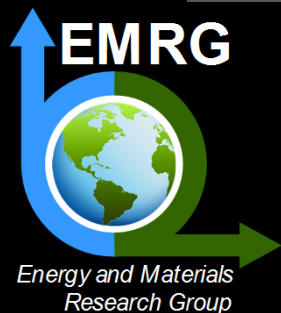


# Linking Plug-in Vehicles to Renewable Energy through Smart Grids



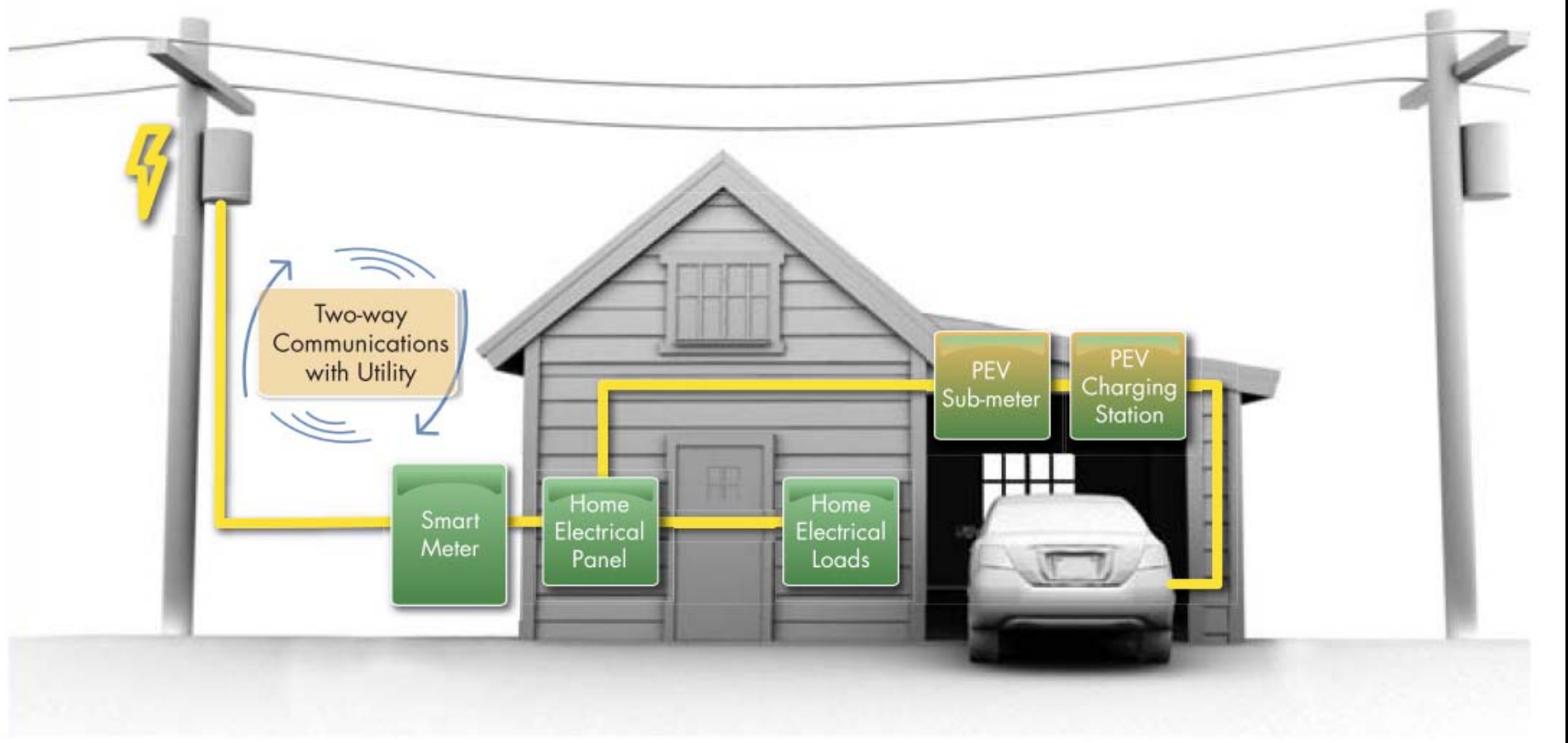
**Jonn Axsen**

**Resource and Environmental Management  
Simon Fraser University**

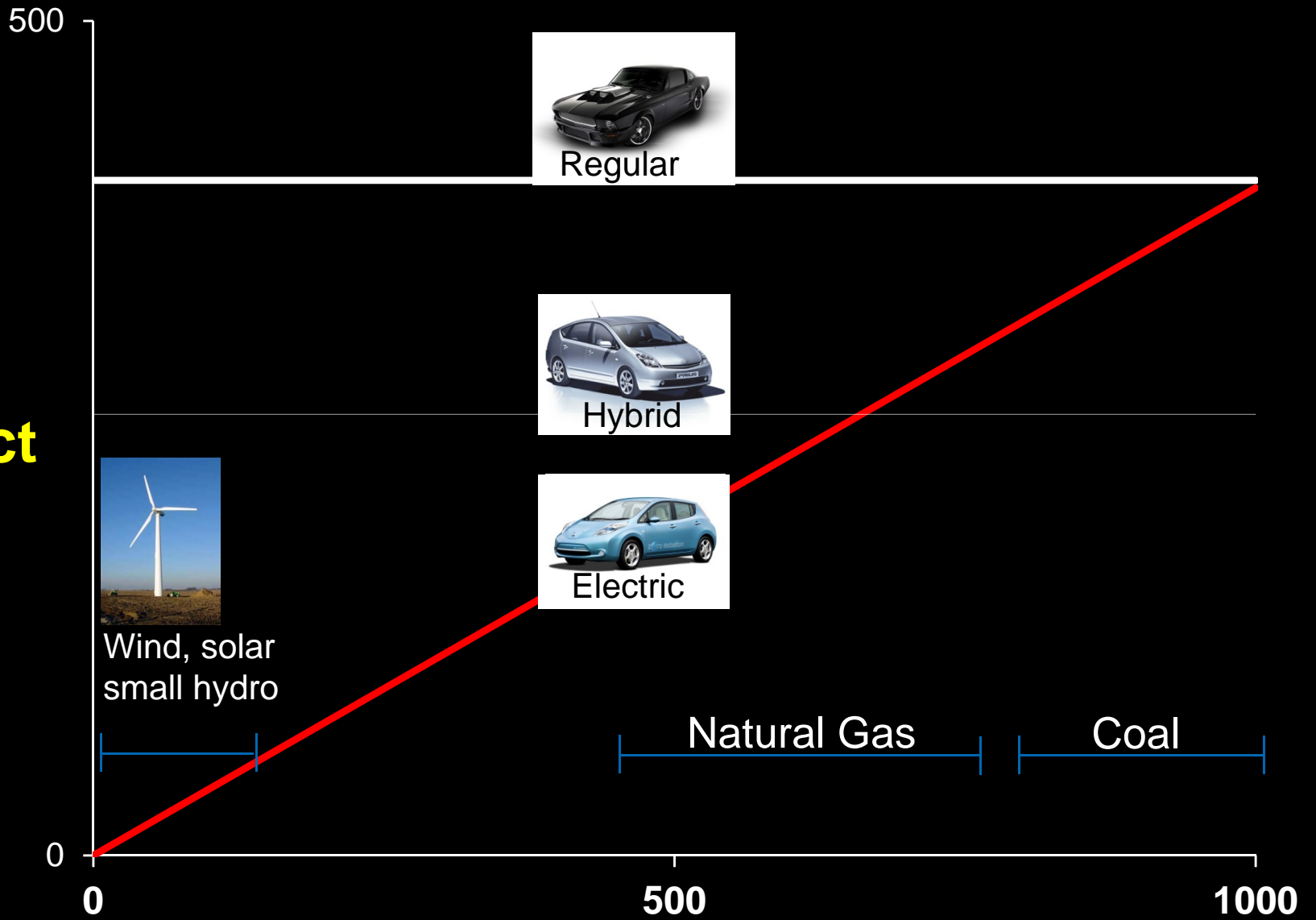
**May 3, 2013**

**SFU**

# A vision of “smart grid” with plug-in vehicles?



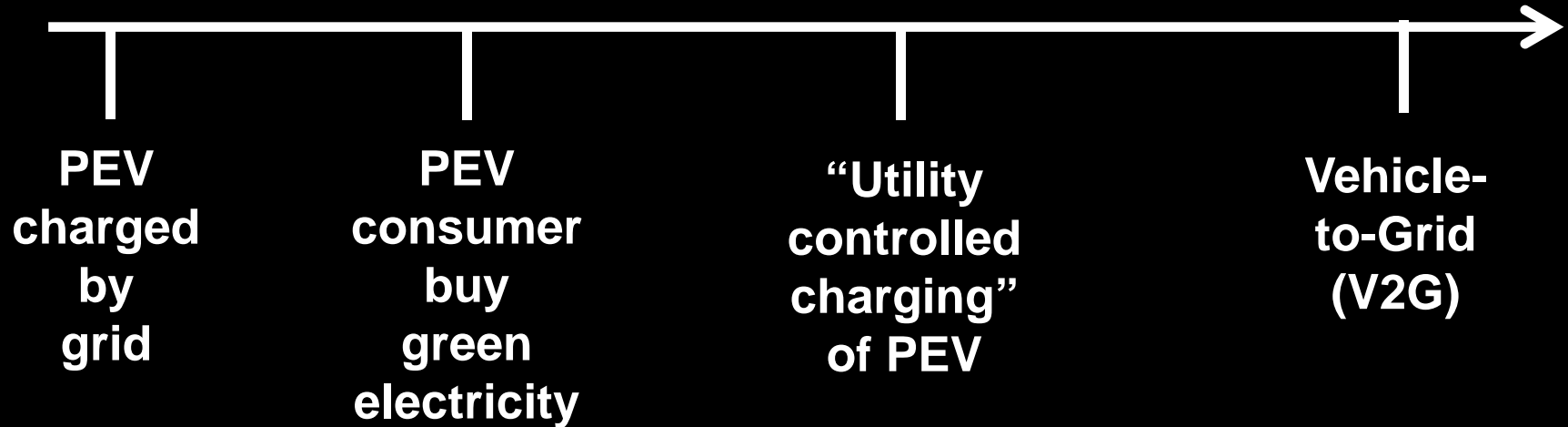
**GHG Impact**



**Carbon intensity of electricity**

# Different levels of PEV-grid integration

Increasing interaction, engagement, or “smart-ness”

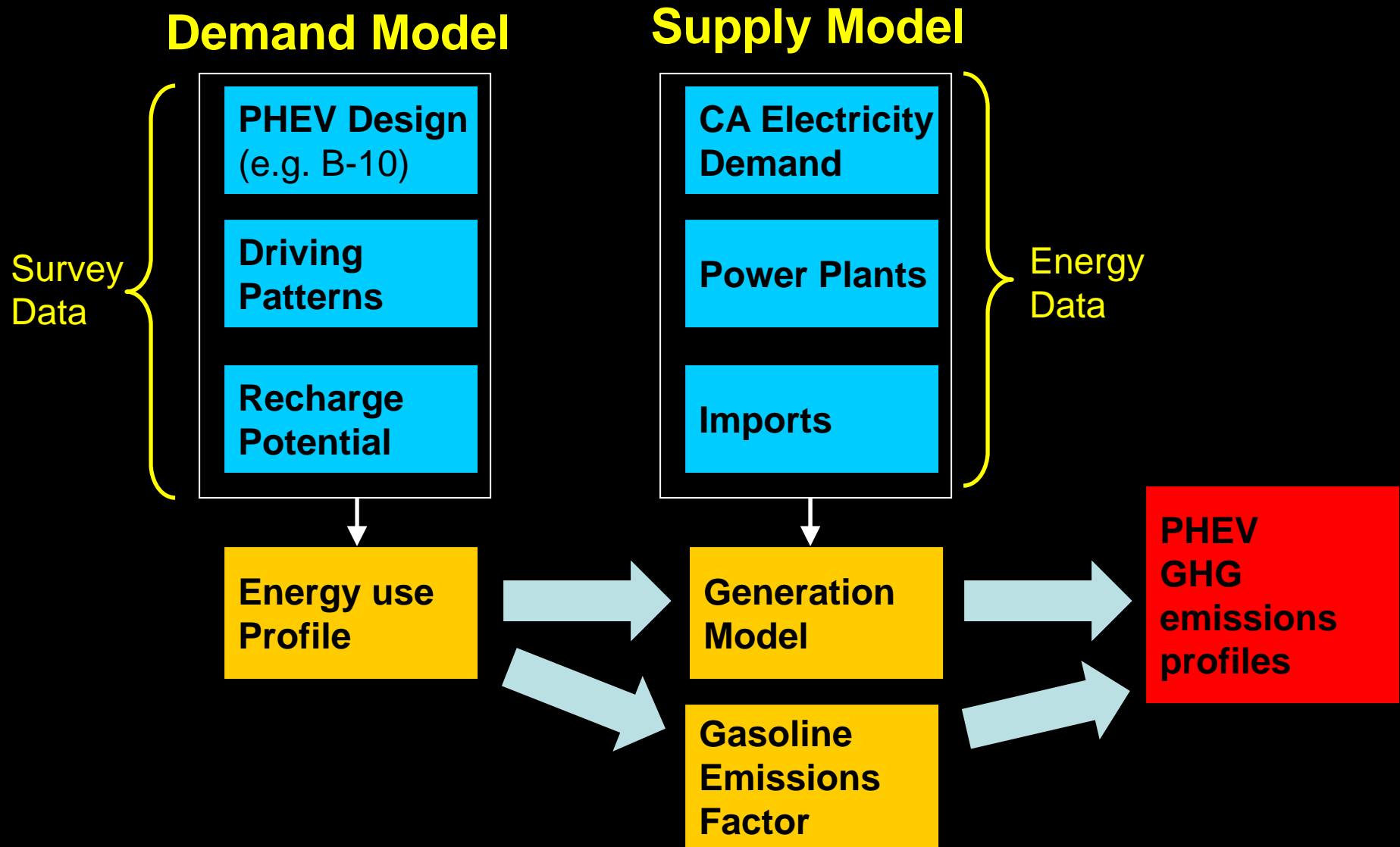


## **Part 1:**

**PEV charged by grid. What impacts?**

***(Energy Policy, 2011)***

# Integrating demand and supply models



# We focus on plausible “early PHEV buyers”

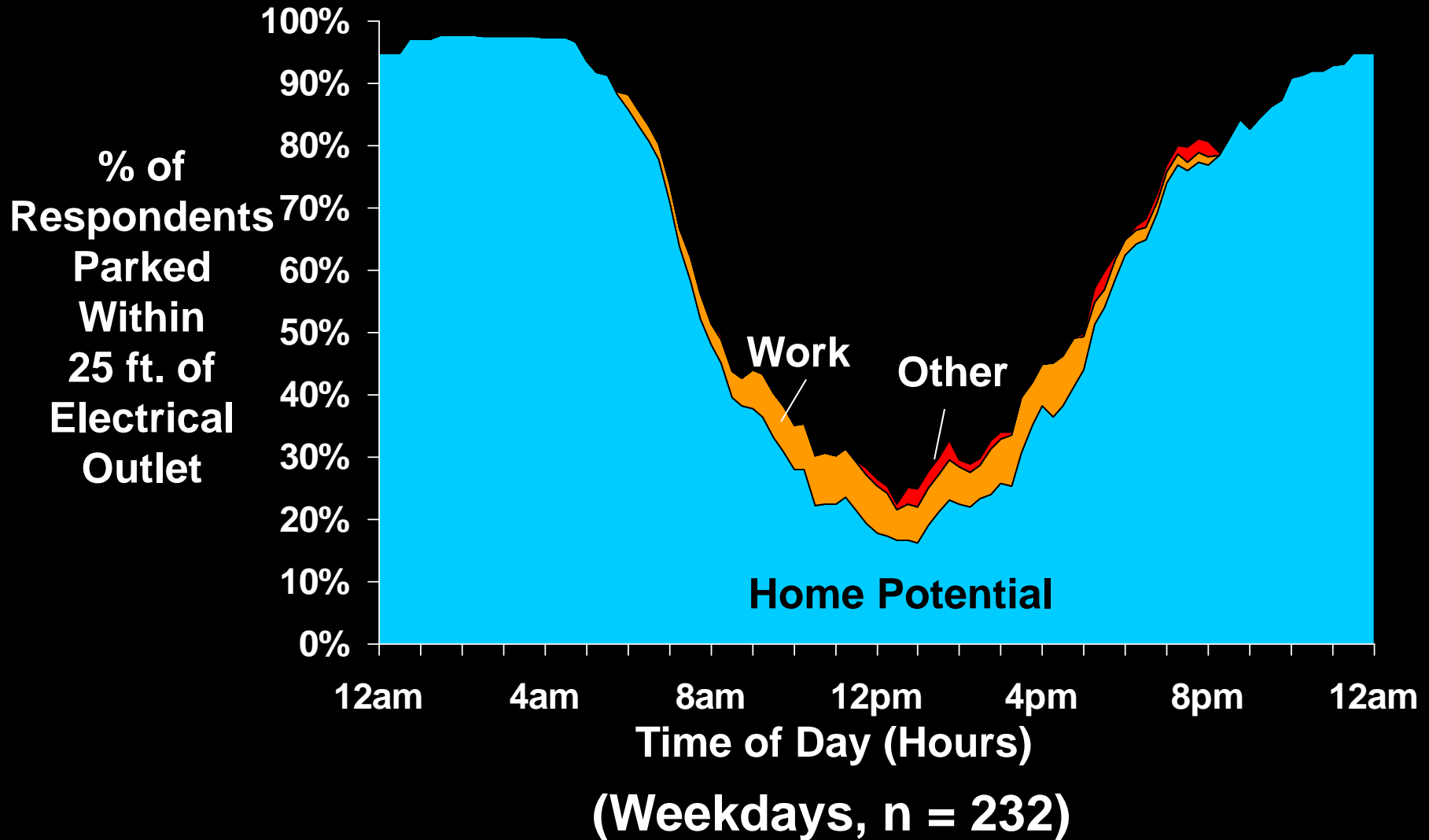


**Total  
(n = 877)**

**“Early PHEV  
Market”  
(n=282)**

1. Want PHEV  
2. Home recharge

# Consumer Recharge Potential: Mostly at home, at night

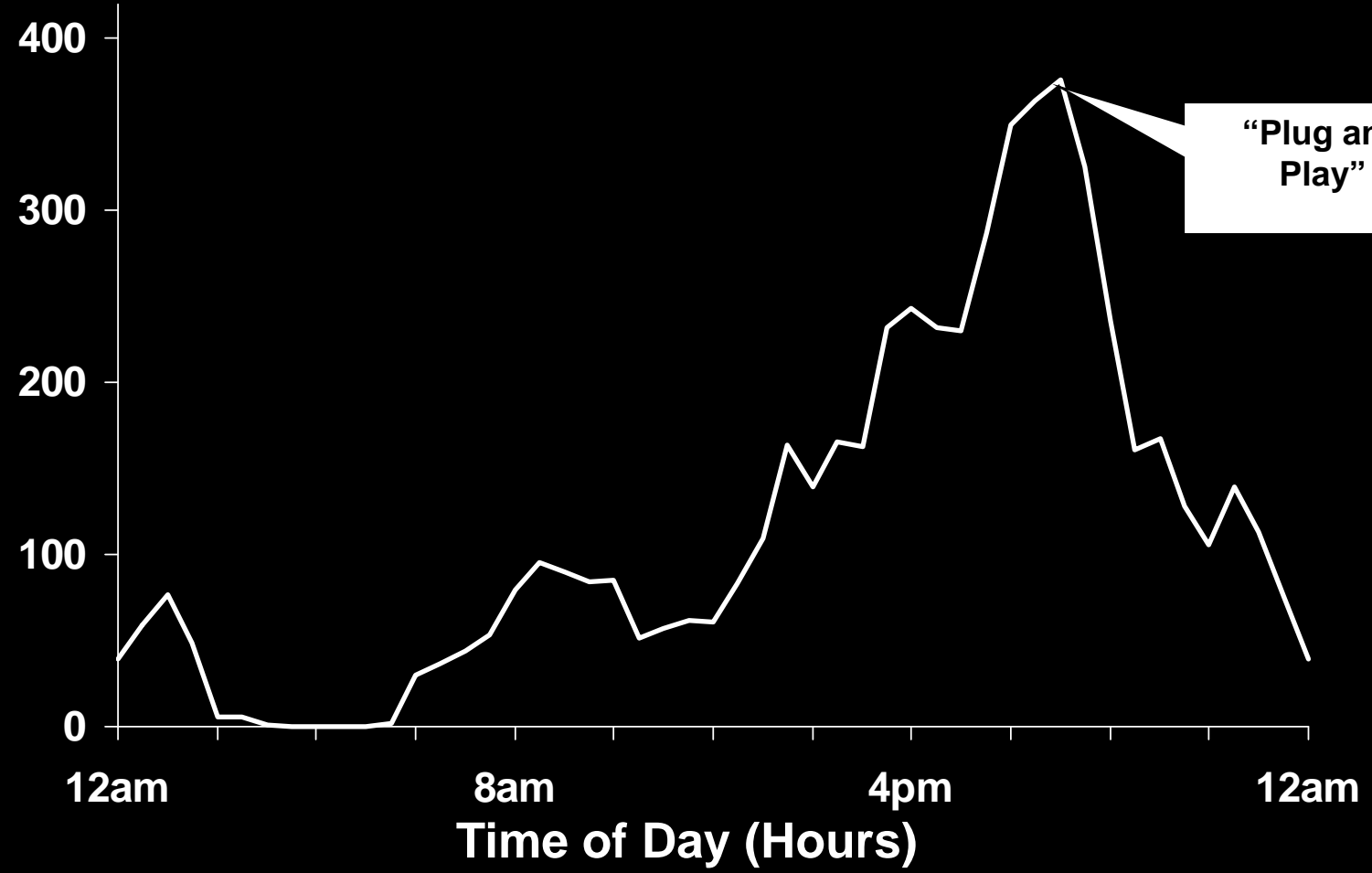




# Uncontrolled, immediate charging would peak at 6pm



MW  
per  
million  
PHEVs

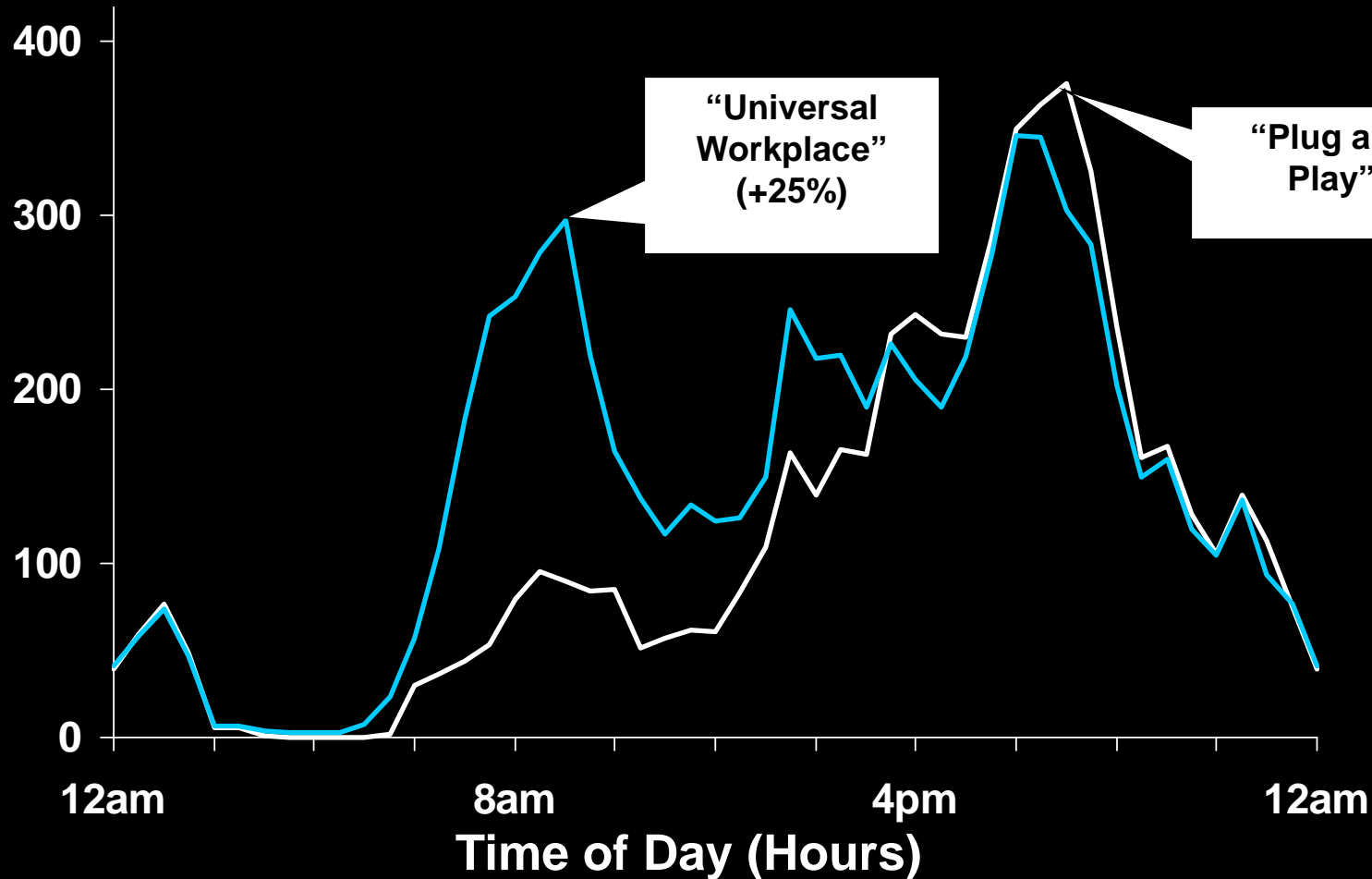


“Plug and Play”

# Additional workplace access would increase daytime load

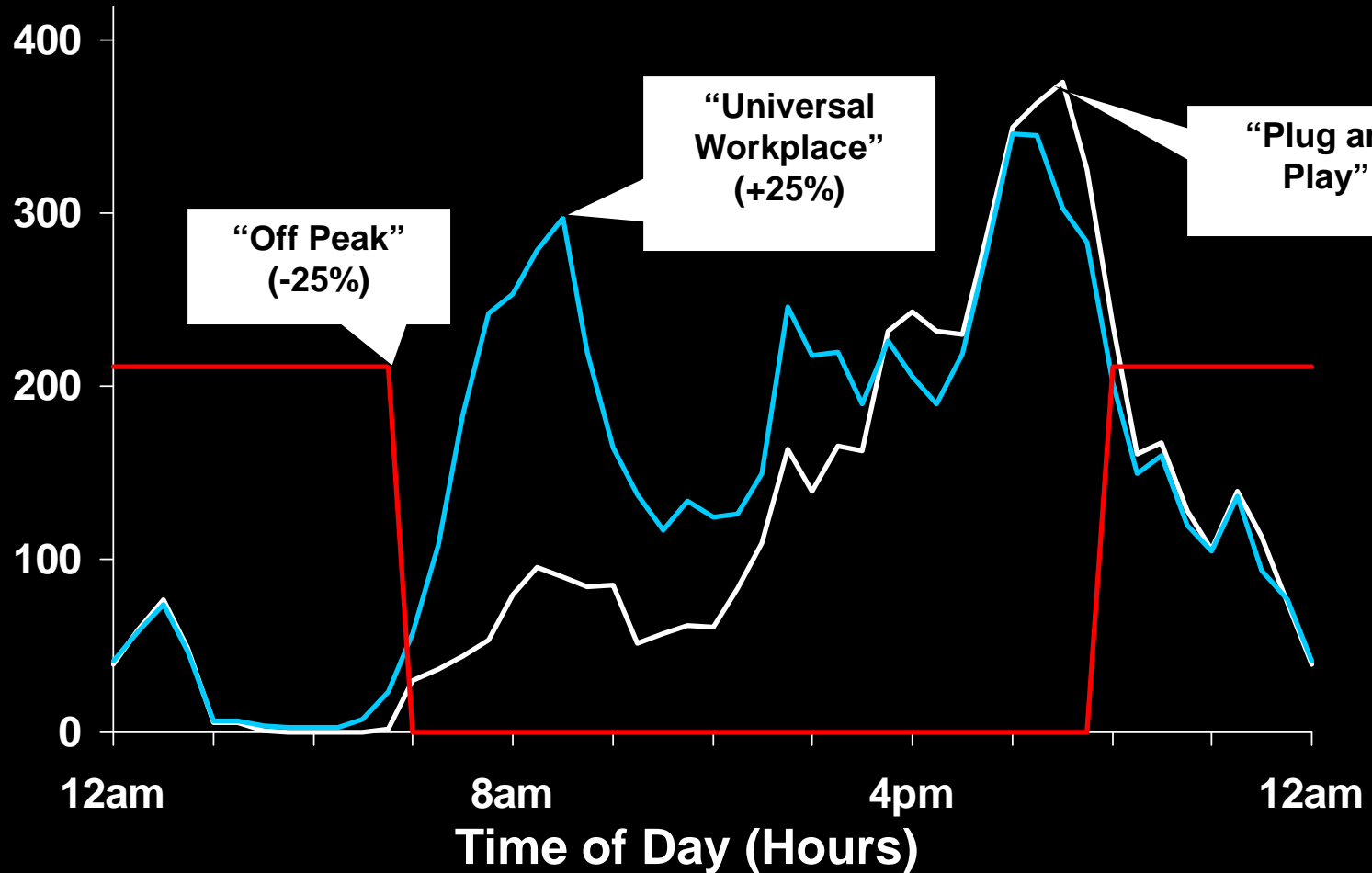


MW  
per  
million  
PHEVs



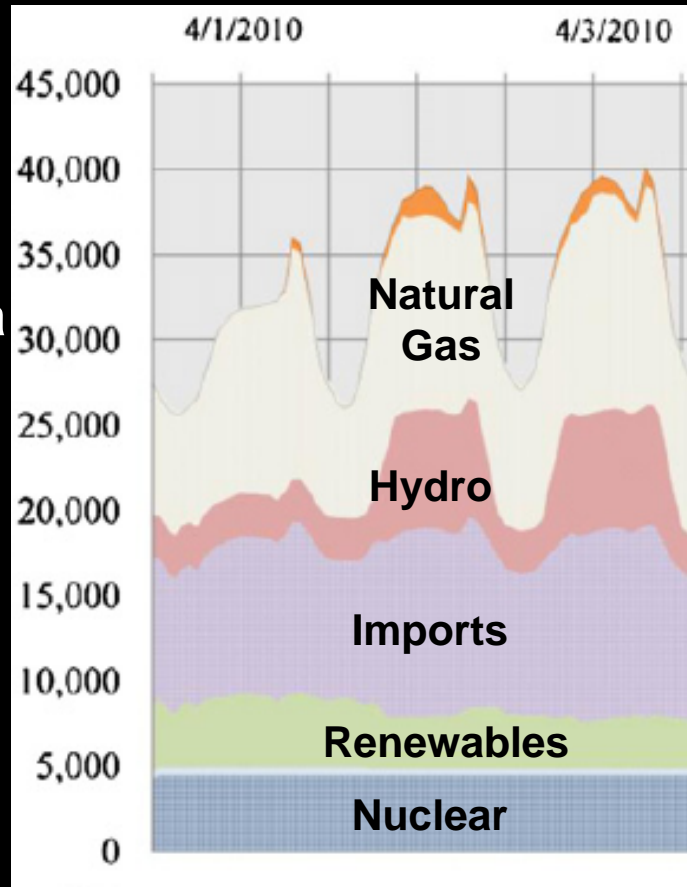
# “Off-peak only” would eliminate daytime load

  
MW  
per  
million  
PHEVs



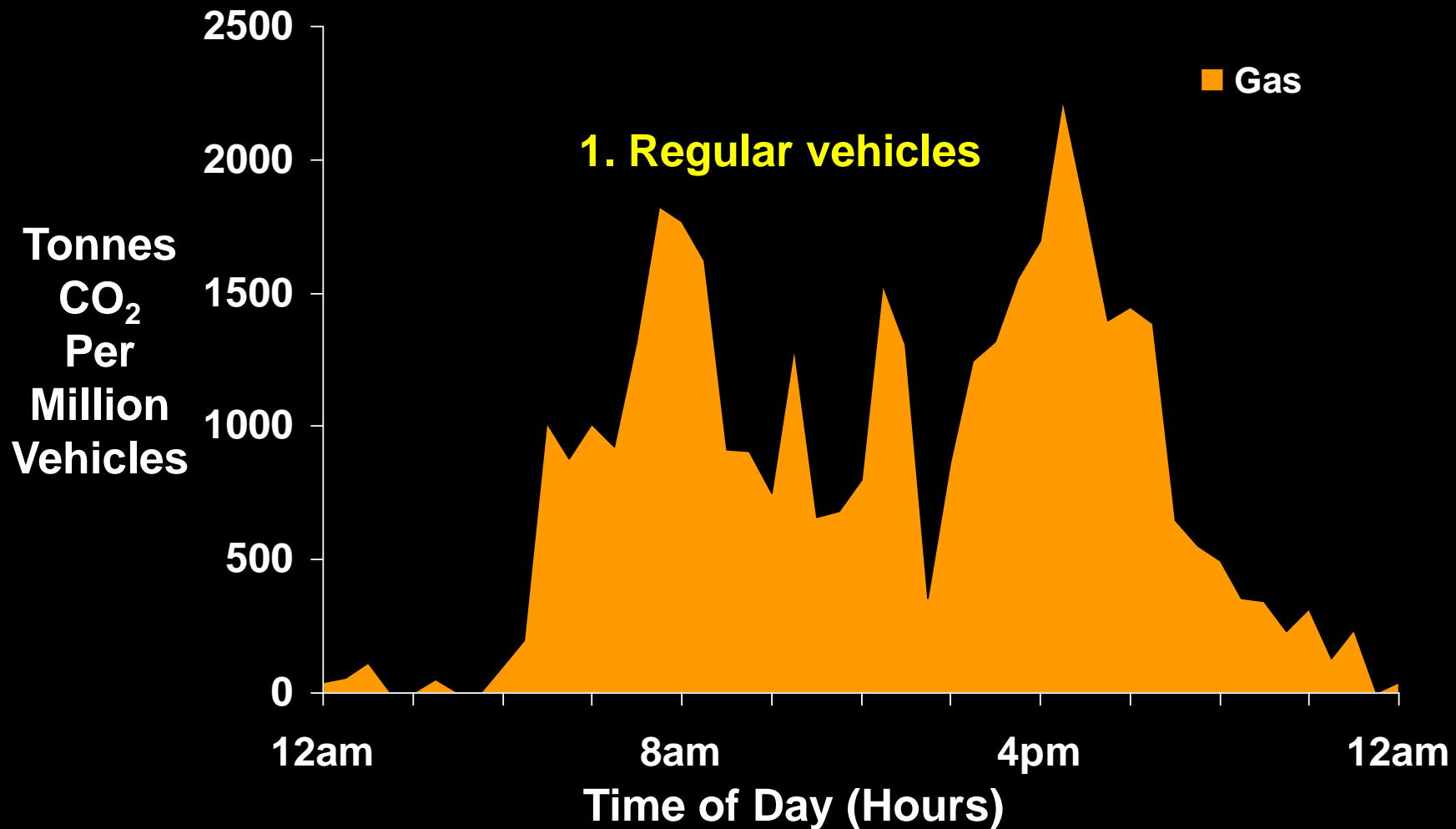
# Modeling 2010 and 2020 emissions with EDGE-CA

California  
Gen.  
Mix  
(MW)

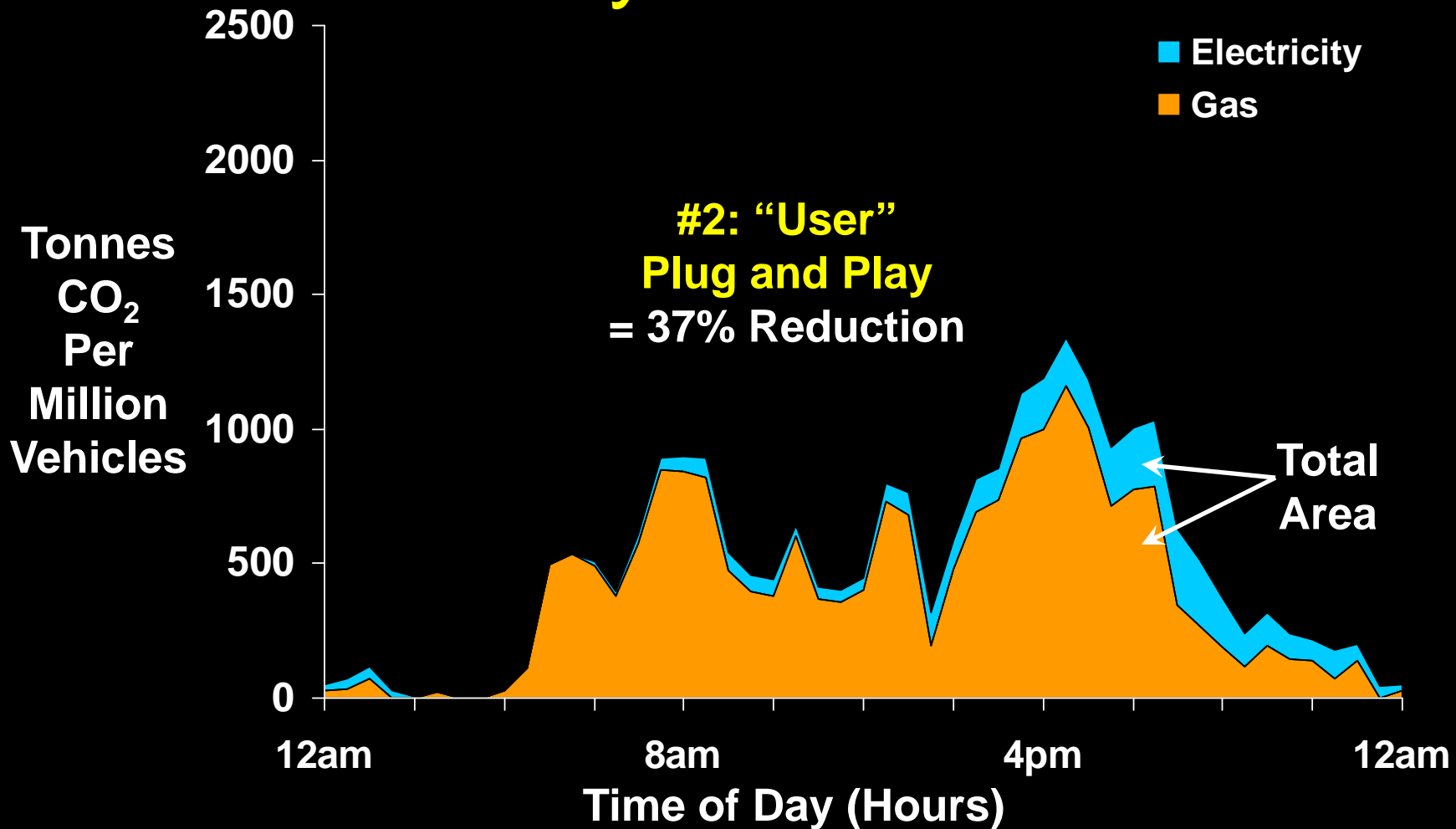


(McCarthy and Yang, 2010)

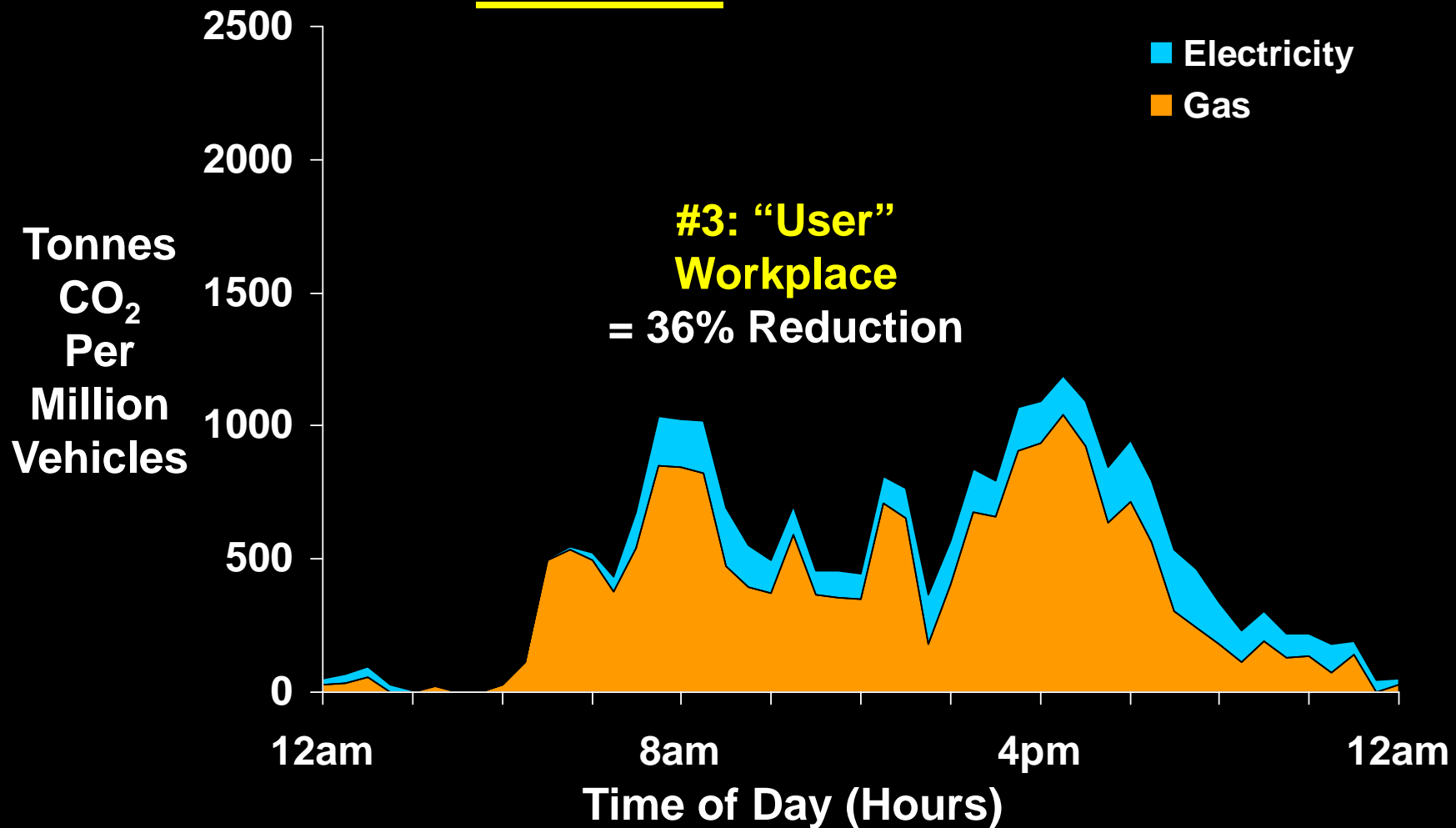
# Modeling time of day GHGs: Baseline



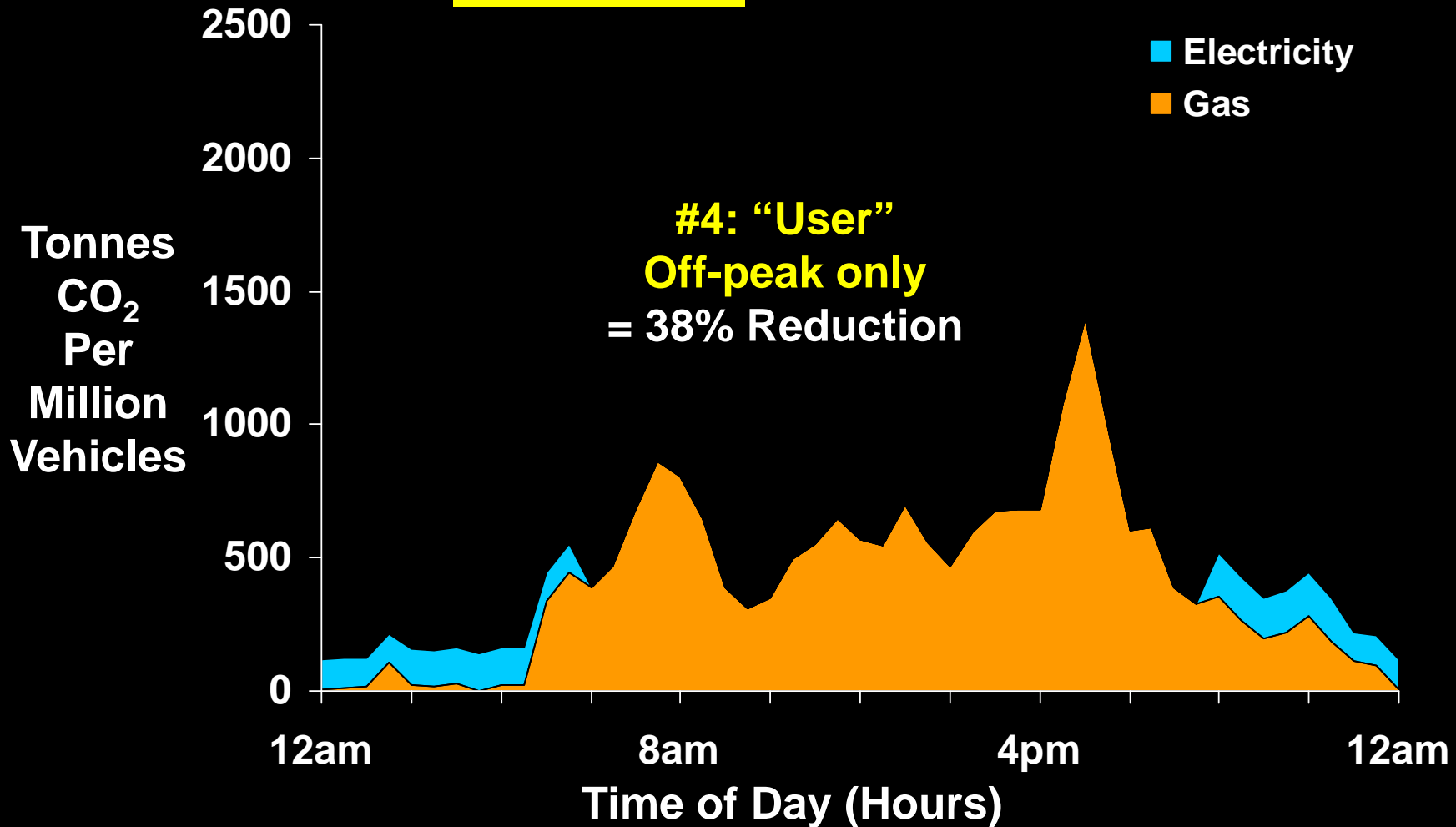
# “User” PHEVs cut GHGs by one-third



# Increased workplace charging is less desirable



# Off-peak charging is more desirable





## **Part 2:**

**Voluntary markets.  
Do you want “green electricity”  
with that PEV?**

*(Environmental Research Letters, 2013)*

# Research Objectives and Method





1. Assess interest in PEVs and green electricity programs.
2. Does combination increase demand for PEVs?
3. Characterize consumer motivations.

## 20-minute web-based survey (n = 1502)

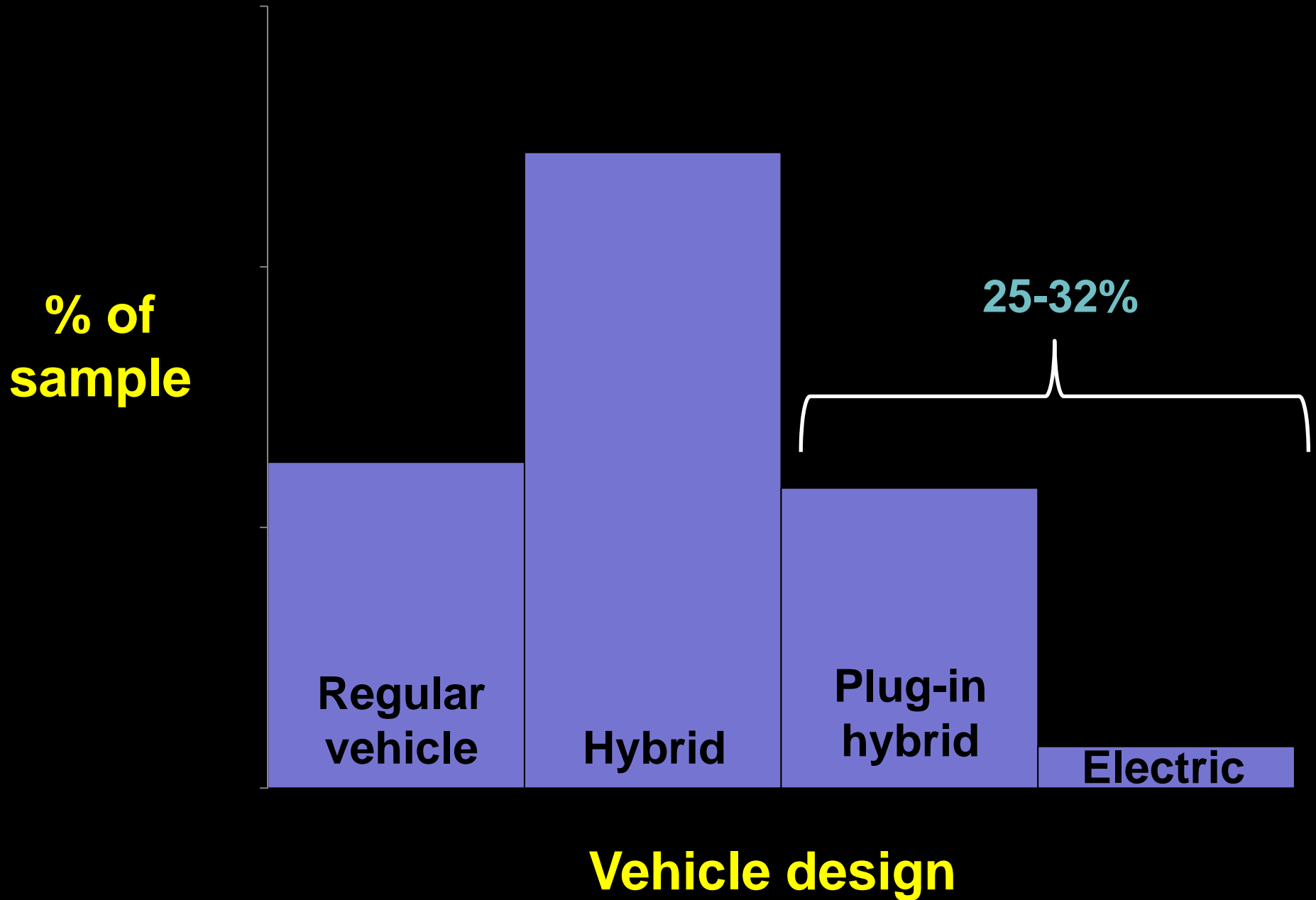
(3 segments: buyers of conventional, HEV and PEVs)

1. **Game 1:** PEV design
2. **Game 2:** Green-electricity design
3. **Game 3:** “Combined” design (PEV and Green-E)

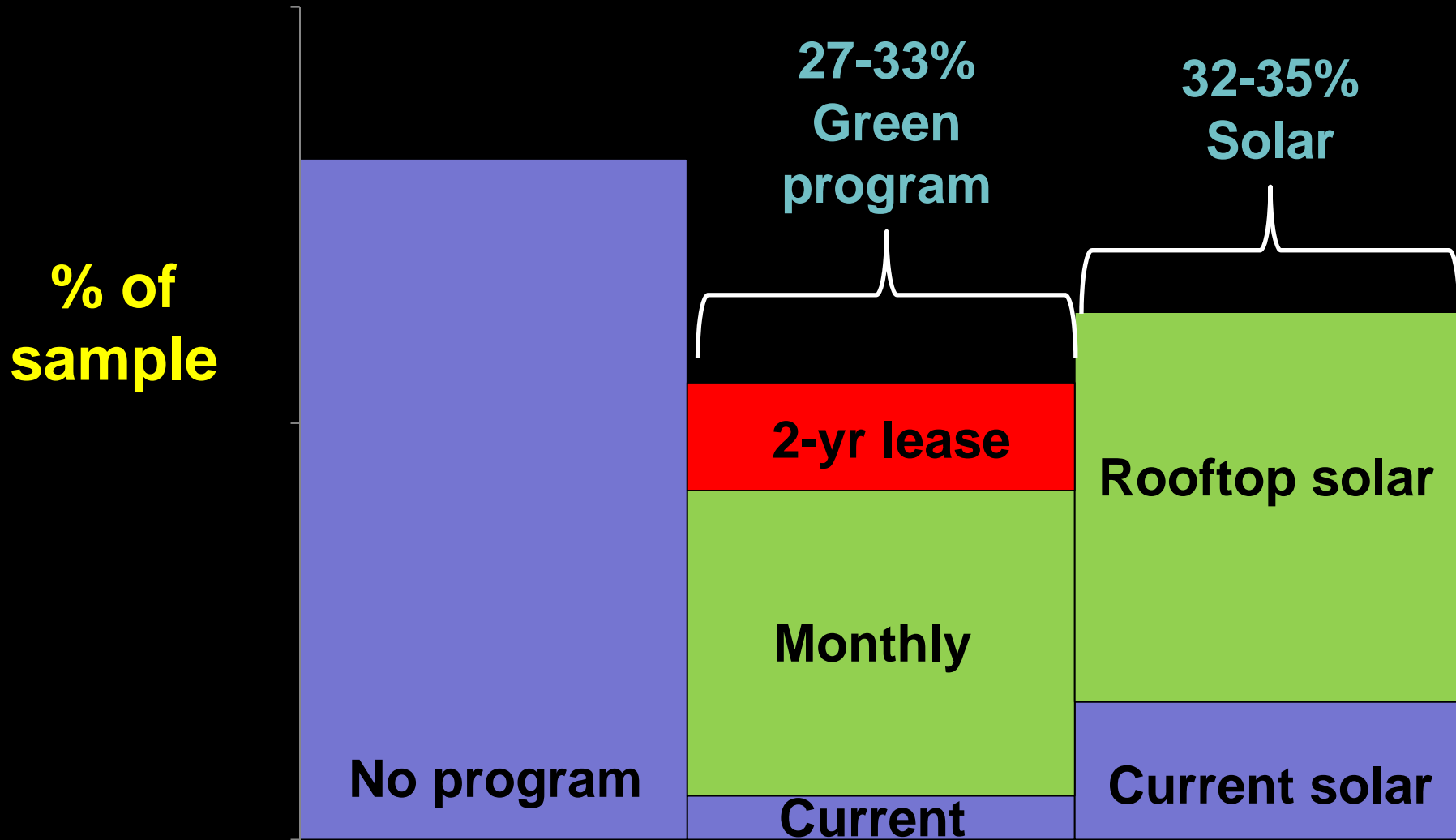
You can only select ONE of the follow vehicle designs. When you have explored the designs as much as you want, select your vehicle design by choosing the button on the right.

	Battery distance	Gasoline Fuel Economy	Electricity Recharge Time	Purchase Price	
 <b>Regular</b>	None	20 MPG	None	\$25,000	<input type="checkbox"/>
 <b>Hybrid</b>	None	26 MPG	None	\$26,080	<input type="checkbox"/>
 <b>Plug-in Hybrid</b>	<b>All-electric for the first:</b> Click here to design ▾ Click here to design 10 Miles: + \$2,710 20 Miles: + \$3,160 40 Miles: + \$4,070			26 MPG    1.5 hours    \$29,070	<input checked="" type="checkbox"/>
 <b>Electric Only</b>	<b>Electric only for:</b> Click here to design ▾				<input type="checkbox"/>

# Game 1: One-third select a PEV design

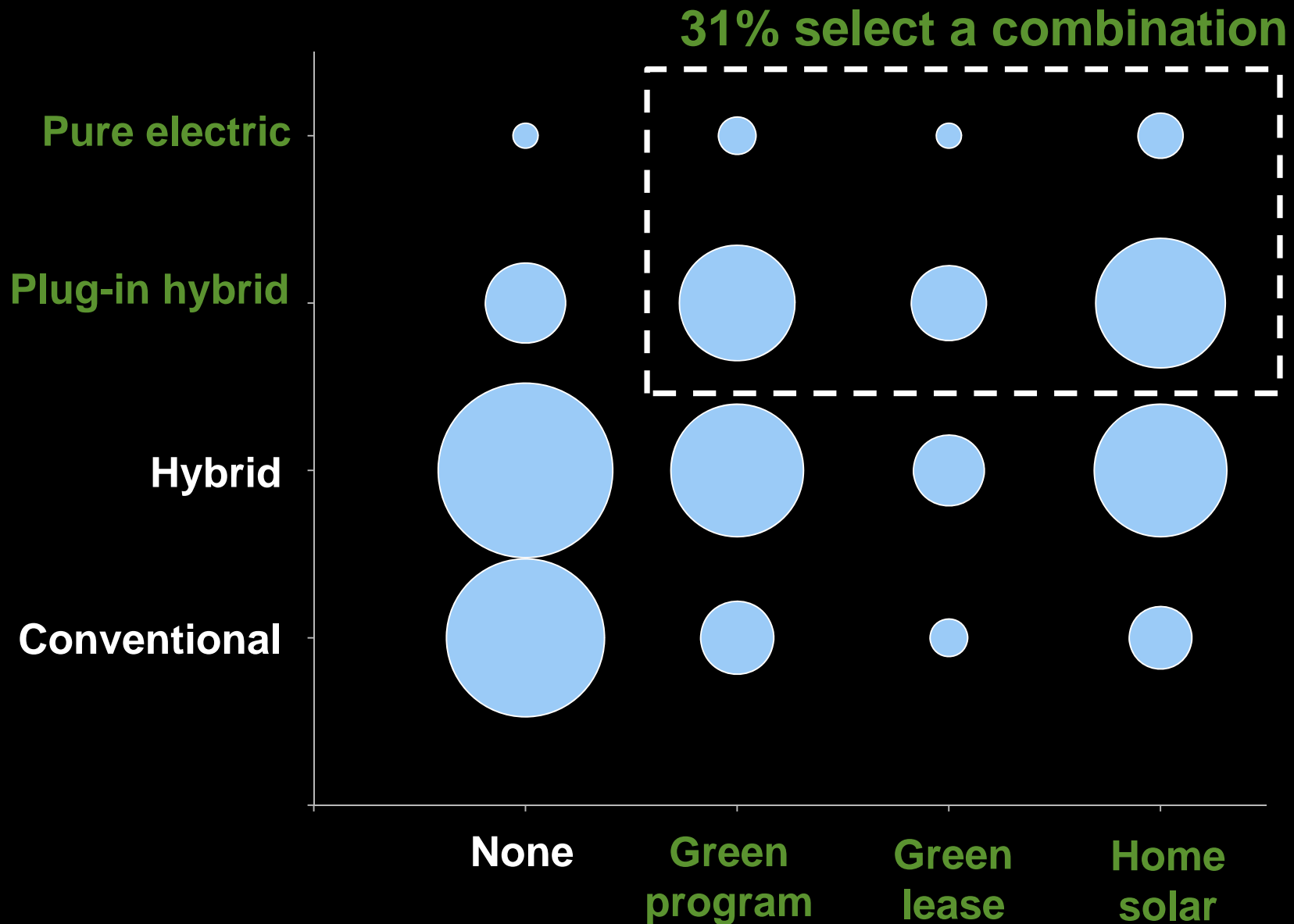


# Game 2: Two-thirds select green-electricity

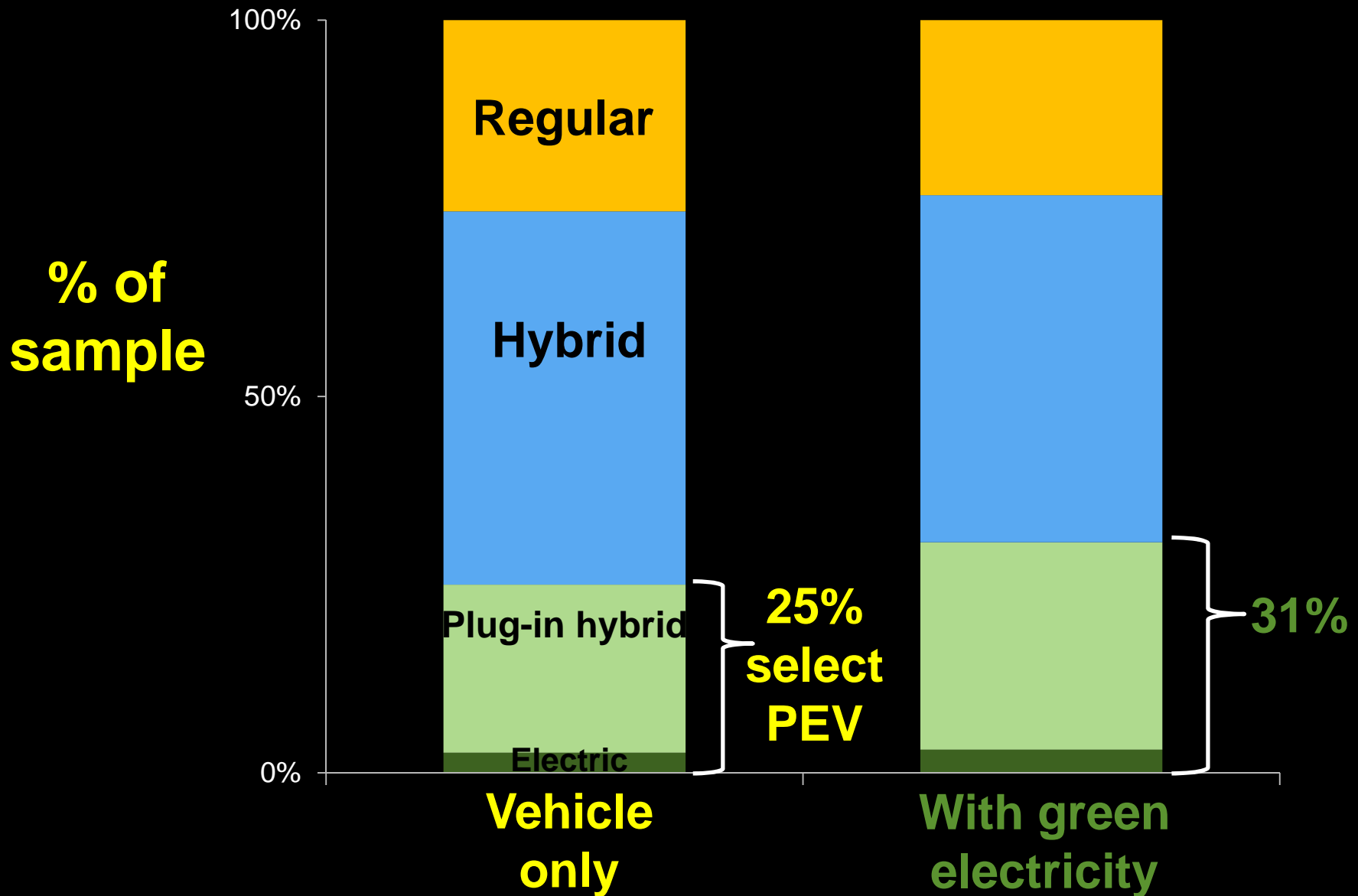


**“Green” electricity design**

# Game 3: And when we offer both together...



# PEV demand increases by ~20%



# Consumer motivations for combining

Environment (air quality)

Oil politics

Supporting renewables

Control over energy

Exploring new technology



## **Part 3:**

# **Considering “Utility controlled charging” for PEVs**

**(Funded but still unnamed grant, 2012-15)**

# What is “utility-controlled charging”?

## **Context:**

- PEV owners want to recharge their vehicle
- PEV is plugged in longer than total required charging time (say, only 6 out of 12 hours needed)

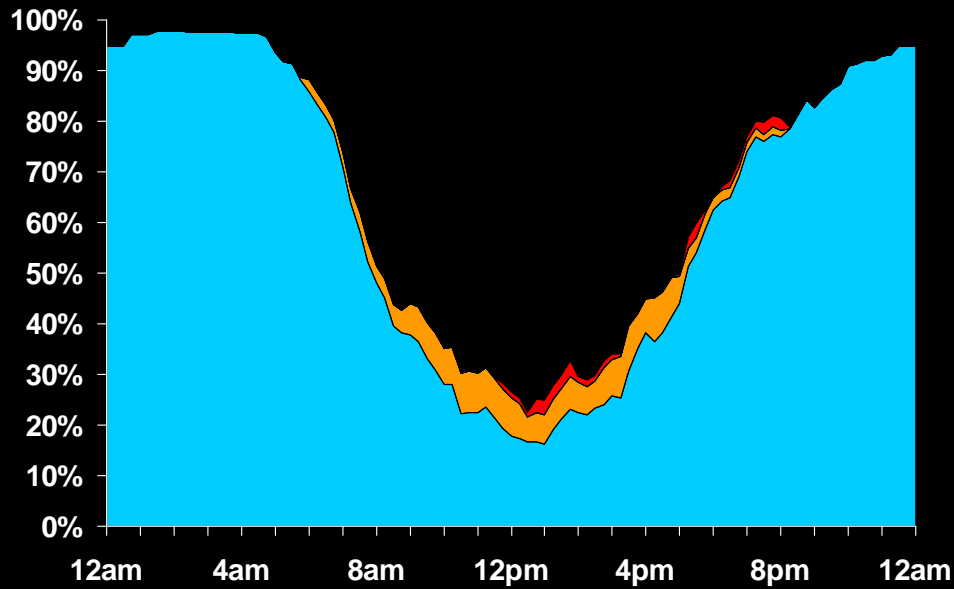
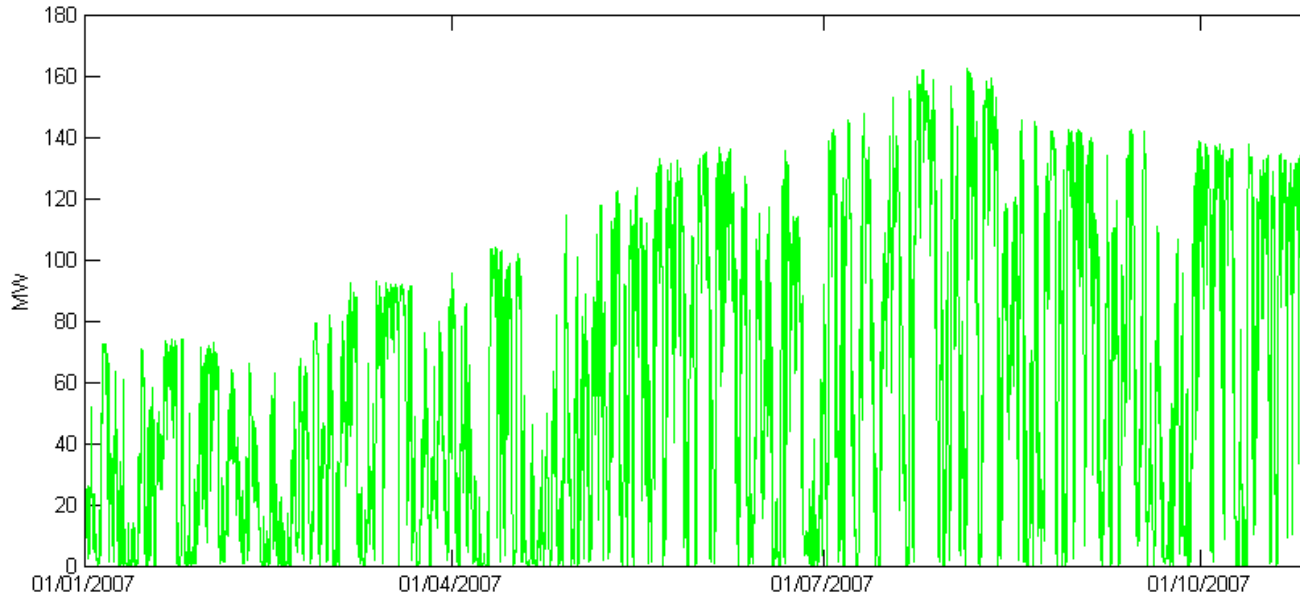
## **Opportunity**

- Electric utility has control over charge timing

## **Framing (Goal)**

- PEV charging can be “matched” to the availability of intermittent renewables

Generation - All Wind



# Assessing demand for “utility-controlled charging”

## Data collection

- Canada-wide survey (in progress)
- Metro Vancouver interviews (PEV and car buyers)
- Other data? (Charger use?)

## Analysis methods

- Discrete-choice modeling (PEV and charging)
- Excel models of recharge profiles
- Energy-economy model of long-term demand (CIMS)
- Content analysis of interviews (narratives?)

# PEV Survey Overview

## Sample

- New vehicle buyers
- Total: 1700 Canadians (not QC),  
BC oversample: ~600
- Representative for gender, income, age, etc.

## Web-based Survey Layout

Part 1: (20 minutes)

Knowledge/perceptions of vehicles, electricity, lifestyle, etc.

Part 2:

Home recharge assessment + 3 day driving diary

Part 3: (25 minutes)





Modeling vehicle and charging preferences

# Survey flow:



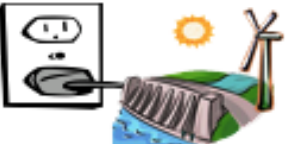
Respondent is given a basic “education” in our terminology, then:

1. **PEV choice model** (vehicle type, electric range, fuel cost, purchase price)
2. **PEV “design space”**
3. **“Charging style” choice model** (% renewables, type of “green”, monthly bill, percent guaranteed charge in morning)
4. **“Green electricity” design space**

# A vehicle preference choice experiment

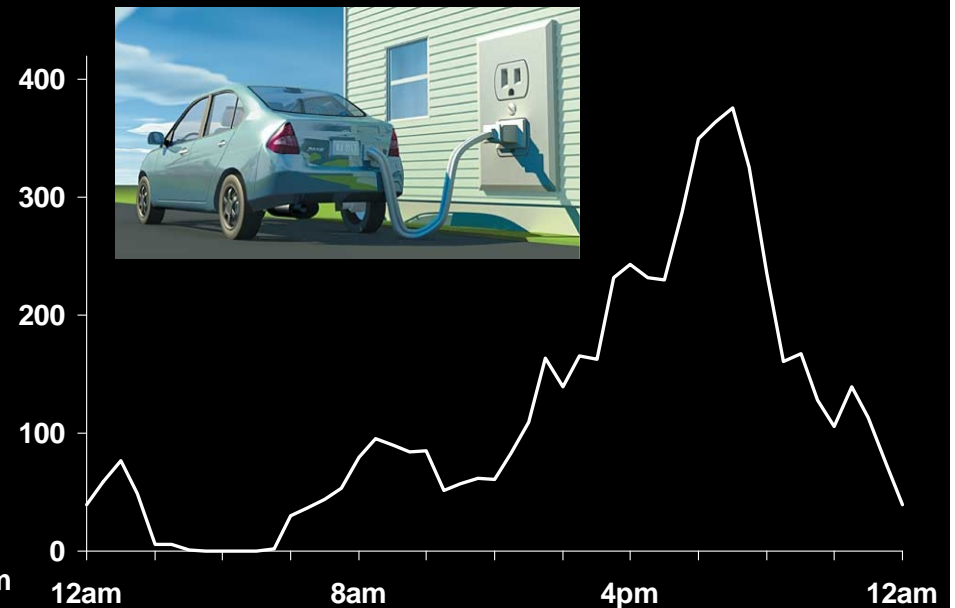
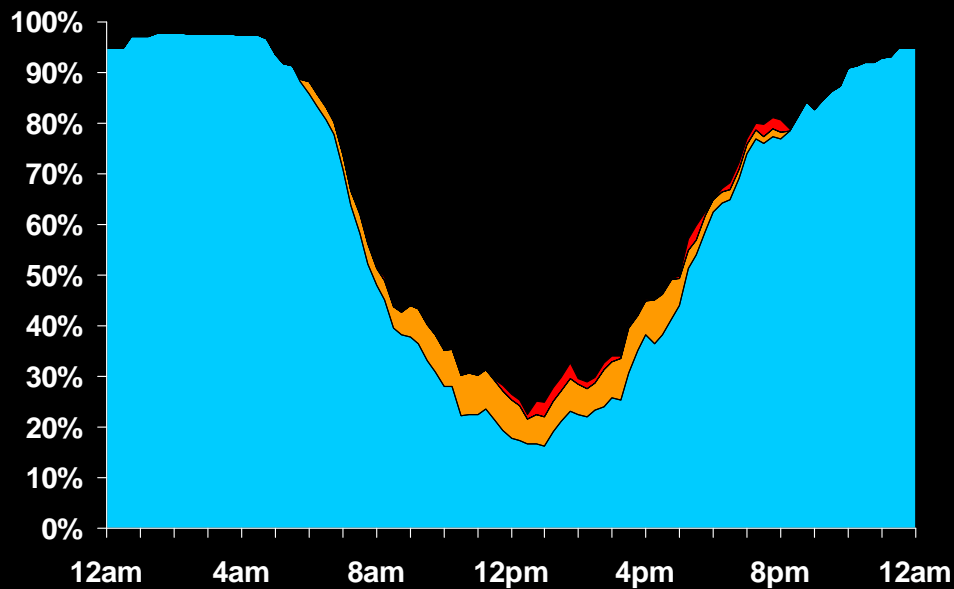
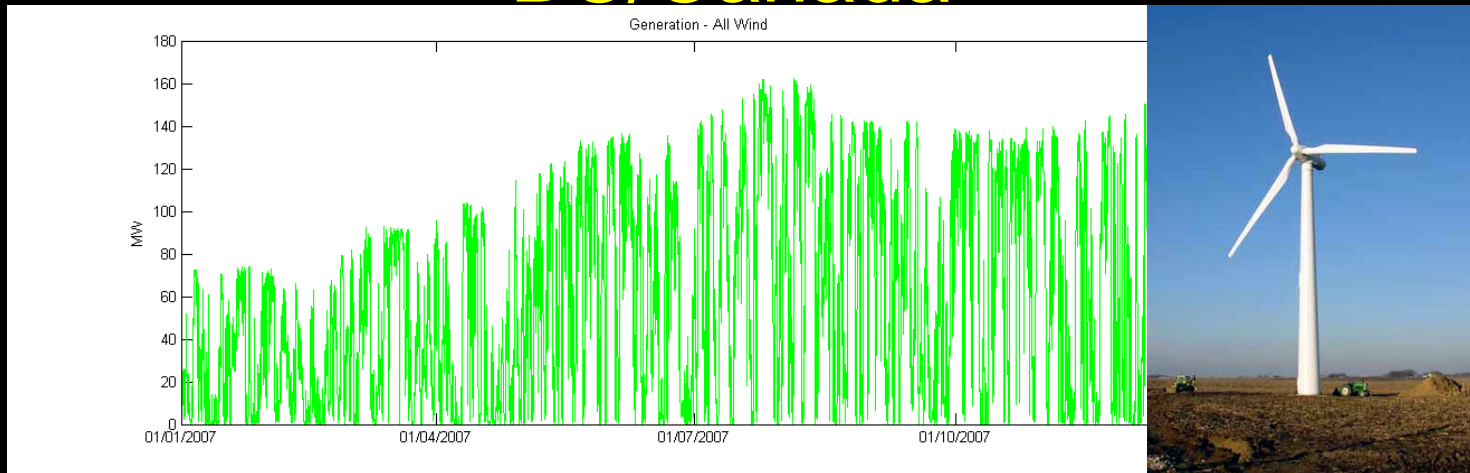
Vehicle Type	Electric Range	Fuel Cost	Refuel or Recharge Time	Purchase Price	I CHOOSE
 <b>A Gasoline</b> HONDA CIVIC	None	\$ 100 /week	5 mins.	\$ 29,000	Gasoline <input type="radio"/>
 <b>A Hybrid</b> HONDA CIVIC	None	\$ 60 /week	5 mins.	\$ 34,800	Hybrid <input type="radio"/>
 <b>A Plug-in Hybrid</b> HONDA CIVIC	Electric for the first: 32 km	\$ 80 /week	5.2 hours to fully recharge (Type 1)	\$ 31,900	Plug-in Hybrid <input checked="" type="radio"/>
 <b>An Electric Only</b> HONDA CIVIC	Electric only for: 160 km	\$ 40 /week	4.3 hours to fully recharge (Type 2)	\$ 37,700	Electric <input type="radio"/>

# A charging style choice experiment

Charge Style	% of Green Electricity	Source of Green Electricity	Guaranteed Minimum Charge	Monthly Electricity Bill	I CHOOSE
 Your Status Quo	Your Current Mix	Your Current Sources	100% 160 km	\$244 /month	Status Quo <input type="radio"/>
 Charge Style 1	75 %	Small Hydro	50 % 80 km	\$244 /month	Style 1 <input checked="" type="radio"/>
 Charge Style 2	25 %	Mixed	100 % 160 km	\$244 /month	Style 2 <input type="radio"/>



# Use consumer data to build more sophisticated models of utility-controlled charging in BC/Canada



**Pulling it all together...**

# Different levels of PEV-grid integration

Increasing interaction, engagement, or “smart-ness” →

PEV  
charged  
by  
grid

↓  
**Static  
grid**

PEV  
consumer  
buy  
green  
electricity

↓  
**Meshing  
ideas of  
green**

“Utility  
controlled  
charging”  
of PEV

↓  
**Actually  
putting  
renewables  
into PEVs**

Vehicle-  
to-Grid  
(V2G)

↓  
**not yet...**

# Where does all this fit into our Smart Grid partnership?

- Personal transport (linking PEVs to grid)
- Grid modernization required for more advanced linking (utility-controlled charging or V2G)
- Understanding consumer perceptions of and willing to interface with (green) electricity
- Consumer relationships with utilities (and potential for “re-framing” smart grid initiatives)
- Link to actual smart grid initiatives in different jurisdictions