The FMEA Annual Conference
July 19-22, 2016
Omni Orlando Resort at ChampionsGate

The Status of Energy Storage – Renewable Energy Depends on It

Pedro C. Elizondo
Flex Energy
Orlando , FL
July 21, 2016

flex

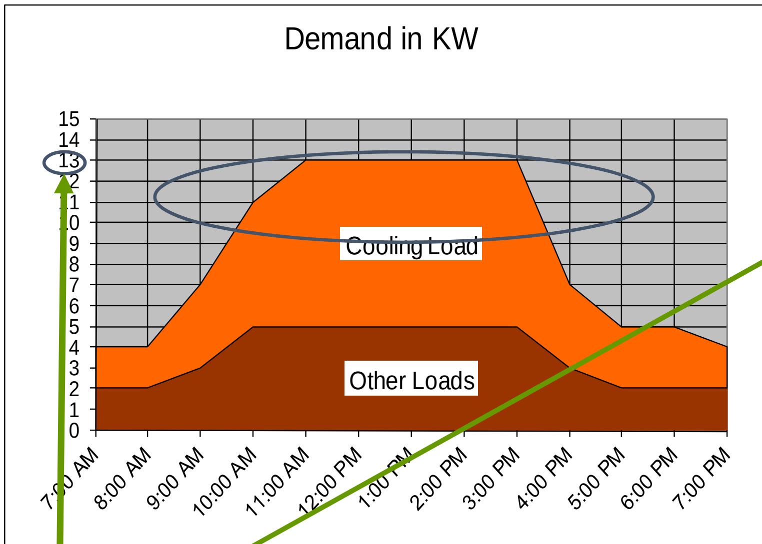
Energy Storage Systems

Current operating mode of electrical networks

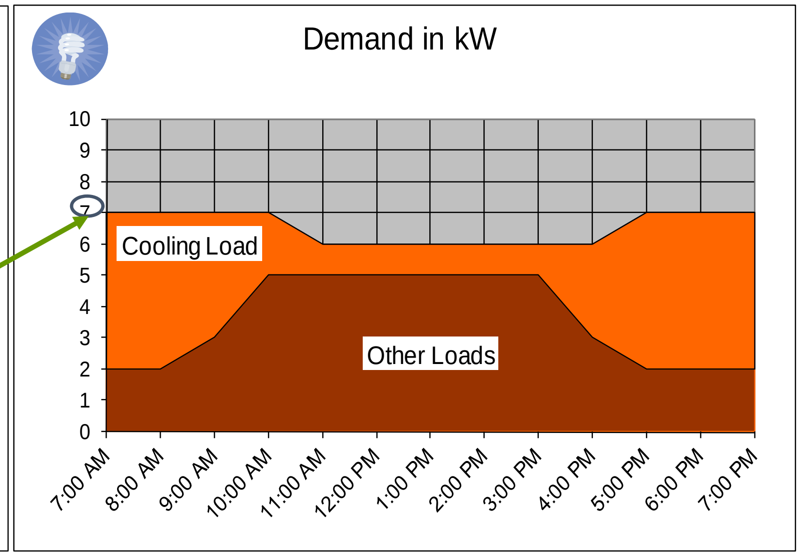
- Electricity must be produced when it is needed and used once is produced.
- The reliability and stability relies on balancing the system => **produced generation** with the **demanded load** on the grid.
- Practice: Build and support a power network designed to meet the highest peak load of the year while a significant part of the installed MVA capacity sits idle most of the time.
- This conventional way to operate the electrical network has been acceptable but it has minimum flexibility to face the challenge of grid's innovations such as **renewable generation sources**.

Peak Shaving and load factor

Demand profile 1



Demand profile 2



- Area under the curve = energy consumed. Same energy consumed for profile 1 and 2
- Demand profile 2 is more efficient, same energy consumed but lower peak demand.
- Load Factor = Energy Used in KW-hr / Time (hours in billing period) ÷ Maximum Demand in kW

$$\text{Load Factor} = \frac{\text{Energy Used in KW-hr / Time (hours in billing period)}}{\text{Maximum Demand in kW}}$$

- Load Factor profile 2 >load factor profile 1, then Demand Profile 2 is more effcient

Energy Storage Systems
Issues in the electrical network operation

- As the electrical networks become more dynamic and faster in the decision processes more tools will be needed to provide the flexibility required for this state.

- One of these tools is energy storage that can contribute in solving the main issues in the electrical networks operation:

- Reliability,
- Network congestions
- Infrastructure utilization factors
- Integration of renewable generation
- Efficiency

Energy Storage Systems
Basic Function

- Energy storage is the capture of energy produced at one time for use at a later time.

- By absorbing or delivering energy at precisely the right time and place, **Energy Storage Systems can move electricity through time**, providing it when and where it has a positive impact on the network's performance.

- Storage technologies convert electrical power into chemical, mechanical or potential energy and have the ability to reinject it into the grid when called on.

Energy storage deployments increasing

Energy storage trends

- Most ‘utility’ deployments are in wholesale energy markets
  - Most existing capacity is in **regulation service**
  - Moving towards storage as peaking generation (esp. CA)
- **Behind-the-meter storage** mostly driven by incentives or high demand charges
  - California SGIP
  - Demand charges >$15/kW for peaks of <2 hours
- **Storage for renewable integration** on the rise
  - Starting with islands and other weak grids
  - Starting to move to mainland grids

Energy Storage Systems
Energy and Power

- Energy storage systems key performance parameters are:

- Power rating - How much power can it deliver at any moment?
- Energy capacity - How much total energy can the system store?

- Energy and Power often seem like interchangeable terms but they are different.

- Energy is the capacity to do work. Therefore, energy measures the total quantity of work done.

- Power is defined as the rate of producing or consuming energy. In relation to the example of energy being the capacity to do work, power would be the speed at which the work is getting done.

Energy Storage Technologies
per storage medium

Mechanical
- Pumped Hydroelectric
- Flywheels

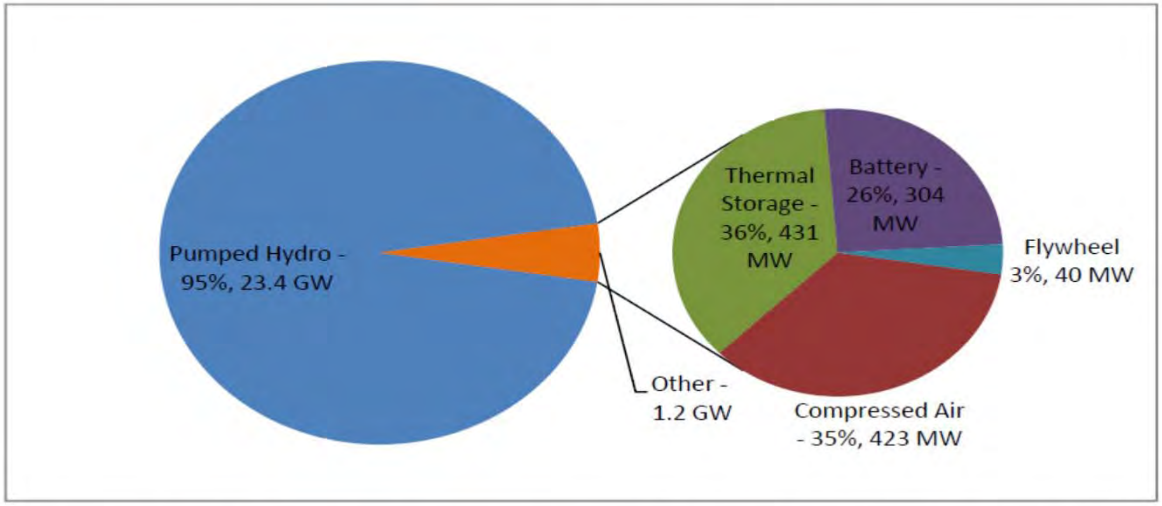
Thermodynamic
- Compressed Air Energy Storage (CAESS)
- Adiabatic CAESS
- Thermal Energy Storage

Electrochemical (Batteries)
- **Conventional**
  - Lead Acid (Pb-Acid)
  - Nickel Cadmium (NiCd)
  - Lithium Ion (Li-Ion)
- **High Temperature**
  - Sodium Sulfur (NaS)
- **Flow Batteries**
  - Vanadium Redox
  - Zinc Bromine
  - Polysulfide Bromide

Electromagnetic
- Capacitors
- Super Conducting Magnetic Energy Storage (SMES)

Energy storage today (DOE information)

Figure 1 – Rated Power of US Grid Storage projects (includes announced projects)



Similarly, Figure 2 shows the wide range of system sizes that have been deployed. The rated power of the various projects ranges from small, residential scale (7 projects are listed as 10 kW or below—this is a reporting artifact, as there are likely many small systems not in the database) to large, utility scale systems of 1 MW or more.[11]

Figure 2 – Number of US installations, grouped by capacity

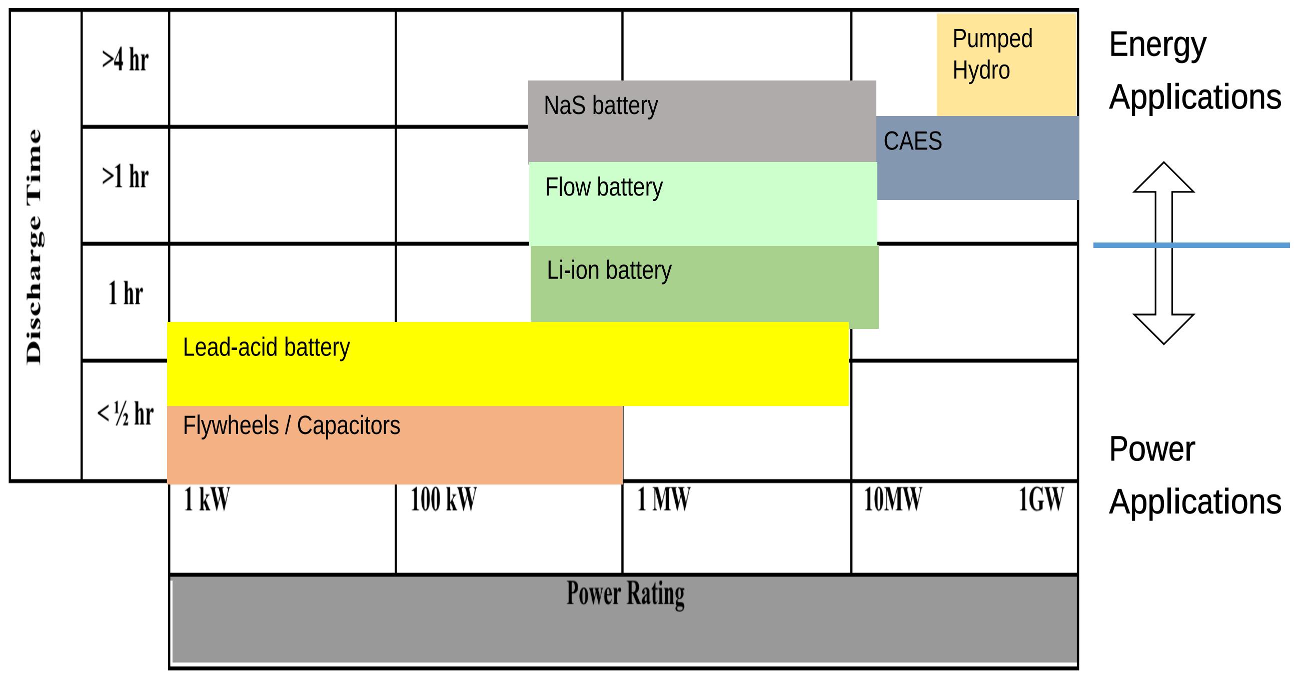
Components of Energy Storage Systems

System Components	Description
Storage Medium	Energy Reservoir. Its main function is to retain the energy for a later usage.
Power Conversion System (PCS)	Majority of the storage technologies requires power electronic equipment to invert the DC into AC to connect the energy storage system to the grid.
Balance of Plant	Include the housing for the Storage Medium and the PCS, and the control system.

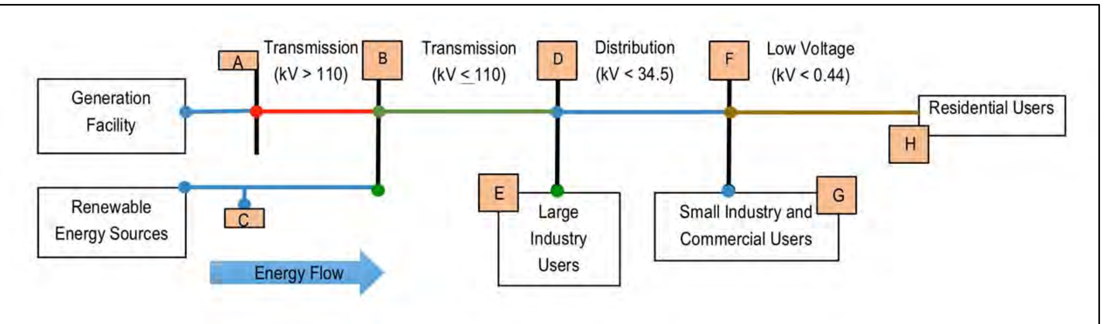
Energy Storage Systems Application Map

Power and Energy Applications

System performance parameter	Power Applications	Energy Applications
Power Rate	Up to 40 MW (depends on the application)	Higher than1 MW (cost effective >10 MW)
Discharge Time	Up to 1 hour	> 1 hour
Response time	Fast (seconds)	Medium (minutes)
Cycles (charging and discharging)	Several cycles per day	One or few cycles per day

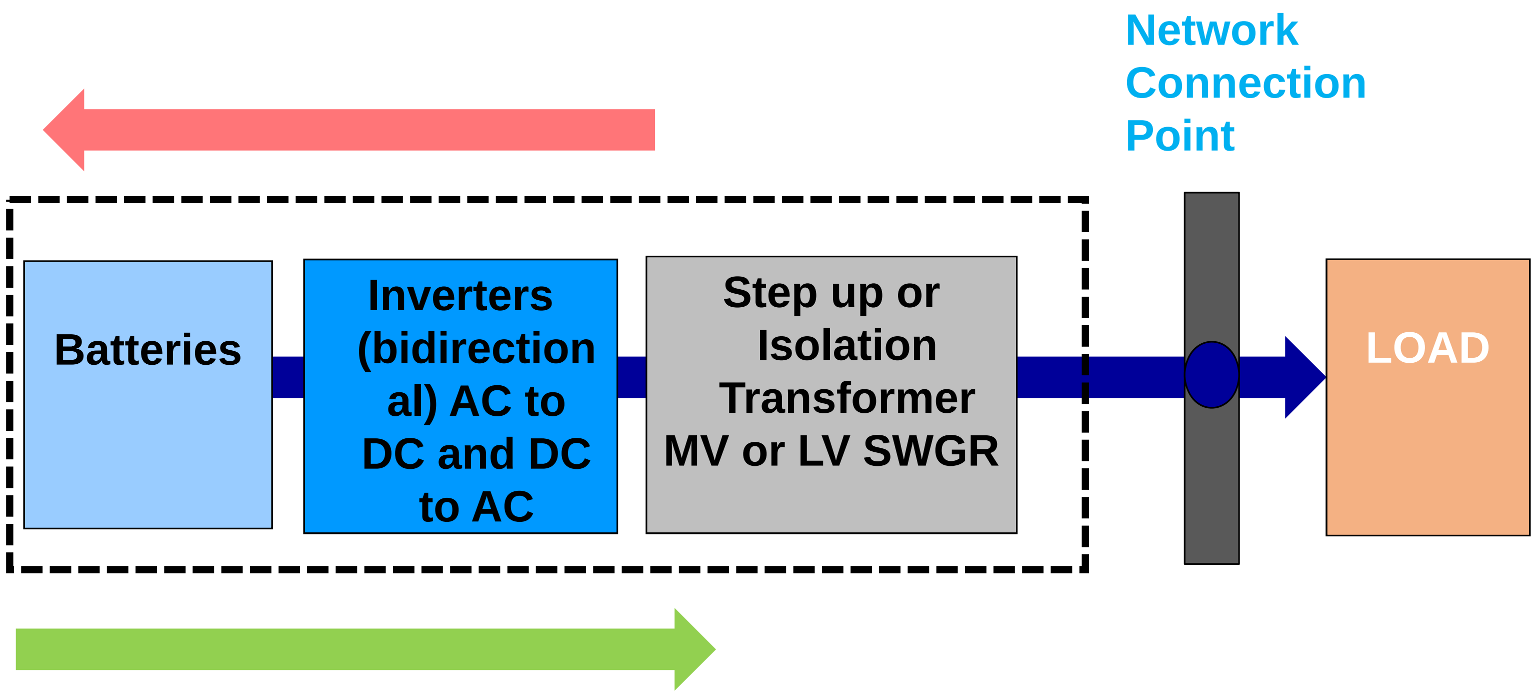


Energy Storage Systems Applications



Network Location	Application Name	Classification	Type of Application
A, B	i) Commodity Arbitrage ii) Load Leveling	Energy Management	Energy
B, D	Spinning and non-spinning reserve.	Energy Management	Energy
A, B	Frequency Regulation	T&D grid Support or Bridging Power*	Power
B, D, F	T&D congestion relief	T&D grid Support or Bridging Power	Power
B, D, F	T&D asset deferral	T&D grid Support or Bridging Power	Power
B, D	Voltage Regulation or Support	Power Quality**	Power
C	Integration of renewable sources to the grid, optimizing the renewable energy usage.	Bridging Power or Energy Management.	Power or Energy depending on the design.
C	Ramp Control and Capacity Firming of renewables	T&D grid Support or Bridging Power	
E, G, H	i)Power Quality ii) Demand Management (peak shaving)	Power Quality / UPS	Power

Battery Energy Storage System (BESS)
Energy Flow



Battery Information
Battery Parameters

Parameters to design the battery bank:

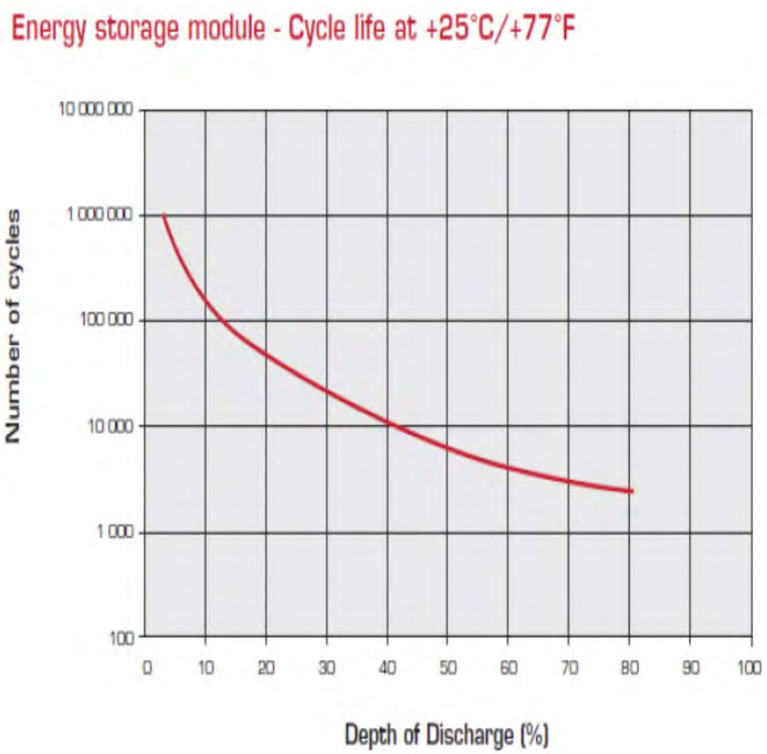
- ❑kW
- ❑kW-hr

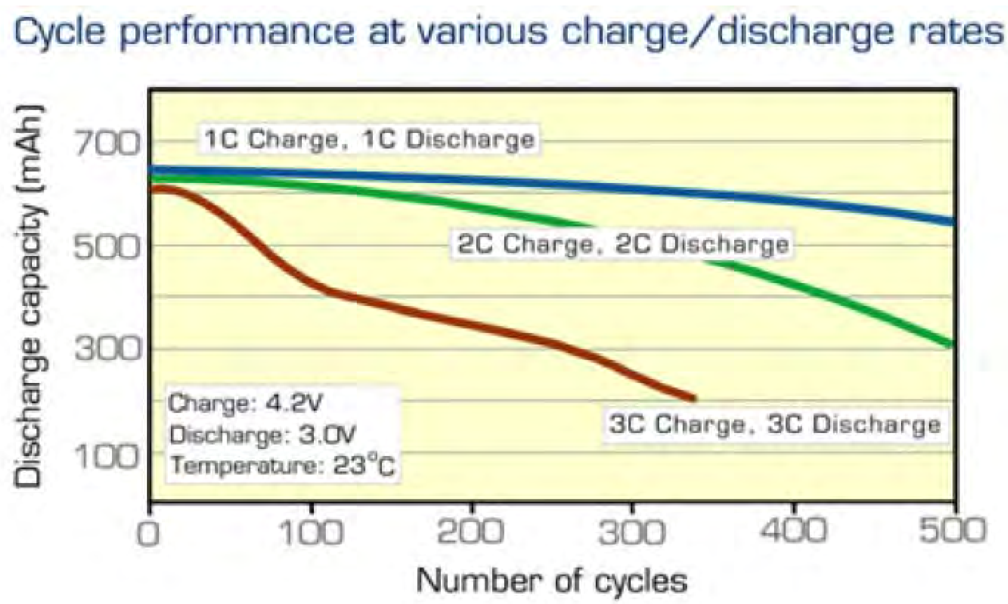
- ❑Number of Cycles per day
- ❑Discharge rate
- ❑Depth of Discharge

Expected Life

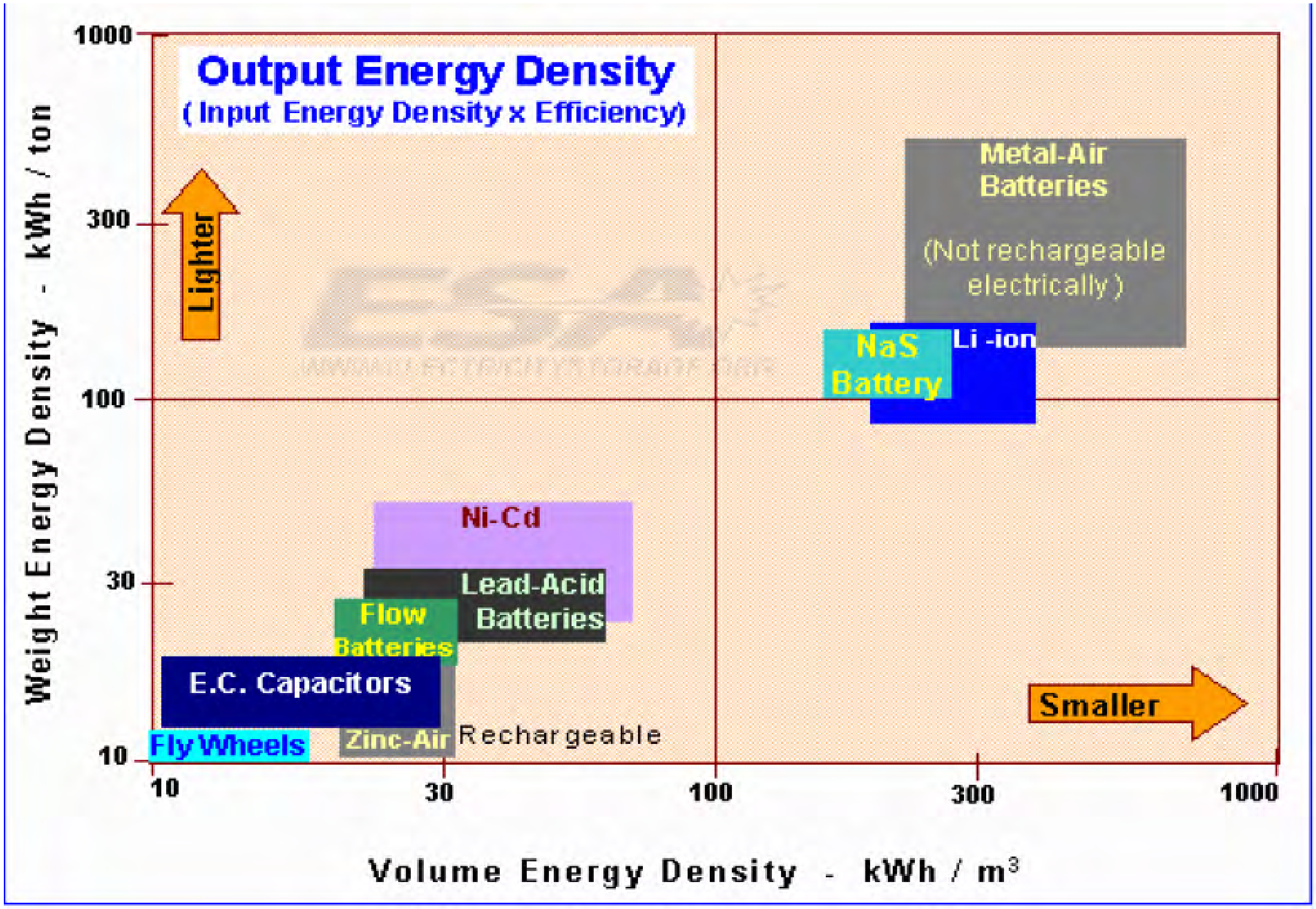
Battery Information

Depth of Discharge and Rate of Discharge

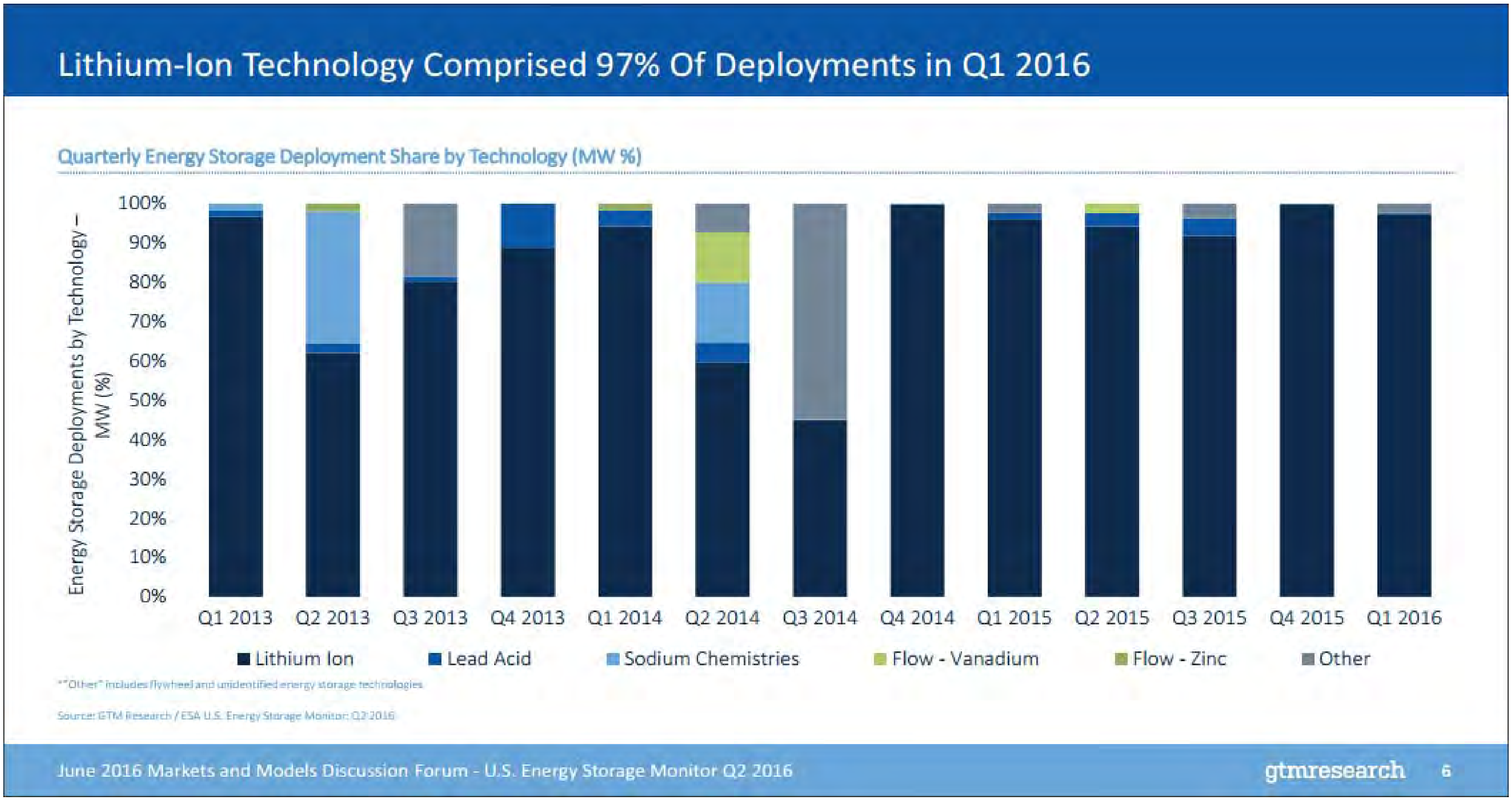




Battery Information
Energy Density according to ESA



Battery Technology trends



Battery Technology Summary

- Li-Ion **Suitable for power applications due to the fast response.** The storage magnitude is medium compared to pumped hydroelectric and compressed air energy storage but the **response time is much faster**.
- Leading battery technologies with more 1 MW and higher deployments in USA are **Li-Ion, NaS, and Pb-Acid.**
- **Nickel Cadmium** is not a cost effective alternative due to the low energy density and efficiency. Also it has the highest annual cost per kW per year ($/kW-year) of all energy storage technologies.
- **Lead-acid** is the oldest rechargeable battery technology and proven for certain type of applications like starting ignition, or industrial where they provide a low power rate for a long period of time. This type has the lowest manufacturing cost but the performance is limited since they cannot be fully discharged.
- **Li-Ion batteries** have gained significant market share in the last years over sodium sulfur due to high density and efficiency, lower operational cost since all modules are sealed and maintenance free.
- **Sodium Sulfur (NaS)** utilizes metallic sodium offering an attractive solution for large-scale energy applications. They have high efficiency and energy density. There are some issues that should be addressed. One is the operating temperature of 300-350 Celsius degrees. Second the highly corrosive nature of sodium discharge products.
- **Flow Batteries*** are in the pilot or demonstration stage and were created to have a long life battery for large-scale energy applications. As part of the strategy to achieve a long life battery the electrolyte in a flow battery is a liquid that can be replaced, refurbishing the battery at a fraction of the cost of installing a new one.
- https://www.youtube.com/watch?v=dEHqXDdhztw

Renewable Energy facts

- Increasing of renewable sources is one of the prime goals of US energy policy makers.
- Energy production potential is generally no coincident with peak demands periods.
- Additional ancillary services are needed to integrate the source into the grid.
- Remote locations in which the transmission lines capacity is restricted and the energy is basically curtailed.
- Need for decoupling production from demand.

Renewable Energy facts

- Wind is highly intermittent power source and electricity is only produced when it is blowing.
- The typical capacity factor for wind-generation farms ranges from 25% to 30%, which means that too often wind is not dispatchable.
- Typical capacity factors for wind turbines range from 0.25 to 0.30. Thus a wind turbine rated at 1 Mega Watt will deliver on average only about 250 kilo Watts of power. (For comparison, the capacity factor of thermal power generation is between 0.70 and 0.90)
- **The fundamental concept of energy storage is simple: generate electricity when wind and solar are plentiful and store it for a later use when demand is up and supplies are short.**

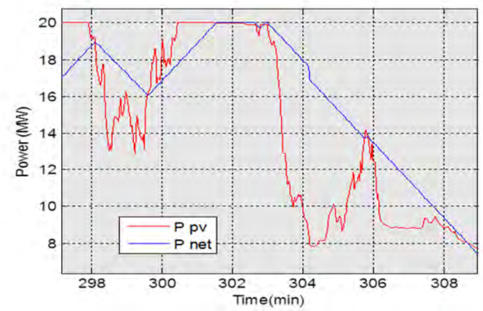
Integration of Renewable sources into the grid

Why is Energy Storage needed in the Wind and Solar energy Sources?

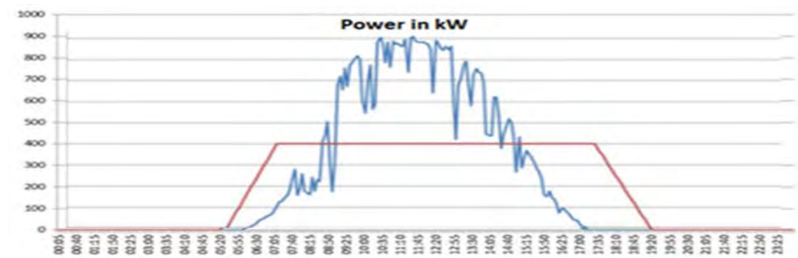
- Renewable energy sources like wind and solar may be part of the solution to improve the environment, but they come at cost, they are sporadic and erratic.
- **Wind and Solar energy is identified as a not dispatchable**. In the other hand Thermal and hydro generation are design to operate continuously , delivering power to the load. This is call dispatchable power, meaning the generator can be turned on and off as needed.
- Without energy storage renewable power can not replace coal, natural gas and nuclear generation on a megawatt-for-megawatt basis.

Energy Storage function in Renewable Energy

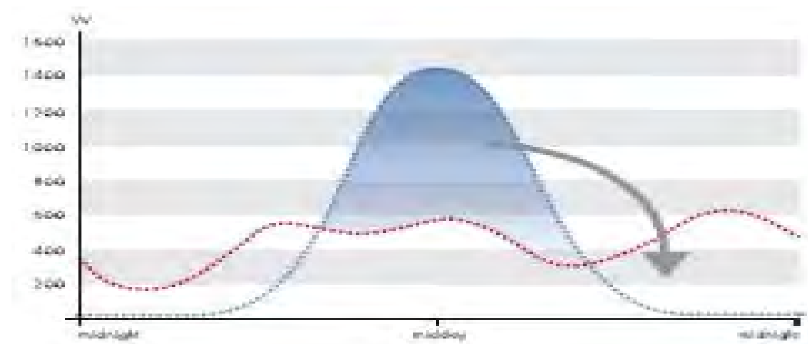
- Compatibility
  - Ramp-rate control & frequency response
  - Low energy requirement
  - Important for weak grids



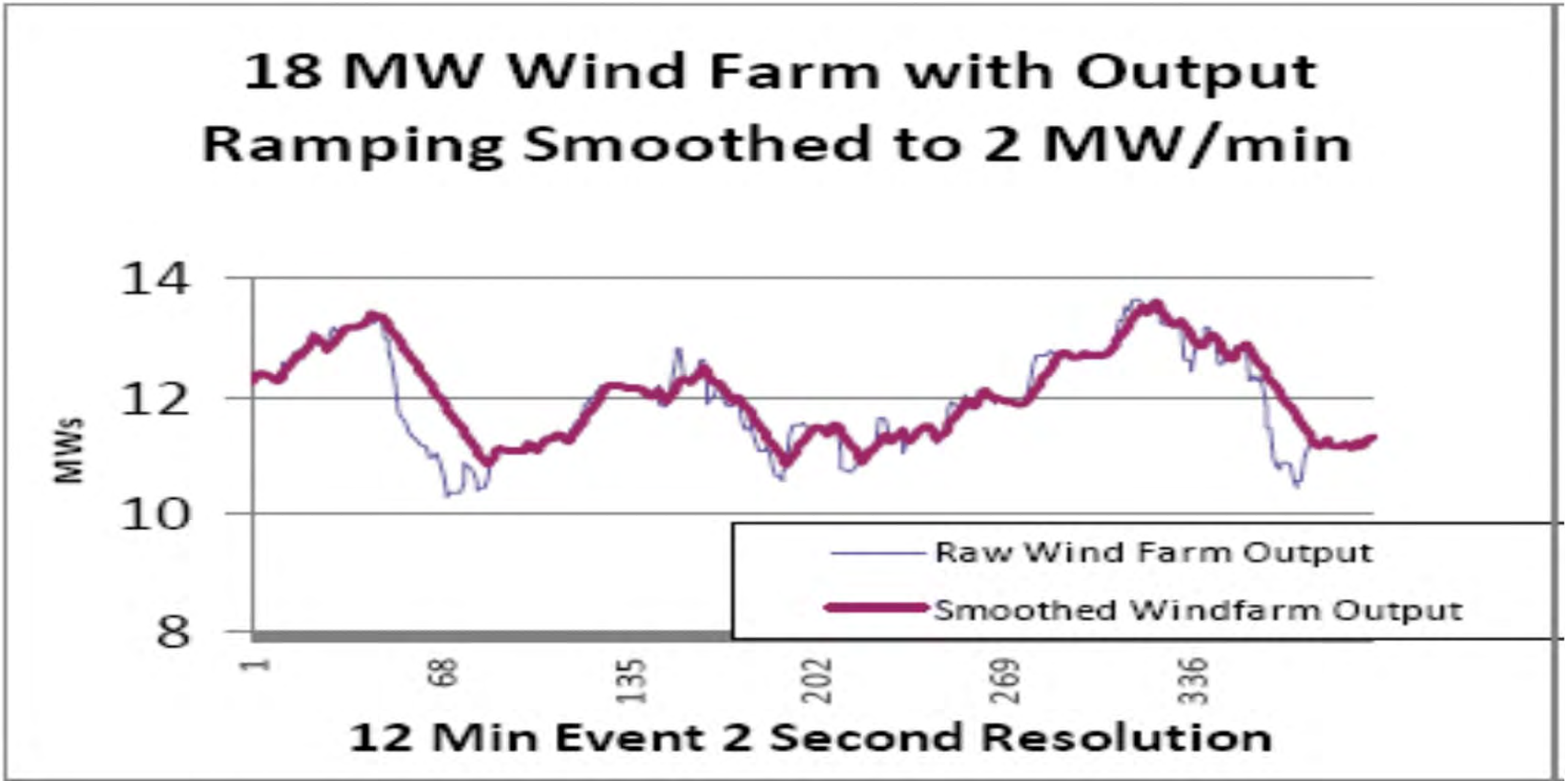
- Predictability
  - Firming to forecast
  - Moderate energy requirement
  - Weak grids and grid management



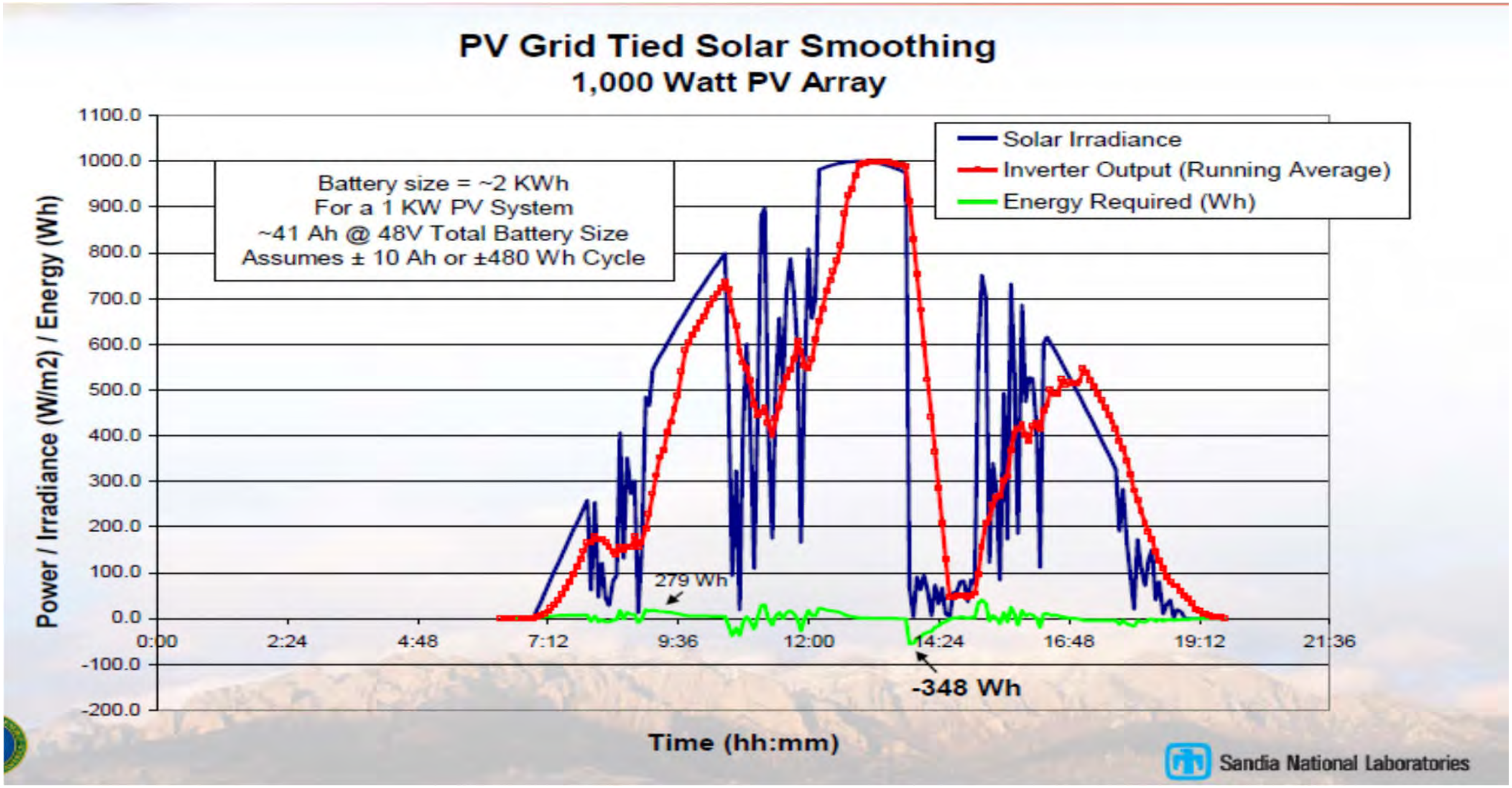
- Dispatchability
  - Shifting to grid peak
  - Hours of energy
  - Competition with conventional generation



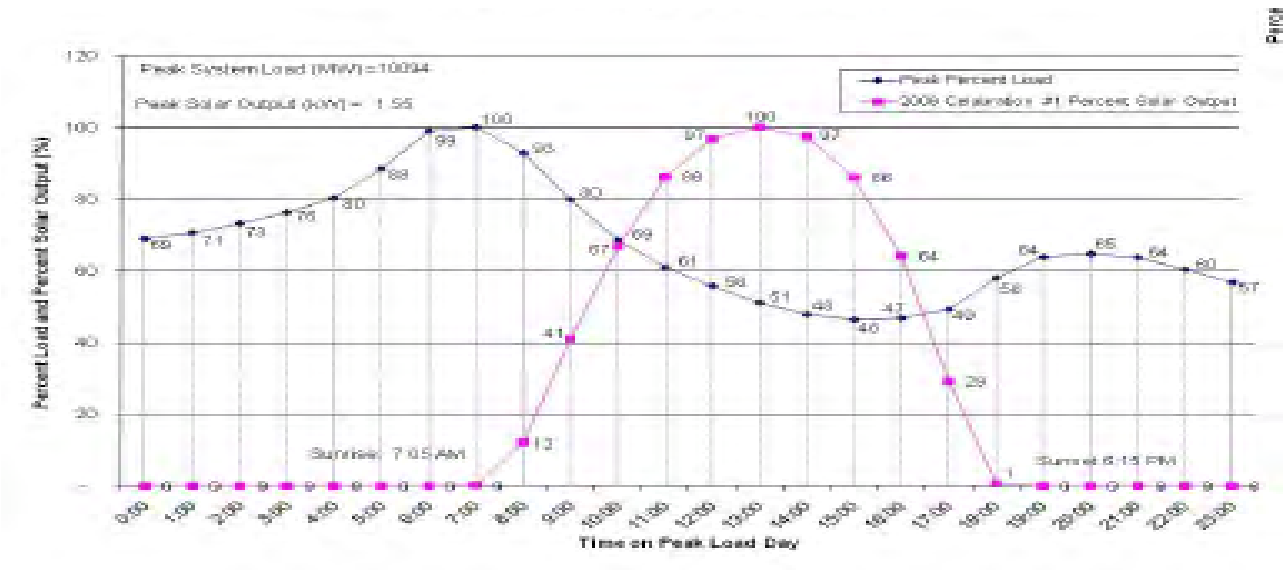
Energy Storage function in Renewable Energy



Energy Storage function in Renewable Energy

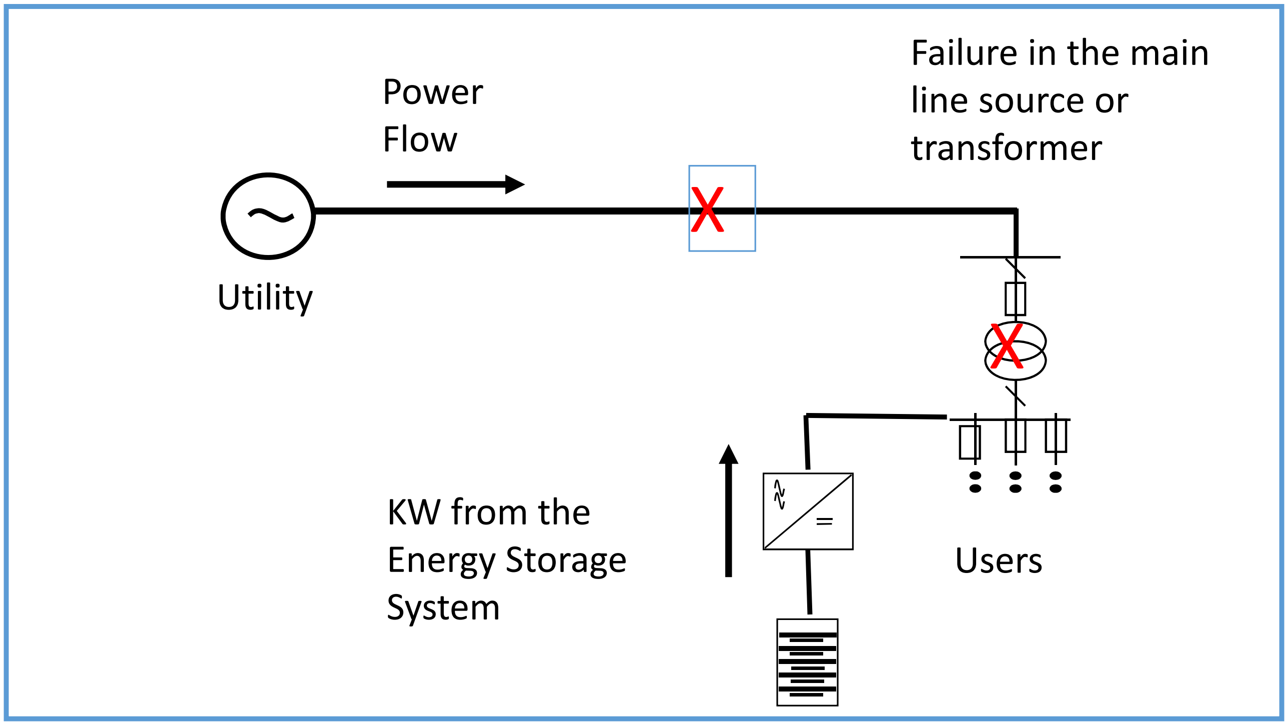


Energy Storage function in Renewable Energy



Applications
Community Energy Storage

Energy Storage System will allow loads to operate through outages



Applications
Community Energy Storage

- The objective of the electricity service is to provide consumers with safe, reliable electricity on demand. Consumers should be free to use electricity whenever they like. It must be the grid that accommodates the consumer.

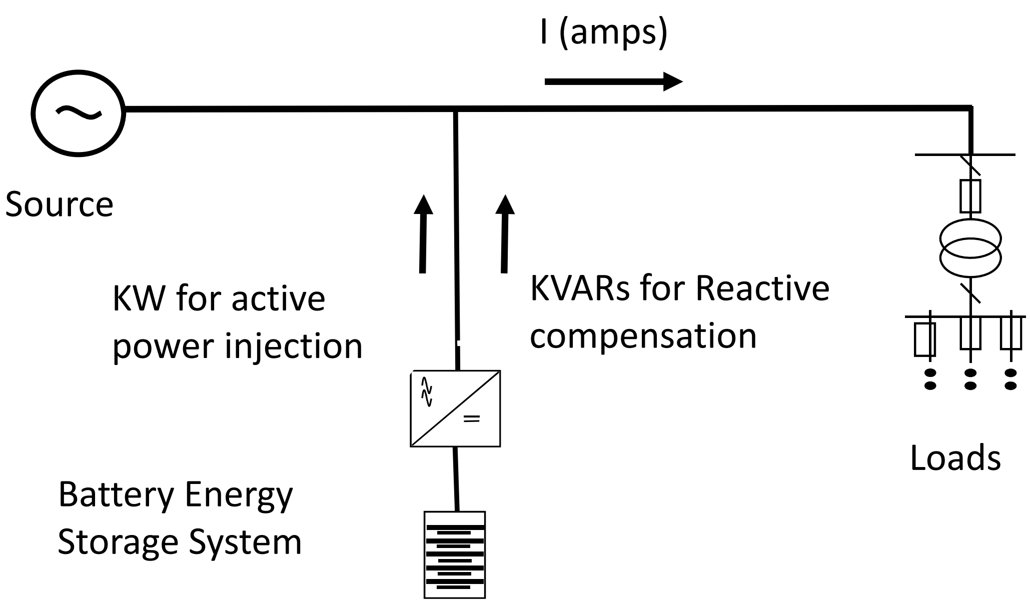
- Sustained and momentary interruptions are very costly for the utility operation.

- In average 50% of total economic losses in the grid operation are due to momentary interruptions of service (five minutes or less)

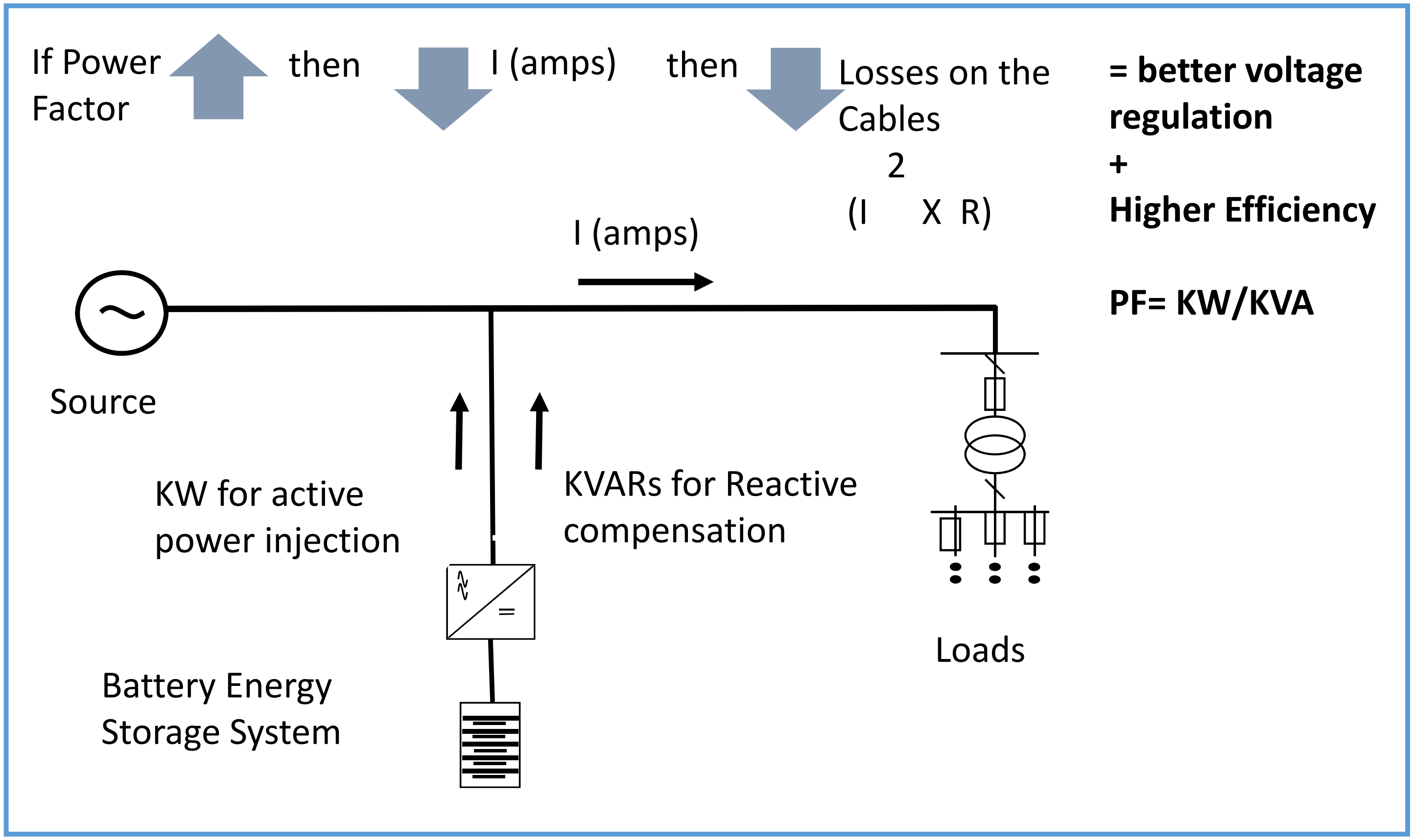
Applications

Voltage Regulation / Injection of reactive power

BESS contributes to maintain the grid voltage by injecting or absorbing reactive power (VAR)



Applications
Voltage Regulation / Injection of reactive power



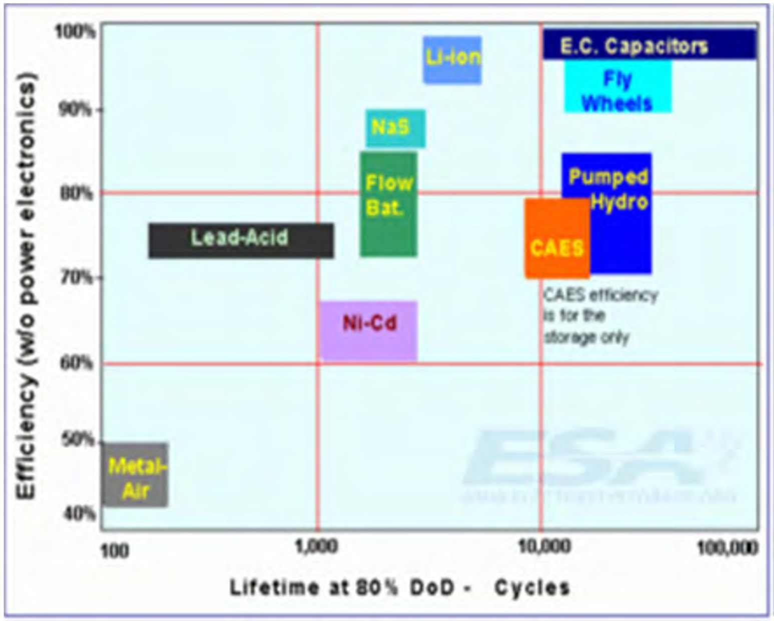
Energy Storage System and Smart Grid

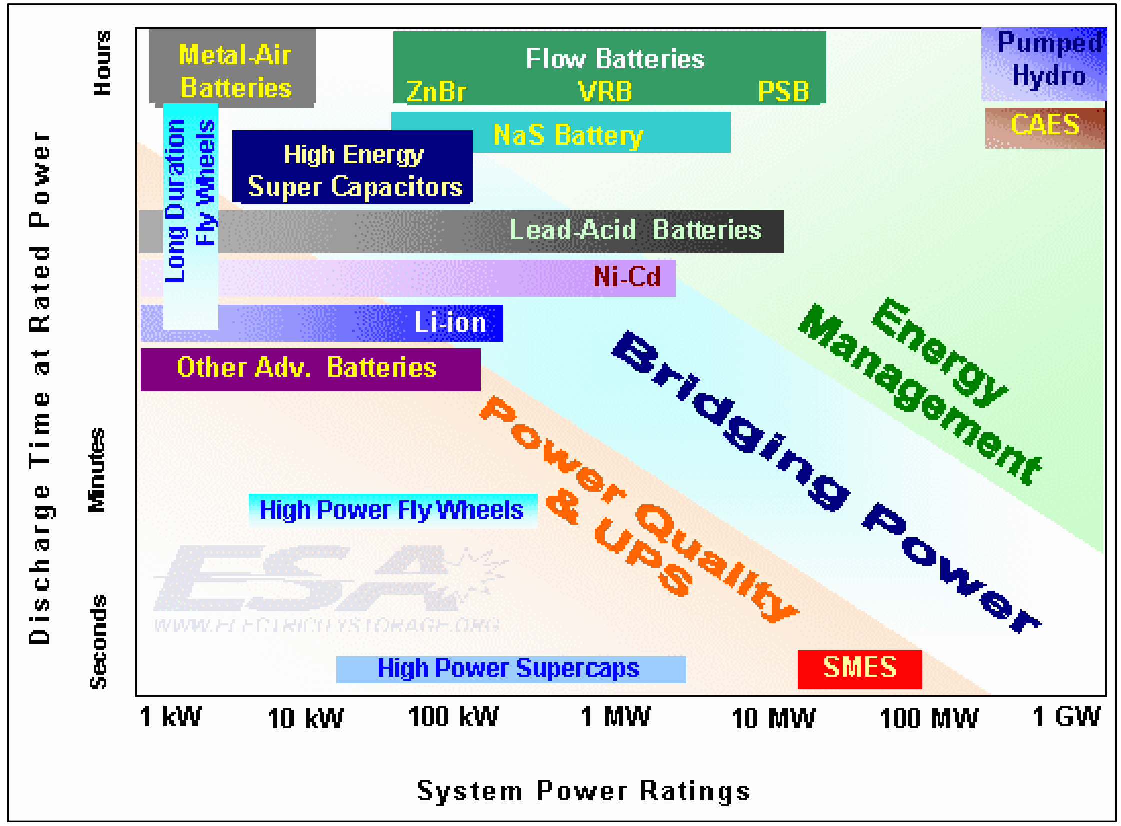
Energy Storage Systems supports the **Smart Grid Priorities based on Customer Value Drivers:**

- **Increased Capacity** – increase power delivery using existing infrastructure
- **Improved Reliability** – reduce number and duration of outages, increase asset life
- **Greater Efficiency –** improve power factor, perform voltage management, provide bidirectional power flow
- **Sustainability** – solutions for distributed generation as well as increased usable life of assets through performance monitoring and analytics
- **Interoperability and Integration of New Technologies**: Storage, Wireless communications, Monitoring/Diagnostics

Applications per Storage Technology

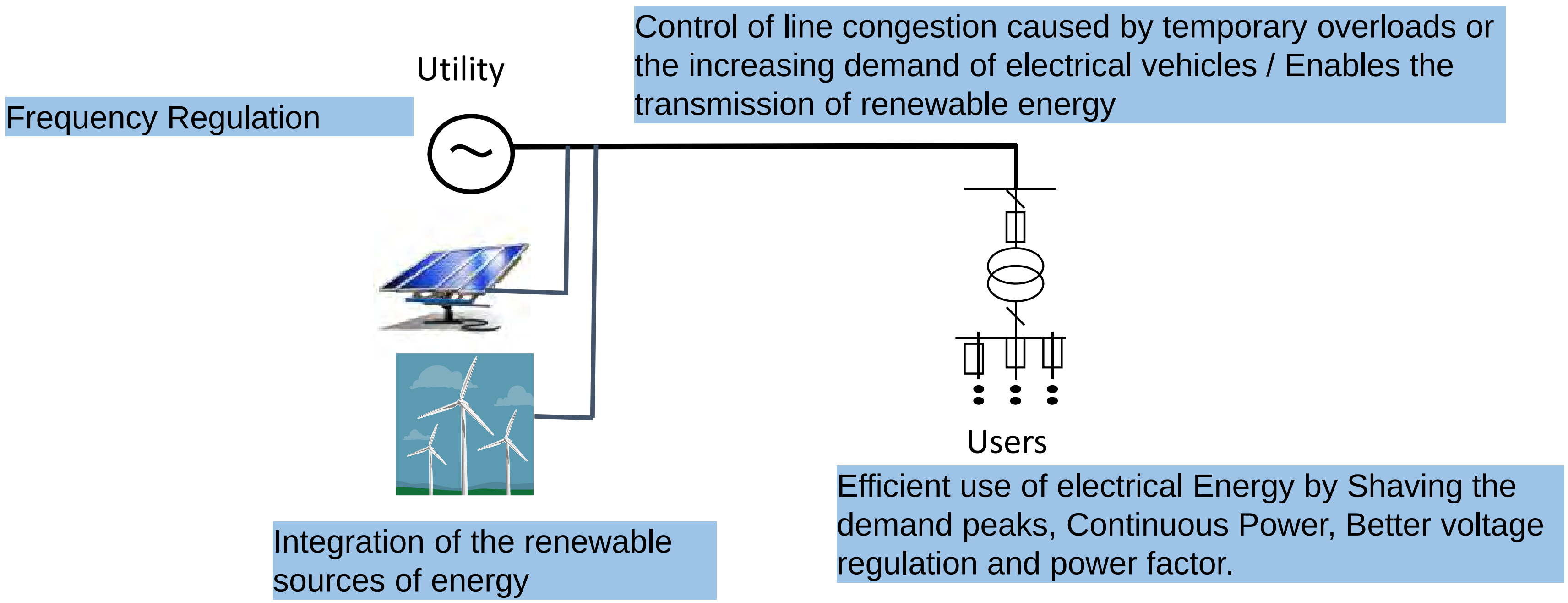
Summary according to ESA





Applications
Summary

The additional electrical power provided by the Energy Storage System (ESS) helps the network to overcome the operational issues and enhance its performance.



Answering the challenge of today's marketplace in the

Age of Intelligence™

Thank You