

# Plug-in Hybrid Electric Vehicles: New Load or New Resource?

UW Energy Institute Seminar Series

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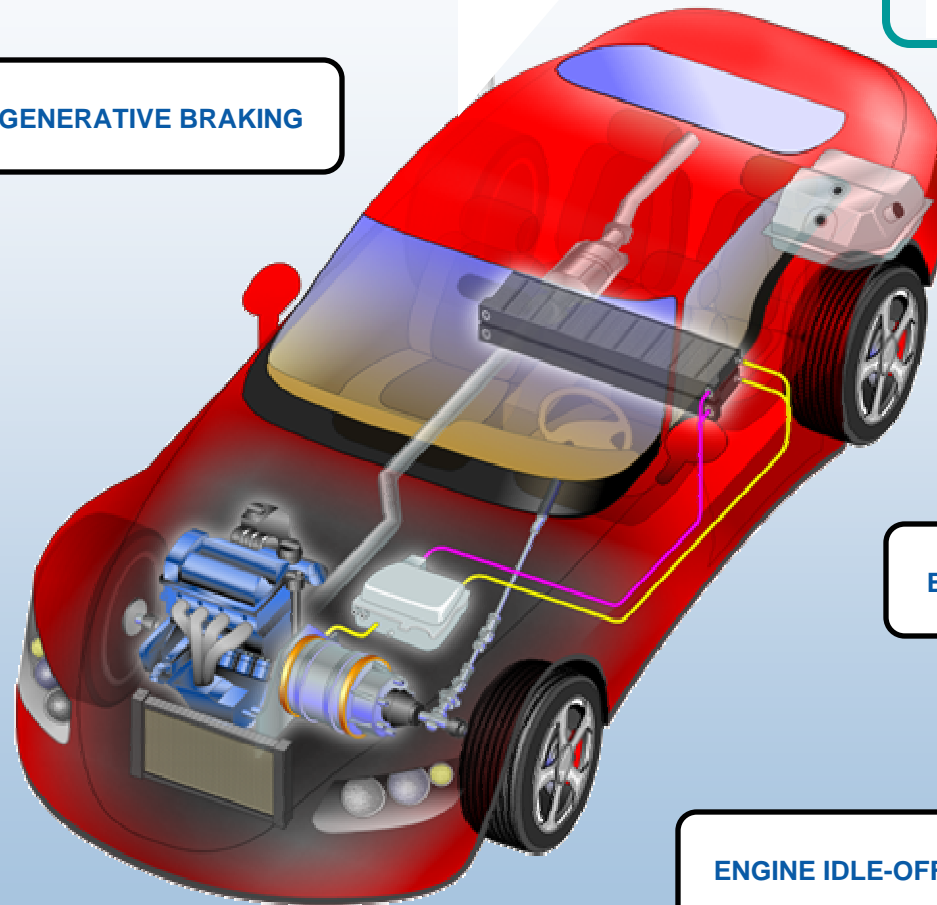
# Today's Presentation

- What is a PHEV?
- Technical Performance
- Charging Impacts
- Vehicle to Grid (V2G)
- Synergies with renewable energy sources

# Hybrid-Electric Vehicle (HEV)

Electric  
Acceleration

REGENERATIVE BRAKING



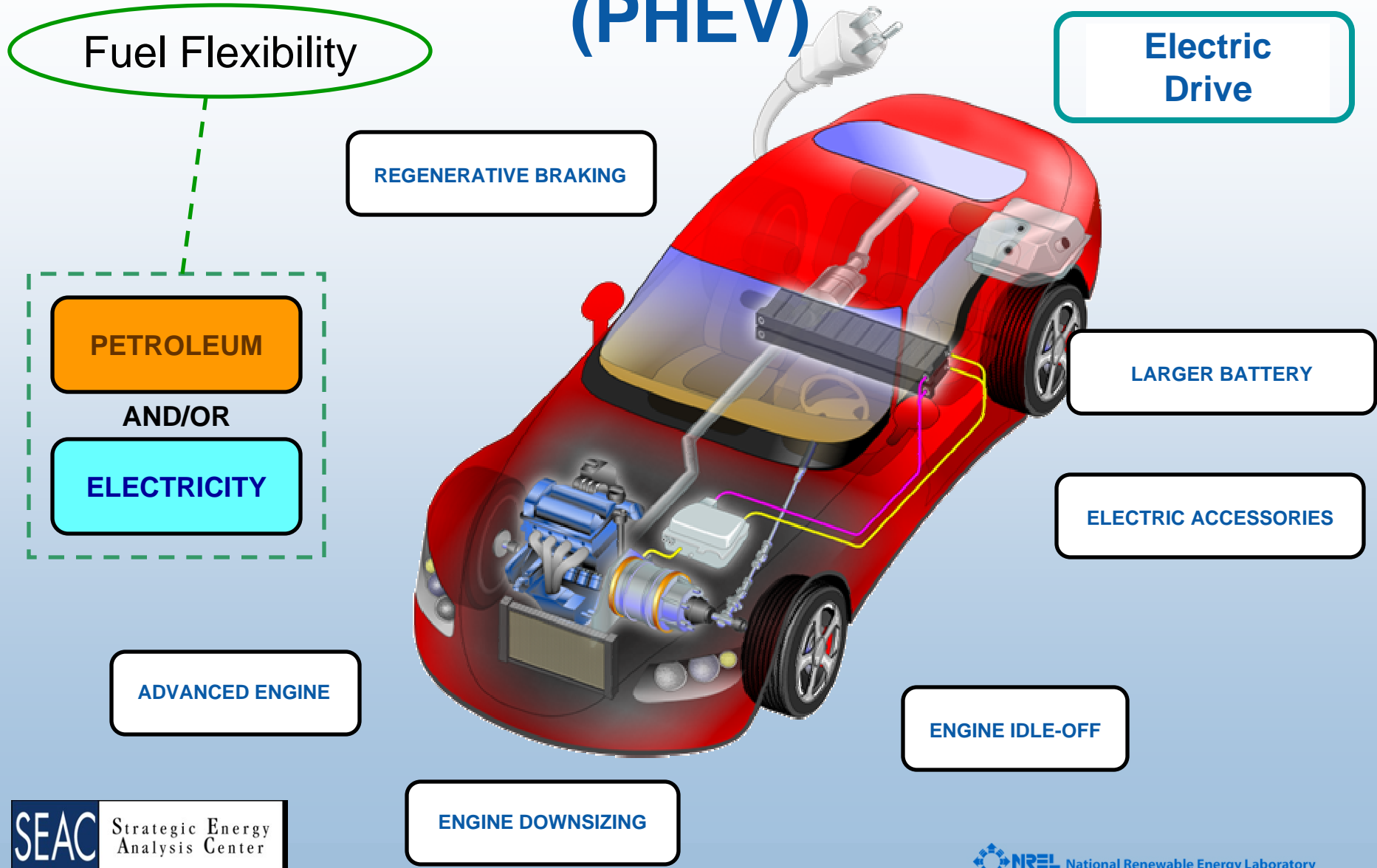
ELECTRIC ACCESSORIES

ADVANCED ENGINE

ENGINE IDLE-OFF

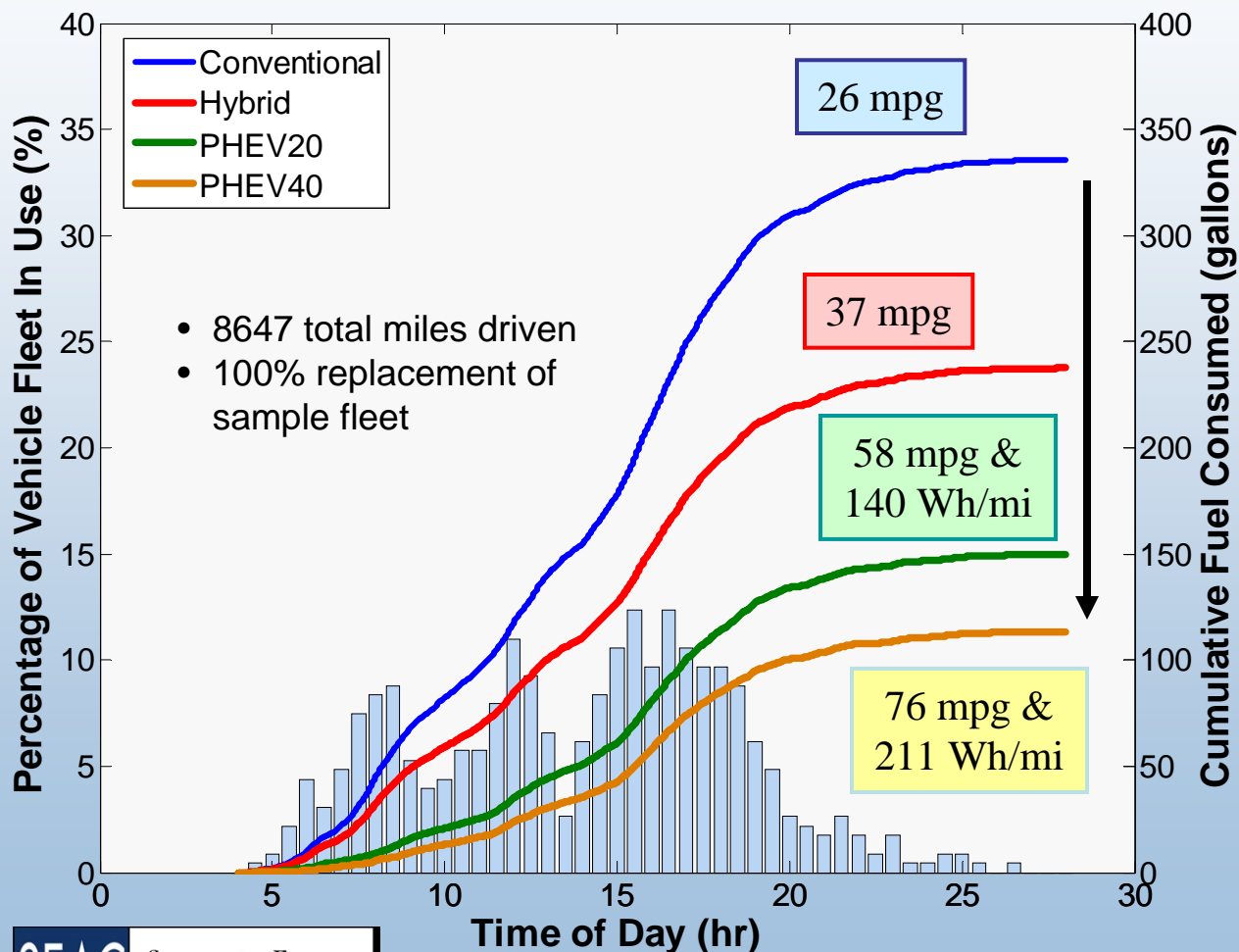
ENGINE DOWNSIZING

# A Plug-In Hybrid-Electric Vehicle (PHEV)



# PHEVs Reduce Fuel Consumption By >50% On Real-World Driving Cycles

227 vehicles from St. Louis each modeled as a conventional, hybrid and PHEV



	Average Daily Costs		
	Gas.	Elec.	¢/mi
CV	\$3.45	---	9.1
HEV	\$2.48	---	6.5
PHEV20	\$1.58	\$0.48	5.4
PHEV40	\$1.21	\$0.72	5.1

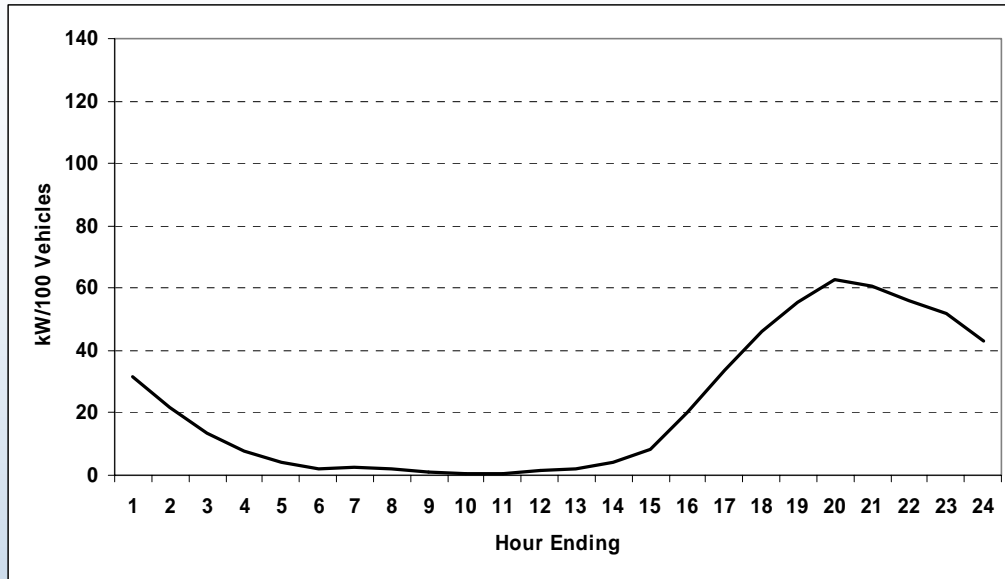
Assumes \$2.41/gal and 9¢/kWh

PHEVs:  
>40% reduction in energy costs  
>\$500 annual savings

# Impact on Electric Grid

- When will vehicles charge?
- Will additional generation and transmission capacity be needed?
- What will be the net emissions?

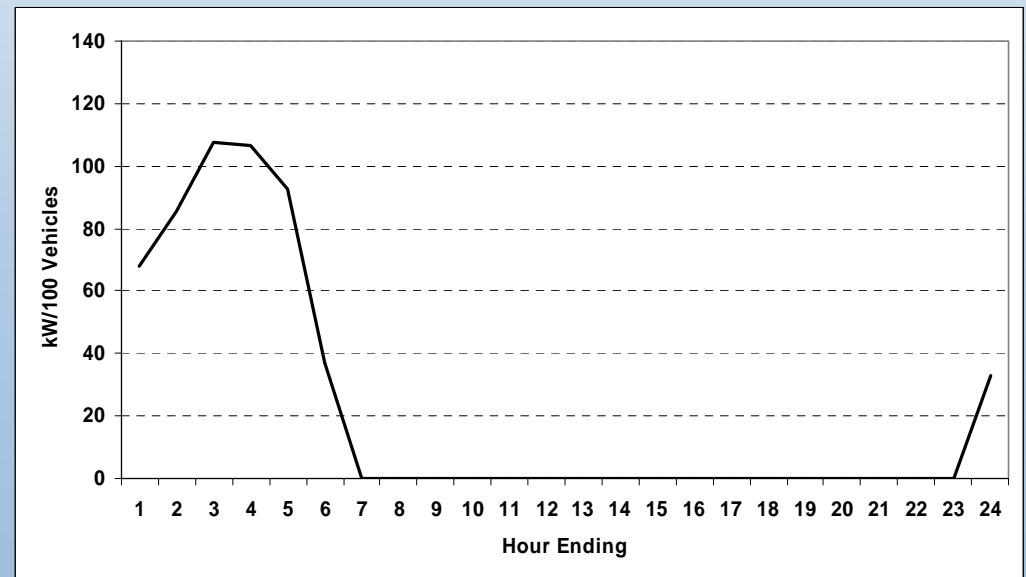
# Example Charging Patterns



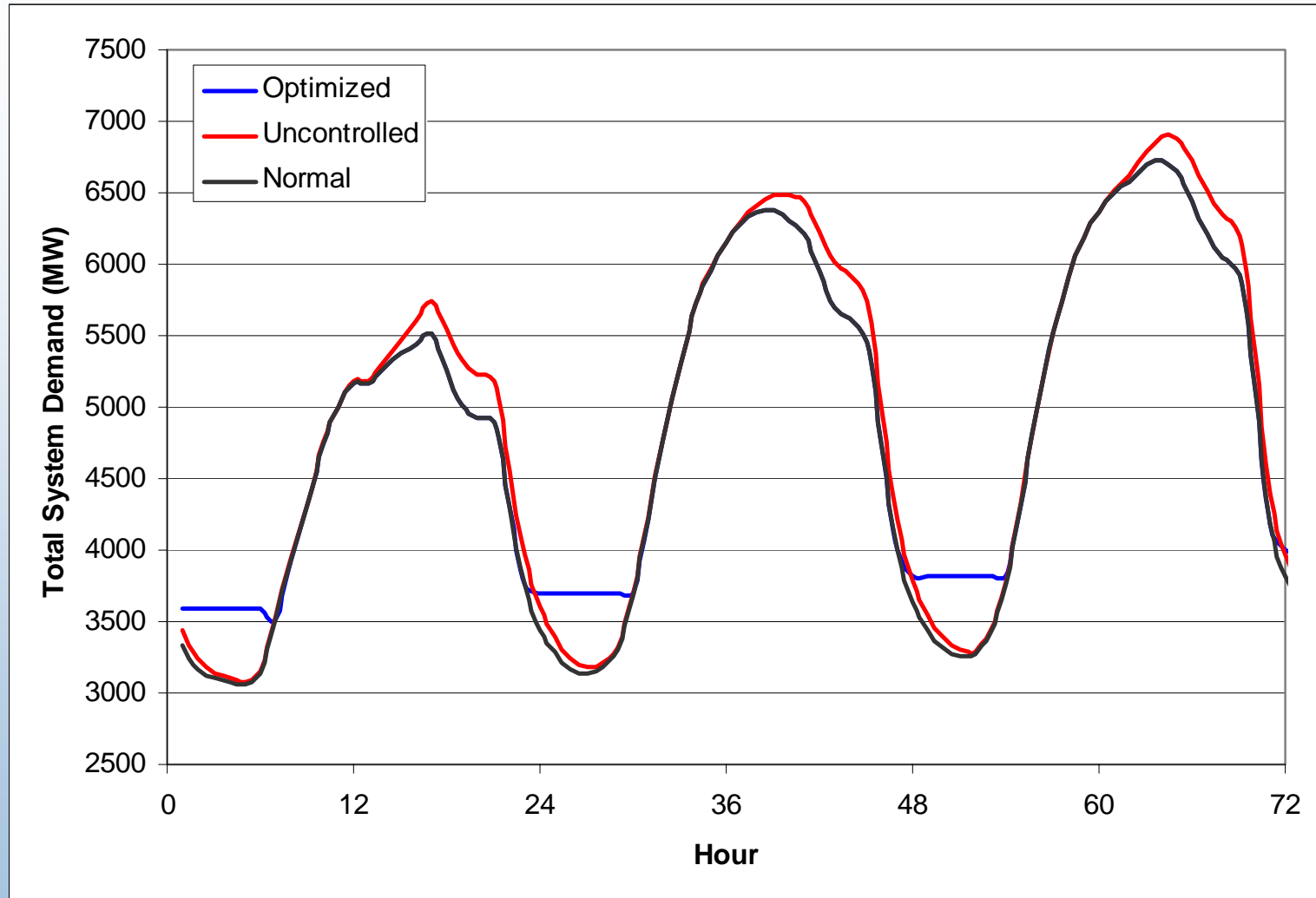
Uncontrolled – owner plugs in at the end of the day.

(Constant 1.4 KW charge rate)

Optimized – utility controls overnight charging, between 10 pm and 7 am

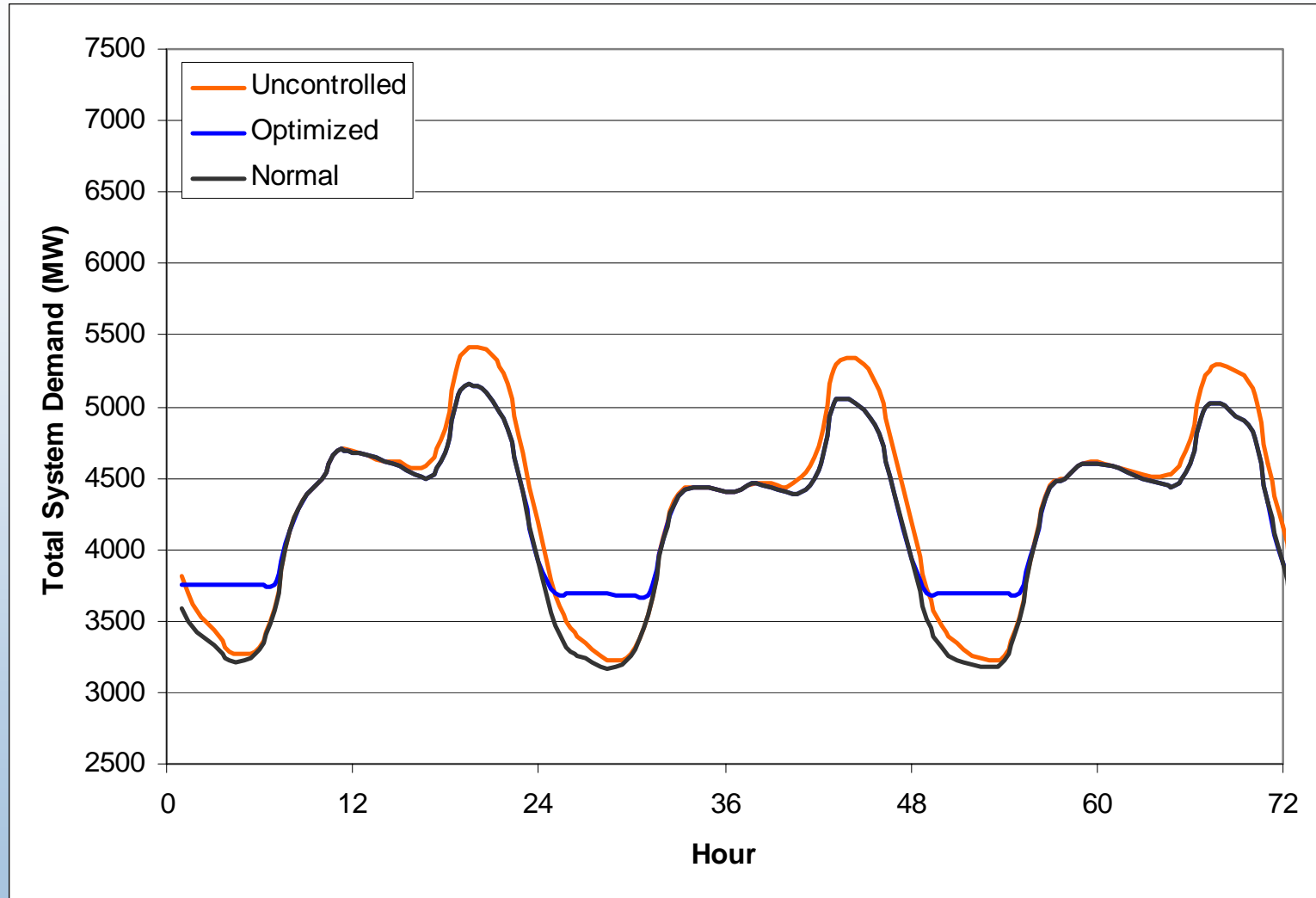


# Load Impacts - Summer



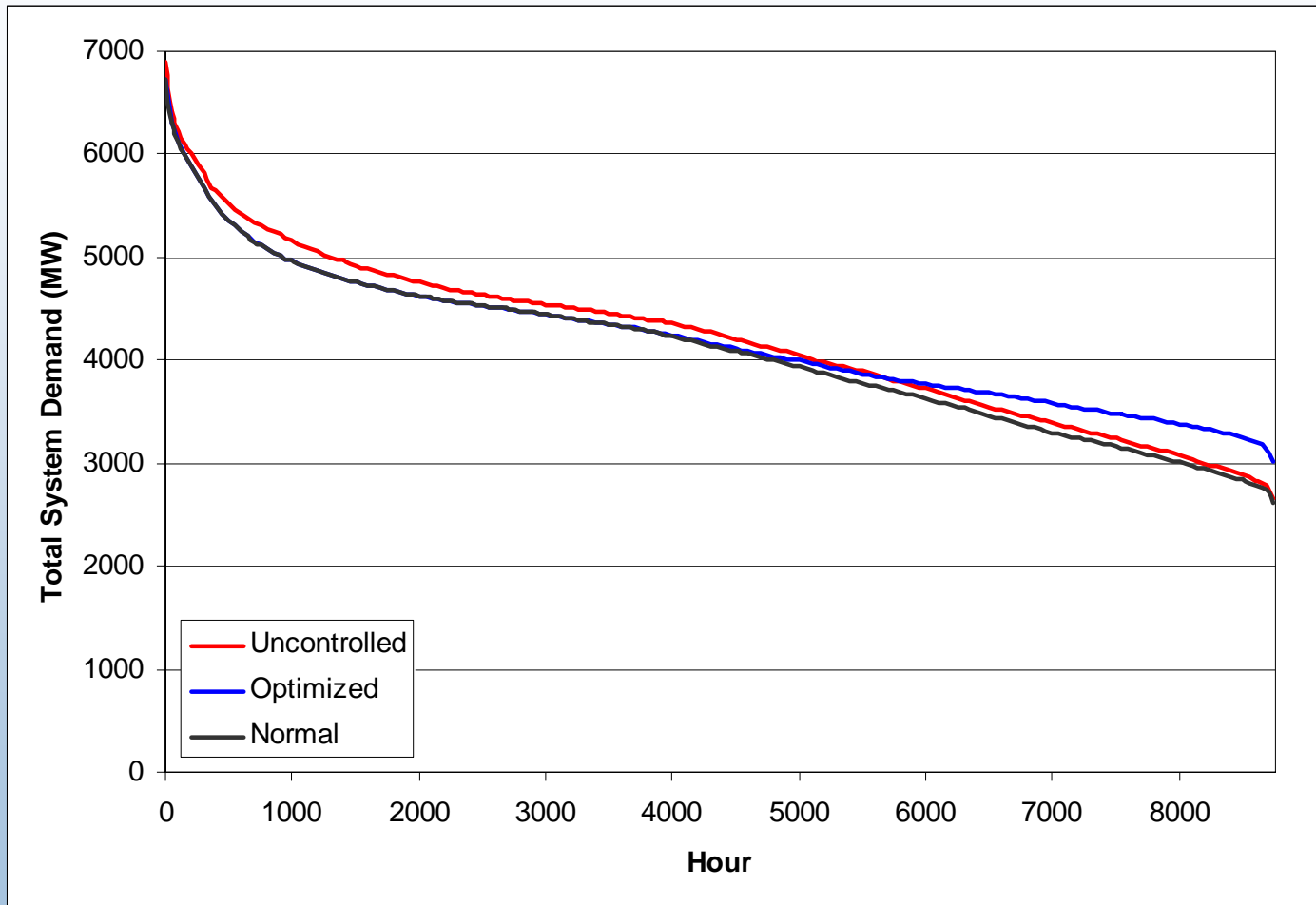
Assumes 30% of Light-Duty Fleet are PHEV-20s

# Load Impacts - Winter

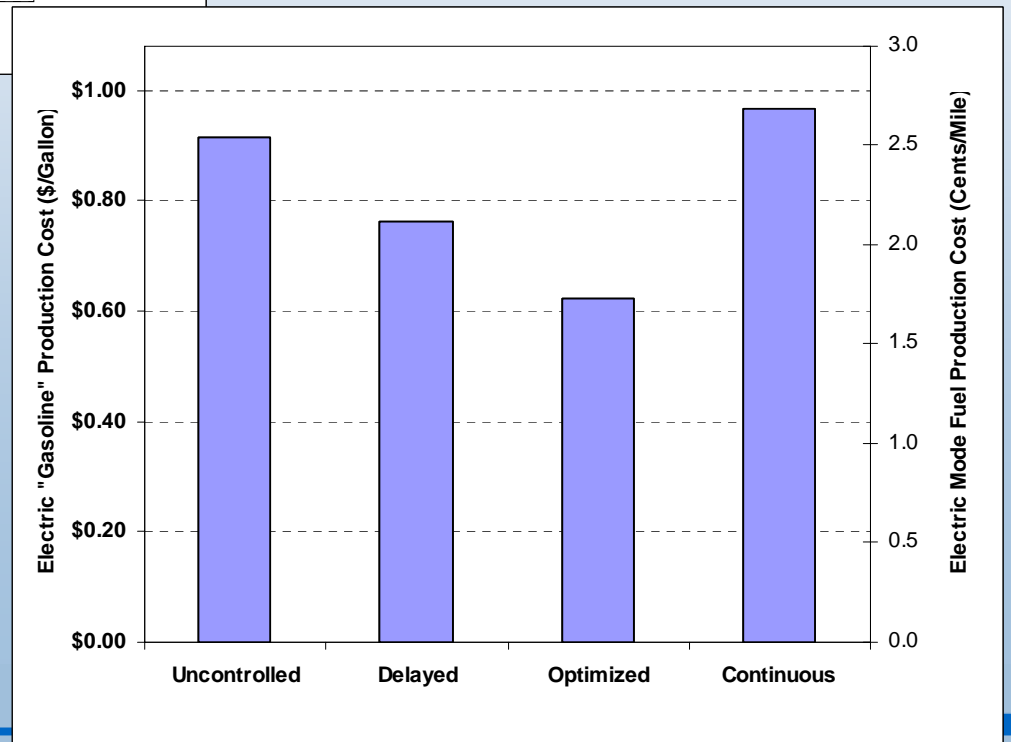
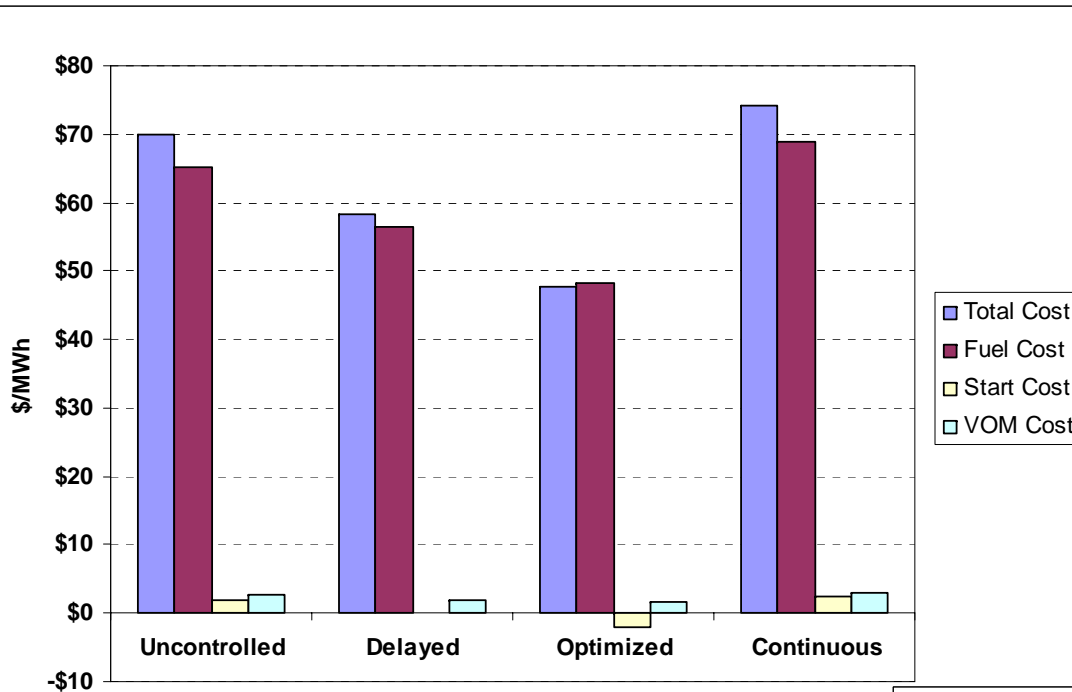


Assumes 30% of Light-Duty Fleet are PHEV-20s

# Optimized Charging Improves System Utilization



# Cost Benefits of Optimized Charging



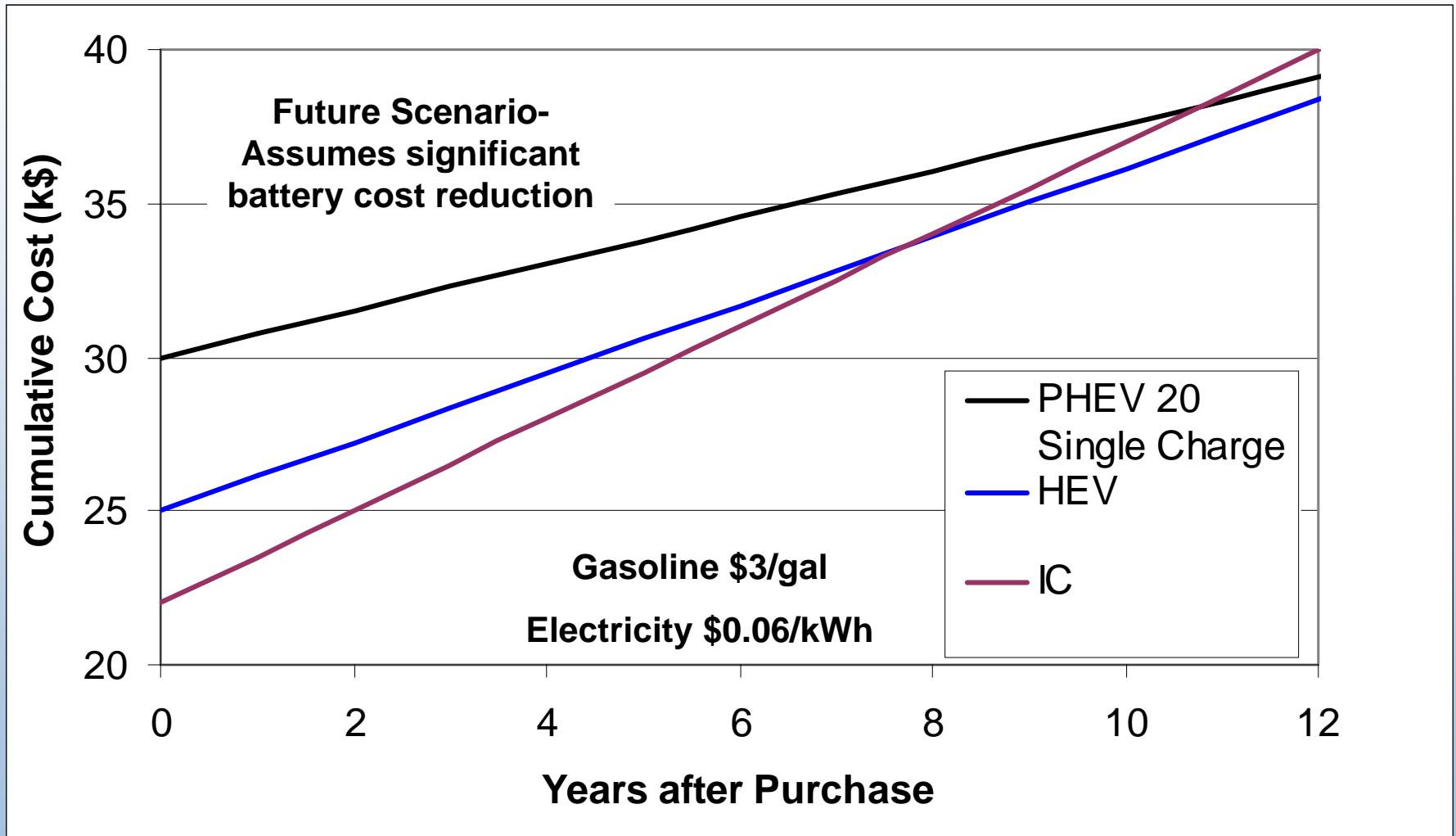
# Charging Conclusions

- End of day charging corresponds with peak load – some controlled charging desirable to limit capacity requirements
- Controlled charging also desirable to optimize cost of energy
- If controlled charging is used, PHEV impacts are small and generally positive. No transmission or generation capacity required.

# Vehicle to Grid (V2G)

- Vehicle discharge as well as charge
  - Additional benefits to the grid
  - Complicated, adds costs to user, requires new markets, new regulations, so why bother?

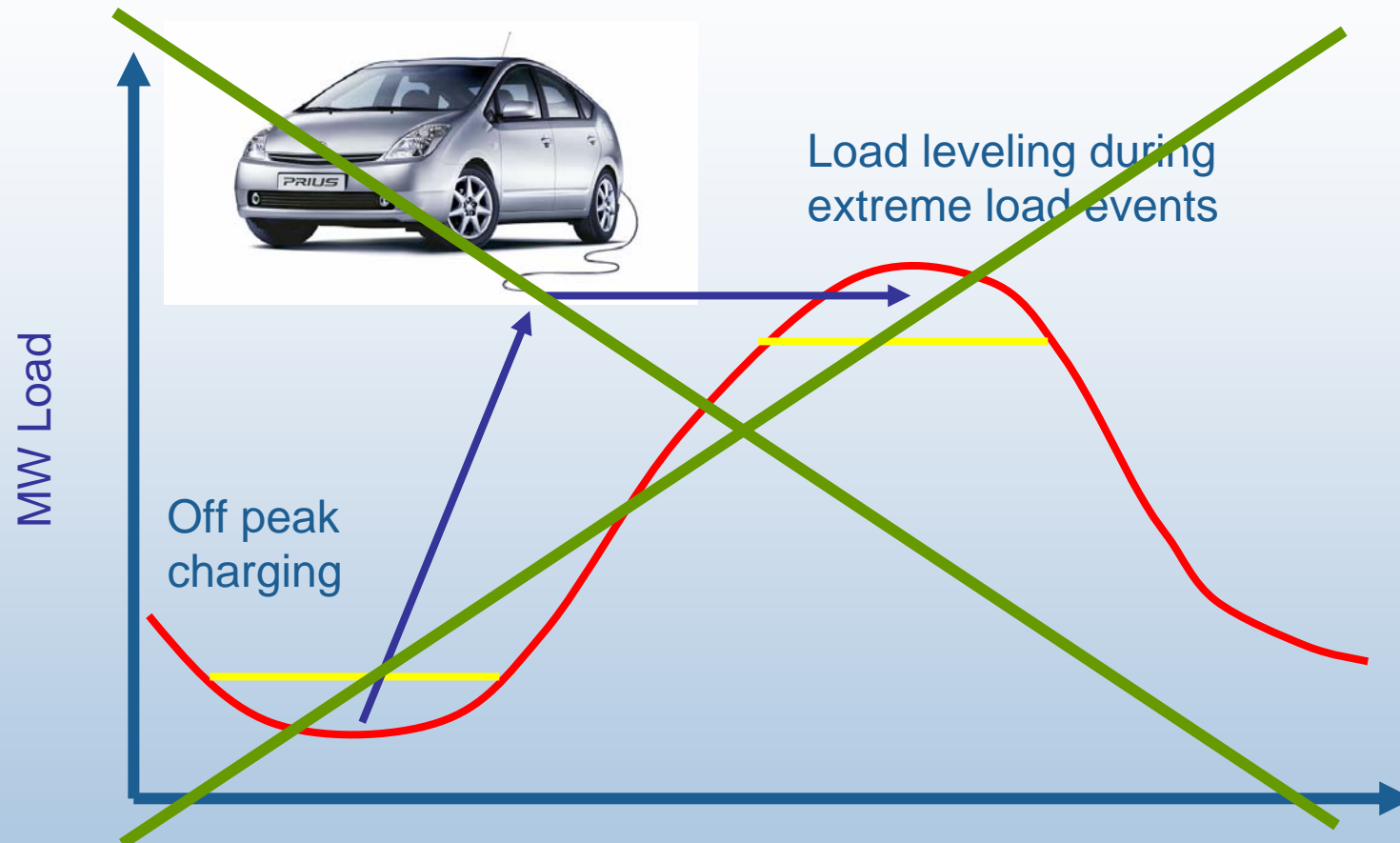
# PHEVs Uneconomic on Fuel Saving Alone



# PHEVs Need Additional Values

- Mid-day charging for extended EV range
- Environmental benefits
- Energy Security
- Ancillary Services via Vehicle to Grid (V2G)
- Others
  - Less Refueling

# V2G is NOT Peak Shaving / Arbitrage

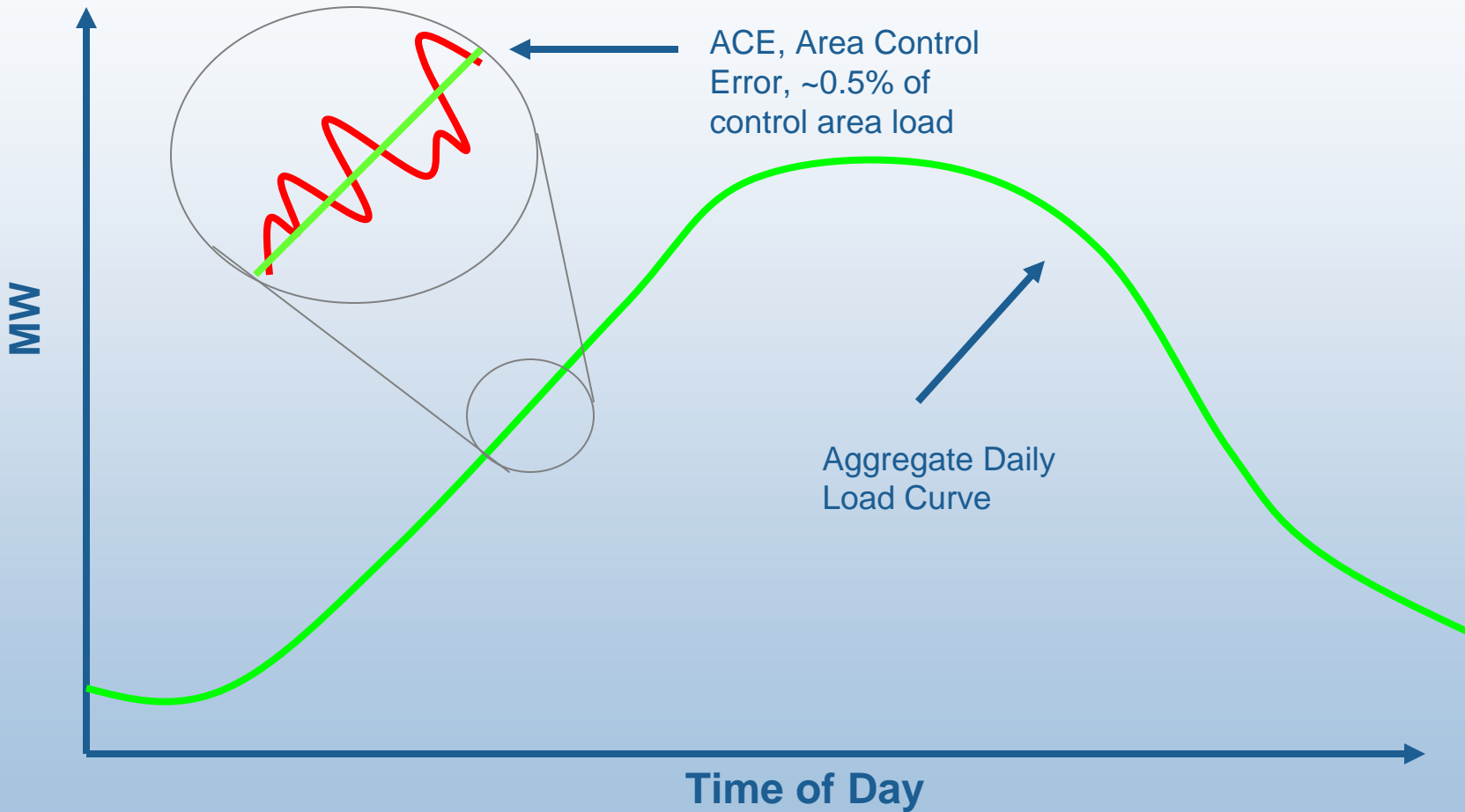


This is a limited and probably unlikely application for PHEVs

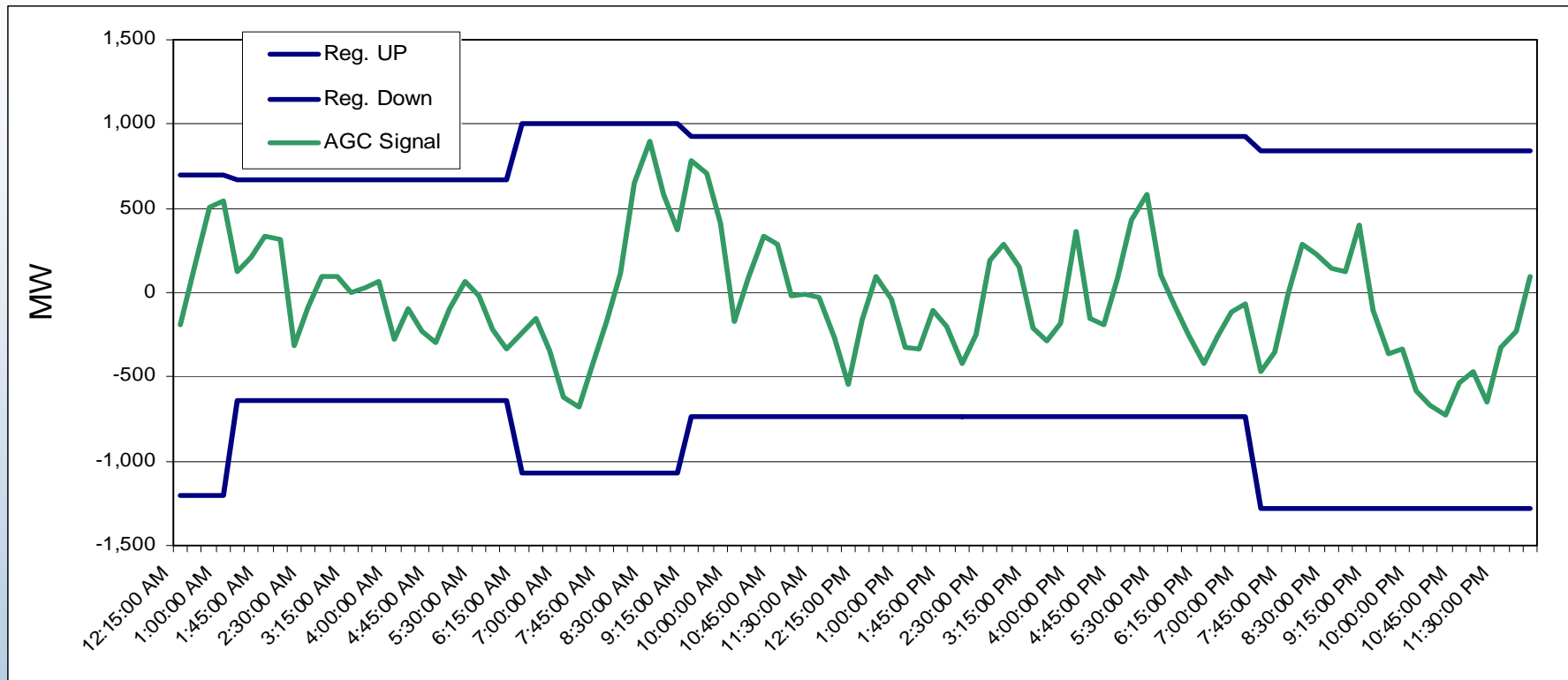
# Ancillary Services

- Services that make the electric power system stable and reliable
- Examples:
  - Regulation Reserve: the instantaneous response to demand variation
  - Spinning Reserve: the instantaneous response to generator failure
  - Both require units operating but not producing energy

# Regulation Serves the “Random” Fluctuations Around Normal Load



## Ancillary Services: Frequency Response



### ERCOT Regulation: Requirement vs. Deployed

# Spinning Reserves

- Generators that are running and ready to provide energy OR responsive load that can be dropped within a few minutes
- Infrequently called upon, and are the first to be restored when a contingency occurs.
- PJM Example- 1.8 GW at 5 kW/vehicle = 360,000 vehicles

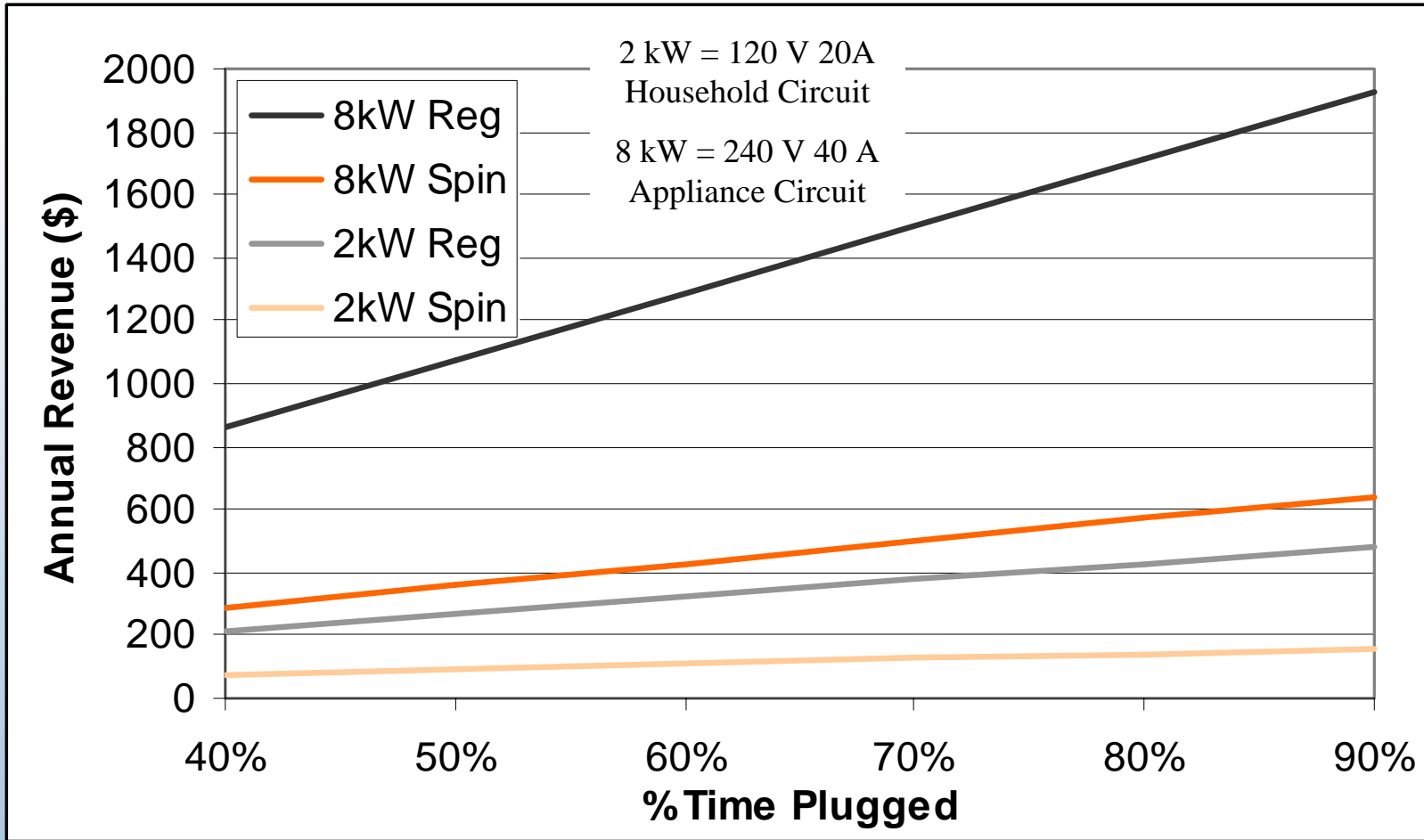
Year	Number of Events	Total Duration	Average Duration
2006	39	6 hours	9 minutes
2005	93	19 hours	12 minutes

# Ancillary Service Market Values

Market / Year	Regulation (\$ / MW-hr)	Spinning Reserve (\$ / MW-hr)
PJM 2003	38	
PJM 2004	43	15
PJM 2005	49	17
NY-ISO 2003	27	
NY-ISO 2004	27	
NY-ISO 2005	39	7.5
ERCOT 2005	23	8
ERCOT 2006	38	
ISO NE 2004	29	15
ISO NE 2005	30	17

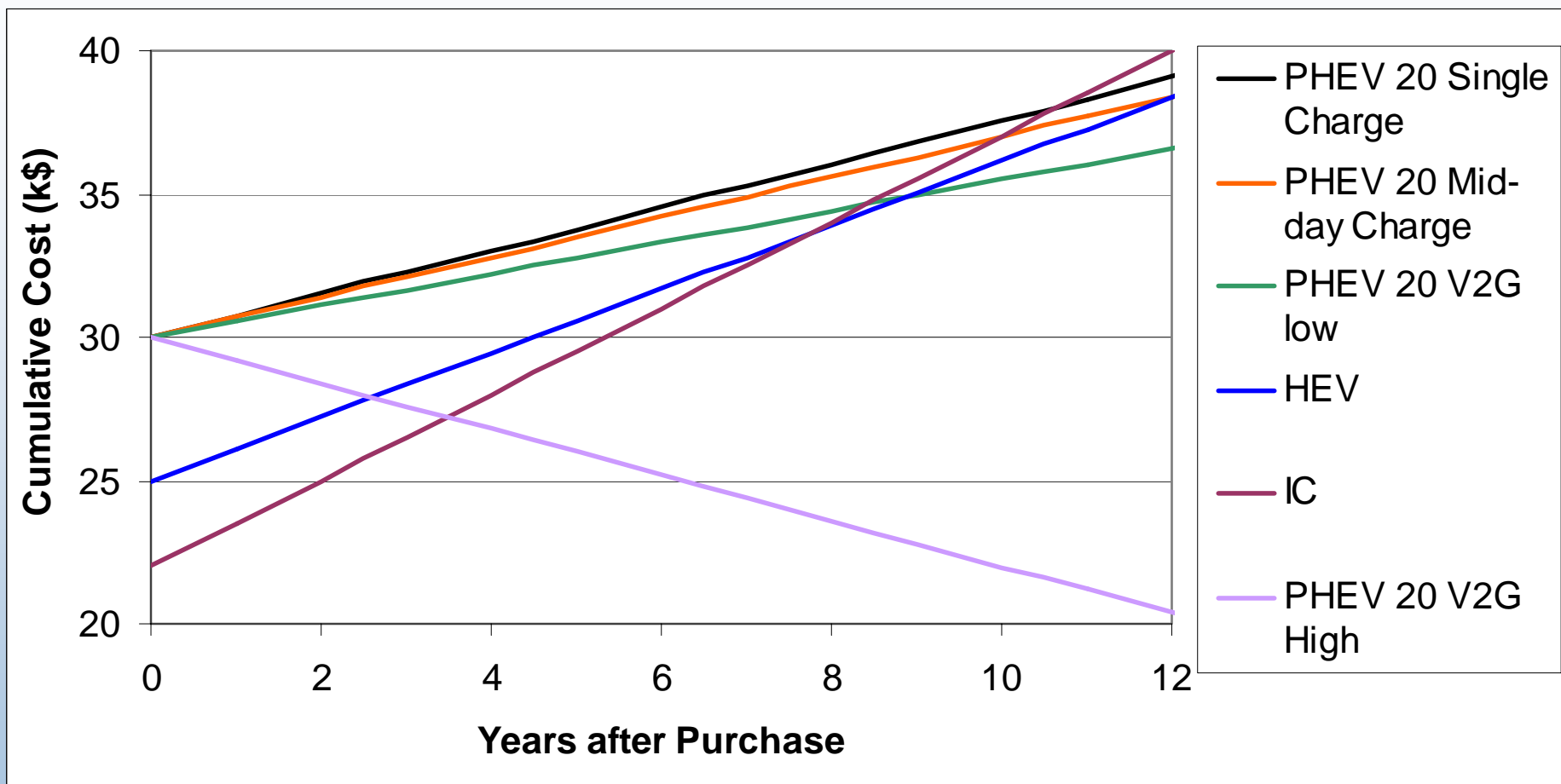
Spinning reserves offer lower value than regulation, but well-suited for V2G due to infrequent use

# Potential V2G Value



Assume Regulation = \$30/MW-h Spin = \$10/ MW-h

# PHEVs Marketable with V2G?



**Gasoline \$3/gal**

**Electricity \$0.06/kWh off peak, \$0.12/kWh on peak**

**Ancillary Services: \$150/year low, \$1500/year high**

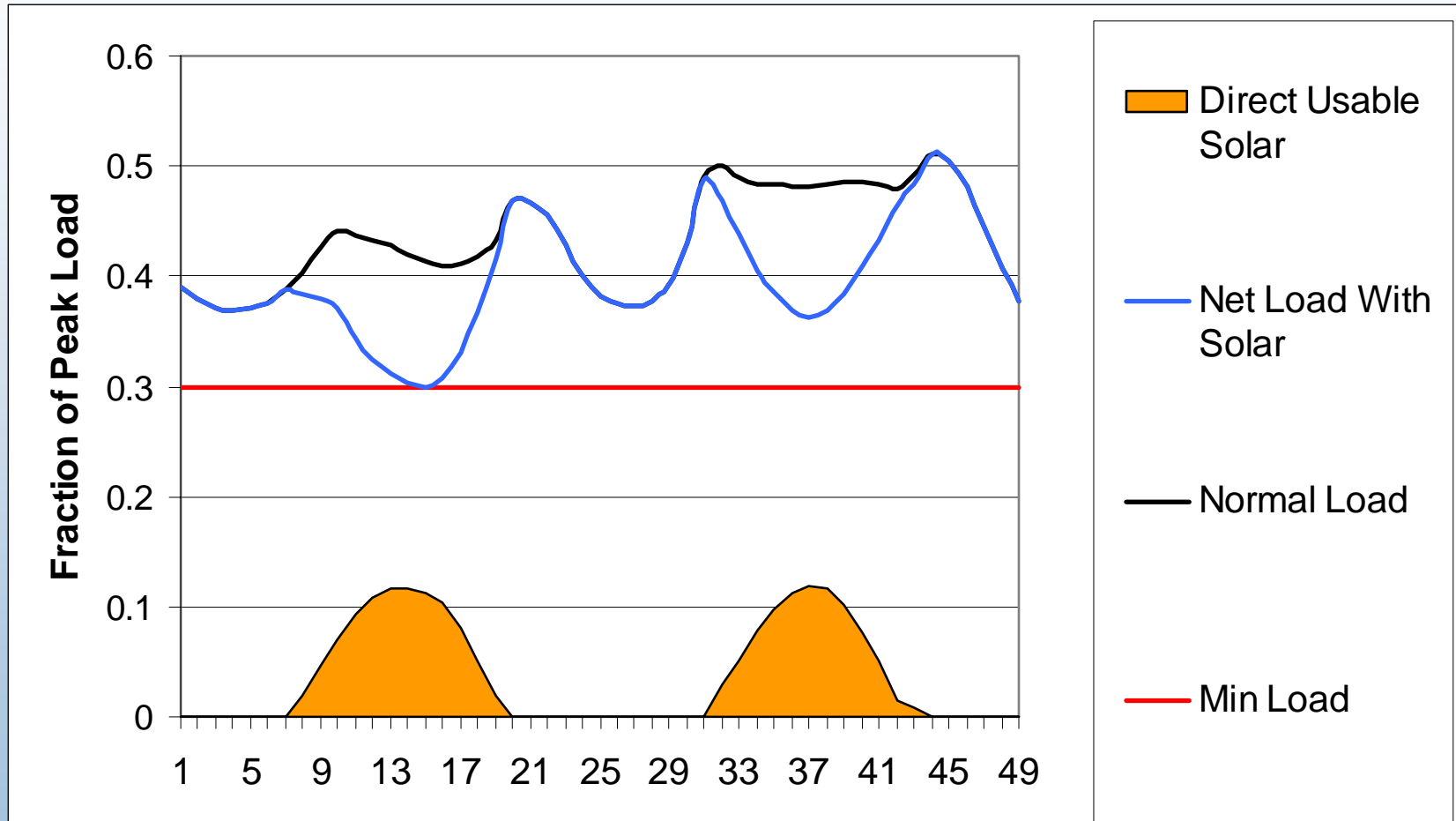
# Barriers to Vehicle to Grid (V2G)

- Markets and Regulation (rules)
- Infrastructure
- Battery Cycling (esp. for regulation)
- Education?

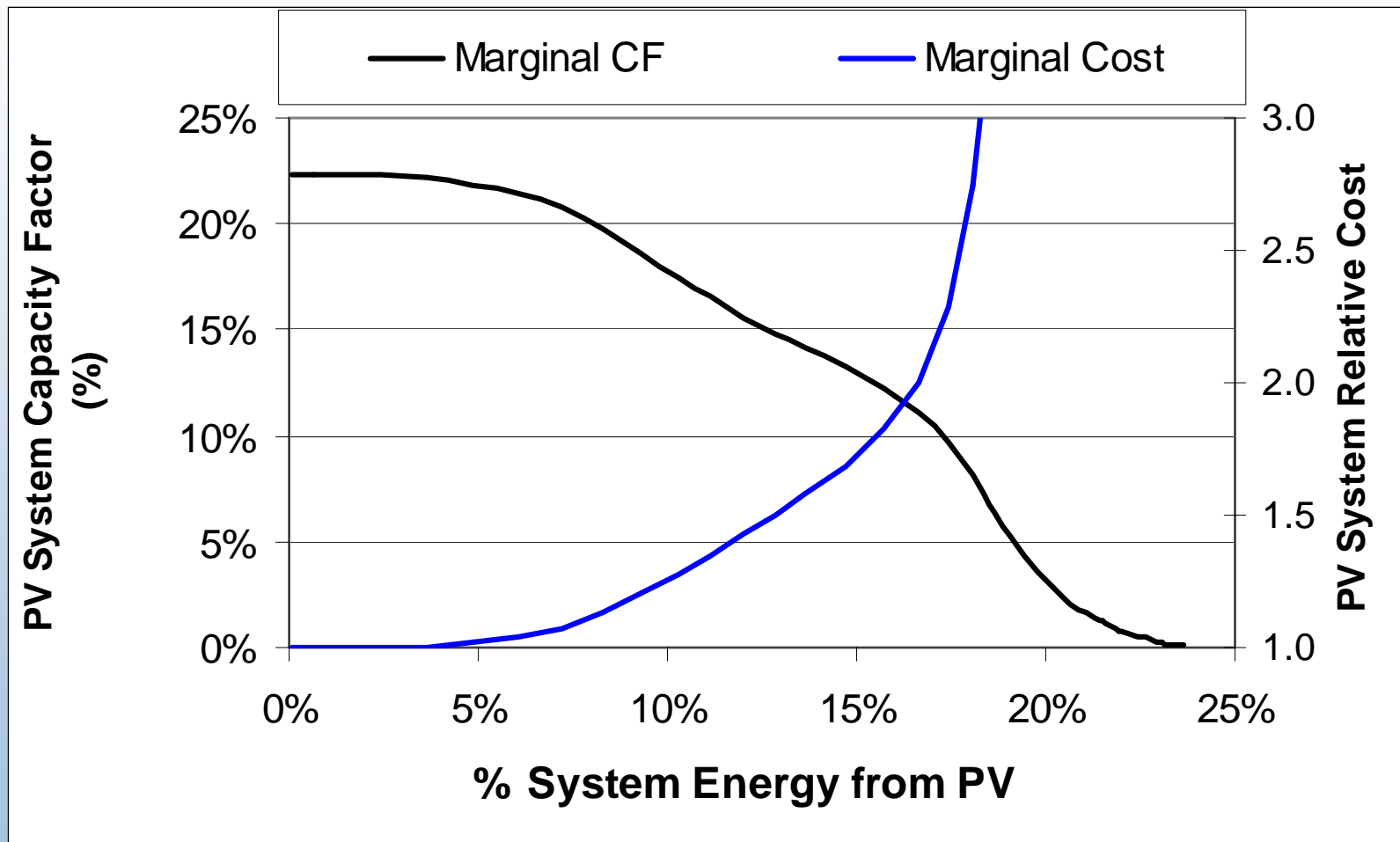
# PHEVs and Renewables

- Many renewables (wind, solar, geothermal) cannot make cost-effective liquid fuels
  - PHEVs offers renewable electric transportation
  - PHEVs provide dispatchable load to reduce impacts of resource variability
- PHEVs reduce liquid fuel demands
  - Enables high penetration of ethanol fuel

# Limits of Solar PV



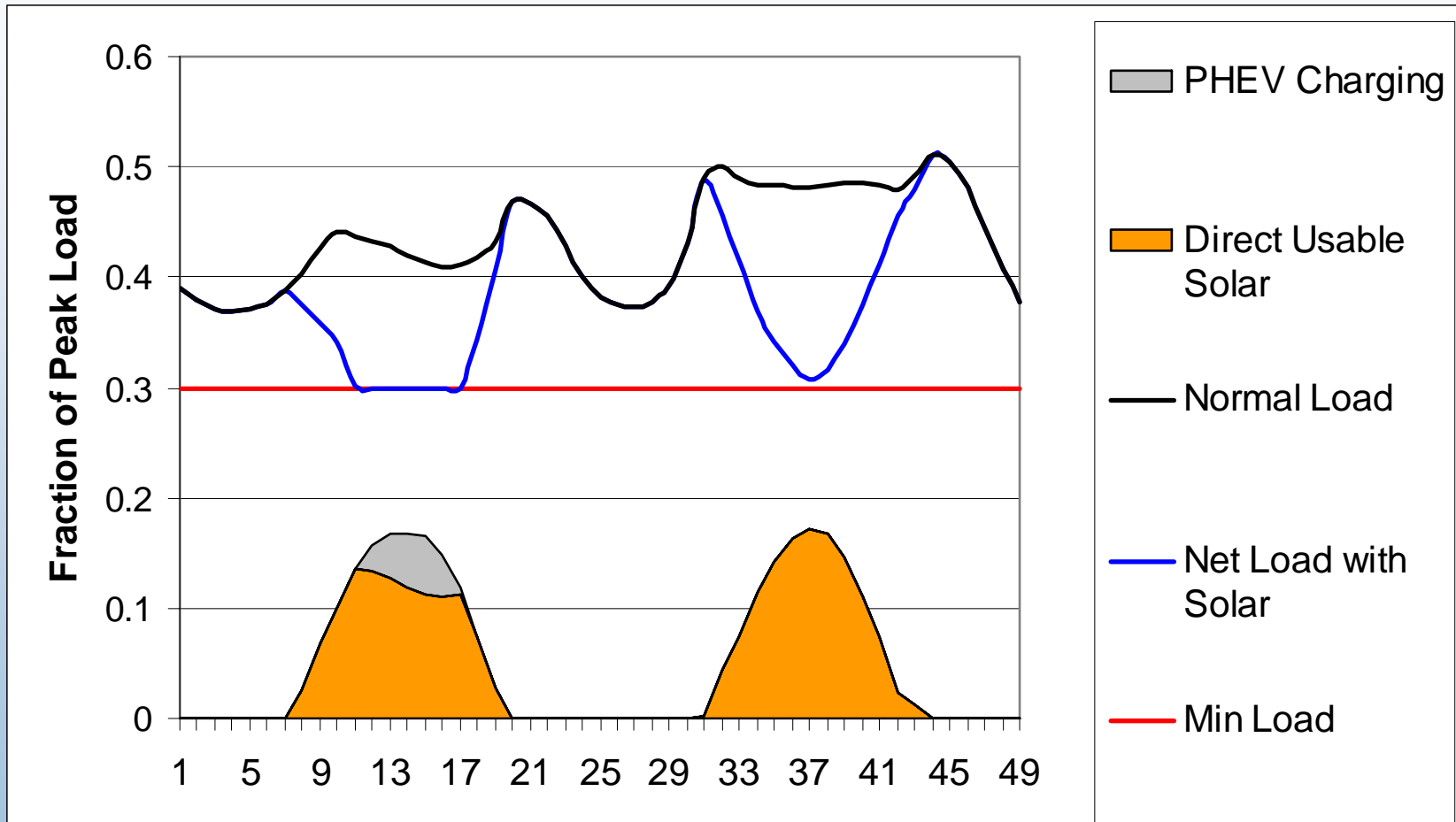
# Limits to PV penetration



# Enabling Technologies for Intermittent Renewables

- System Flexibility
- Spatial Diversity
- Transmission
- Demand Response and Load Shifting
- Energy Storage
- Increased Dispatchable Load

# PHEV Benefits



# Conclusions

- PHEVs are a technically viable method of reducing petroleum use beyond HEVs
- Limited grid impacts
- Gasoline savings won't justify PHEVs <\$4-\$5 / gallon
- Other values such as V2G might enable market adoption
- PHEVs could be an enabling technology for renewable energy

# Questions?

