World Bank Training Program
Module 6: Renewable Grid Integration

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Document number

DNV KEMA Energy & Sustainability Overview

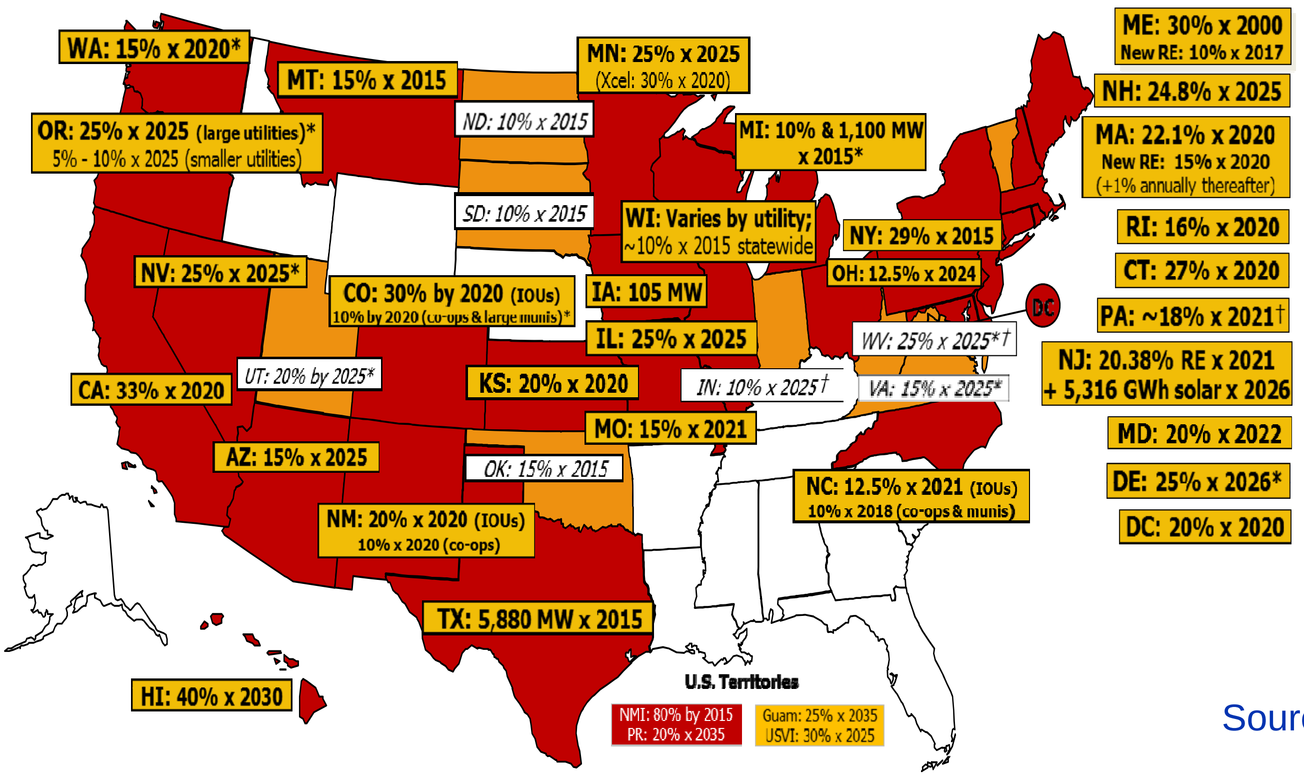
- DNV KEMA Energy & Sustainability offers innovative solutions to customers across the energy value chain, ensuring reliable, efficient and sustainable energy supply, now and in the future.
- 3000+ energy experts across all continents
- KEMA and DNV combined: a heritage of nearly 150 years
- Headquartered in Arnhem, the Netherlands
- Offices and agents in over 30 countries around the globe
- **World-Renowned Engineering, Consulting, and Testing**

How is storage used for Renewable Integration?

- The issue is really focused on variable renewable integration – wind and solar – where the output can be unpredictable
- Please note output patterns are not consistent across the Globe...what we encounter in the western part of the United States does automatically map to Europe or Southwest Asia
  - Weather patters for particular area is really the driver for wind & solar
- Still, some lessons can be learned from case studies we have seen
- Agenda for Today
  - Impact of Wind
  - Impact of Solar
  - Benefits – Where we are seeing applications today
  - Technologies
    - Bulk Storage
    - Utility Scale

Challenges to Integrating Renewables – Penetration Rates

- Chart shows renewable portfolio standards across the U.S.

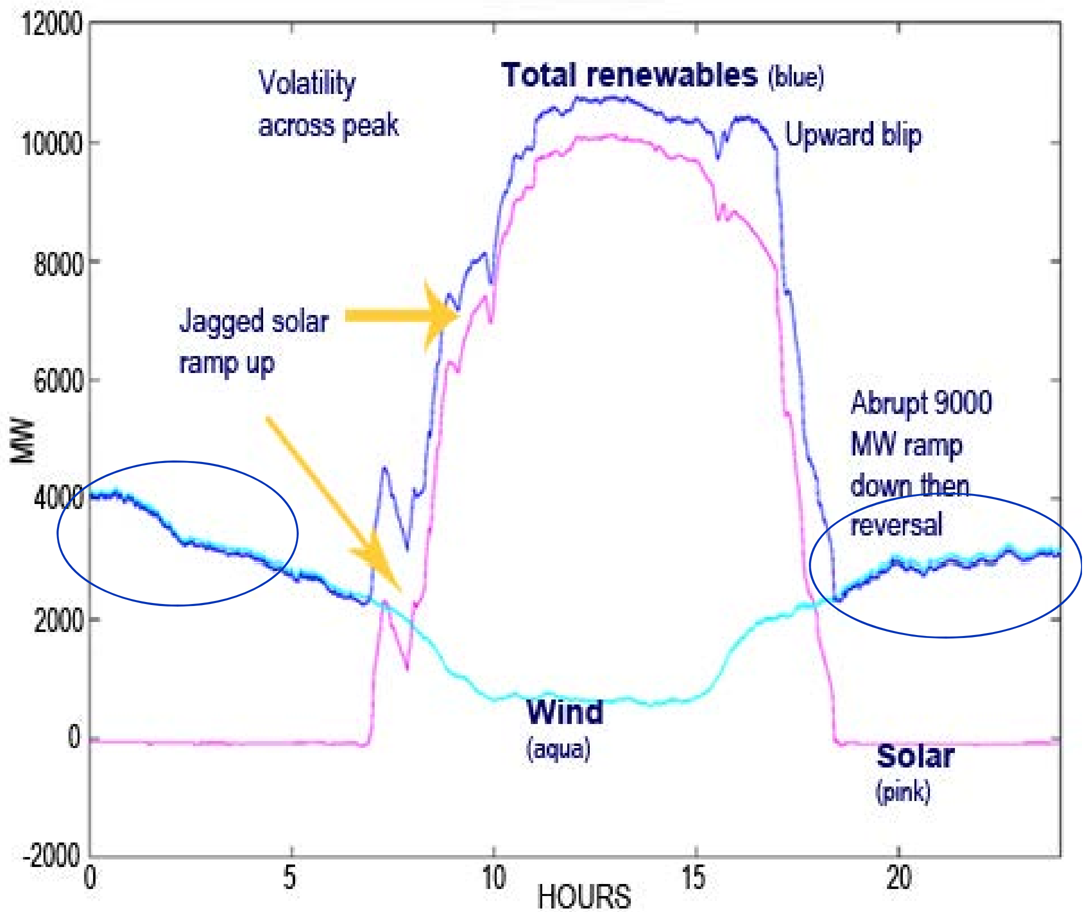


Source: dsireusa.org

- Consensus is that as penetration rates of variable generation surpasses 20-25%, problems are created for system operators as the try to balance generation with load

Example: July Renewables 2020HI – *Challenges*

- Issue 1: Wind often blows in "off peak" hours when there is no load to accept it
- Issue 2: Chart shows challenges of solar and wind MW production during 24 hours in July
  - Some swings in diagram represent up to 3,500 MW
- Challenge is simply where will this come from?



source: DNV KEMA

For Distribution: Are the Issues Similar?

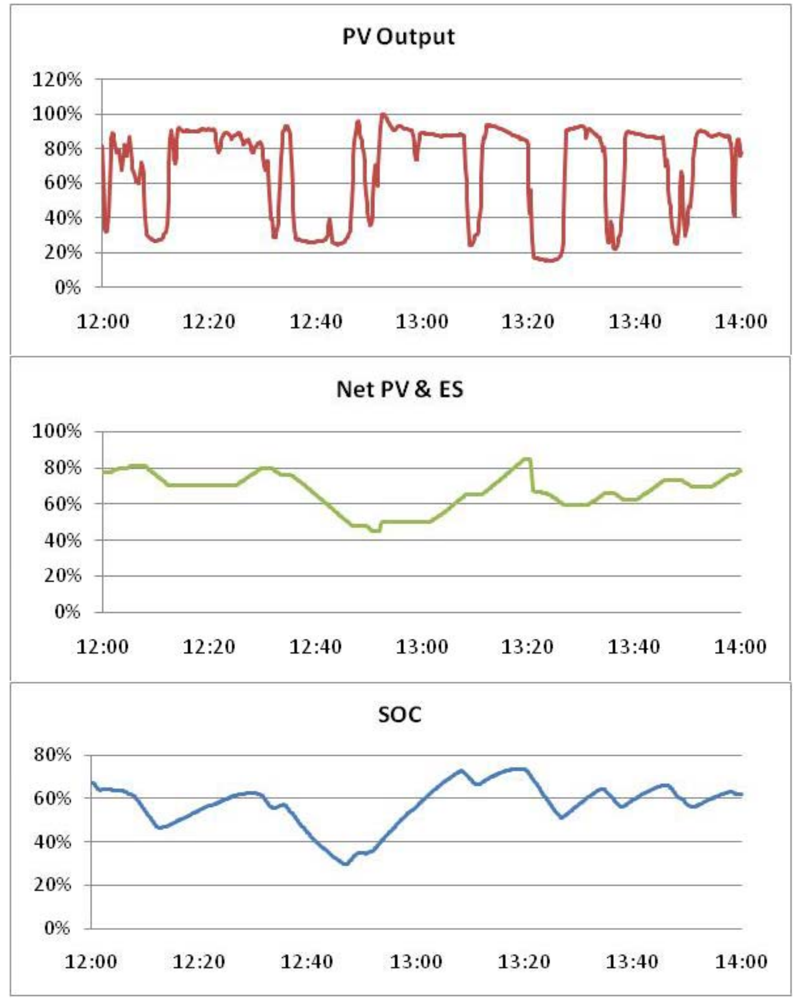
- Problems seemed to be focused on solar and protection due to the variability – similar problems to solve but for different reasons

- Storage is often discussed as a potential option to be used with solar technologies

- What are these applications?
  - Solar Grid Integration
  - Energy time shifting
  - Capacity firming

Solar Generation Grid Integration

- Benefit: Smooth intermittent output due to cloud cover and maintain morning/afternoon ramp rate limits
- Control: Low-pass smoothing filter in conjunction with storage charge bias
- Location: Generation location, downstream of impacted circuit
- Discharge Duration:15-60 minutes
- Cycle Duty: Multiple cycles per day during intermittent operating days
- Benefit Impact? Grid Operator, Utility



Renewable Capacity Firming

- Benefit: Storage fills in "gaps" in intermittent renewable output to allow for use as an almost constant power source

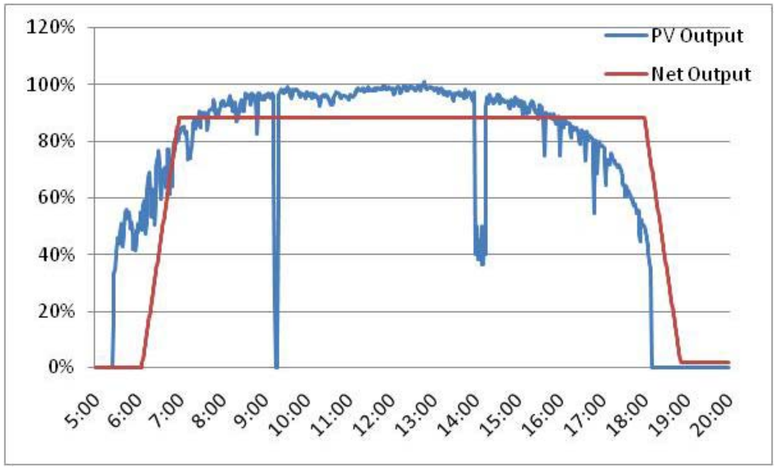
- Control: Modulate storage for net constant output for scheduled time period (hour ahead, day ahead) based on forecast level of intermittency

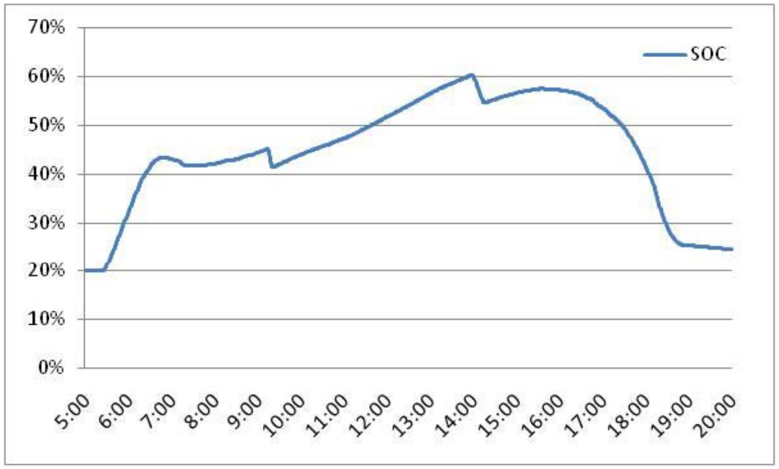
- Location: Interconnection between grid and renewable source

- Discharge Duration: 2 – 4 hours on low or moderate variable days

- Cycle Duty: Multiple cycles per day

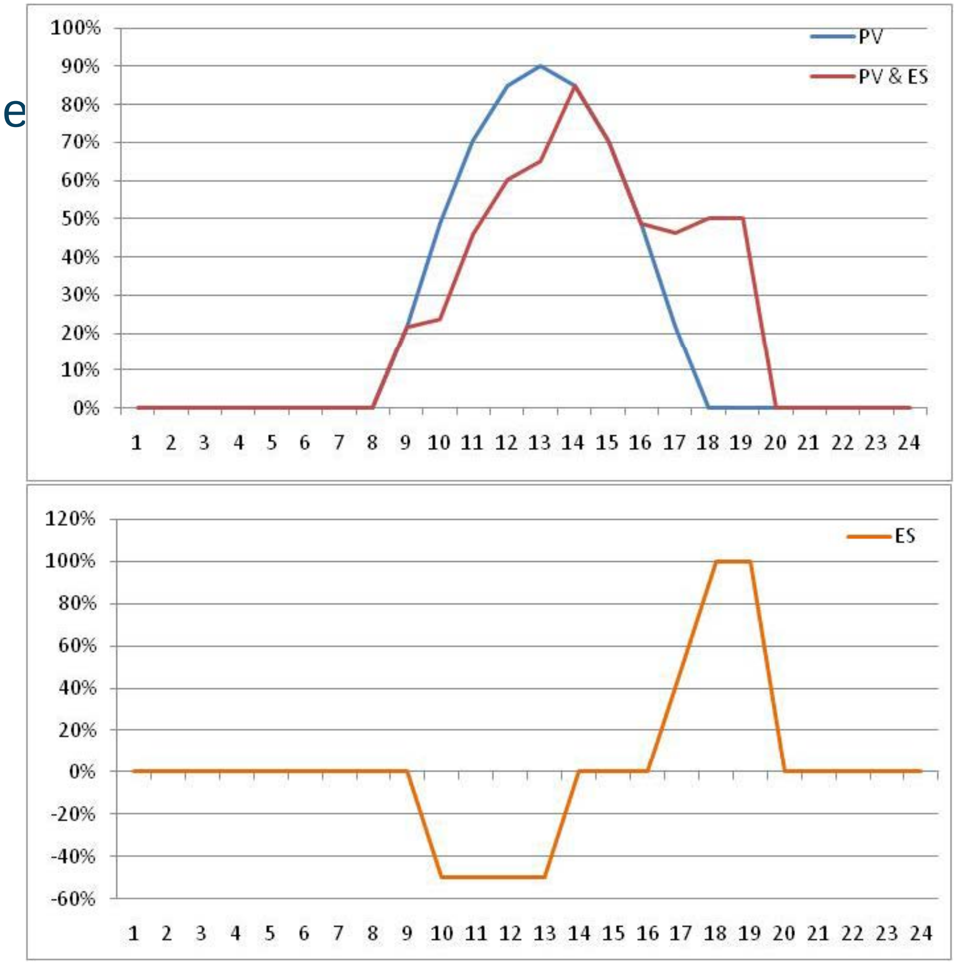
- Benefit Impact: Customer Side





Renewable Energy Time-Shift

- Benefit: Increase value of energy by shifting output from off to on-peak time
- Control: Adaptive scheduling control with on/off peak time frames and generation forecast
- Location: Renewable generation source, aggregation point near load
- Discharge Duration: 2-5 hours, depending on local load peak
- Cycle Duty: One cycle per day
- Benefit Impact: Typically Customer Side

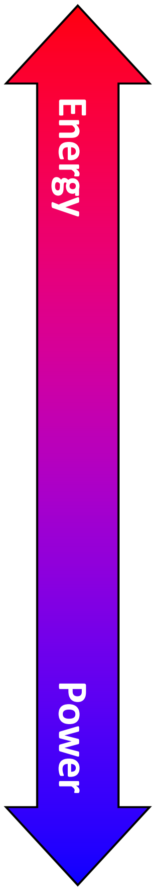


So the Solutions is simple?

- Many issues that make addition of storage difficult to implement
- Question with any added component to a system – How to pay?
  - Will a customer want to adopt this
    - If it has an economic benefit, of course they will
  - Will a utility want to see storage adopted?
    - If it can protect the grid, of course they will
- Options and Hurdles being faced today
  - Will policies allow Applications are a mix of Power and Energy – can technologies available provide all services needed?
  - developers to get compensated for adding a technology that is protecting the system?
    - → Answer: There is work that still needs to be done
- Where is this solution working today
  - Island applications where the price of electricity is high enough to absorb the additional component (Hawaii, Puerto Rico)

Today's Storage Technology Options

The Technologies Range from Power (< 1 hour) to Energy Applications (multiple hours)



- **Compressed Air Energy Storage –** will be utilized for "centralized" applications
- **Above Ground CAES –** Gen II, projected as 5MW, above ground
- **Sodium Sulfur (NaS) battery –** Long duration, Transmission back-up
- **Vanadium Redox Battery** – Long duration, flow battery, used for back-up applications
- **Advanced Lead Acid Batteries** – 1 to 4 hours, used for renewable integration
- **Sodium Nickel Chloride Battery** – Targeting vehicles and small backup (Telecom)
- **Li-ion – High Energy** – Used for CES, renewable integration, maybe regulation
- **Li-ion – High Power** – used for frequency regulation, renewable integration
- **Flywheels** – 15 minute, many cycles, used for frequency regulation

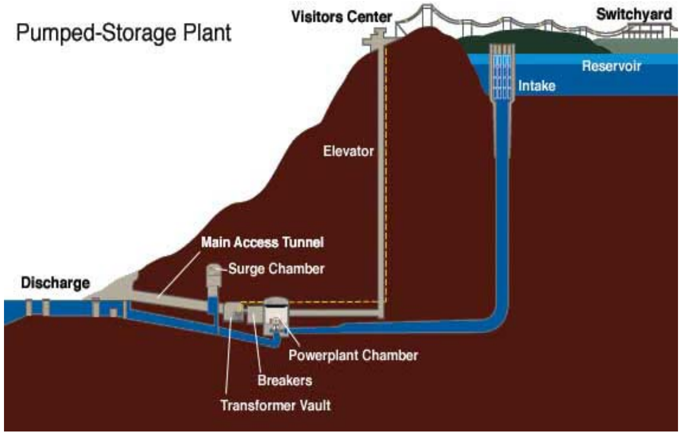
What are the Technology Options For Renewable Integration?

- Bulk Storage Technologies
  - Addresses the problem from a centralized approach with very large systems
  - Typically greater than 300 MW
  - Addresses issue more from a grid support, ancillary service perspective or project that targets a group of renewable projects
  - Compensation from regulation services provided

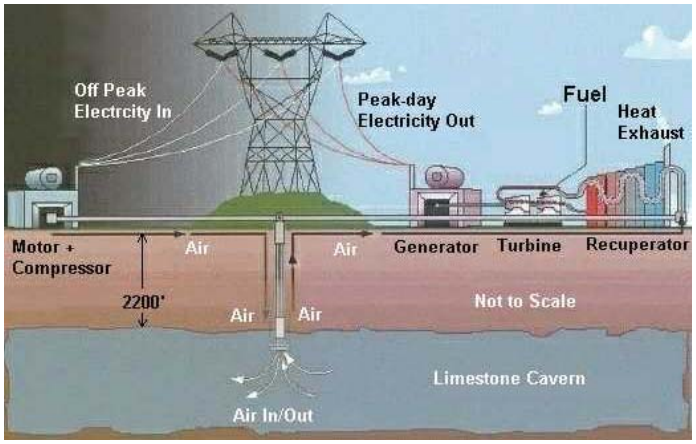
- Utility-scale Solutions
  - Addresses the problem from a decentralized “solution at the source” approach
  - Typically kW to aggregated 50MW applications
  - Compensation challenges – usually applied to meet interconnection guidelines
  - Attempts being made to bundle the solution to perform multiple applications

Bulk Storage Options

- Pumped Hydro is terrific if available. However, most potential sites have been built out
  - New construction suffers from long permitting and commissioning processes (up to 10 years)
  - Highly regional/geographic



- Compressed Air Energy Storage
  - Hurdles to construction are similar to pumped hydro but more exaggerated because of overall conceptual design and cost



Bulk Storage Options (Continued)

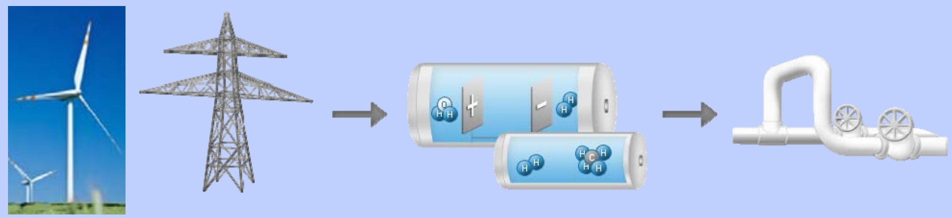
- Concentrating solar thermal is beginning to make advancements today
  - Systems are still relatively expensive on a capital cost basis

- But when storage is added to plants that are already constructed – incremental cost are small

New concepts - What is Power to Gas?

- Using the natural gas infrastructure to support the conversion of power into gas

Power to Gas



- Why Discuss?
  - As renewable penetration increases on electricity grid, there is going to be a need for low cost, bulk storage to help integrate the technologies
  - This generation needs to be flexible and not increase emissions
  - Historically, efficiency issues were problematic for the concept, but developments in electrolysis technologies and injecting into the pipeline system (utilizing existing infrastructure) has increased interest in concept

Utility Scale Applications

- Advanced storage applications are being used at the site of the project to meet the immediate “interconnections issues” of ramping
- The devices can then be used to perform other applications
- Case where ramping needs are being coupled ancillary services to help pay for the application

Courtesy: AES Energy Storage

What Technologies are being for these needs?

- Advanced Lead Acid Batteries
  - Advantages: Low capital cost, higher power and lower internal resistance, lower maintenance, proven technology
  - Companies: Xtreme Power, East Penn, Exide, Axion
  - Deployments: Kahuku Wind Farm
- Lithium-ion Batteries
  - Advantages: High energy and power density, high efficiency for "power" cells, good cycle life
  - Companies: A123, Altairnano, SAFT, EnerDel, International Battery, Greensmith
  - Deployments: AES 12 MW Frequency Regulation Chile Installation, AES 20 MW Westover Installation
- Sodium Batteries
  - Advantages: High energy and power density, good cycle life, long discharge times (6 hours)
  - Companies: NGK Insulators, FZ Sonick (FIAMM), GE
  - Deployments: Many sites in Japan, Multiple AEP sites (most recent Presidio, TX 4 MW), XCEL Energy 1 MW

Storage Trends

TECHNOLOGIES

- **Flow Batteries**
  - Advantages: Potential for extended discharge cycles since energy relates to volume of electrolyte tanks.
  - Companies: ZBB Energy, Premium Power, Redflow, Prudent (vanadium)

- **Flywheels**
  - Advantages: High power density, long lifetimes, low maintenance.
  - Companies: Beacon Power, Active Power, Boeing
  - Deployments: Beacon 20 MW Frequency Regulation, Stephentown, NY

- **Compressed Air Energy Storage**
  - Advantages: Potential for bulk energy storage at lowest cost.
  - Companies: Energy Storage Power Corporation, SustainX
  - Deployments: 110 MW unit in McIntosh, Alabama in 1991

Storage Projects ≥ 2 MW

(Courtesy of Electricity Storage Association)

SPONSOR	PROJECT & STATE	MW/ MWh	APPLICATION	SUPPLIER & TECHNOLOGY	TARGET DATE	CO-FUNDING
Primus Power	Modesto Irrigation, CA	25 / 75	WS, LS, AS	Primus Power, RFB	2012	ARRA grant
First Wind	Kaheawa Wind Power II, HI	10/ 20	WS	Xtreme Power, ALA	2012	Private
Duke Energy	Notrees Wind Storage, TX	36 / 24	WS, AS, AR	Xtreme Power, ALA	2012	ARRA grant
SCE	Tehachapi Wind ES Project, CA	8 / 32	WS, E	A123, LI	2012	ARRA grant
East Penn Mfg.	Ancillary Services, PA	3 / 1-4	AS	Ecoult, ALA	2012	ARRA grant
Kodiak Electric	Pillar Mountain, AK	3 / 2	WS, AS	Xtreme Power, ALA	2012	Private
A123	Alternative Technology Regulation , MA	2 / .5	AR	A123, LI	2012	Private
Premium Power	Peak Demand Reduction, CA	3.5 / 3	D	Premium Power, Flow	2011	ARRA grant
Beacon Power	Stephentown, NY	20 / 5	AR	Beacon Power, FW	2011	DOE loan
AES Energy Storage	Laurel Mountain , WV	32 / 8	WS	A123, LI	2011	Private
First Wind	Kahuku Wind Project , HI	15 / 10	WS	Xtreme Power, ALA	2011	DOE loan
AES Energy Storage	Johnson City, NY	8 / 2	AR	A123, LI	2010	Private
AEP	Presidio/TX	4 / 25	T&D	NGK, NAS	2010	Rate base
AEP	Bluffton, OH	2 / 14	T&D	NGK, NAS	2007	DOE loan
AEP	Balls Gap/ WV	2 / 14	T&D	NGK, NAS	2007	DOE loan
AEP	Churubusco/ IN	2 / 14	T&D	NGK, NAS	2007	DOE loan

ALA = Advanced Lead Acid RFB= Redox Flow Battery LI = Lithium Ion NAS = Sodium Sulfur FW = Flywheel D = Demand
WS = Wind Support LS = Load Shifting AS = Ancillary Services AR = Area Regulation E = Experimental T&D = Deferral

Policy Initiatives Shaping the U.S. Storage Market

Initiative	Description	Market Impact / Timeframe
ISO/RTO Ancillary Service Markets Open to Storage	Five open-bid ancillary services markets are now (or shortly will be) directly accessible to energy storage: PJM, NYISO, ISO-NE, MISO and CAISO	***In place*** ▪ Creates large-scale markets for storage-based regulation
FERC Final Rule (RM11-7-000; Final Order No. 755)	Clarifies frequency regulation compensation for fast-response storage in organized markets (Oct. 2011)	***Near-term*** ▪ Increased revenues for storage-based regulation due to value of fast response
ERCOT Ancillary Services for Storage	ERCOT is considering new rules for storage participation in the ancillary services markets. (In process as of 2011)	***Mid-term*** ▪ Expands market for regulation; pending
California State Law (AB 2514)	Sets energy storage procurement targets in the State of California (Enacted 2010)	***Mid-term*** ▪ Increased awareness of storage capability and benefit
U.S. STORAGE Act of 2011 (S.1845)	Legislation would provide tax incentives for grid storage as well as for on-site and residential applications. (Introduced Nov. 2011)	***Long-term*** ▪ Would accelerate growth of national market by defraying initial investment
Renewable Portfolio Standards (29 states)	State-driven RPS mandates and goals to increase renewable generation. Targets from 10% - 40%	***Current to Long-term*** ▪ Greater need to mitigate intermittency
FERC Order 1000 Enacted Jul. 25, 2012	States that energy storage should also be evaluated as a potential solution for applicable T&D issues	***Current to Long-term*** ▪ Opens door to storage solutions for T&D
FERC Declaratory Order; Western Grid Development LLC Approved Jan. 2012	FERC determined that the batteries will operate as wholesale transmission facilities and granted Western Grid the advanced transmission incentives subject to California ISO transmission planning	***Current to Long-term*** ▪ Opens door to rate base storage for T&D; basis point and other incentives may apply for advanced technology

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