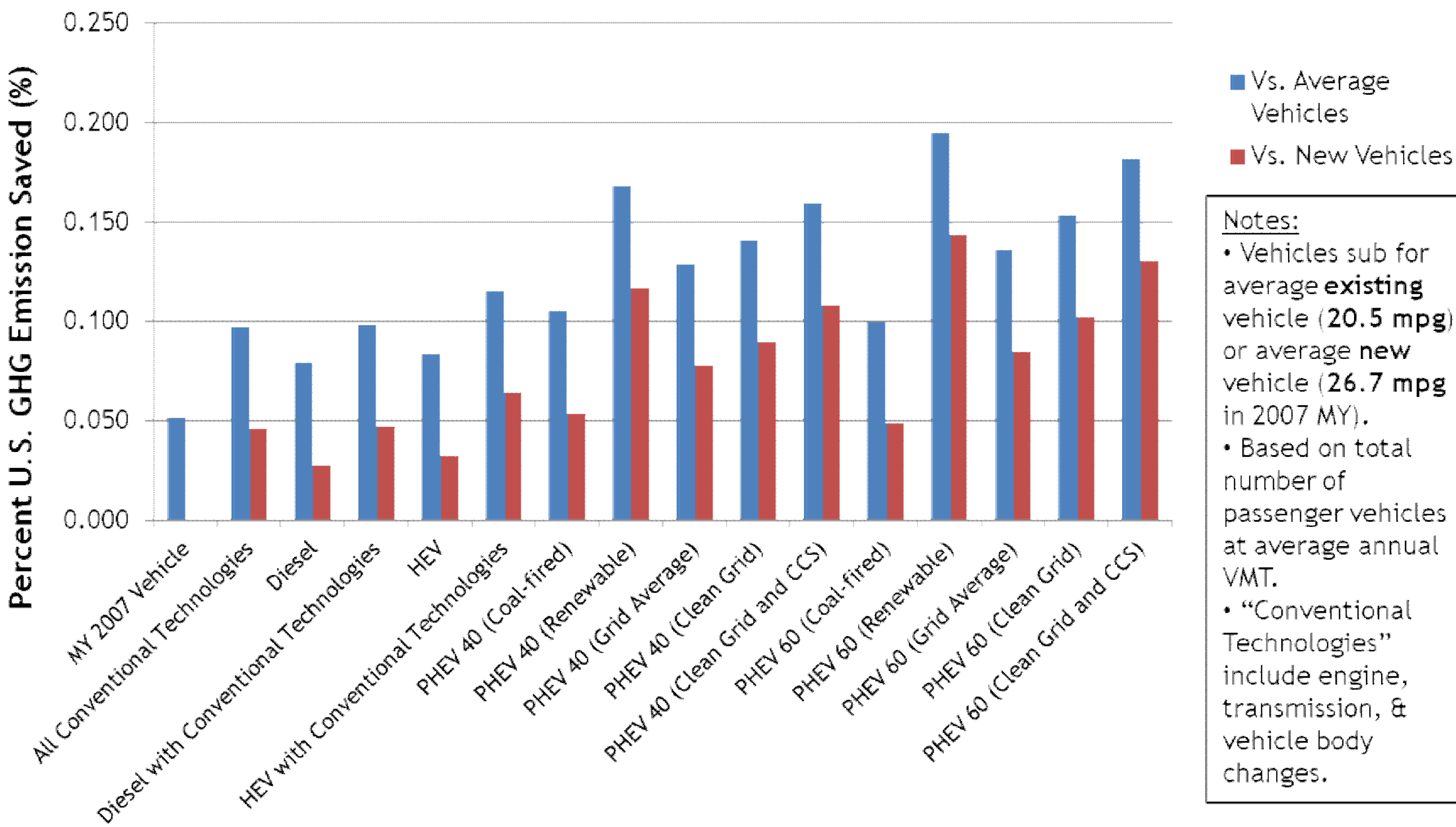
Winning Strategies: Mode Shifting



80% of 2000 Levels

$$\text{Fraction of 80 Percent Reduction Target} = \frac{\text{1\% Adoption Savings (2006 “Feasible Market”)}}{\text{2006 GHG Emissions} - 0.2 \times \text{2000 GHG Emissions}}$$

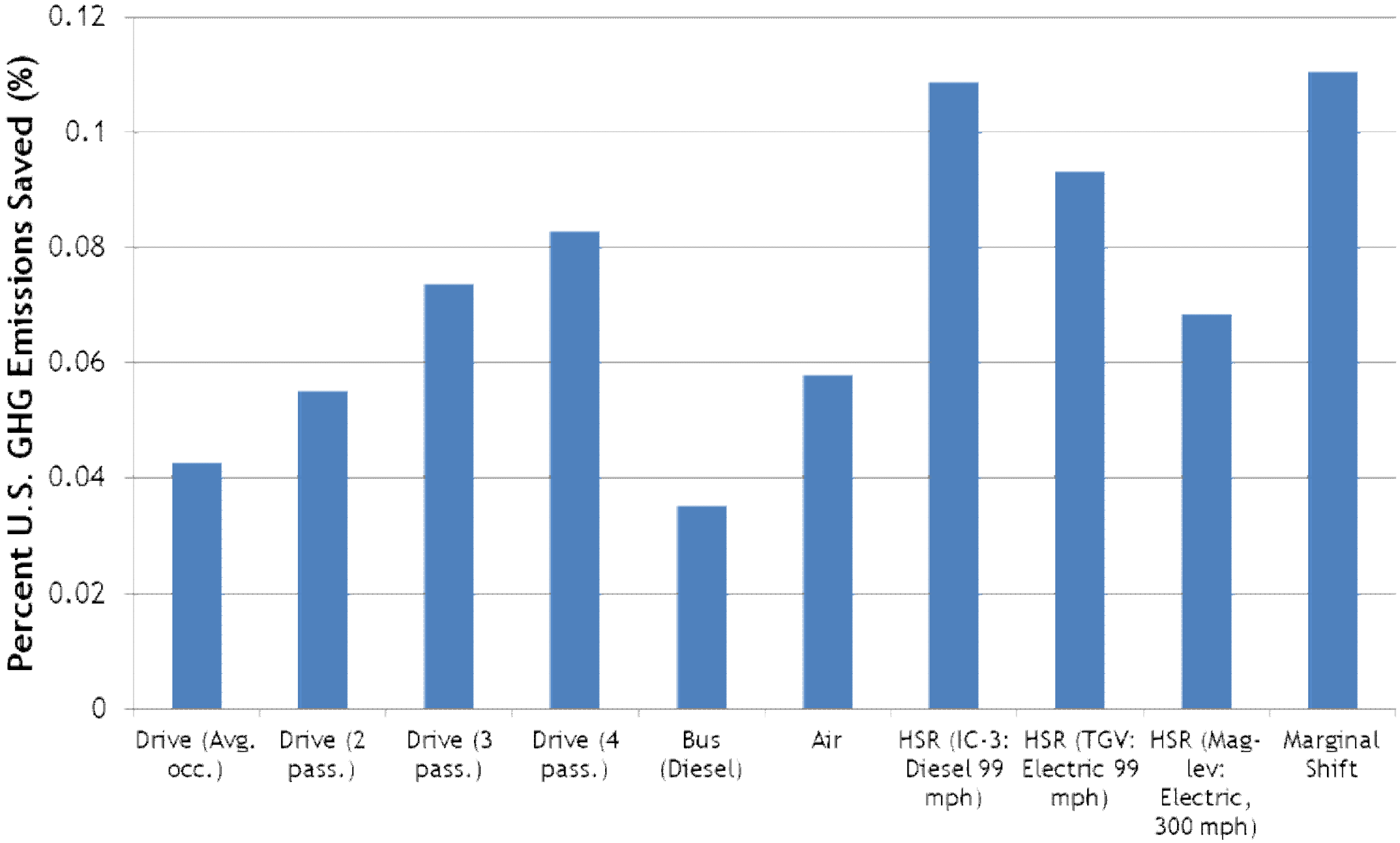
1% Adoption of Vehicle Technologies



Notes:

- Vehicles sub for average **existing** vehicle (**20.5 mpg**) or average **new** vehicle (**26.7 mpg** in 2007 MY).
- Based on total number of passenger vehicles at average annual VMT.
- "Conventional Technologies" include engine, transmission, & vehicle body changes.

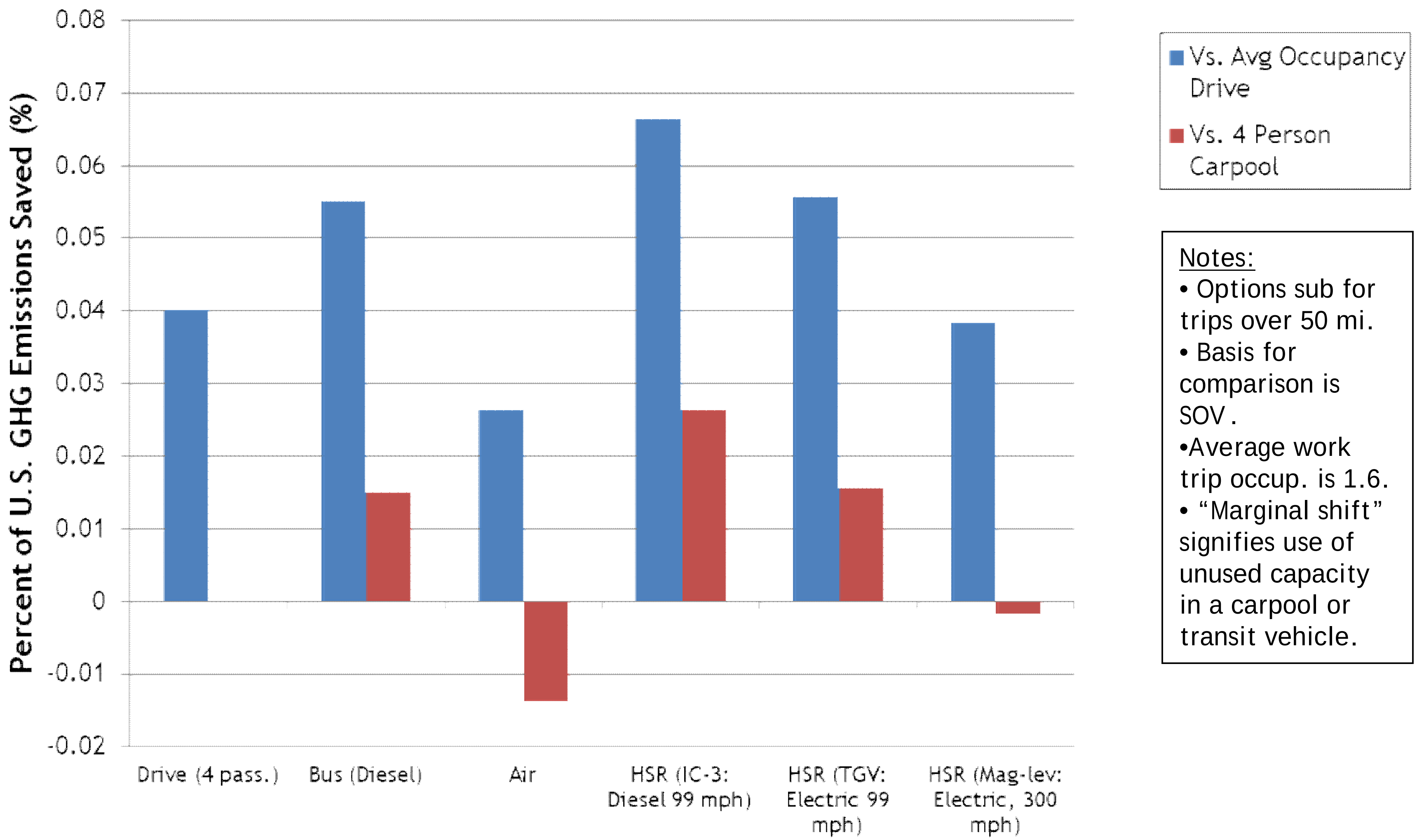
1% Long Distance Travel Mode Shift
(At ***Average*** Occupancies)



Notes:
- Options sub for trips over 50 mi.
- Basis for comparison is SOV.
- Average driving occup. is 1.6 pass.
- "Marginal shift" signifies use of unused capacity in a carpool or transit vehicle.

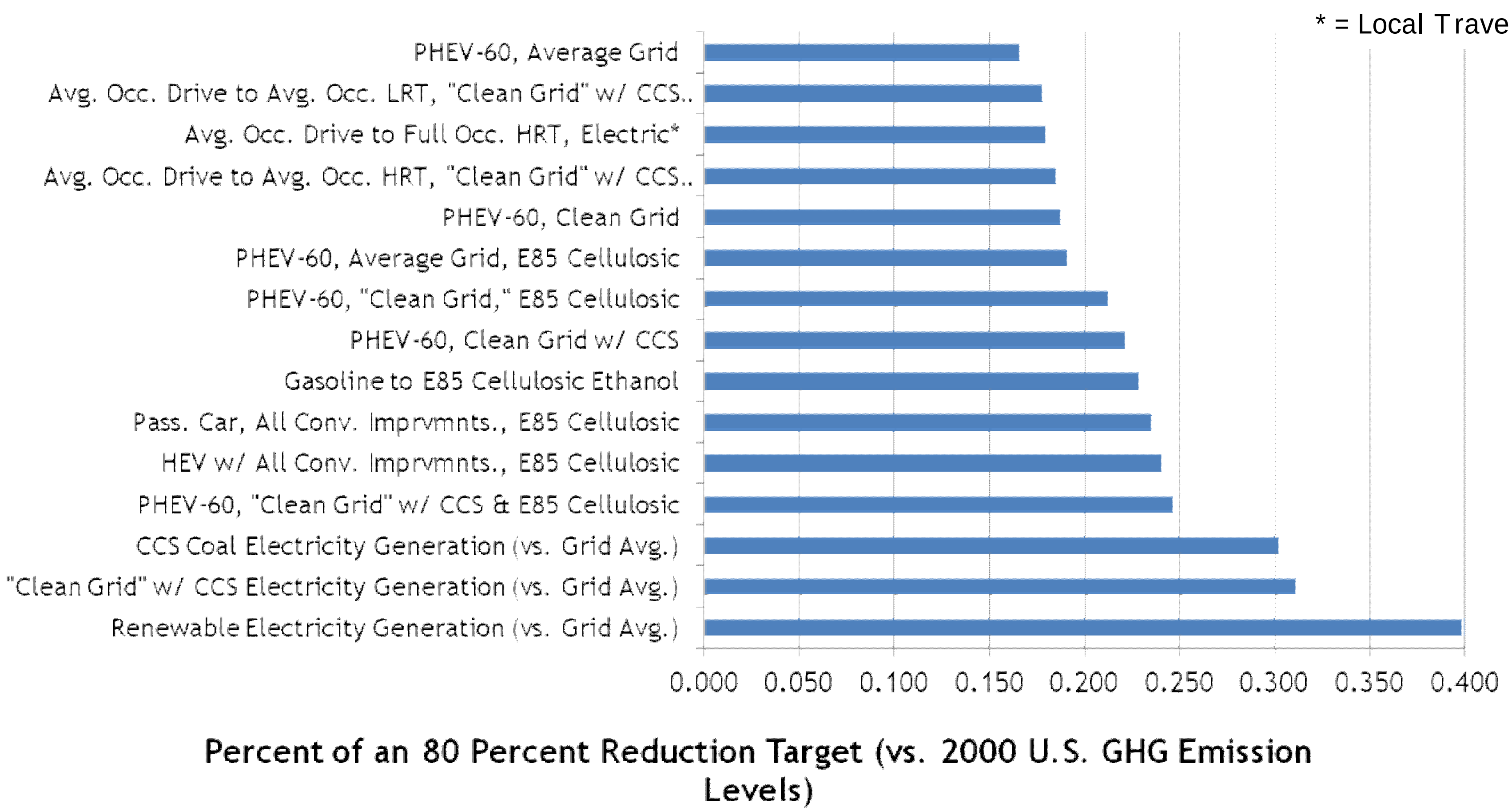
1% Long Distance Travel Mode Shift

(Alternative Modes at ***Full Occupancy***)



Notes:
- Options sub for trips over 50 mi.
- Basis for comparison is SOV.
- Average work trip occup. is 1.6.
- "Marginal shift" signifies use of unused capacity in a carpool or transit vehicle.

Overall Vehicle & Power Winners



Top Strategies: Power Generation, Fuels, & Vehicle Technologies