Northwest Power and Conservation Council

November 6, 2008

MEMORANDUM

TO: Council Members

FROM: Massoud Jourabchi

SUBJECT: Impact of the Plug-in Electric Vehicles in the Western Grid

Plug-in hybrid electric vehicles (PHEVs) and electric vehicles (EVs) are expected to make inroads into the US and global market place starting in 2010. Announcements by GM, Ford, Chrysler, as well as foreign automakers such as Toyota, Nissan, BMW, Renault, and Daimler confirm the serious intent of the auto industry to introduce PHEVs and EVs to the consumer.

In a July 2008 presentation to the Power Committee, I presented results of an analysis measuring the impact of PHEVs in the Pacific Northwest. That analysis evaluated two "what if" scenarios that showed plug-in electric vehicles could have a significant impact in reducing the carbon footprint of the region.

At the November 2008 Council meeting, Dr. Michael Kinter-Meyer, staff scientist at the Pacific Northwest National Laboratory (PNNL), will present their findings on impacts of the plug-in electric in the western grid. Dr. Kinter-Meyer is PNNL's lead for PHEV analysis and technology development of smart chargers. This presentation will show the results of several impact assessments performed by PNNL including:

- Technical potential analyses estimating the maximal numbers of PHEVs that today's regional electric infrastructure could support without building new power plants or transmission lines;
- Adequacy studies of distribution system in the PNW to accommodate new PHEV load; and
- Impacts of different charging profiles of PHEVs on the production cost, generation dispatch, and emissions from fossil generation resources.

851 S.W. Sixth Avenue, Suite 1100
Portland, Oregon 97204-1348
www.nwcouncil.org

Steve Crow
Executive Director

503-222-5161
800-452-5161
Fax: 503-820-2370

PHEV- Grid Interactions
PNNL

Michael Kintner-Meyer, Ph.D., PNNL
Ye Li, Ph.D., PNNL
Tony Nguyen, Ph.D., PNNL

November 18, 2008

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

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PNNL-SA-63585

PNNL – DOE's PHEV/Grid Lead Laboratory

- Technical potential analysis (2006)
- Detailed bulk-system analyses (2007-2009)
- Detailed distribution system (2007-2009)
  - PUDs
  - IOUs
- Smart Charger Technology development (2007-2010)
  - Building a prototype working with
    - Automotives
    - SAE on standards
  - Price-based charging
  - Frequency responsive
  - V2G-one-half

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Technical Potential Analysis of Today's Grid

Can the US 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*

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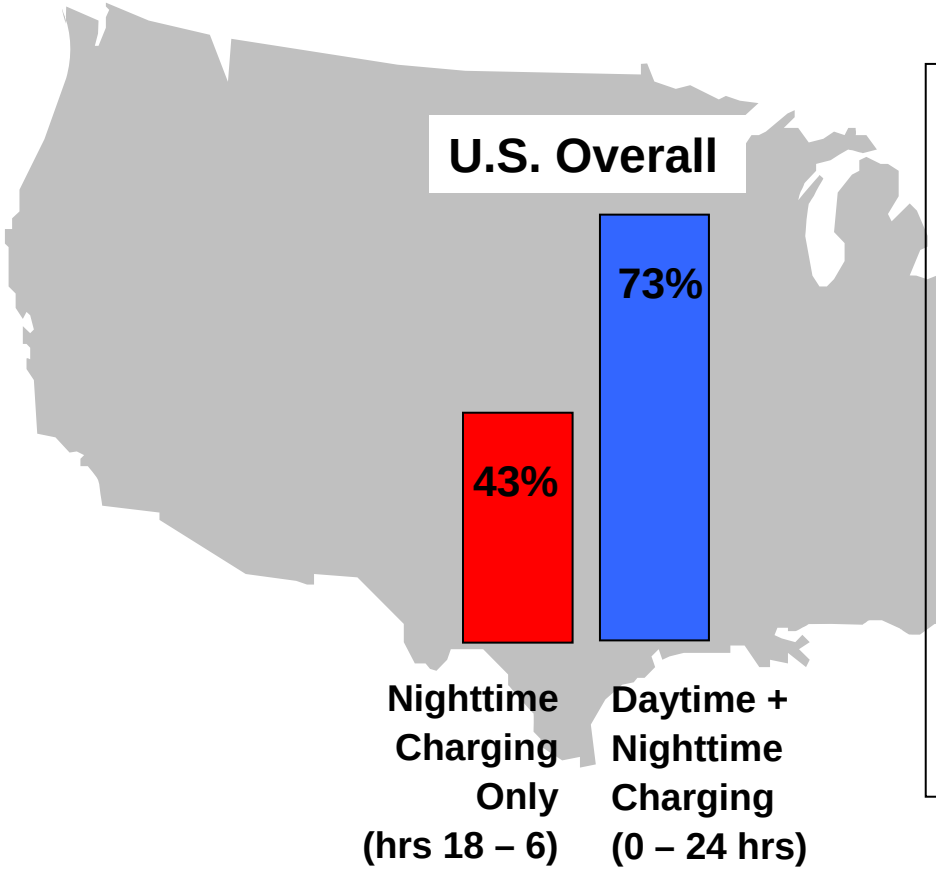
Over 70% of the existing U.S. light-duty vehicle fleet (if PHEVs) could be fueled with available off-peak electric capacity



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

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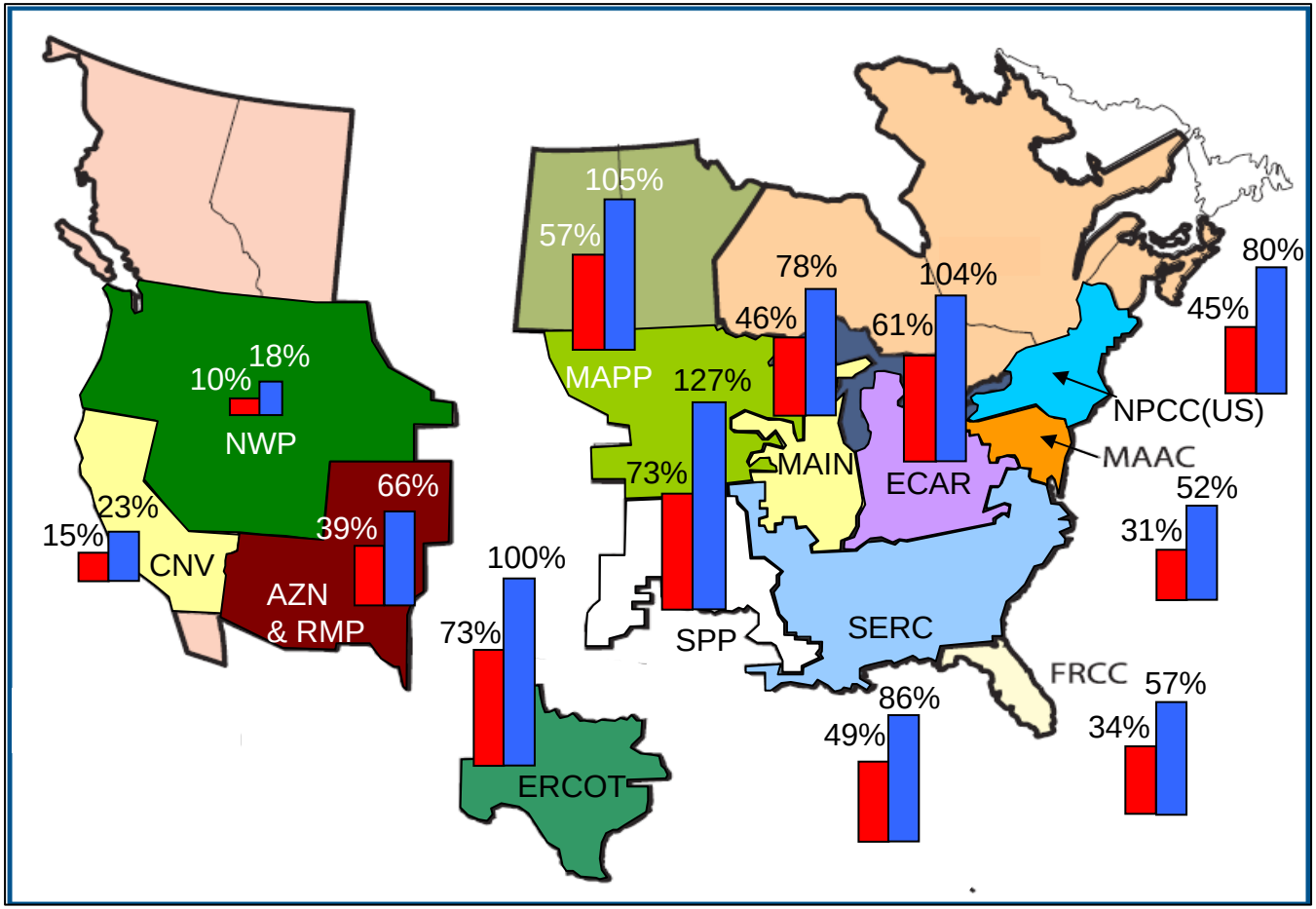
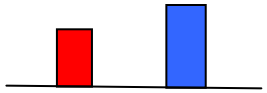
Analysis by North American Electric Reliability Corporation (NERC) Region





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

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Regional Emissions Impacts (Well-to-Wheel*) with Today's Generation Mix

**** Argonne National Laboratory's GREET well-to-wheel model***

Existing coal plants break even on greenhouse gases

Nationally, greenhouse gases reduced 27% despite increased reliance on coal

Plant mix for valley fill	ECAR	ERCOT	MACC	MAIN	MAPP	NPCC	FRCC	SERC	SPP	PNW	AZ RMP	CNV	US total
	Power Generation Composition												
Natural Gas	32%	94%	74%	42%	1%	91%	69%	57%	78%	43%	63%	93%	
Coal	68%	6%	26%	58%	99%	9%	31%	43%	22%	57%	37%	7%	
Emissions	**Emissions Ratio (Electric Vehicle/Gasoline Vehicle)**												
Greenhouse gases	0.87	0.60	0.69	0.83	1.01	0.61	0.71	0.76	0.66	0.84	0.73	0.61	0.73
VOC: Total	0.11	0.04	0.06	0.10	0.14	0.04	0.07	0.08	0.06	0.10	0.07	0.04	0.07
CO: Total	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NOx: Total	1.02	0.38	0.59	0.93	1.35	0.41	0.64	0.76	0.54	0.93	0.71	0.39	0.69
Particulates	1.55	0.81	1.06	1.45	1.94	0.86	1.13	1.26	0.99	1.46	1.19	0.84	1.18
SOx	3.94	0.42	1.68	3.59	5.96	0.64	2.05	2.67	1.34	3.77	2.35	0.53	2.25
Urban: VOCs	0.00	0.01									0.01	0.01	
CO	0.00	0.01						0.00	0.00	0.00	0.00		0.00
NOx	0.10	0.11						0.10	0.11	0.10			0.10
Particulates	0.60	0.62											0.61
SOx	0.35	0.04	0.14	0.30	0.51	0.05	0.17						0.19

SOx from vehicles doubles: cap-and-trade will require investment in cleaner plants

Urban air quality emissions greatly reduced:
VOCs/CO/NOx > 90%
SOx = 80%
Particulates = 40%

- Moving emissions from tailpipes to smokestacks:
  - solves an intractable problem for CO_2 capture
  - improves cost effectiveness for other emissions

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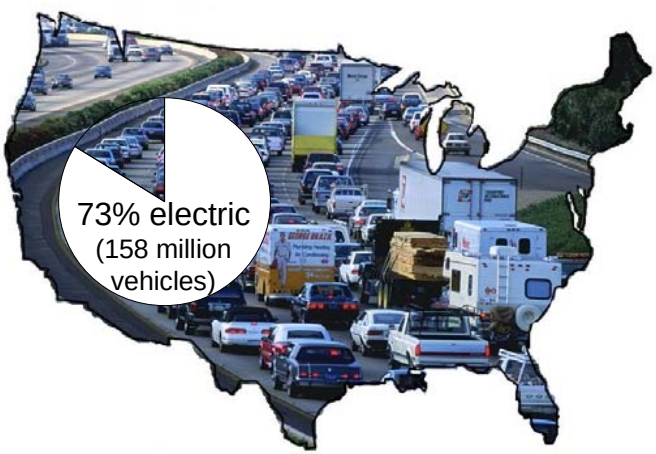
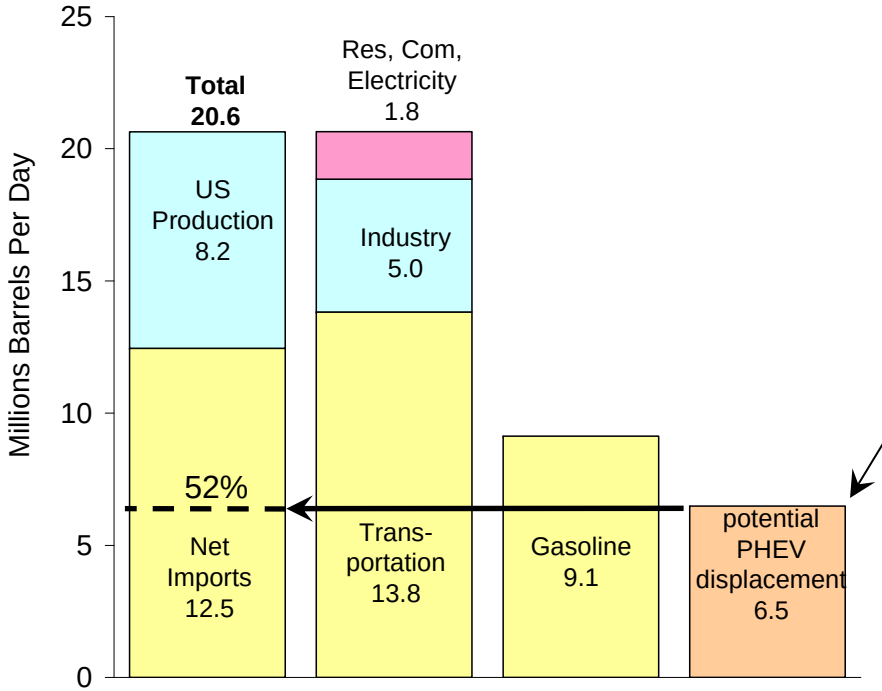
Summary

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
if charging of vehicles is managed





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

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Detailed Production Cost Analyses of High Penetration PHEVs

- After establishing an upper bound for PHEV penetration in today's grid, current work focuses on scenario analyses of future grids and PHEV fleets
- Questions:
  - Production costs impacts
  - LMP impacts
  - Emissions impacts
- Methodology
  - Production cost model (PROMOD by Ventyx)
  - Capacity expansion model (MarketPower by Ventyx)
- Scope
  - National context by regions
  - Can do regional analyses at high resolution

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Assumptions

- Consumption from electric transportation (MWh)
  - PHEV penetration: used a Delphi Approach with structured interviews by domain experts from
    - Battery industry
    - Automotive industry
    - Suppliers
    - Research community
- Charging Profiles
  - Rigorous analytical approach deriving charging profiles from DOT's 2001 National Household Travel Survey

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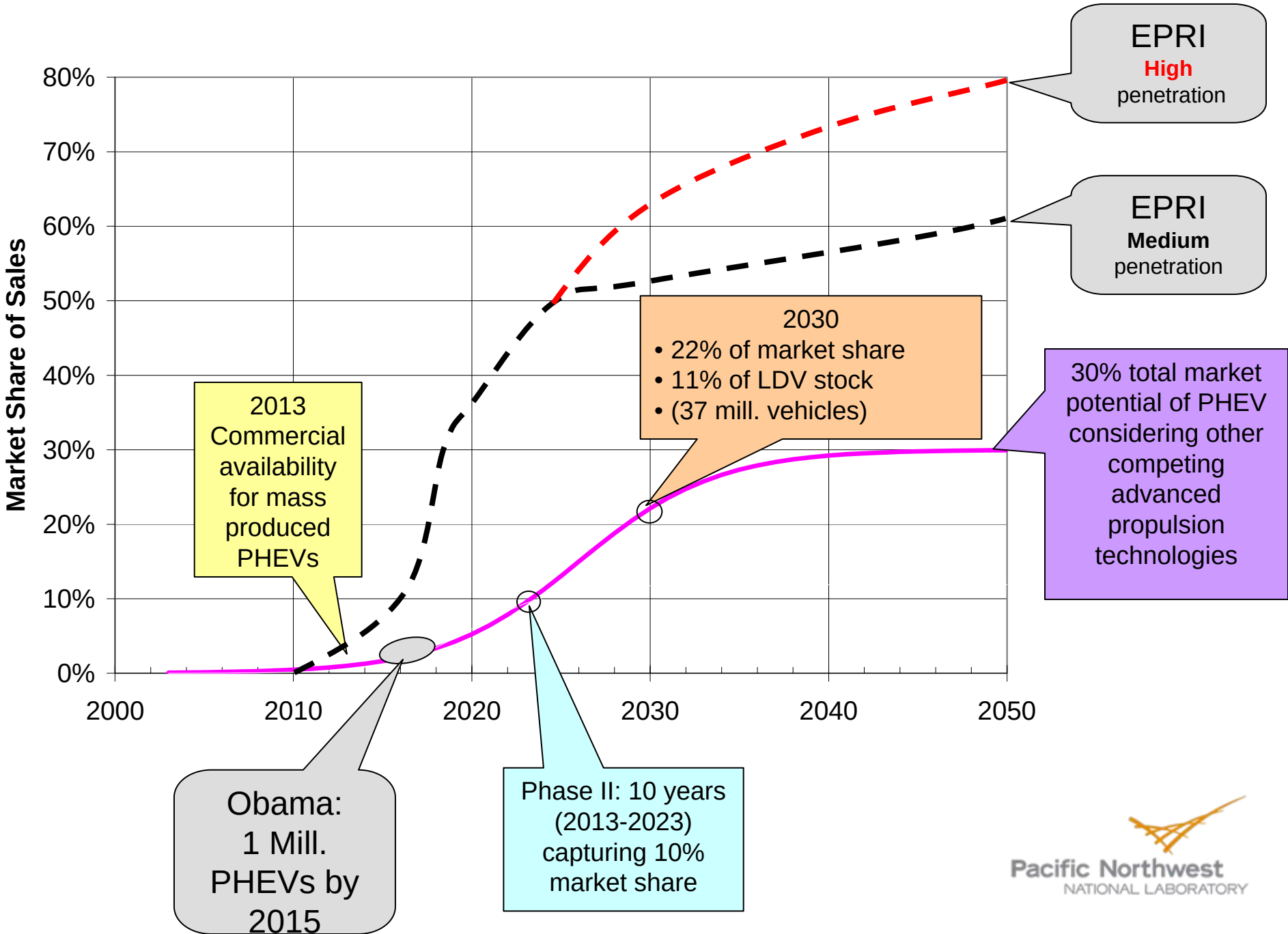
Penetration results



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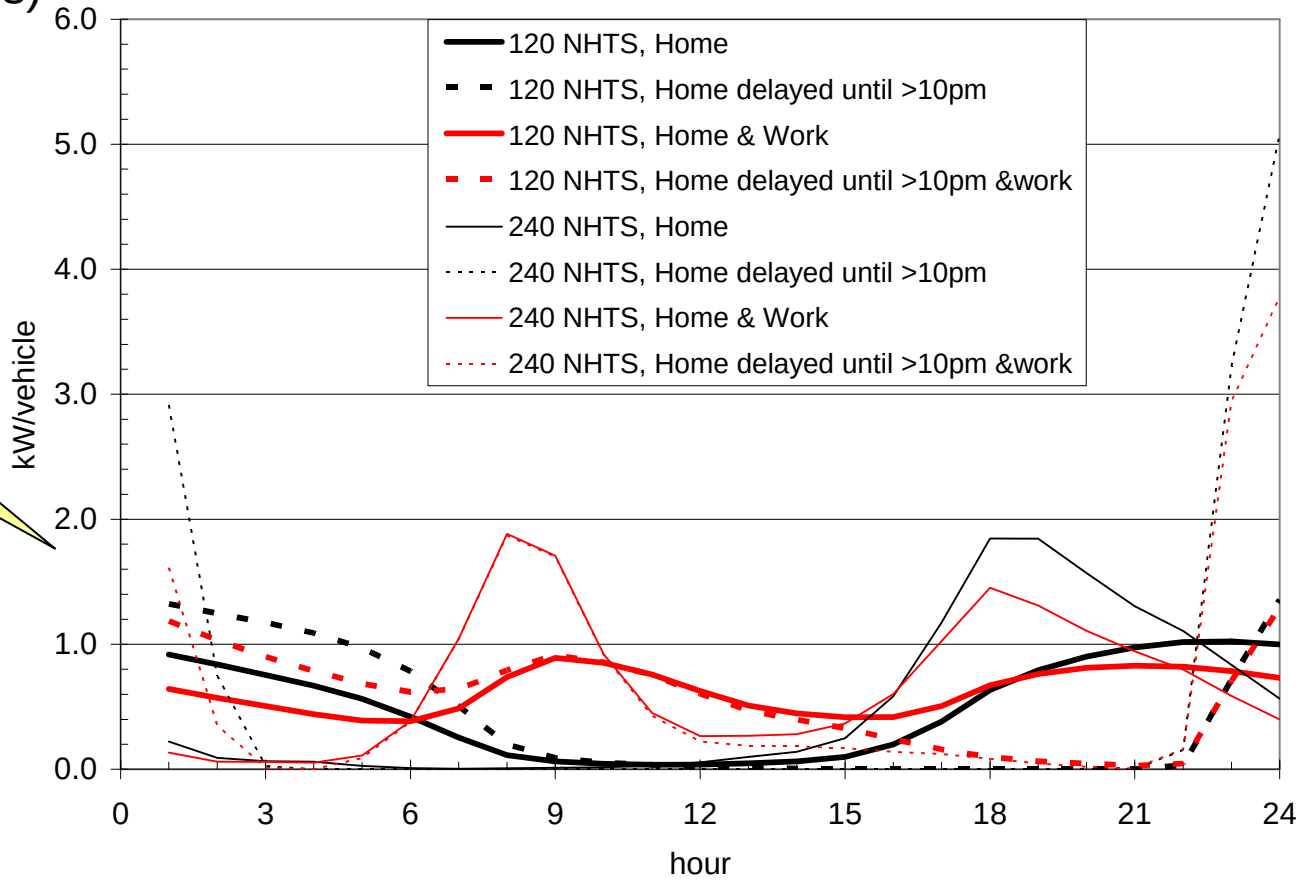
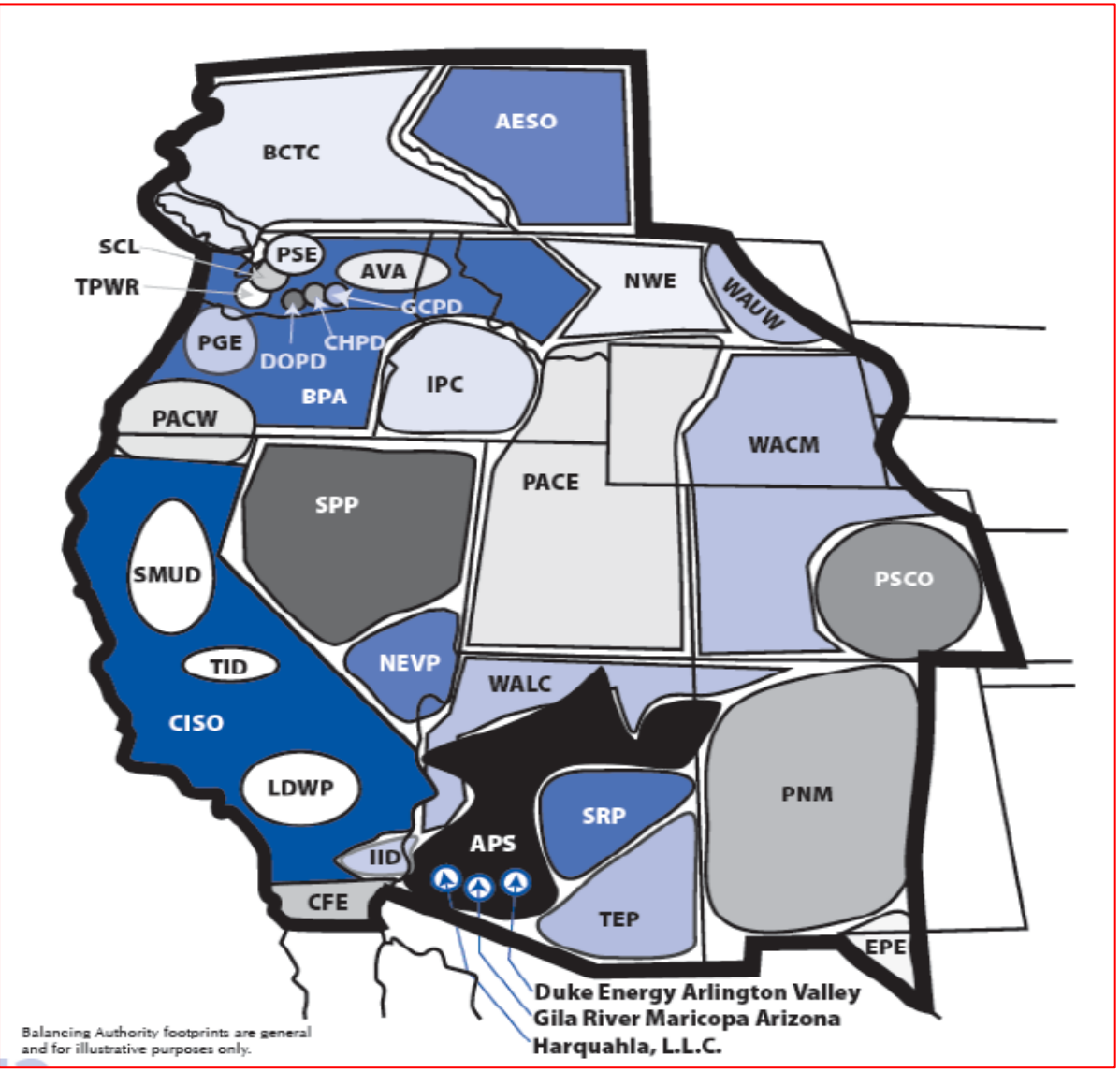
Developed Plausible PHEV Charging Profiles

- Need for PHEV charging profile
  - Most researchers use EPRI “W” shaped profile based on notion of 120V/12A charging
- Refined PHEV profile with DOT 2001 National Household Travel Survey to reflect “resting periods” of vehicles
- Considered both 120V and 240V charging (automakers announced 240V charging capabilities)

Diversified average charging profiles for PHEVs



Detailed Electricity Market Impact Analysis for WECC



Impacts to the grid

- 9.2 Million PHEVs in WECC in 2030
- Majority of PHEVs in California

Grid Analysis

- Production cost model
- 1900+ generator units
- 64 balancing zones
- EIA's capacity additions to 2030
- Meeting regional RPS
- Additional capacity for PHEVs
- Determine
  - Cost impacts
  - Emissions impacts

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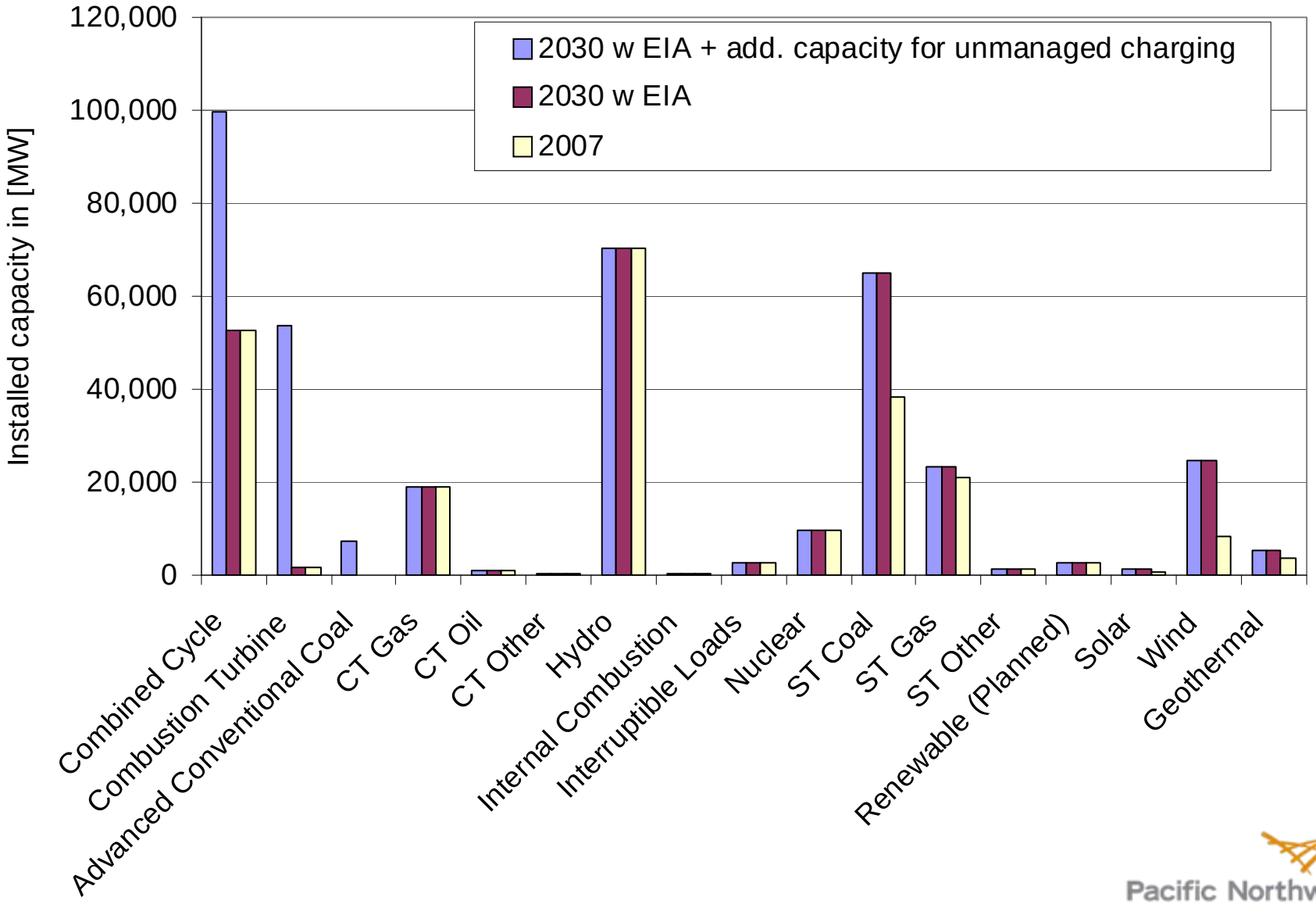
Preliminary Results for WECC



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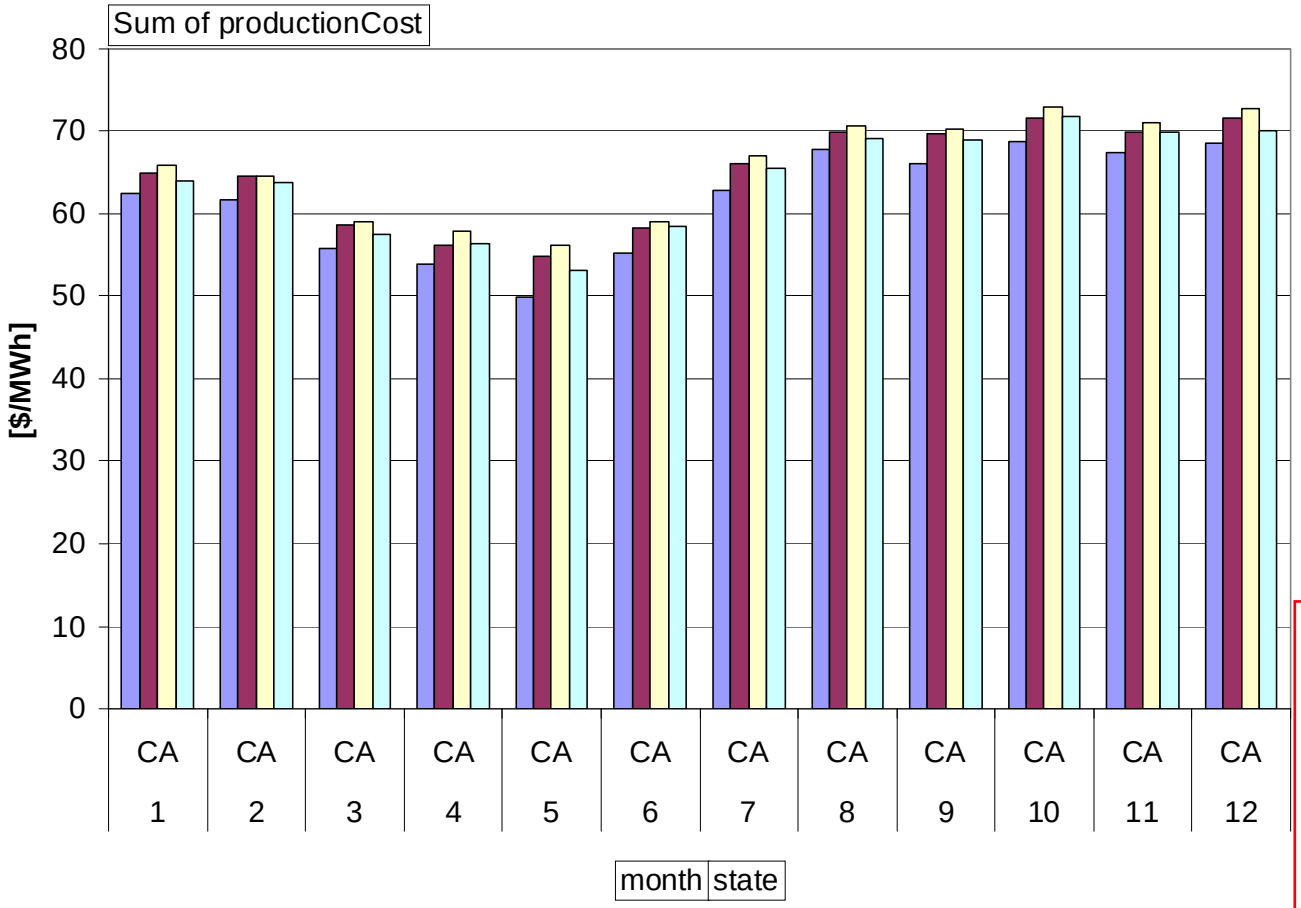
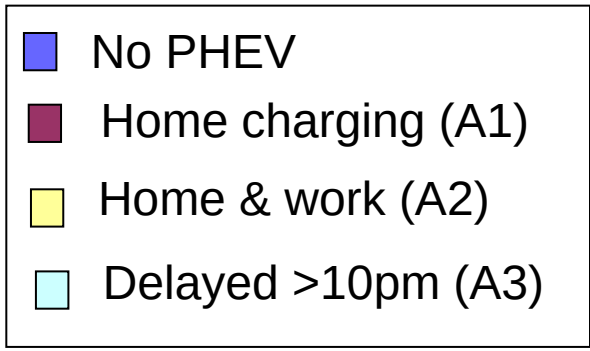
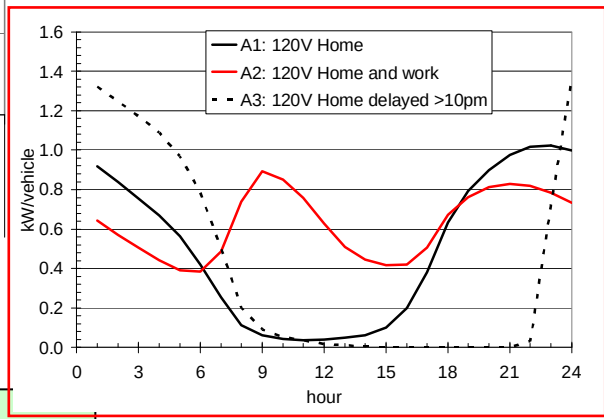
Preliminary Results: Average Production Cost for California by Months







- PHEV load about 6% of total generation
- Average cost are likely to go up with PHEV load
- Night charging will be lowest cost charging

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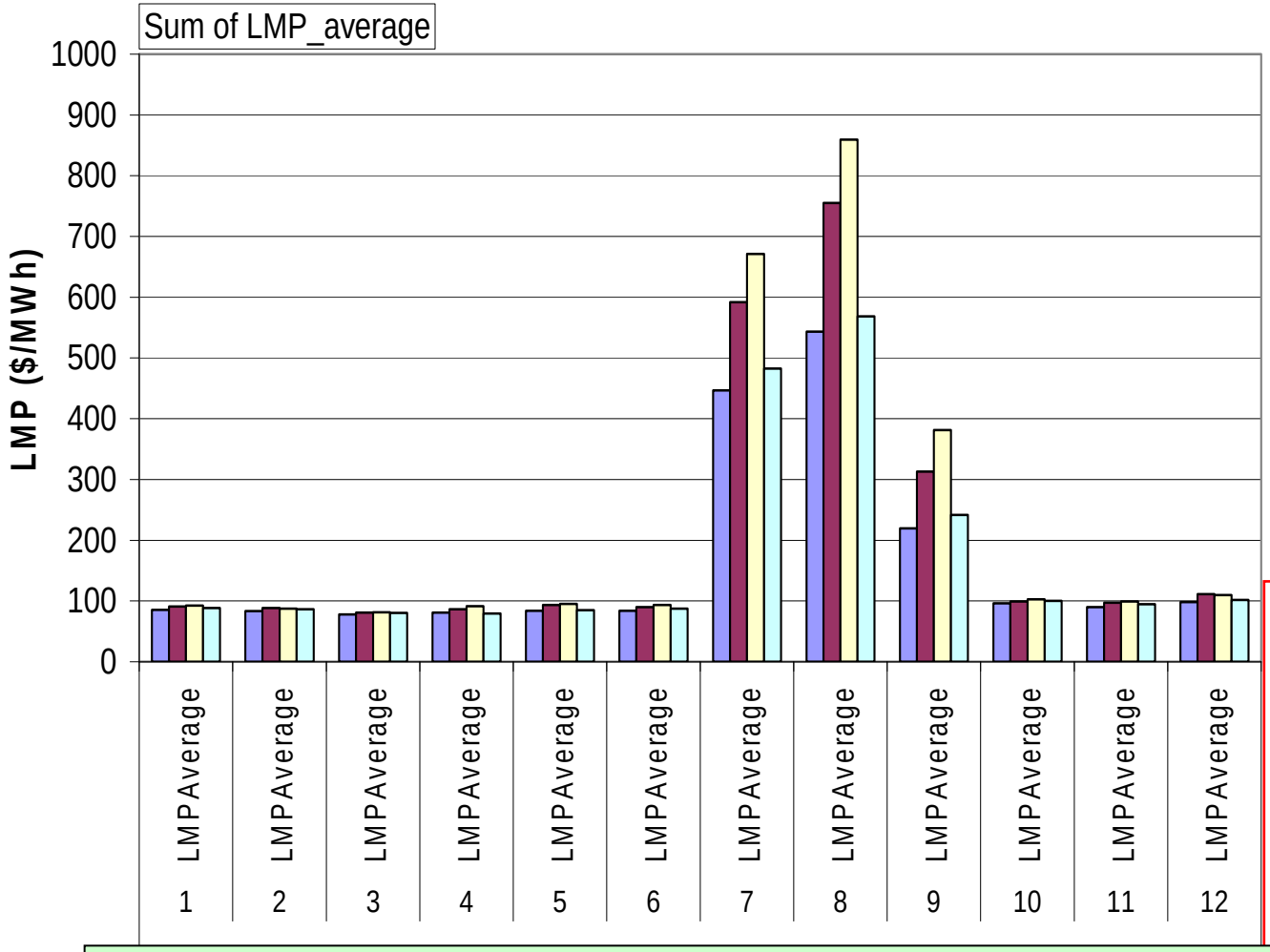
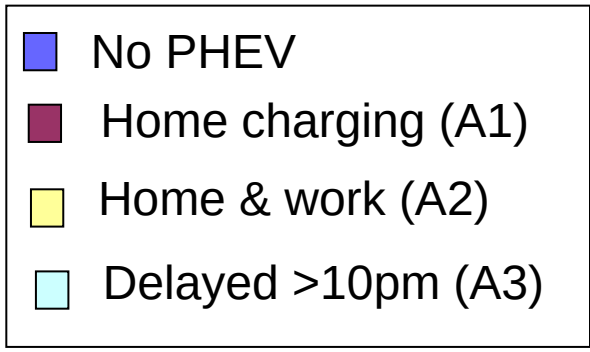
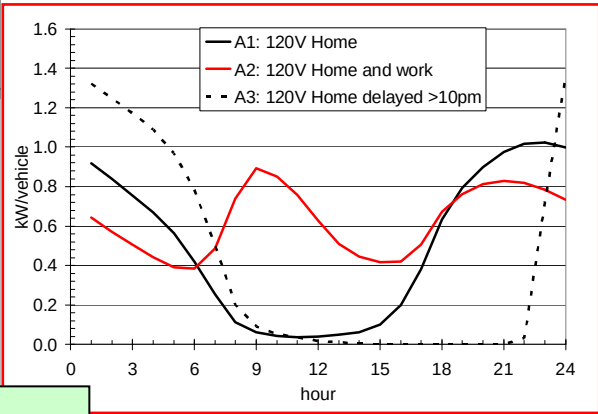
Preliminary Results: LMP for California by Months







- PHEV load about 6% of total generation
- Congestion even without PHEV for summer months
- Night charging will be lowest cost charging

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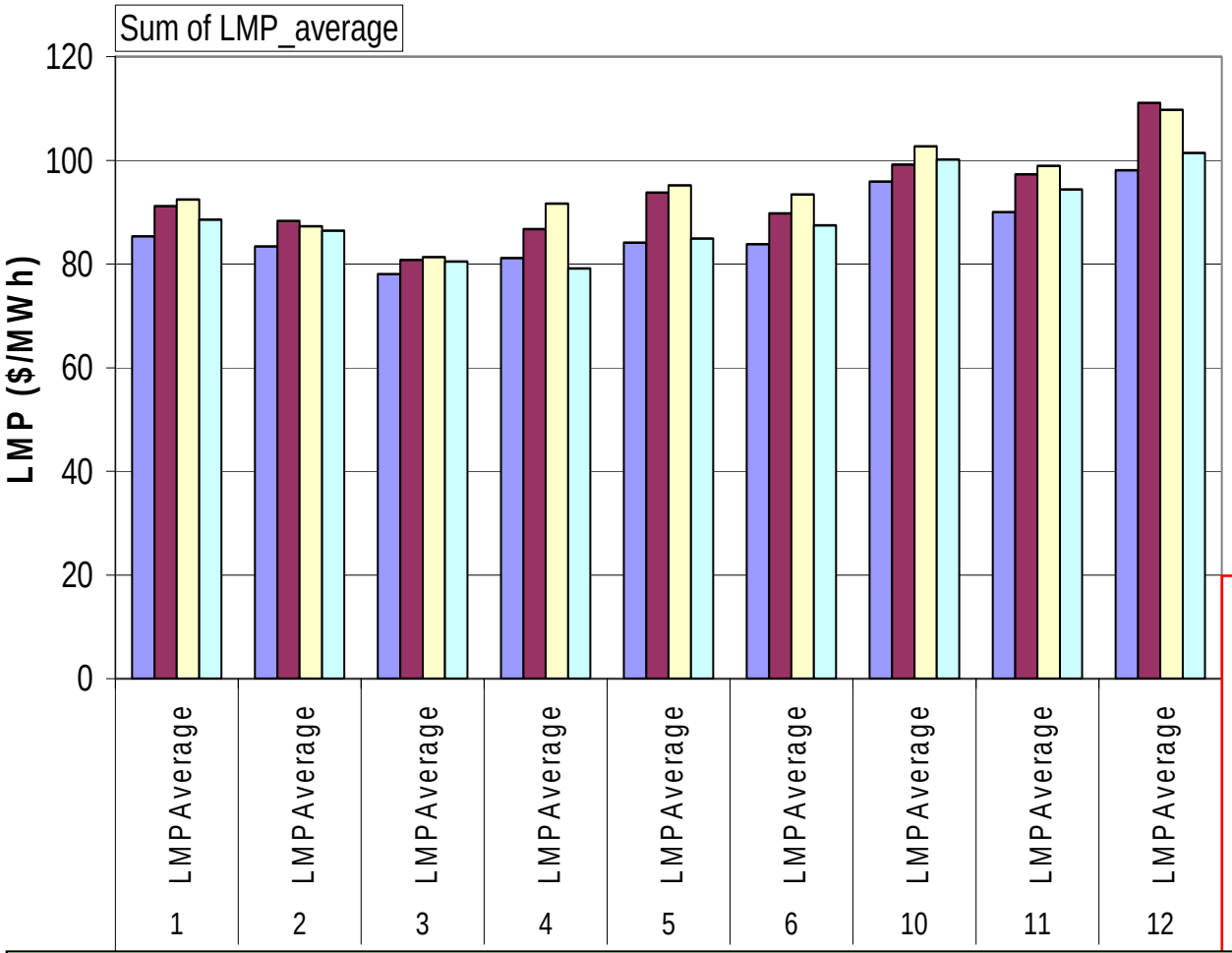
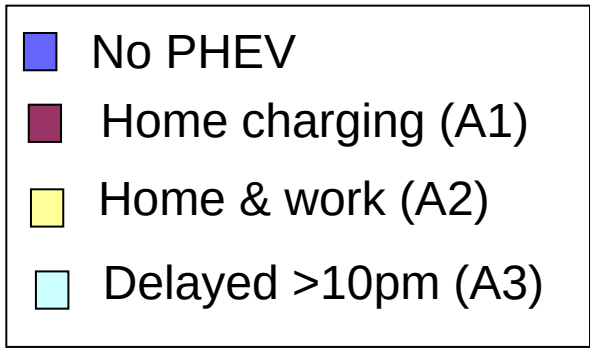
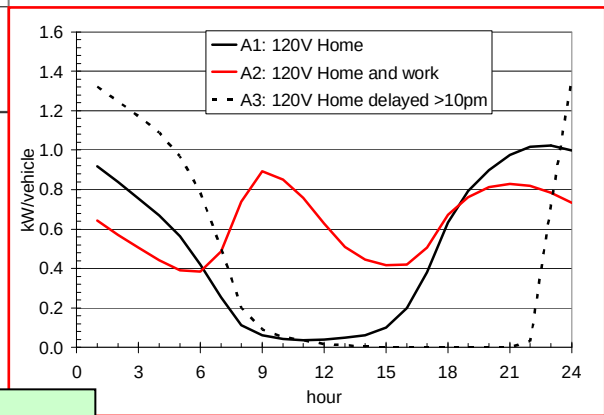
Preliminary Results: LMP for California by Selected Months







- PHEV load about 6% of total generation
- Congestion even without PHEV for summer months
- Night charging will be lowest cost charging

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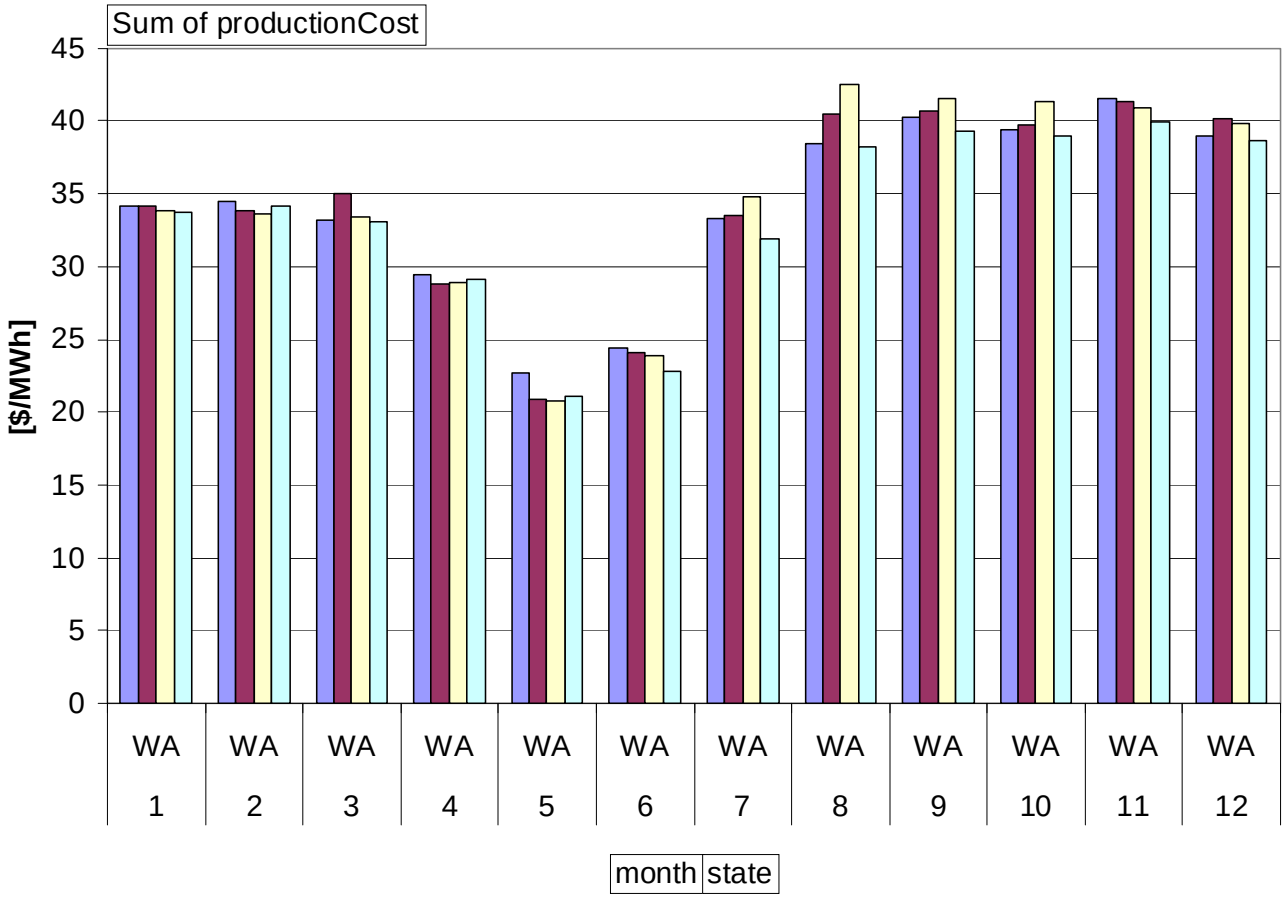
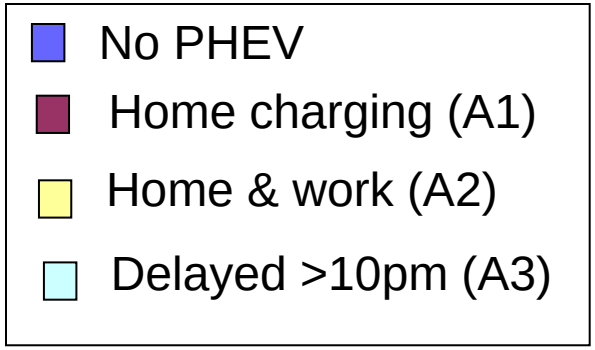
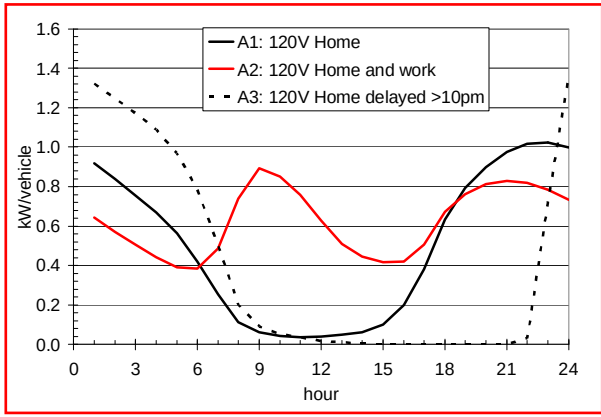
Preliminary Results: Average Production Cost for Washington by Months







- PHEV load is about 1% of total generation
- Average cost may go up or down based on charging profile
- PHEV night charging may lower average cost below that without PHEVs

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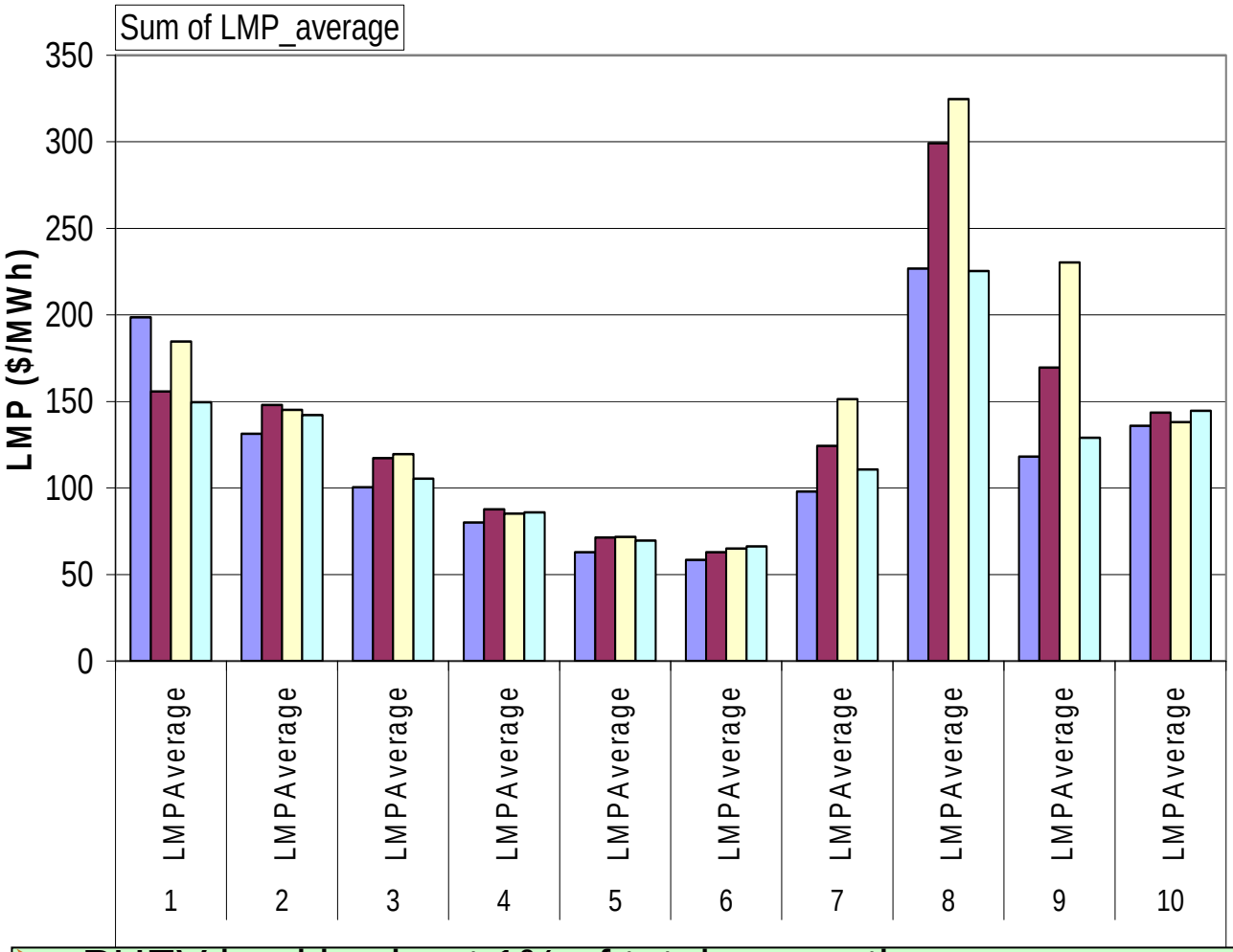
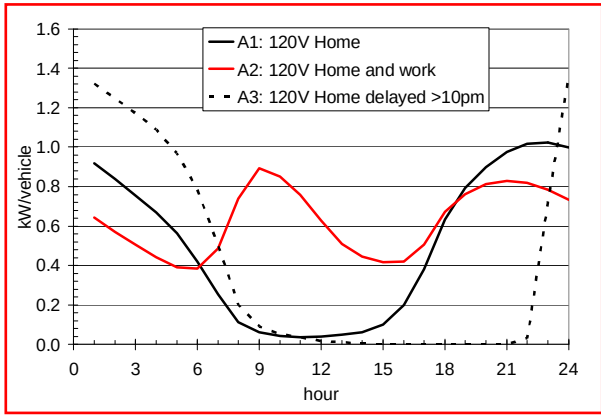
Preliminary Results:LMP for Eastern Washington by Months



No PHEV
Home charging (A1)
Home & work (A2)
Delayed >10pm (A3)



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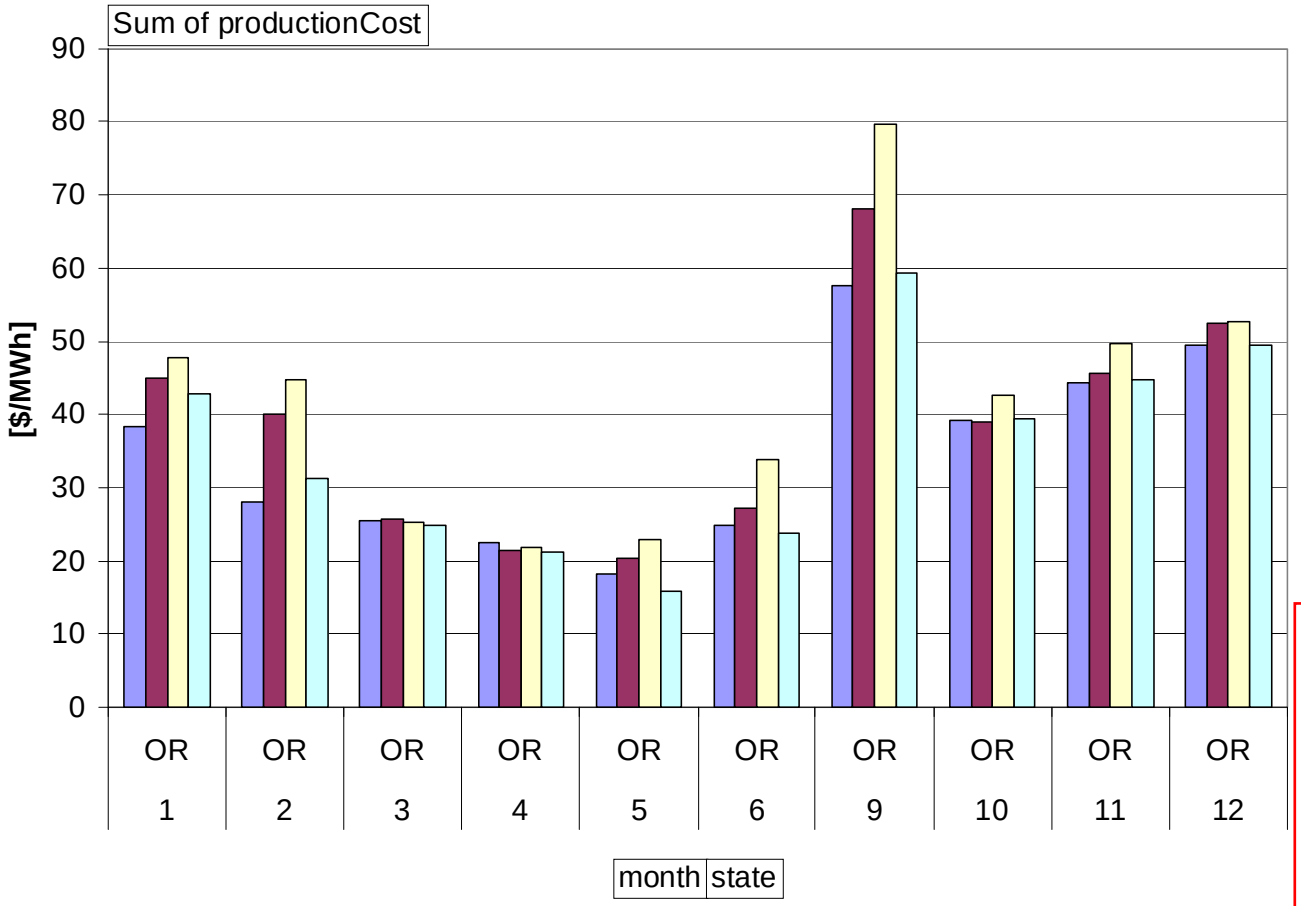
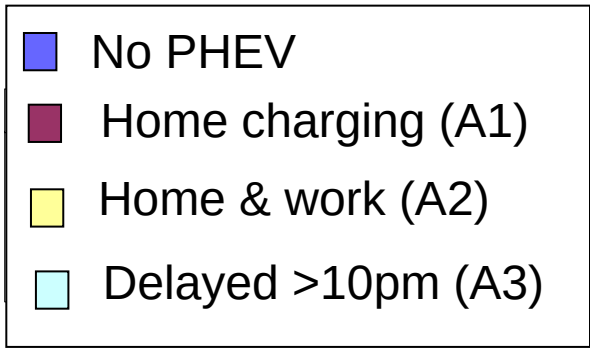
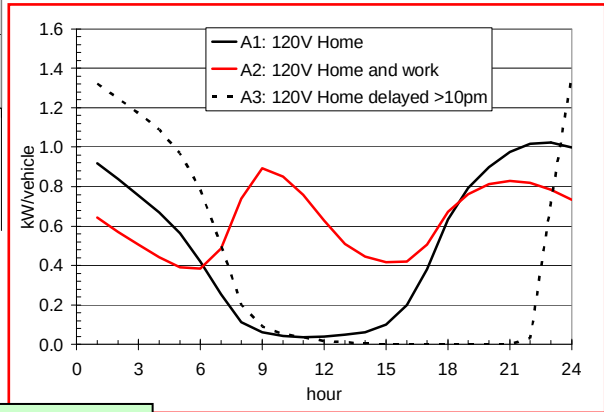
Preliminary Results:Average Production Cost for Oregon by Months







- PHEV load is about 1% of total generation
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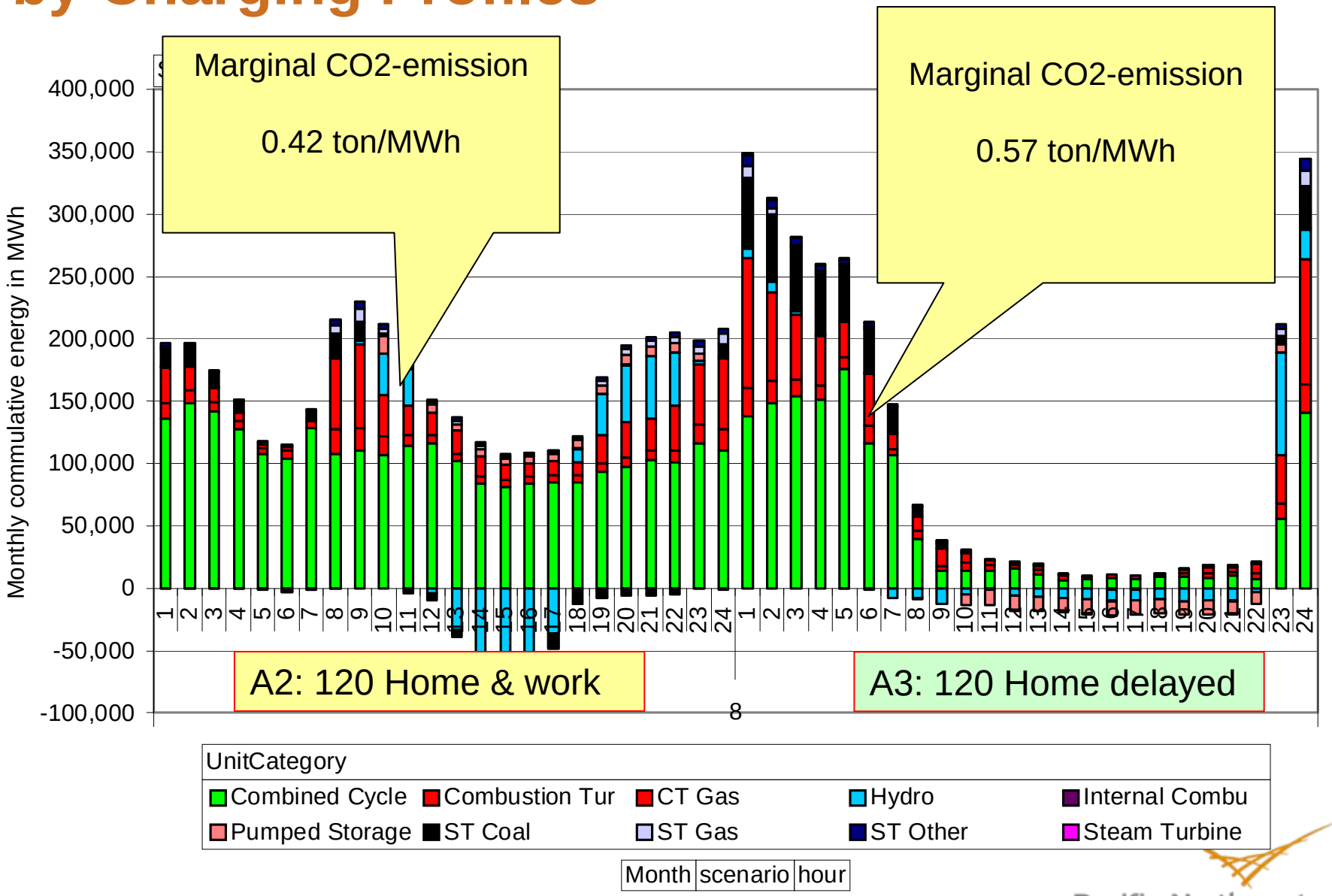
Comparison of WECC's Marginal Generation by Charging Profiles



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Summary

- Technical potential analysis using today's grid and today's vehicles
  - 73% of the LDV could be supported by today's grid if careful load management is performed
  - Emissions depend on marginal generation (gas vs. coal).
    - CO2 emission improves compared with today's car (21 mpg) by about 27%
    - Even under worst case condition (100% coal), CO2 from electric vehicle may be equal to gasoline vehicle
    - With EISA 2007, CAFÉ standards increased to 35 mpg by 2020. This raises the bar
- Production cost analysis of 2030s grid
  - PHEV/EV load makes economic sense to move to off-peak hours, particularly during congested periods
  - Generation at the margin is primarily gas and secondarily coal.
  - CO2 emissions from night charging are about 26% larger compared to day charging
- Policy recommendations
  - Demonstrations of smart charging of PHEV to manage load
  - Reap huge opportunity to introduce smart PHEV charging as the grid becomes smarter
    - Frequency responsive
    - Voltage responsive

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