

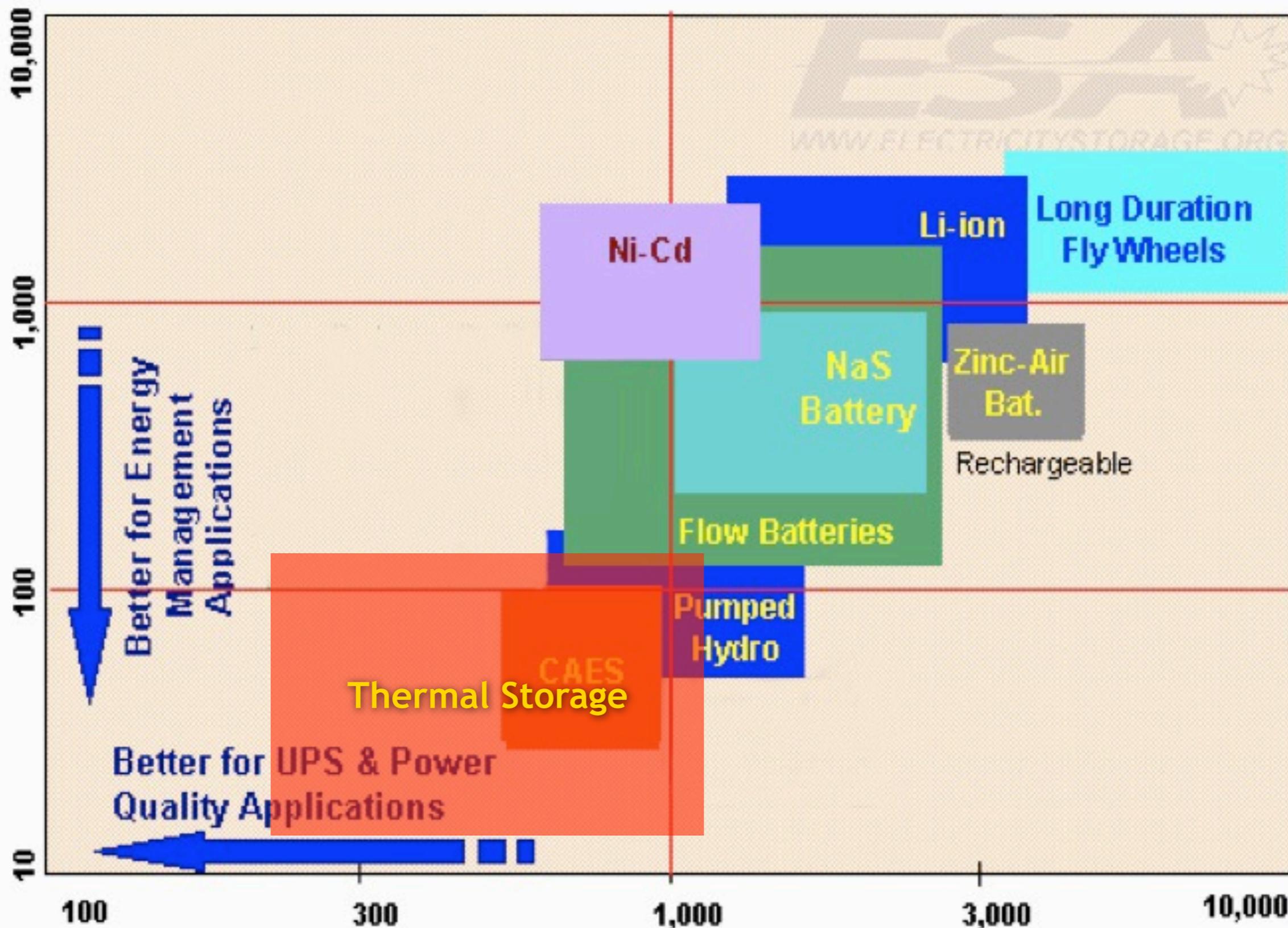
An aerial photograph of an industrial facility, likely a power plant or energy storage site. The image shows a large complex of white buildings, numerous large cylindrical storage tanks, and intricate piping systems. A large rectangular reservoir is visible on the left side. The facility is surrounded by a mix of paved areas, dirt, and greenery. The text "Electrical Energy Storage Applications and Technologies (EESAT) 2013" is overlaid in the center of the image.

# Electrical Energy Storage Applications and Technologies (EESAT) 2013

October 21, 2013  
San Diego, CA



Capital Cost per Unit Energy - \$/kWh-output  
(Cost / capacity / efficiency)



Capital Cost per Unit Power - \$/kW

ESR  
WWW.ELECTRICITYSTORAGE.ORG

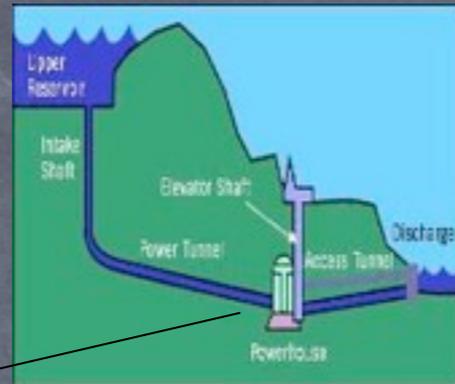
### Pumped Hydro - 70%

**Grid Storage**  
1.45kWh to create  
1 ton-hr of Cooling



**Building Storage**

1.07kWh to create  
1 ton-hr of Cooling



### On Peak - Daytime

Transmission    Distribution

95%

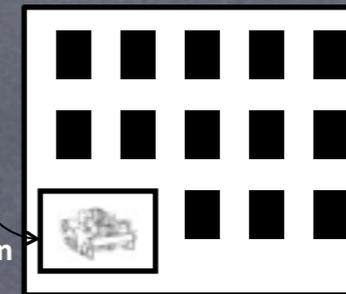


93%



0.9 kW/ton

1 ton-hr of Cooling  
13,000 Btu's  
Source Energy\*



### Off Peak - Nighttime

Transmission    Distribution

97%



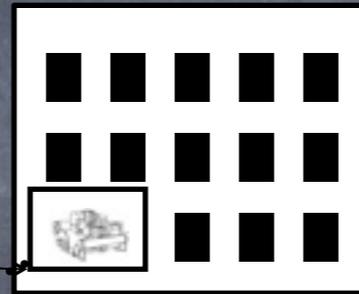
96%



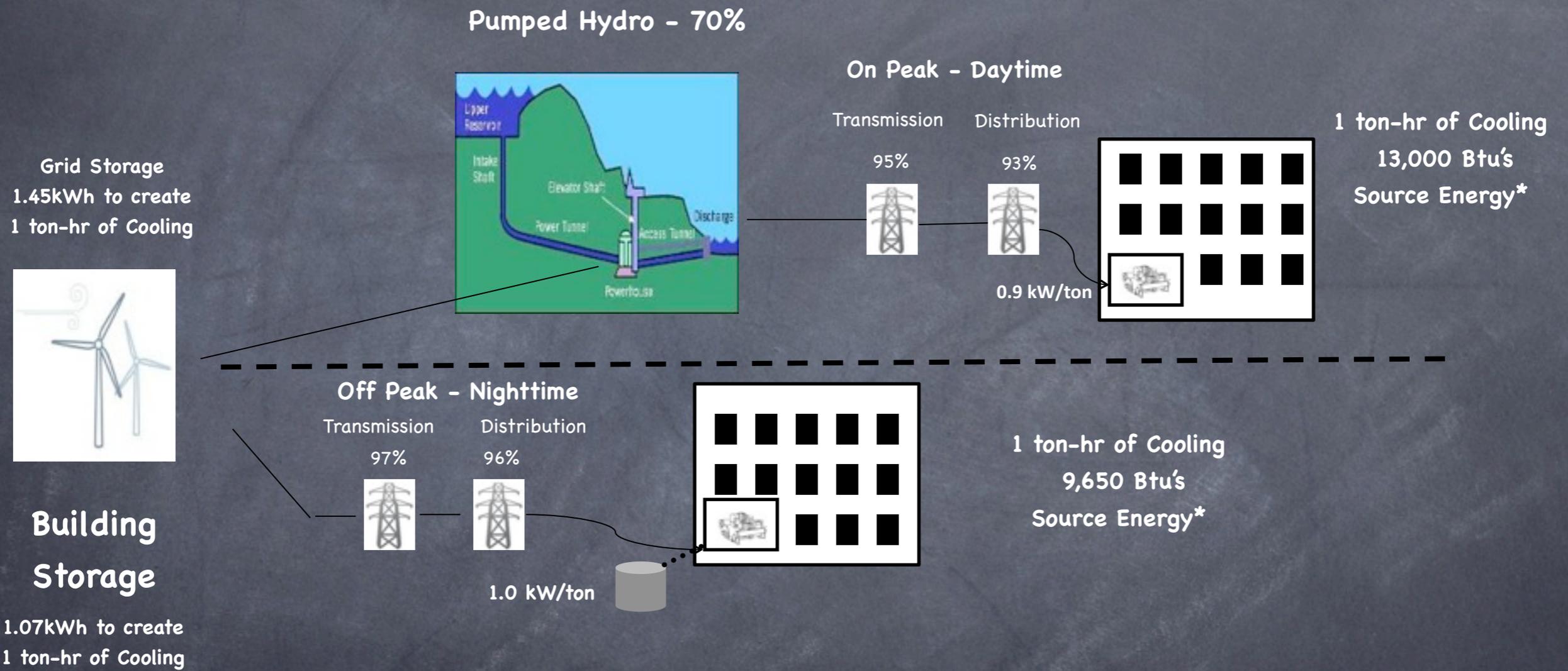
1.0 kW/ton



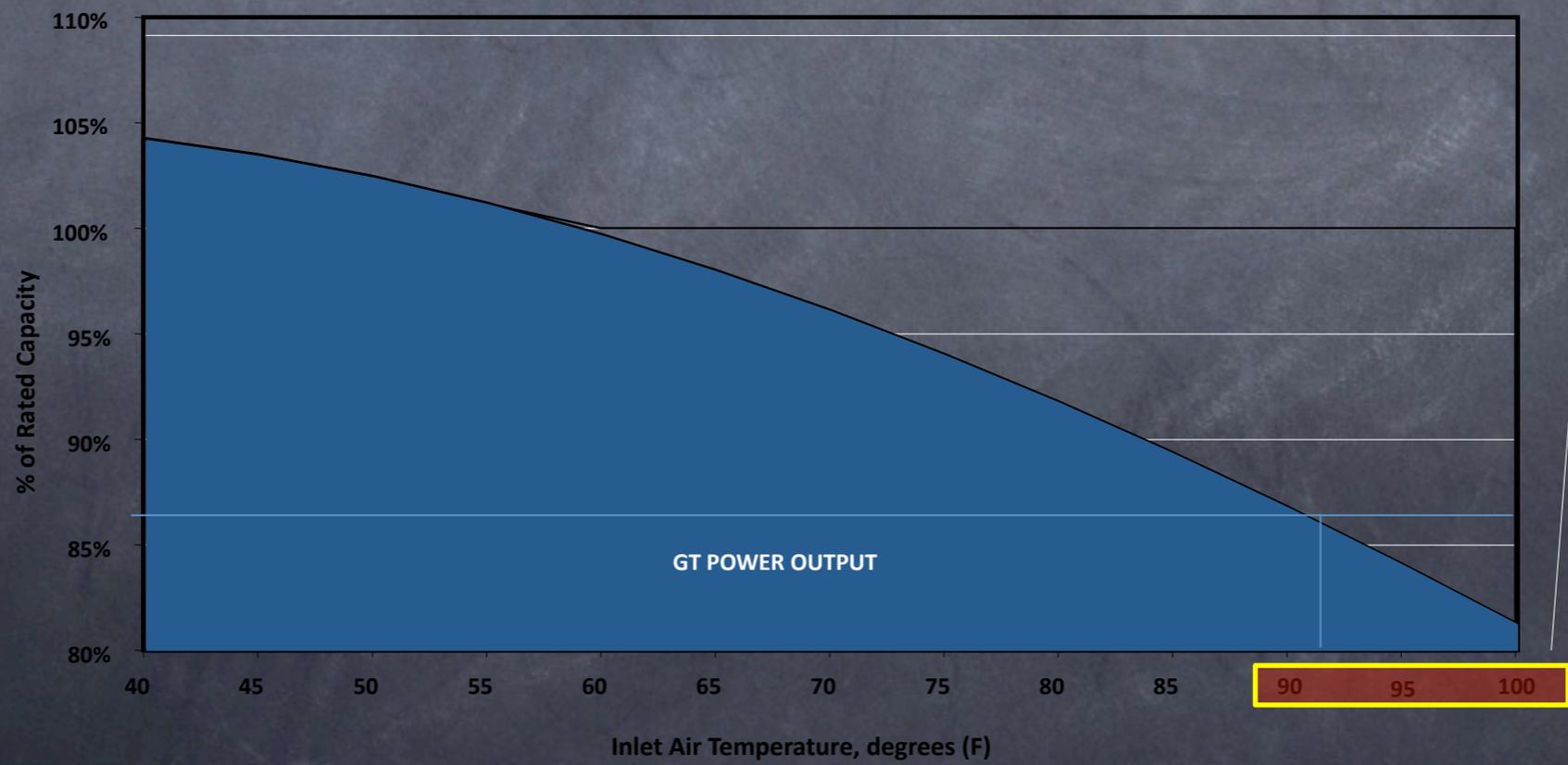
1 ton-hr of Cooling  
9,650 Btu's  
Source Energy\*



# Understanding End-to-End Cycle Efficiency Grid Storage vs. Building Energy Storage

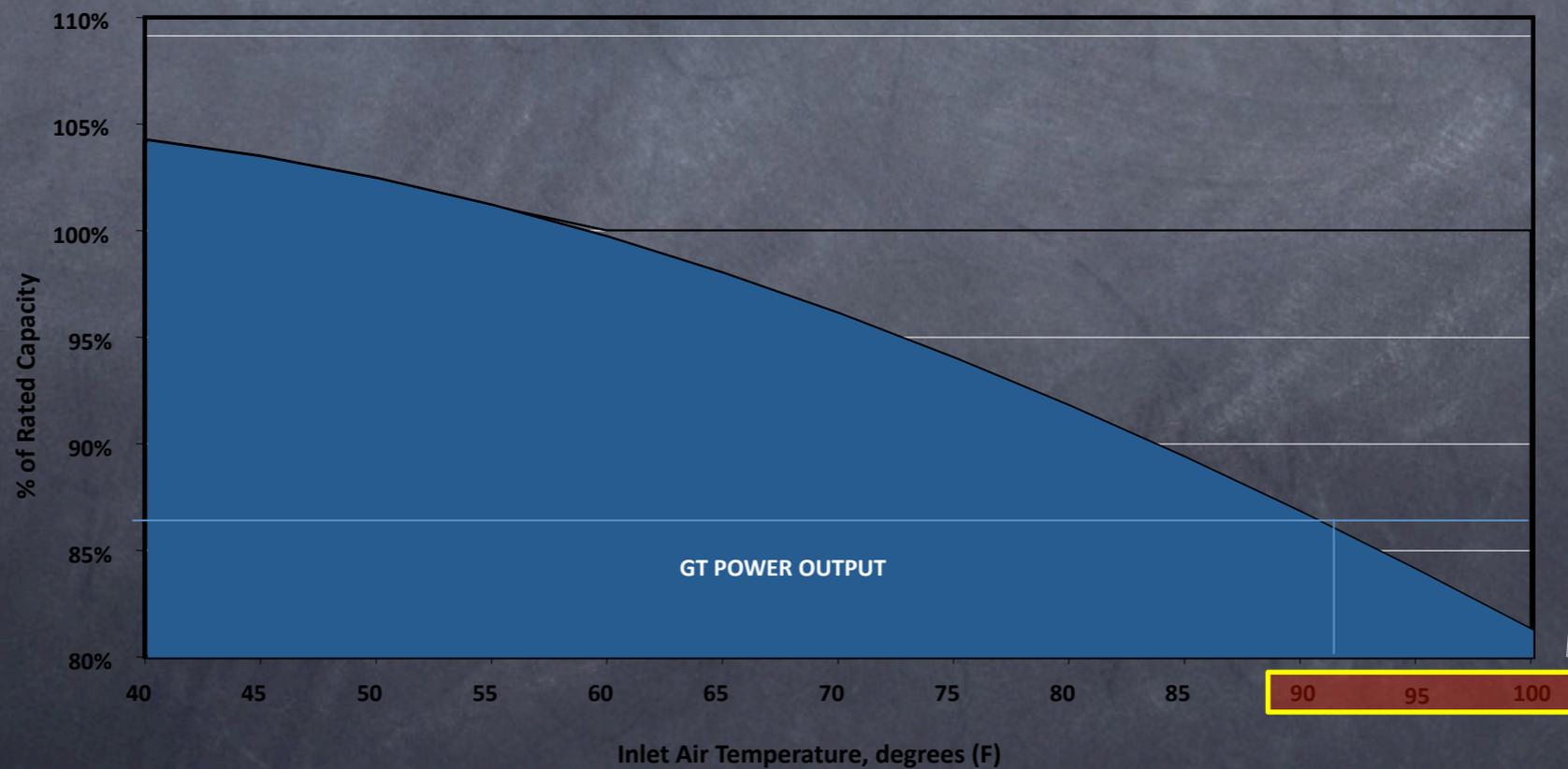


\* Fossil Fuel Power Plant Eff.= 38%



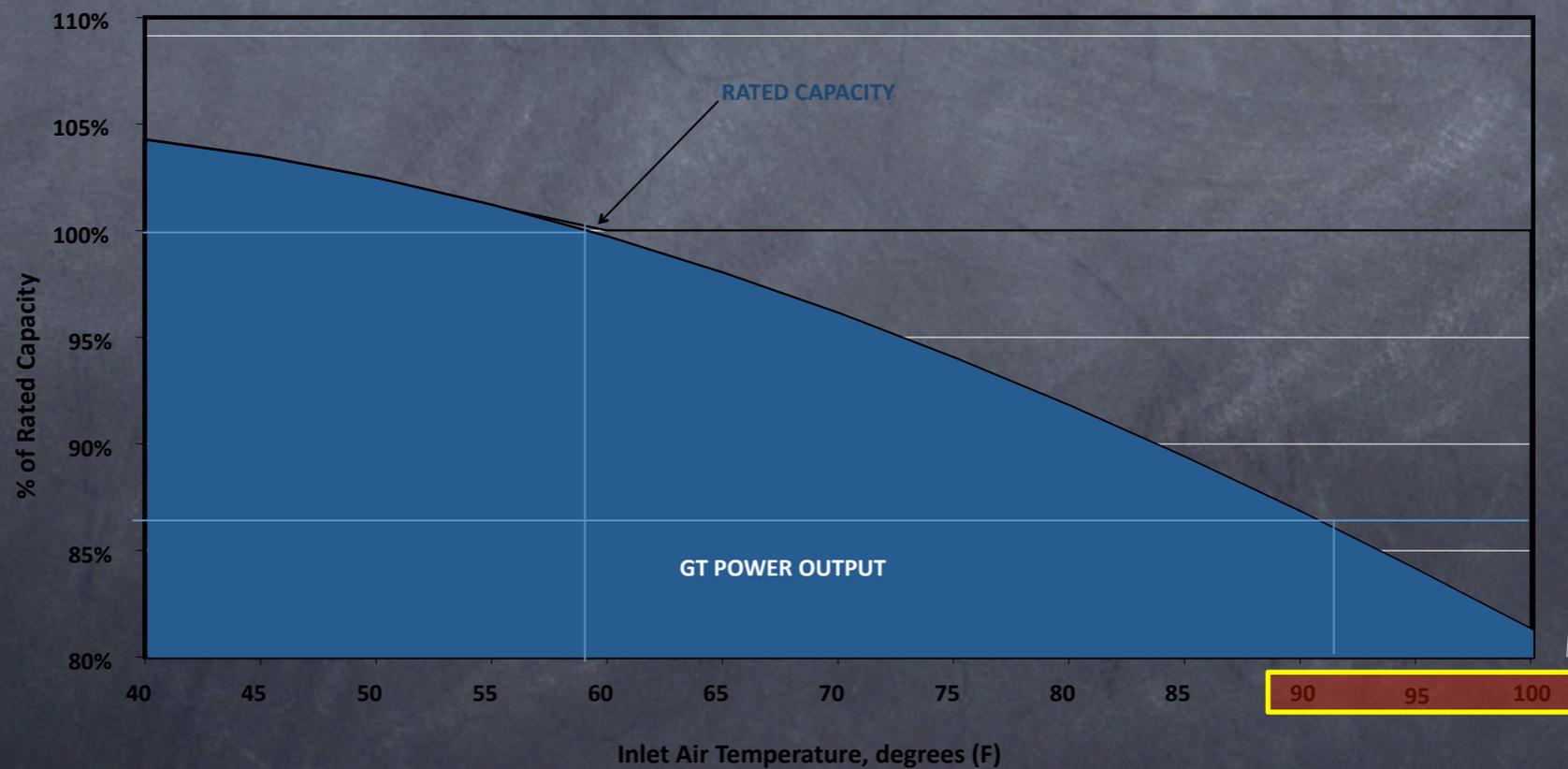
# Generation Storage: Storage for Gas Plants

- Gas turbines only operate at 100% of their rated capacity when the temperature outside is 59F.



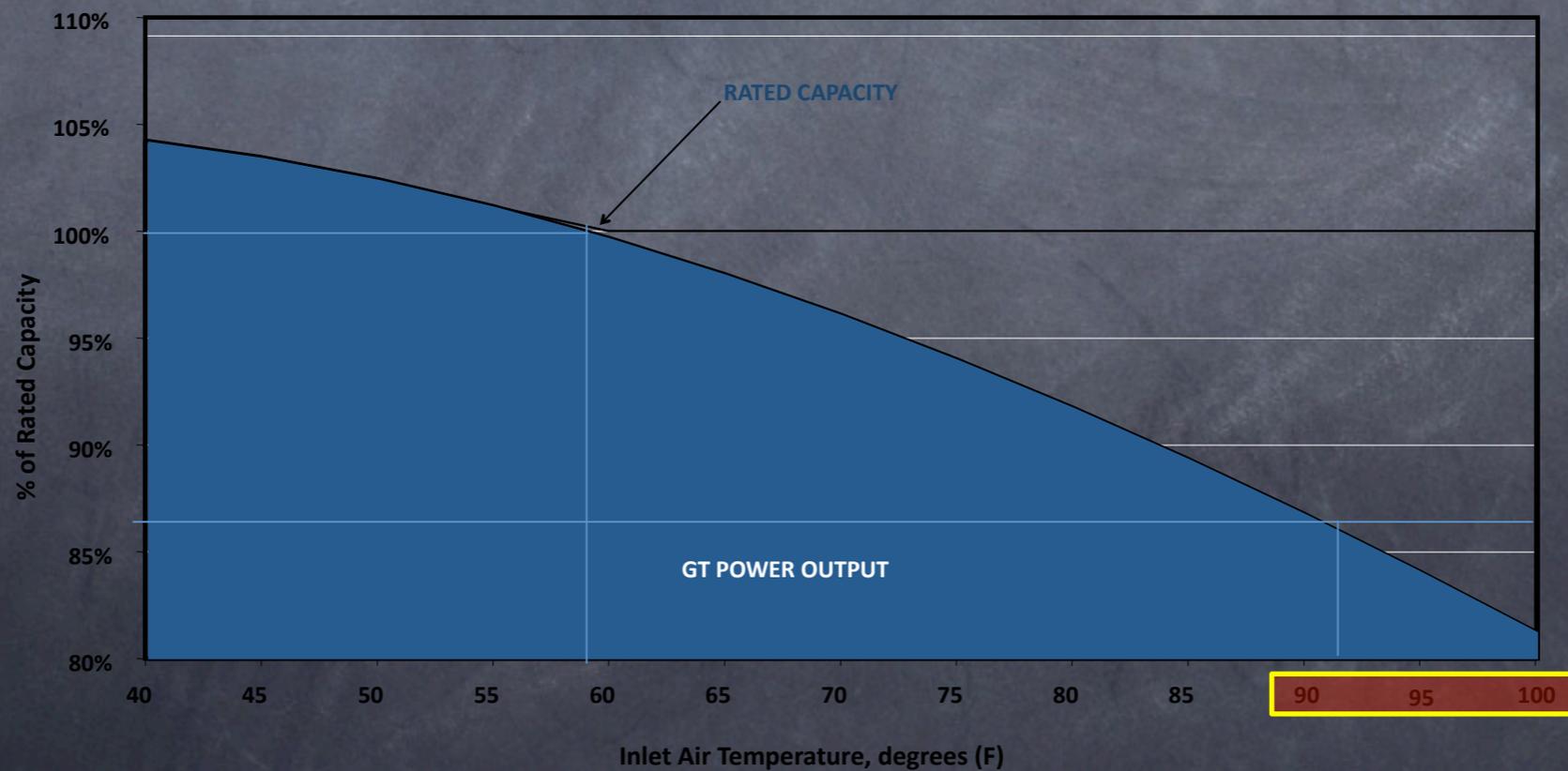
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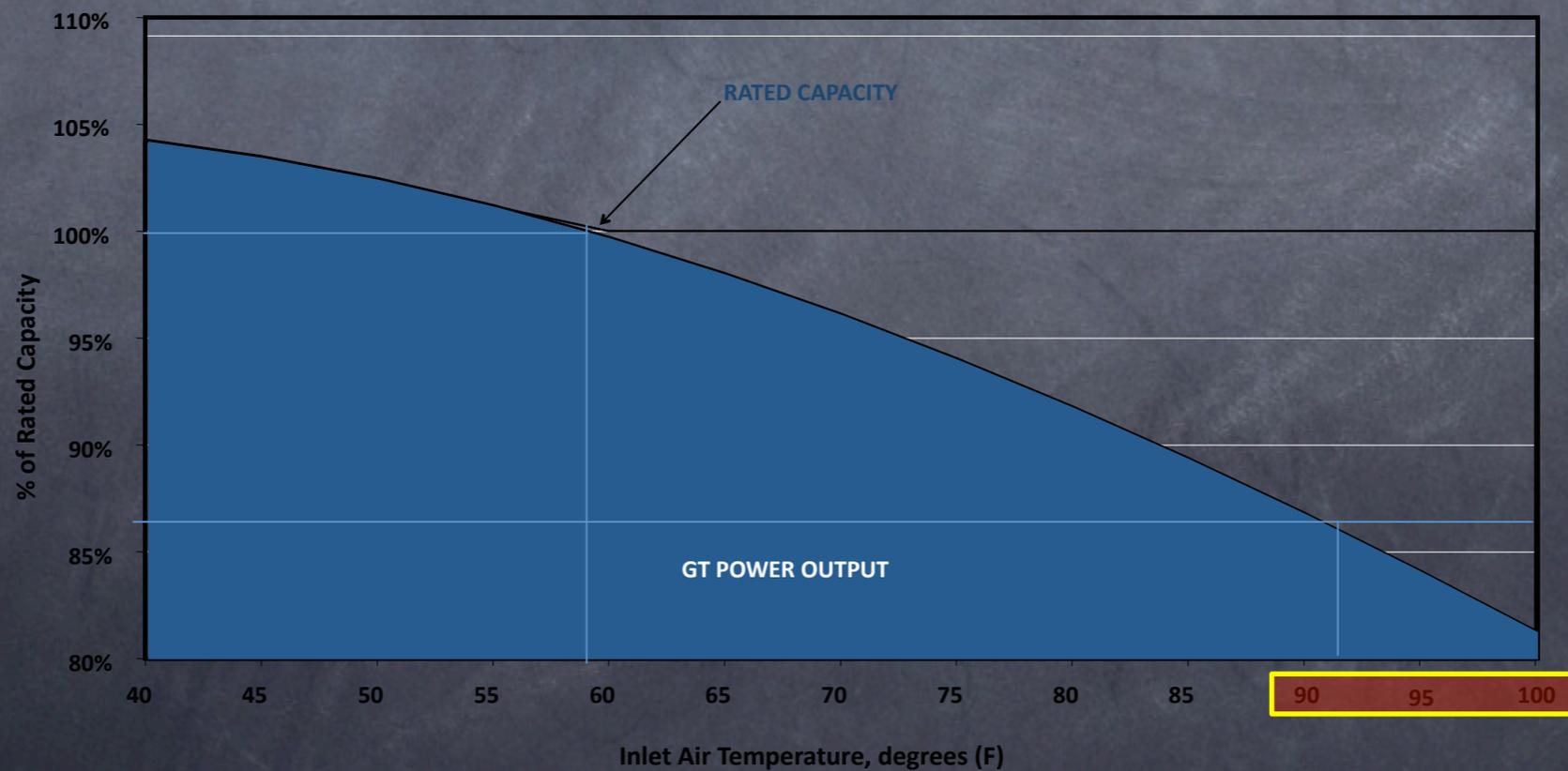
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- As temperatures climb into the 90's and beyond, greater than 10% of the capacity of the turbine disappears.



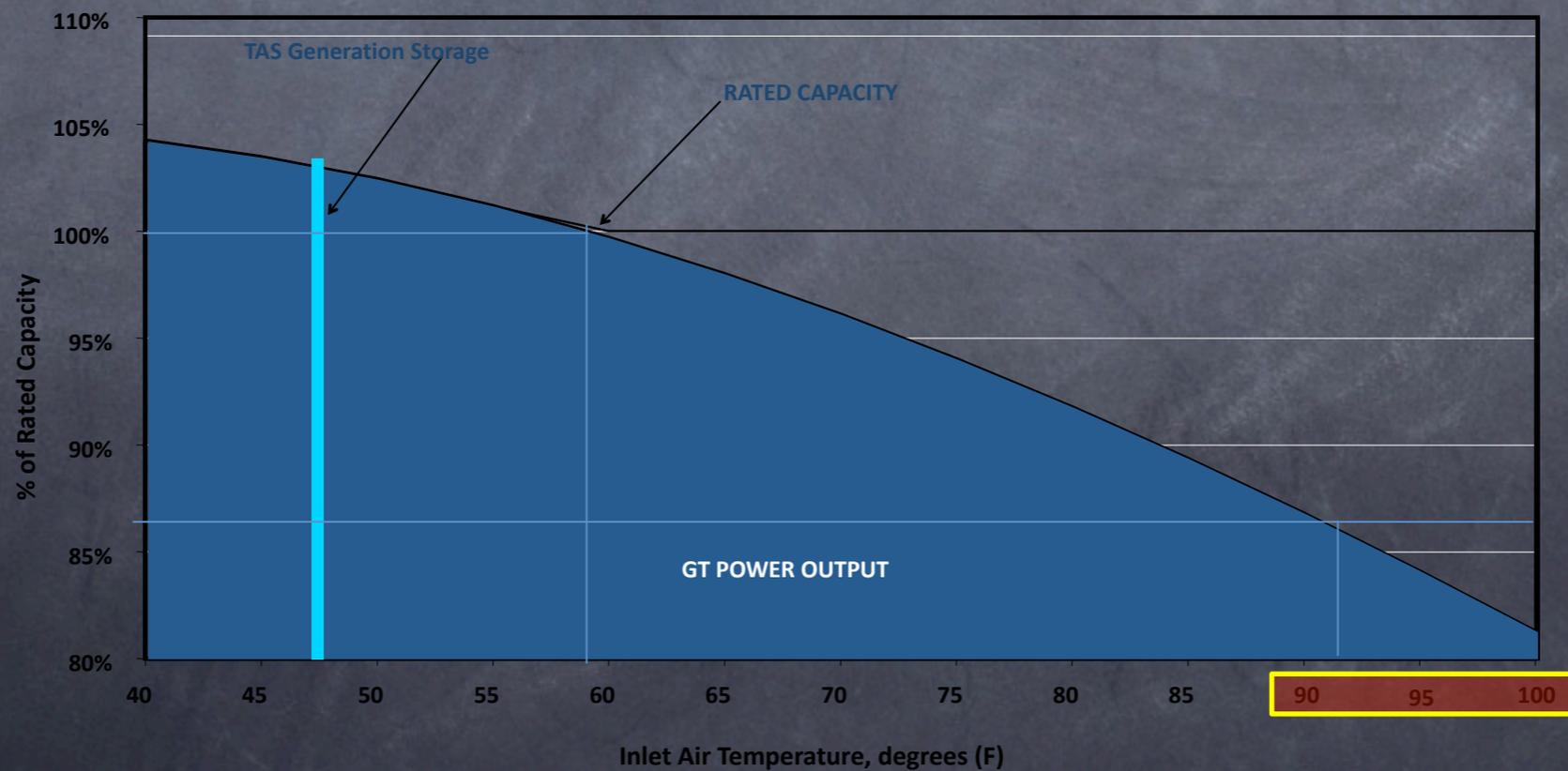
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- As temperatures climb into the 90's and beyond, greater than 10% of the capacity of the turbine disappears.
- By chilling below rated capacity and adding storage all lost power is recovered, and additional power is generated.



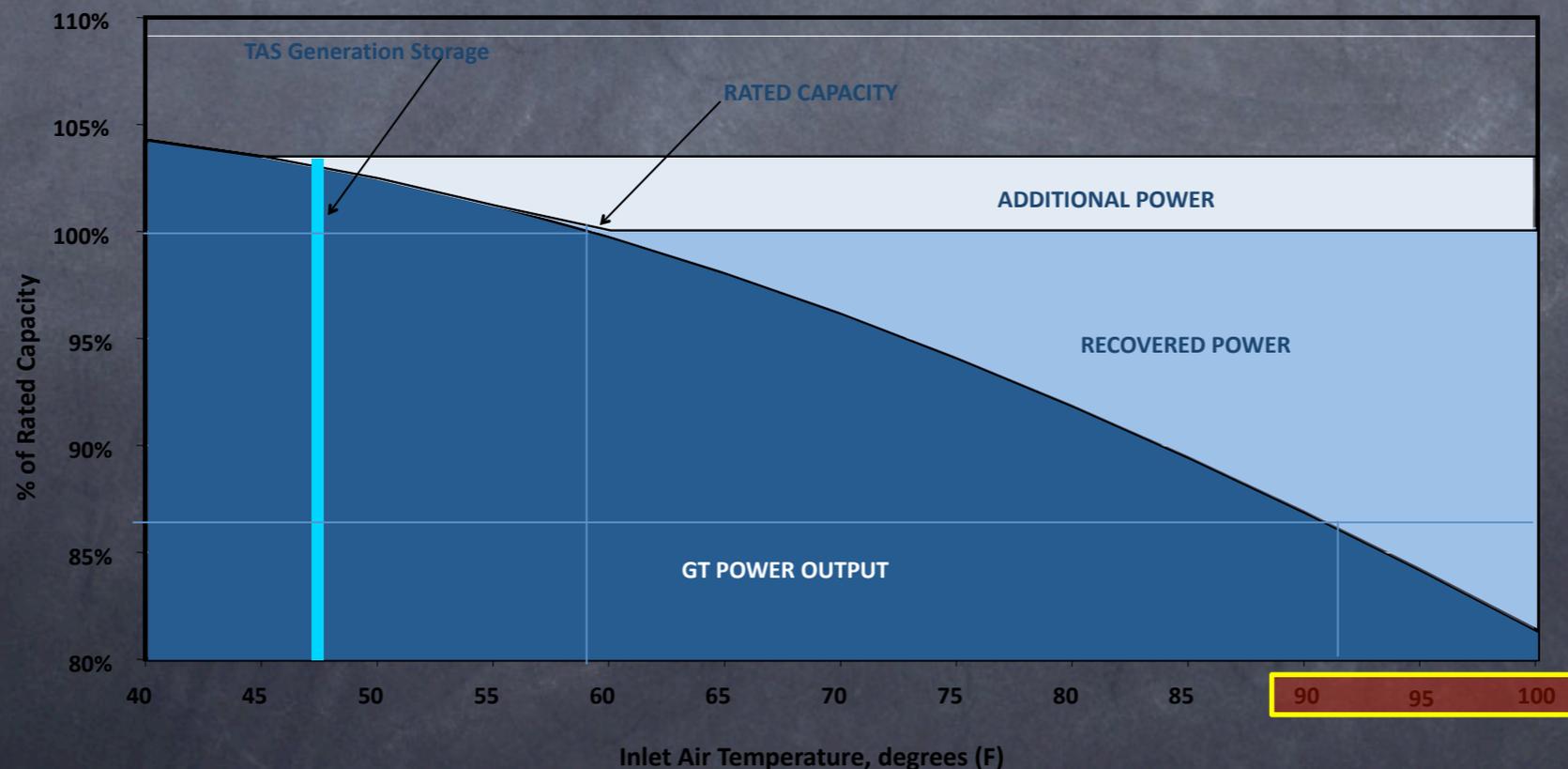
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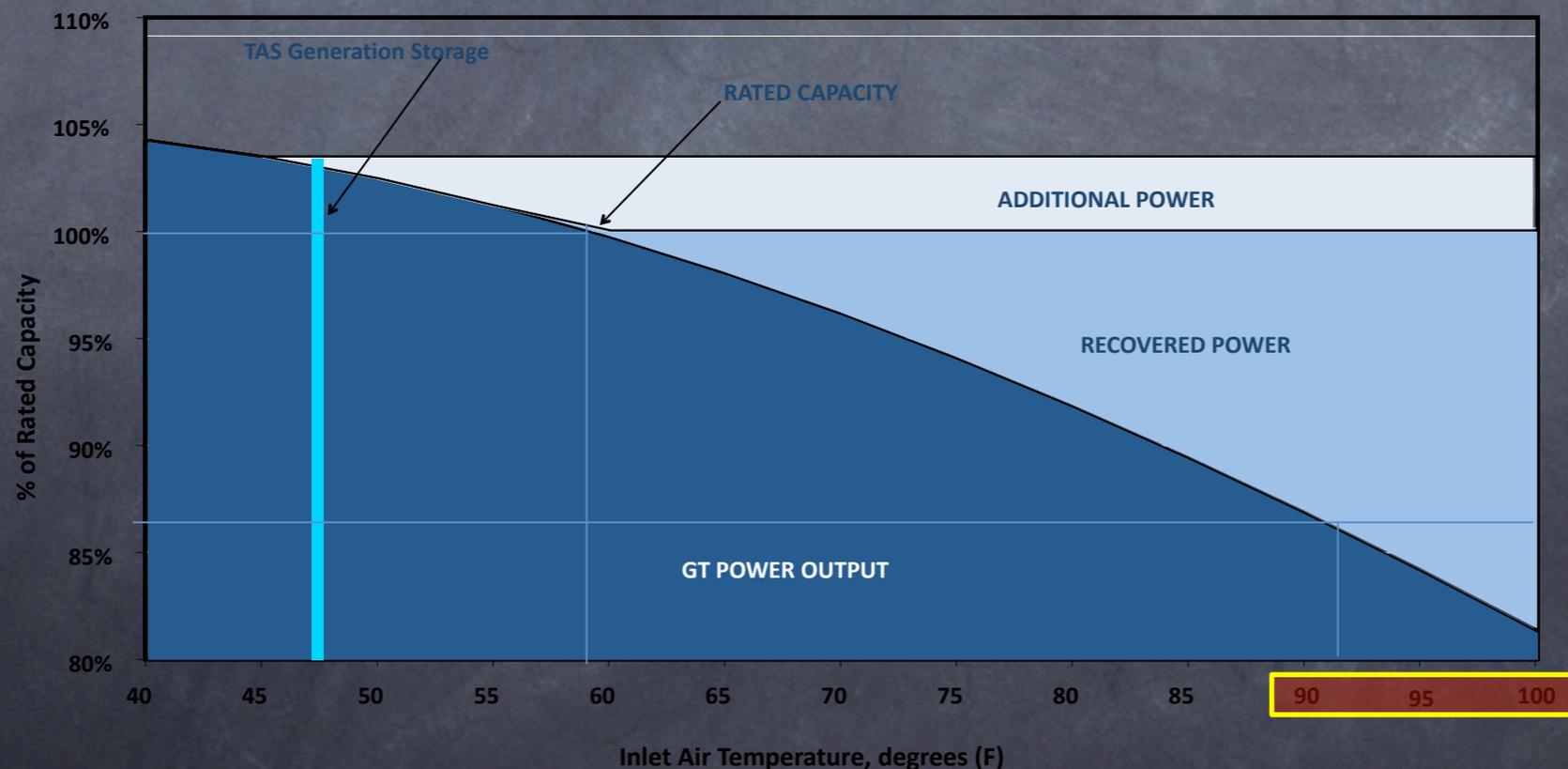
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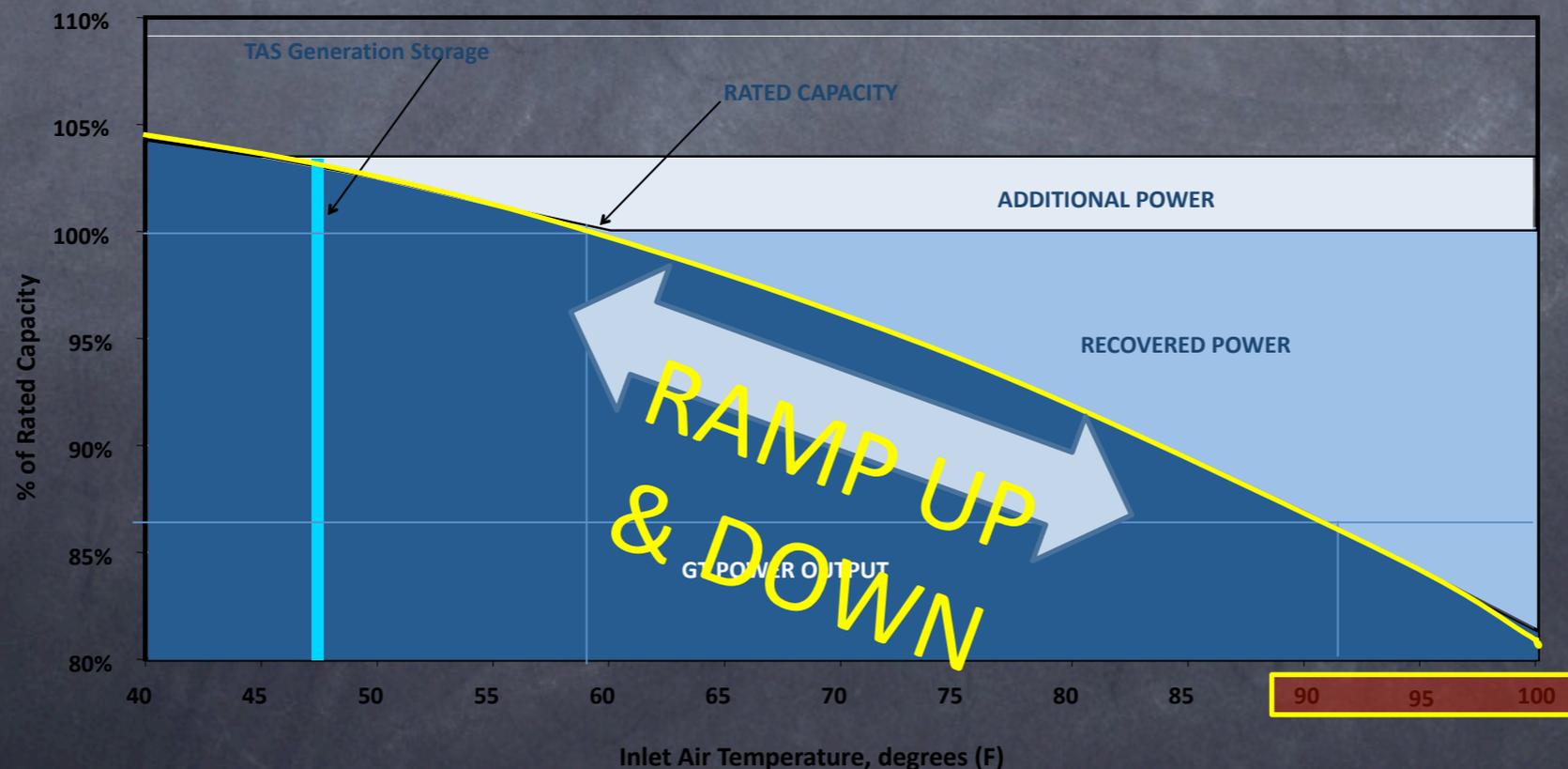
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- Storage and ancillary services including ramping benefits are captured as well.



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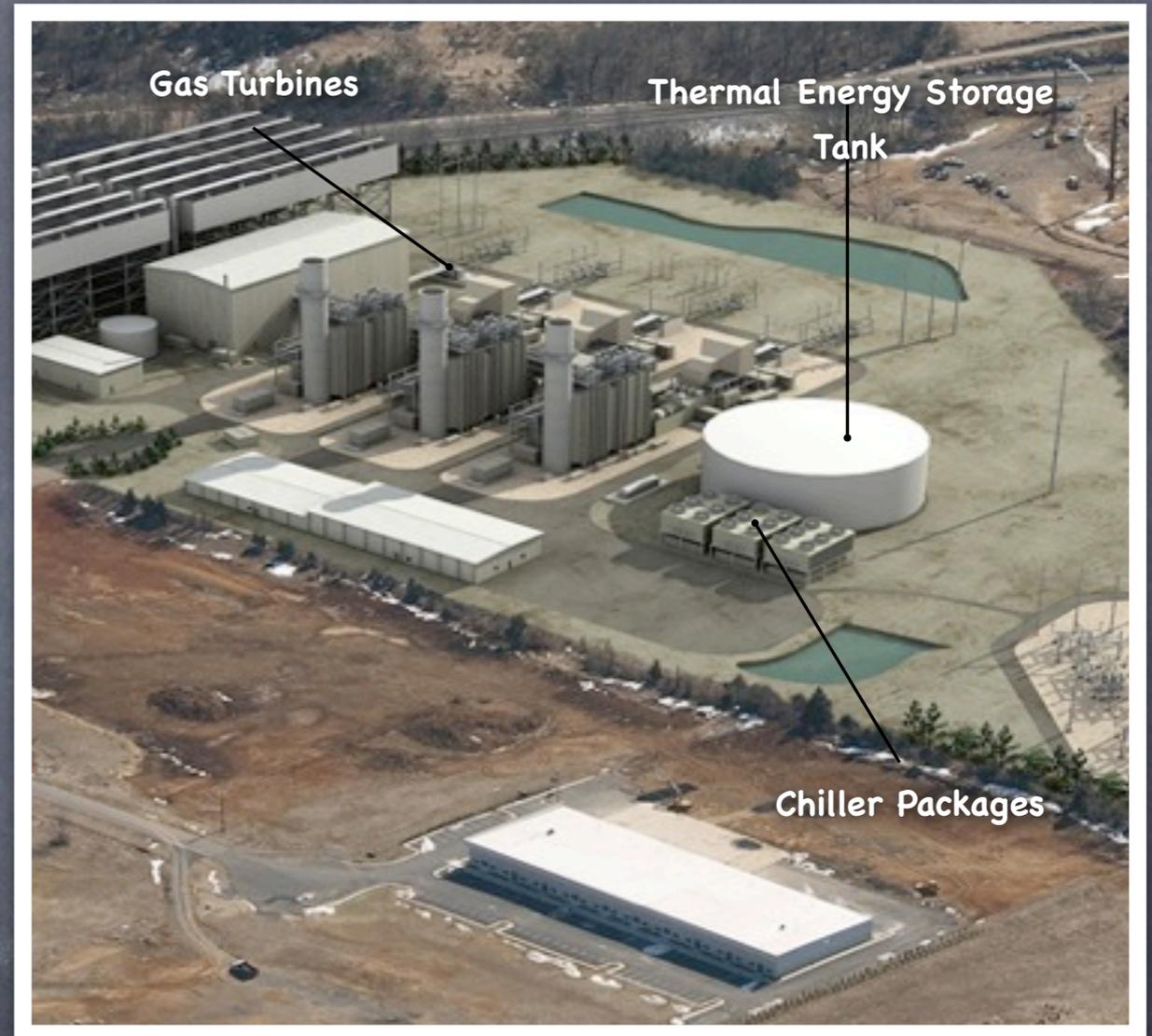
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# Generation Storage: Storage for the Gas Fleet

\* Stores off-peak power in form of chilled water for use following day to increase gas plant's peak output

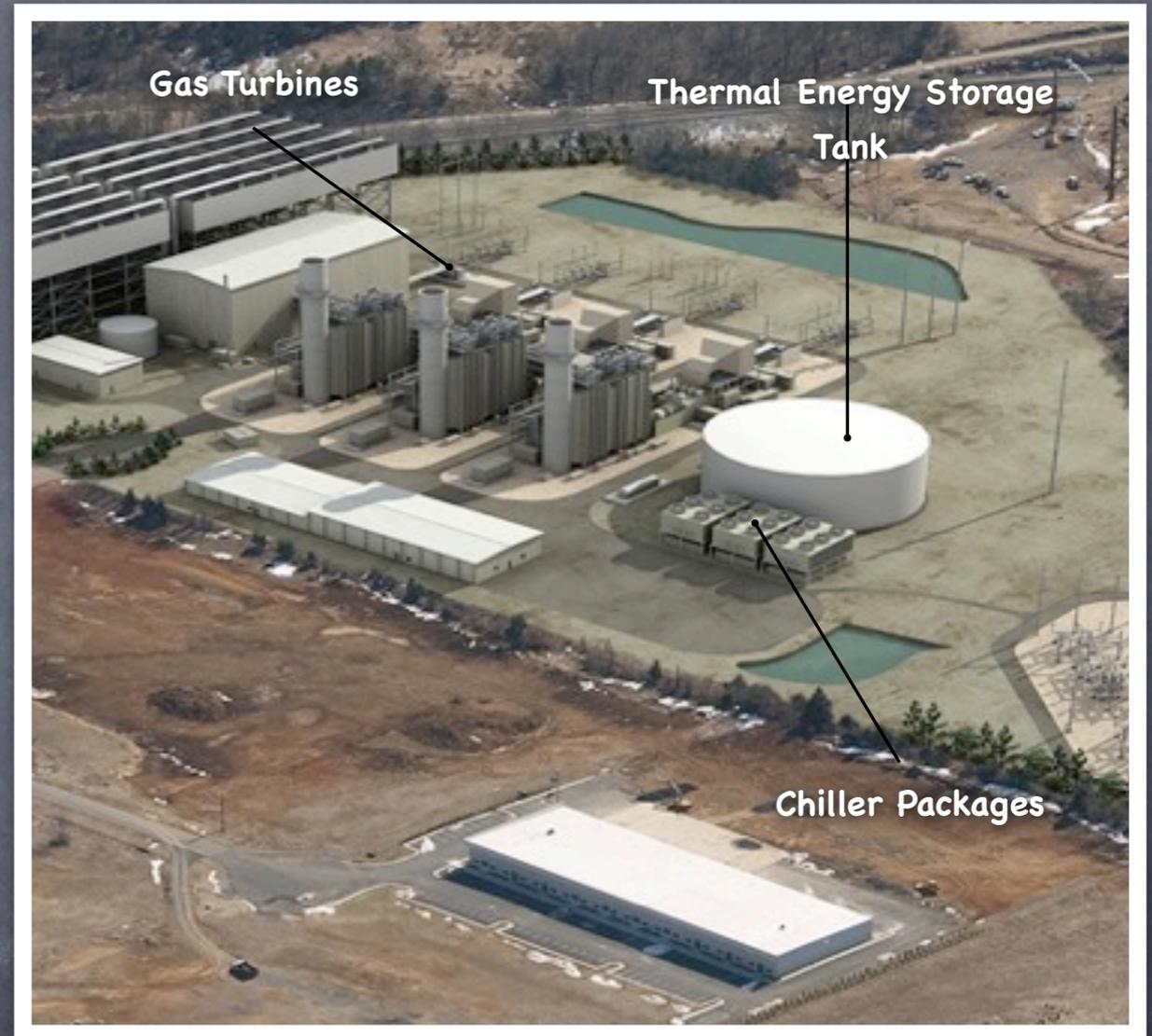


Dominion Power- Warren County

Source: TAS Energy

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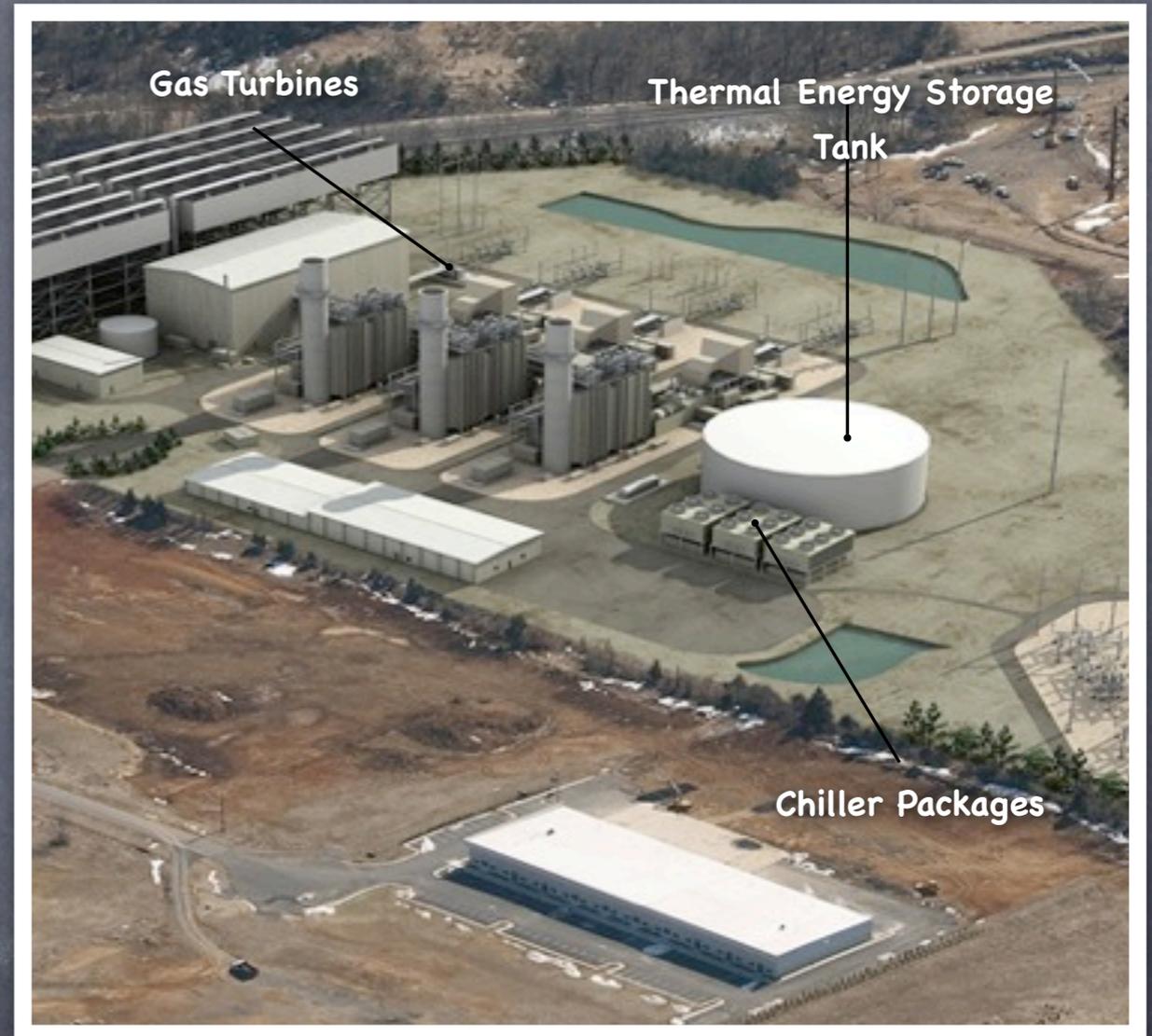


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- \* More than 400MW installed in U.S.

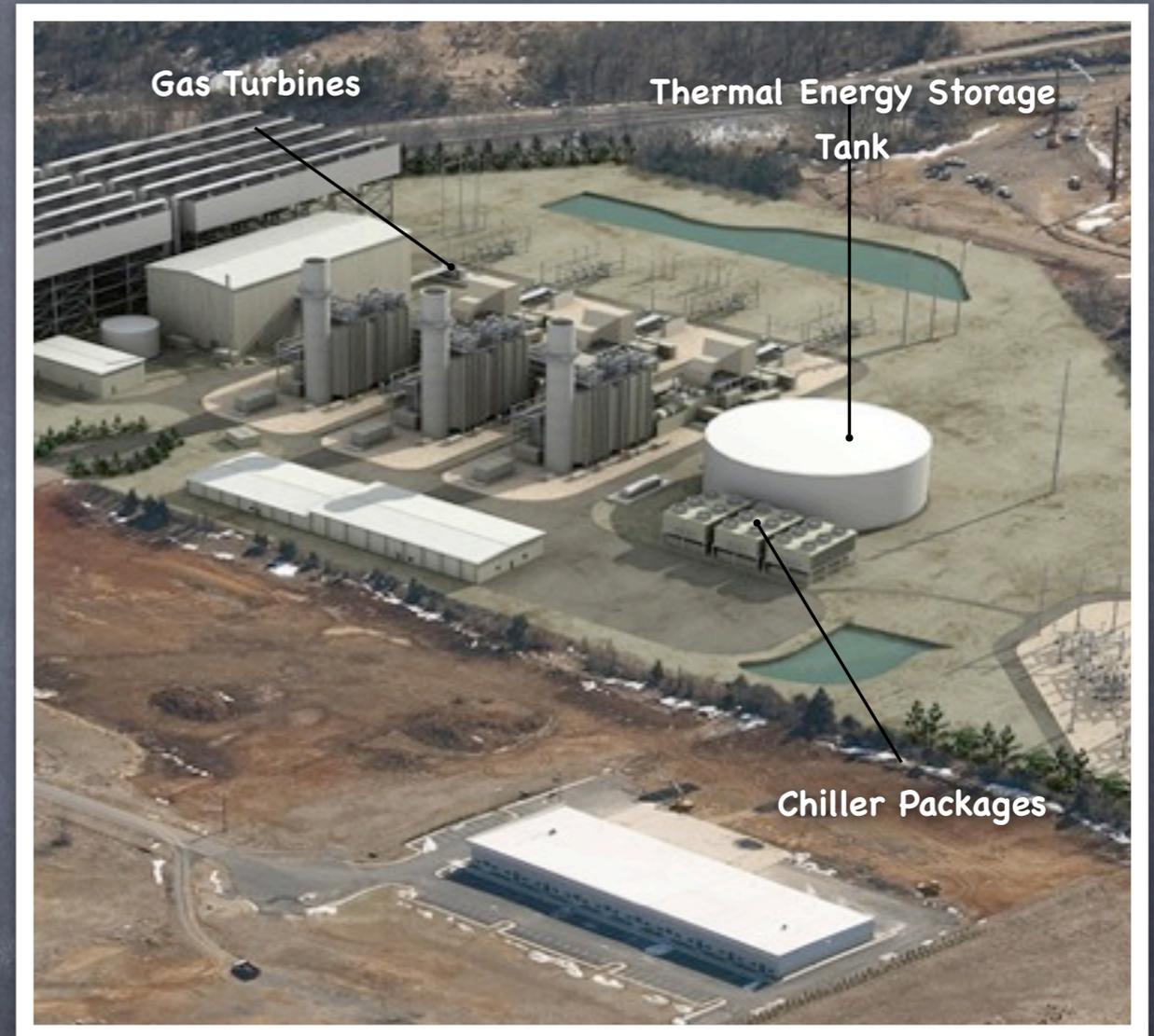


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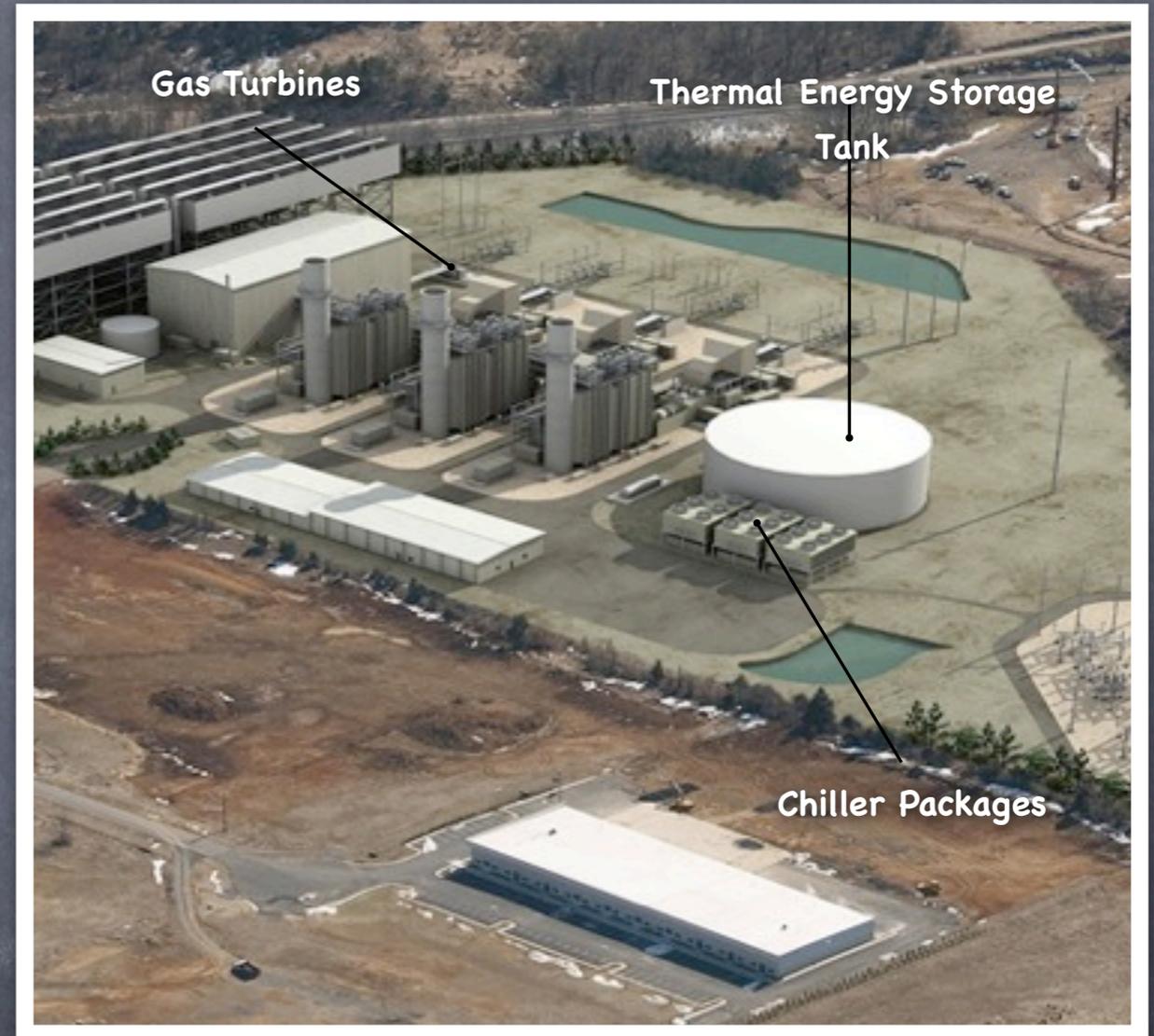


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- \* Provides flexible capacity with discharge up to 12 hours and ramp capability under 4 minutes



Dominion Power- Warren County

Source: TAS Energy

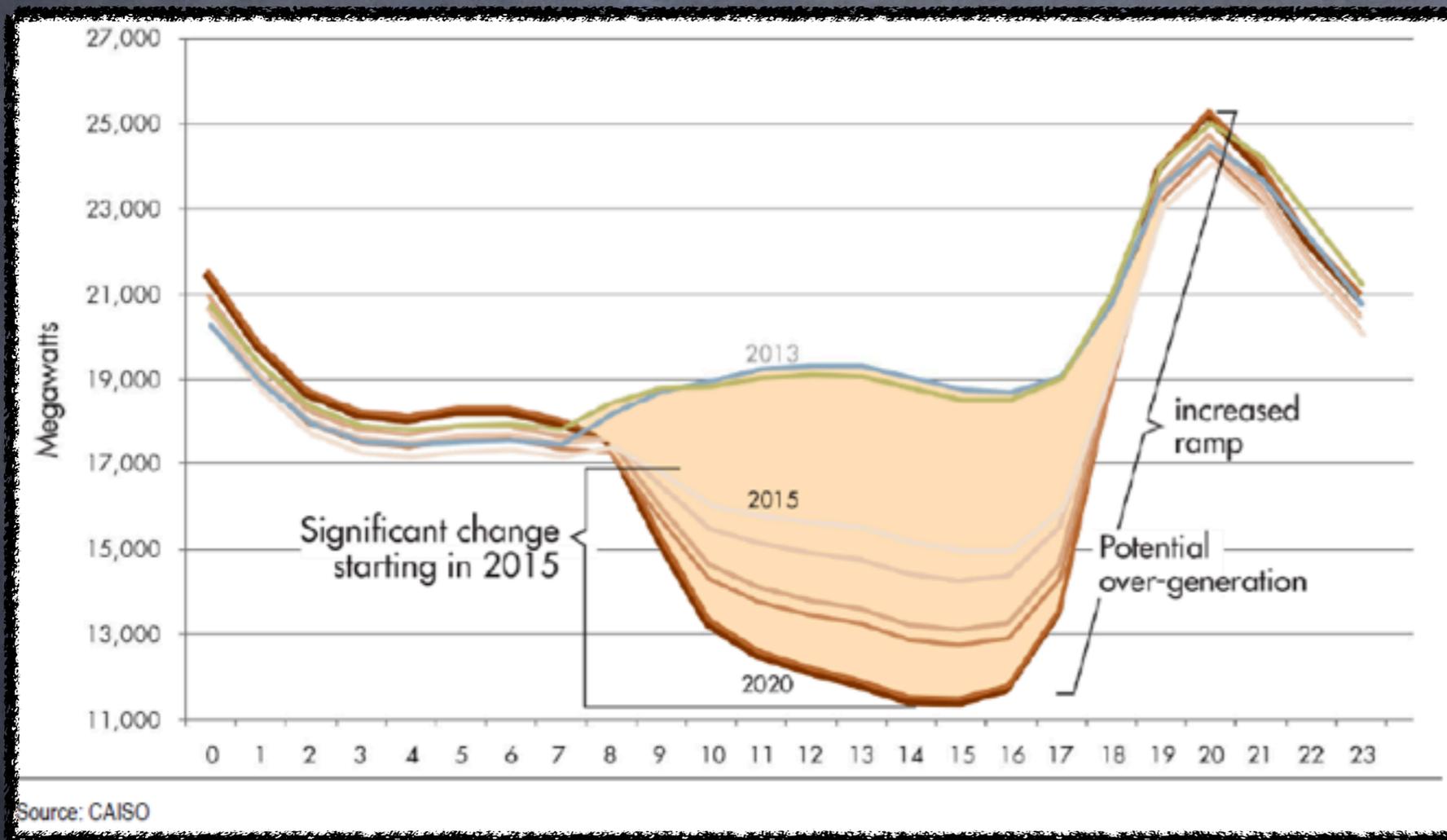




Monday, November 4, 2013



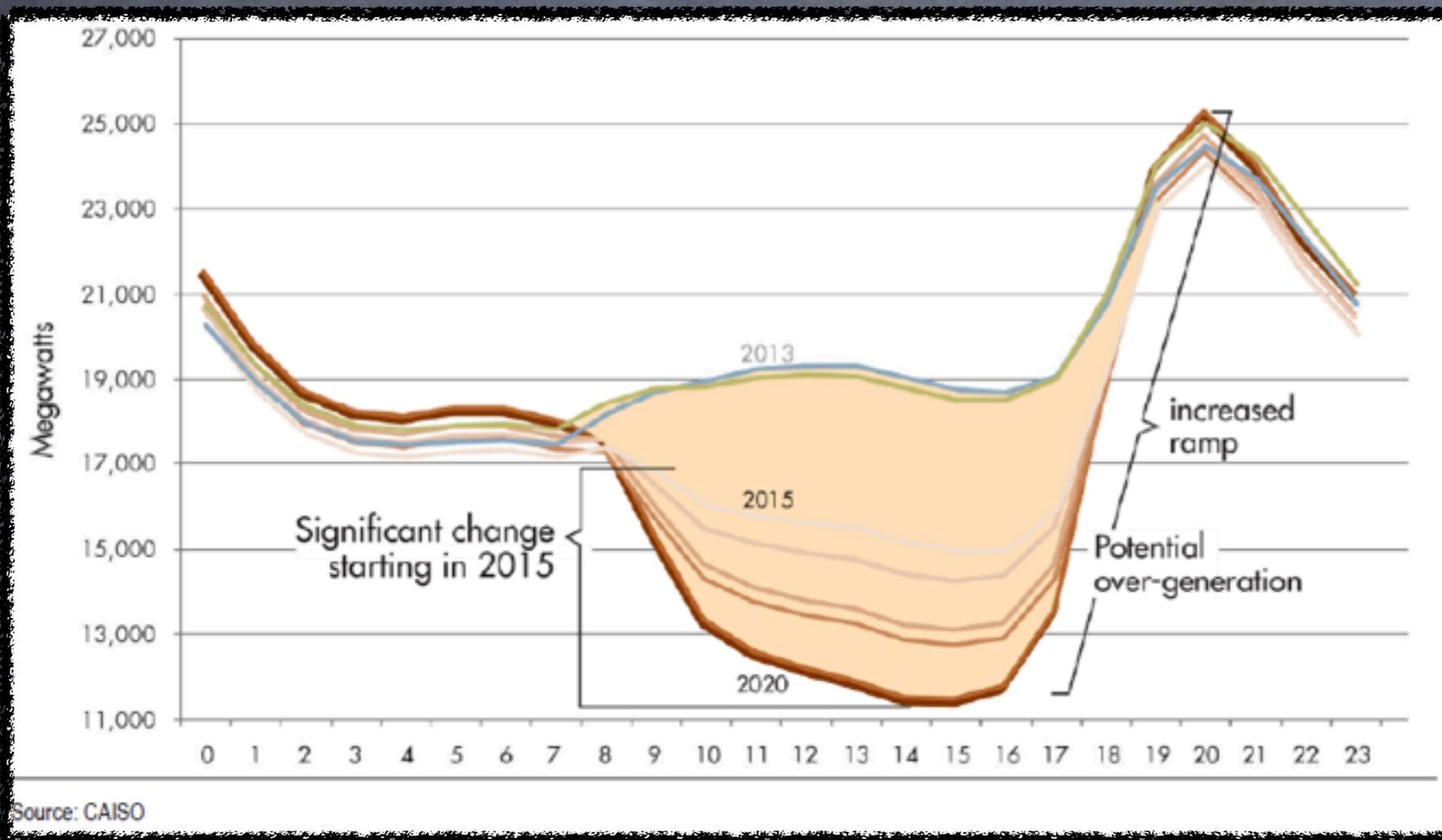
# California's Duck Curve: CAISO Projected Net Load, 2013-2020



\*As a result of ramping and intermittency, wind/solar increase risk of overgeneration

Source: Dumoulin-Smith, Julien. *Not All Capacity is Created Equal*. UBS Investment Research. June 19, 2013

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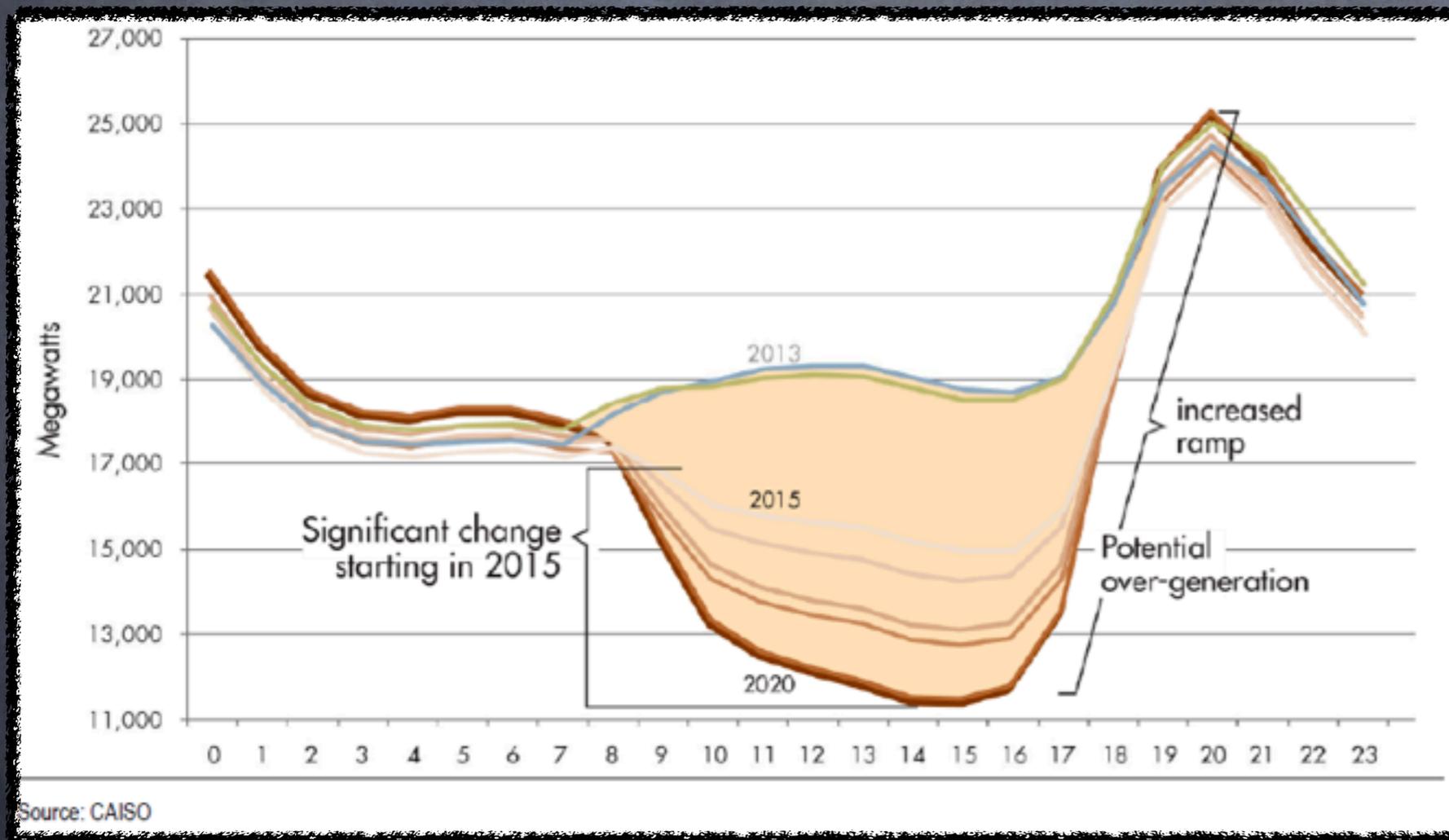


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\*Wind poses significant overgeneration challenges because wind plants produce most electricity at night during low loads

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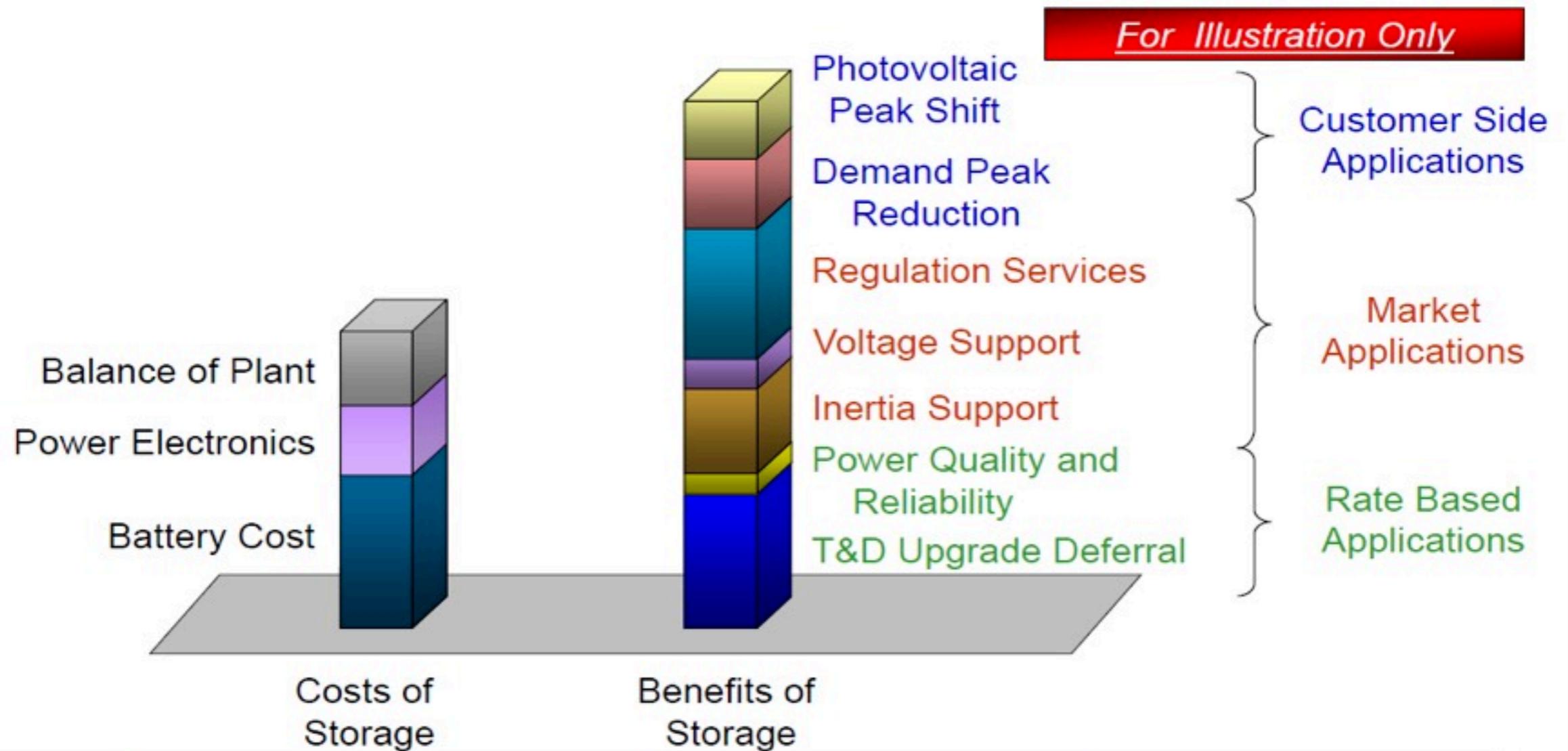
\*Wind poses significant overgeneration challenges because wind plants produce most electricity at night during low loads

\*Overgeneration also concern during large/steep ramps, which will be exacerbated by increasing renewable energy portfolios

Source: Dumoulin-Smith, Julien. *Not All Capacity is Created Equal*. UBS Investment Research. June 19, 2013



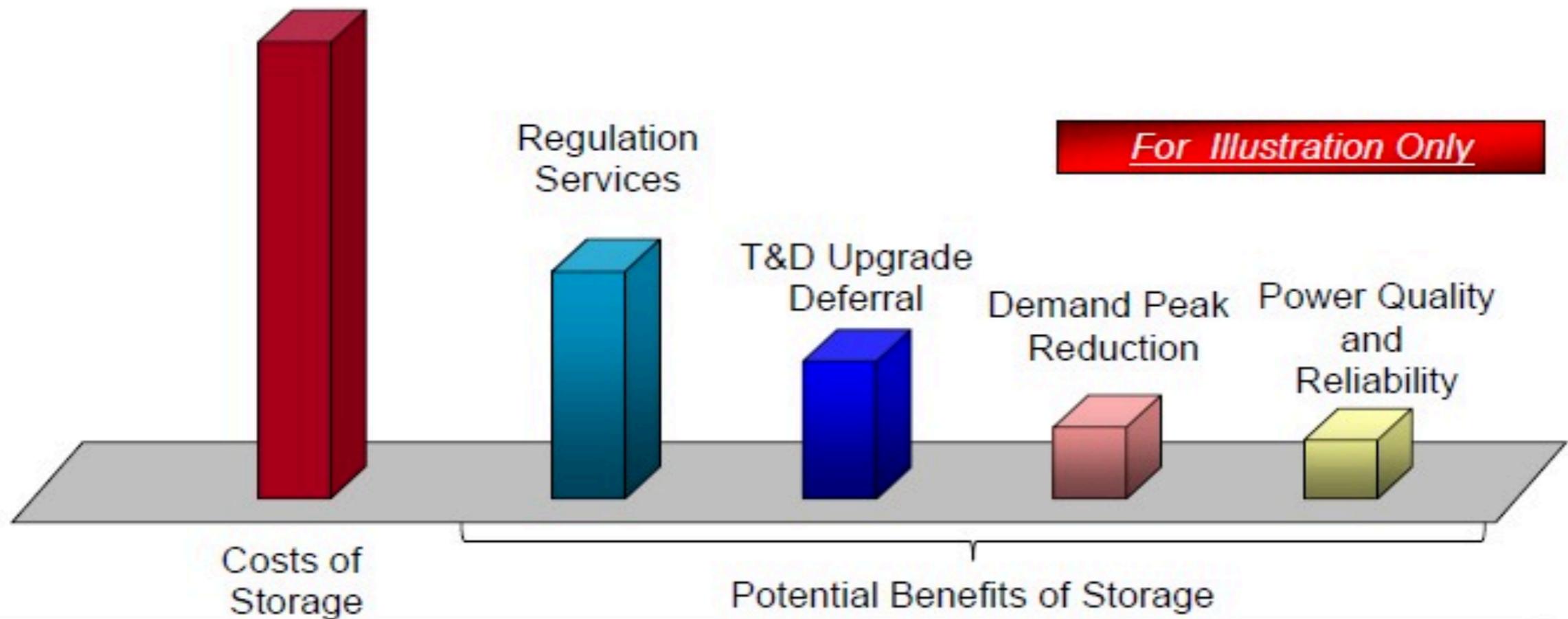
# Analyzing the Value of Storage



**Using storage for multiple applications can be effective, but is highly site-dependent**

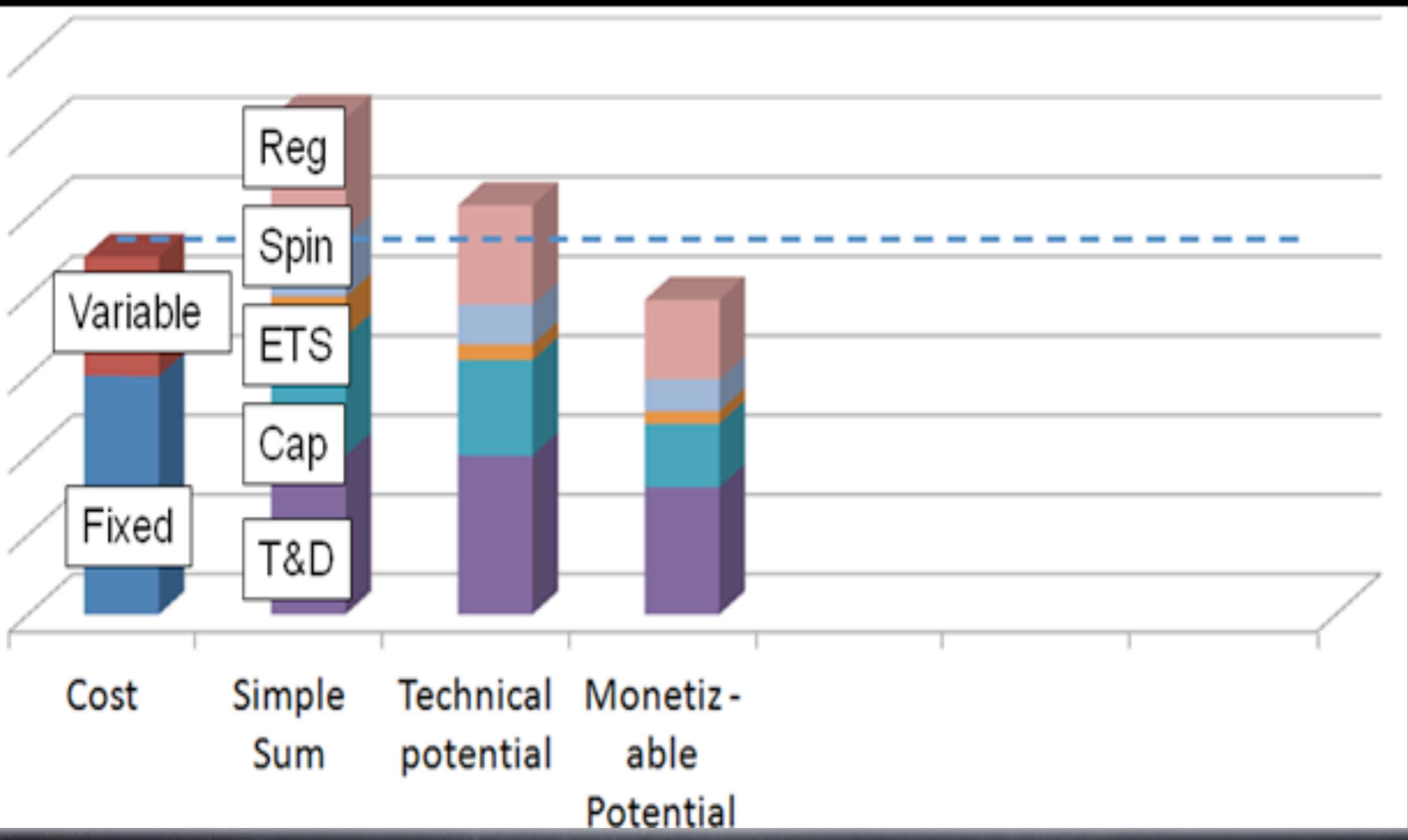


# Challenges to the Use of Energy Storage



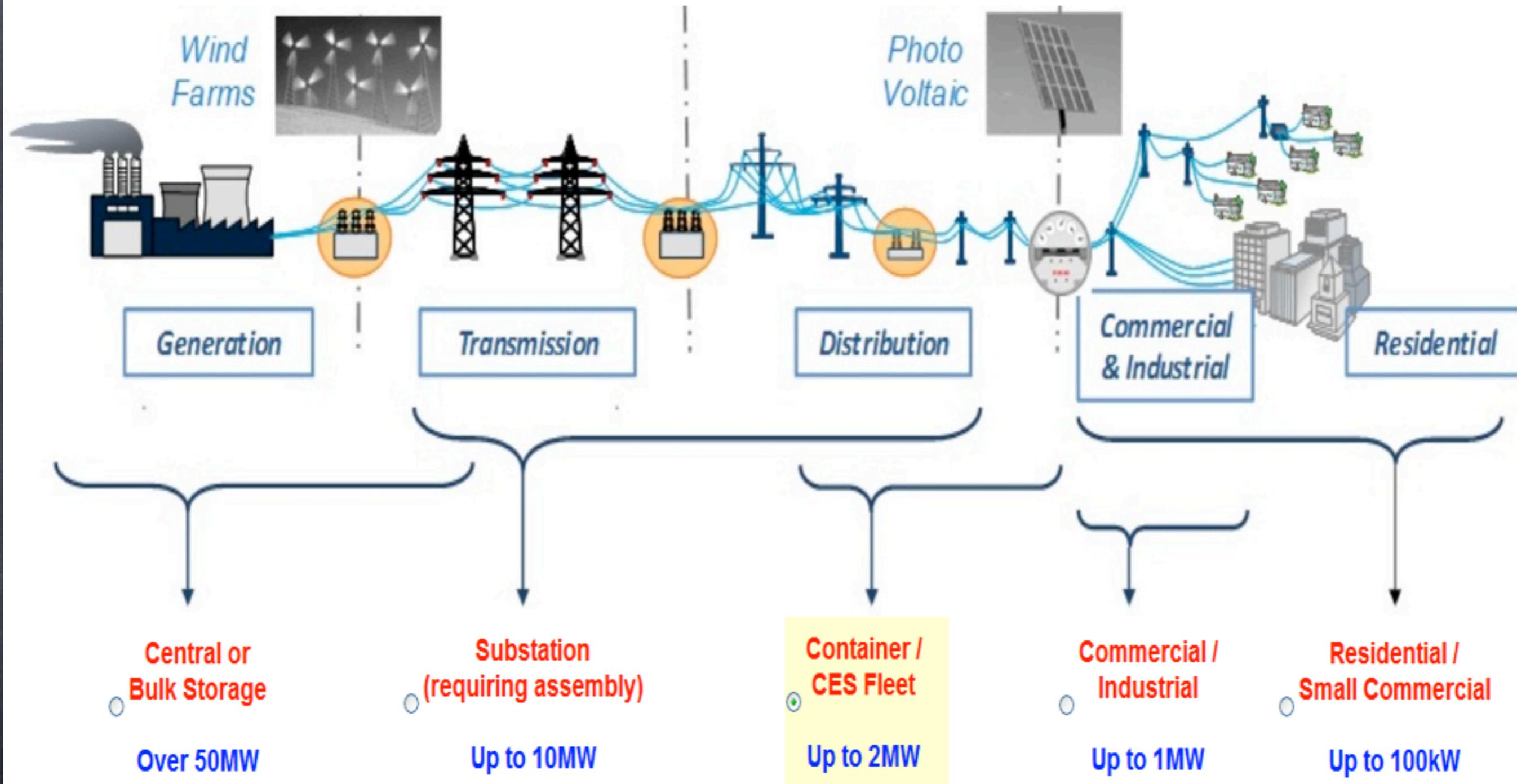
**The economic case for energy storage has not been straightforward**

*For Illustration Only*



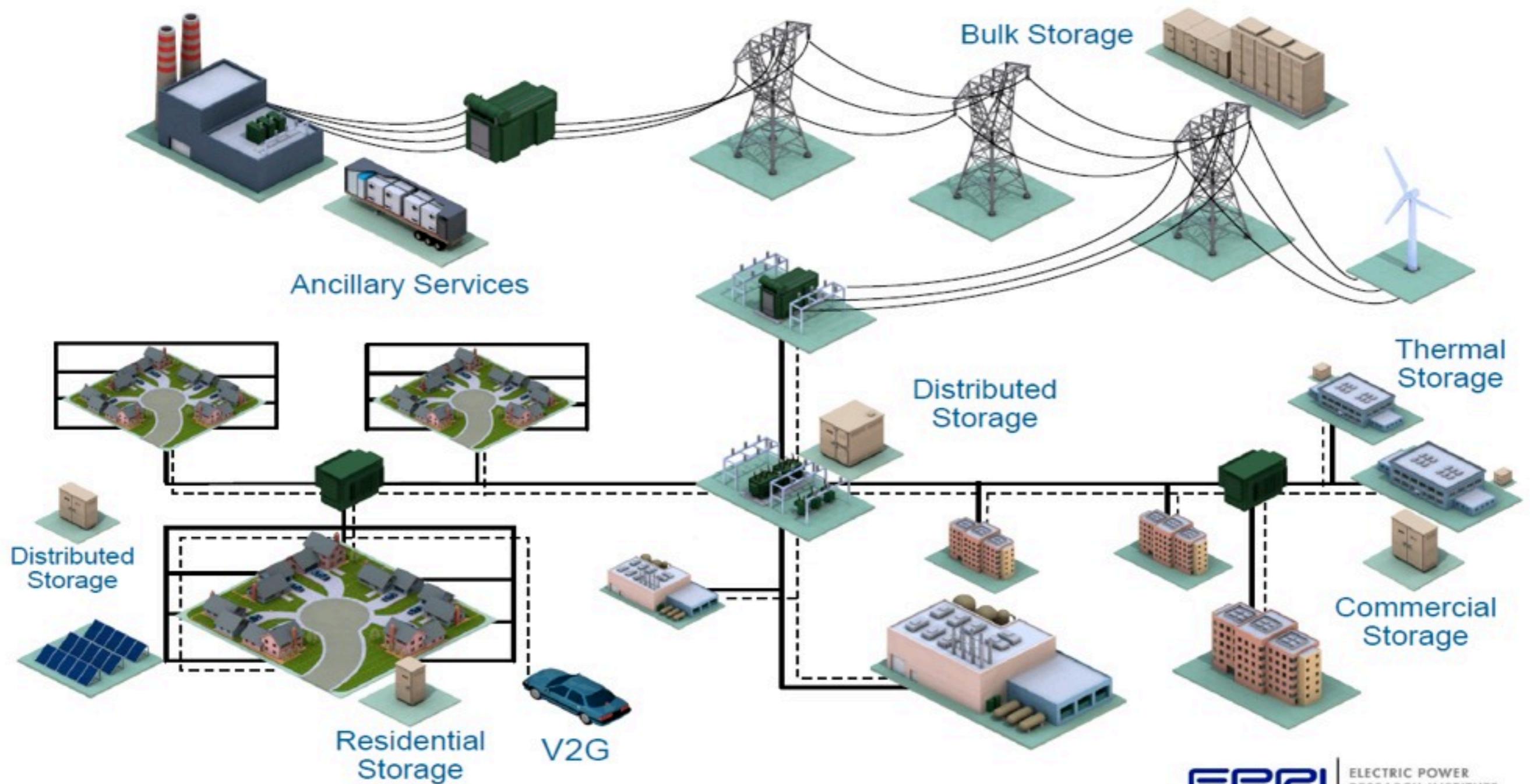


## Possible Locations for Grid-Connected Energy Storage



NOTE: Each location imposes restrictions on both the number of applications available for that location as well as the ES technologies appropriate for the site. Click on "Location Constraints" for more details.

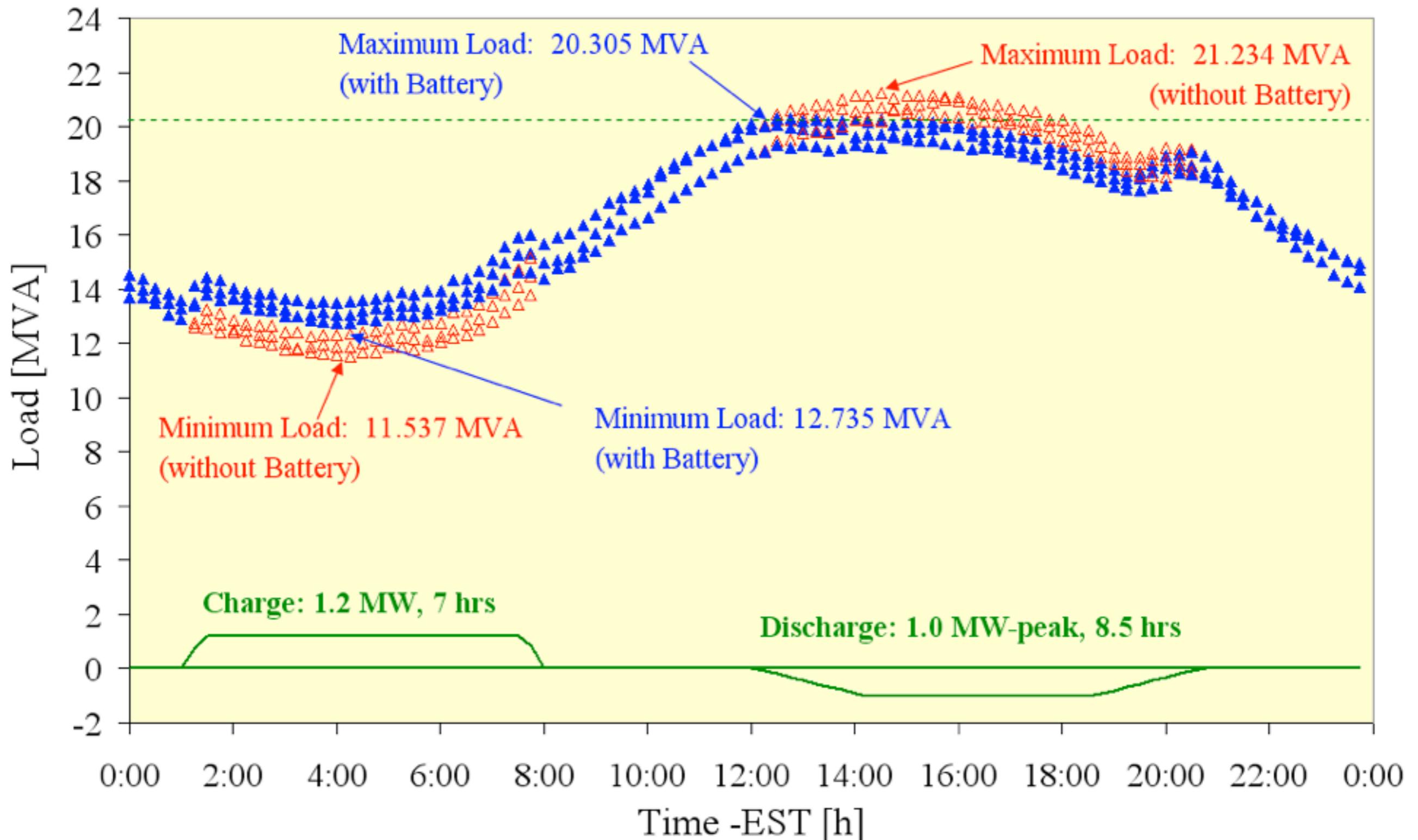
# The Roles of Storage on the Grid





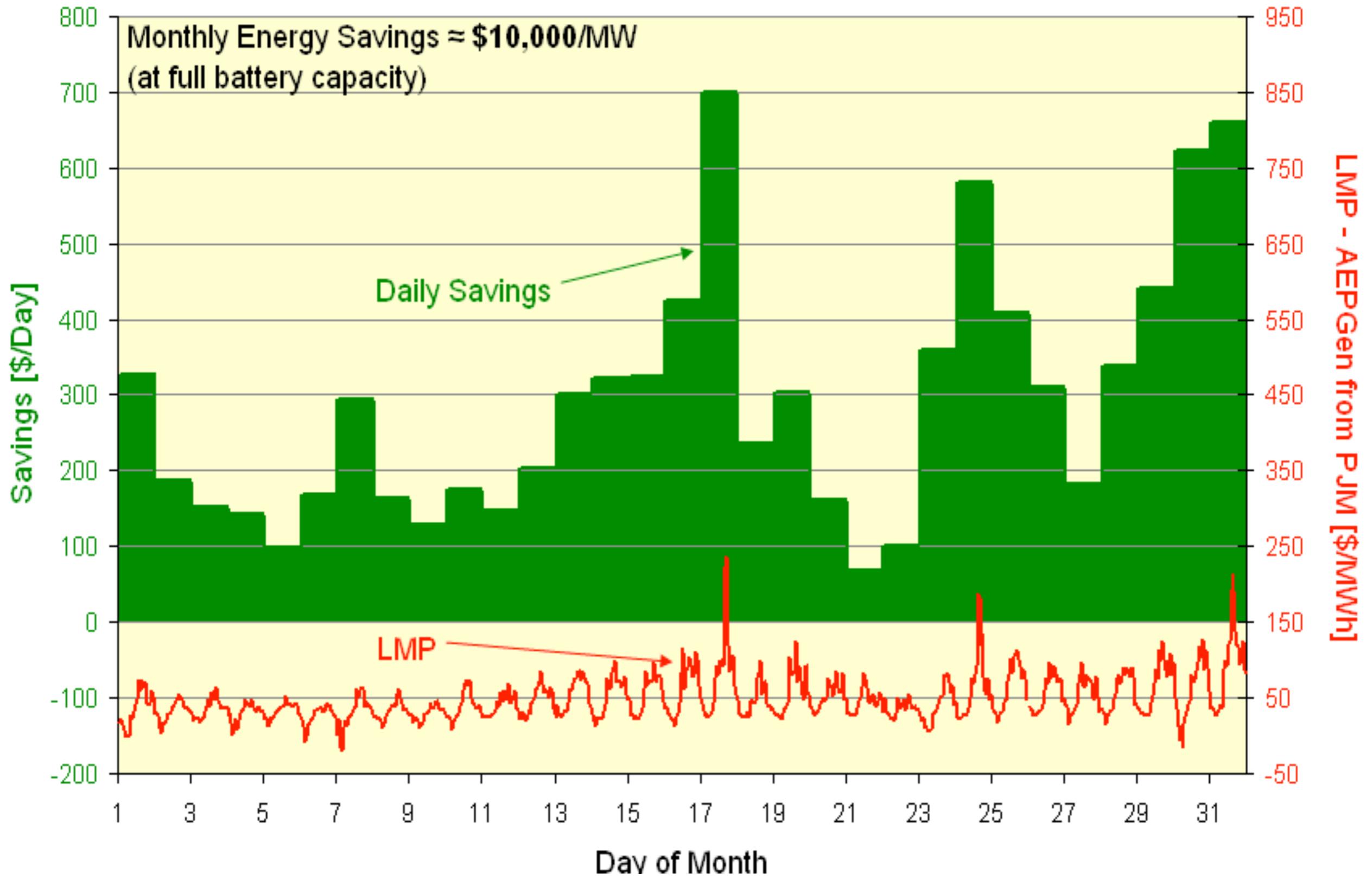
# Chemical Substation: Transformer Load

## Three Worst Days of Summer (7/19, 8/2, and 8/3/2006)



# Daily Energy Savings from AEP Energy Storage

(July 2006)



## Chemical Substation: Transformer Load

### Estimated Monthly Savings from AEP Energy Storage

(July, 2006 - May, 2007)





## 1.2 MW, 7.2 MWh Distributed Energy Storage System in Chemical Station, North Charleston



Started Operation on June 26<sup>th</sup>, 2006

**AEP APPALACHIAN  
POWER**  
*A unit of American Electric Power*

*NGK Insulators Ltd  
S&C Electric Co.  
DOE / SANDIA*





**98 MW Laurel Mountain Wind Project  
with 32 MW BESS  
Serving PJM Market**