

Plug-in Hybrid Benefits to the Xcel Energy Colorado System

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A Plug-In Hybrid Electric Vehicle (PHEV)

Fuel Flexibility

PETROLEUM

And
/Or

ELECTRICITY

ADVANCED ENGINE

ELECTRIC ACCESSORIES

ENGINE IDLE-OFF

ENGINE DOWNSIZING

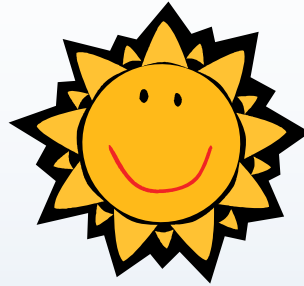
REGENERATIVE BRAKING

BATTERY RECHARGE



76hp gasoline engine, 67hp electric motor, 9.0kWh battery (30mi)

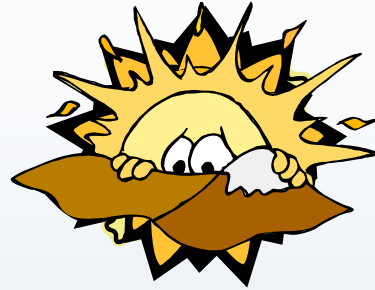
Daily Charging Strategies



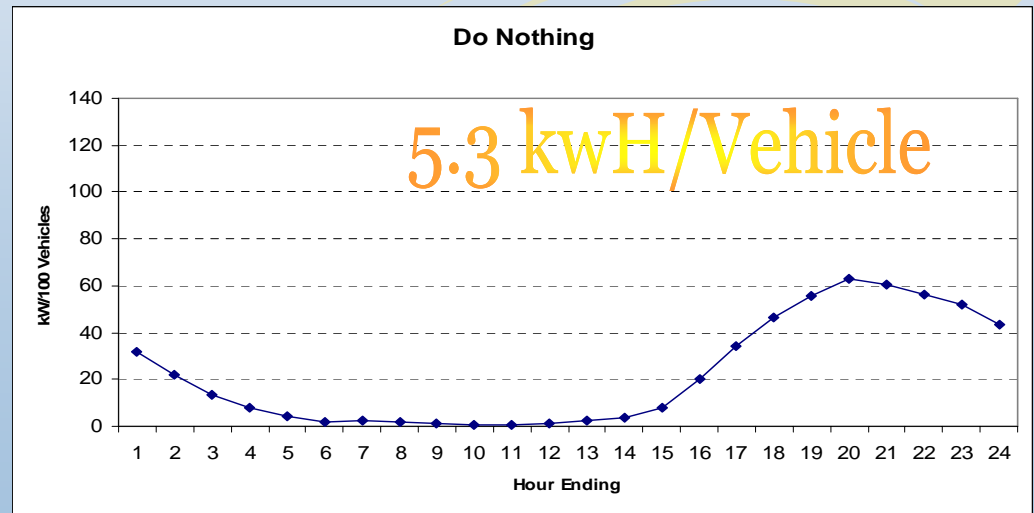
Given driving habits, what is the effect of many vehicles on the electricity system?



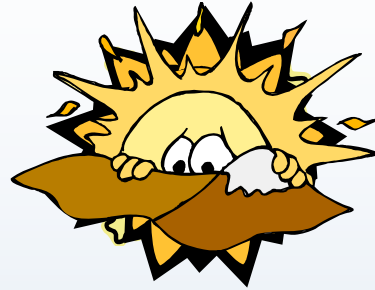
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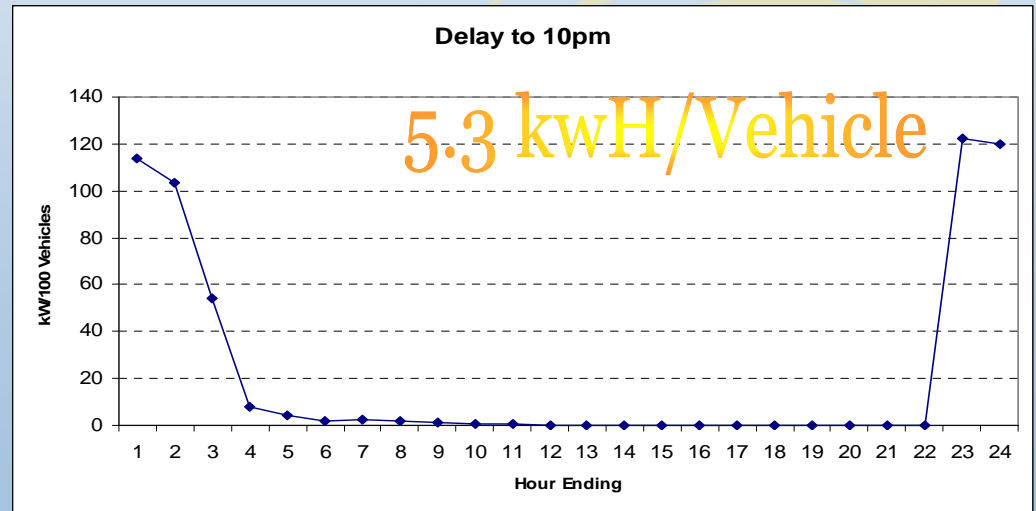
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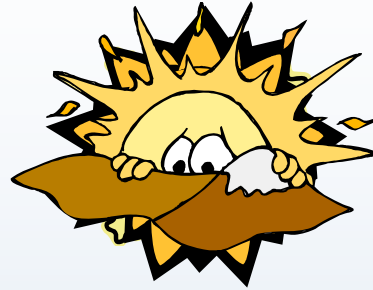
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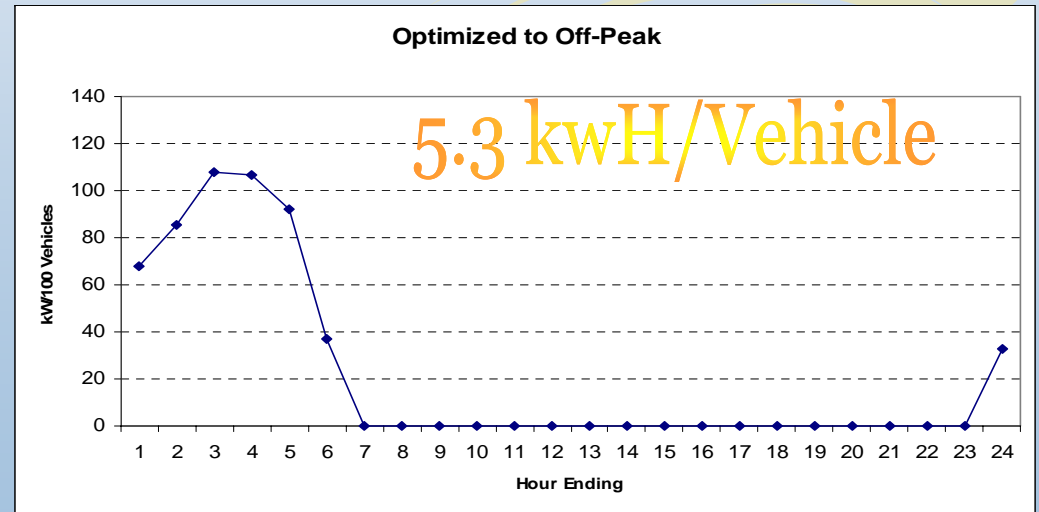
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Daily Charging Strategies



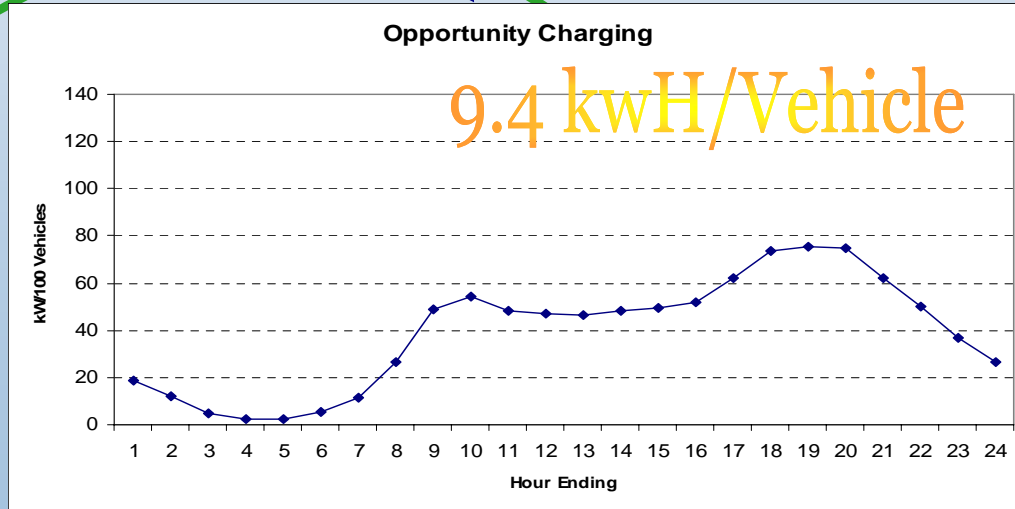
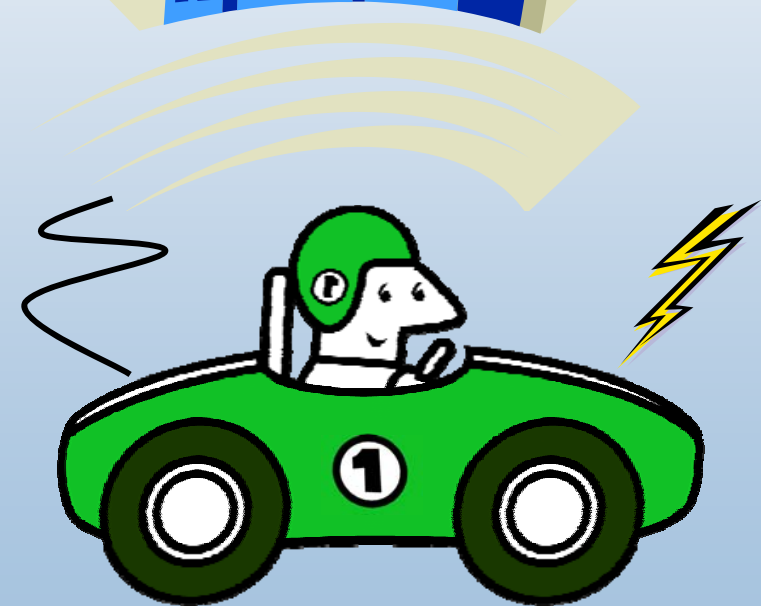
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Daily Charging Strategies

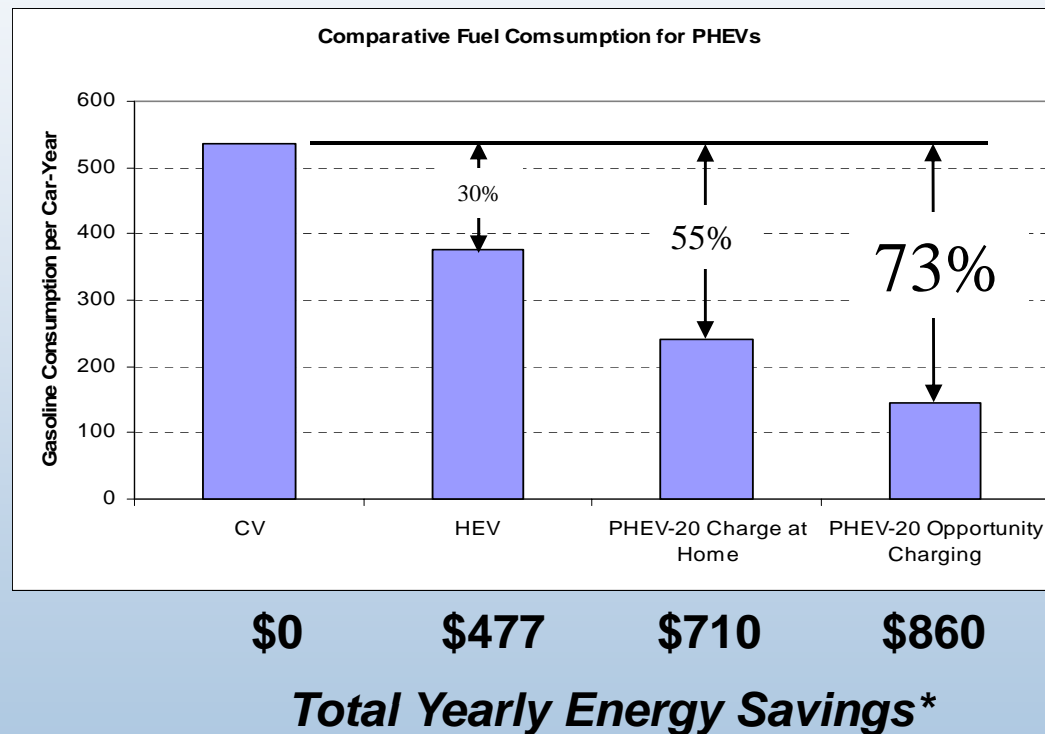


Given driving habits, what is the effect of many vehicles on the electricity system?



Gasoline Savings

The largest benefit of PHEVs is gasoline savings



Huge reductions in gasoline use are possible...

*Assumes gasoline at \$3.00/gallon and electricity at \$0.09/kWh

Combustion vehicle (CV) is a standard sedan (13,900 miles/year @ 26 mpg)

Hybrid Electric Vehicle (HEV) is the same sedan, but with hybrid drive technology (13,900 miles/year @ 36 mpg)

What are the Impacts to Xcel Energy?

- Infrastructure Utilization
- Additional Load
- Production Costs
- Capacity Impacts
- Emissions

UNKNOWN

Can Xcel Energy mitigate adverse impacts with controls or incentives?

We have to first understand what the impacts are.

Sneak Preview

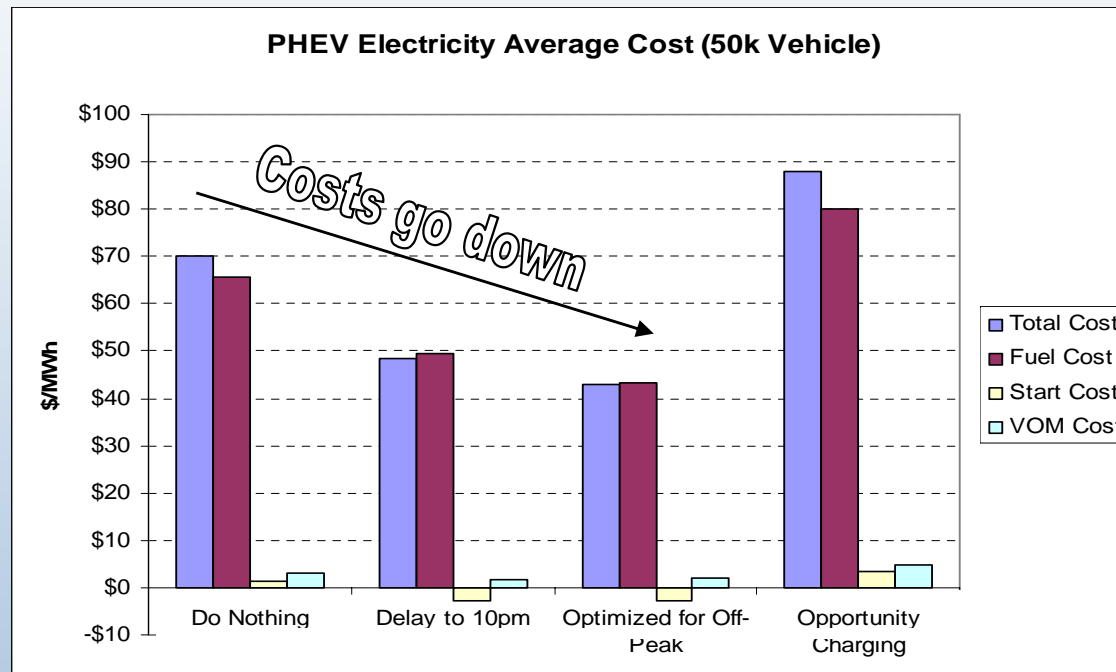
Time of charging matters...

Coincident peak loading matters...

Tailpipe versus upstream emissions matters...

Incremental Cost (Generation Capacity)

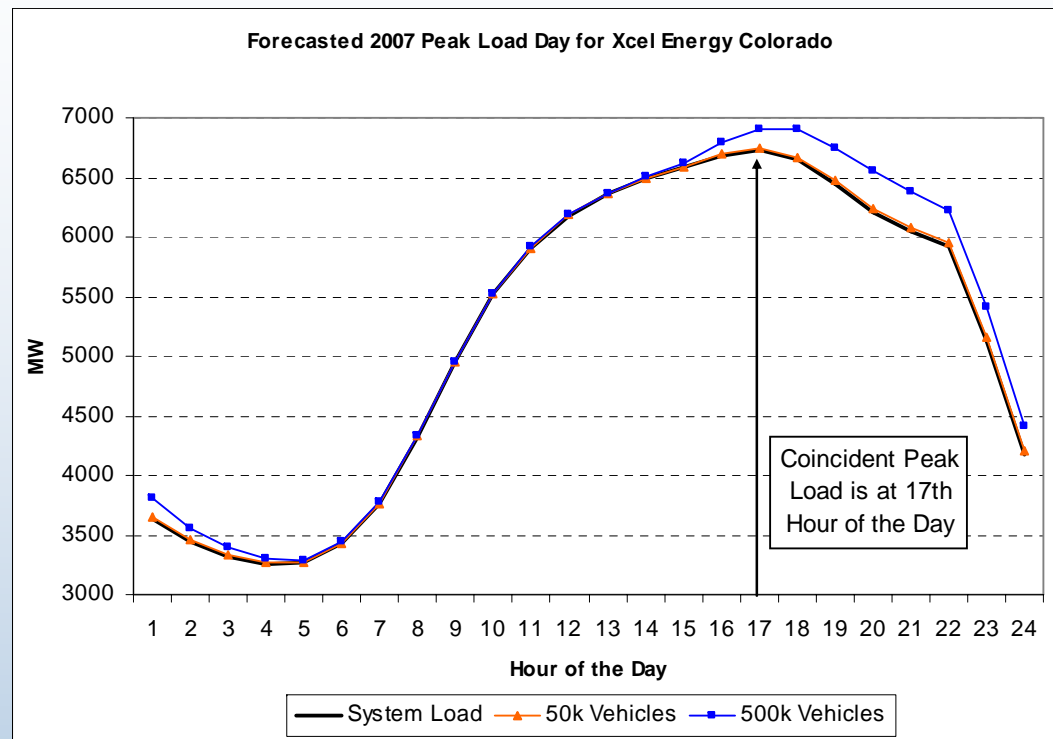
- Costs are dominated by fuel cost
- As power is moved to the off-peak period...



- Opportunity charging is the most costly charging strategy, but utilizes 75% more energy

Incremental Cost (Generation Capacity)

- Coincident peak loading necessitates additional generation capacity
- *Delayed to 10pm and Optimize to Off-Peak* scenarios avoid capacity expansion costs

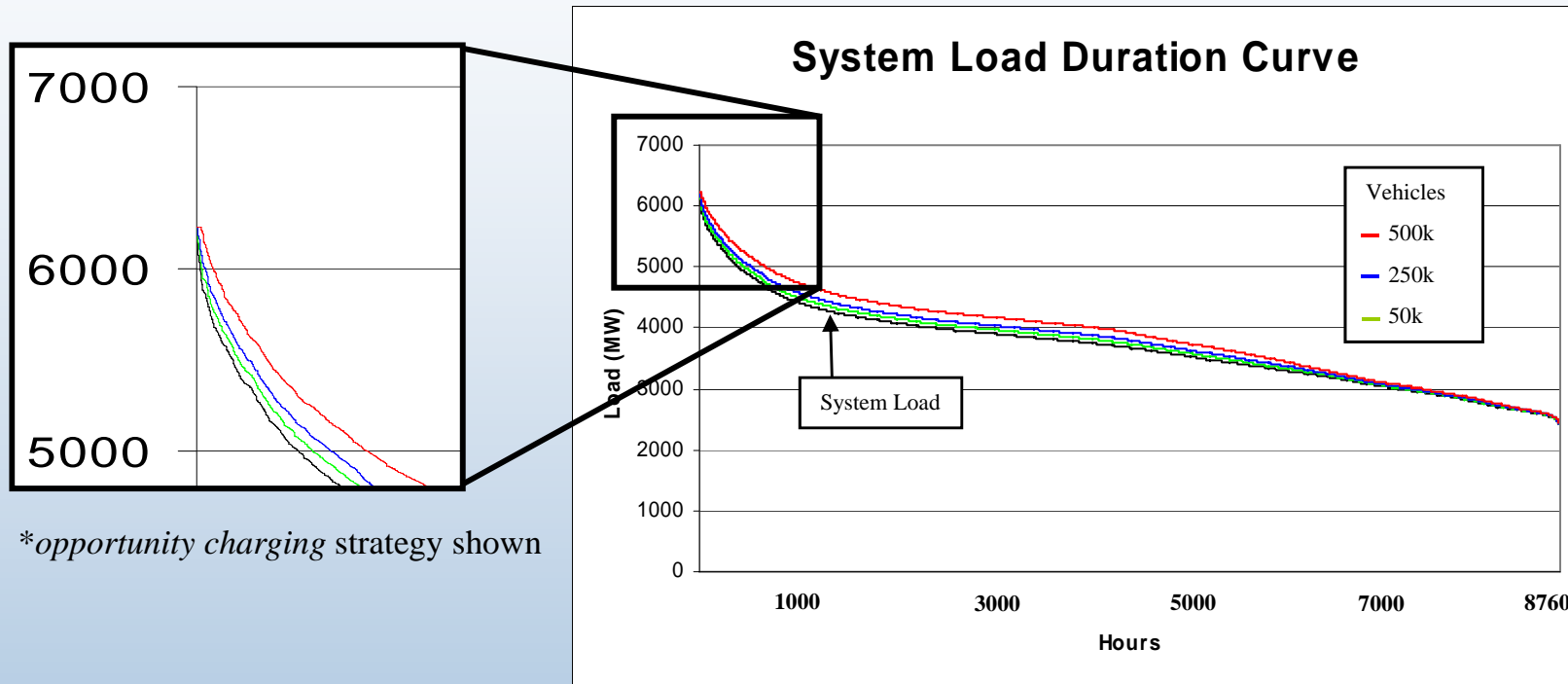


Charging Scenario	Annual Capacity Costs
Do Nothing/Status Quo	\$126/kW* @ .339 kW/car = \$43/car
Opportunity Charging	\$126/kW* @ .619 kW/car = \$78/car

*Assumptions: 15% ROI; 20% Capacity Margin; \$700/kW overnight cost (Combustion Turbine)

Incremental Cost (Generation Capacity)

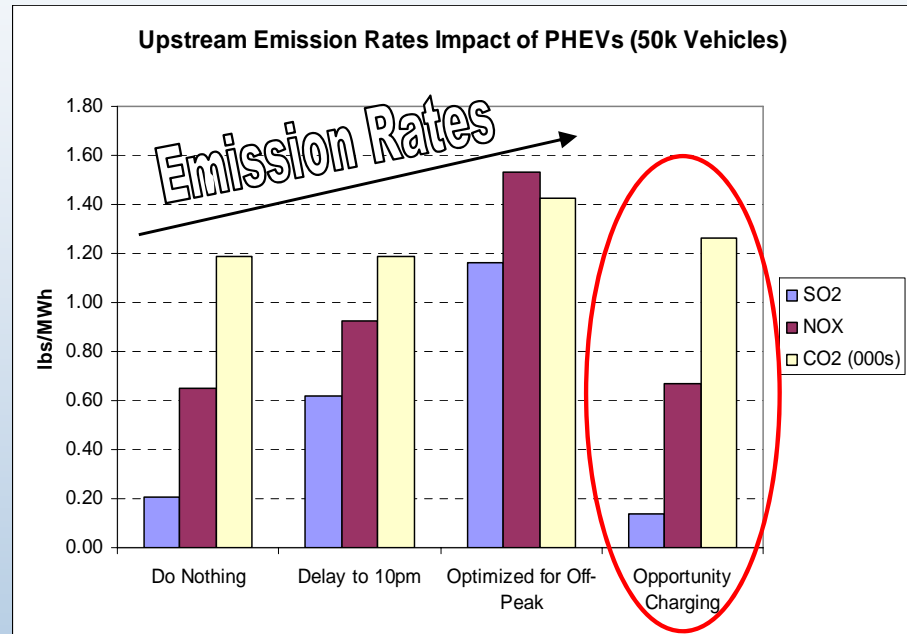
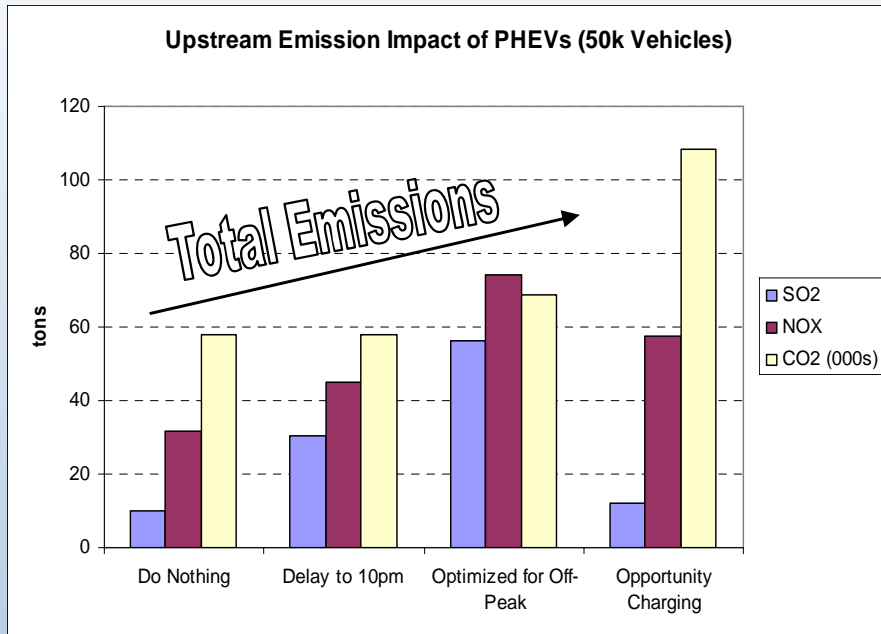
- Coincident peak loading is critical only a few hours per year



Hours of the year PHEV load increases system peak load			
Number of PHEVs	50k	250k	500k
Do Nothing/Status Quo	2	3	5
Opportunity Charging	3	6	17

Emission Footprint

- Time of day matters with regard to emissions
- As power is moved to the off-peak period...



Incremental emission rates are less than half the Xcel Energy Average

Xcel Energy Average Emission Rates

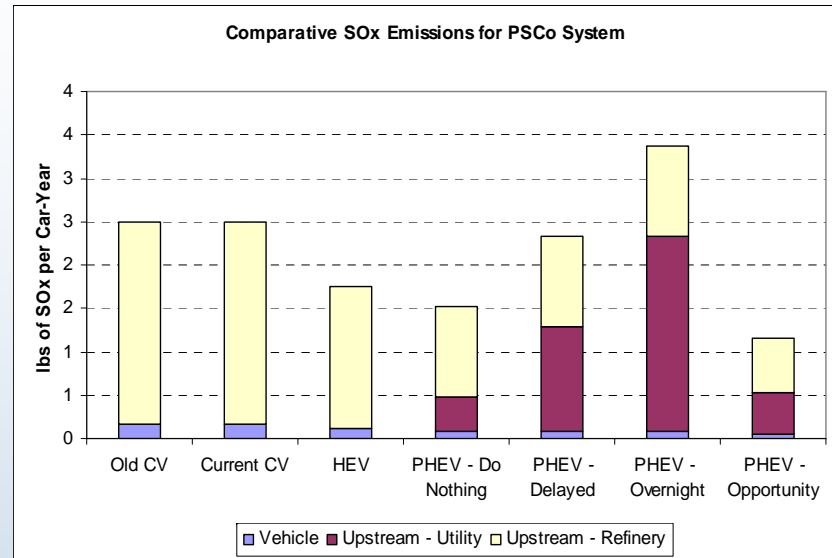
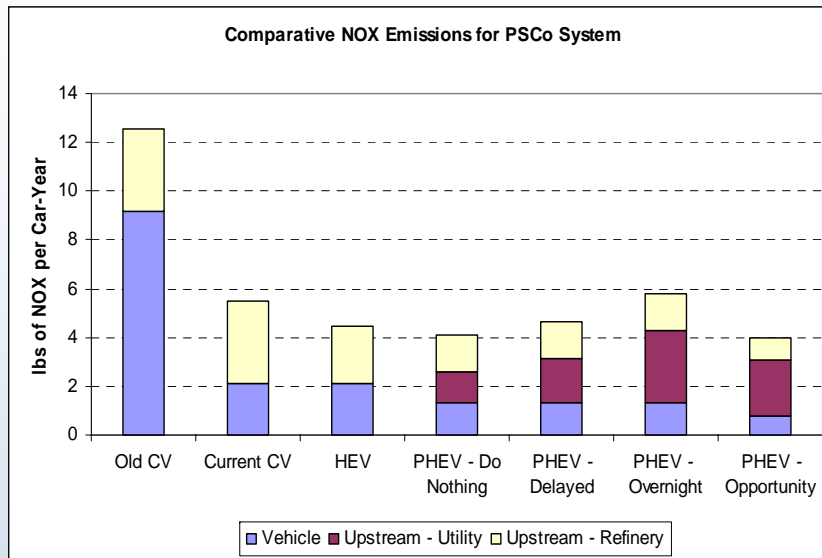
NOX – 2.34 lbs/MWh

SO2 – 2.69 lbs/MWh

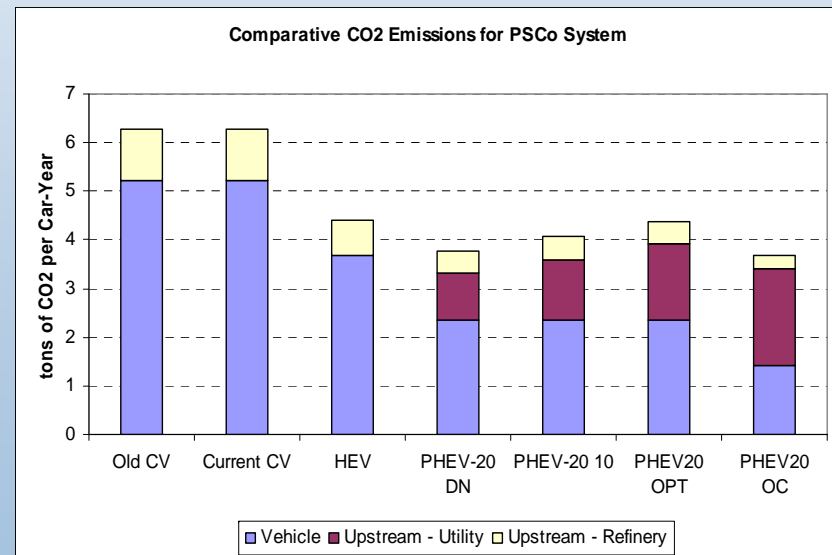
CO2 – 1,775 lbs/MWh

Source: Forecast PROSYM 2007

Total Vehicle Emissions (PHEVs vs. Gasoline)



- Tailpipe NOX decreases while total NOX emissions remain the same
- Total SO2 emissions depend on charging scenario
- CO2 emissions reduced by
 - 40% vs. combustion vehicles
 - 15% vs. hybrid vehicles



Current combustion vehicle (CV) is 2003 National Low Emission Vehicle (NLEV) standard of **0.3 gms/mi** which is phased out from 2004-2006.
Future combustion vehicle (CV) is 2007 Tier 2 Bin 5 rating of **0.07 gms/mi**. This is the standard all manufacturer's fleets must meet.

Compare and Contrast

<i>Scenarios</i>	<i>Production Cost</i>	<i>Capacity Cost</i>	<i>Avoided Gasoline</i>	<i>Emissions</i>	<i>Distribution Impacts</i>
Do Nothing	Good	Worse*	Good	Better	Worse*
Delay to 10pm	Better	Best	Good	Good	Best
Optimized to Off-peak	Best	Best	Good	Worse	Best
Opportunity Charging	Worse	Worse*	Best	Best	Worse*

***Could be mitigated with control technology/incentives**

Future Work

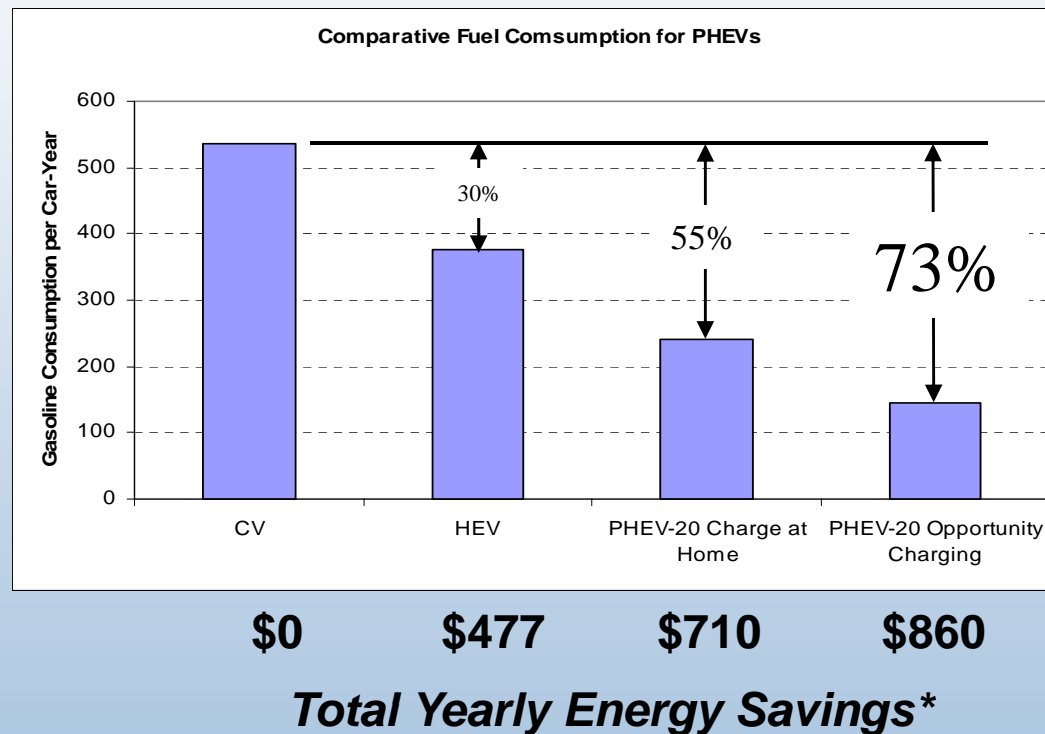
- Vehicle to Grid
 - How does V2G effect MPG?
 - What is the turn-around efficiency?
 - Is there a charging/dispatch strategy that is a win/win for the consumer and the utility?
 - How does availability effect value?

Future Work (continued)

- **Xcel Energy has announced a six-month test drive of PHEVs**
 - Partners: Hybrids Plus, NREL, V2Green
- **Converts six Ford Escape Hybrids to PHEVs with V2G technology, one of the nation's first tests of this emerging technology**
- **Examines PHEV performance in varied climates and geographic regions**
 - Three vehicles assigned to employees for personal use; Three assigned to utility fleet

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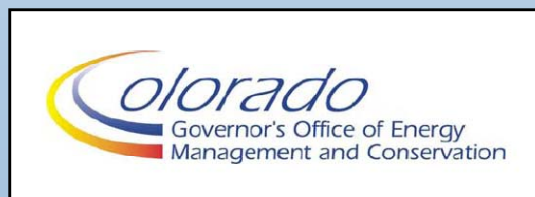
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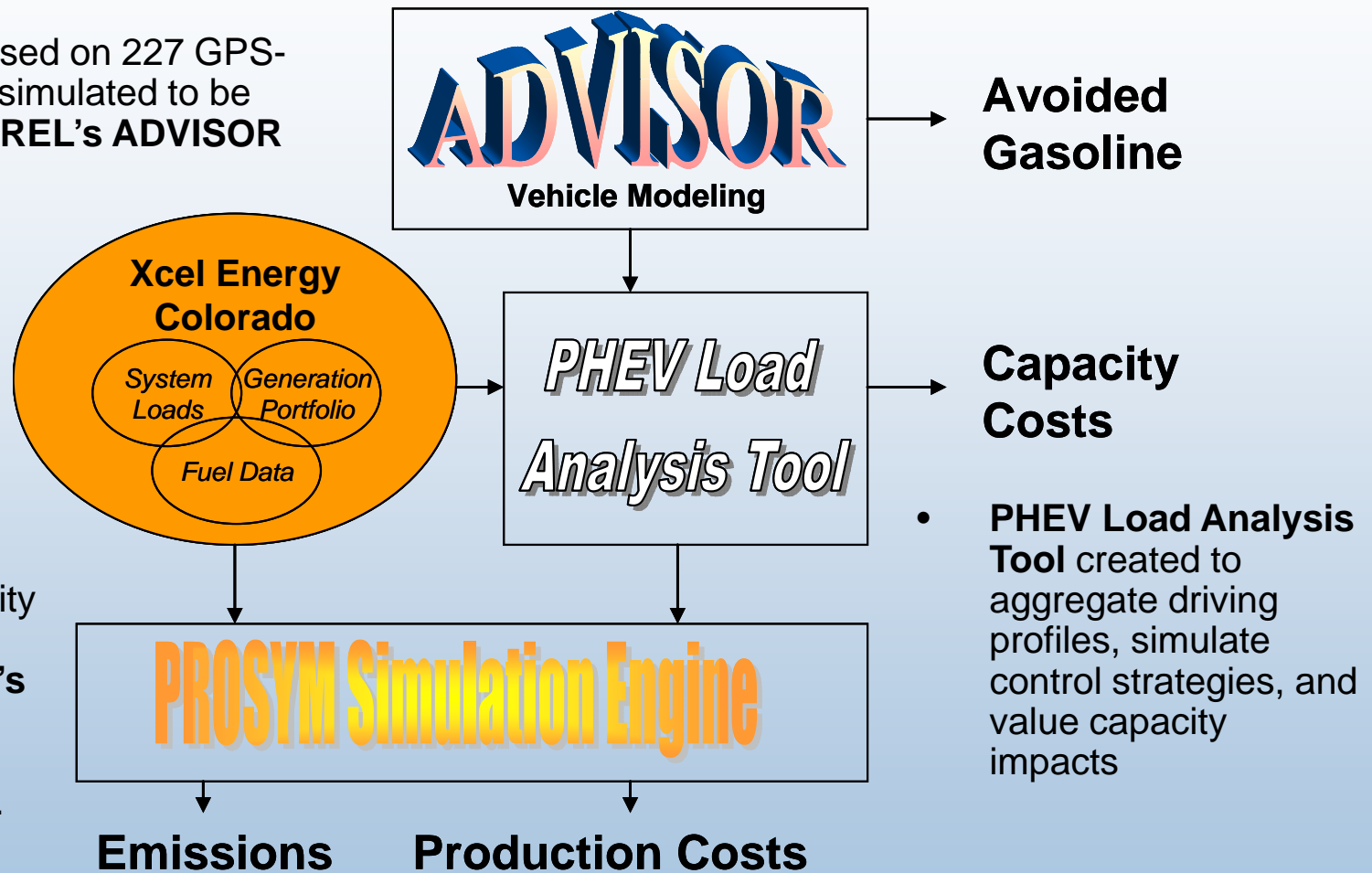


Thank you to **Xcel Energy's Utility Innovations, Global Energy Decisions** and **NREL** for sponsoring this project. Thanks to the **Office of Energy Management and Conservation** and **Hybrids-Plus** for their innovation and enthusiasm.



Methodology

- Driving profile based on 227 GPS-tracked vehicles simulated to be PHEV20 using NREL's ADVISOR model.
- System detail provided by Xcel Energy's Generation Modeling team.
- Simulated electricity grid using Global Energy Decision's PROSYM unit commitment and dispatch software.



- **PHEV Load Analysis Tool** created to aggregate driving profiles, simulate control strategies, and value capacity impacts

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