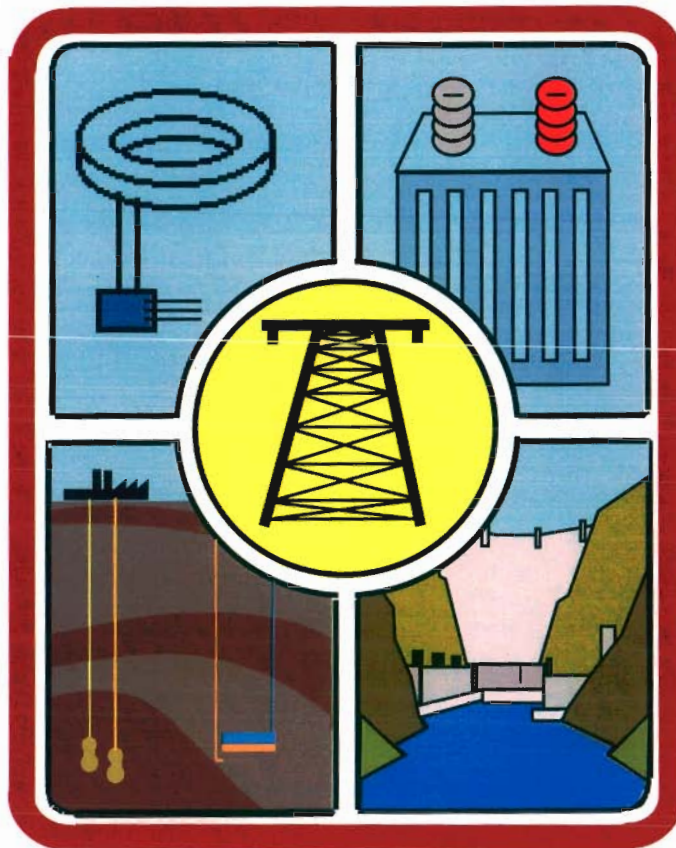




ELECTRIC POWER
RESEARCH INSTITUTE



Executive Summary: Electric Energy Storage Can Stabilize And Make Wind Resources More Efficient and Valuable

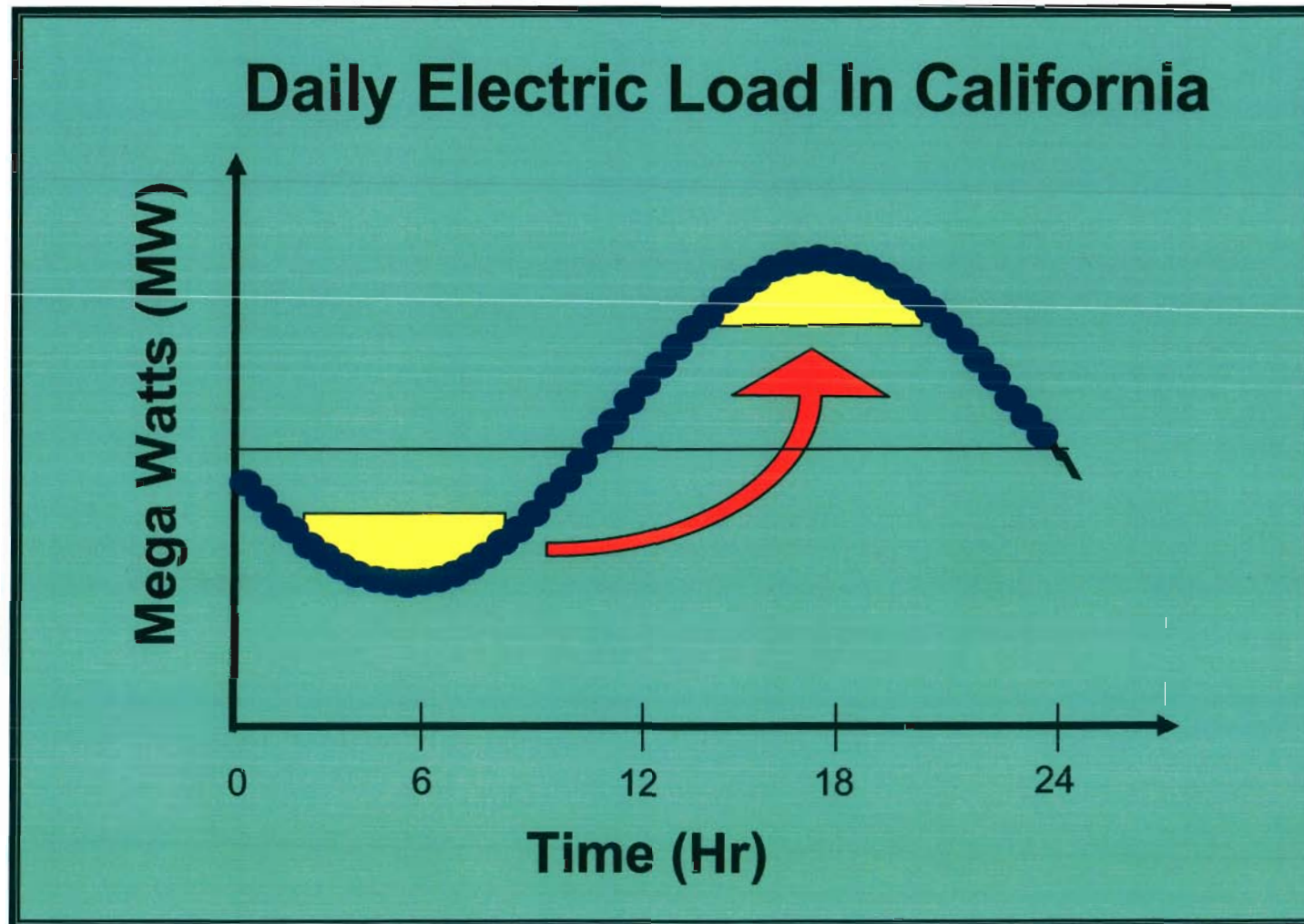
Presented to:
California Energy Commission
Energy Efficiency Workshop

Presented by:
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Electric Power Research Institute
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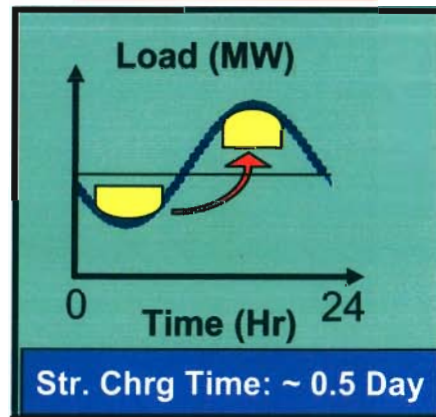
March 3, 2008

Energy Storage Efficiently Resolves Wind Power Load Management Issues



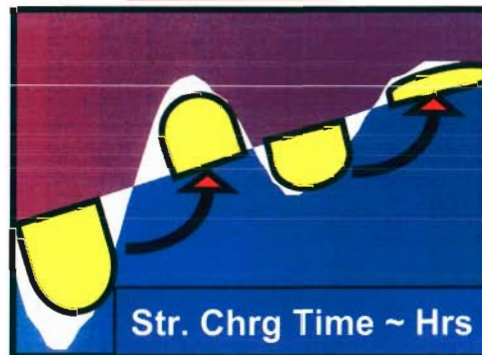
Energy Storage Efficiently Resolves Wind Power Fluctuation, Ramping and Load Management Issues

Load Leveling



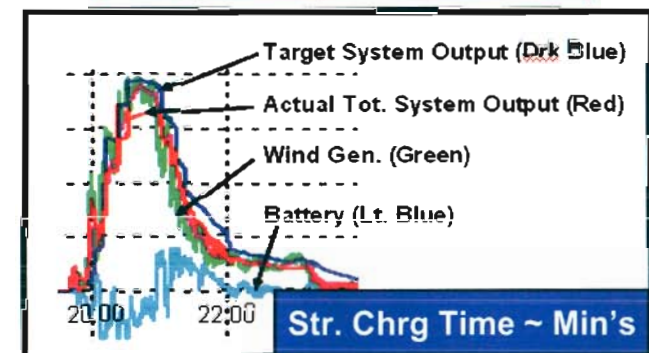
- CAES
- Pumped Hydro

Ramping:



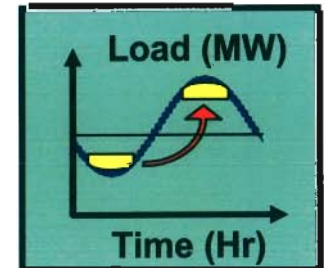
- CAES
- Pumped Hydro
- Battery, Flow type
- Note: In California ramping is a big issue

Frequency Regulation:



- Battery, Regular or Flow Type
- SuperCap
- Flywheel
- SMES

Don't Let The Texas Grid Emergency Caused By Wind Generators Happen In California



Reuters New Flash

Loss of Wind Causes Texas Power Grid Emergency

Wed Feb 27, 2008 8:11pm EST

HOUSTON (Reuters) - A drop in wind generation late on Tuesday, coupled with colder weather, triggered an electric emergency that caused the Texas grid operator to cut service to some large customers, the grid agency said on Wednesday.

Electric Reliability Council of Texas (ERCOT) said a decline in wind energy production in west Texas occurred at the same time evening electric demand was building as colder temperatures moved into the state.

The grid operator went directly to the second stage of an emergency plan at 6:41 PM CST (0041 GMT), ERCOT said in a statement.

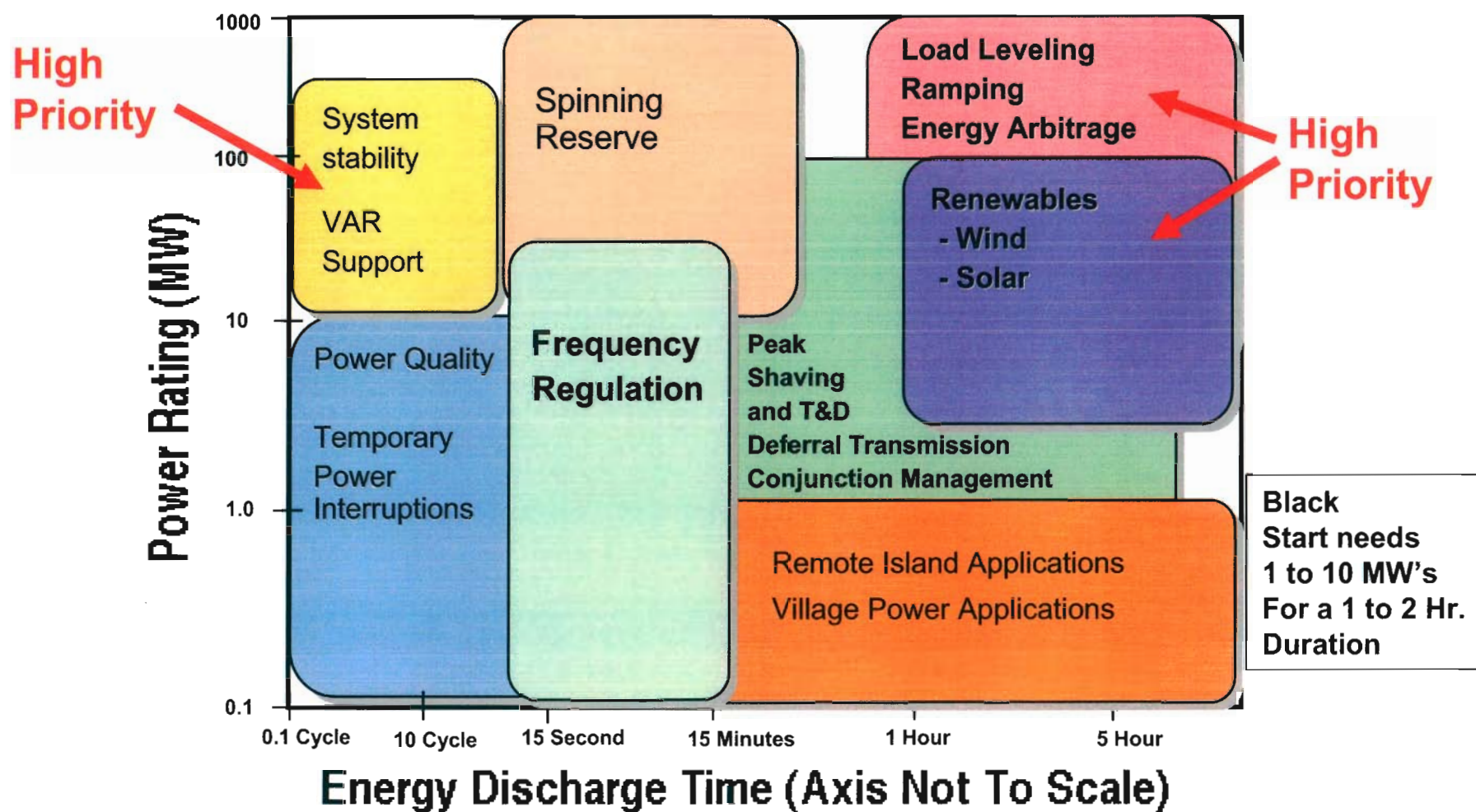
System operators curtailed power

Types of Electric Energy Storage Technologies

- **Pumped Hydro**
- **Compressed Air Energy Storage (CAES)**
- **Flywheels**
- **Batteries**
- **Super-Capacitors (SuperCaps)**
- **Superconducting Magnetics**
- **Thermal Storage**
- **Fuel Cells (reversible)**
- **Hydrogen Storage**

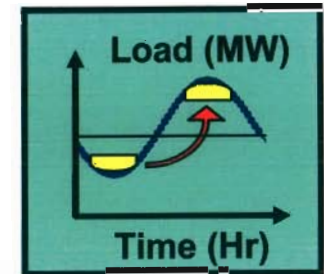
Electric Energy Storage Applications

(All Boundaries Of Regions Displayed Are Approximate)



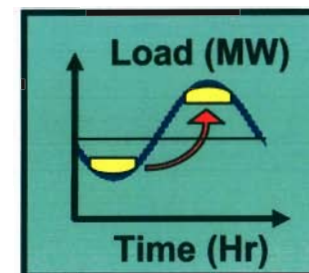
Storage Options Vs. Utility Application

(Based on Current Technology and Current Trends)

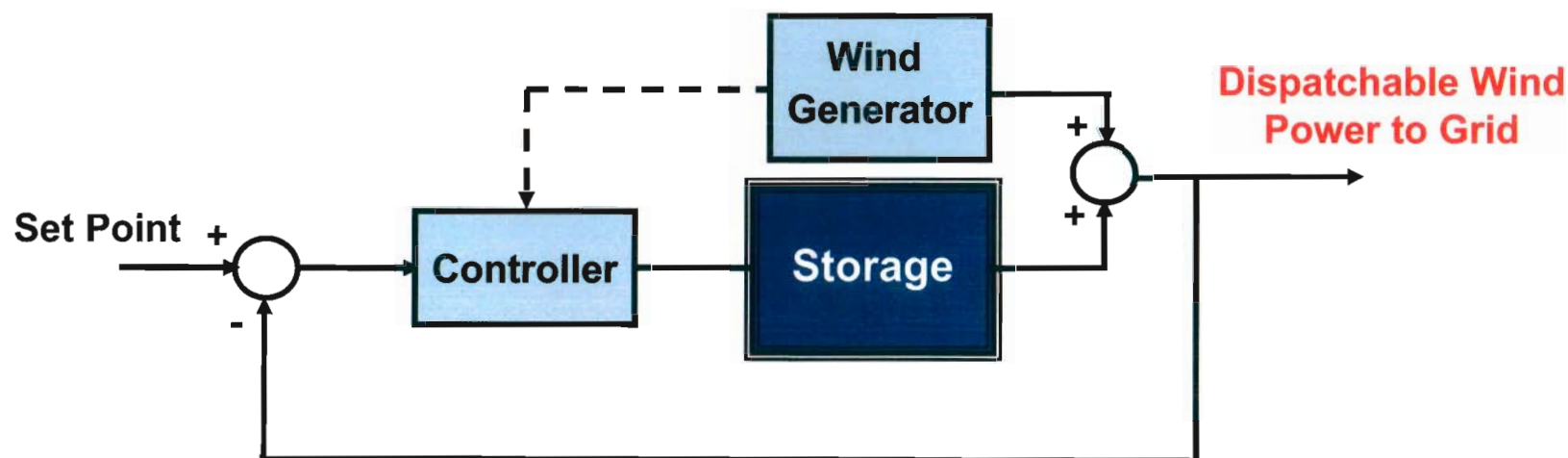


Application → ----- Storage Option ↓	Transmission Stability, Power Quality	Spinning Reserve, Freq. Regulation	T/D Deferral, Transm.Decong. Peak - Shaving	Bulk Power Arbitrage, Ld .Lev'lg Rp, Ren'w
Compressed Air: Lrg. (Salt, Por.M., Rk)		X	X	X
Small (Abv. Grd.		X	X	
Pumped Hydro		X	X	X
Underground		X	X	X
Battery Types: Adv LdAcid / NaS / Adv. Flow - Redox Systems	X	X	X	X
Flywheel	X	X		
SMES	X	X	X	
Super-Capacitor	X	X	X	
Hydrogen, Lg-Term Goal				X

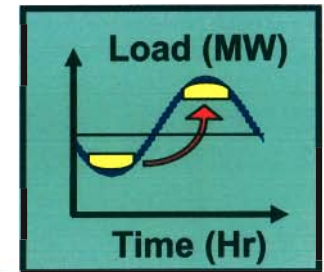
Problem: Wind Plants Produce Off-Peak and Output Power Fluctuations That Limit Their Value



Solution:
Deploy Energy Storage “Shock Absorber” Plant, Sized and Controlled To Resolve Wind Resource Power Fluctuation, Ramping and Load Management Issues



Capital Cost Comparison of CAES to Other Storage Plants



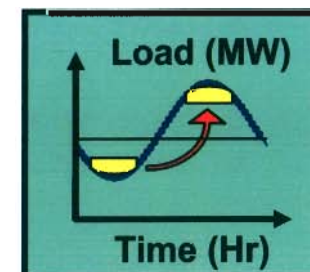
Technology	\$/kW	\$/kWh*	x	H	= Total Capital, \$/kW
Compressed Air, CAES					
- Large (100-300 MW)	540	1	10		550
- Small (10-20MW) AbvGr Str	800	80	2		960
Pumped Hydro, PH					
- Conventional PH (1000MW)	1300	40	10		1700
Battery, BES (target) (10MW)					
- Lead Acid, commercial	300	300	3		1200
- Advanced (Flow)	300	200	3		900
Flywheel (target) (100MW)	300	500	2		1300
Superconducting (1000MW)	300	700	2		1700
Magnetic Storage, SMES (target)					
Super-Capacitors (best today)	300	12000	1/60		500
(target)	300	1200	1/60		320

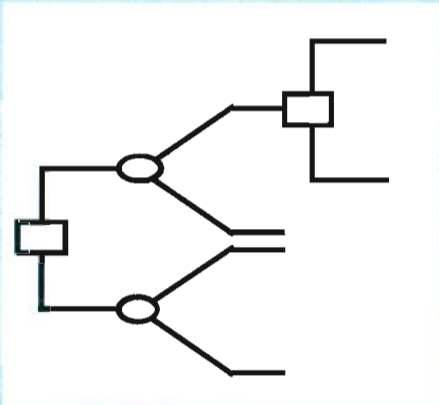


This column determines the most cost-effective energy storage device to deploy and how many discharge hours to build.

* This capital cost is for the storage "reservoir", expressed in \$/kW for each hour of storage. For battery plants, costs do not include expected cell replacements.

EPRI updates these costs on an annual basis

Electric Energy Storage: Value Proposition



Types of Benefits	Physical System GenerationT&D	Corporate Perspective	Customer Perspective												
<u>Strategic</u> <ul style="list-style-type: none">• Improve Efficiency• Enhance Renewables• Mitigate Uncertainty• CO₂ Reduction															
<u>Operational</u> <ul style="list-style-type: none">• Efficiency• Dynamic• Load Leveling		<div>STRATEGIES</div> <div>SCENARIOS</div> <div><table><tr><td>Risks</td><td></td></tr><tr><td>And</td><td></td></tr><tr><td>Opportunities</td><td></td></tr></table><table><tr><td></td><td></td></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr></table></div>	Risks		And		Opportunities								
Risks															
And															
Opportunities															

One of Edison's Most Famous Quotes:

*"In Periods of Profound Change, The Most Dangerous Thing Is to Incrementalize Yourself Into The Future."
Bottom Line: Think "Out of the Box"*

