ENERGY STORAGE 101

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38th Utility Energy Forum

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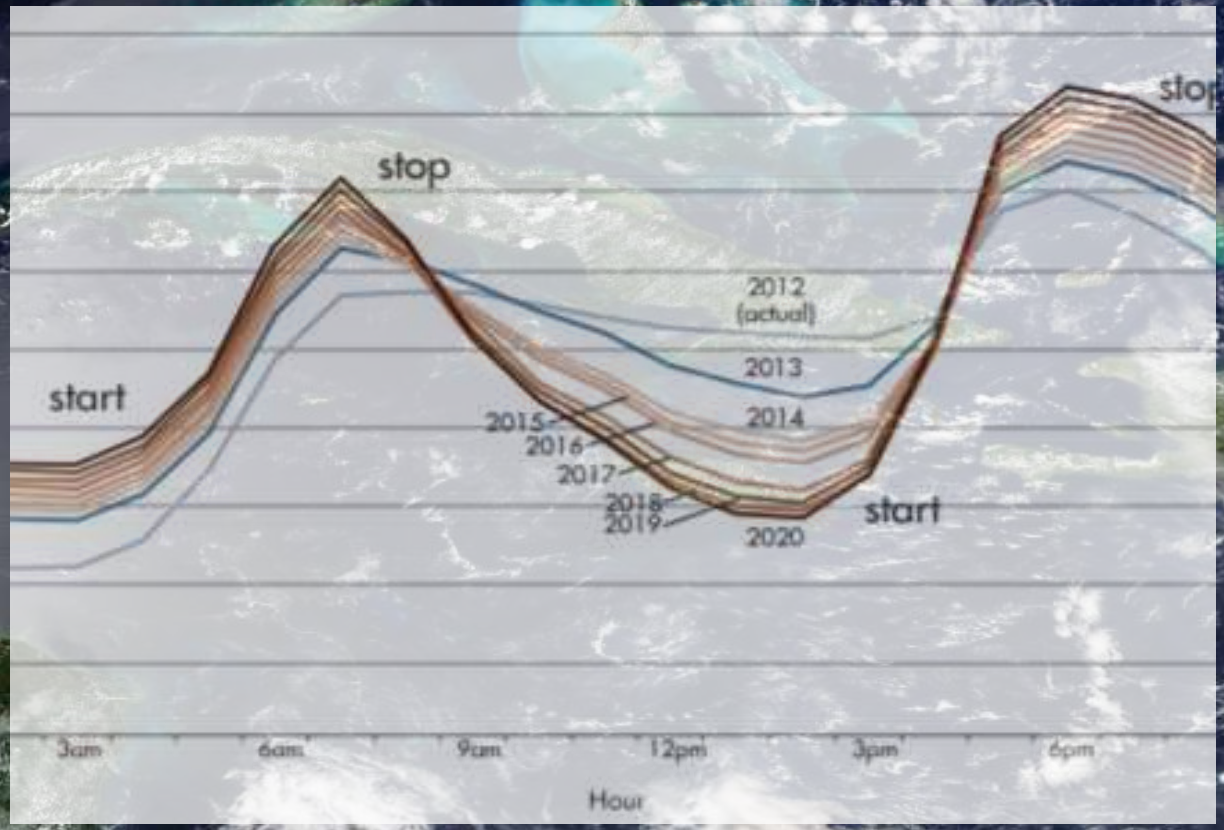
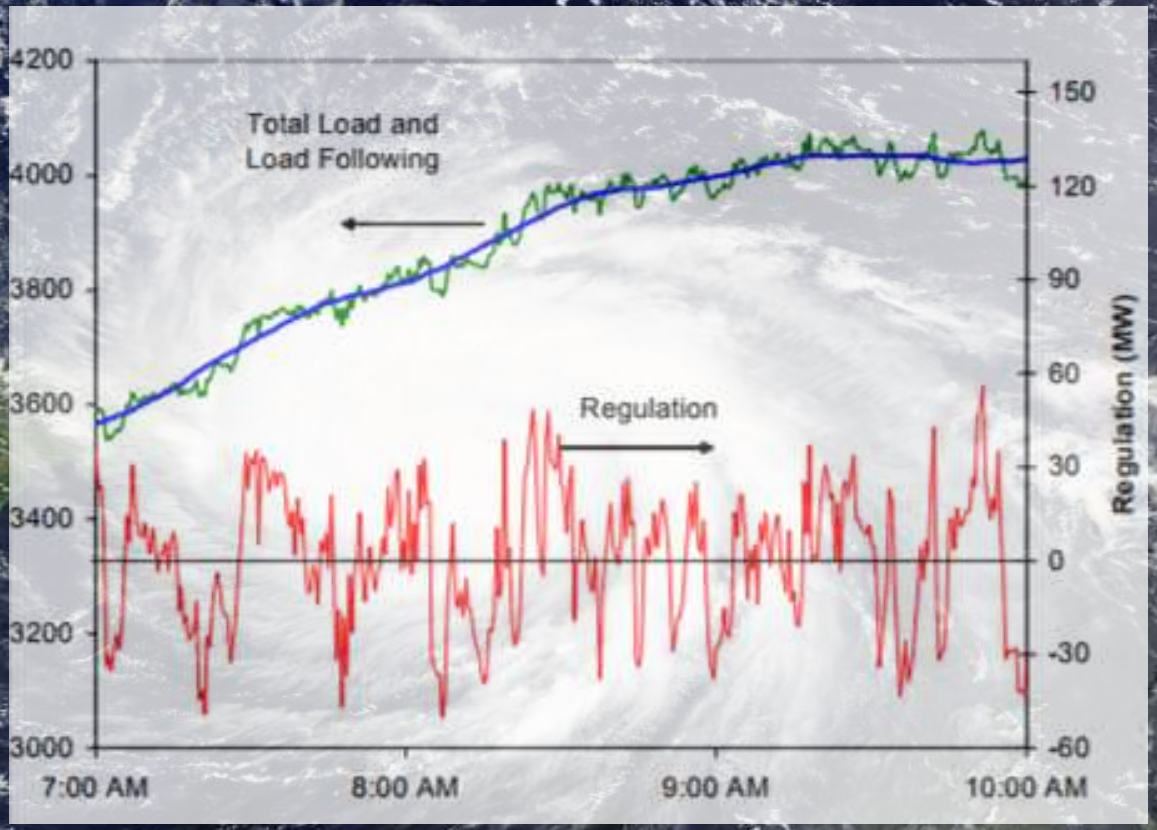
Why Energy Storage?





Sources: CAISO and ORNL

Agenda

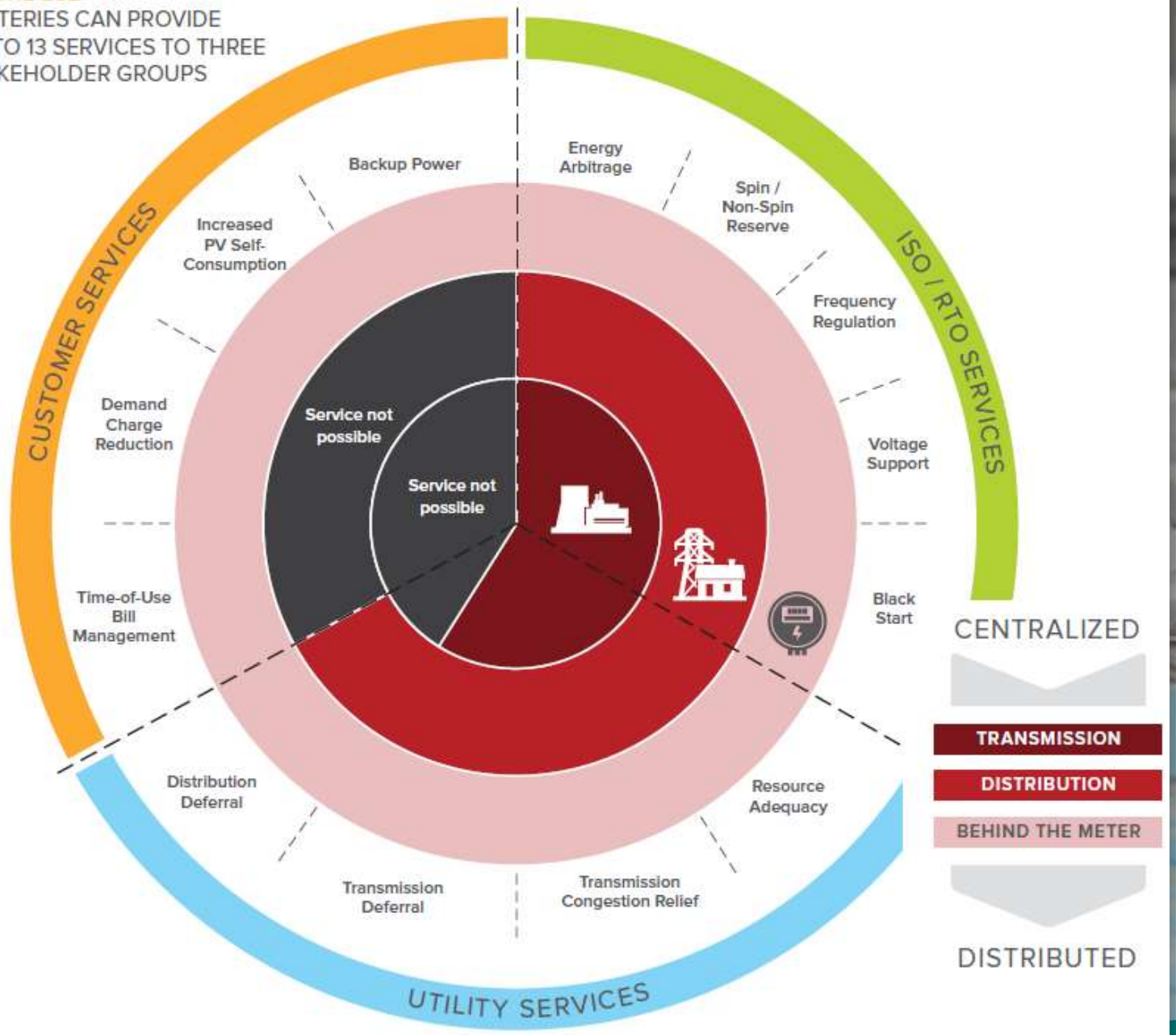
1. Definitions and key terminology
2. Facility vs. grid scale storage
3. Energy storage technologies
4. Technical and market barriers

Key Terminology

- Power/capacity = rated kW
- Energy = rated kWh
- Discharge time = $\frac{\text{Energy capacity}}{\text{Avg. power output}}$
- Depth of discharge (DOD) = capacity used
- Roundtrip efficiency
- Cycle life = number of useful cycles
- BTM & FTM = behind and front of the meter

Facility vs. Grid Scale Services

FIGURE ES2
BATTERIES CAN PROVIDE UP TO 13 SERVICES TO THREE STAKEHOLDER GROUPS



Source: RMI Economics of Battery Energy Storage, 2015

Power Quality and Backup

Systems that require high power quality or uninterruptible power supply (UPS):

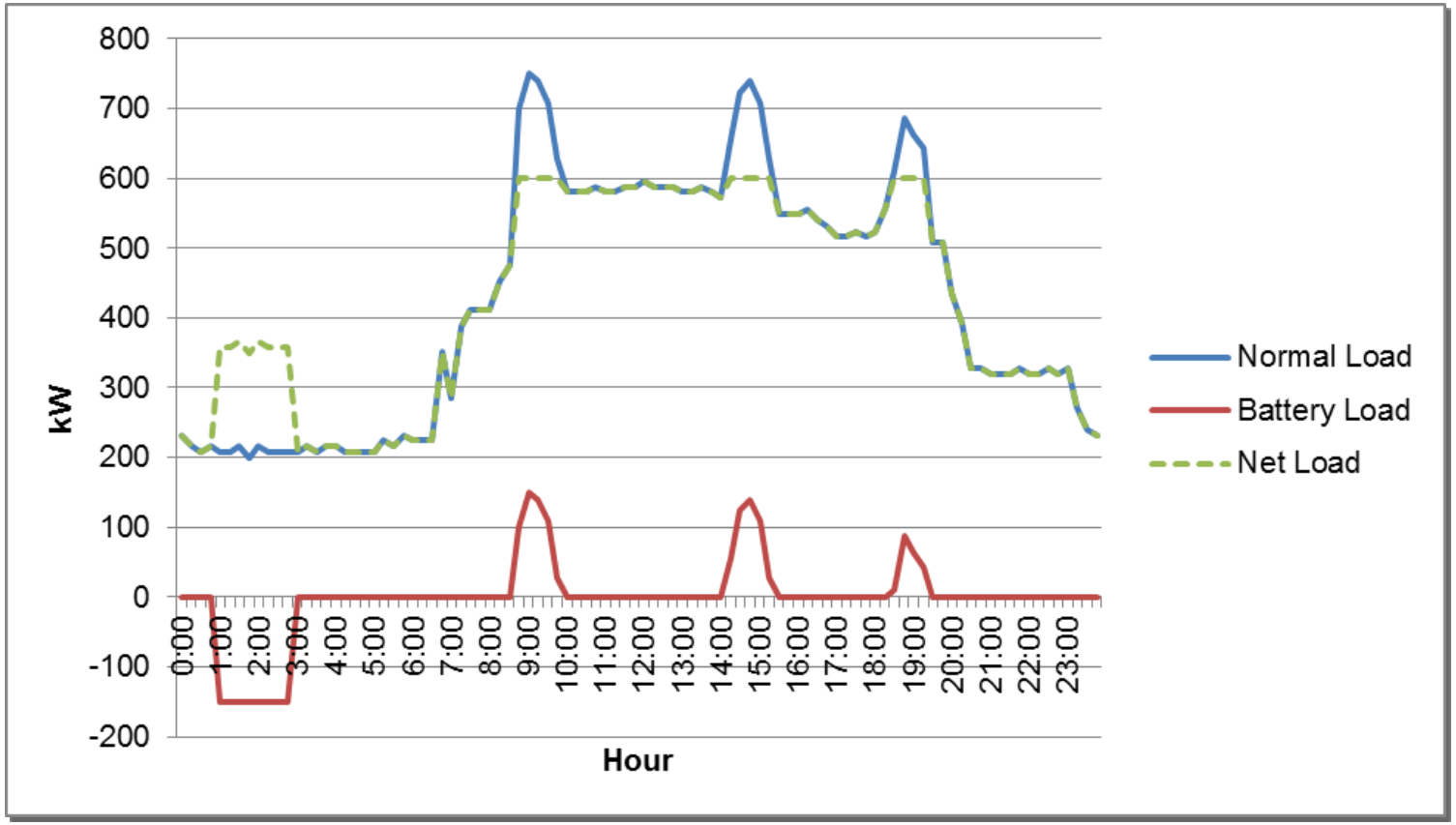
- Data centers
- Emergency response
- Medical
- Industrial

UPS systems are very common!

Demand Charge Reduction

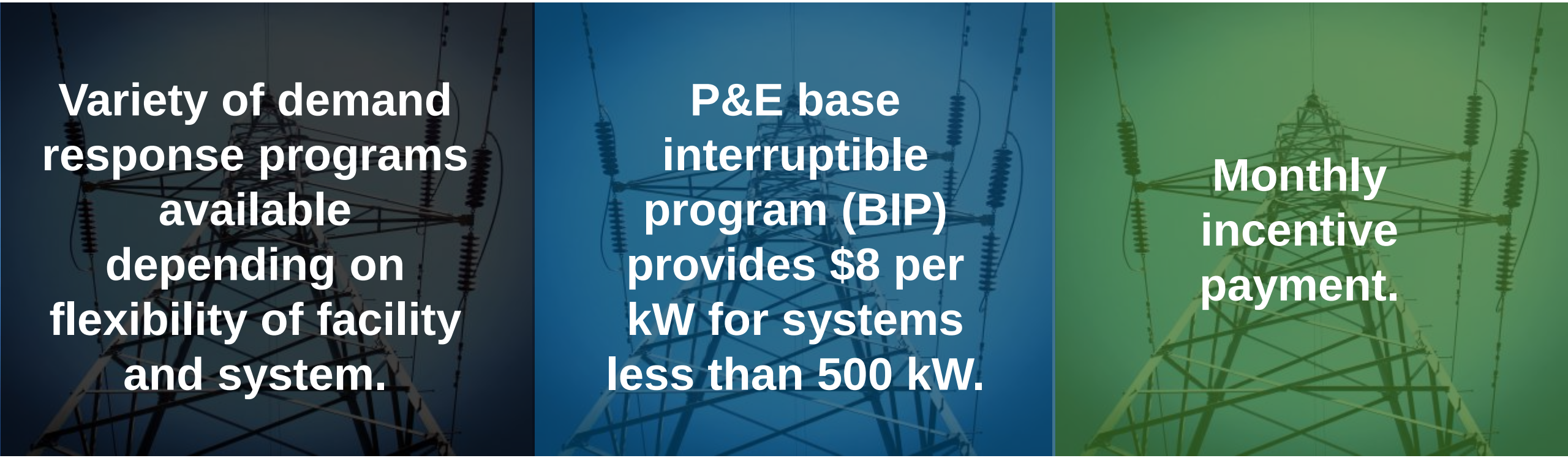
Facilities with > 50% of their electric bill from demand charges are key candidates.

- Simple payback approximately 5 years



Demand Response

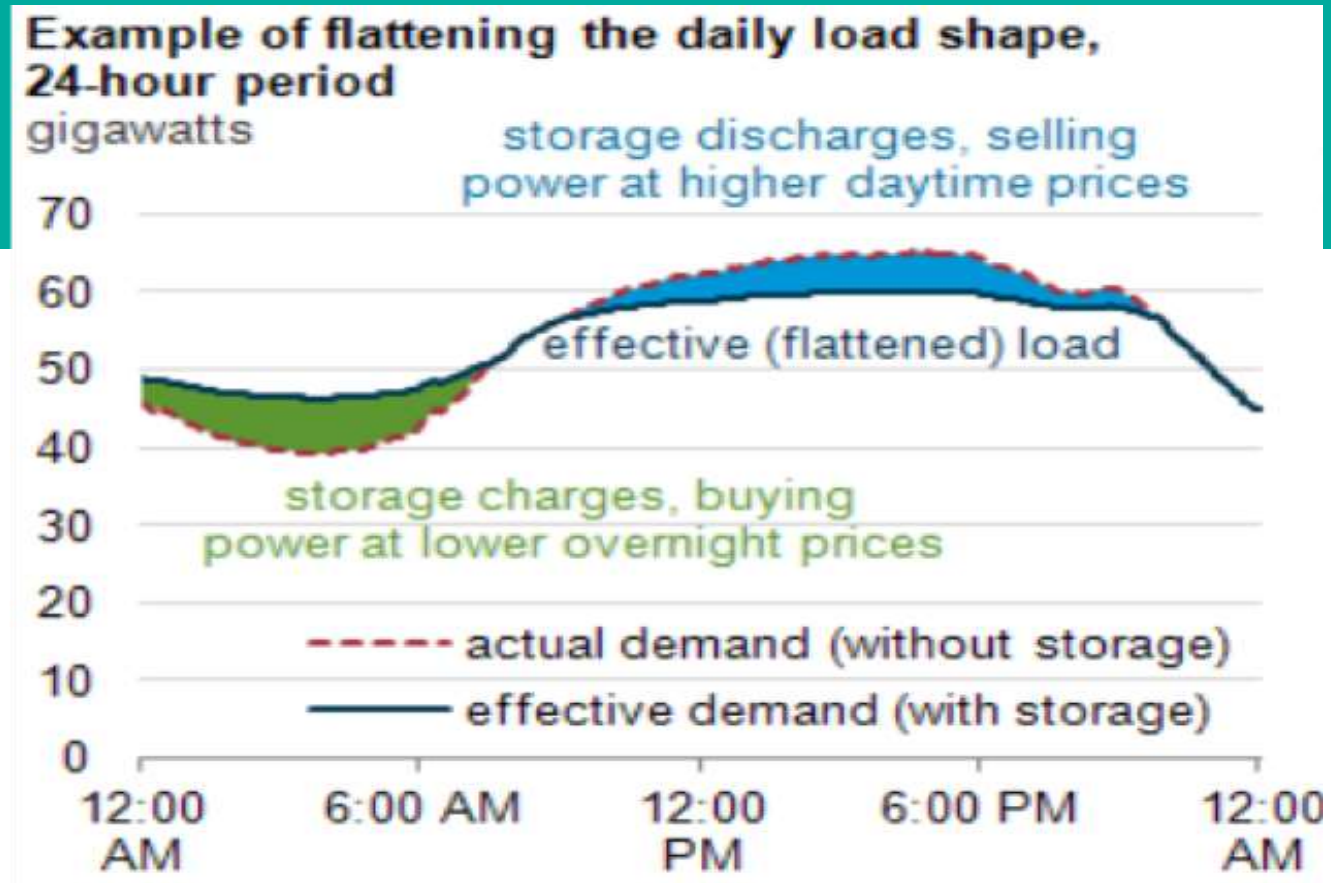
Many utilities and independent aggregators incentivize demand reduction during peak demand events



Source: http://www.cpuc.ca.gov/General.aspx?id=5925

Time of Use (TOU) Management

Also called “retail energy time shift” and “energy arbitrage”



Source: https://www.eia.gov/todayinenergy/detail.php?id=6350

Shifting use from high cost periods to low cost periods

- On peak = price of electricity during the on peak periods (daytime)
- Off peak = price of electricity during off peak periods (nighttime)

Renewables Integration

Energy storage is critical for the integration of large amounts of grid scale renewable generation.

- Retail = price you pay per kWh
- Wholesale = price they pay you per kWh

SGIP program offers $0.50/Wh to $0.25/Wh

BTM Services Summary

Purpose	Power	Discharge	Usage	Payback (w/o incentives)
Resiliency and power quality	100 kW to 1 MW	≤ 15 minutes	Variable	NA (Critical to production)
Demand charge reduction	50 kW to 1 MW	1 to 4 hours	Daily	4-6 years
Demand response	50 kW to 1 MW	4 to 6 hours	Infrequent	>> equipment life
Time of use management	100 kW to 1 MW	4+ hours	Daily	>> equipment life
Renewables integration	100 kW to 500 MW	4+ hours	Daily	>> equipment life

FACILITY SCALE TECHNOLOGIES

COMMERCIAL

1. Lead acid batteries
2. Lithium ion
3. Sodium sulfur
4. Flywheels
5. Thermal

OTHER PROMISING TECHNOLOGIES

1. Flow batteries
2. Zinc air
3. Magnesium salt
4. Other?

UTILITY SCALE TECHNOLOGIES

1. Pumped hydro
2. CAES

Lead Acid

STATUS

- Most mature, lowest capital cost, widely used
- $500 to $700/kWh
- Widely accepted by building codes

PRO

- Advanced lead acid batteries improve performance
- Easily recycled

CON

- Performance lacking
- 300 to 500 cycle life, 3 to 5 year shelf life
- efficiencies of 70% to 80%

Lithium Ion

STATUS

- NYC building fire code approval seems imminent

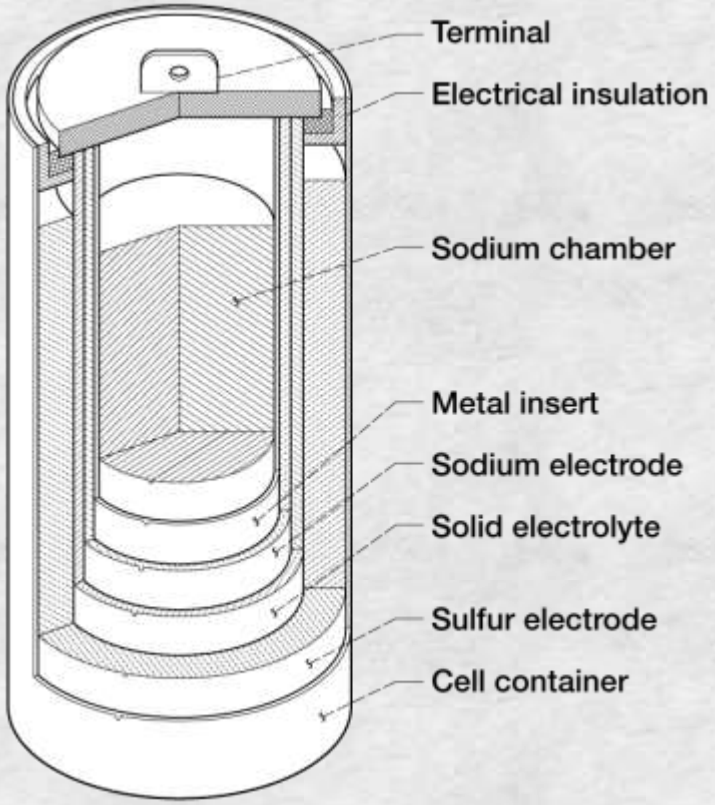
PRO

- High performance
- 2,000 to 5,000 cycles
- 10 to 15 year lifetime
- Efficiencies upwards of 98%

CON

- High cost: $500 to $2,000/kWh
- Tesla Powerwall: 13.5 kWh for $7,000 = $500/kWh

Sodium Sulfur (Molten Salt)



STATUS

- Best suited to larger capacity
- Competitive cost: $750 to $2,000/kWh
- Not widely accepted by codes

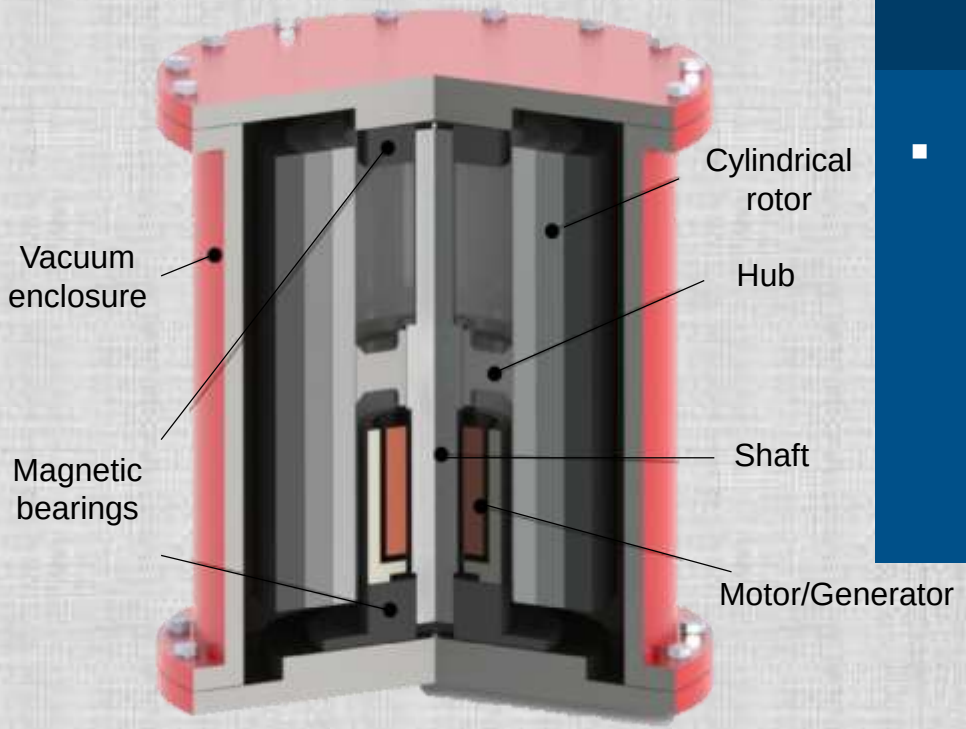
PRO

- Good performance
- 2,000 to 4,500 cycle life
- 10 to 15 year shelf life
- Efficiencies of 70% to 80%

CON

- Limited manufacturers
- High operating temp (>300F)

FLYWHEELS



STATUS

- Several commercial suppliers in the USA

PRO

- Costs very high: $2,000 to $4,000 per kWh
- Not practical for large capacity energy storage

CON

- Performance and lifetime is very good: indefinite lifetimes and high efficiencies

TECHNOLOGY SUMMARY

Market	Battery Type	Installed Energy Cost ($/kWh)		Roundtrip Efficiency	Useful Life	
		Outdoors	Indoors		Cycle Life	Expected Lifetime (Years)
Commercial Technologies	Lead acid	$400 - $700	$600 – $1,000	70% – 80%	500 – 1,500	3 – 5
	Lithium ion	$400 – $2,000	$500 – $2,500	85% – 98%	2,000 – 5,000	10 – 15
	Sodium Sulfur (salt)	$750 – $900	$1,000 – $2,000	70% – 80%	2,500 – 4,500	10 – 15
	Flywheel	$2,000 - $4,000	N/A	85% - 90%	> 10,000	>15 yrs

State of Emerging Technologies

Tech Type	Manufacturer	Status
Flow	Vionx, EnSync (ZBB), Redflow, and others	Many projects and manufacturers
Zinc Air	EOS	Partnered with Siemens, seem to be gaining momentum
Magnesium Salt	Aquion	Ch 11 recovery, April 2018 anticipated release
Liquid Metal	Ambri	Recent redesign, significant VC funding, not commercially available yet

Technical and Market Barriers

- High costs & limited lifetimes
- Large, heavy, toxic
- Fire hazards
- Public perception of hazards
- Challenging to find suitable locations in urban environments
- Local fire codes are especially wary of newer commercial systems

ers energy & resource solutions

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Additional Resources

- http://www.sandia.gov/ess/handbook.php
- http://www.ease-storage.eu/technologies.html
- http://amberkinetics.com/
- http://www.johnsoncontrols.com/content/us/en/products/power-solutions/battery-brands.html
- http://www.teslamotors.com/powerwall
- http://www.aquionenergy.com/
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