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Energy Sources for the Grid

The electricity grid does a fairly good job in "releasing" the energy stored in many fuel types:

- ✓Coal
- ✓Natural Gas
- ✓Uranium

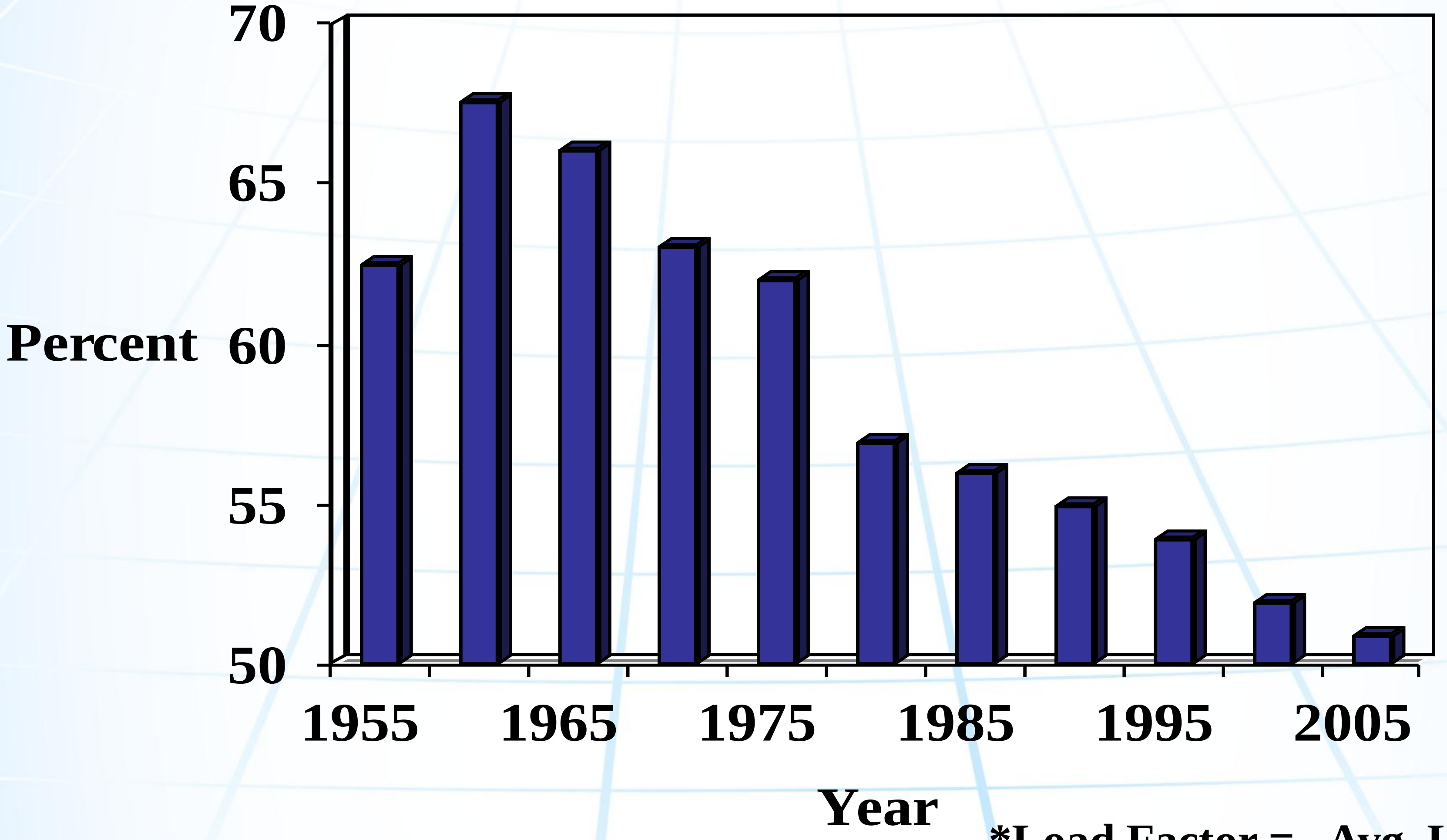
What Is Electricity Storage?

Electricity Storage is the process of using grid power to transform electricity to a storage media for release back to electricity when needed.

The Electricity Storage Dilemma

- Storage Programs (Natural Gas, Water) are very successful and key to productivity in the US
- Electricity Storage is a driver for the entire consumer electronics industry
- Moving Electricity Storage to Grid-Scale is meeting a lot of resistance
- Wind Power advocates insist Electricity Storage is too expensive and not needed to meet the nation’s RPS goals

Utility Grid Load Factor Decline



*Load Factor = Avg. Load / Peak Load

EPRI and IEA data

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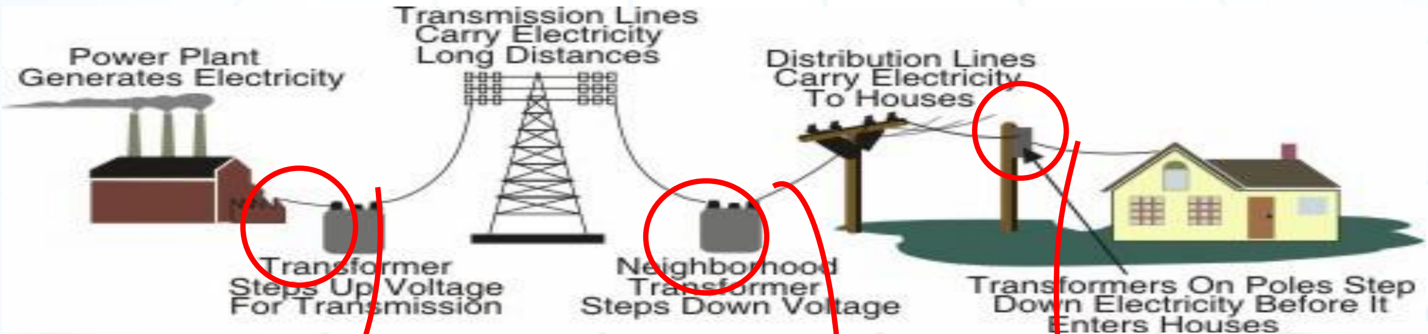
Impact of Renewables on Grid Operation

- Growth of wind resources remote from load centers
  - ✓ Mismatch between load and source peaks
  - ✓ Transmission constraints
- Large amounts of rooftop solar will start to impact distribution voltage control
- Achieving RPS standards will create need for more ancillary services and balancing energy sources to insure reliable performance of grid
- Optimizing bulk-power production is becoming much more difficult

Grid Energy Storage Spectrum



Large Central Units
100's of MW

Substation Batteries
10's of MW

Storage at Grid Edge
10's of kW

Graphics adapted from an EPRI Presentation by Joe Hughes

Grid Storage Benefits

3- Market Benefits

- Energy Arbitrage
- Frequency Regulation
- Generation Capacity

All three must work together synergistically to justify widespread storage deployment

2- Service Benefits

- T&D Capital Deferral
- Service Reliability (DA)
- Improve System Efficiencies
- Voltage Regulation

1- Strategic Benefits

- Prepare for new Revenue Models
- Prepare for new Renewable & Reliability Mandates
- Prepare for new Customer Behaviors

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Value of Electricity Storage

- Pumped hydro power has played a valuable role in grid operations
- Need for storage in the grid is receiving more attention
- Storage will be a major facilitator of Smart Grid deployment
- A “small amount” of storage will have a “large impact” on the future grid

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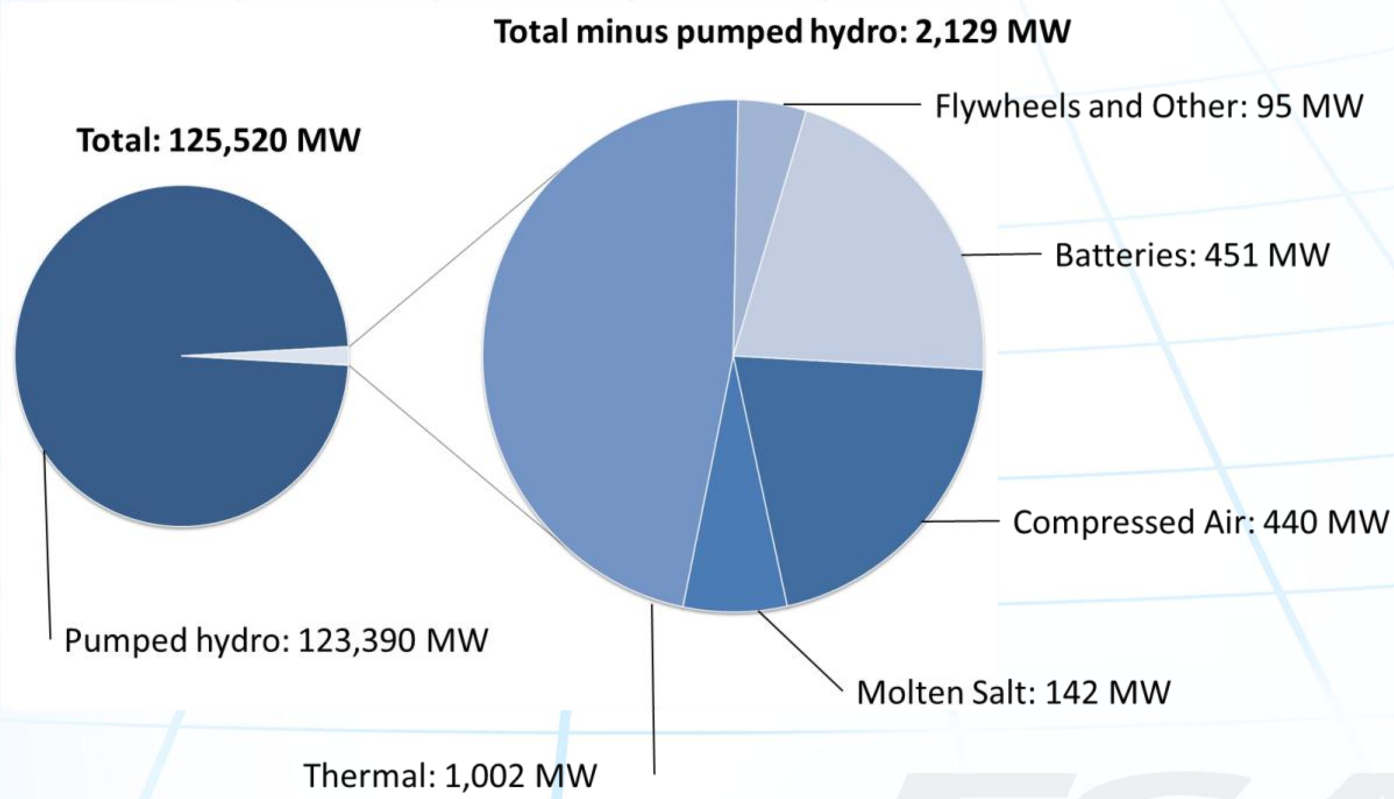
Grid Electricity Storage Alternatives

- Pumped hydro
  - ✓ Typically greater than 200 MW and days of storage
- Compressed Air Energy Storage (CAES)
  - ✓ 50 - 500 MW based on blended gas/air generation
- Distributed Energy Storage System (DESS)
  - ✓ Batteries up to 50 MW (> 2 hours)
  - ✓ Flywheels/lithium-ion up to 20 MW
- Community Energy Storage (CES)
  - ✓ 25 – 50 kW, 1 – 2 hour pad-mounted

The Grid Connected Energy Storage Market is Large …

Estimated Global Installed Capacity of Energy Storage



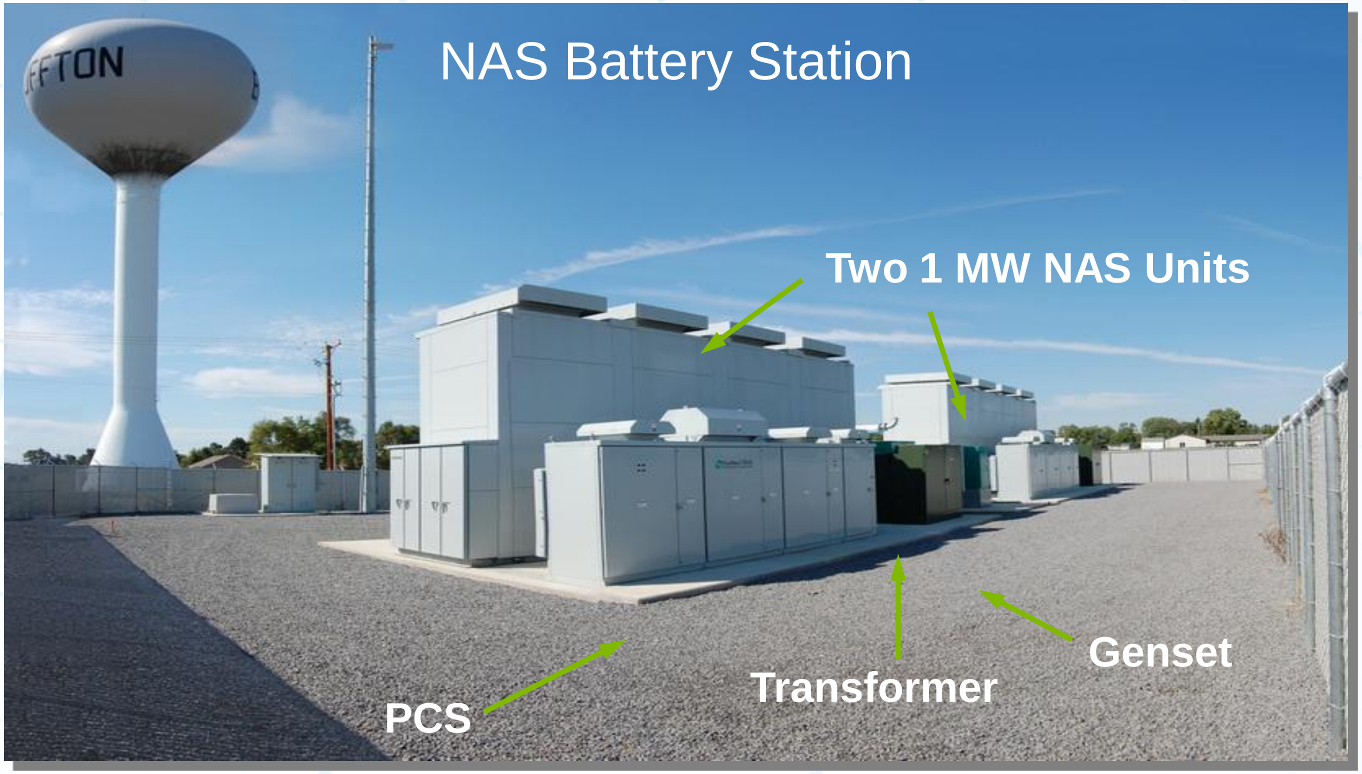
Source: StrateGen Consulting, LLC research; thermal storage installed and announced capacity estimated by Ice Energy and Calmac.
Note: Estimates include thermal energy storage for cooling only. Figures current as of April, 2010.

Pumped Hydro Storage

Compressed Air Electricity Storage

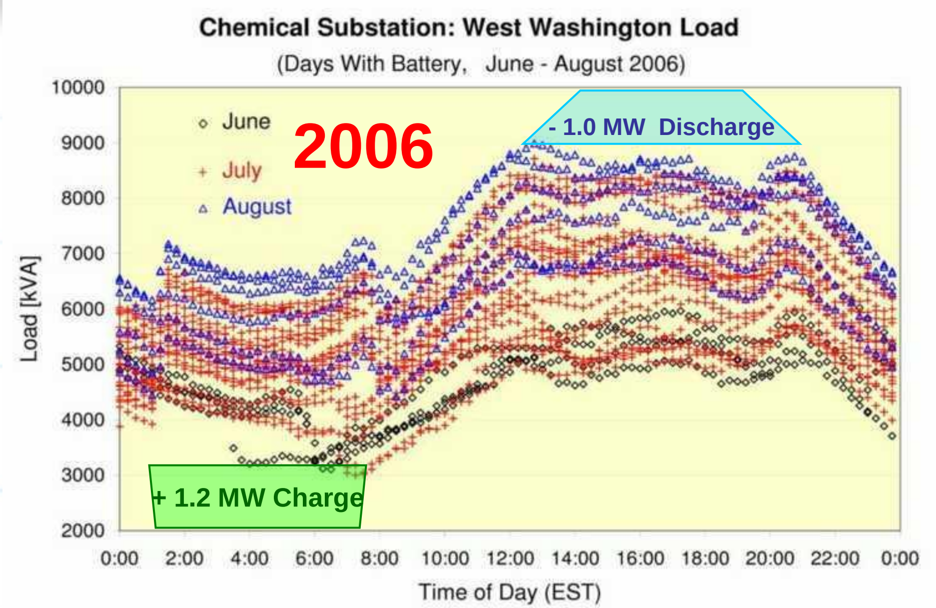
Distributed Electricity Storage

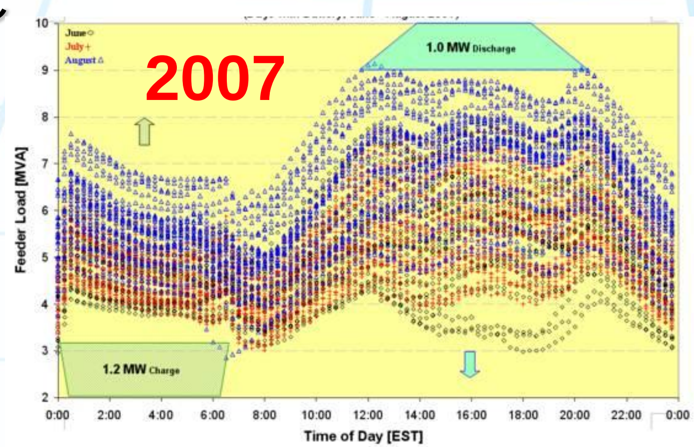
- 2 MW, 14.4 MWh in Bluffton, Ohio
- Two other identical sites in West Virginia and Indiana (2008)
- All with dynamic islanding

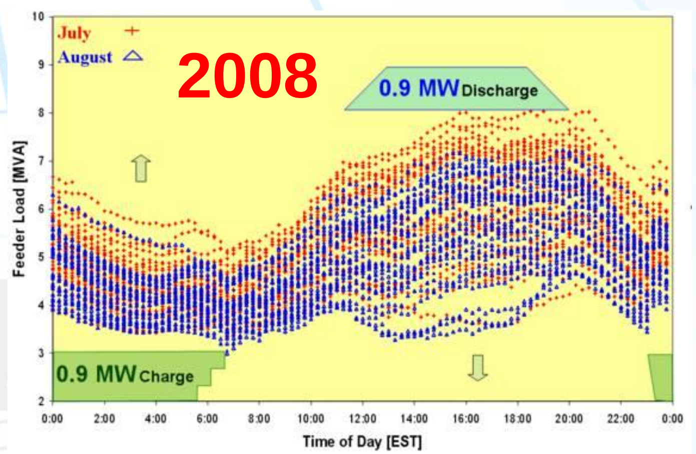


Performance Results

- Scheduled trapezoidal Charge & Discharge profiles
- Improved the feeder load factor by 5% (from 75% to 80%)
- Reduced the oil temperature of the 20 MVA supply transformer by about 4 degrees C







Electricity Storage with Renewables

34 MW, 7 Hour Battery with 51 MW Windfarm

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Flywheels (Kinetic Energy)

- Ancillary Service Application
  - ✓ 1.0 MW example (10 X 100 kW, 15 min.)

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Community Energy Storage (CES)

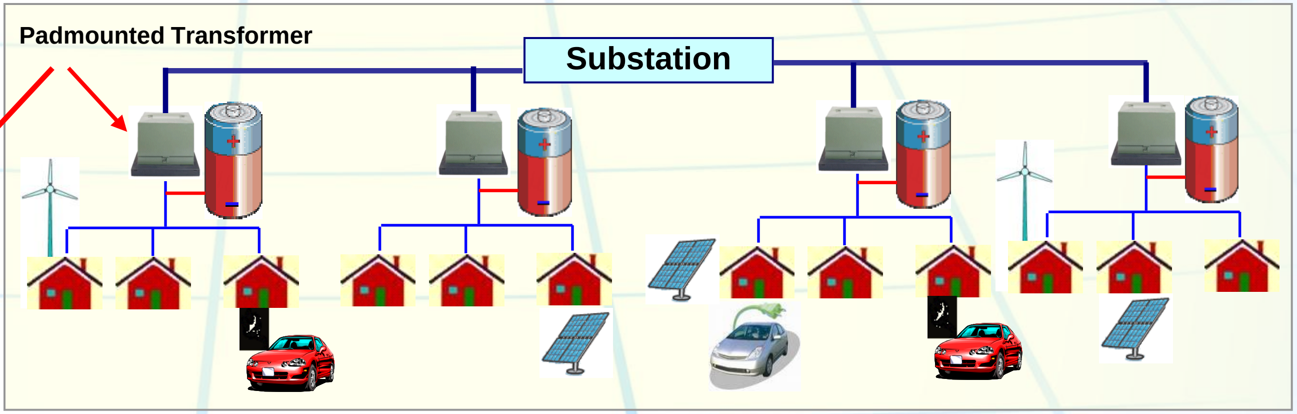
CES is a small distributed energy storage unit connected to the secondary of transformers serving a few houses or small commercial loads

Key Parameters	Value
Power (active and reactive)	25 kVA
Energy	25 - 75 kWh
Voltage - Secondary	240 / 120V
Battery - PHEV	Li-Ion
Round Trip AC Energy Efficiency	> 85%

- No maintenance – "set it and forget it"
  - No fans, no air filters

Community Electricity Storage

- Improved service reliability and efficiency (close to customers)
- Voltage sag mitigation and emergency transformer load relief
- Multi-MW, Multi-hour ***when aggregated,*** (leverage AMI[1])
- Potentially low cost (synergy with PHEV[2])

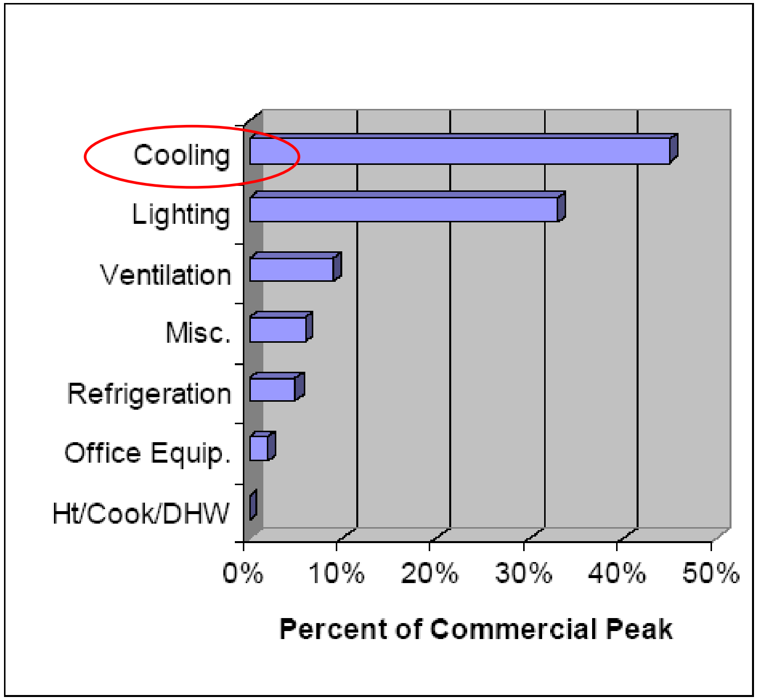


1- AMI = Advanced Metering Infrastructure

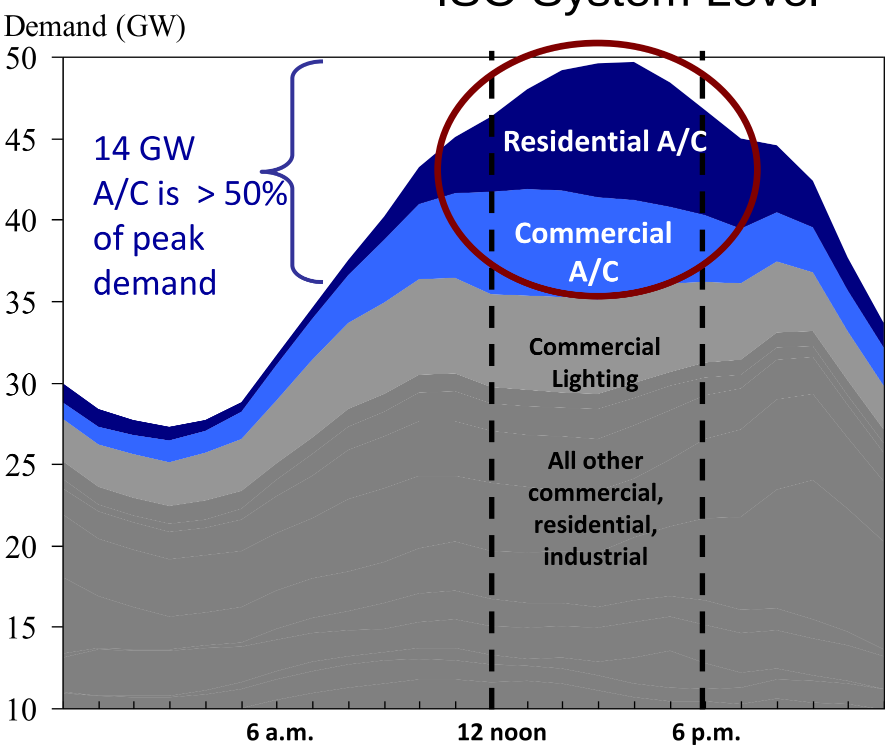
2- PHEV = Plug-in Hybrid Electric Vehicle

Thermal Storage: Peak Demand driven by Air Conditioning

Commercial Building Demand



ISO System Level



- Cooling is becoming about ½ the commercial load
- Commercial A/C load extends beyond the utility peak period

Electricity Storage Future – What's Needed?

- Better understanding of the value of storage
- Improved storage economics
- Drive storage technology, innovation and application

Impact of Large Amounts of Renewable Energy

- Curtailment of renewables could become significant
- Baseload plant operation could become uneconomic
- Major expansion of HV transmission line may not keep pace with broader development of wind

Why is There Opposition to Electricity Storage?

- Lack of understanding beyond bulk storage concept
- Perceived slow development of distribution storage technologies
- Lack of stimulus funding at the Federal Level until 2009
- Idea that storage is too expensive.

The Real Game Changer! Electric Transportation

- Two huge industries (utility and automotive) are in a transformation process
- Energy Storage is the problem and the solution
- Smart changing of PHEVs and EVs will be a valuable Smart Grid component
- 30 million electric vehicles by 2030 will be 500 GWs of new load
- Both will benefit from battery technology and production acceleration

For Further Reading

- Department of Energy, Electricity Advisory Committee
  - ✓ Keeping the Lights On
  - ✓ Smart Grid: Enabler of the New Energy Economy
  - ✓ Bottling Electricity: Storage as a Strategic Tool for Managing Variability and Capacity Concerns in the Modern Grid

  Reports available at: www.oe.energy.gov/eac.htm

- IEEE Power & Energy Magazine
  - ✓ Volume 7, Number 4, July/August 2009 "Energy Storage Issue"

  Available at: www.ieee-pes.org