GREEN MOUNTAIN COLLEGE

Vermont Plug-In Hybrid Electric Vehicle Grid Impacts Study

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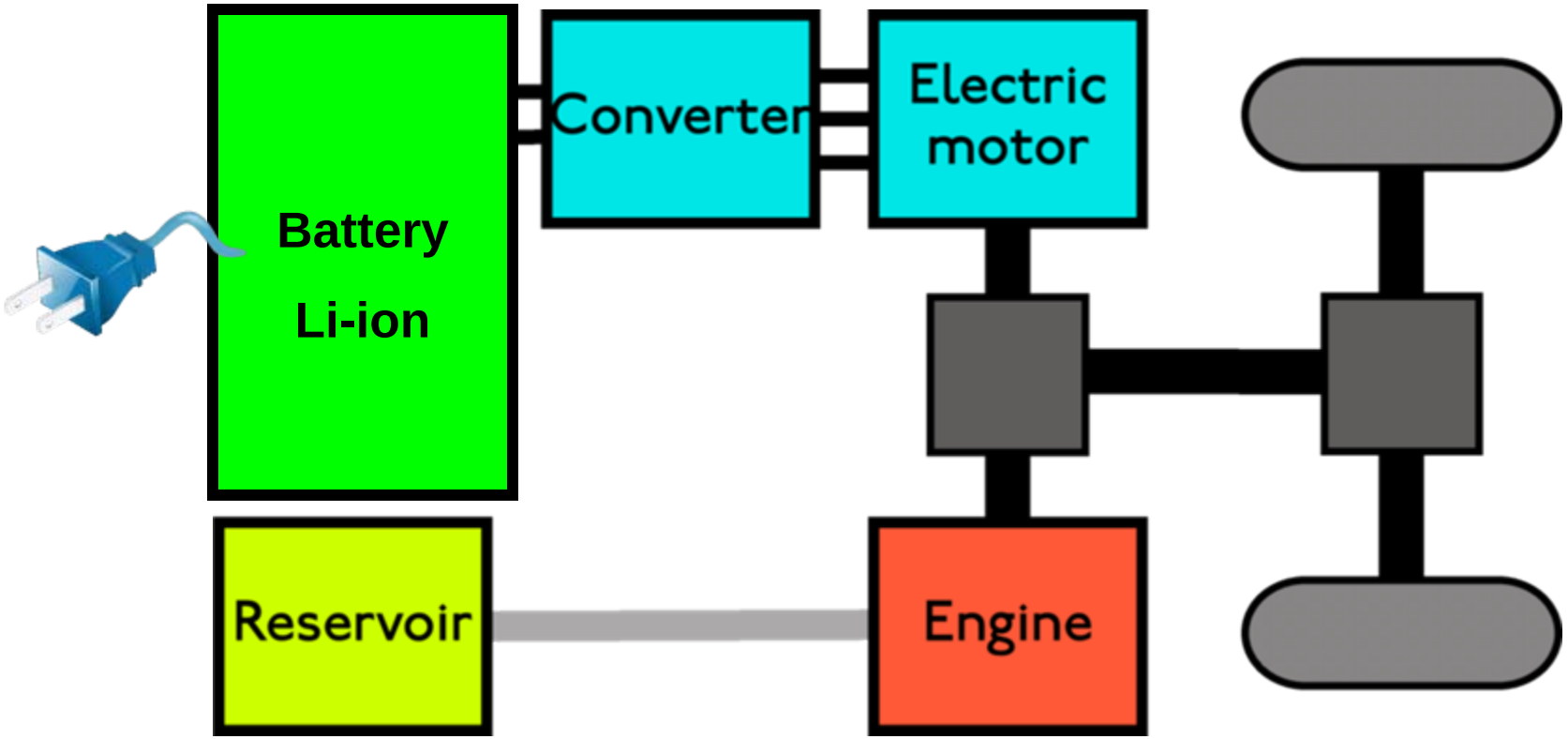
Agenda

- Overview of PHEV Technology
- Draft PHEV Grid Impact Results
- End-Use Economic Consideration
- Next Steps

The Electric Drive Revolution

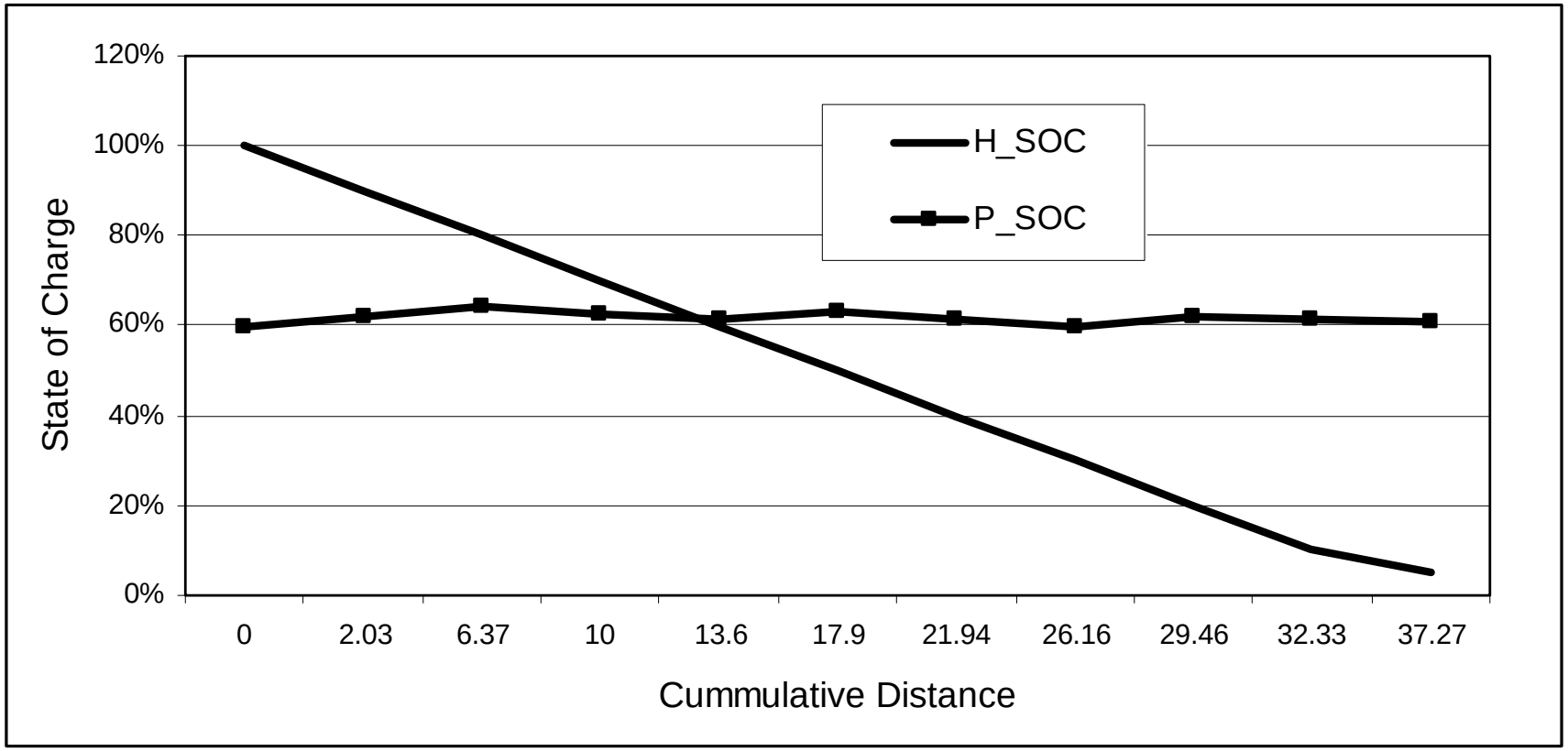
Plug-In Hybrid Vehicle Technology

Hybrid Electric Vehicles, 1.5% of new car sales in US, 2006



CVPS/GMC PHEV Test Program: Initial Results

Charge Depleting vs. Charge Sustaining



Plug-In Hybrid Vehicle Technology

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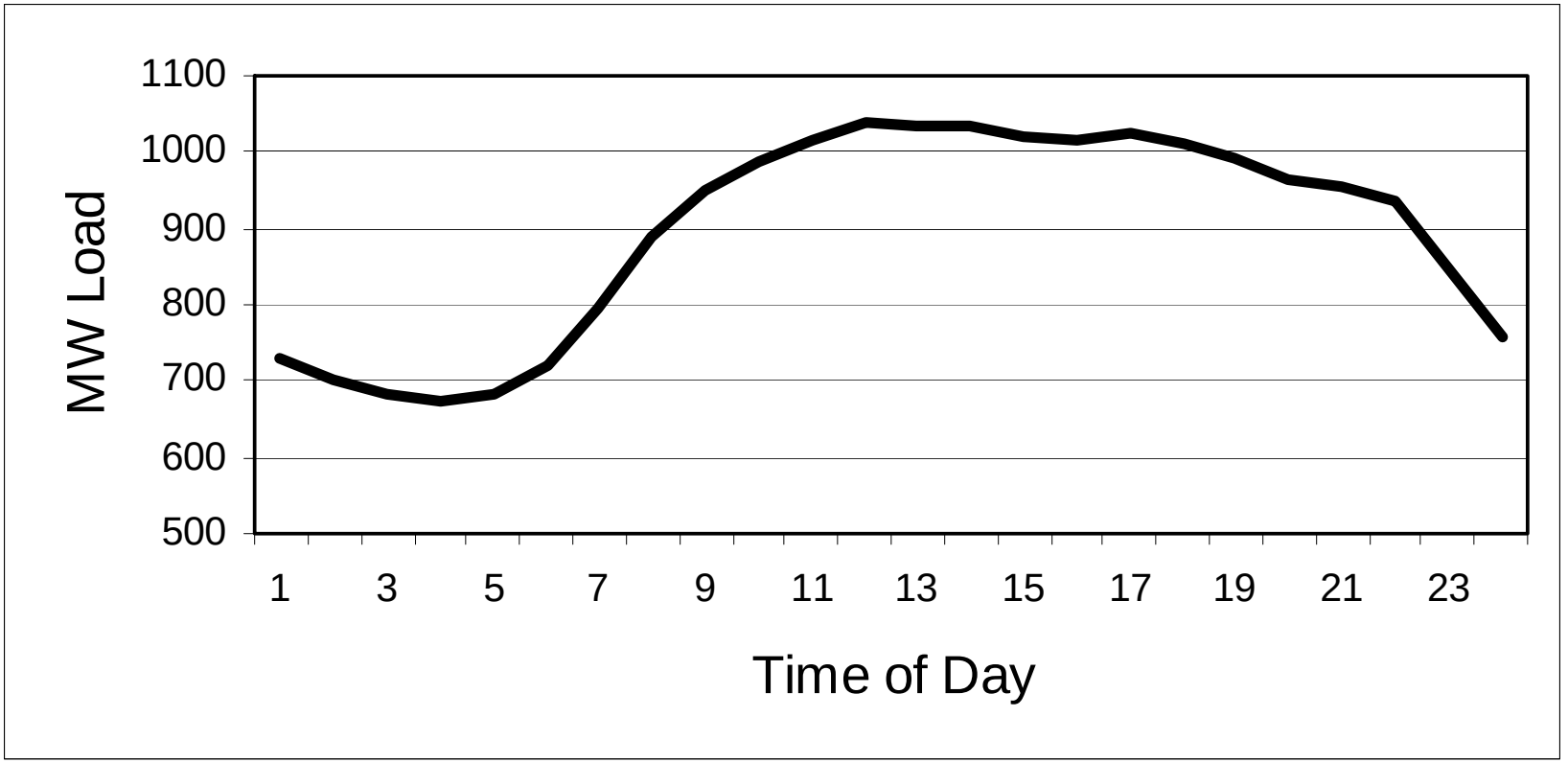
Grid Impacts: Vehicle Specifications

PHEV 20 Technical Specifications

Nominal Battery Pack Size	7.5 kWh
Usable Energy in Battery Pack	6 kWh
Round Trip Battery Efficiency	85%
Charger Efficiency	82%
Charge Rate	1.4 kW / hour
Time for Full Charge	6 hours
Purchased Electricity per Charge	8.4 kWh
Electric Efficiency	3.49 miles / kWh
All Electric Range	20 miles

Grid Impacts: Demand vs. Energy

Peak Summer Day 2005: August 19th



Grid Impacts: Penetration Scenarios

Capacity Requirements vs. PHEV Fleet

	50,000 PHEVs	**100,000 PHEVs**	**200,000 PHEVs**
Demand	74 MW	148 MW	297 MW
% Summer Peak (1,038 MW)	7.15 %	14.30 %	28.59 %
% Winter Peak (1,054)	7.01%	14.03 %	28.05 %

Note: assumes 6% average line losses

Grid Impacts: Penetration Scenarios

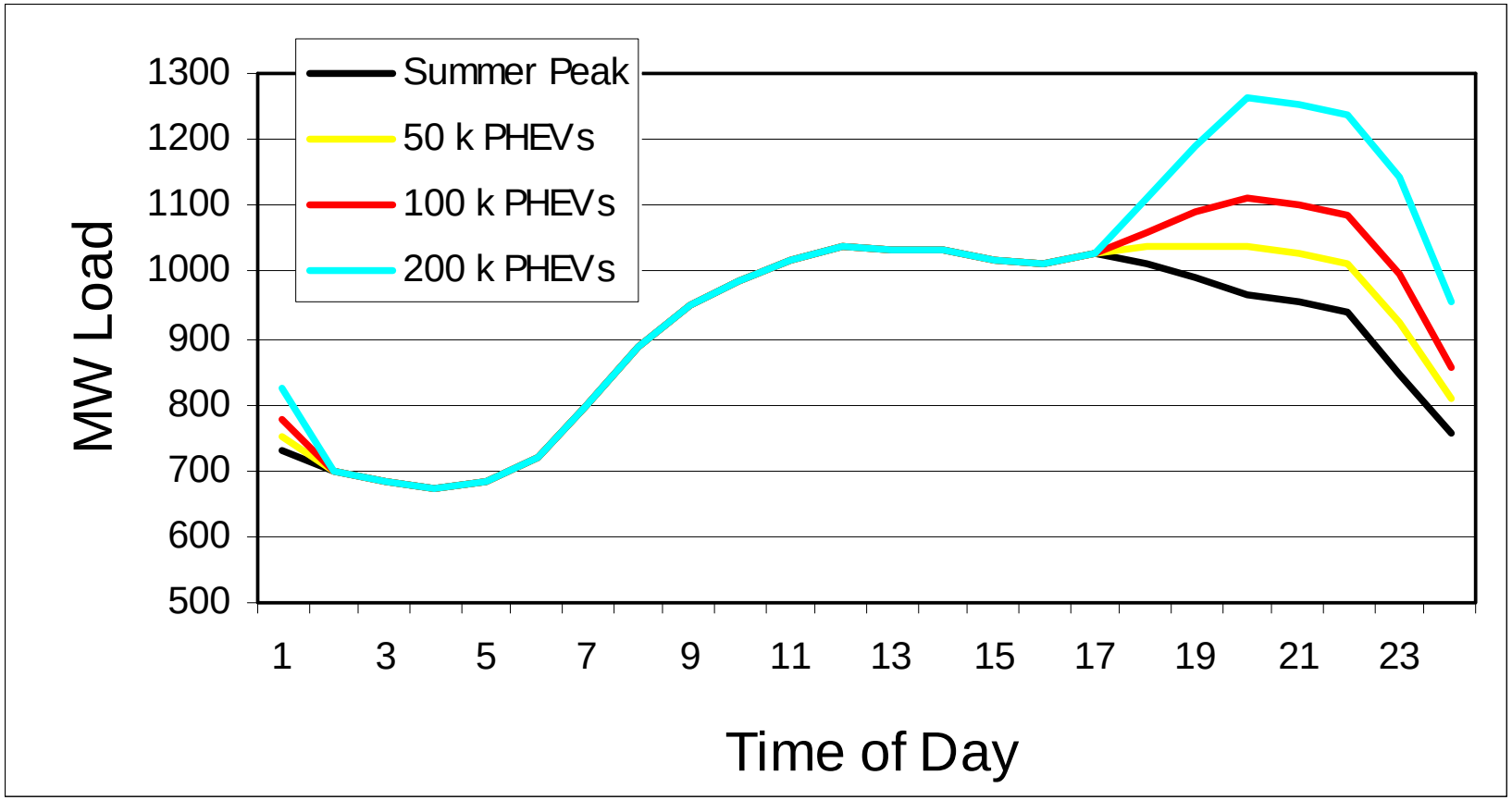
Capacity and Energy Requirements vs. PHEV Fleet

	50,000 PHEVs	100,000 PHEVs	200,000 PHEVs
Daily Energy (1 charge per day)	445 MWH	890 MWH	1,781 MWH
Annual Energy (1 charge 365 days)	162,498 MWH	324,996 MWH	649,992 MWH
% 2005 MWH (6,325,960)	5.14 %	10.27 %	20.55 %

Note: assumes 6% average line losses

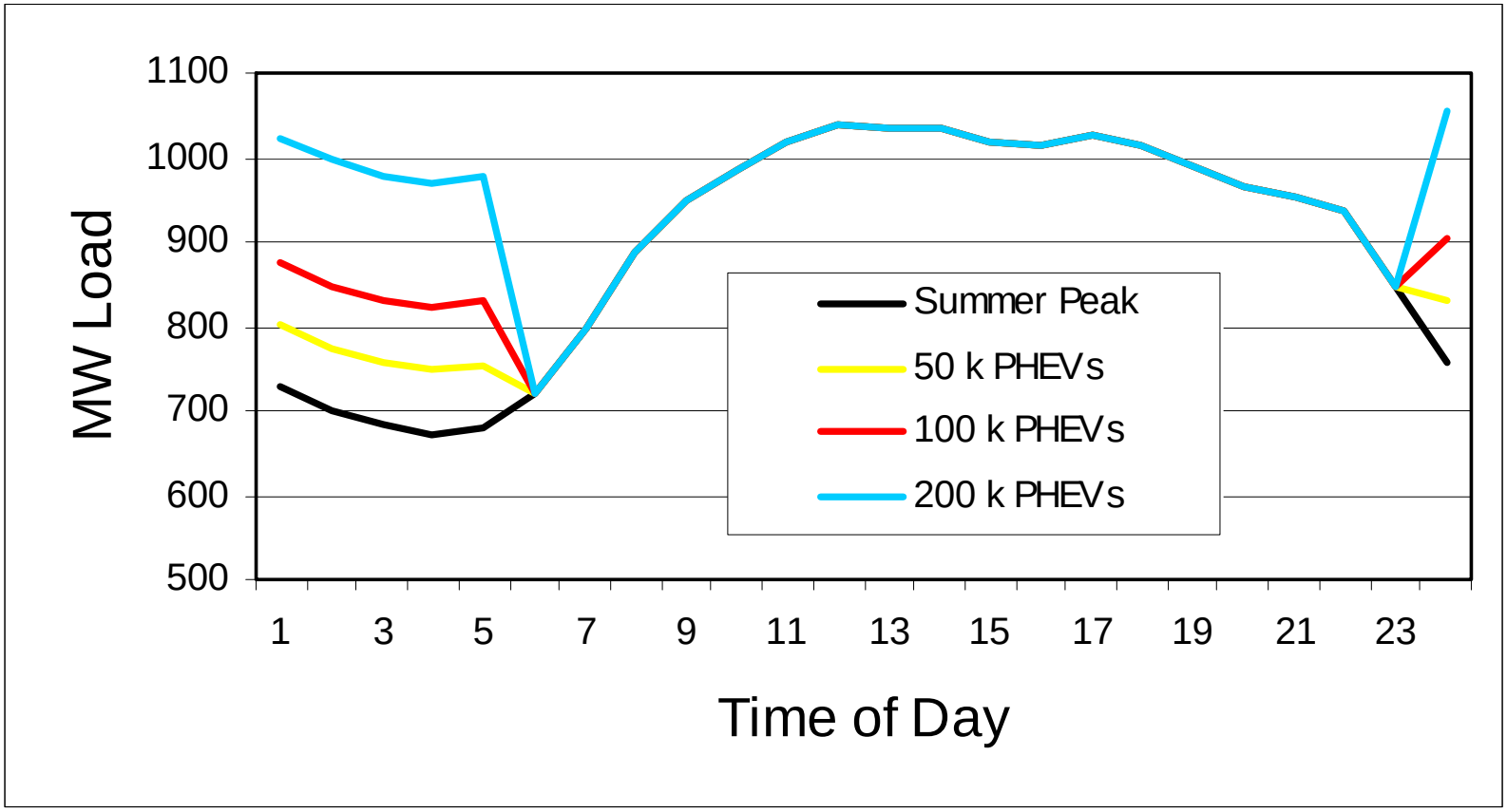
Grid Impacts: Load Impacts

Worst Case: Uncontrolled Charging



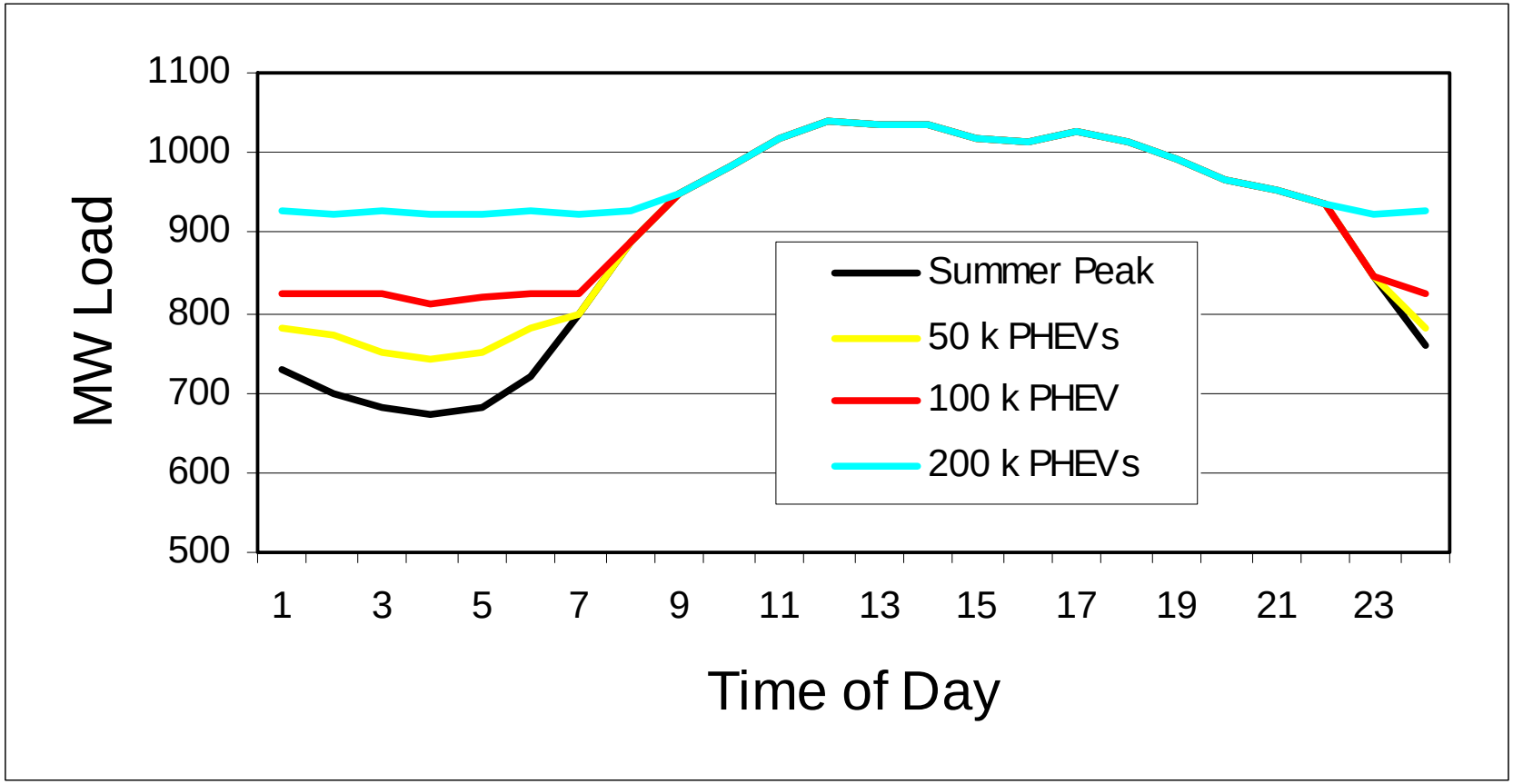
Grid Impacts: Load Impacts

Delayed Nighttime Charging



Grid Impacts: Load Impacts

Optimal Charging: Using Smart Grid Technology

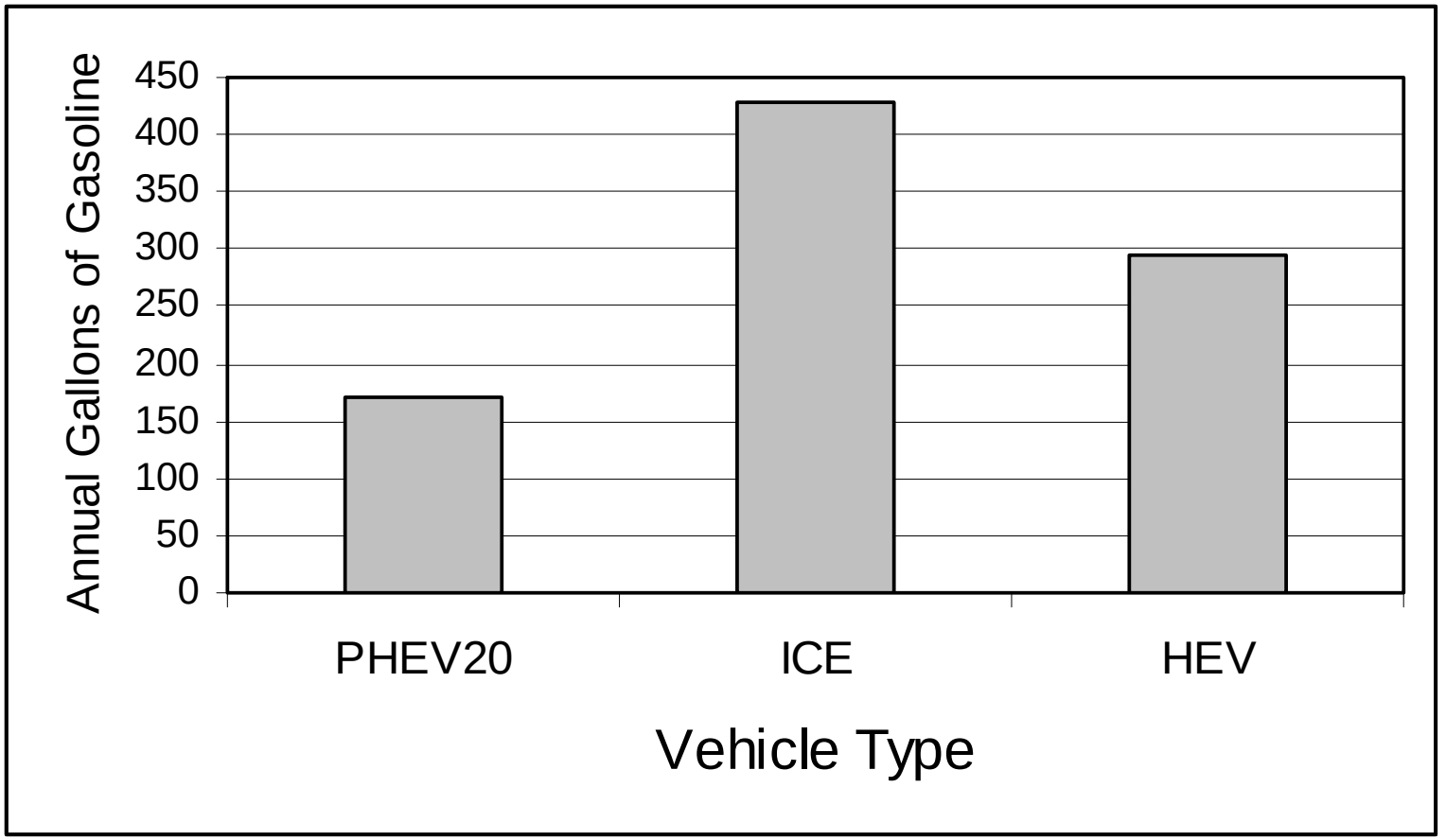


Plug In Hybrids: Charging from the Grid

Domestic energy source…less expensive.

PHEVs: Gasoline Savings Potential

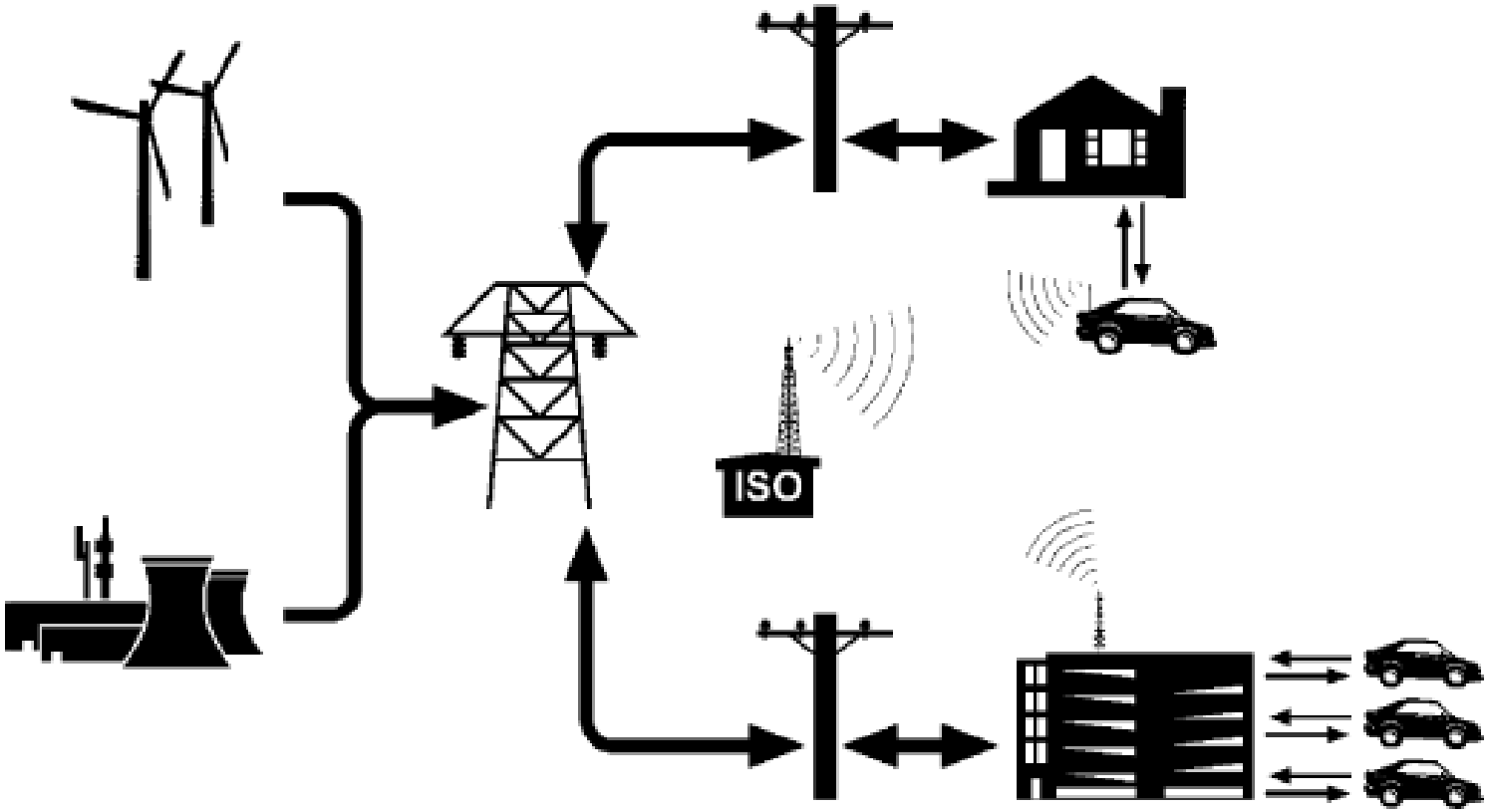
Annual Fuel Savings Potential



Plug In Hybrids: End-Use Cost Considerations

- **With off-peak rates, it costs less than $1 to buy the electricity that would deliver the same miles of travel as one gallon of gasoline**
- **Easily ½ the per mile cost of travel using electricity ($0.05/mile vs. $0.12/mile)**
- **PHEV will costs more ($2,500 - $5,000)**

Next Steps: Vehicle to Grid (V2G)

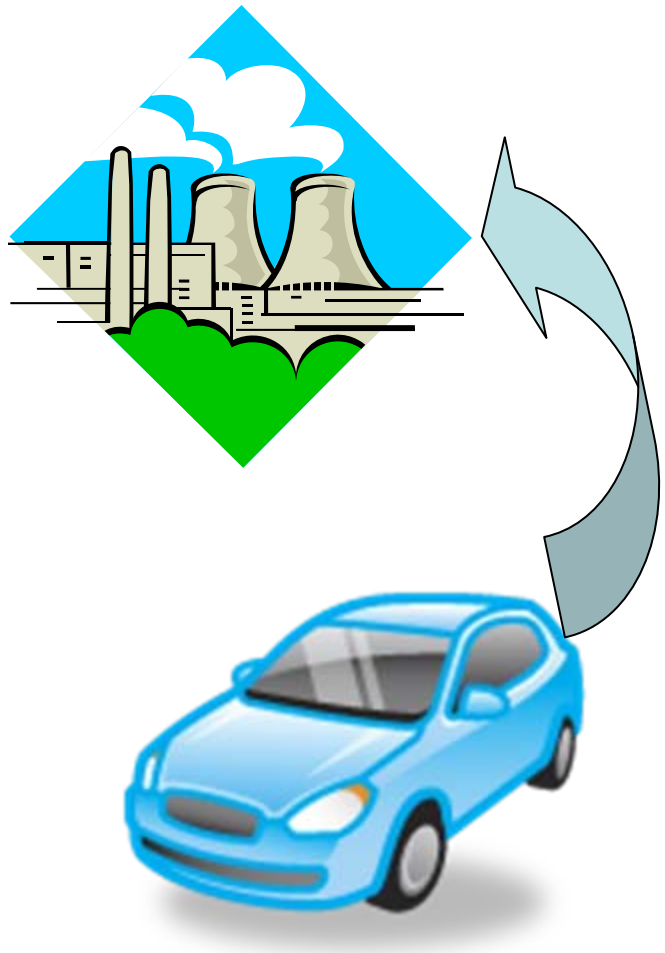


Vehicle to Grid (V2G) Demonstration

PHEV Load Impacts: Initial Conclusions

- PHEV technology is coming!
- The Vermont grid can accommodate a large PHEV fleet
- PHEVs have lower fuel costs, but a higher initial purchase price
- More work needed to understand smart charging technology, rate structures, realistic PHEV penetration scenarios, and V2G benefits in Vermont

Plug In Hybrids: Charging from the Grid



National Resources Defense Council and the Electric Power Research Institute PHEV Emissions Study:

- **significant GHG reductions could be achieved**
- **small but significant improvements in ambient air quality**