Northwest Power and Conservation Council

July 2, 2008

MEMORANDUM

TO: Power Committee

FROM: Massoud Jourabchi

SUBJECT: Impact of Plug-in Hybrid Vehicles on Northwest Power System: A Preliminary Assessment

Higher gasoline prices, combined with a growing concern over climate change, have increased the demand for alternative modes of transportation. This has lead to an increase in market share for hybrid passenger and light truck vehicles. The next step in the development of alternative fuel sources may be plug-in hybrids. Using a combination of battery storage and gasoline engine, where batteries are charged during off-peak hours, it is projected that plug-in hybrids can provide benefits in the form of improved gas mileage, reduced cost of travel, and reduced CO2 emissions. At $4 dollars per gallon and 20 MPG fleet efficiency, using a plug-in hybrid vehicle can lower daily commuting costs from an estimated $7 dollars to about 80 cents, or the equivalent of 45 cents/gallon of gasoline, with a net reduction in CO2 emissions.

Using a simplified "what if" model, staff estimated the impact of plug-in hybrids on Northwest electricity loads for the years 2010-2030. Depending on the market penetration rate assumptions, availability of battery technologies, and a number of other assumptions, average annual energy requirements (MWa) in the Northwest could increase by 1 to 3 percent. Off-peak loads (MW) could increase by 4 to 10 percent. CO2 emissions from the transportation sector could decrease by between 7 and 14 million metric tons per year in 2020. A reduction in CO2 emissions from the transportation sector is partially off-set by increases in CO2 emissions from the power plants.

Staff estimated the impact of the additional load on electricity prices and CO2 emissions from the power plants in the Western Electricity Coordinating Council (WECC) area using AURORA$^{xmp©}$ and one of three plausible penetration scenarios. This study showed CO2 emissions from power plants increased by about 1 million tons in 2020. When combined with the decreased CO2 from vehicle emissions, there is a net reduction on CO2 emissions of about 6 million metric tons in 2020.

In addition, staff tested a Vehicle to Grid (V2G) scenario, where a modest 25 MW of vehicle

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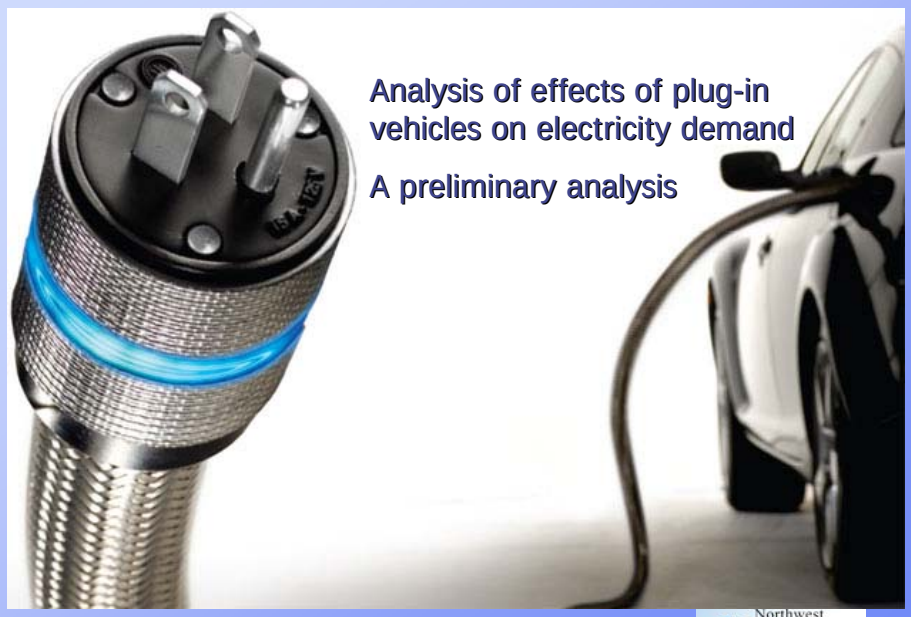
battery storage was connected to the grid. The batteries of participating vehicles are assumed to be charged during off-peak hours and be available for discharge by the grid operator during the peak hours. Our preliminary partial analysis shows that this program would have a marginal effect on prices and emissions. Further evaluation of this program is underway and results will be reported to the Power Committee when available.



Analysis of effects of plug-in vehicles on electricity demand

A preliminary analysis

Photo illustration by George Lange, with Michael Miller (Plug) –Popular Mechanics

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Potential Impact of Plug-in Electric Vehicles

- State of transportation for passenger and light trucks past 30 years.
- Potential impact of Plug-in Hybrid vehicles
- Potential impact of Vehicle to Grid

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We have two modes:
”Complacency and Panic”

James Schlesinger

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Credits

- Dr. Anup Bandivadekar MIT “Evaluating the Impact of Advanced Vehicle and Fuel technologies in U.S. Light-duty Vehicle Fleet “
- Michael Kinter-Meyer, Kevin Schneider and Robert Pratt from Pacific Northwest National Lab. Impacts Assessment of Plug-in Hybrid Vehicles on Electric Utilities and regional U.S. Power Grid.

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Background

- About 230 million passenger vehicles and light trucks on the roads today.
- Vehicles per 1000 people
  - US ~ 800 per thousand
  - Western Europe/Canada- 600
  - China- 20
- MPG ~ in low 20s

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Changes in Transportation

US totals	1970	2005
Number of Vehicles (millions)	110	235
Miles traveled (Trillion)	1.1	2.9
Miles per vehicle	10,303	12,482

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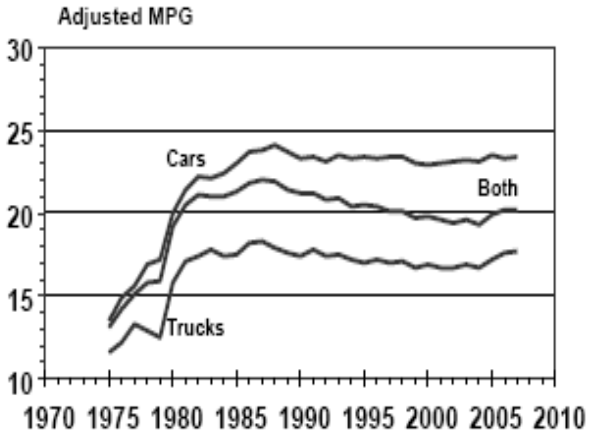
Adjusted Fuel Economy by Model Year (Annual Data)



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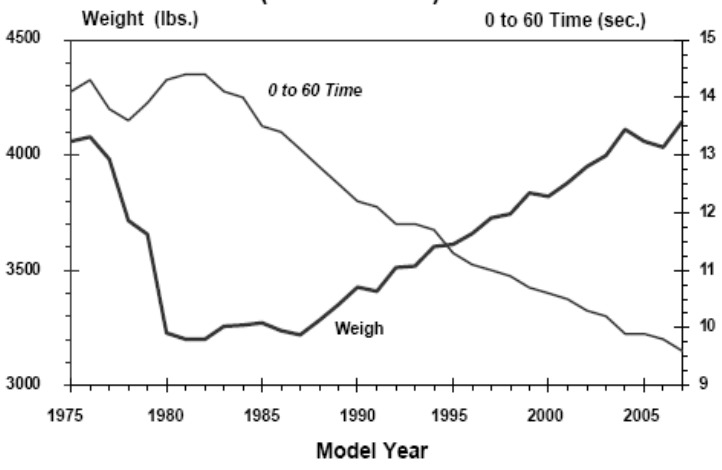
Weight and Performance (Annual Data)



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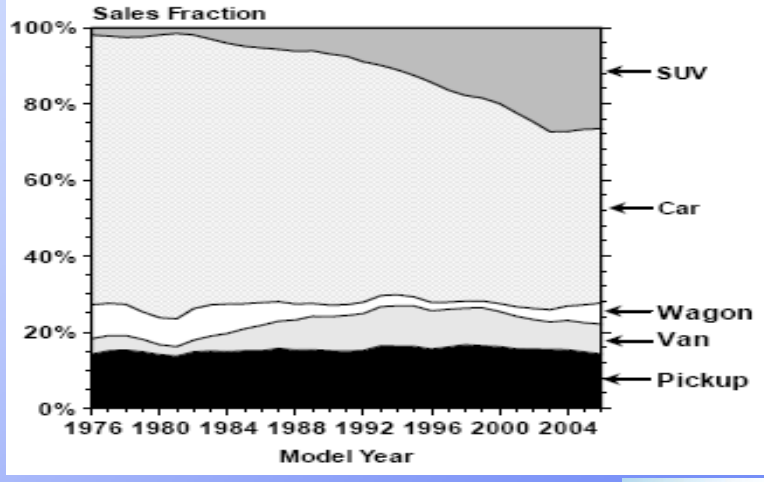
Sales Fraction by Vehicle Type (Three Year Moving Average)



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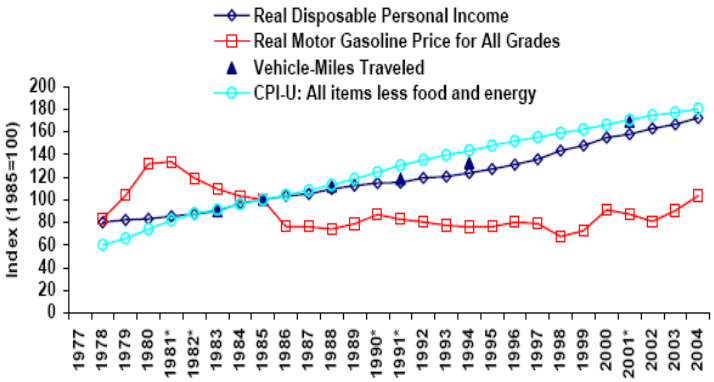
Trends in Cost of Transport

Figure 10. Annual Indices of Real Disposable Income, Vehicle-Miles Traveled, Consumer Price Index (CPI-U), and Real Average Retail Gasoline Price, 1978-2004, 1985=100



Sources: Energy Information Administration, Annual Energy Review 2004; Bureau of Economic Analysis.
*Note * = recession year.*

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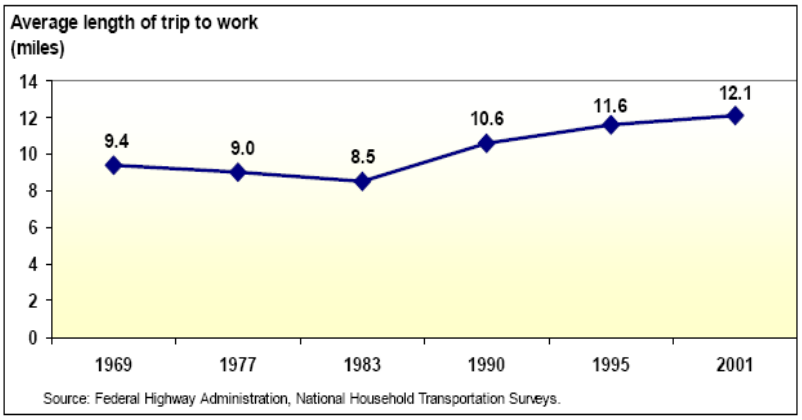
Figure 5. Average Commuting distances, 1969-2001



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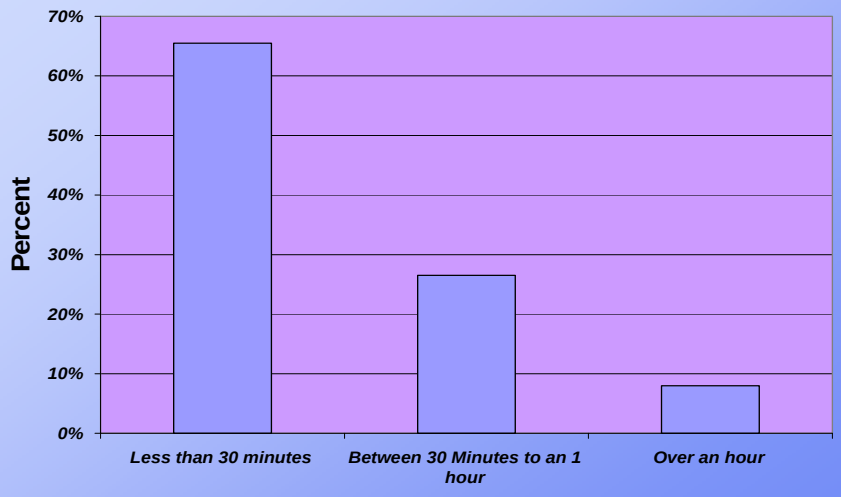
Travel Time to Work



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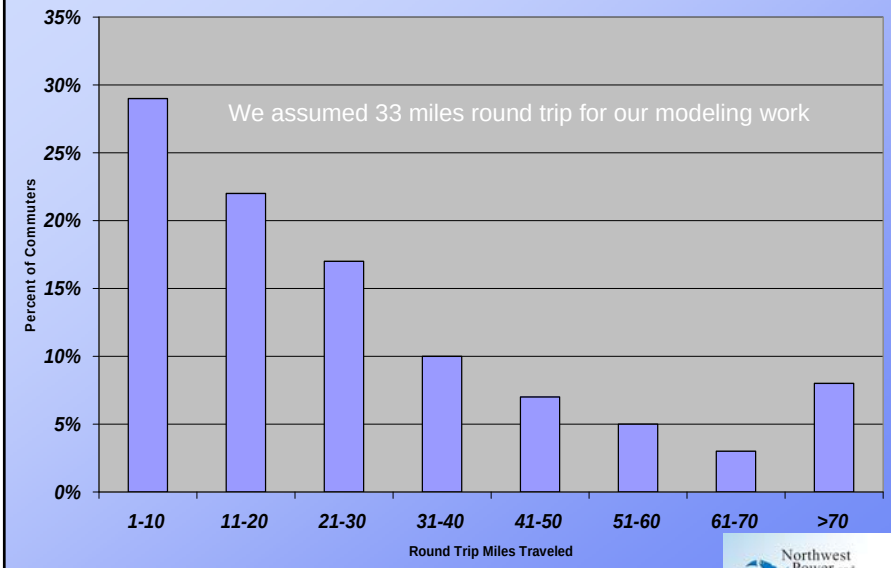
Typical US Commute Distance



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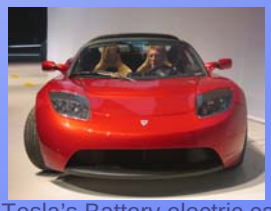
Description of different options

- Current options
  - Gasoline system
  - Turbo Diesel
  - hybrid
- Future options
  - Gasoline
  - Turbo Diesel
  - Hybrid
  - plug-in hybrid
  - Battery electric
  - Fuel Cell

Audi Turbo Diesel

GM Volt

Hyundai's Fuel Cell



Tesla's Battery electric car

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Barriers to new alternative fueled vehicles

- Demand
  - High first cost for vehicle
  - Fuel storage/limited range
  - Reliability and durability
  - Lack of refueling infustructure
  - Market entry barriers (high entry cost)
  - High discount factors and risk aversion

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Barriers to new alternative fueled vehicles

- Supply side constraints
  - Lead times for new product line
  - High Capital investment requirements
  - Limitations of critical supply components
  - Global market response / increase in price of components/ backlog

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Simple " What If " model

- Forecast of passenger and light trucks –Global Insight
- Market share fraction ~ 3% to start 26% in 10 years
- Miles traveled per day ~33 held constant
- Energy requirement ~ 0.26-0.46 KWh/mile (0.3 midsize)
- Energy efficiency improvement -5% per year
- Battery size 10 KWh
- Available battery type Lithium-Ion
- T&D and conversion efficiency losses ~20%
- Recharge at 110 v 15 amp in 8 hours
- Recharge at 220 v 30 amp in under 2 hours
- Assumed 95% recharge off peak, 5% during peak hours
- Current average MPG for gasoline vehicles 20.2
- CO2 emissions for gasoline ~ 1 lb/mile

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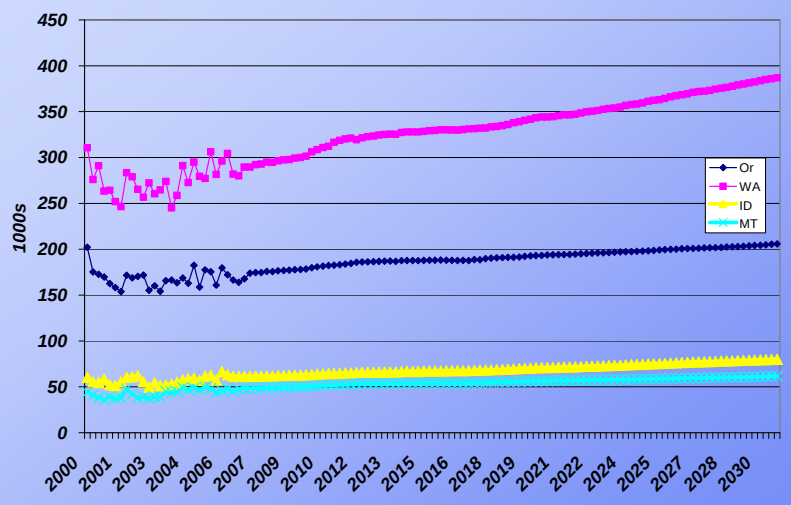
2000-2030 New Passenger and Light Trucks



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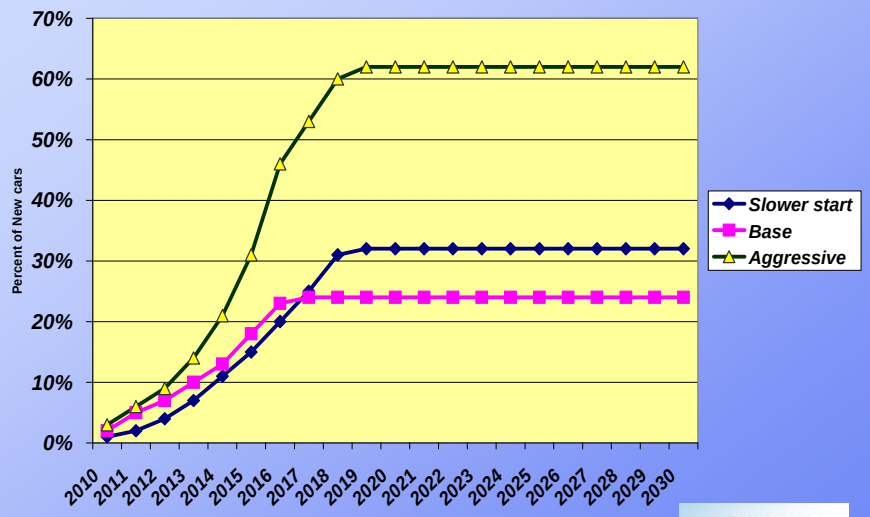
Market Share Scenarios



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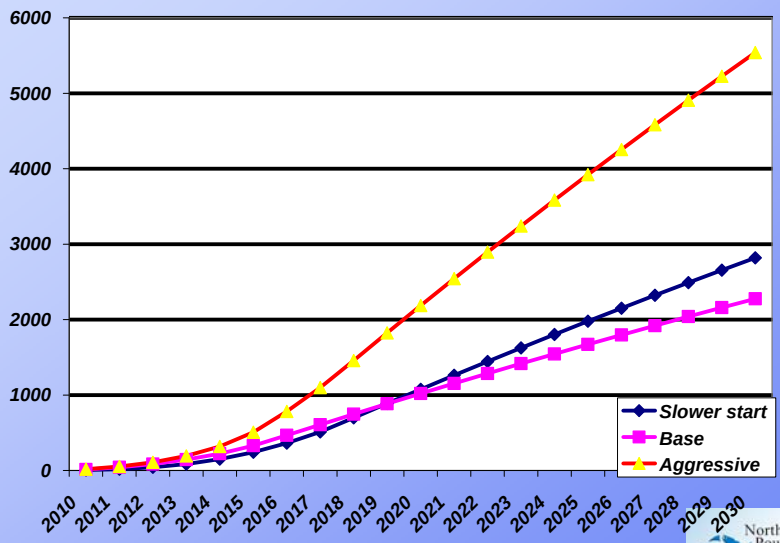
Plug-in Vehicles on the Road (1000s)



48% of new vehicle purchases 2010-2030

20%-24% of new vehicle purchases 2010-2030

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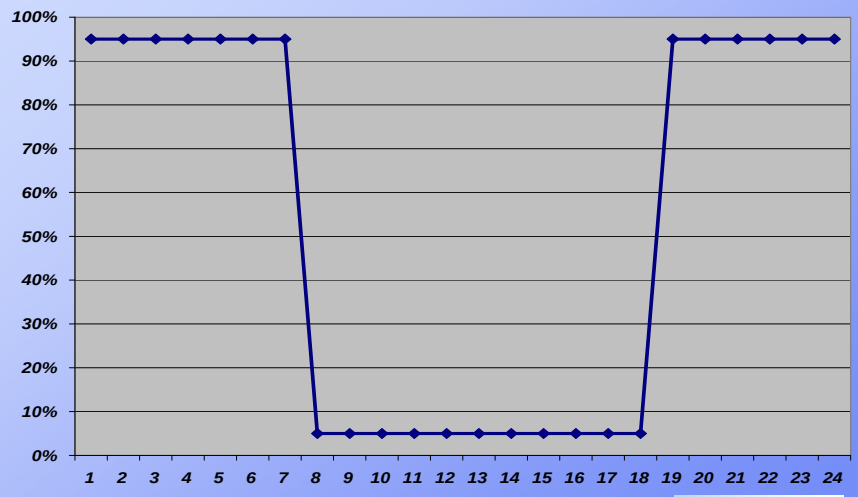
Assumed Daily Recharge Schedule



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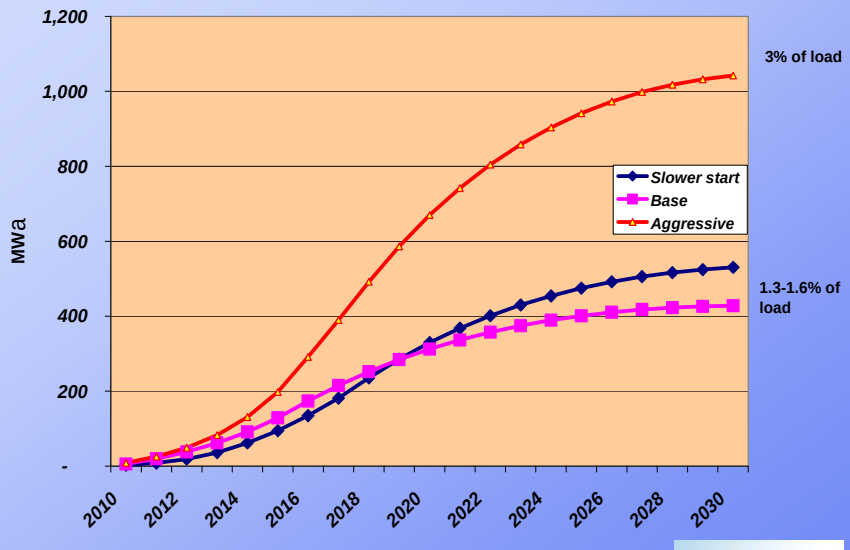
Impact on Northwest Energy MWa



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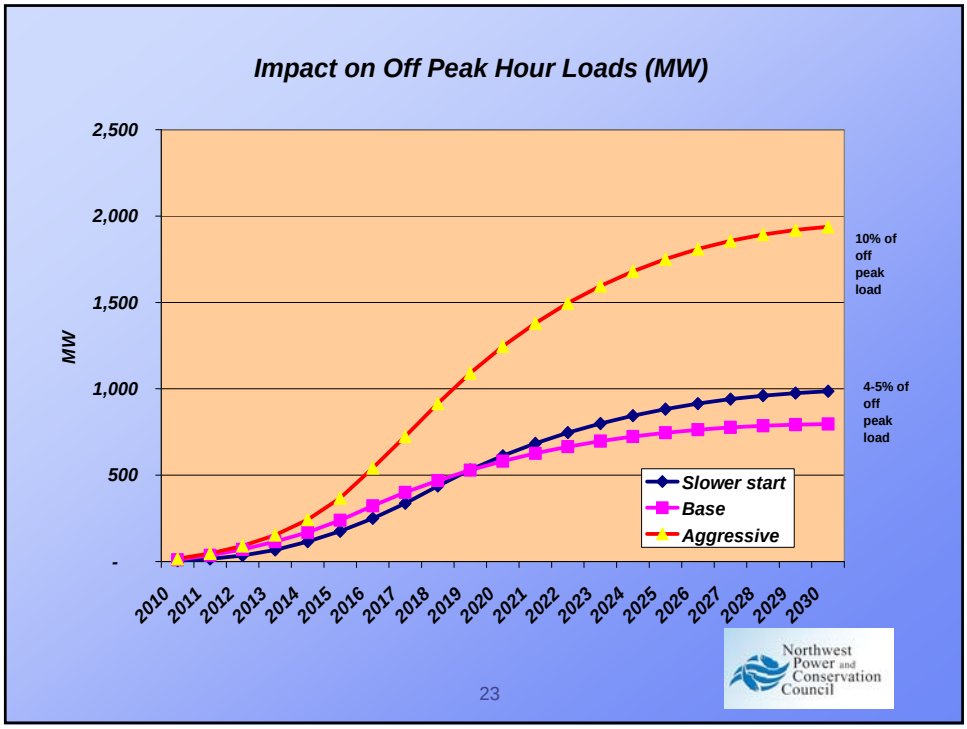
Impact on Off Peak Hour Loads (MW)
MW
2,500
2,000
1,500
1,000
500
-
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
10% of off peak load
4-5% of off peak load
Slower start
Base
Aggressive
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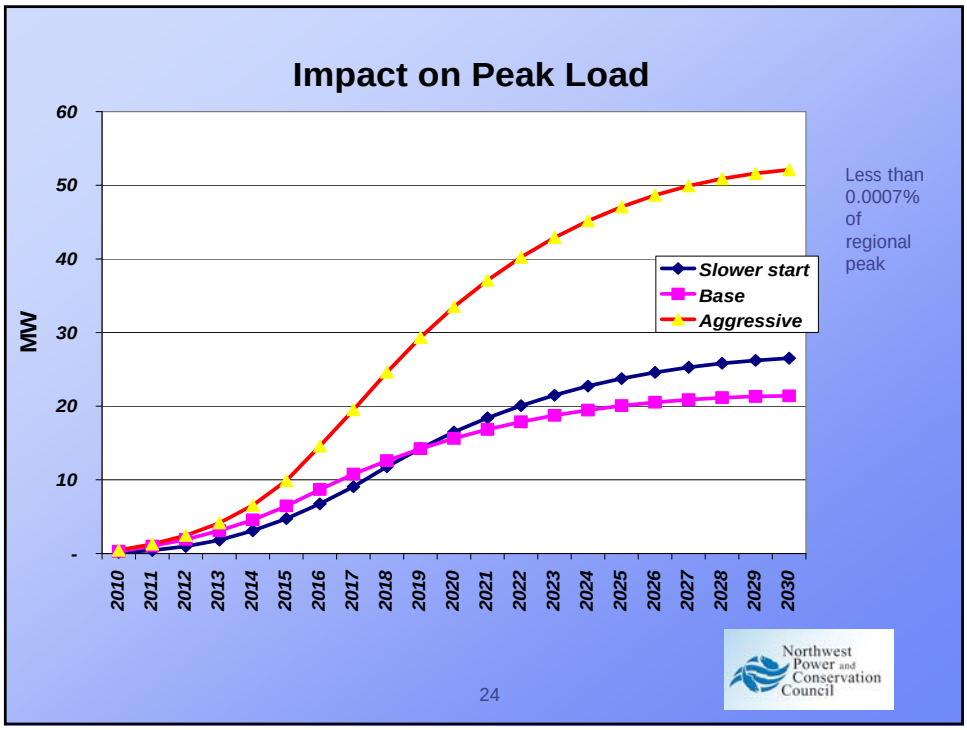
Impact on Peak Load
MW
60
50
40
30
20
10
-
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Slower start
Base
Aggressive
Less than 0.0007% of regional peak
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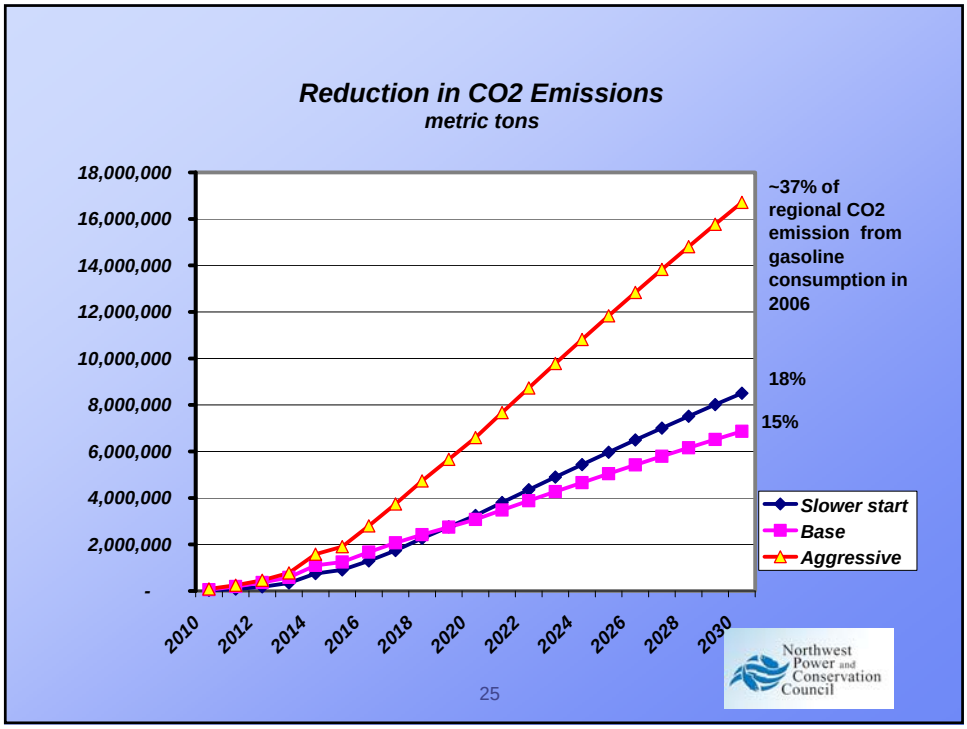

Impact of Plug-in Hybrids on the Power System

- In year 2020

  Base Case without Hybrids

  Annual Average Mid-C price: $ 64.57/mwh

  Annual CO2 Emissions from power plants: 443.3 million tons

  Plug-in Hybrid Electric Case

  Annual Average Mid-C price: $ 65.27/mwh

  Annual CO2 Emissions from power plants: 444.7 million tons

  Average price and CO2 emissions go up slightly.

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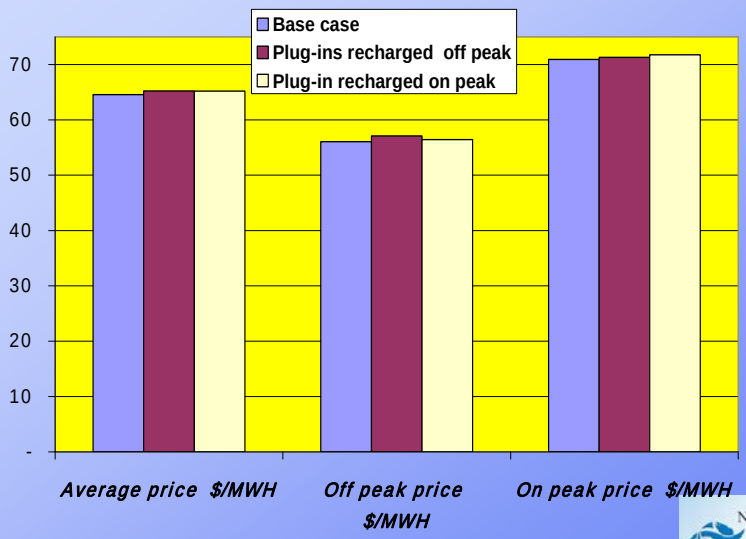

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Modeling Storage Opportunities Vehicle 2 Grid

- First assumed that 25 MW of storage can be placed in the Plug-in vehicles.
  Charge period: 11 pm-5 am
- Discharge Period: 11am to 4 pm
- Assumed efficiency: 80%
- Impact of Prices and CO2 emissions were marginal.
- Then evaluated impact of a 250 MW storage unit.

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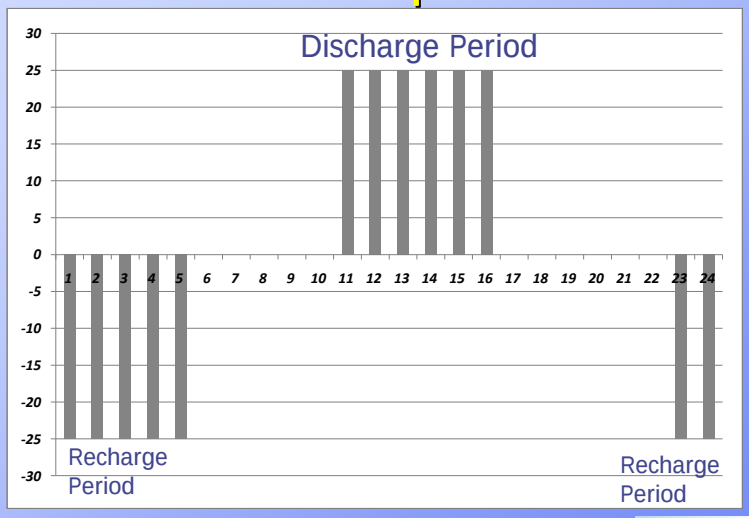
Storage Charge and Discharge Shape



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Impact on Prices and CO2 Emissions

Storage	Charge Period	Discharge period
Base case	52.3	70.75
With plug-ins	53.7	70.96
with plug-ins and V2G	54.3	69.94

- Power Plant CO2 Emissions (WECC wide)
  - Base case - 443 million tons
  - With Plug-ins - 444.7 million tons
  - With Plug-in and V2G- 444.8 million tons

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Optimizing a larger storage unit

- Assumed that 250 MW of storage can be placed in the plug-in vehicles
- Allowed Aurora Model to optimize charging and discharging
- Model chose discharge periods in response to higher market prices, to lower market price.
- Discharge Periods were early evening winter peak period and early afternoon summer peak period.
- Finding: Similar impact to earlier analysis

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Incorporating Plug-in Hybrids in Load Forecast

- Plug-in hybrid characteristics will be incorporated into Energy2020 model
- Penetration rates can be exogenously set as a policy or endogenously modeled as a customer choice.

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Summary

- Plug-in hybrids can have modest impact on energy demand in the NW.
- Plug-in hybrids can have significant impact on off-peak loads
- Plug-in electrics increase CO2 emissions from power plants but significantly reduce emission from transport sector.

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