

UC Davis' PHEV Demonstration and Market Research Project

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Household PHEV Consumer Research

1995-97: PHEVs in UCD ZEV market study

2006-07: Interviews with PHEV pioneers

2007-08: National Survey I: PHEV design priorities

2007-09: PHEV Household Experiment

- Funding and support > \$2 million.
- California Air Resources Board AFIP; California Energy Commission PIER Program; American Automobile Association Northern CA, Nevada & Utah; Idaho National Laboratory

2009-10: National Survey II: electric-drive design priorities

Research Questions

1. Recharging and refueling behavior
 - Will people recharge a vehicle they don't have to recharge?
 - If yes, when, where and how much?
2. Driving behavior
 - Do PHEVs change peoples' driving behavior?
 - Trips, accelerations, braking, top speed etc.
3. How does energy and cost information affect driving and recharging?
4. What do people value about PHEVs?
 - What PHEV designs do people create?
 - High fuel economy, all-electric driving?
5. How do social networks affect drivers evaluations of PHEVs?

Who is eligible?

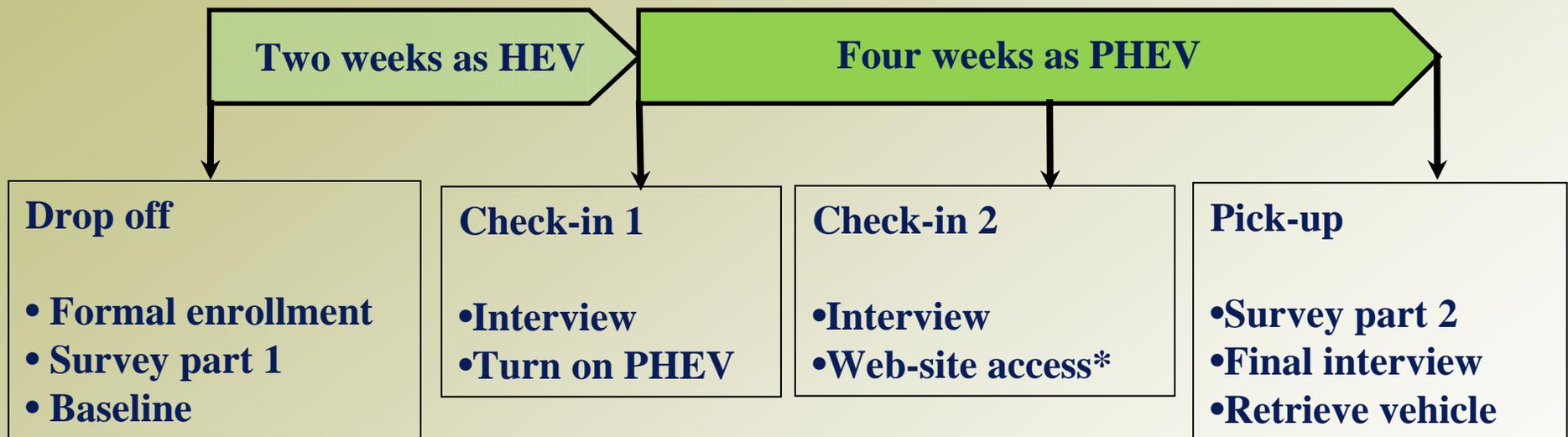
- Sampling Frame
 - AAA Northern California, Nevada & Utah membership
 - Good drivers within geographic study area, some HEV owners
 - Meet minimum insurance coverage
 - Invitation letters sent by AAA
- Volunteers fill out online screening questionnaire on UCD server
 - Place to charge at home, HH composition, vehicles owned, etc.
- Initial UCD phone contact
 - Confirm drivers license, insurance coverage, internet access, availability, etc.
 - Explain participation requirements; schedule drop-off

Realized sample to date

- 60 households to date
 - Mix of households, vehicle types, drivers and travel
 - A few pre-existing HEV owners
 - Good match to new car buyers
 - Wide variation of e-drive knowledge, environmental and political beliefs
 - All SMUD or PG&E electricity customers
- Gasoline prices from < \$2.00/gal to \$4.50/gal

Six Week PHEV Placements

(Substitute for existing household vehicle)



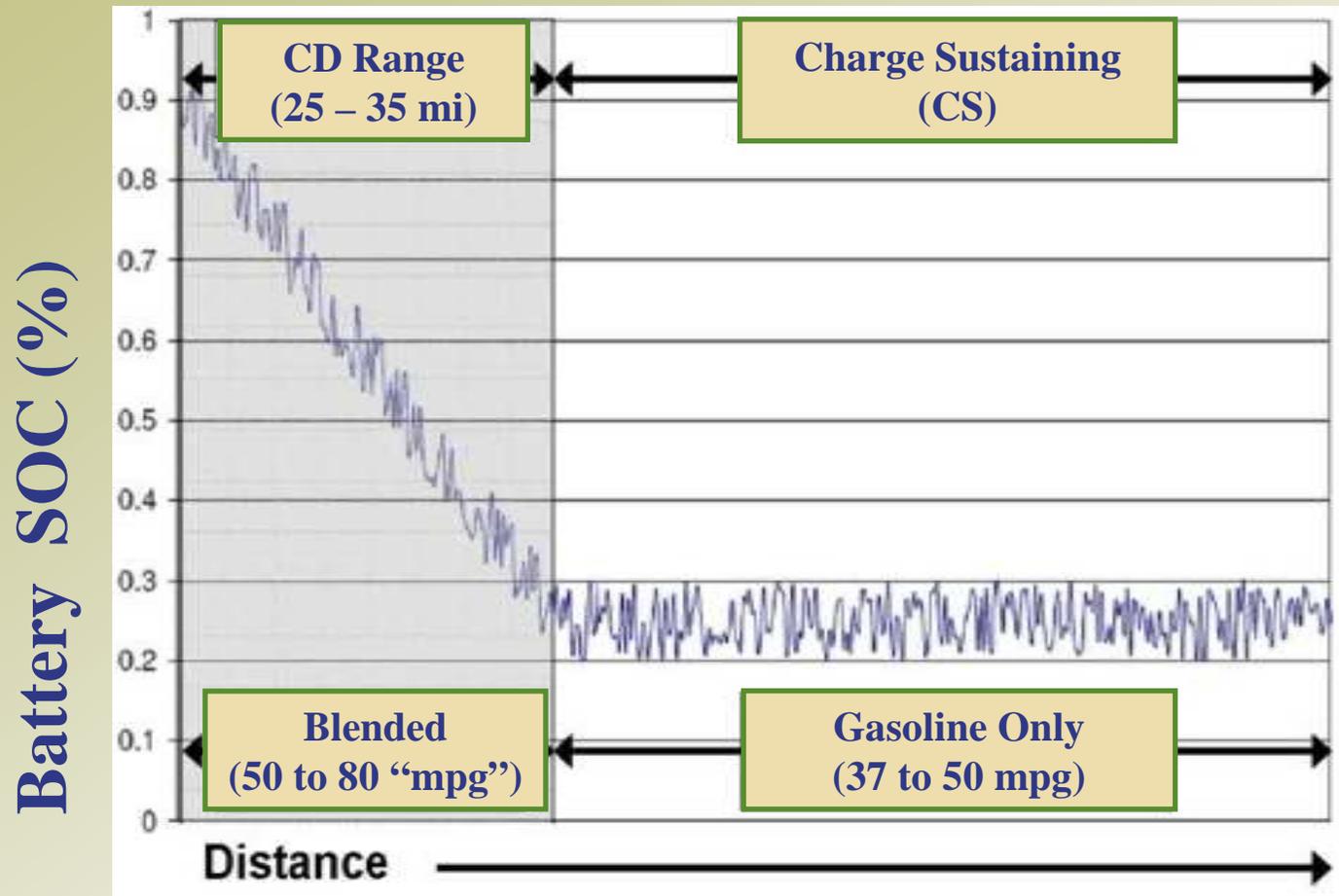
Data Collection: vehicle data loggers, refueling log, online questionnaires, four to six hours of interviews/discussions

Research outputs: travel, vehicle, and charging data; households' narratives

Which PHEVs?

- 2007-8 MY Priuses converted to PHEVs with Hymotion/A123 conversion package
 - 5 kWh supplemental charge-depleting battery
 - 110 volt recharging
 - Maintains Prius' blended mode operation
 - Noticeable differences from stock Prius: electrical outlet, spare tire storage, small antenna, occasional “glitches”

PHEV Conversion Characteristics



Citation: Figure adapted from Kroemer and Haywood, 2007

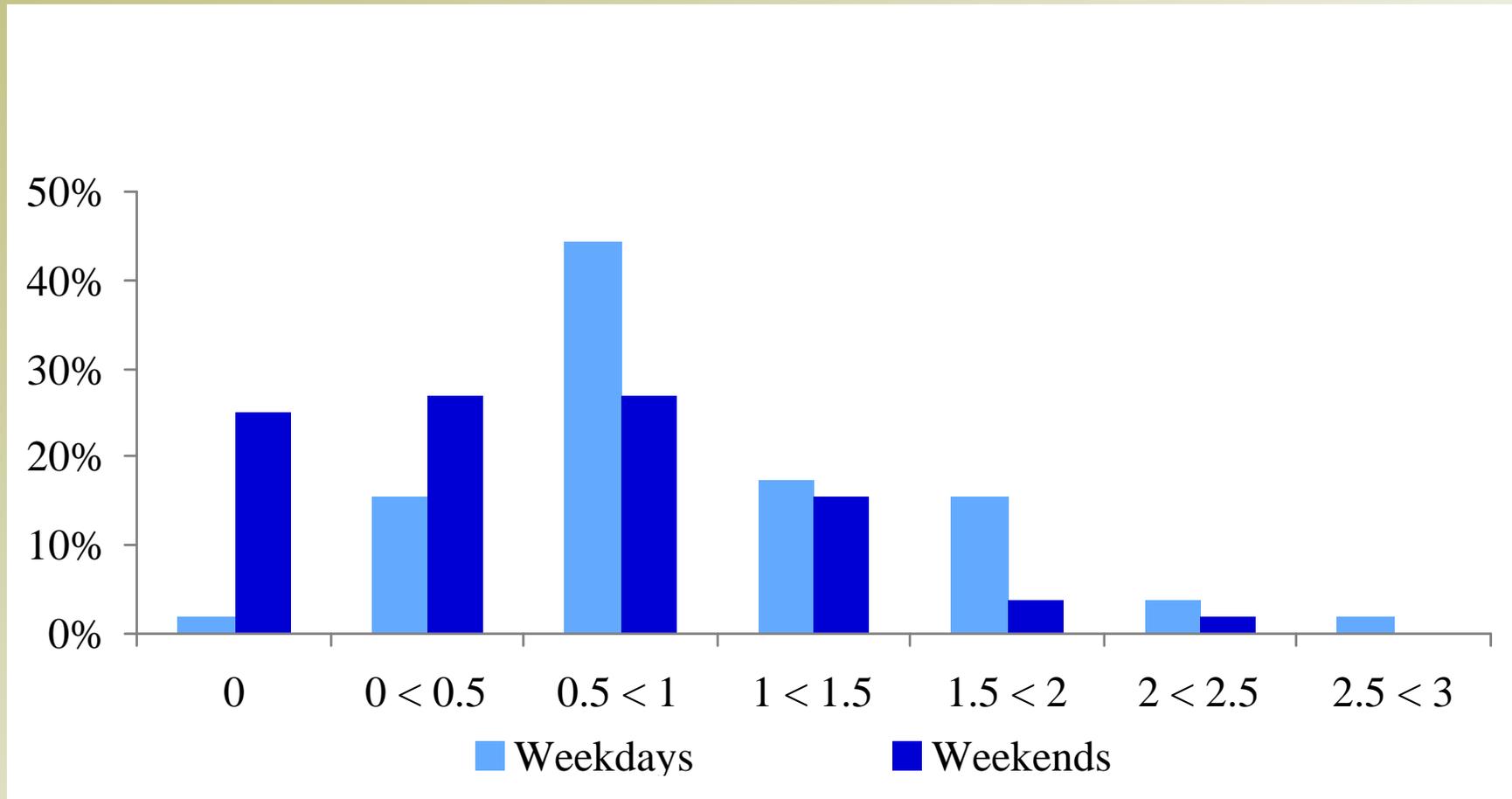
Recharging: when, where, and how much?

- Recharging as a process of discovery by households
- All data shown here are from the households' last week of PHEV driving and recharging
 - A common period of days and days of the week
 - Most representative of long-term behavior
 - As though all recharging and driving during same calendar week
 - Recharge via 110volt/10 amp.
 - Power demand standardized to 1 kW

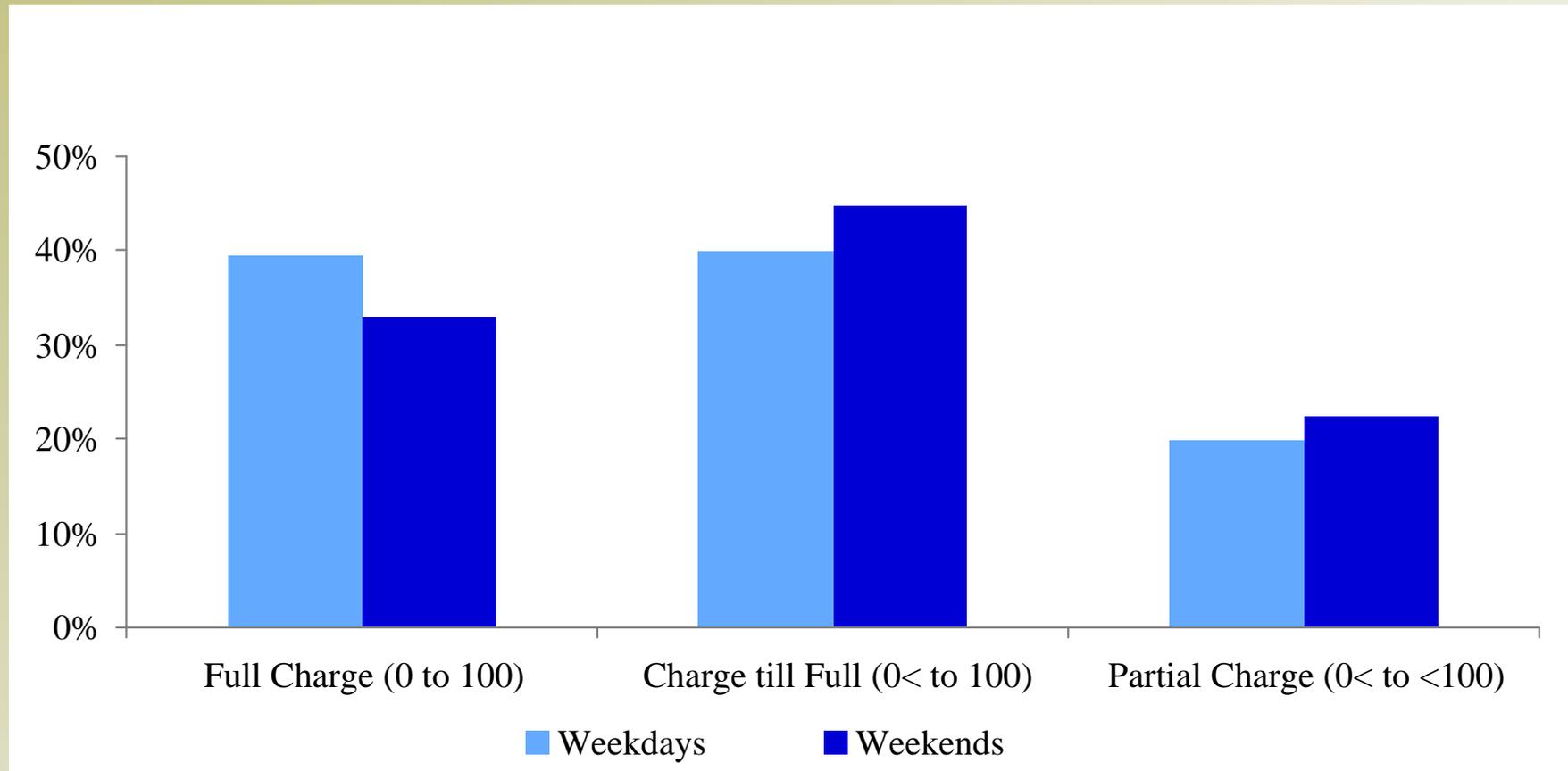
Recharging: when, where, and how much?

- Context to interpret results
 - All demo households can recharge at home
 - Social norms of recharging are unformed
 - Limited infrastructure perceived away-from-home
 - Did not purchase a PHEV
 - Using one type of PHEV
- What about sample size?
 - Plausible boundary of plug-in frequencies:
0 to ~3 times per day

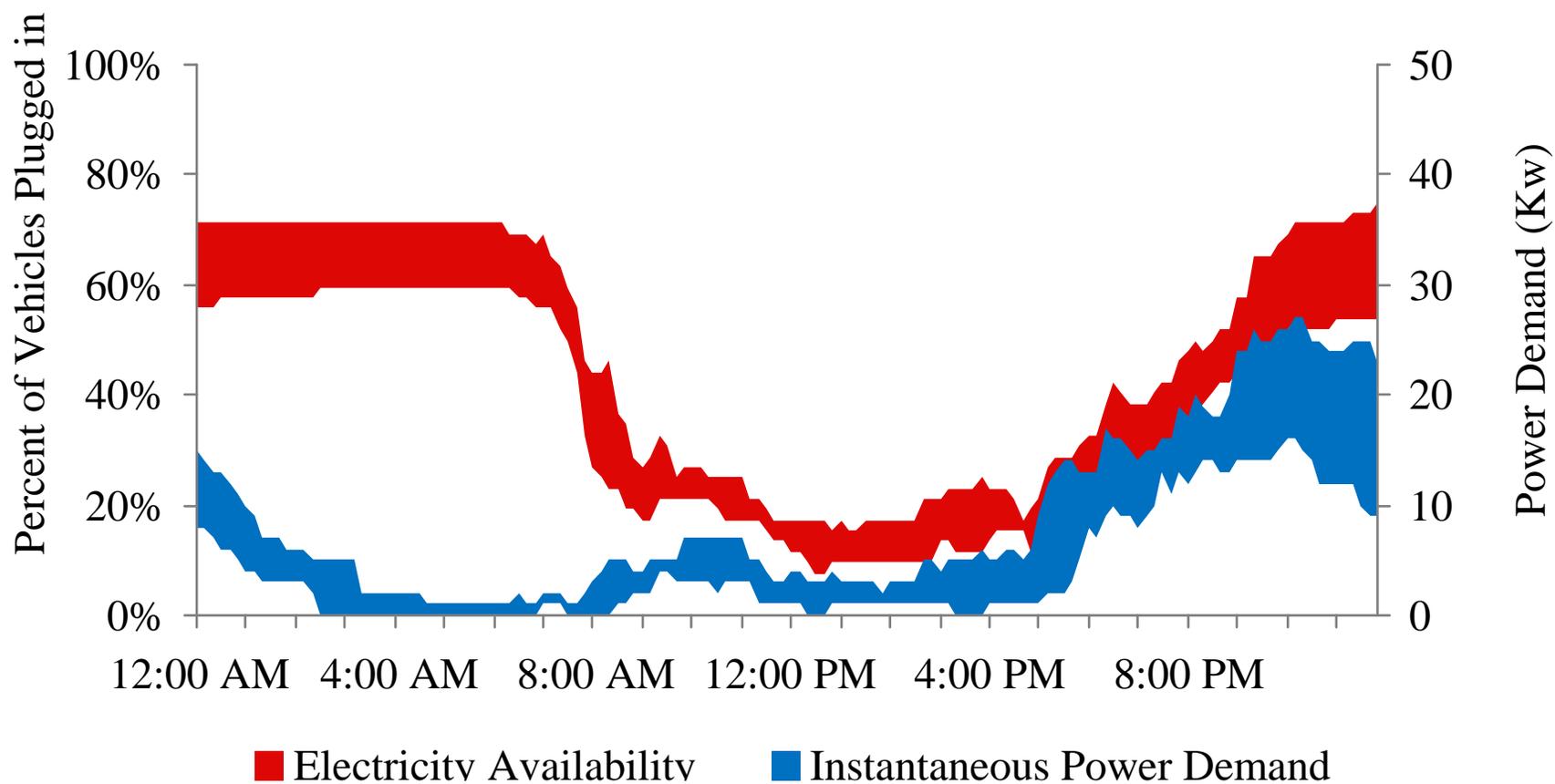
Households' mean daily incidence of plugging-in



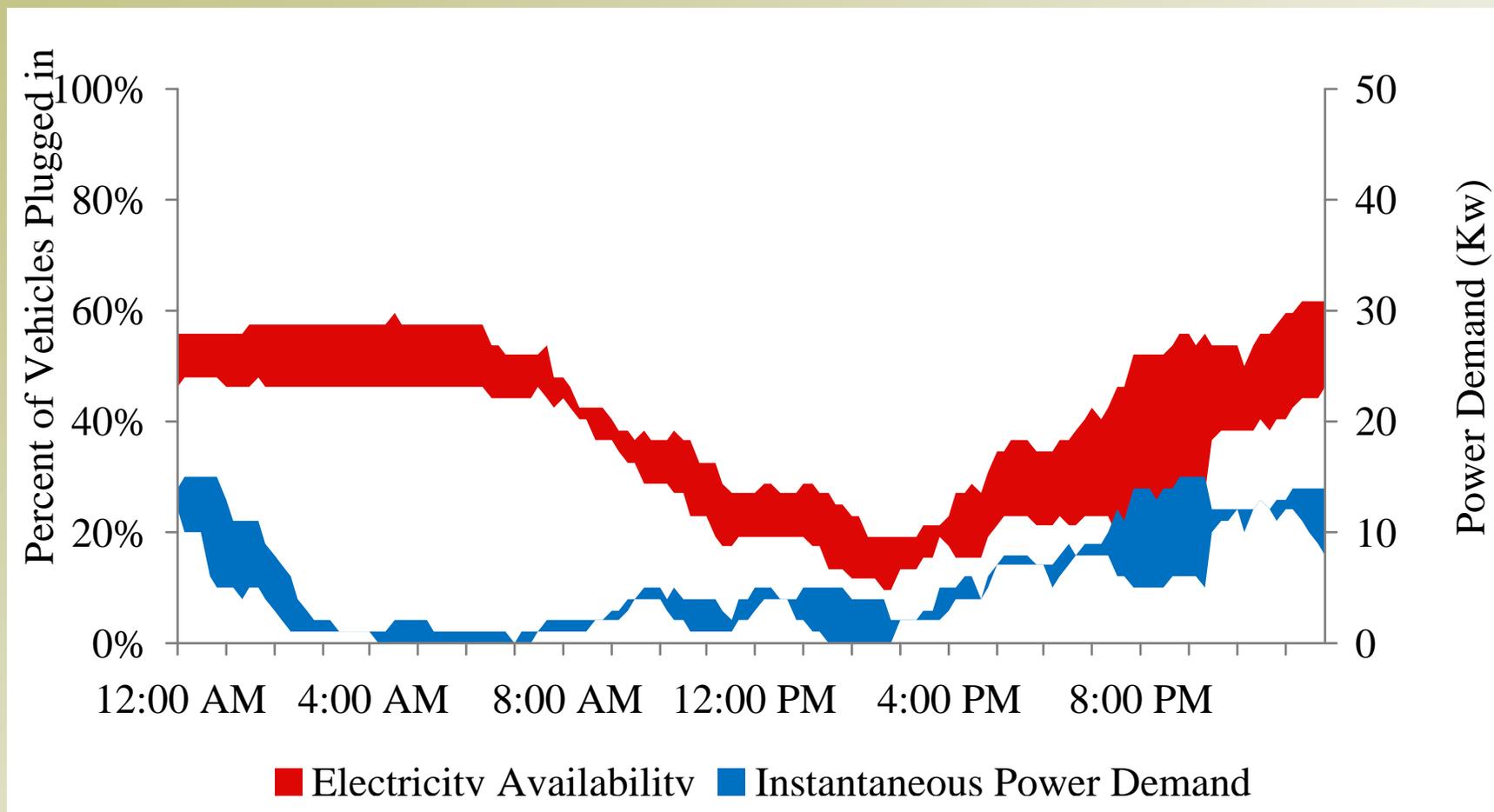
Types of Plug-in events



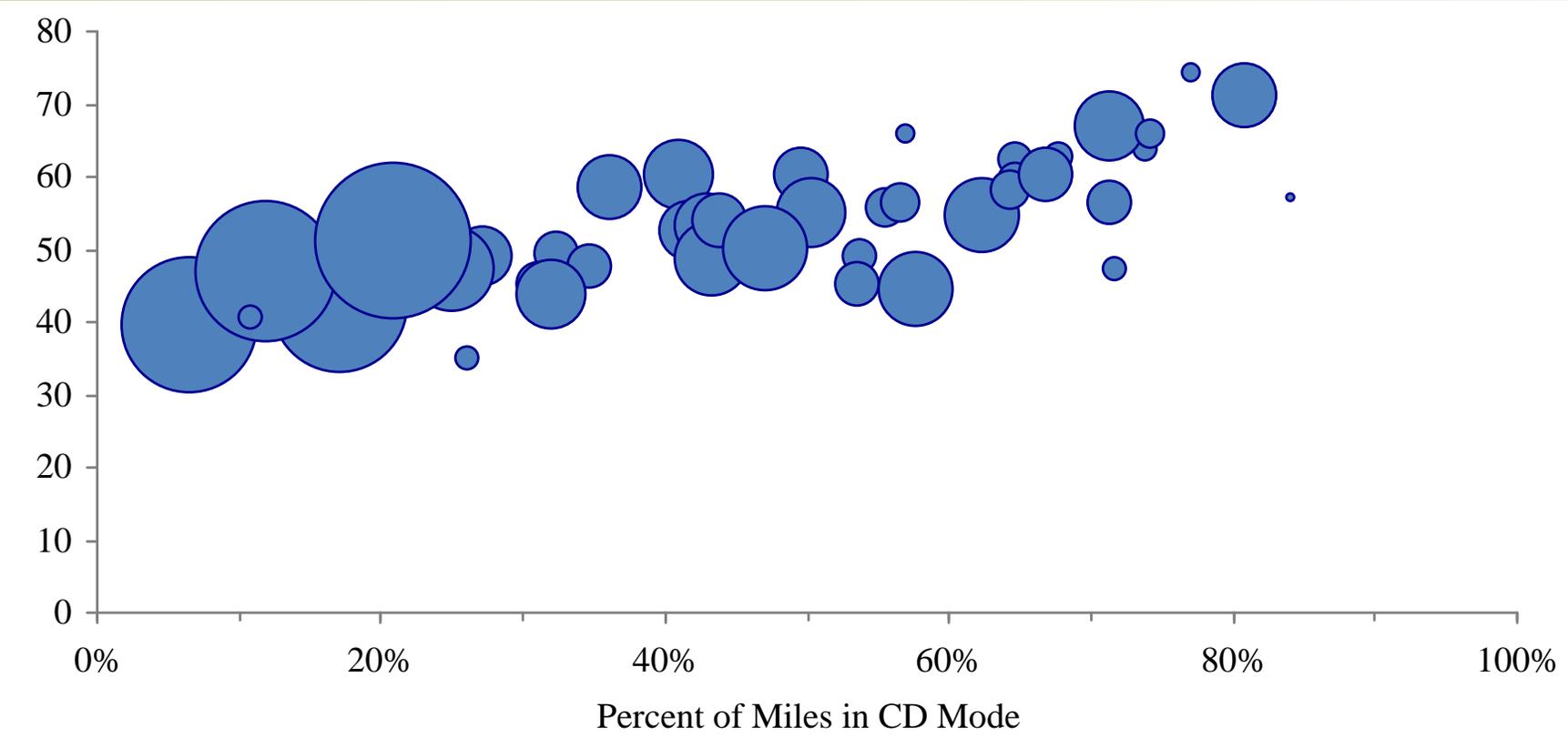
Weekday recharging, n = 52



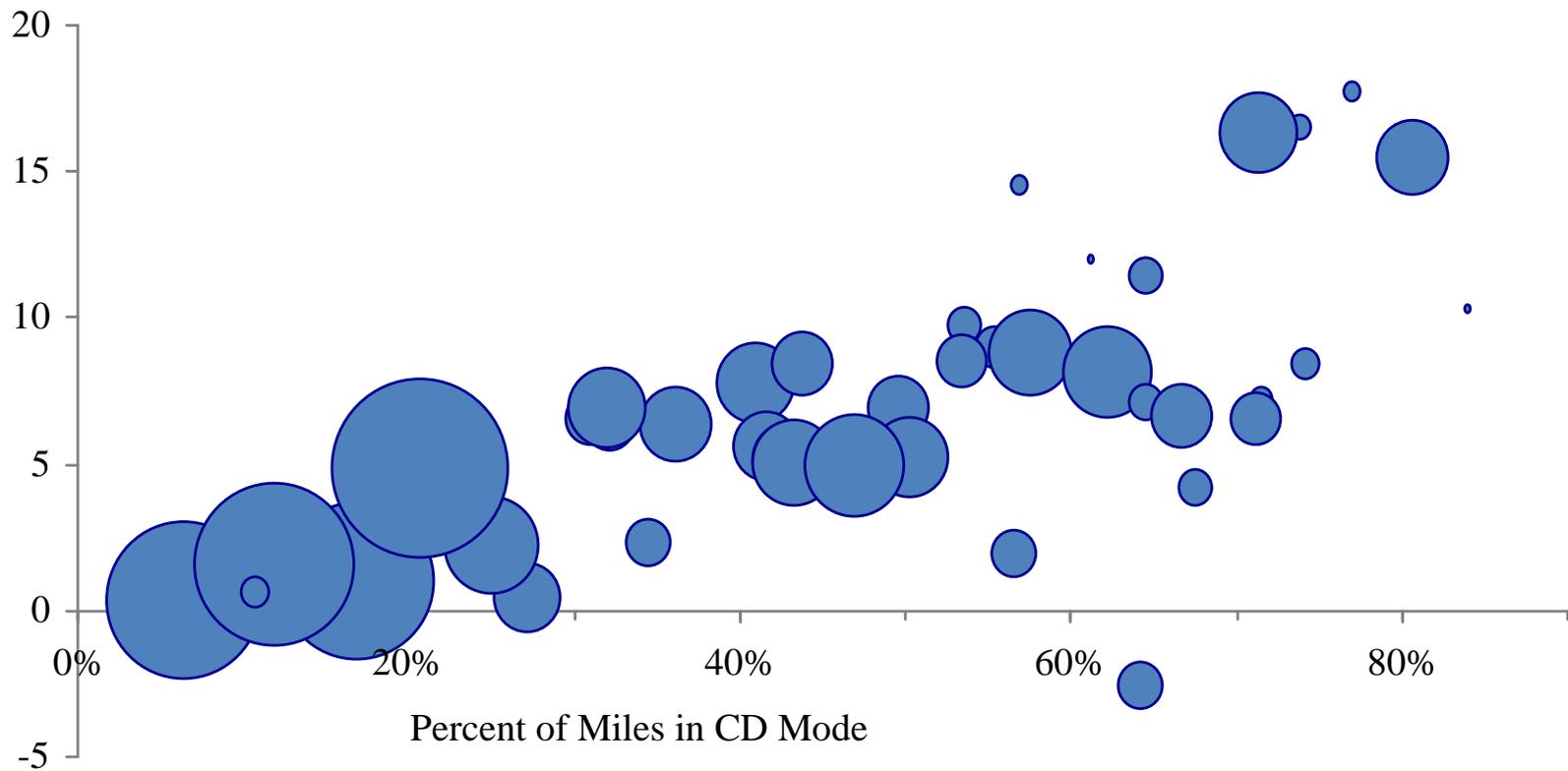
Weekend recharging, n = 52



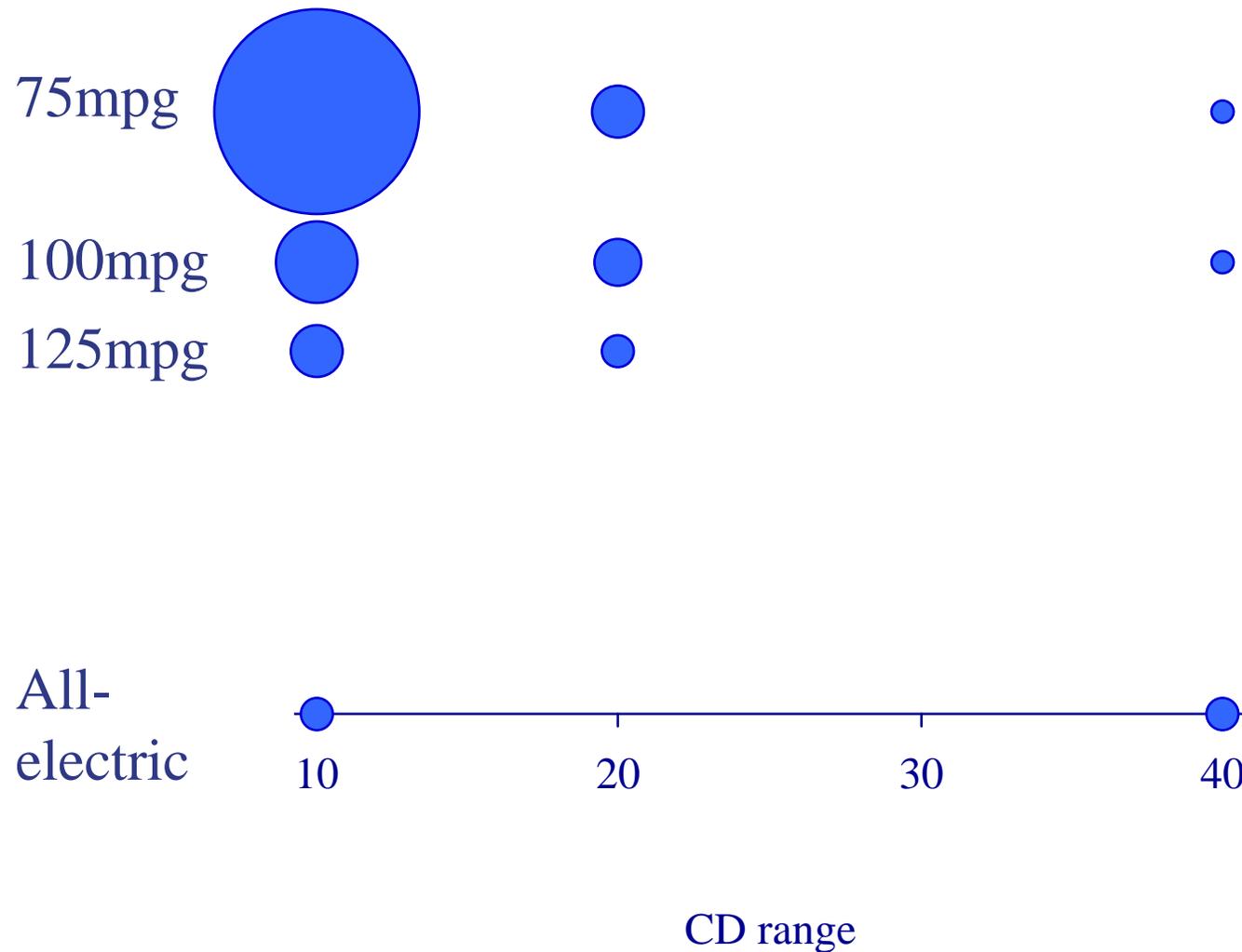
Fuel economy (gasoline only) by Percent CD driving, n = 44



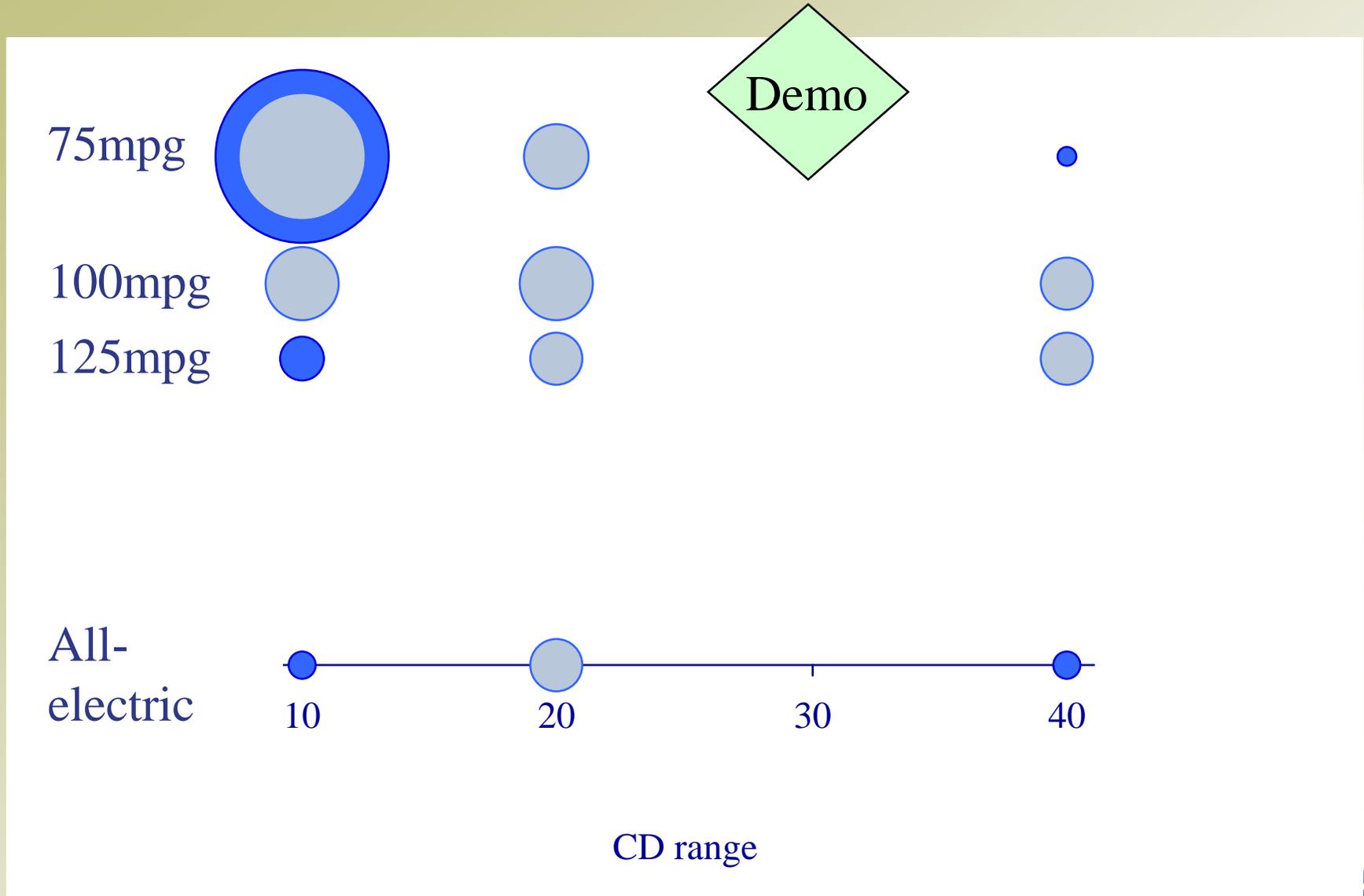
Energy Reduction by Driving in Charge Depleting Operation, n = 44



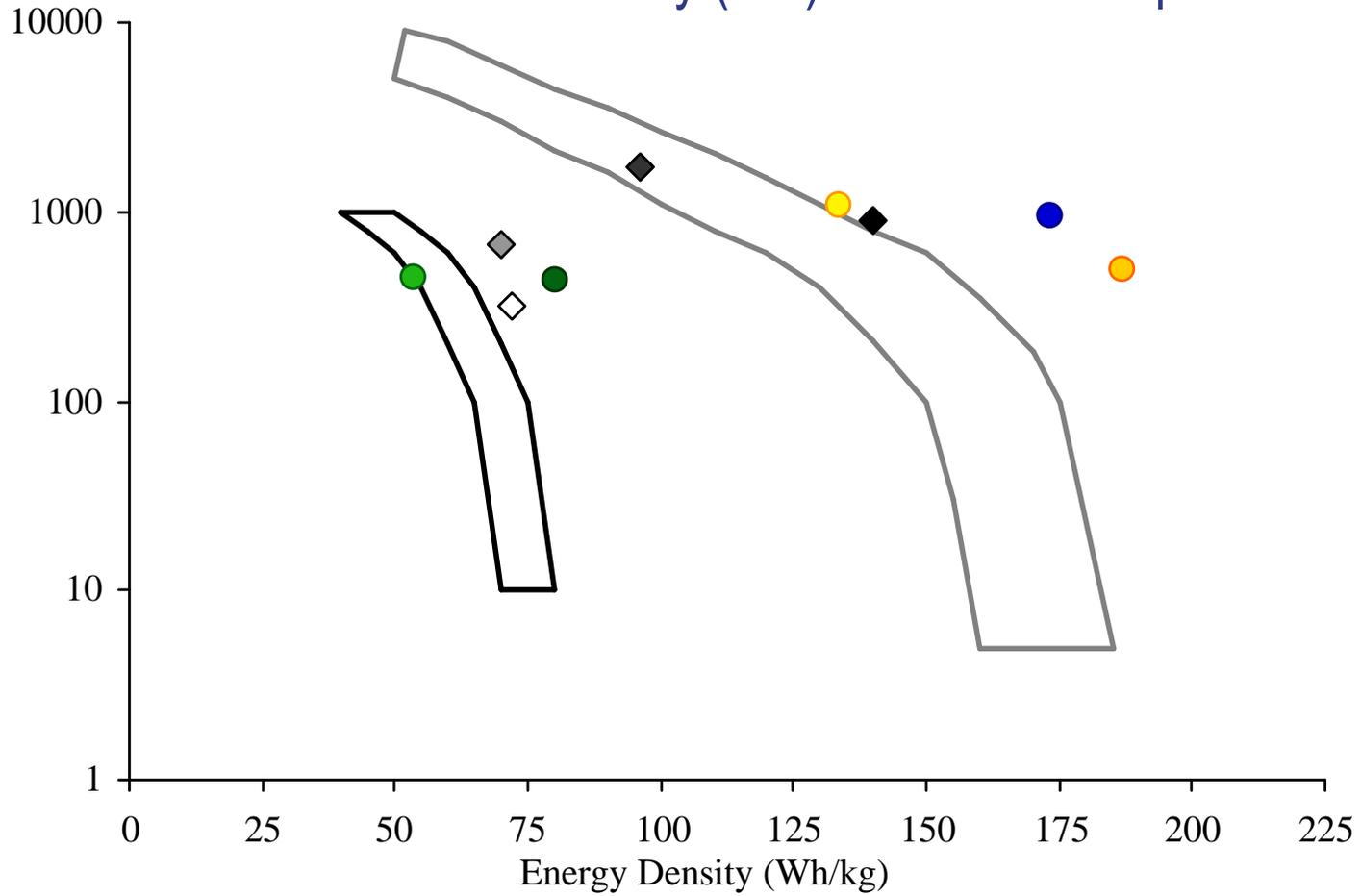
PHEV Designs from National Survey, n = 854



PHEV Designs, adding Demonstration Households

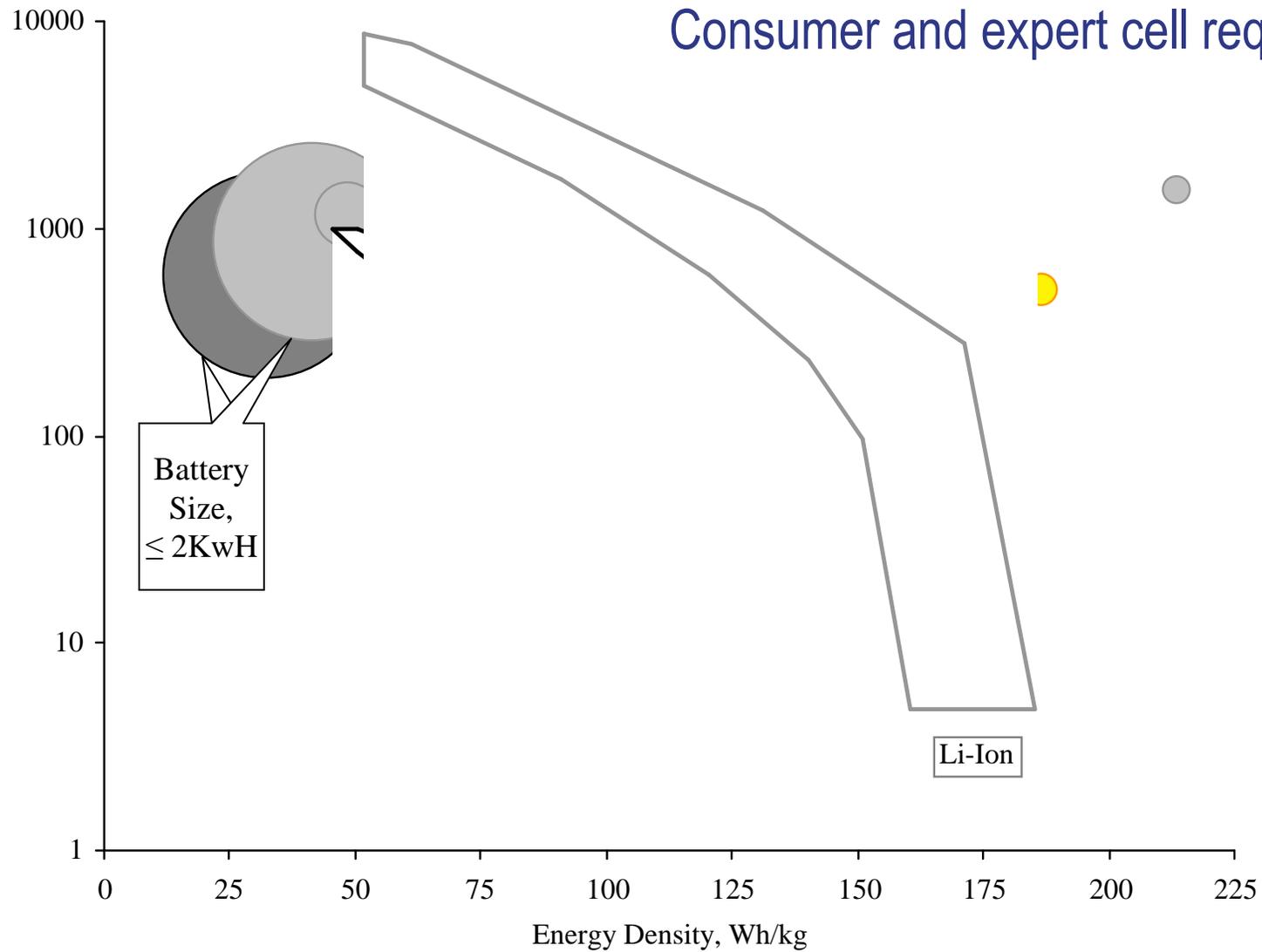


Battery (cell) values and requirements



- ◇ NiMH
- ◆ LMS
- ◇ LTO
- ◆ NCM
- EPRI_20
- EPRI_60
- USABC_10
- USABC_40
- MIT_30
- NiMH
- Li-Ion

Consumer and expert cell requirements



- UCD Cars
- UCD Trucks
- EPRI AE20 (car)
- EPRI AE60 (car)
- USABC AE10 (car)
- USABC AE40 (truck)
- MIT B30 (car)

Recharging conclusions

- People will plug in PHEVs, and many will do so more than once a day
 - Recharging behavior is variable across households
- Public infrastructure and social norms will likely result in more plugging in and increased variation in time-of-day demand
 - The “infrastructure problem” is likely the more than half of households who can’t recharge at home
 - Weekdays present greater problem and opportunity for electricity demand
 - Deeper time-of-day “trough” in demonstration households’ demand
 - Unconstrained by prices, technology, norms, or other mechanisms
 - Weekends, fewer vehicles plug-in and power demand is lower because fewer vehicles are at home

Driving and energy conclusions

- Consumers use of (gasoline-only) fuel economy to value PHEVs (vs HEVs) isn't qualitatively wrong
 - No households have created an integrated—gasoline + electricity—evaluation
 - Longer household placements?
 - More information in the car?
- Valuations are not “expert”
 - Gasoline bad; electricity less bad
 - Reduced frequency of fueling with gasoline
 - Perceived reduced spending on gasoline

PHEV Design Priority Conclusions

- Fuel economy is emphasized over all-electric operation
 - Blended, not all-electric operation
- Shorter CD range
- Consumers' PHEV designs point to very different batteries than experts' assumptions
 - Less expensive PHEVs in the near term as springboards to increased electrification of transportation

End