INFRASTRUCTURE MARKETS, STAKEHOLDERS, AND NEEDS THROUGH 2025-2030

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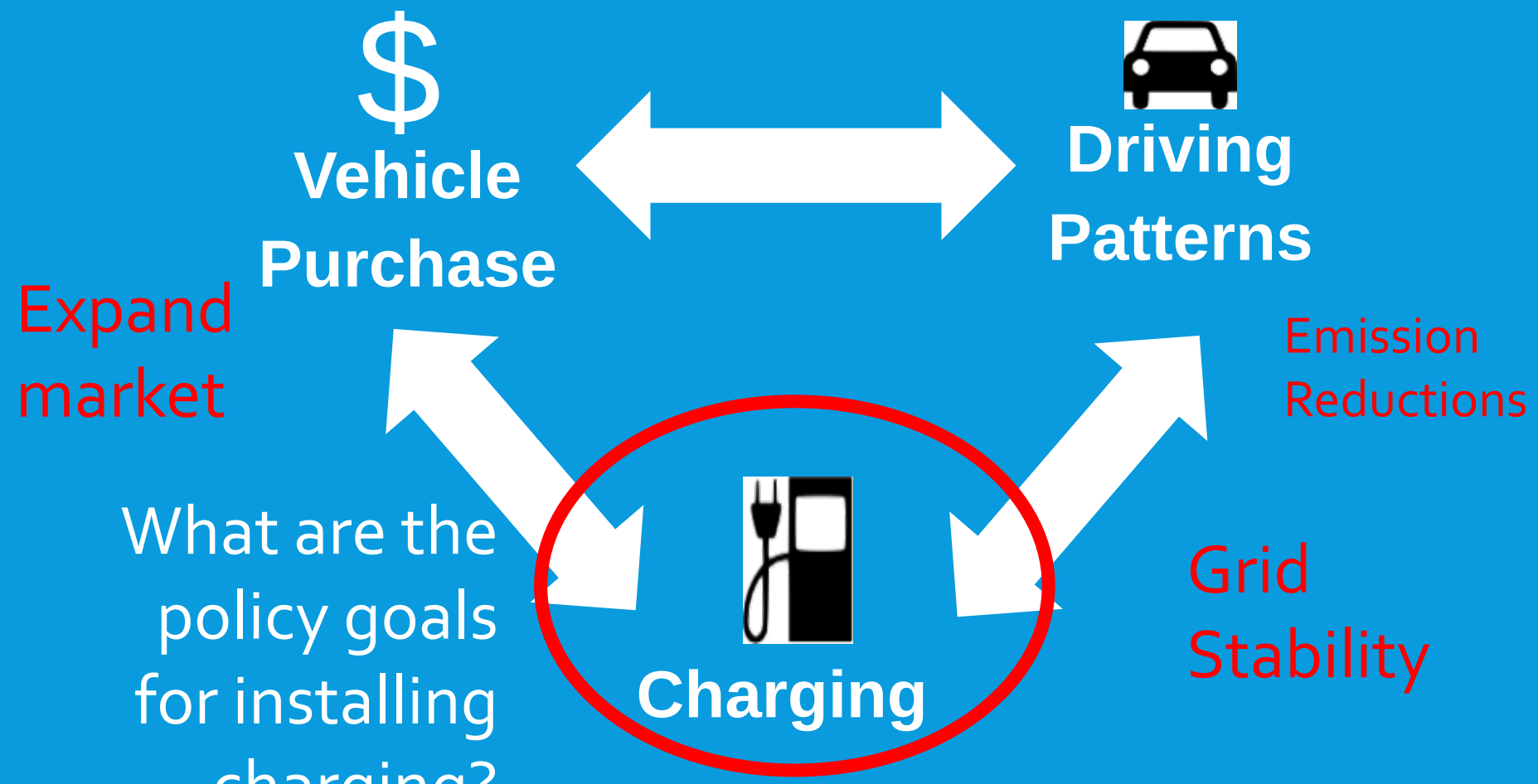
VEHICLE PURCHASE, DRIVING, AND CHARGING AFFECT EACH OTHER

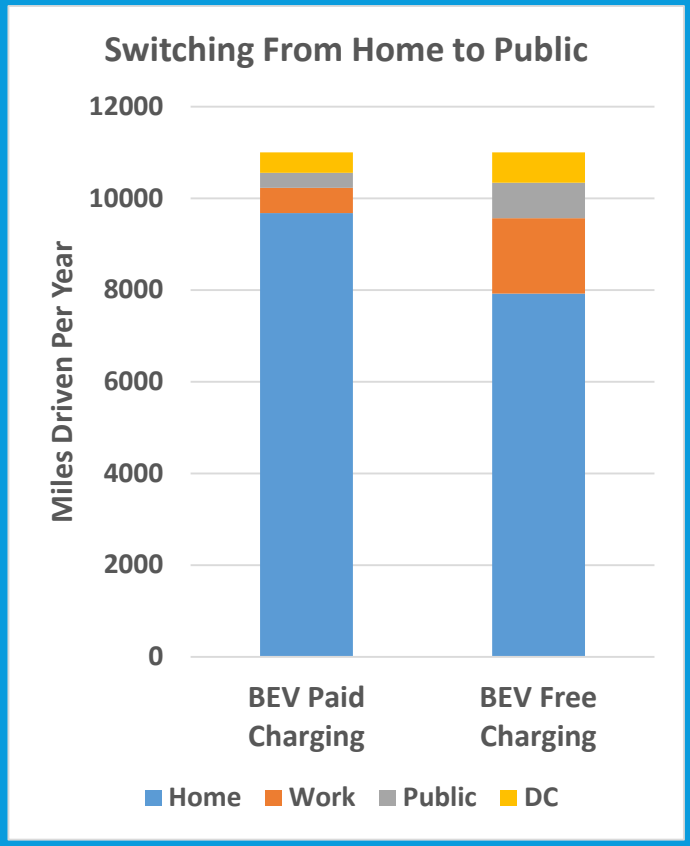


WHAT POLICY GOALS DO WE WANT TO ACCOMPLISH WITH CHARGING AND WHICH ONES CONTRADICT EACH OTHER?

- Increase PEV sales as a substitute for conventional vehicles
  - More chargers
  - Encourage free charging in public?
- Greatest displaced petroleum for least infrastructure cost
  - Fewer managed chargers (networked, "smart", etc.)
  - Make charging more expensive than home, but less than gasoline
- Reduce greenhouse gas and criteria pollutants
  - More managed chargers, charge at work on renewable power
- Help stability of the grid
  - Encourage work charging, more work charging

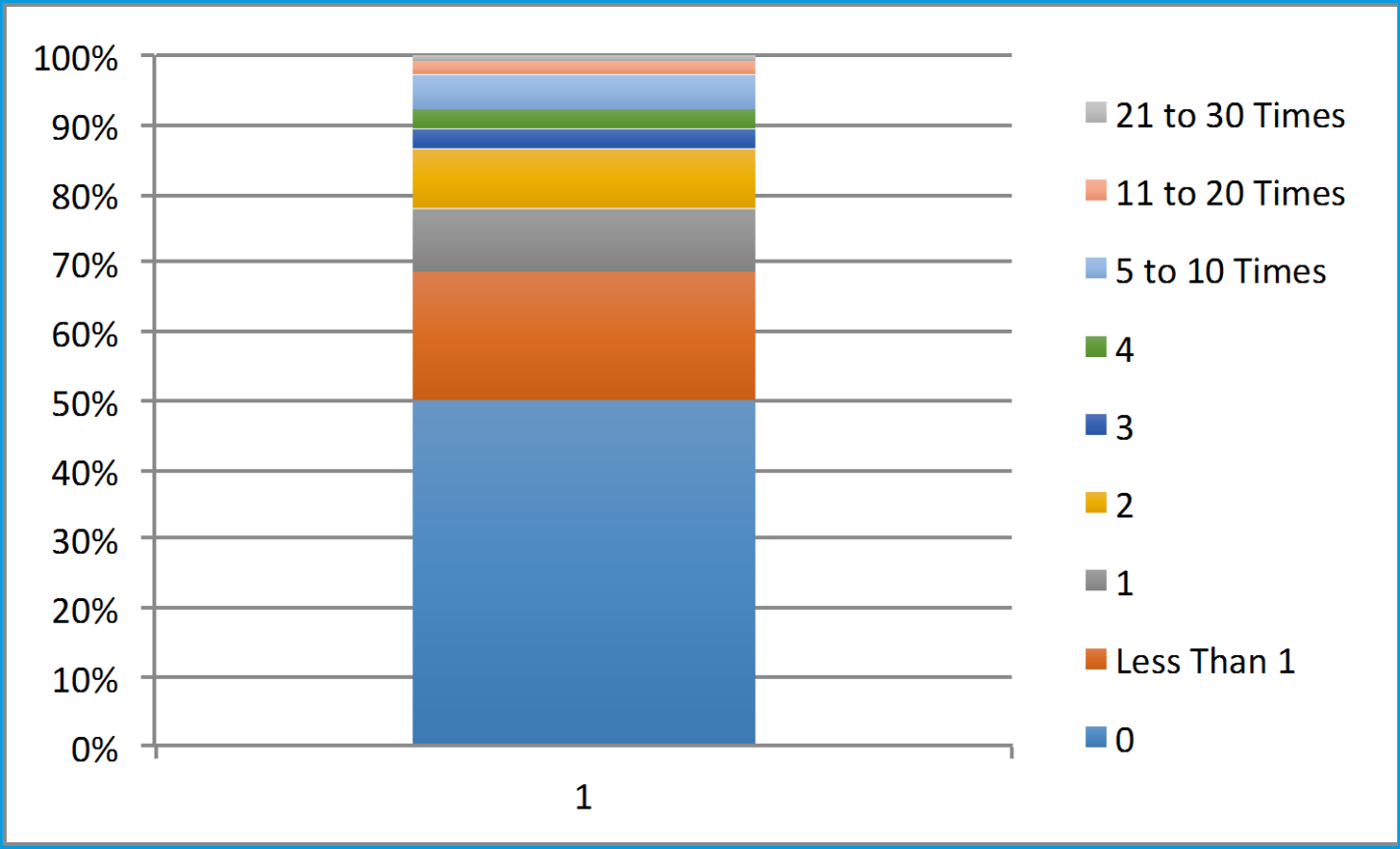
A TALE OF TWO BEVS: INCREASING CHARGER USAGE DOES NOT EQUAL INCREASED MILES

- Is switching charging from home to public with no increase in miles a success?
  - Sales – Maybe
  - eVMT – No
  - Emissions - Depends
  - VGI - Depends
- Who benefits? Who pays?



30 % OF BEV80S NEED CHARGING TO GET HOME AT LEAST ONCE/MONTH

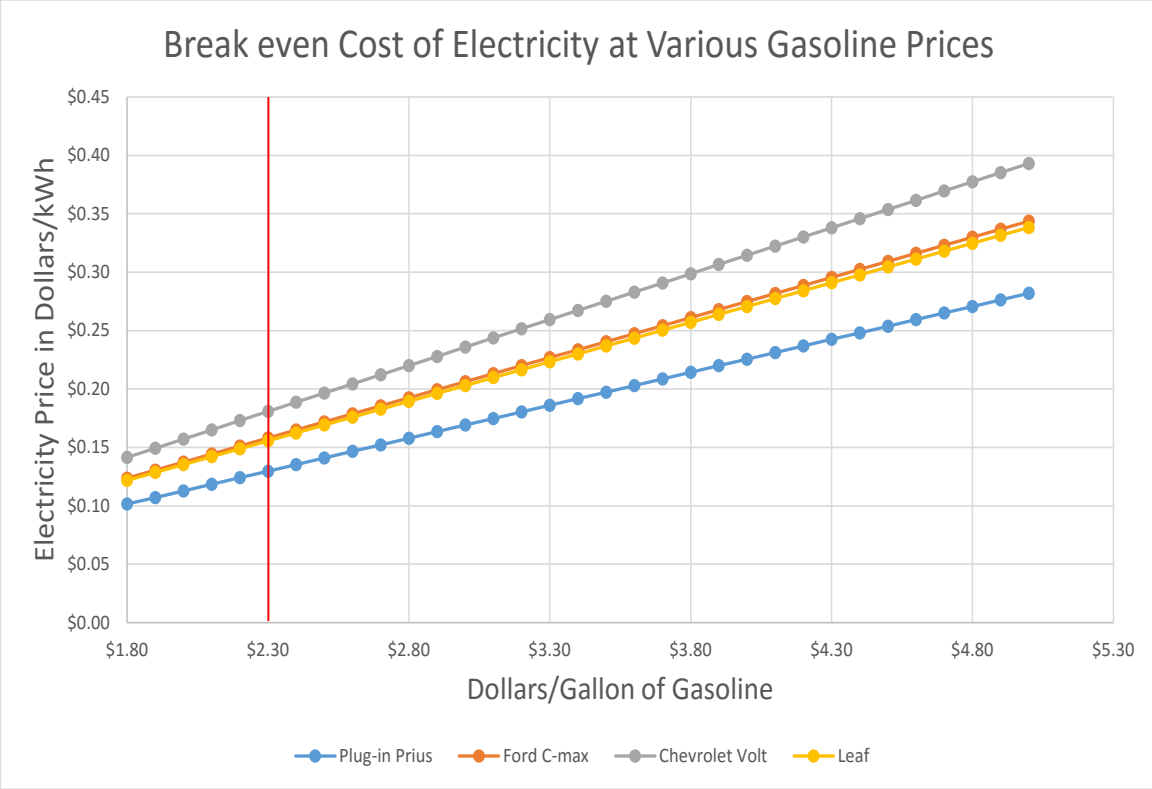
How many times in the last 30 days did you need out of home charging to complete your travel?



HOW DIFFICULT DOES FALLING GAS PRICES MAKE IT TO SELL ELECTRICITY?

- What are the economics of a charging station?
  - Buy a kWh at 10 cents
  - People will pay 13-18 cents/kWh
  - Costs Total 18 cents/kWh including charger
- If Gas is $2.30, Break-even cost for:
  - Plug-in Prius is 13¢/kWh
  - C-Max is 13¢/kWh
  - Volt is 18¢/kWh
- $5000 to install over 10 years equals 8 cents/kWh

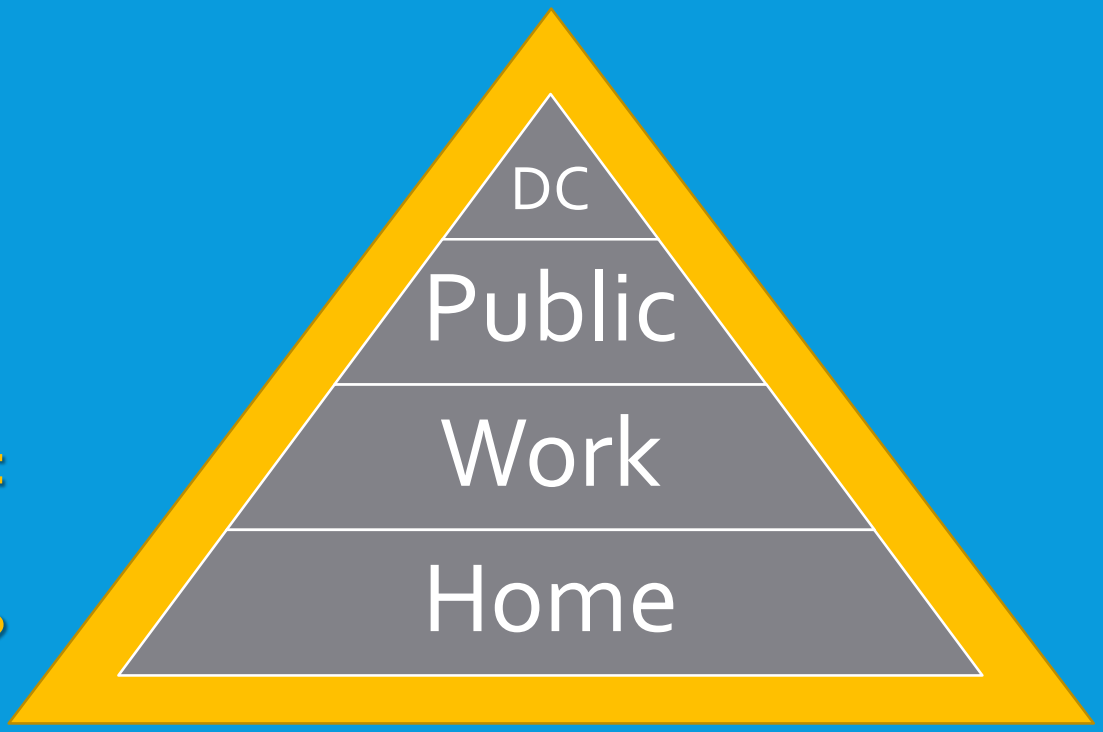
=Challenging business case



HOW SHOULD WE DESIGN AND PLAN FOR A CHARGING NETWORK ? A FRAMEWORK FOR DISCUSSION

Modeling – How to forecast for the future

In-Use Charger Data 2015: What do drivers do?



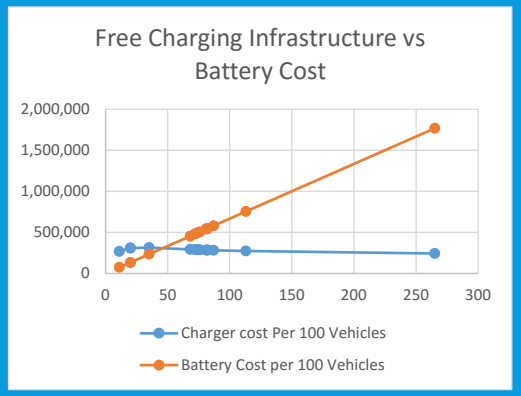
Surveys 2013-15: What do drivers want?

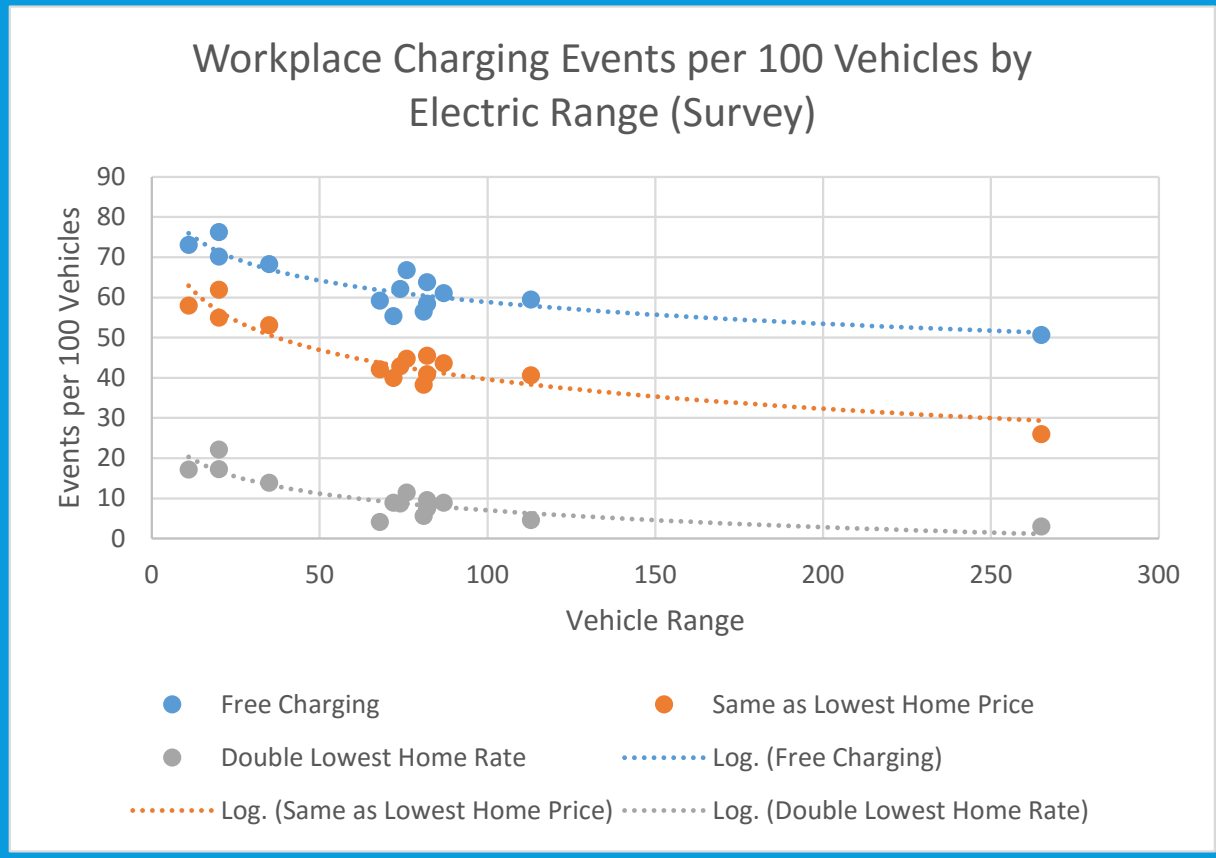
HOW DO LARGER BATTERIES SHAPE THE ROLE FOR CHARGING INFRASTRUCTURE?

- Expands the market for vehicles. Garage orphans may buy. Increases the demand for charging
- Decreases the need for away from home charging for those with garages
- Increases the utility of L2 at home
- Fast charging demand stays relatively constant
- Increases the flexibility for Vehicle-Grid Integration.
  - Public charging is more desirable than home charging. Solar/wind peaks.
  - Larger battery PHEV capacity is effectively used
  - Large battery BEVs relieve range concern. More will participate in VGI.

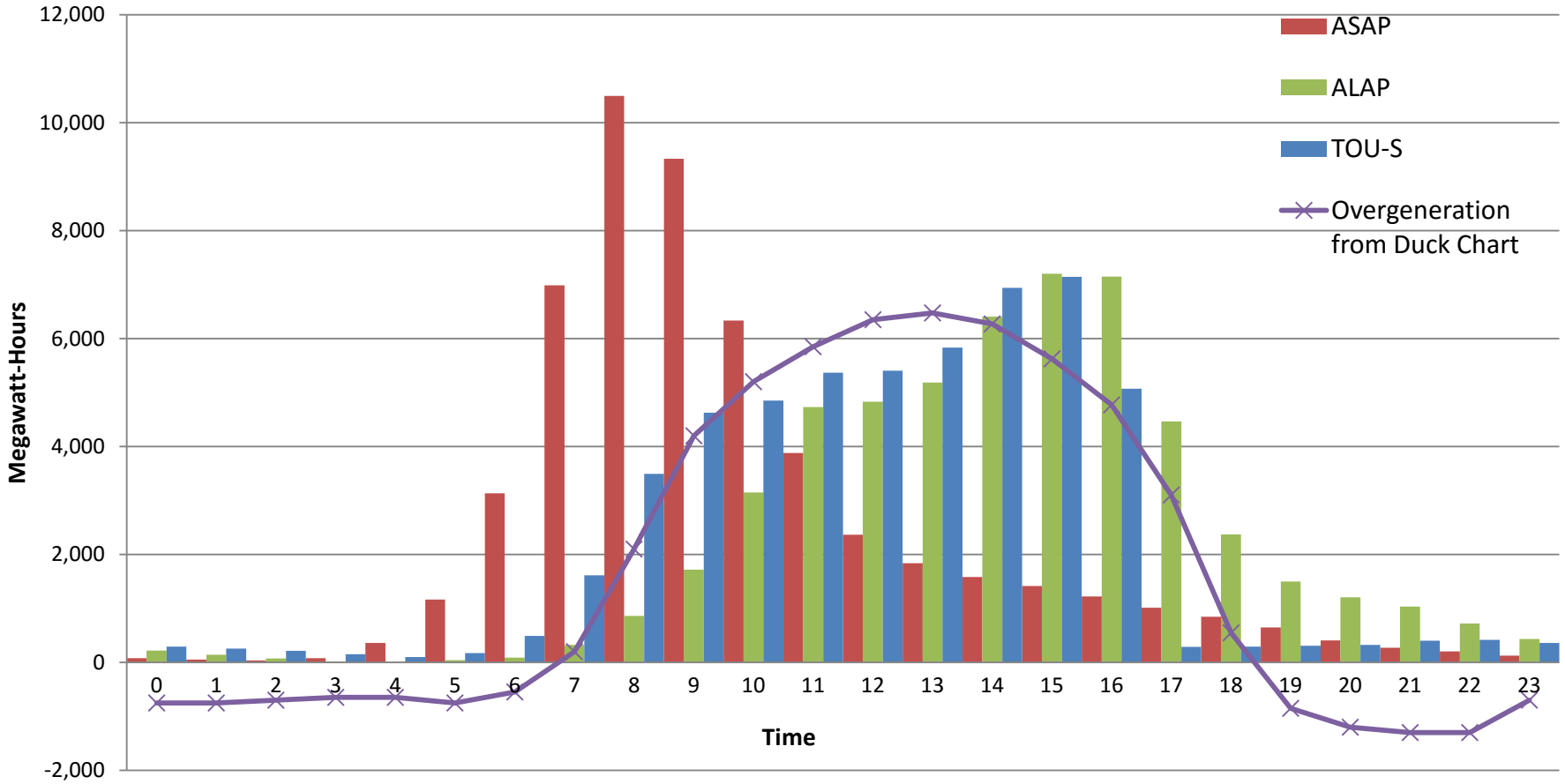
RESPONSE TO PRICE AT THE WORKPLACE SHOWS RANGE IS A SUBSTITUTE FOR CHARGERS

- In the charger or on the hood?
- Charging cost for vehicles vs Battery cost for vehicles
  - Free - any range above 45-55 miles chargers are cheaper
  - Home price – above 20-30 miles chargers are cheaper
  - Double home price – chargers are always cheaper than the batteries

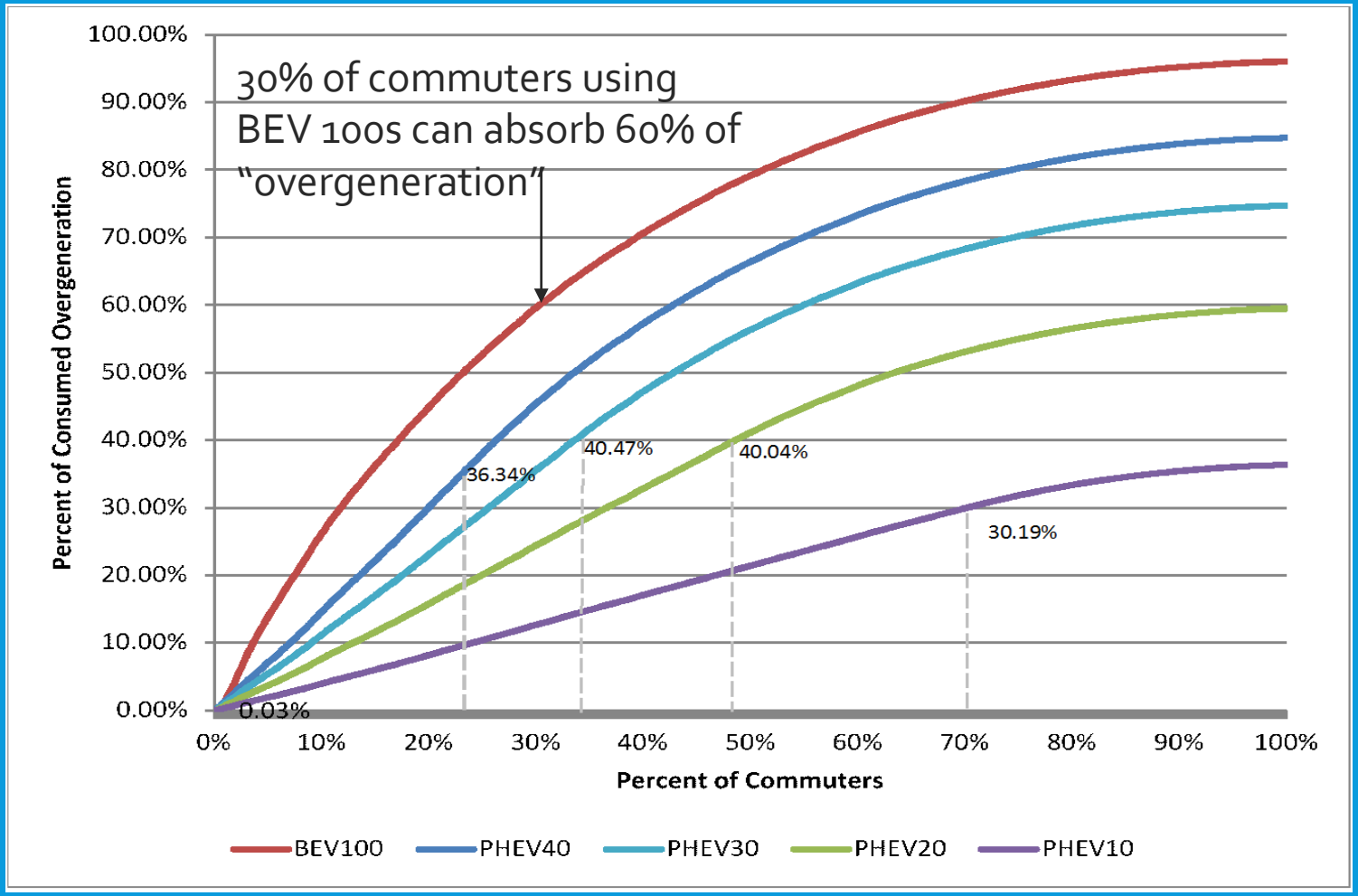




WHAT IF WE WANTED TO SWITCH ALL CHARGING TO WORK FOR SOLAR VGI?



BEVS HAVE LARGER BATTERIES BUT PHEVS HAVE RISK TOLERANCE



SUMMARY

- Different policy goals result in different strategies for charger needs. Policy makers must decide what the goals are.
- Free charging is expensive from an infrastructure point of view
- Range is a substitute for charging and batteries are getting larger. Large BEVs may only use L2 at home or fast charging. PHEVs maybe the primary users of public L2
- V2G matches workplace charging demand
- Managed charging at a low cost will address many policy goals.
- Selling electricity is not profitable accounting for installation and low gasoline prices. Role for policy to cover Capital?
  - Infrastructure costs 8 cents/kWh
  - Admin costs cents 2-4 cents/kWh
  - Electricity cost 10 cents/kWh
- If break even costs are 15 cents what will fill in the gap?
  - EV feel? VGI low cost electricity? Policy intervention? Gas increase?

RECOMMENDATIONS

- Mix of power levels to match usage. L1, L2, DC Fast
- Home –
  - Level 1 is being used effectively at home even for small battery BEVs
  - Major barrier is utility rate structure and cost of electricity vs gas
- Work –
  - Only 30% of people need workplace charging to return home on electricity
  - Congestion is caused by lack of chargers *and* inefficient use
  - Pricing should be encouraged where practical
- Public
  - Public charging can be work charging and vice versa (20%)
  - Retail public charging is more often an amenity than a real benefit
- Fast Charging
  - Network is too sparse to encourage reliable long distance charging. Consider "charging plazas" to increase reliability
  - Fast charging is a backup to level 2 and should be encouraged as a companion where level 2 congestion is likely (near workplace).

QUESTIONS?

Thank you

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