What Plug-in Hybrid-Electric Vehicles Can Do for the Grid?

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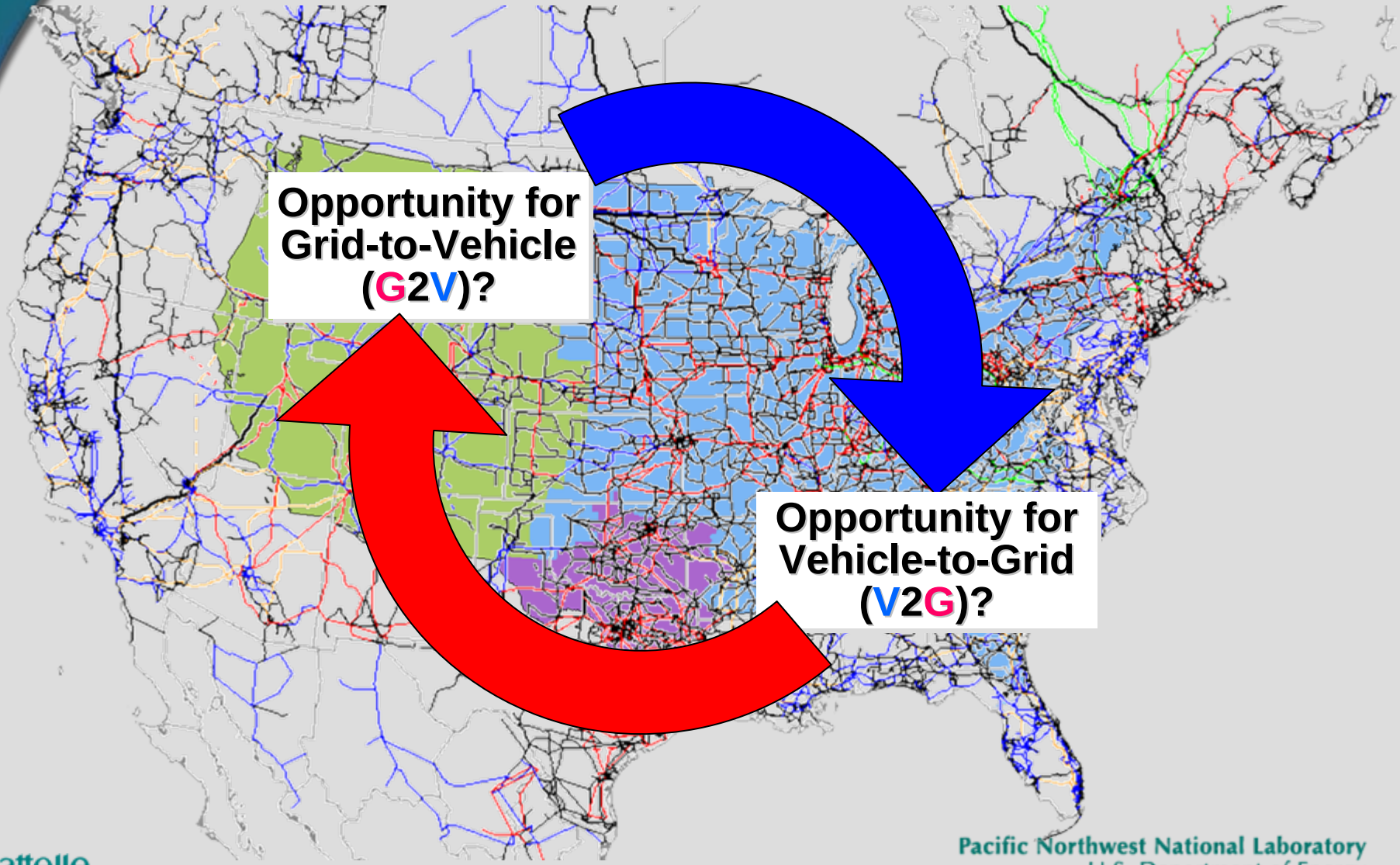
What is the Opportunity for PHEVs and EVs?



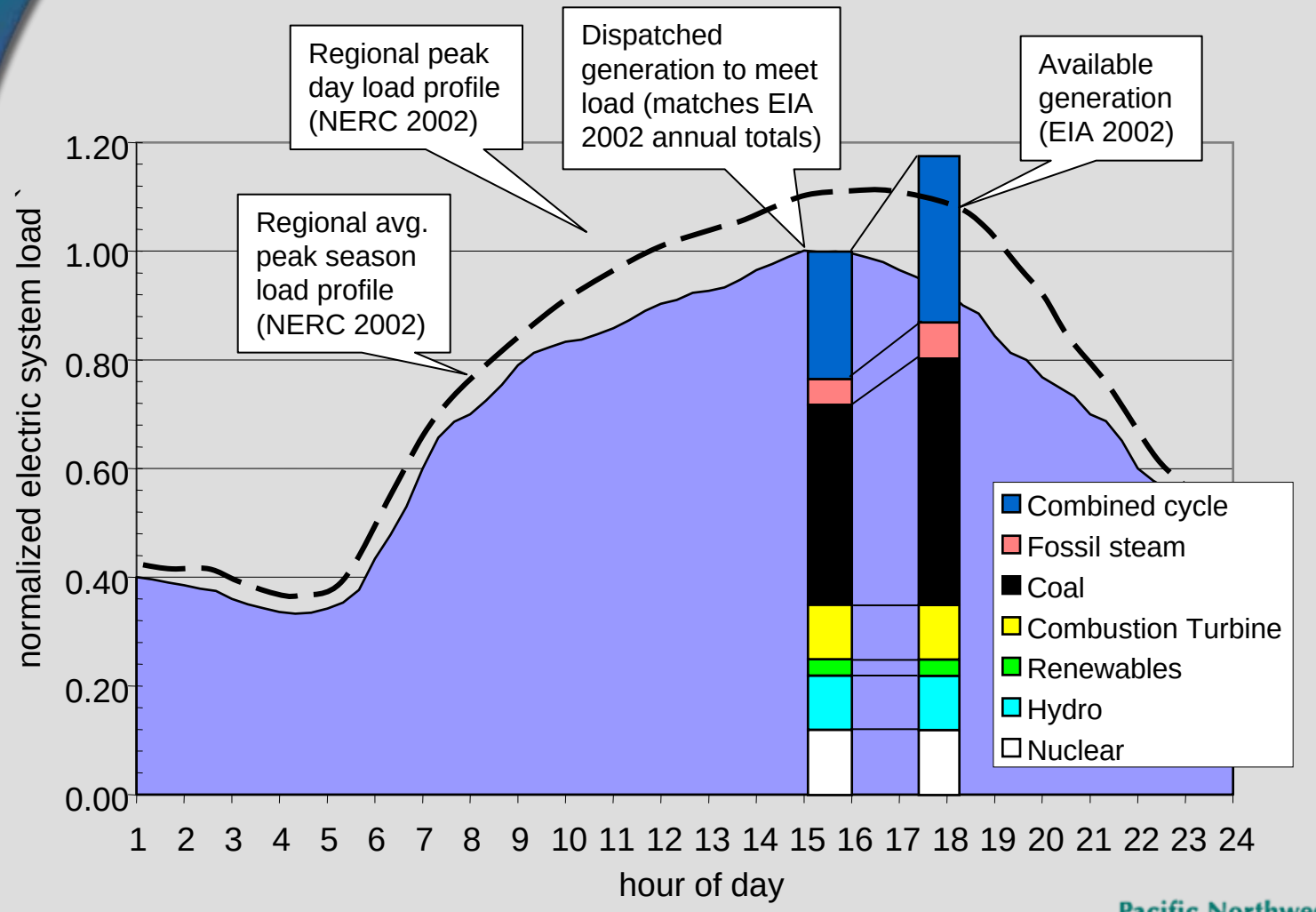
Grid Impact Study* of High Penetration Scenarios for PHEVs

Can the U.S. electric grid become a strategic national asset for addressing our dependence on foreign oil?

- How much energy could the idle capacity of the grid deliver for the U.S. light duty vehicle fleet (cars, pickups, SUVs, vans)?
  - assume grid looks much like today's (worst case; likely to be cleaner)
  - assume vehicle mix is unchanged (worst case; likely to be lighter)
  - i.e., don't allow outcome to be driven by assumptions about the future power plant mix or vehicle fleet
- What would be some of the impacts be on:
  - gasoline/crude oil displacement
  - emissions
  - utility revenue requirements

** funded by Office of Electricity Delivery and Energy Assurance*

Fundamental Approach 1: Determine Available Marginal Generation

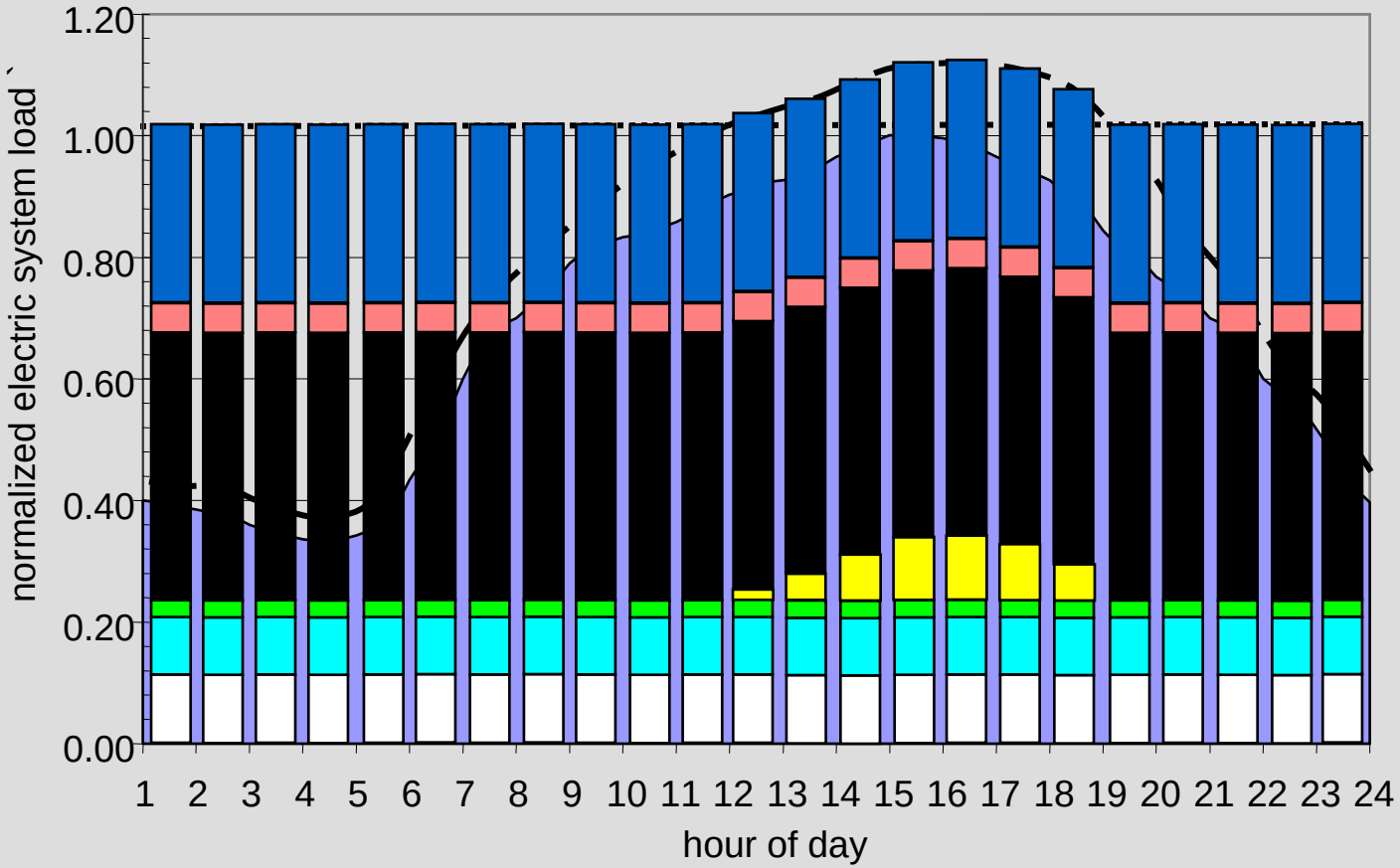


Assumptions:

No <u>additional</u> generation from existing:

- *Nuclear*
- *Hydro*
- *Renewables*
- *Combustion Turbines (peaking plants)*

Fundamental Approach 2: "Fill the Valley" in the Load Shape

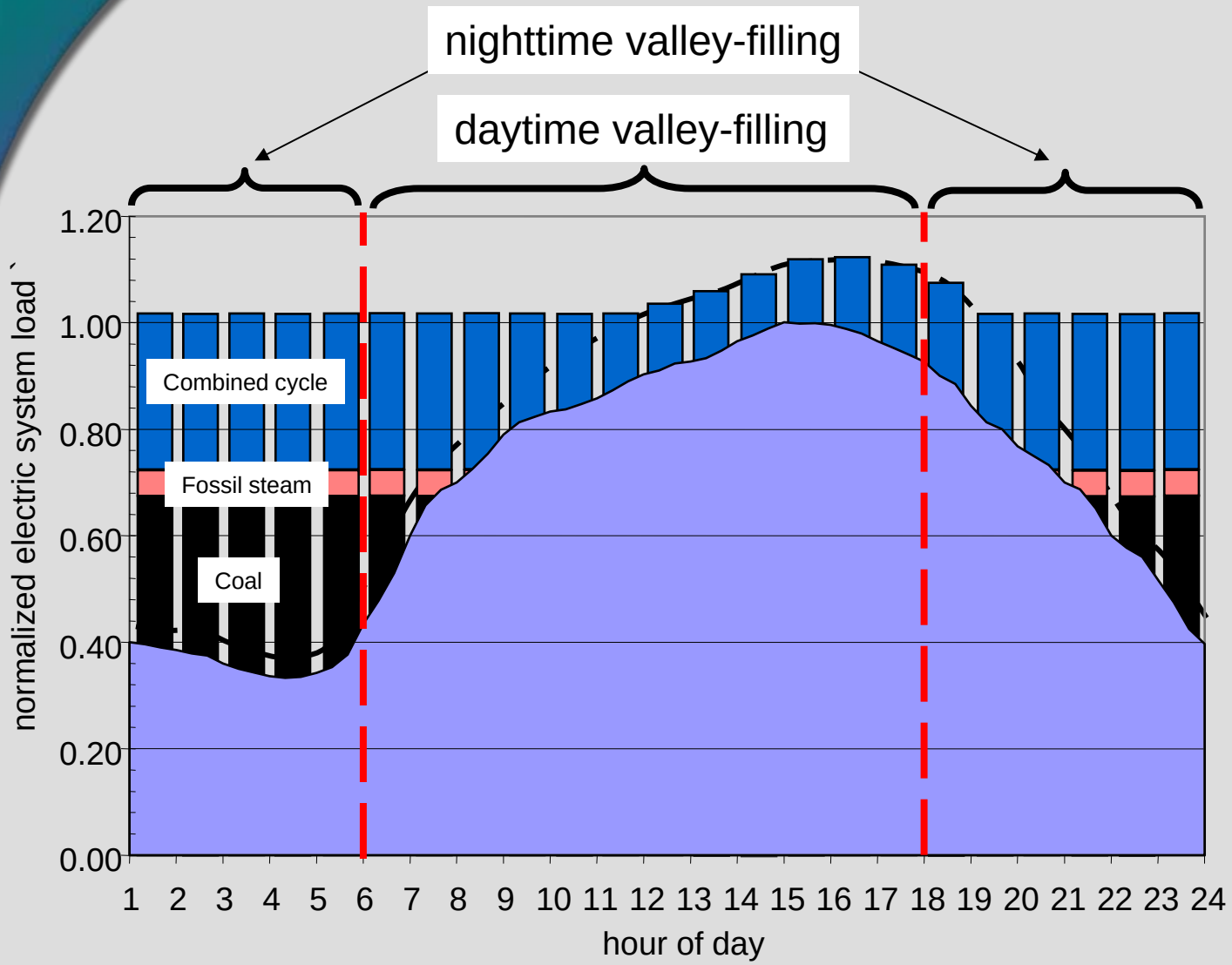


Assumption:

Additional valley-filling generation constrained to lesser of:

- *Available marginal generation @ 85% capacity factor*
- *Peak load*

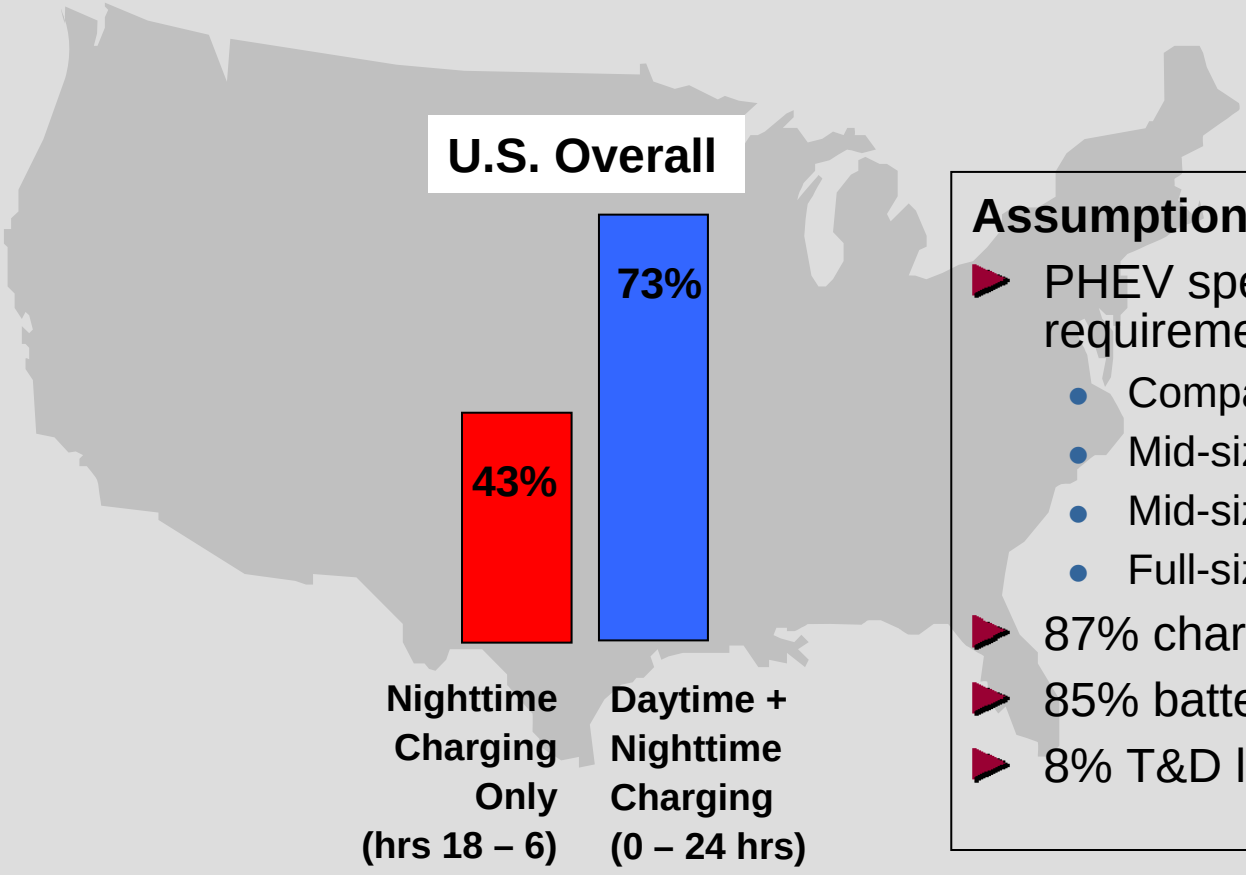
Coal, Nat. Gas Power Plants Fill the Valley



Summary

- Determine size of valley in MWh
  - Floor: average day in the peak season
  - Ceiling: lesser of available marginal generation @ 85% or peak load
- No marginal added generation in valley from:
  - Hydro
  - All other renewables
  - Nuclear
  - Peaking plants

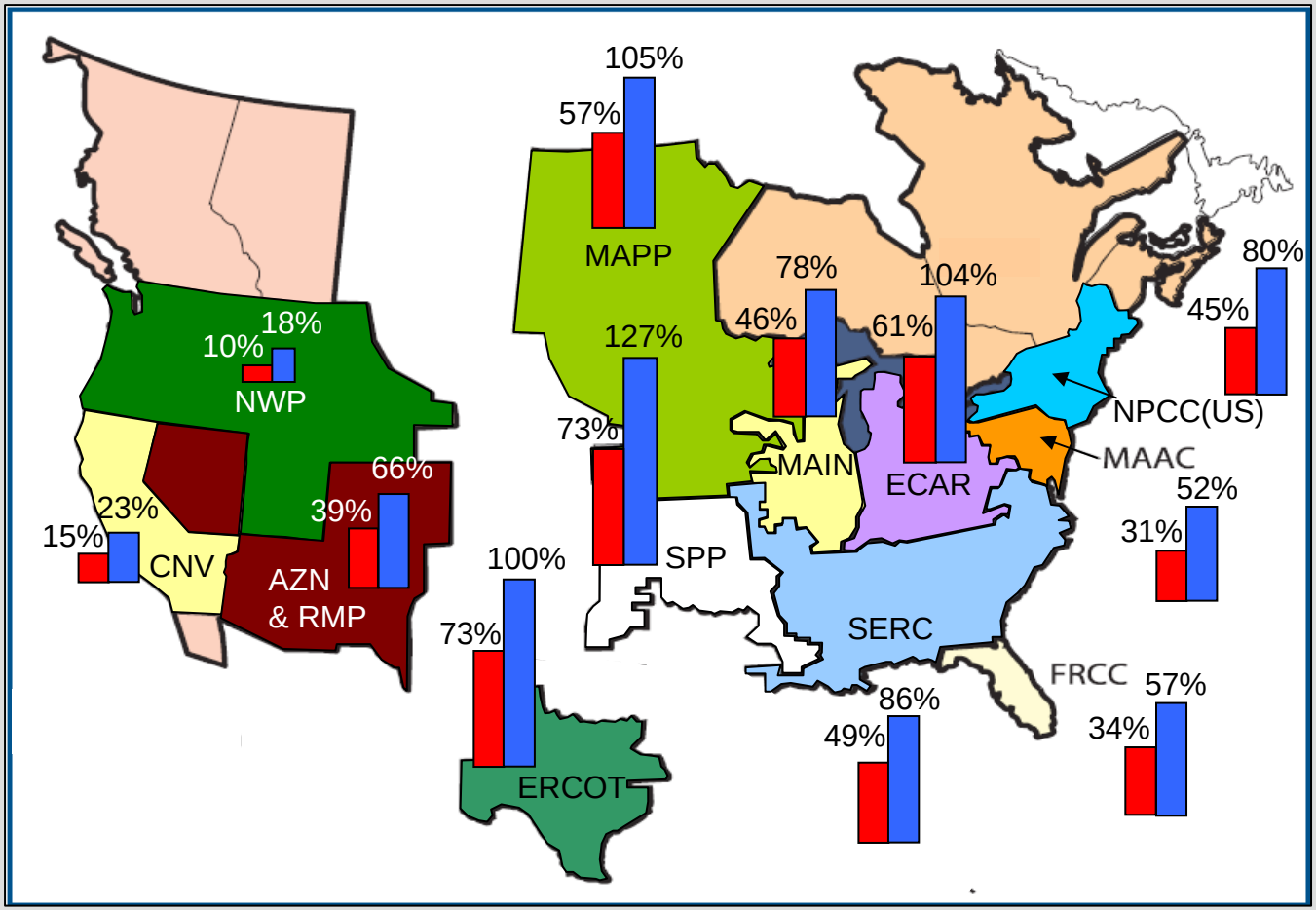
Over 70% of the existing U.S. light-duty vehicle fleet (if PHEVs) could be fueled with available off-peak electric capacity



Assumptions

- PHEV specific energy requirements (EPRI 2004):
  - Compact 0.26 kWh/mi
  - Mid-size 0.30 kWh/mi
  - Mid-size SUV/Vans 0.38 kWh/mi
  - Full-size SUV 0.46 kWh/mi
- 87% charger efficiency
- 85% battery efficiency
- 8% T&D loss

Analysis by NERC Region*



Nighttime Charging Only (hrs 18 – 6)

Daytime + Nighttime Charging (0 – 24 hrs)

Summary

- Midwest: support almost the entire LDV fleet
- East: somewhat smaller potential
- West: supports fewer vehicles

% figures denote the percentage of LDV fleet supported by idle electric capacity

Increased Sales of Electricity from PHEVs Produce Downward Pressure on Electricity Rates*

Increased sales

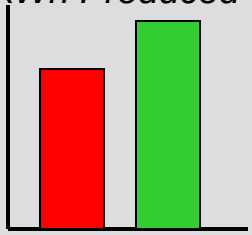
+

Same infrastructure, same capital investment

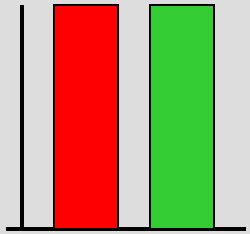
=

Lower electricity rates

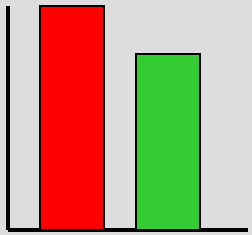
kWh Produced



MW Capacity, Capital Investment

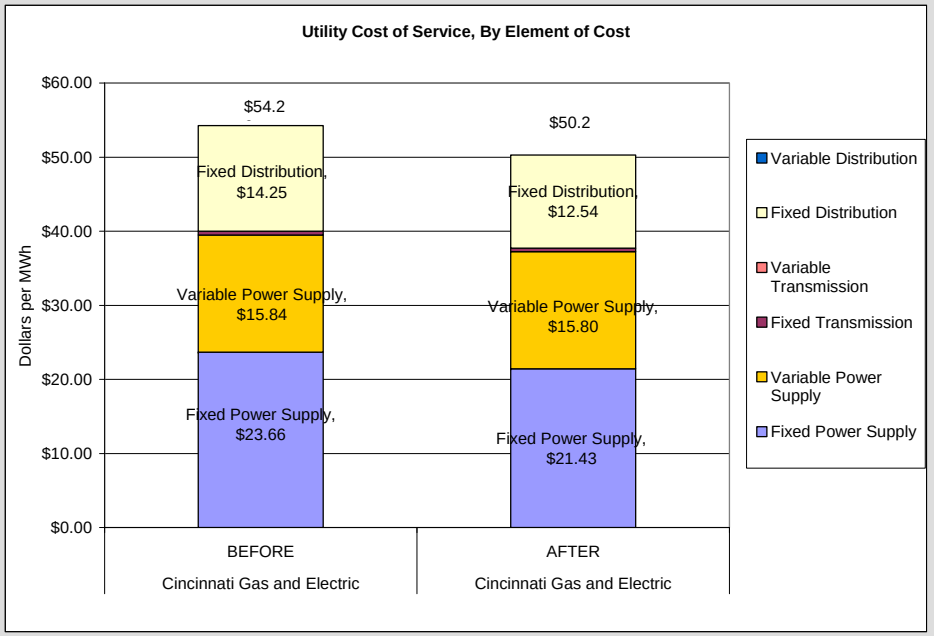


$/kWh



* analysis of Cincinnati Gas & Electric and San Diego Gas & Electric

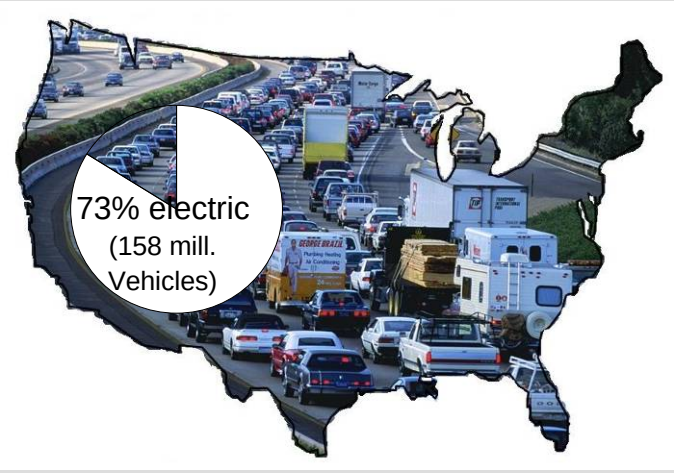
Cincinnati Gas & Electric Costs/MWh with PHEV Valley Filling

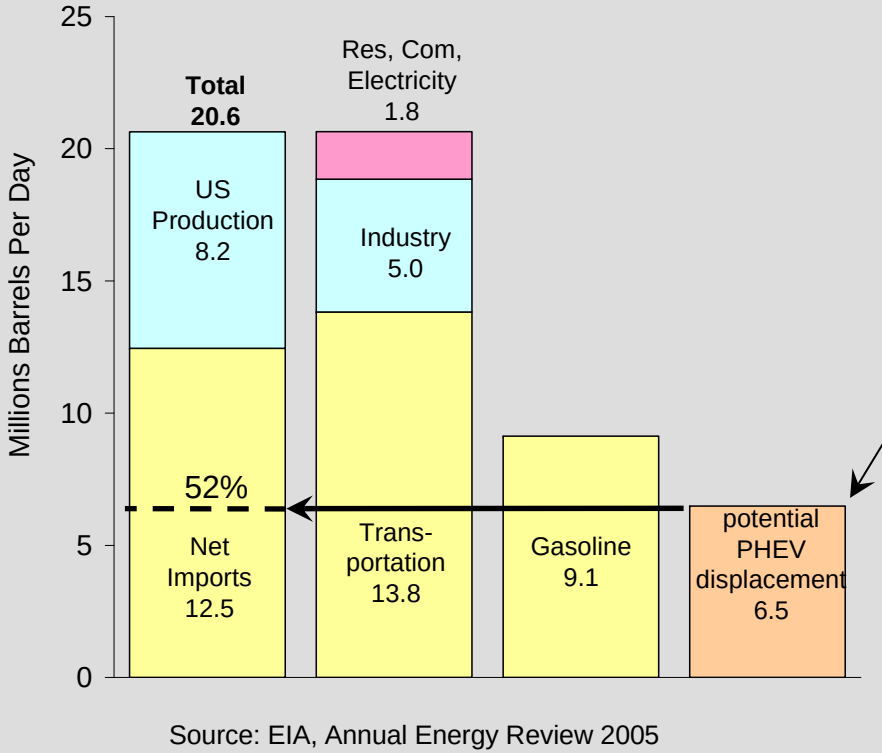


Opportunity of National Significance

The idle capacity of the U.S. grid **could supply 73%** of the energy needs of today's cars, SUVs, pickup trucks, and vans…

without adding generation or transmission

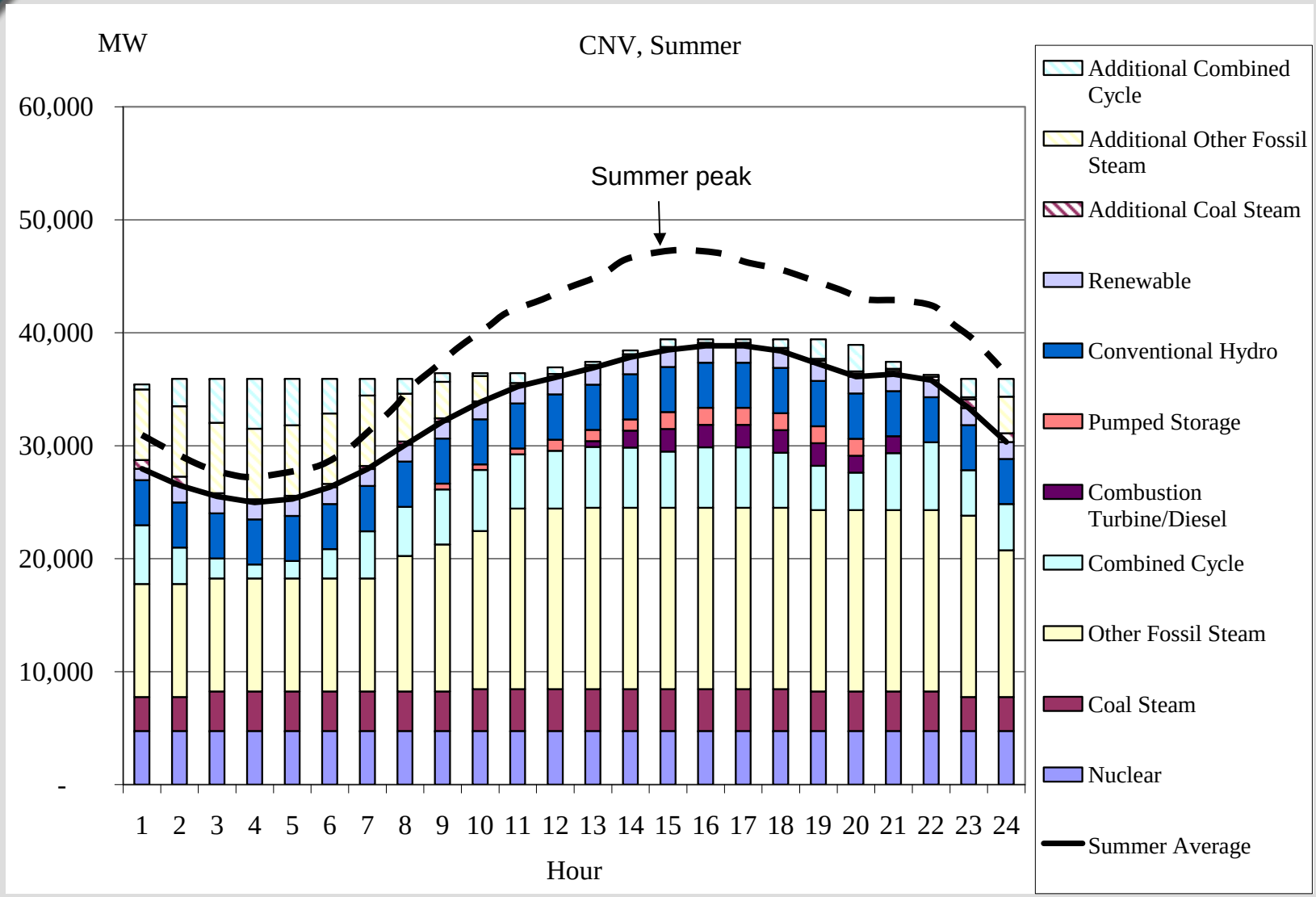




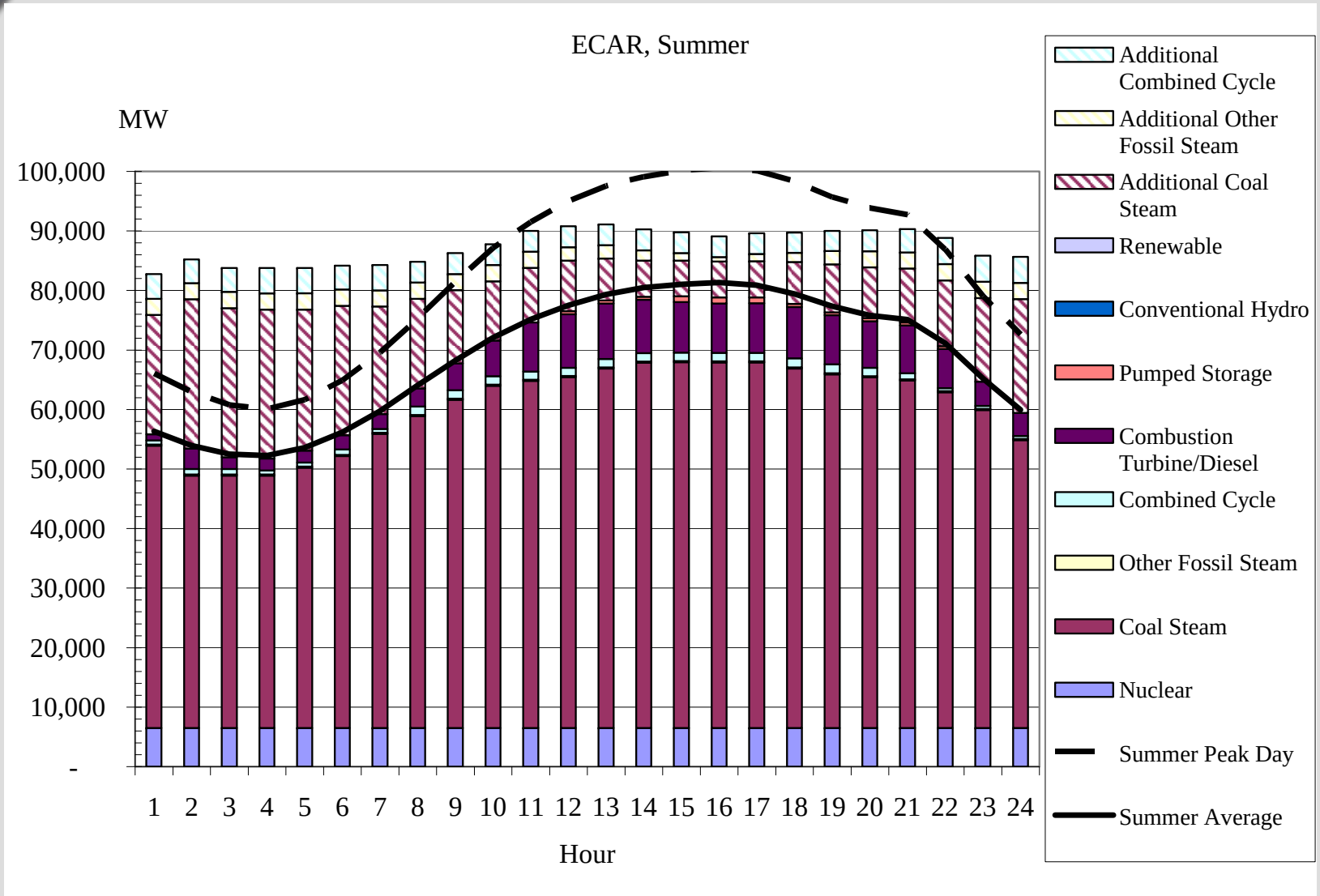
Source: EIA, Annual Energy Review 2005

- Potential to displace 52% of net oil imports (6.7 MMbpd)
- More sales + same infrastructure = downward pressure on rates
- Reduces CO_2 emissions by 27%
- Emissions move from tailpipes to smokestacks (and base load plants) … cheaper to clean up
- Introduces vast electricity storage potential for the grid

Current Generation and "Valley-Filling" CNV, Summer



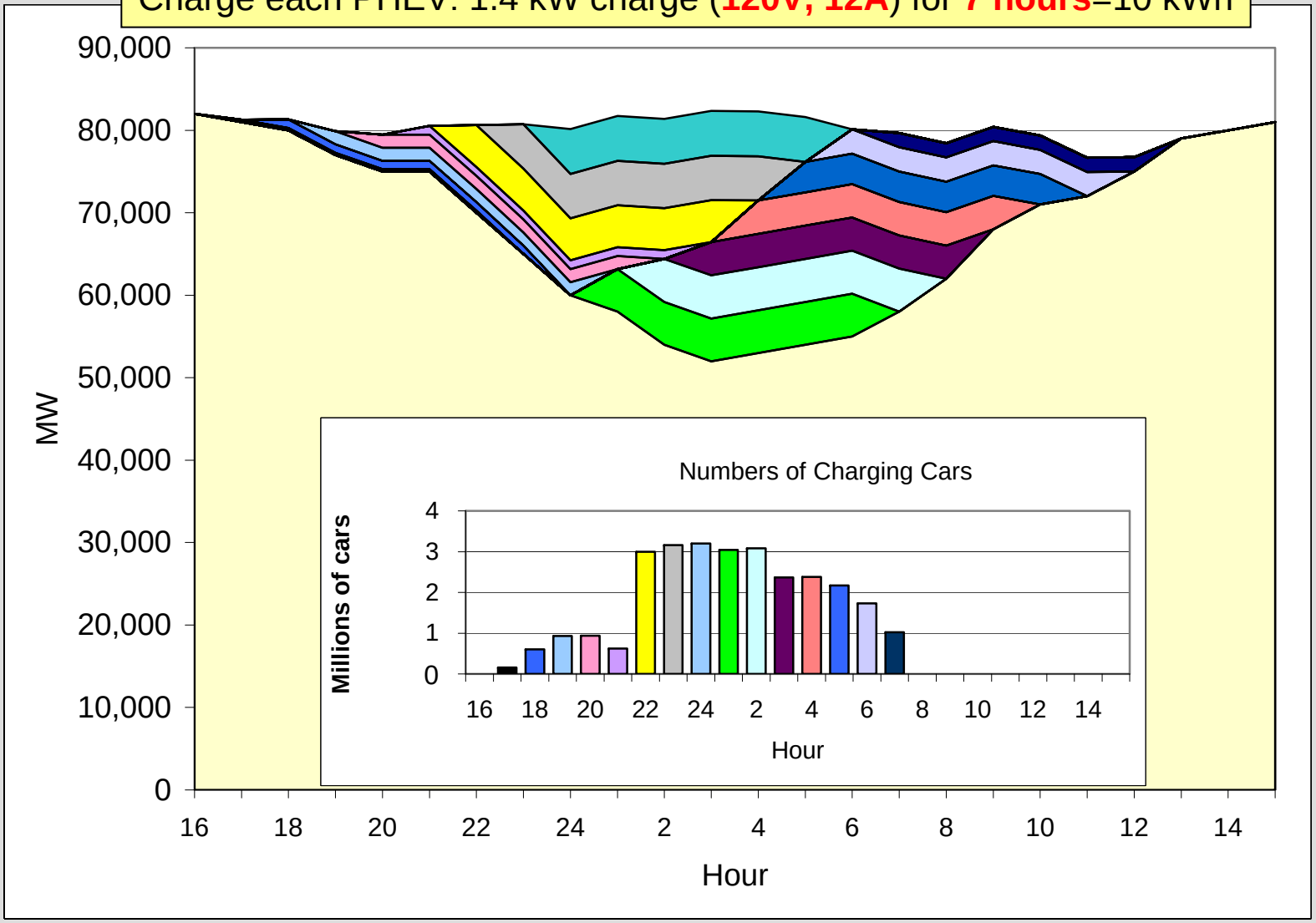
Current Generation and "Valley-Filling" ECAR, Summer



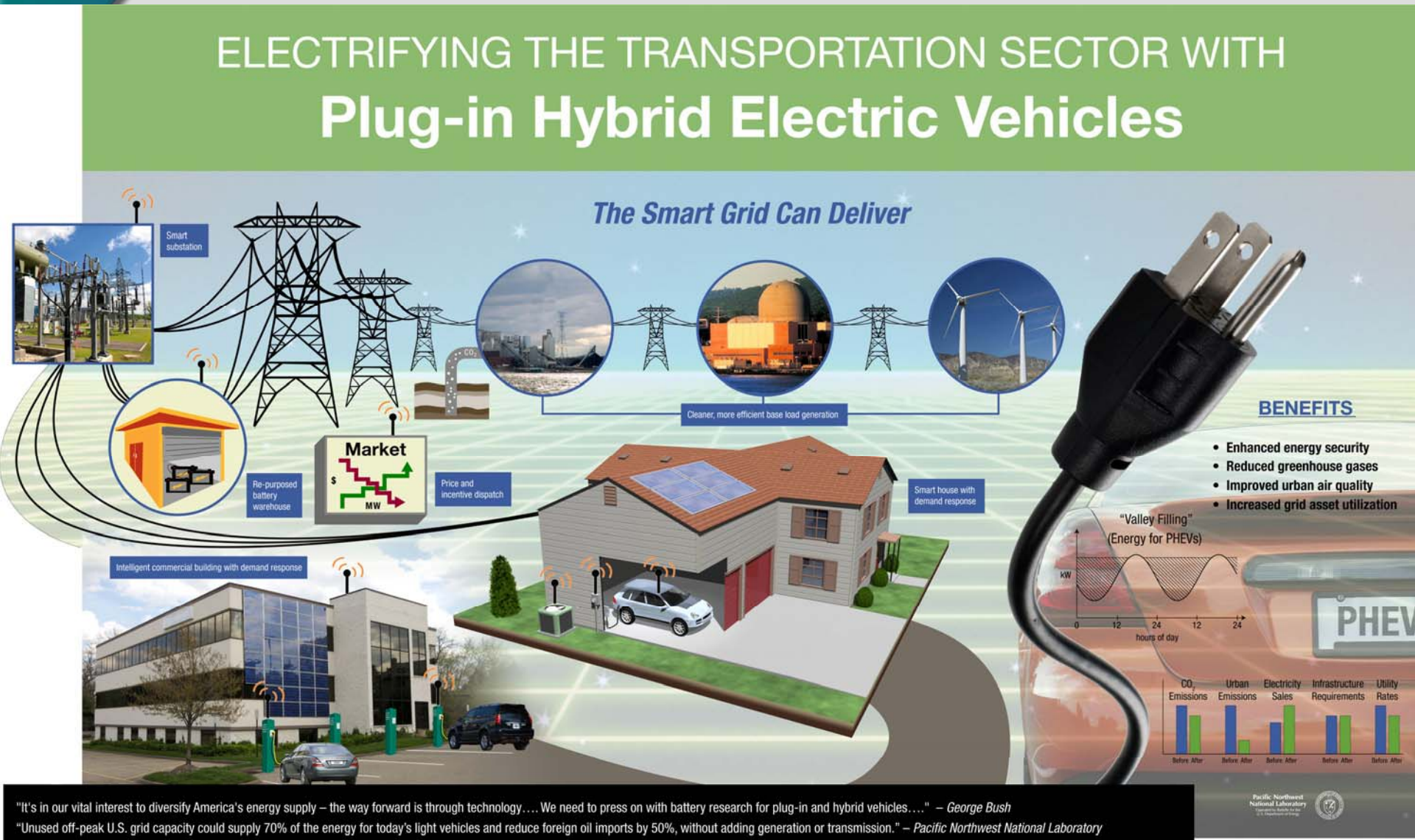
Perfect Valley Filling

ECAR Summer Load Profile

Charge each PHEV: 1.4 kW charge (**120V, 12A**) for **7 hours**=10 kWh



Smart Grid Can Deliver Electricity to Millions of PHEVs



"It's in our vital interest to diversify America's energy supply – the way forward is through technology…. We need to press on with battery research for plug-in and hybrid vehicles…." – *George Bush*

"Unused off-peak U.S. grid capacity could supply 70% of the energy for today's light vehicles and reduce foreign oil imports by 50%, without adding generation or transmission." – *Pacific Northwest National Laboratory*

"Nationwide adoption of plug-in hybrids will increase the use of domestically produced electricity and can ultimately reduce greenhouse gas emissions by up to 800 million tons per year." – *EPRI*

"Rarely in history has an emerging technology offered such an attractive opportunity … as both a new load and resource, to enhance overall performance of the electric power infrastructure." – *National Renewable Energy Laboratory*

"Working with automakers and local utilities, we need to understand how large numbers of PHEVs will be used, and their effect on the grid." – *University of Michigan*

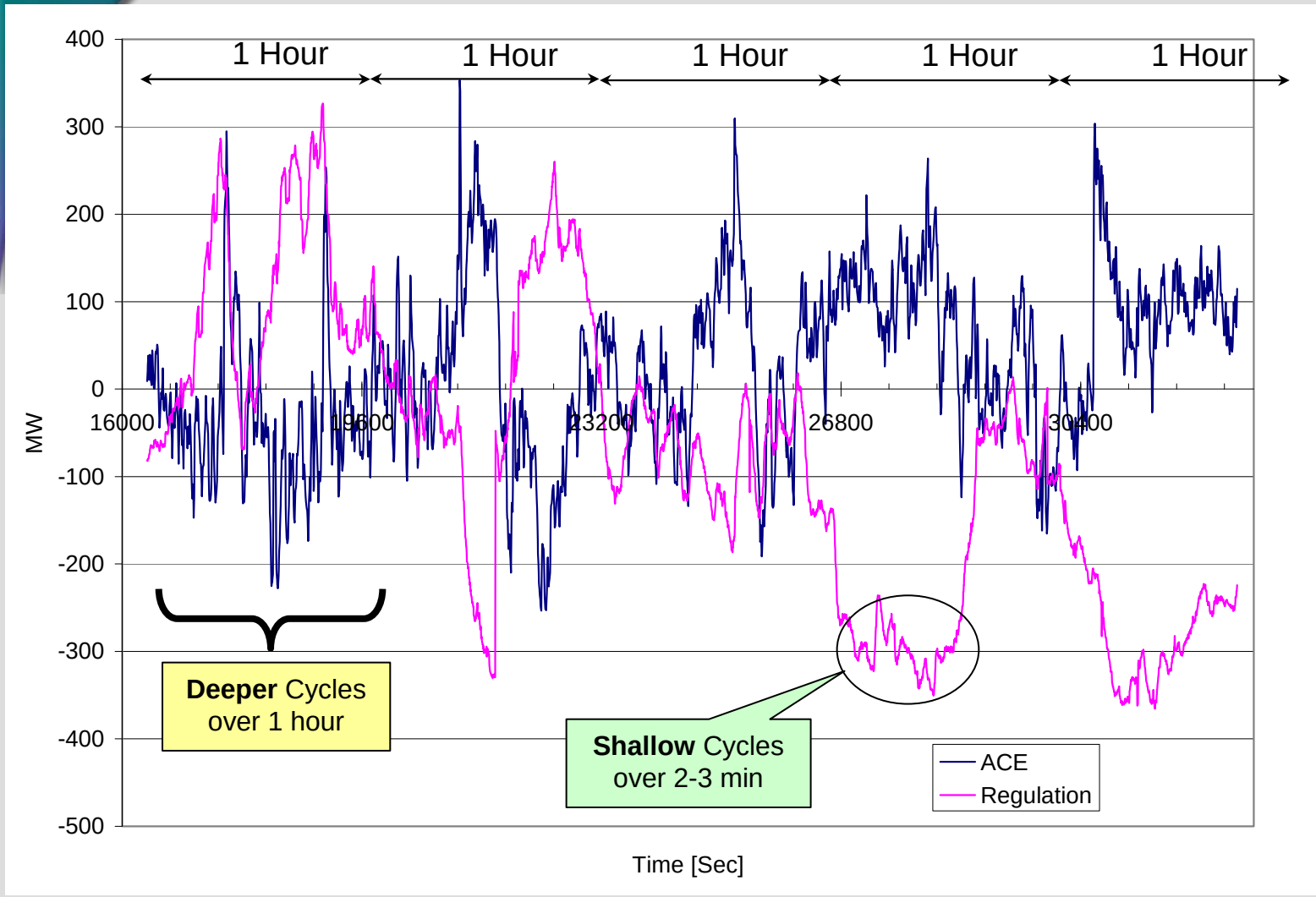
Why Is There So Much Talk About V2G?

- Customer's perspective:
  - PHEV economics are unclear given other competing alternatives. Revenue (cash-back) for grid-services may provide more economic incentives for rapid market growth
  - V2H (vehicle-to-home) provides backup power
- Utility's perspective:
  - Energy storage is desirable for grid operation
    - Regulation and spin reserve purpose
    - Economic dispatch
  - Meeting growing ancillary services requirements because of RPS
    - CAISO: Current regulation: 350 MW, with RPS: 500-700 MW
    - BPA: Current regulation: 150 MW, with RPS: 500+ MW
  - Innovative ownership model of PHEV batteries
    - Leasing to Owner
    - Re-purposing batteries after life for transportation
  - Carbon credits

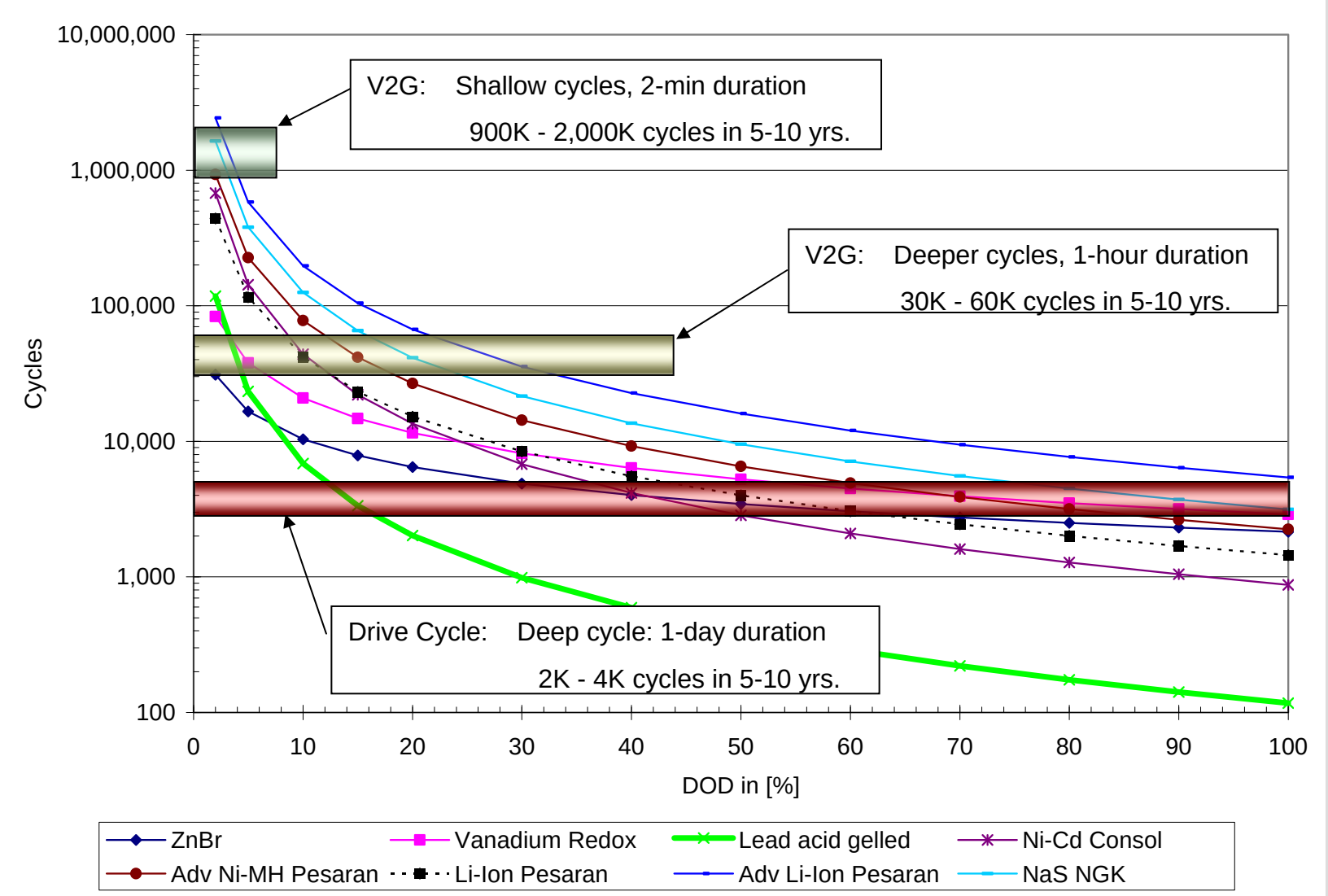
Migration from Smart Charging to V2G

- Smart charging is:
  - Grid-aware
  - Cash-back from regulation services ($2 - $5K) to offset the higher first cost of
  - Batteries
  - Communications
  - Metering

Regulation Signals for California

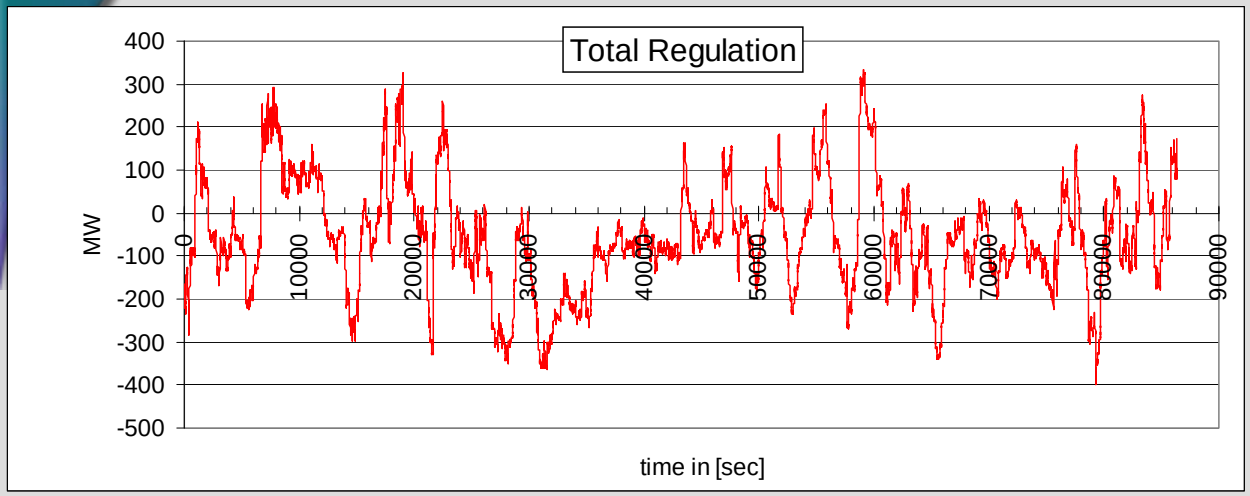


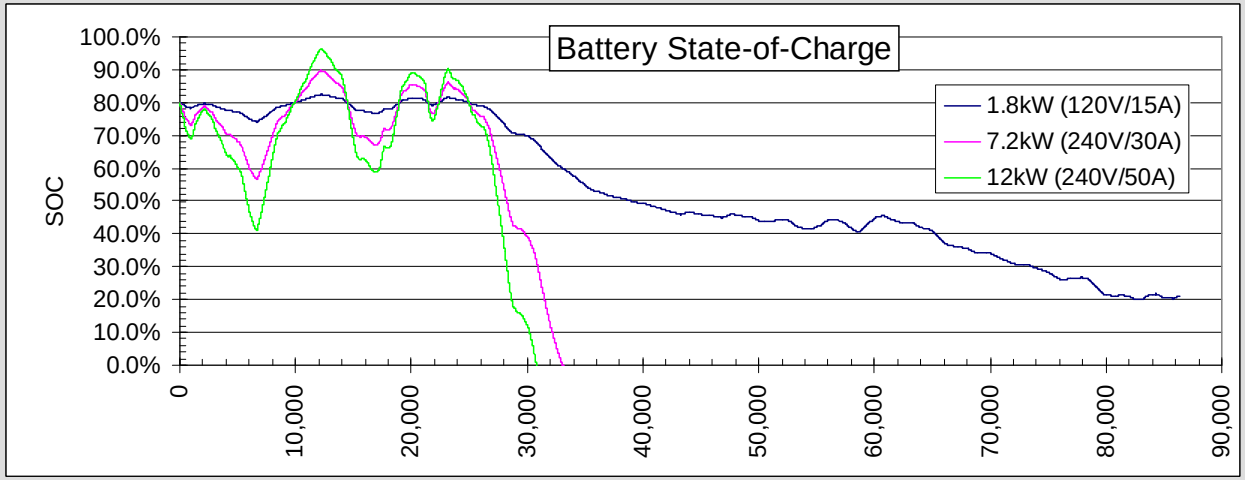
Multi-Use of Batteries Impacts Life



Assumed: resource availability (acc. AC Propulsion): 5 days/week, Home: 5:30pm-7:30am, Work: 8:00am – 5:00pm

V2G Control Strategies Need To Be Developed





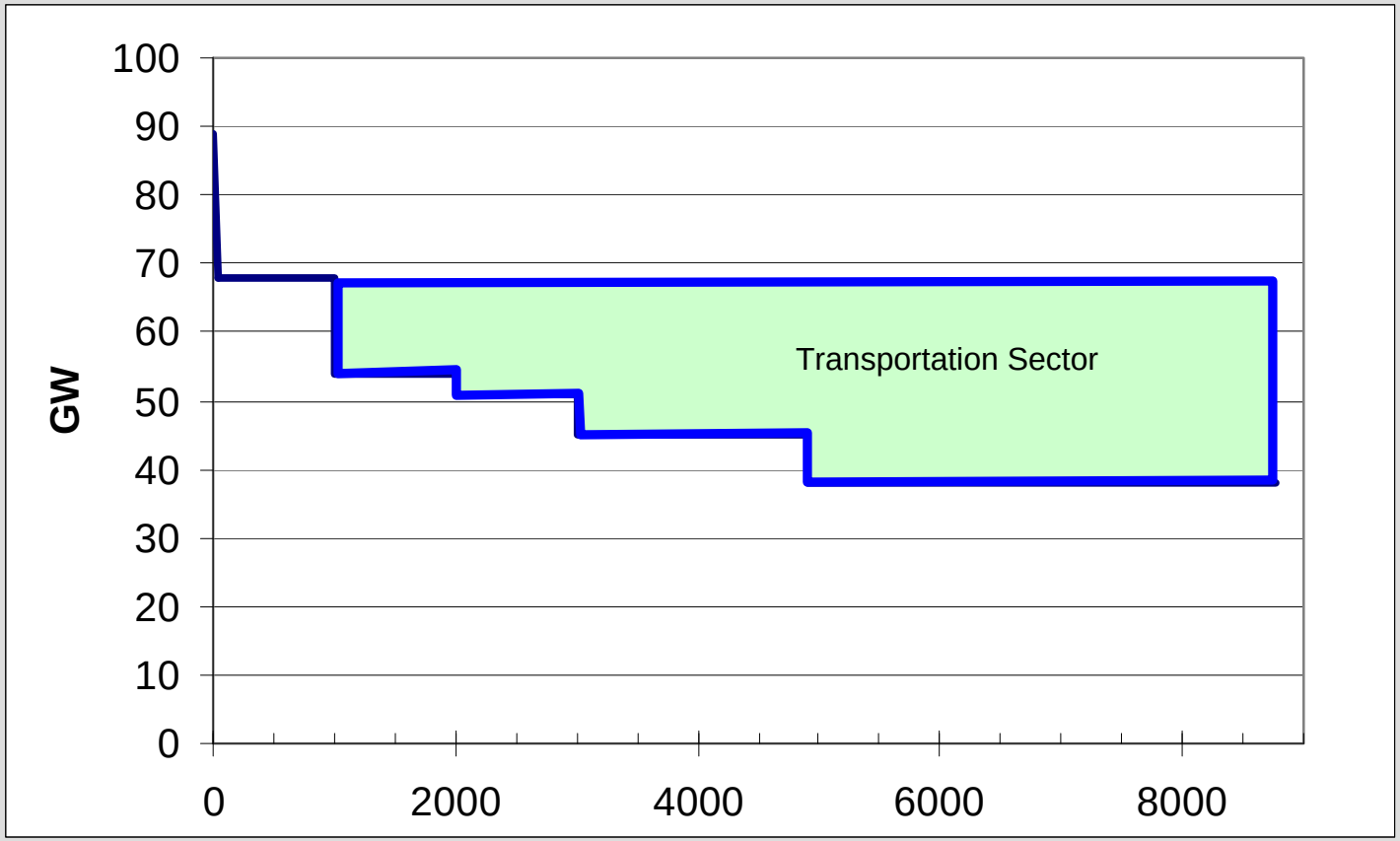
- Battery needs to be first topped off to provide maximum swing. SOC is expected to be low when arriving
- lower/upper bounds need to be set by customer and communicated to grid-operator (impact to resource size)
- Integral of regulation up/down may not be zero during duration of service (home/work) leading to drainage of battery. Normalization of regulation up/down with zero energy exchange required.

Workshop Questions

- Where are the major inefficiencies and losses in the power system (excl. generation and end-use)?
  - Insufficient load participation in ancillary services
    - Operationally, load resources are much faster responding to contingencies than generators
    - Economically, loads can be cost effective
  - Low utilization of entire electric infrastructure
    - 50% for the generation *
    - <50% for T&D

* EIA, for 2006. Total generation 4096 TWh, total capacity: 930 GW

How Could the Grid of the Future Be Operated ?



Workshop Question (cont.)

- What are breakthroughs are needed?
  - Low cost electric energy storage
  - New control paradigms (migration from central control to hybrid central/distributed control)
    - Integration into Microgrid
  - New analytical tools for complex infrastructure development
- What are the enabling technologies
  - Ubiquitous communications

Additional Slides