Smart Charger Technology for Customer Convenience and Grid Reliability

EVS 24
Stavanger, Norway

Michael Kintner-Meyer

Pacific Northwest National Laboratory (PNNL)
Richland, WA
U.S.A.

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Contact: email: Michael.Kintner-Meyer@pnl.gov
phone: 509.375.4306

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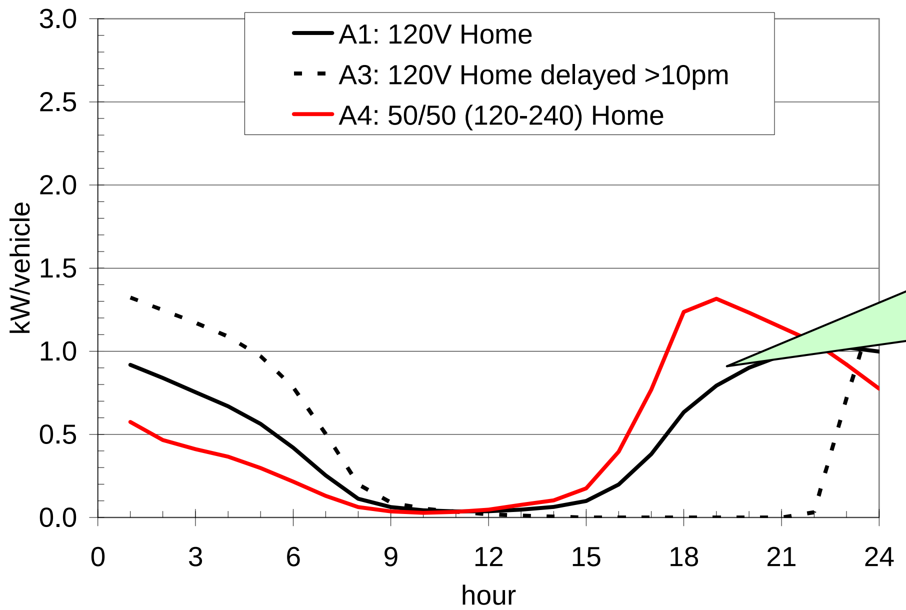
Definition of smart charging

- Customer perspective
  - Automation of charging. Customer plugs vehicle in and forgets about it
  - Minimizes electricity cost
  - Provide additional revenue for providing grid services (“Cash back”)
- Grid-operator’s perspective
  - Responsive load <u>resource</u>
  - Could provide “ancillary services”, necessary to operate the grid reliably
    - Contingency reserve
    - Regulation service
  - Load resource has superior performance over that of a generator
    - Very fast responding
    - Never causes congestion in the grid
- Smart charging is **<u>NOT</u>**
  - Turning the PHEV/EV into a generator and feeding electricity into the grid

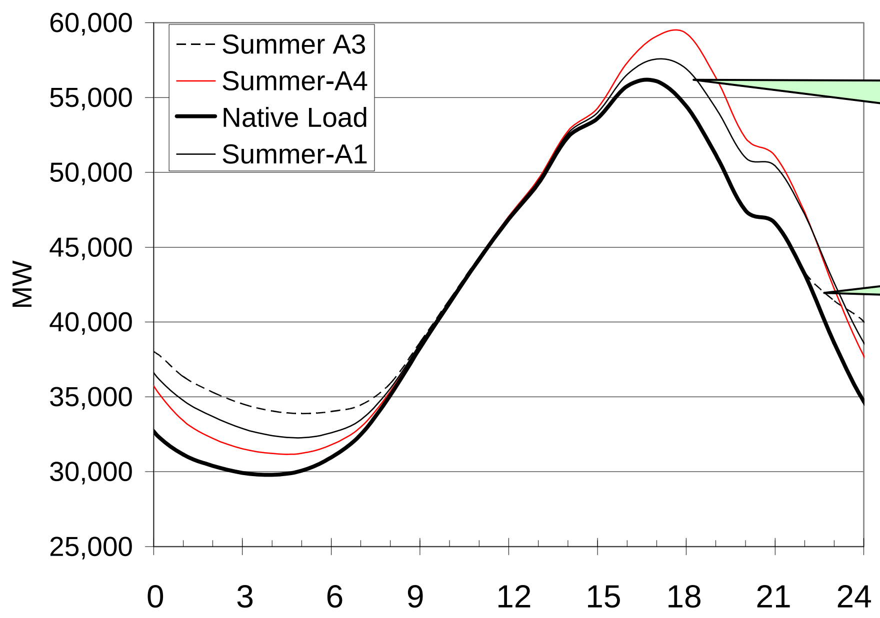
Features of smart charging

- **Charging scheduling**
  - Price-based charging to perform majority of charging during off-peak
    - Enable customer to optimize between cost and convenience
  - Demand response services
    - Direct load control, modulating/reducing load
    - Scheduling load
- **Ancillary services**
  - Increase grid reliability by fast (autonomous) voltage- and frequency control
  - Regulation services (V2Ghalf) modulate load
- Mobile billing
  - ‘Roaming’ capabilities to support charging everywhere and bill at home

Why is it important to schedule the charging?



“Dump” charging profiles based on 37,000 observations from US National Household Travel Survey (2001)

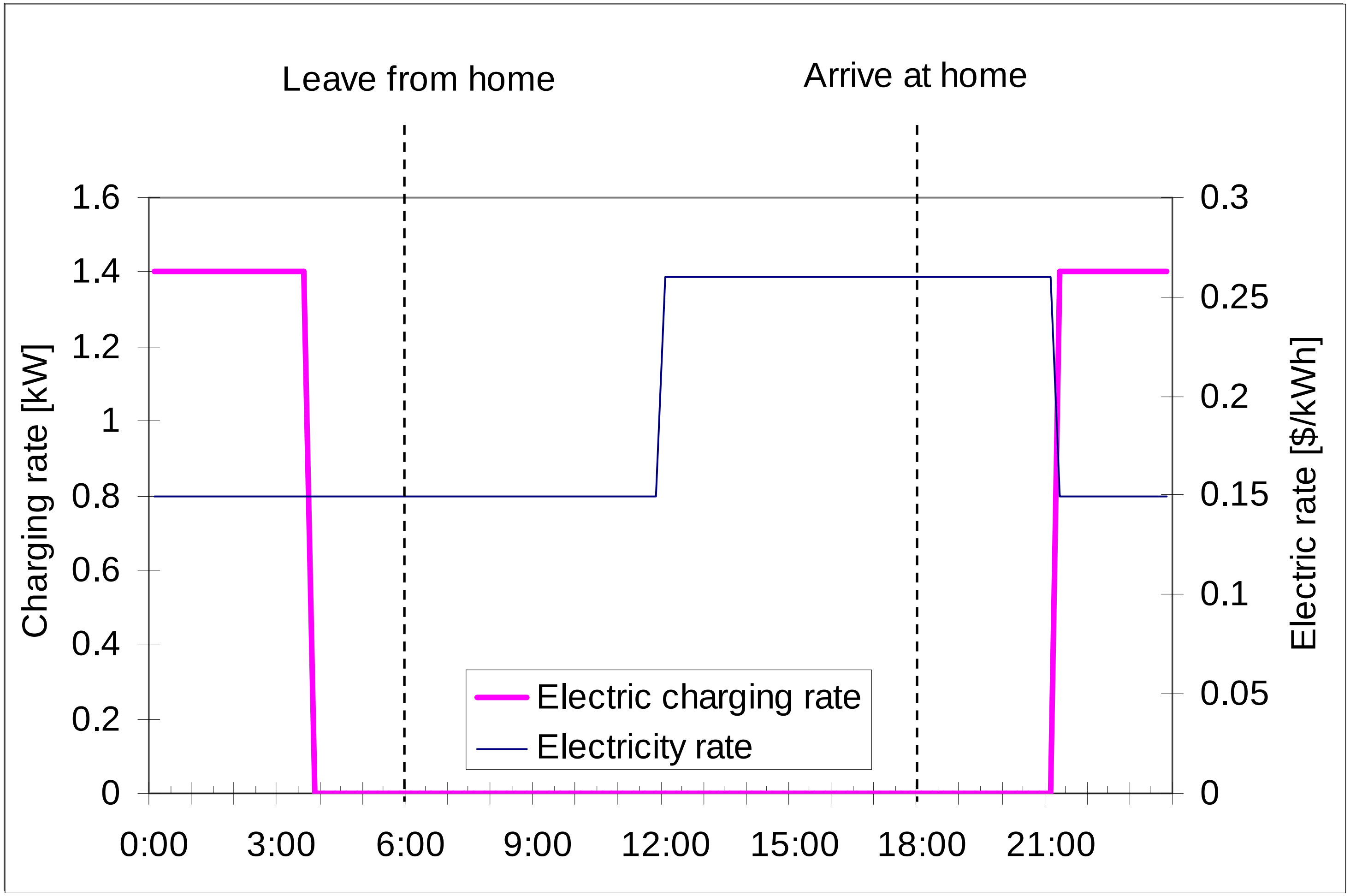


“Dump” charging at home exacerbate system peak

Delayed charging moves majority of load into low-load conditions

Based on 6 mill. PHEVs in CAISO footprint for 2030

Price-based scheduling



Stop charging

Wait until off-peak

Start charging

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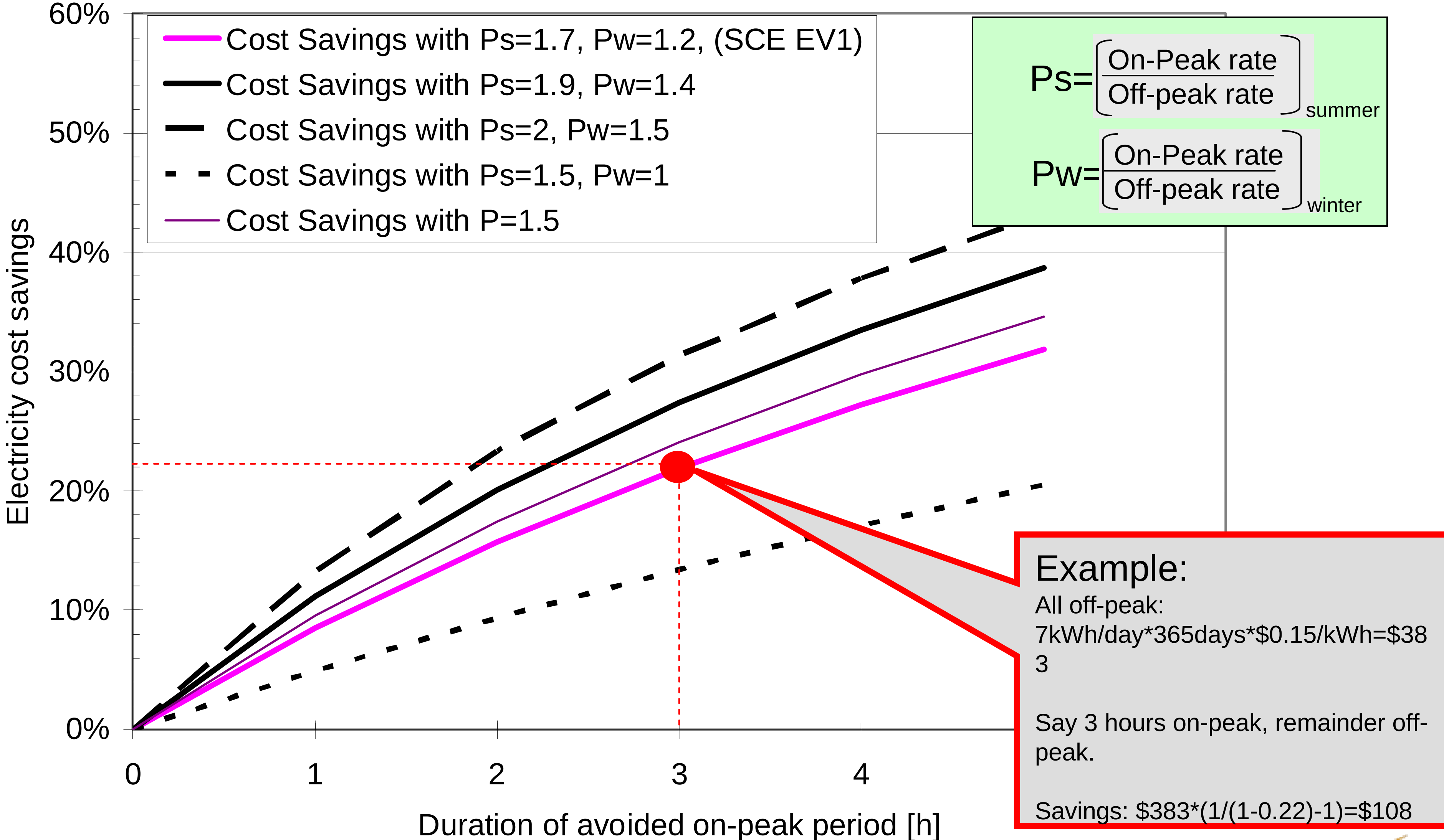
Value of price-based scheduling to customers



Price-based scheduling

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Annual cost savings potential for customers

SCE case

	off-peak electricity rate [c/kWh]											
	5				10				15			
	on-peak/off-peak				on-peak/off-peak				on-peak/off-peak			
	1.5				1.5				1.5			
	avoided peak hours				avoided peak hours				avoided peak hours			
Charging Rate	1	2	3	4	1	2	3	4	1	2	3	4
1.4 kW (120V/12A)	$ 13	$ 26	$ 38	$ 51	$ 26	$ 51	$ 77	$102	$ 38	$ 77	$115	$153
7.2 kW (240V/30A)	$ 66	$131	$ 197	$ 263	$131	$263	$394	$526	$197	$394	$591	$788

	off-peak electricity rate [c/kWh]											
	5				10				15			
	on-peak/off-peak				on-peak/off-peak				on-peak/off-peak			
	2				2				2			
	avoided peak hours				avoided peak hours				avoided peak hours			
Charging Rate	1	2	3	4	1	2	3	4	1	2	3	4
1.4 kW (120V/12A)	$ 26	$ 51	$ 77	$102	$ 51	$102	$153	$ 204	$ 77	$153	$ 230	$ 307
7.2 kW (240V/30A)	$131	$263	$394	$526	$263	$526	$788	$1,051	$394	$788	$1,183	$1,577

- Cost savings depend on:
  - Electricity rate
  - Differential between peak and off-peak rate
  - Duration (number of hours) of avoided peak period charging
  - Charging rate
- Cost savings can range significantly
  - In low-cost electricity in **Pacific Northwest**: annual savings likely to be less than $100
  - In high cost **California**: annual savings could be several 100s of dollars

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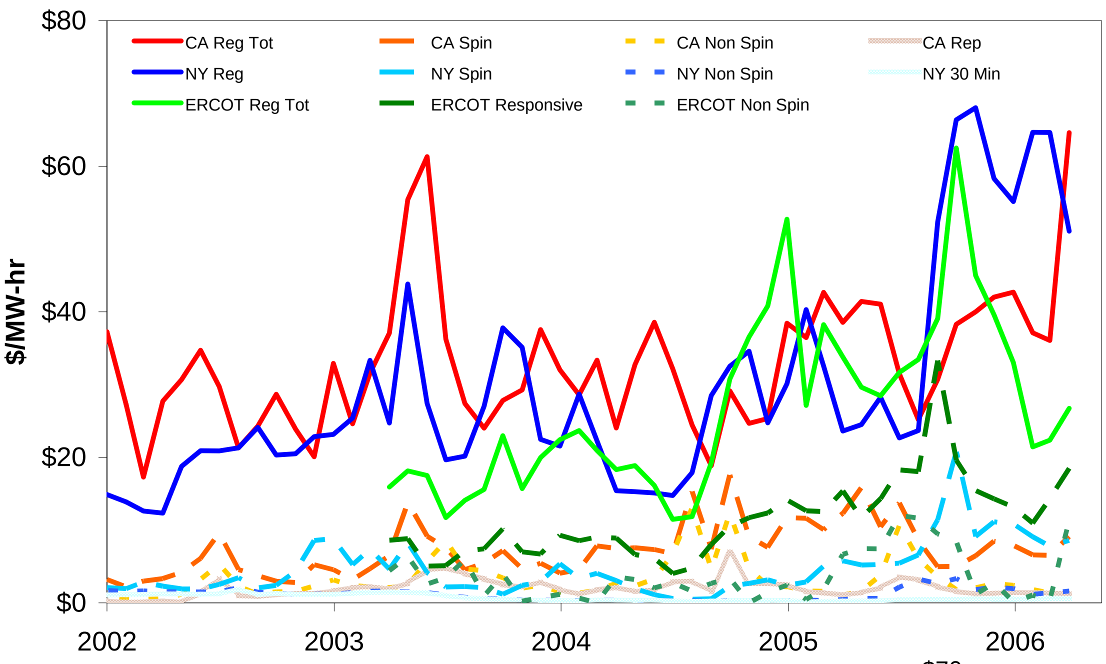
What are the Regulation Services worth?

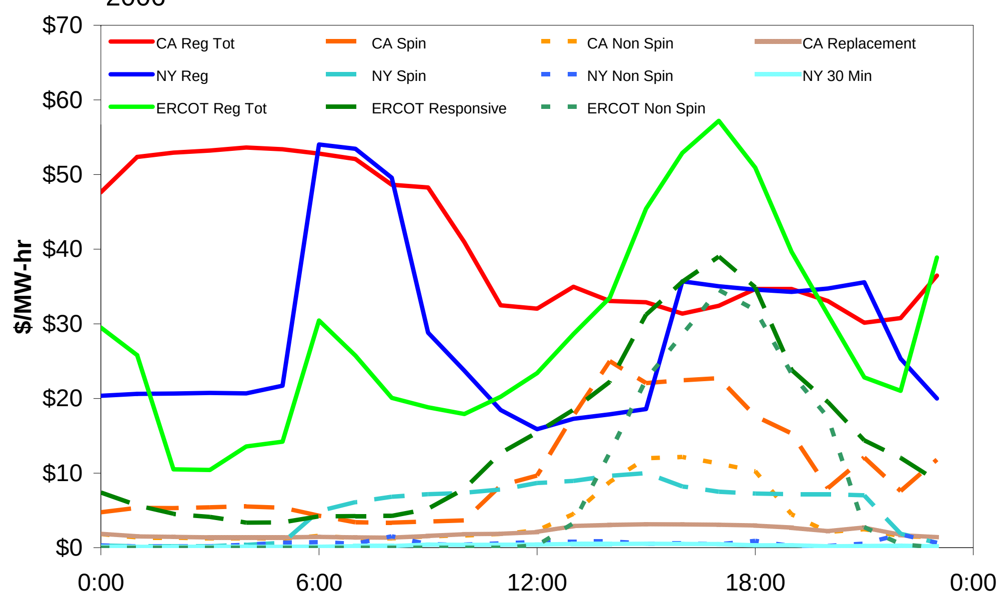
Average Monthly Ancillary Service Prices



Source: B. Kirby, ORNL

Market-based prices in organized US wholesale power markets

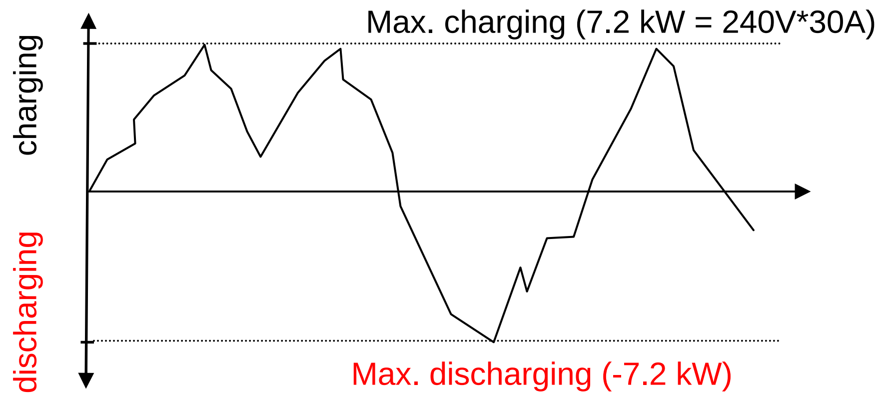
June 2005 Ancillary Service Prices



Load can provide regulation services (V2G half): Definition and value

V2G

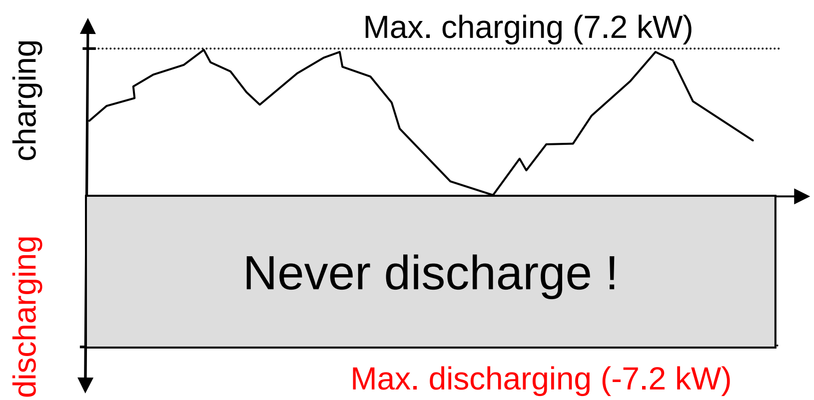
- provides regulation service as a load and generator
- requires charging and discharging according to grid operators signal



Capacity value
(-7.2 to 7.2=14.4kW)

V2G half

- provides regulation service as a load only
- requires only charging
- modulates charging

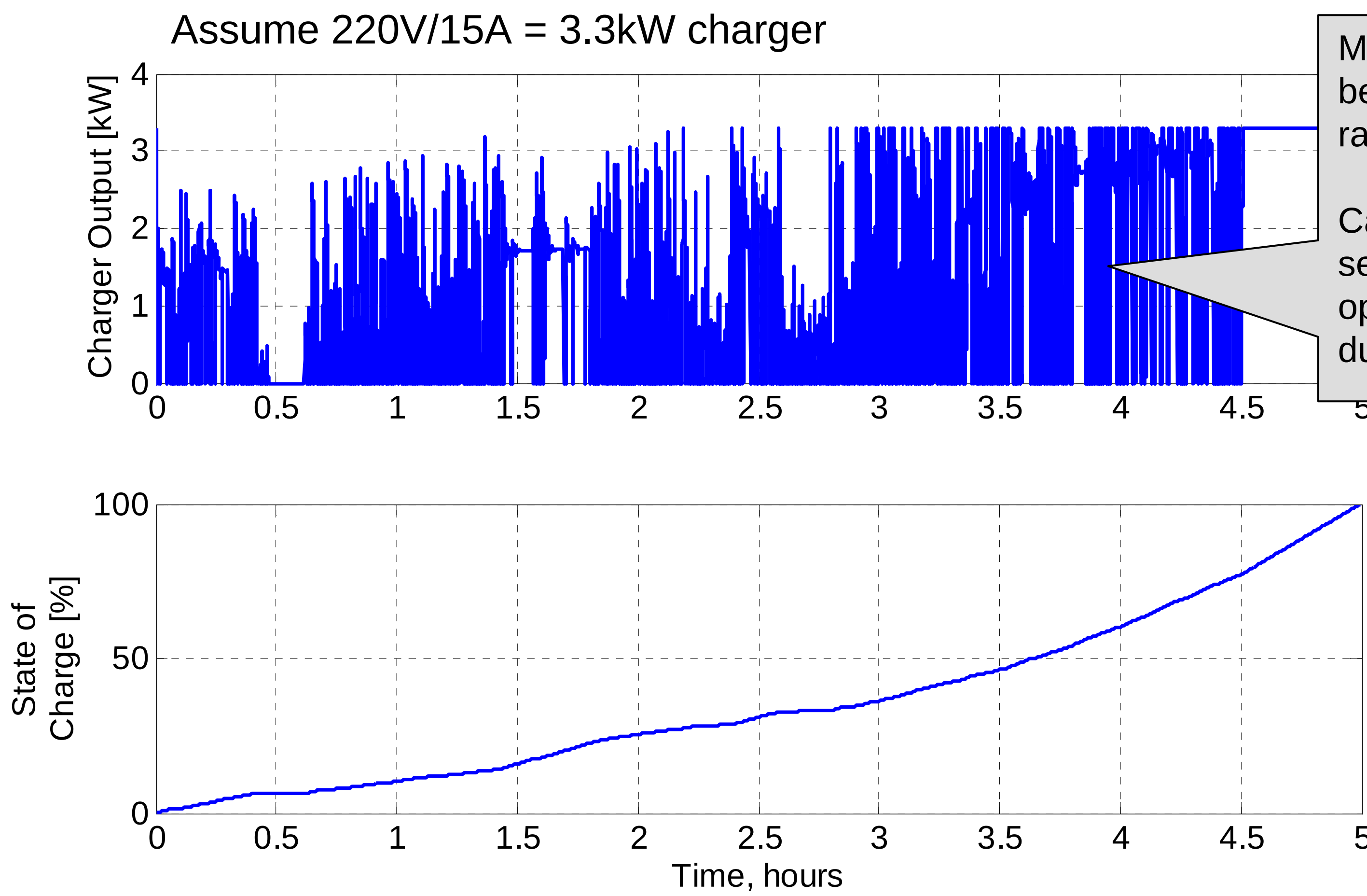


Capacity value
(0 to 7.2=7.2 kW)

Attribute of "V2G half":

- provides regulation service with ½ the capacity value of V2G
- however, less than half the cost because
  - no interconnection gear with grid necessary because no electricity goes back into grid
  - removes any uncertainties regarding battery life reduction because of extra cycling

V2G half for PHEV battery charging



Modulation of charging between 0 – full charging rate (3.3 kW)

Capacity value regulation services to the grid-operator = 3.3 kW for duration of charging

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Value of V2G half

Battery size	Annual Value of V2G half regulation services [$/MWh]			
	$20/MWh	$30/MWh	$40/MWh	$50/MWh
5 kWh	$ 36.50	$ 54.75	$ 73.00	$ 91.25
10 kWh	$ 73.00	$ 109.50	$ 146.00	$ 182.50
15 kWh	$ 109.50	$ 164.25	$ 219.00	$ 273.75
20 kWh	$ 146.00	$ 219.00	$ 292.00	$ 365.00
25 kWh	$ 182.50	$ 273.75	$ 365.00	$ 456.25
30 kWh	$ 219.00	$ 328.50	$ 438.00	$ 547.50
35 kWh	$ 255.50	$ 383.25	$ 511.00	$ 638.75
40 kWh	$ 292.00	$ 438.00	$ 584.00	$ 730.00

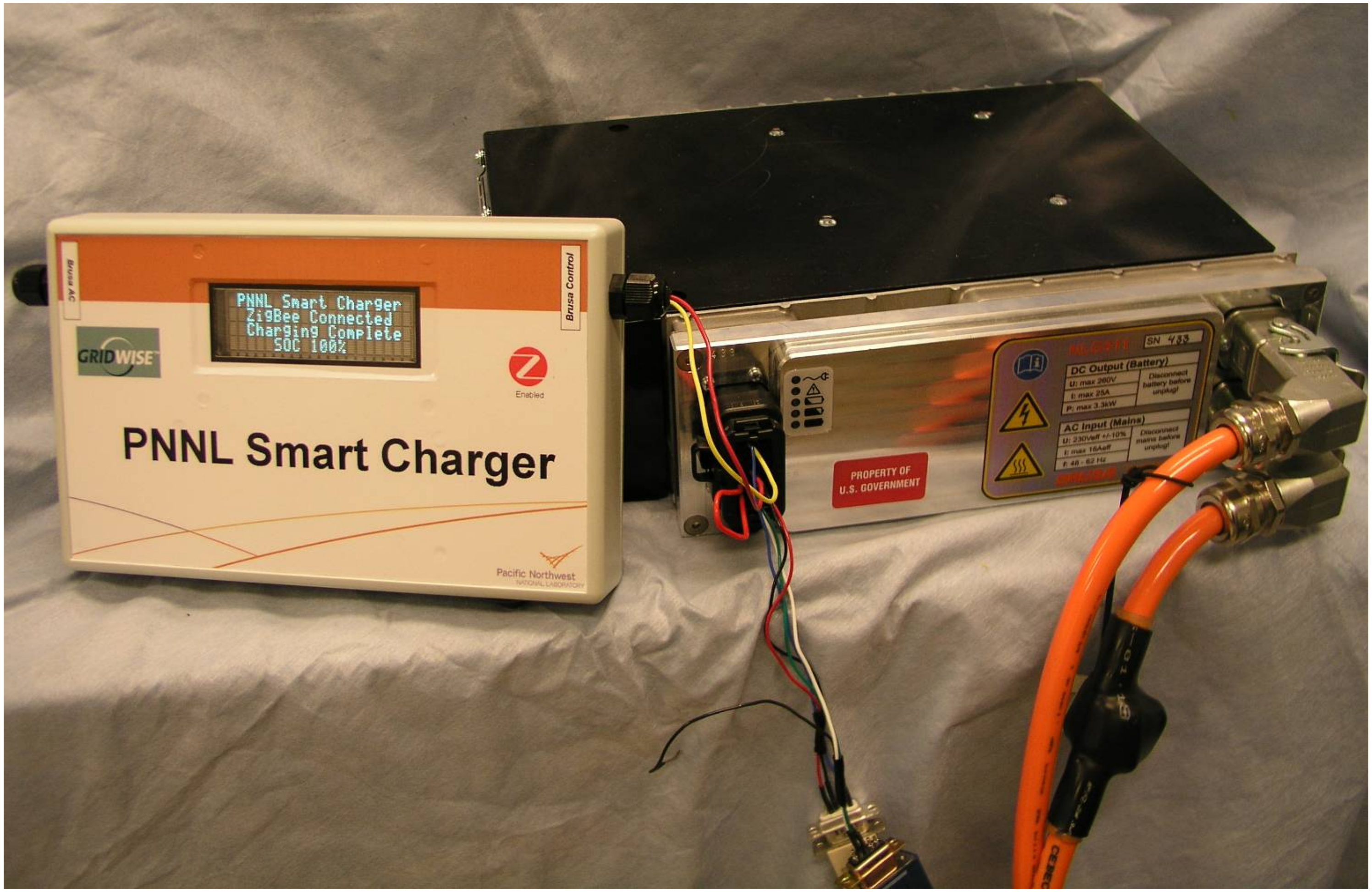
California, Texas case

PHEVs (5–15 kWh)

EVs (20–40 kWh)

- Value of V2G half depends on size of battery, which determines the duration for service delivery
- Duration of service provided to the grid operator is limited by the time it takes to re-charge the battery
- Charging rate (kW) is important. It determines how many vehicles must be aggregated to reach minimum size requirement for regulation markets (e.g., 1 MW)
- <u>Regulation services value is most likely larger for customer than savings from optimal scheduling</u>

Prototype of *Smart Charger Controller* together with Brusa Charger



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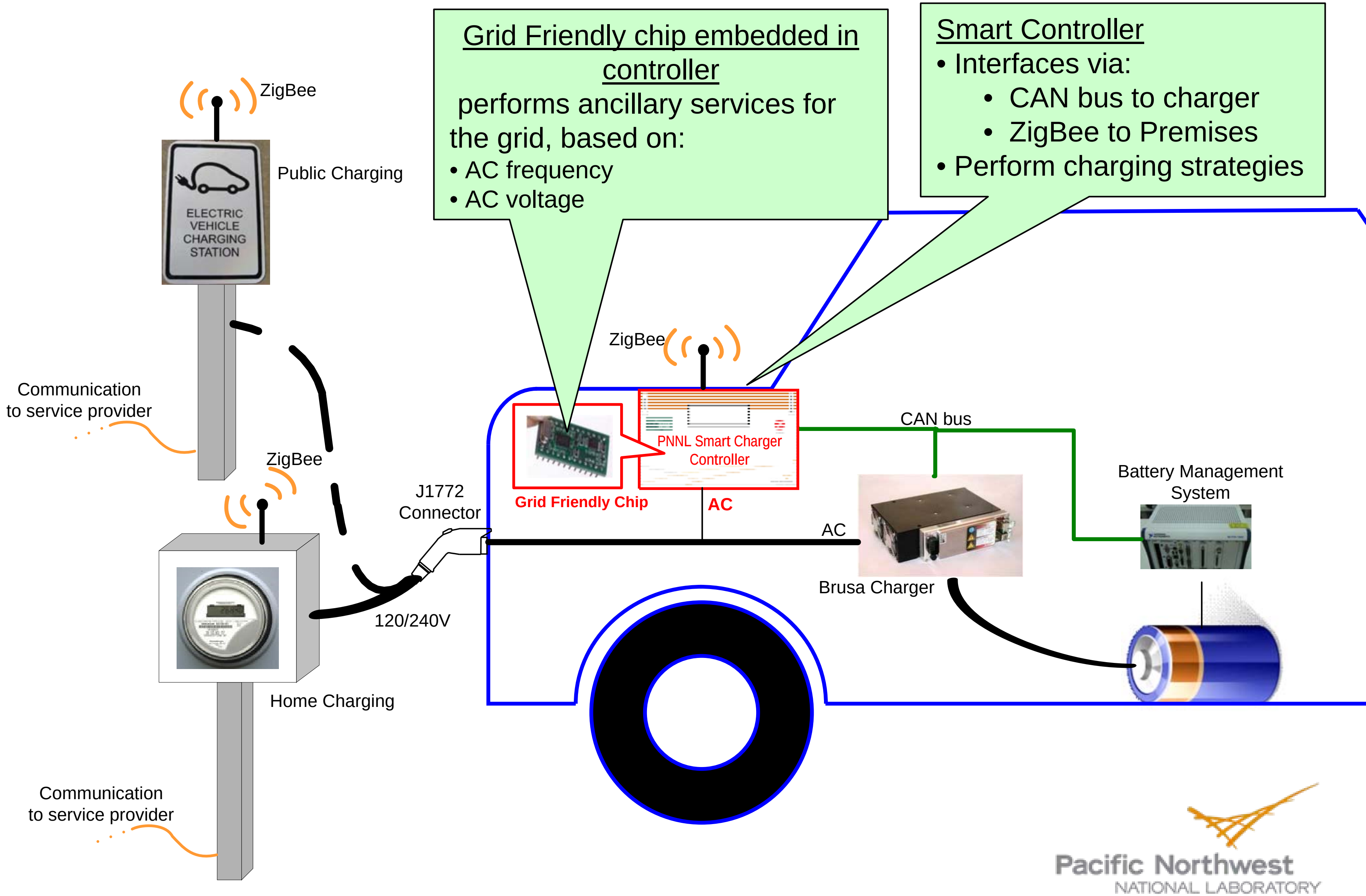
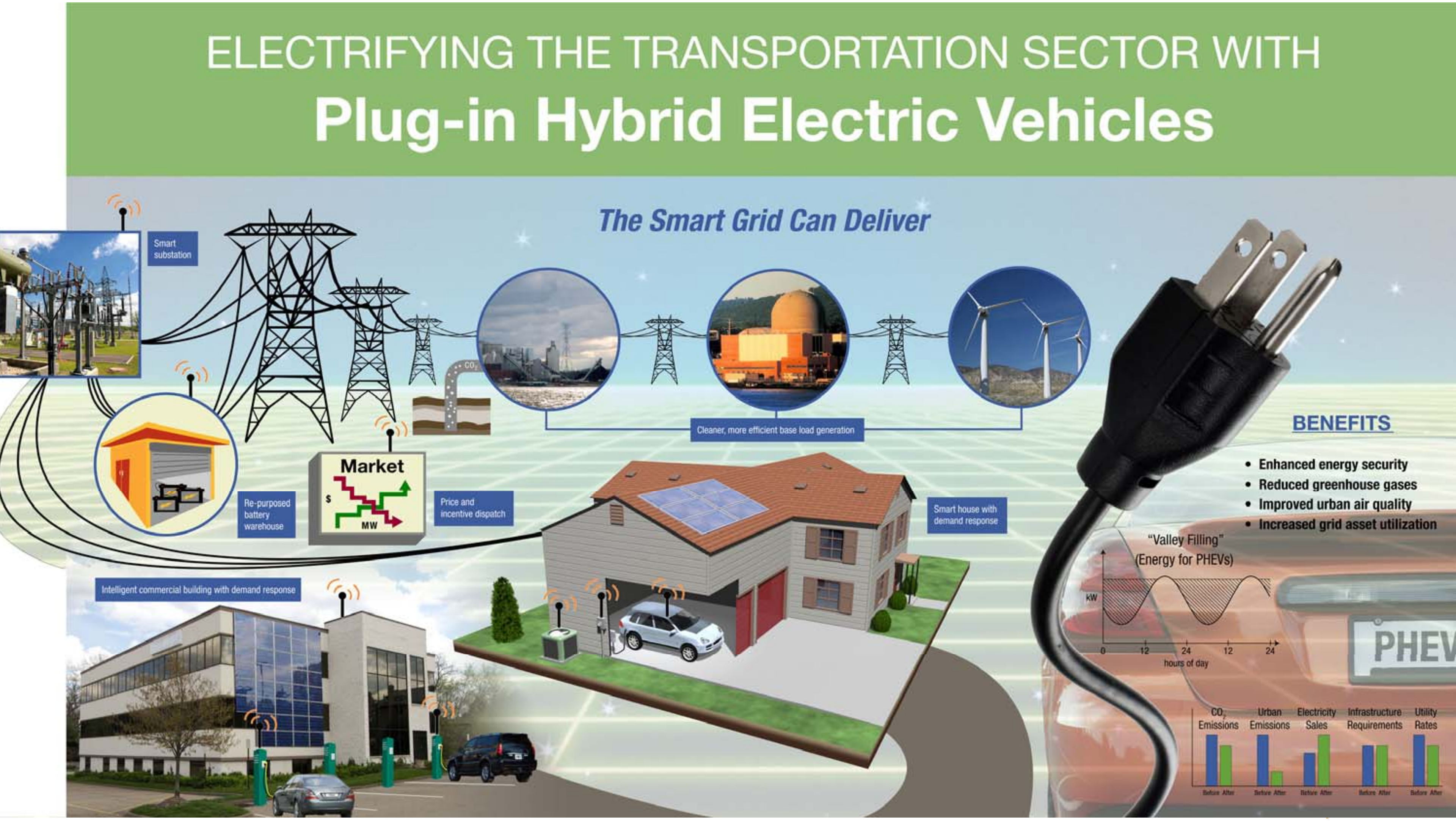
Use Scenario: PNNL Smart Charger Controller Integrated in the Vehicle



Smart Grid with Smart Chargers Can Deliver the Electricity for Millions of PHEVs



Customer interface in the vehicle

Default could be price-based charging

Override option "Charge NOW"

For price-based charging, customer sets time when battery is to be charged 100%