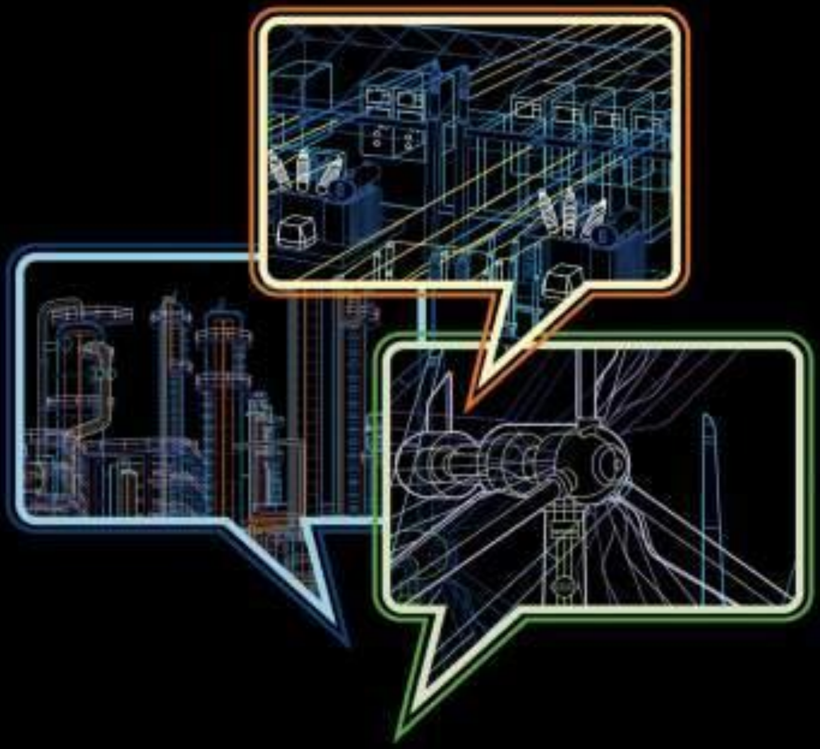

ABB Automation & Power World: April 18-21, 2011

WPO-109-1
Distributed energy storage
Enhances distribution network performance

WPO-109-1
Distributed energy storage

- Speaker name: Pedro C. Elizondo
- Speaker title: Global Product Marketing Manager
- Company name: ABB Inc
- Location: Lake Mary, FL-USA

Co-presenter

- Speaker name: Pablo Rosenfeld
- Speaker title: DES Project Manager
- Company name: ABB Inc
- Location: Lake Mary, FL-USA

Safety tips

Your safety is important to us
Please be aware of these emergency procedures

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- In the event of an alarm, please proceed carefully to the nearest exit. Emergency exits are clearly marked throughout the hotel and convention center.
- Use the stairwells to evacuate the building and do not attempt to use the elevators.
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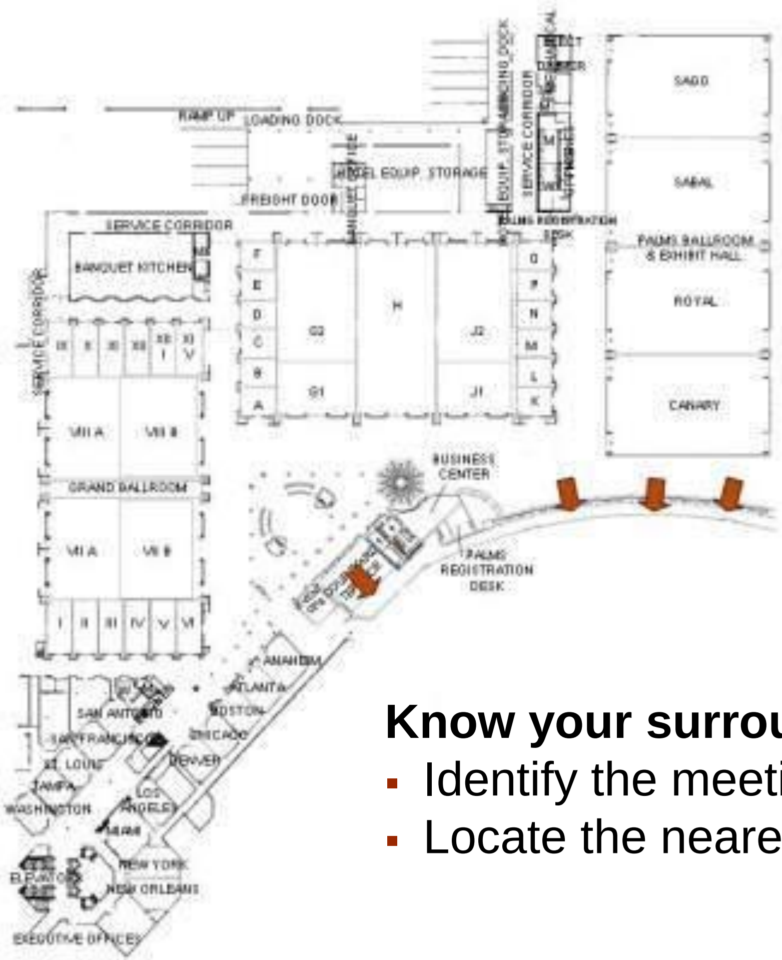
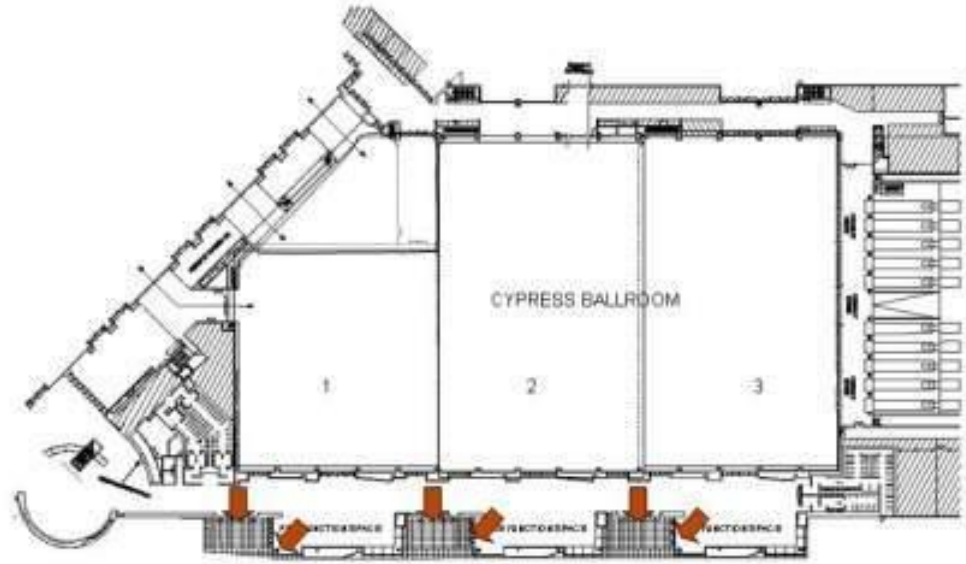
Your safety is important to us
Convention Center exits in case of an emergency





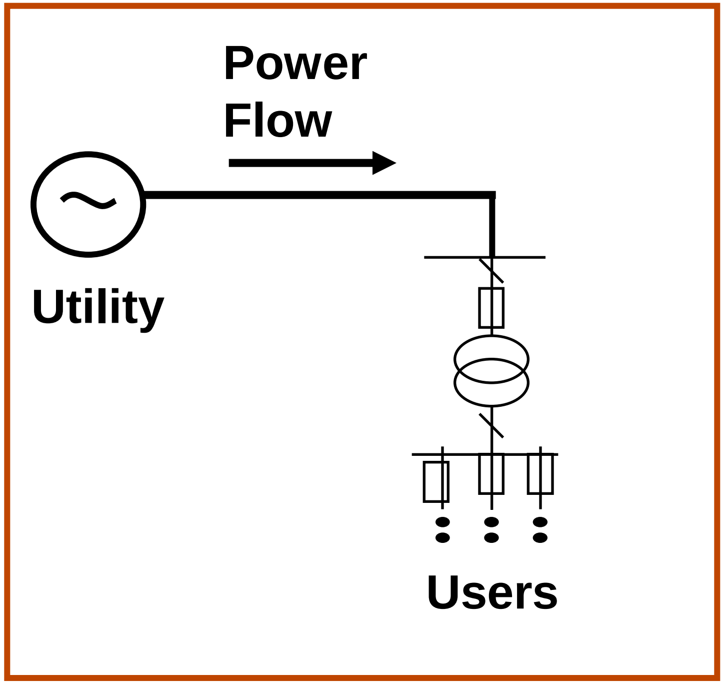
Know your surroundings:
- Identify the meeting room your workshop is being held in
- Locate the nearest exit

Distributed energy storage

Optimizes renewable energy and enhances distribution energy performance

Distributed energy storage
Network issues

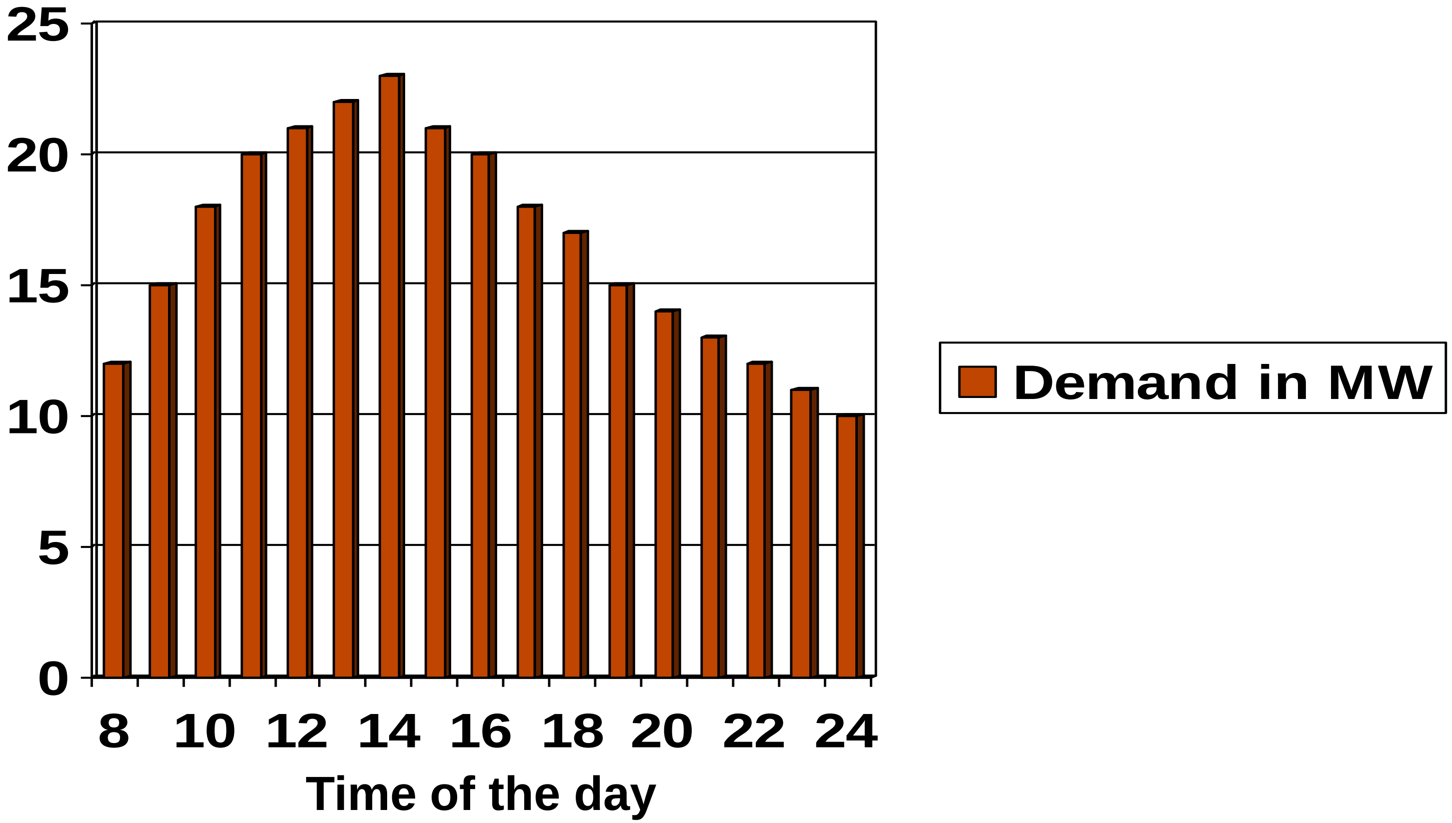
Power generation and consumption
Introduction



- Utility would like to supply power on a smooth continues basis, **with no peaks and valleys** which **require a large swings in the amount of generating equipment** being called into service.

Power generation and consumption
Introduction

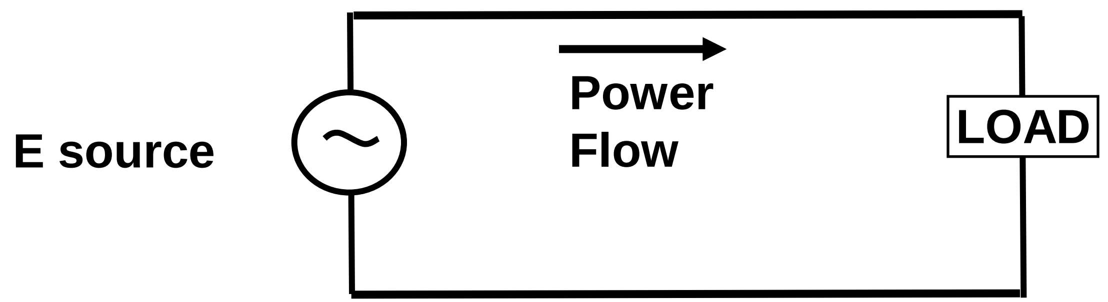
- The reality is that loads are not constant

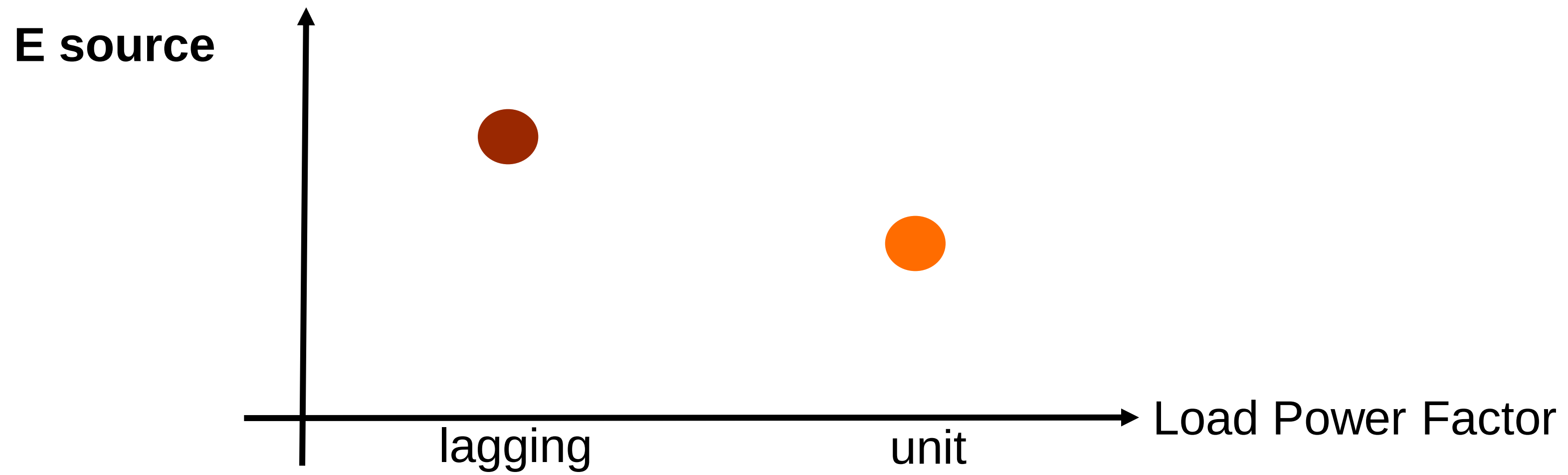


Typical Electrical Energy Consumption Pattern / Commercial

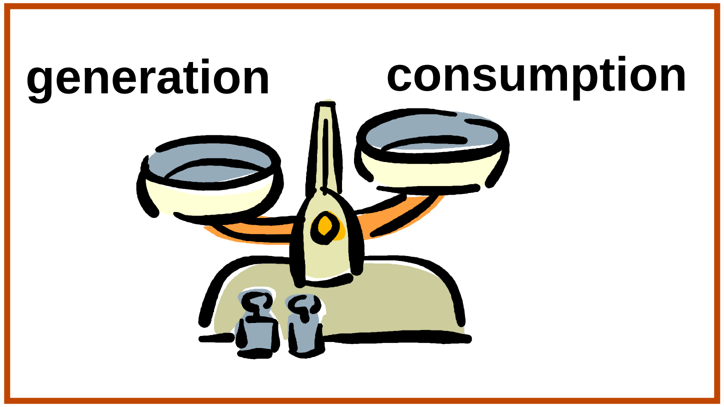
Power generation and consumption
Introduction

- Loads have different Power Factor





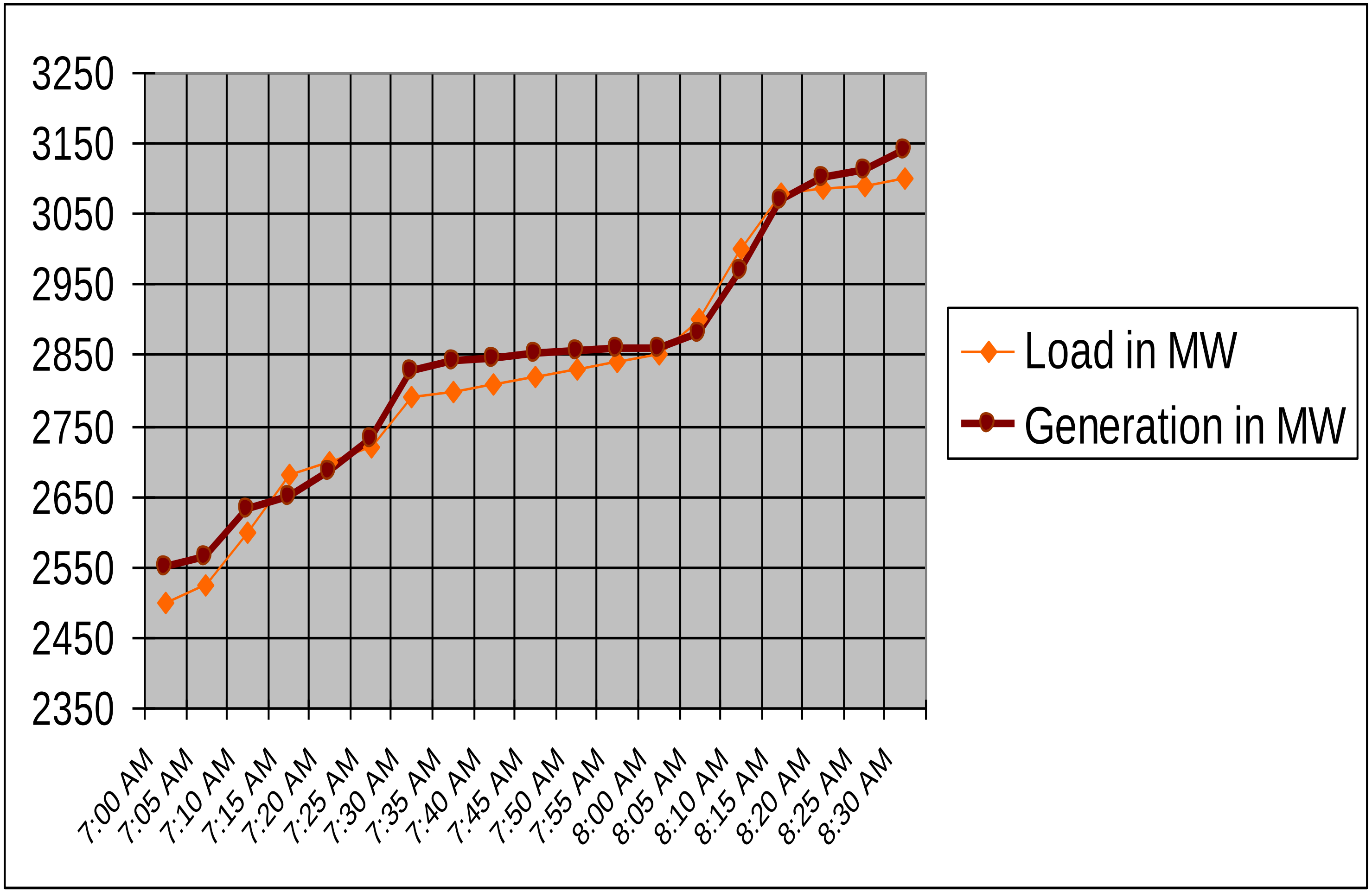
Power generation and consumption
Energy balance



- The electricity market requires that power generation and consumption are perfectly balanced.
- The challenge is to **maintain a near real-time balance between generation and consumption**.
- In absence of energy storage, at each moment **the electrical energy consumed should equal the electrical energy generated.**

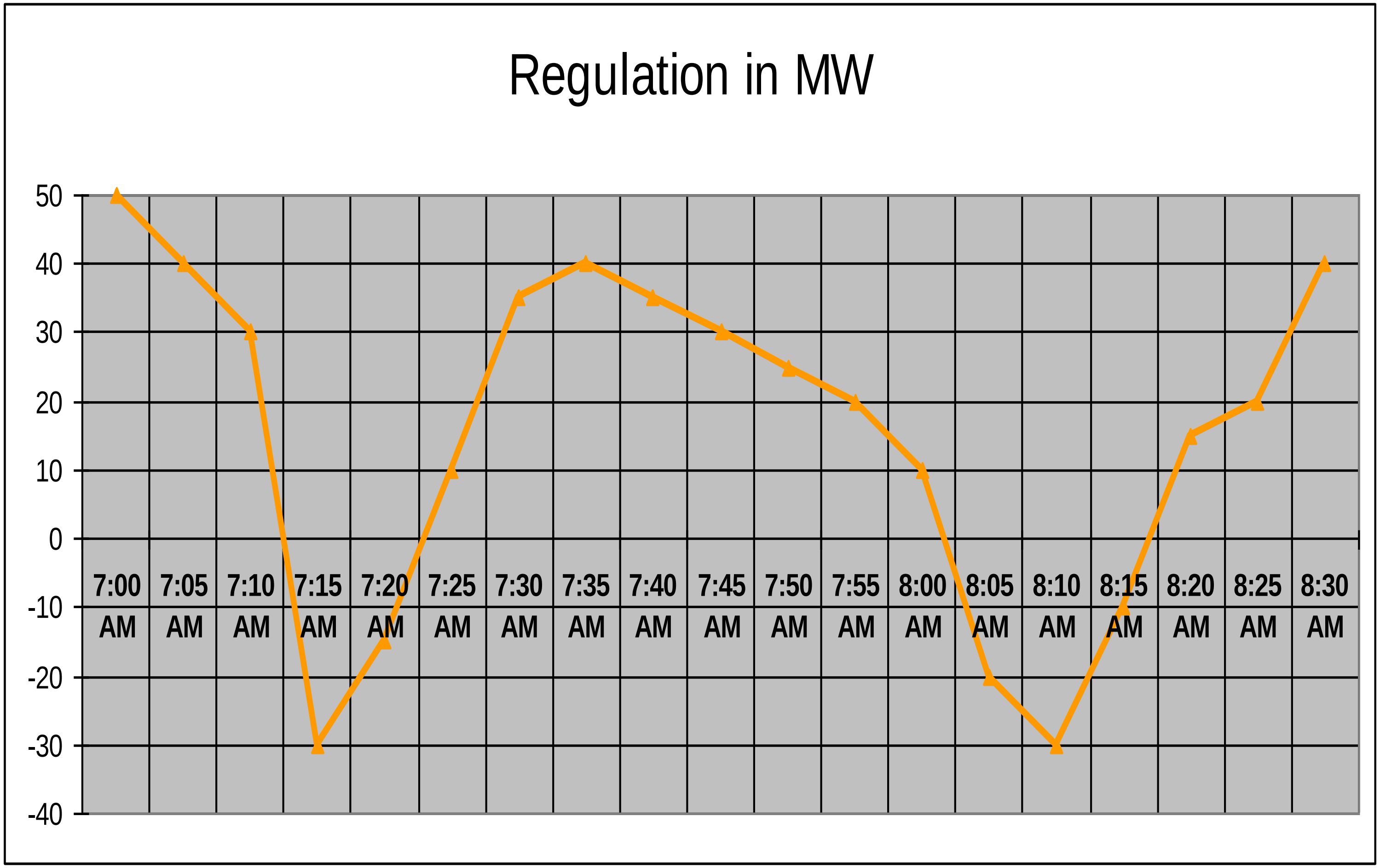
Power generation and consumption
Energy balance challenge

Balancing generation and load instantaneously and continuously is difficult because the **loads and generator are constantly fluctuating**



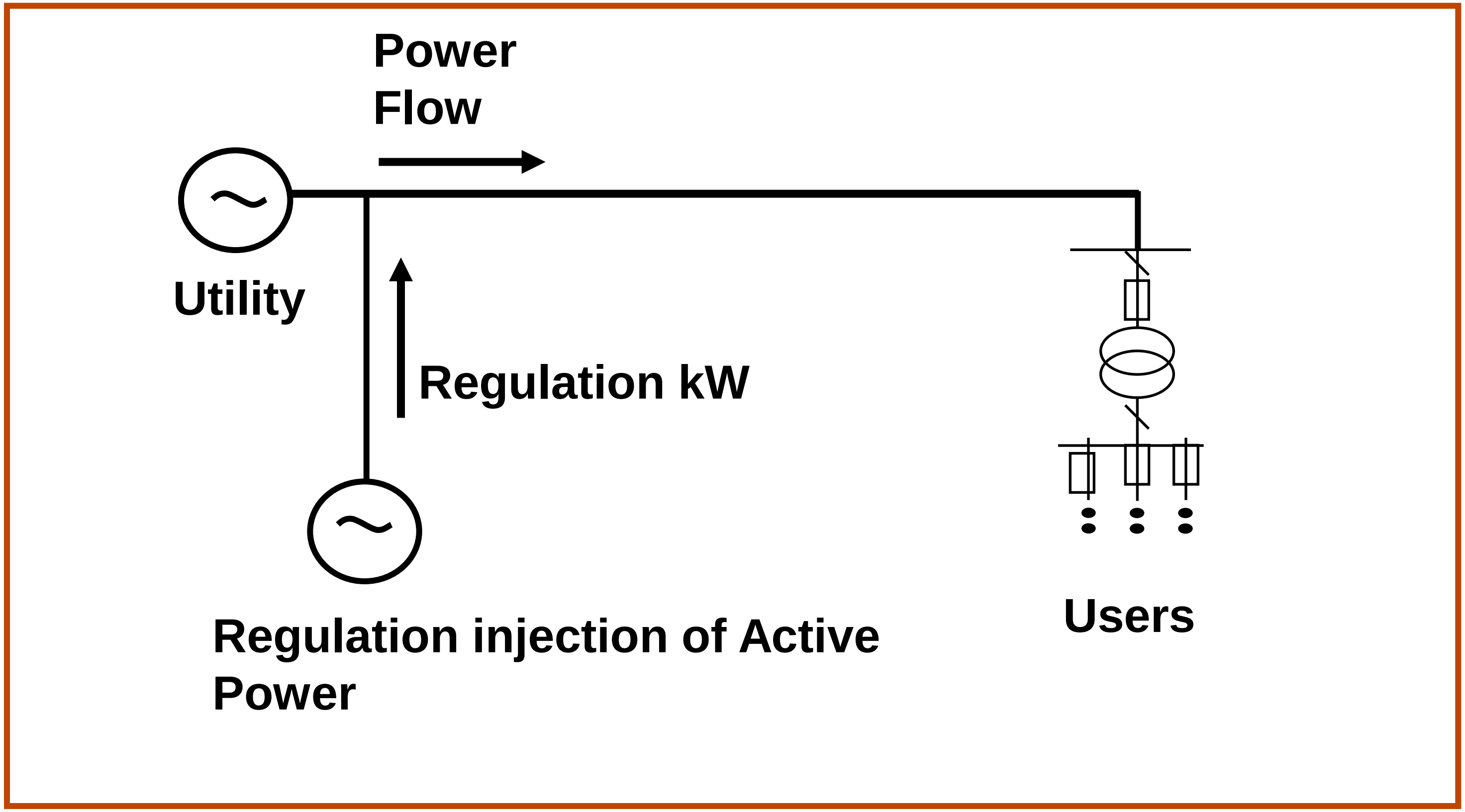
Power generation and consumption
Regulation and load following

Regulation helps to balance the generation and load within the control area

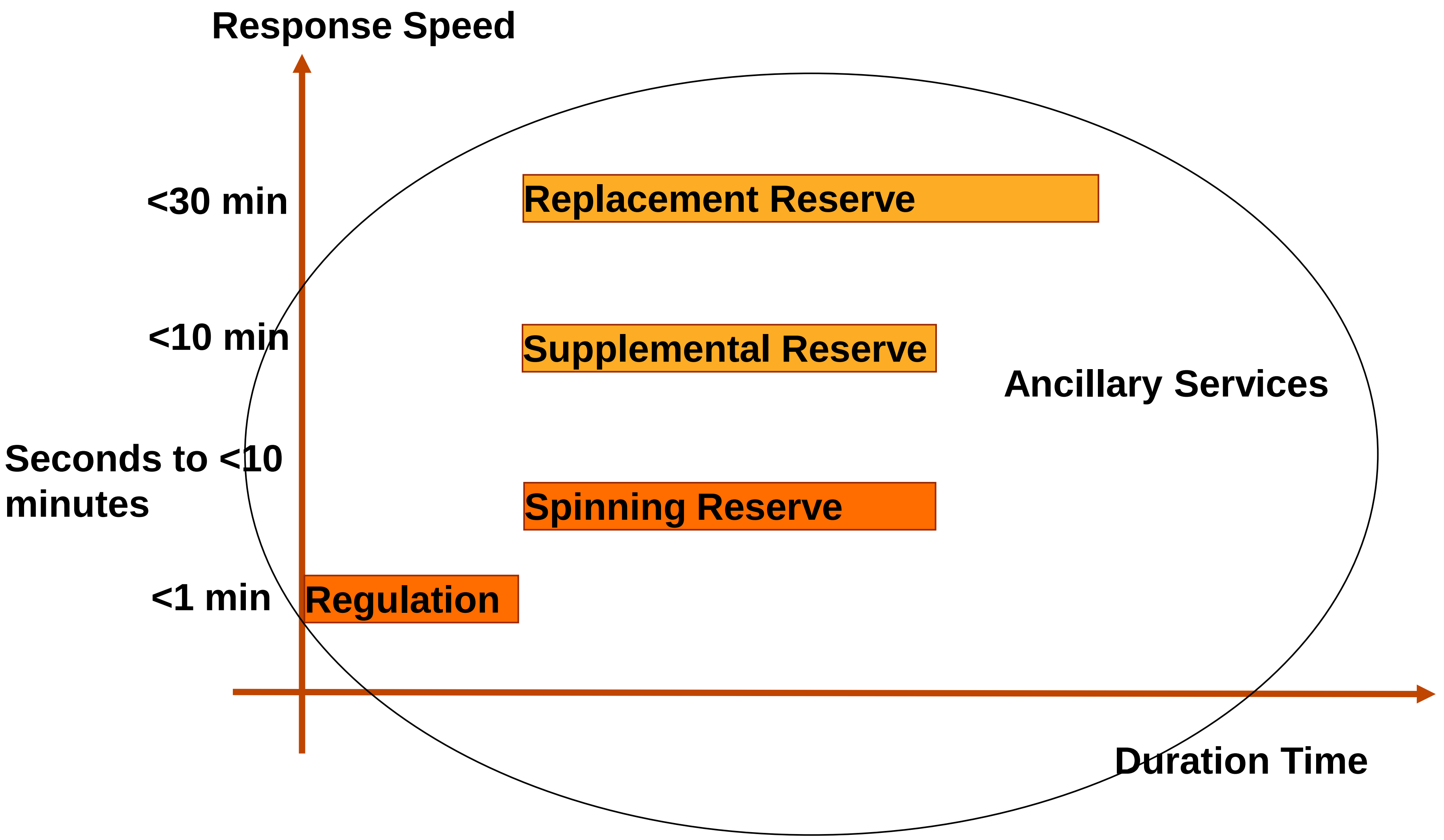


Power generation and consumption Regulation requires fast response time

- Match generation to load within the control range
- Fast response time (<1 minute), Duration typically 10 minutes.

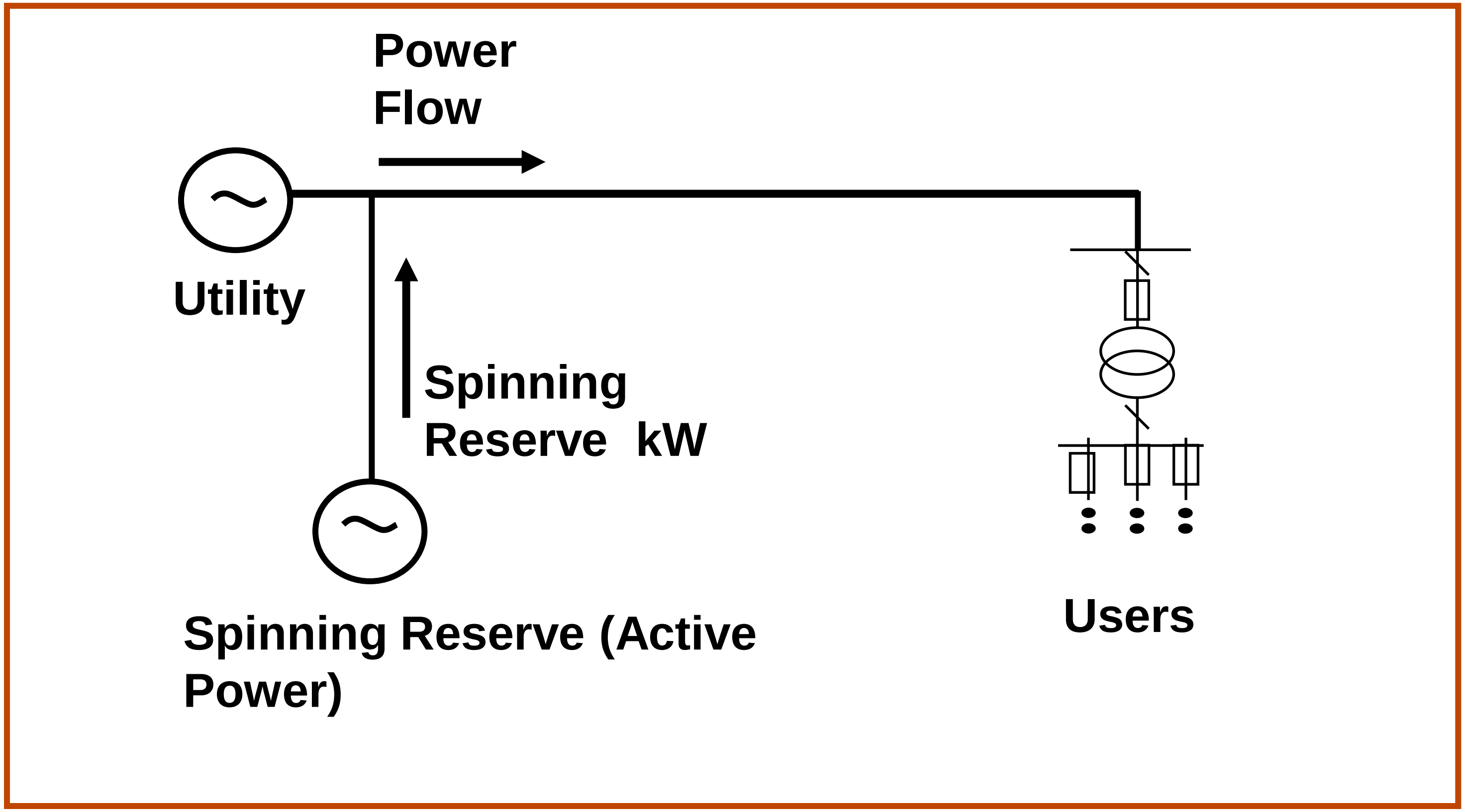


Power generation and consumption
Ancillary Services

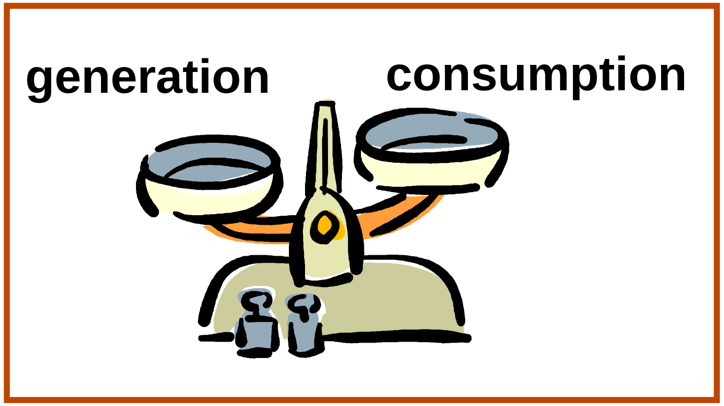


Power generation and consumption
Spinning reserve

- **The unused capacity which can be activated on the decision of the system operator**. Response time: seconds to 10 minutes. Duration from 10 to 120 minutes.



Power generation and consumption
Ancillary services helps to achieve energy balance

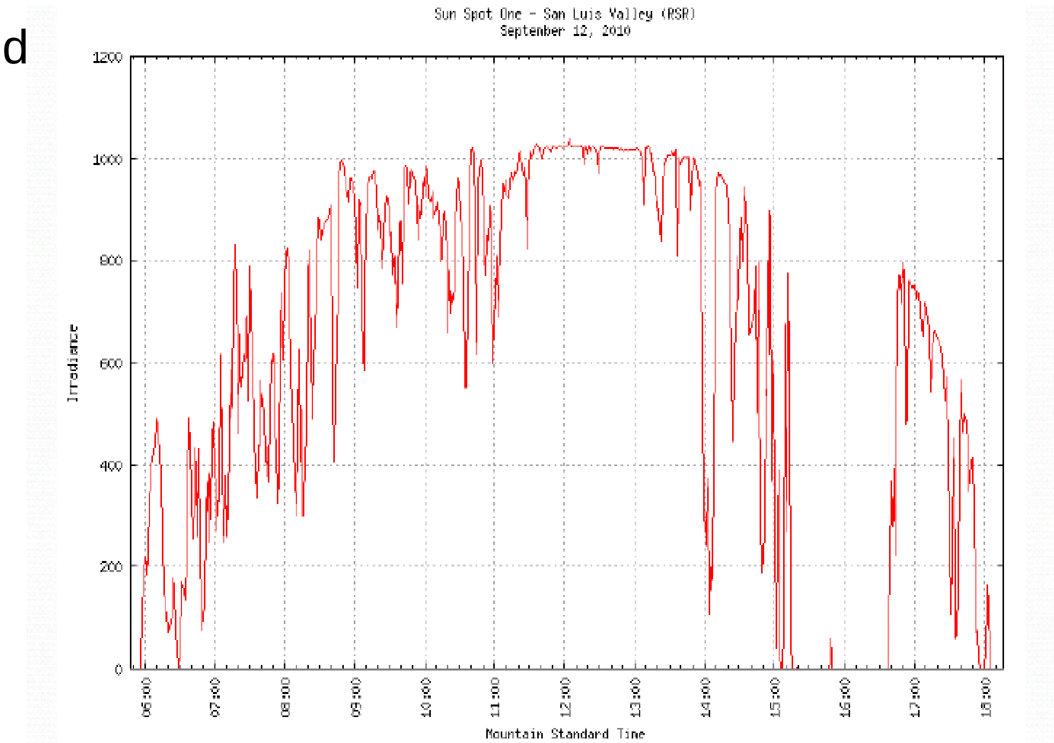


- Ancillary services are capacity services rather than energy services
- Faster response has greater value to the network
- Generators reduce output in order to create room to supply power for regulation
- When a generator supplies regulation, it moves above and below a base operation point

Power generation
Renewable source of energy = Variability

• Proliferation of intermittent renewable energy around the world such as wind and solar energy

San Luis Valley Solar Data (09/12/2010) Bad Day [1]



"Courtesy of Dr Frank S Barnes - University of Colorado at Boulder"

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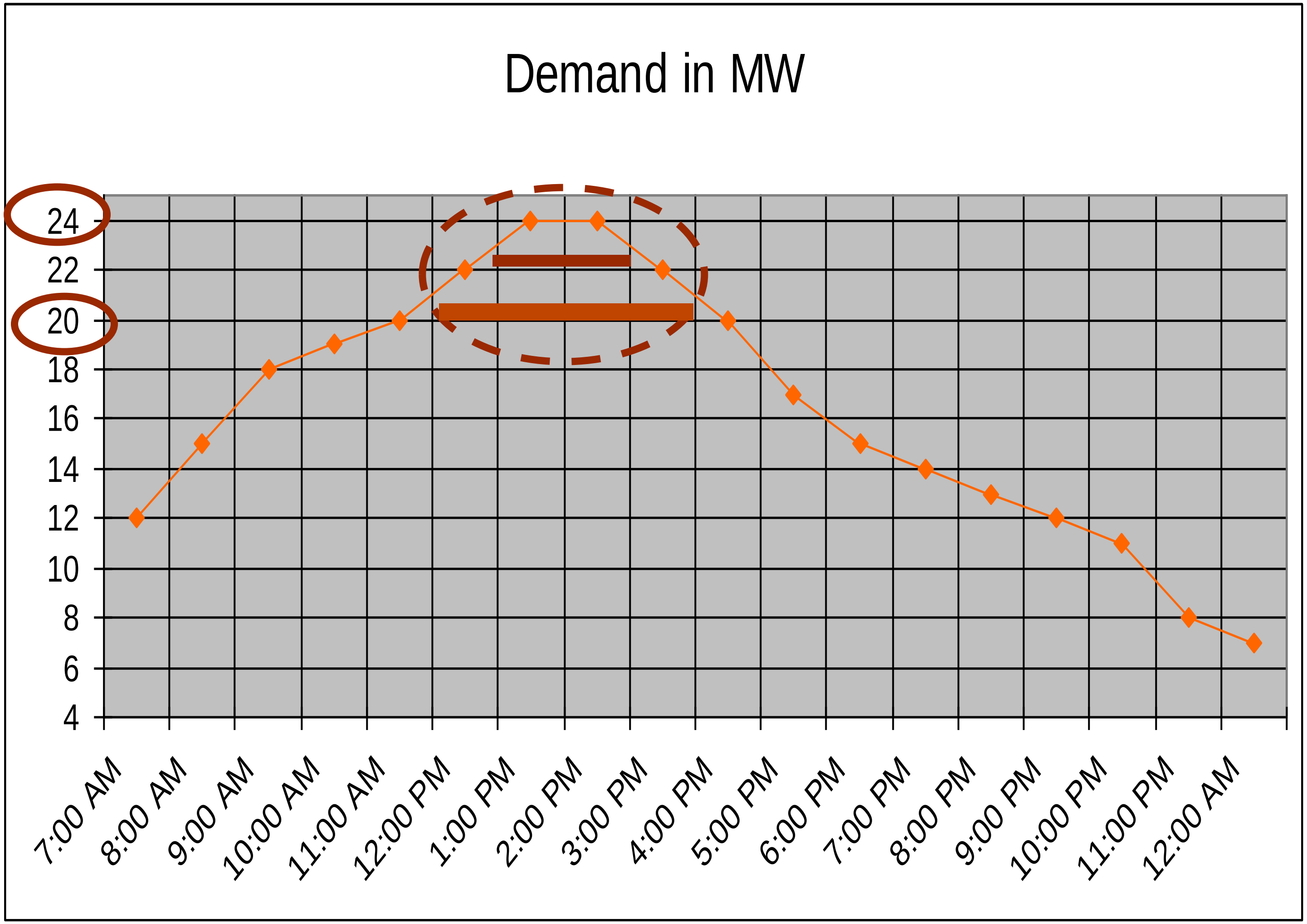
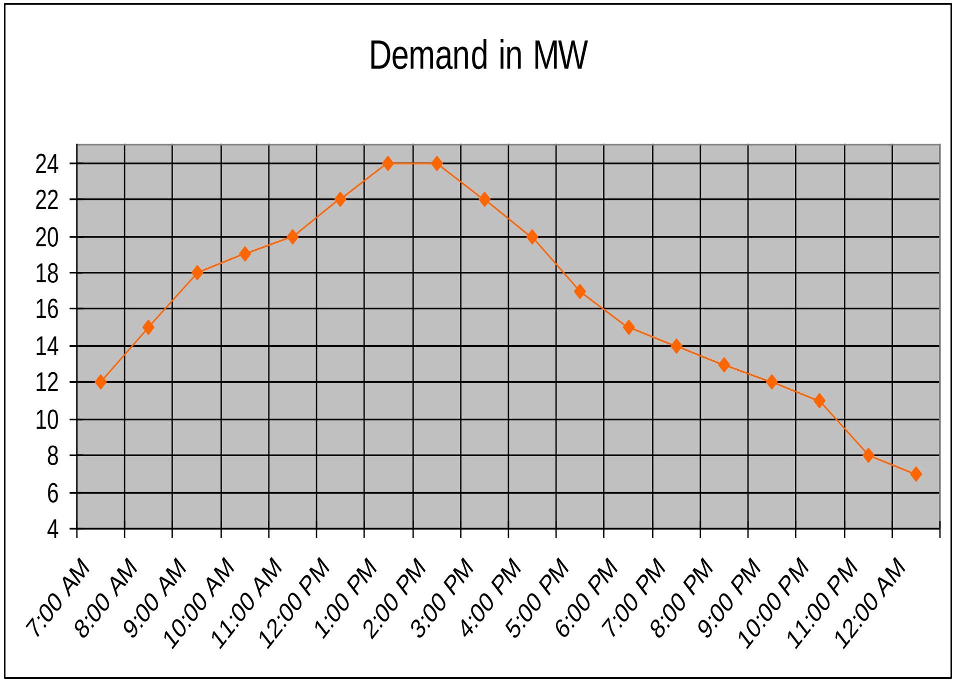
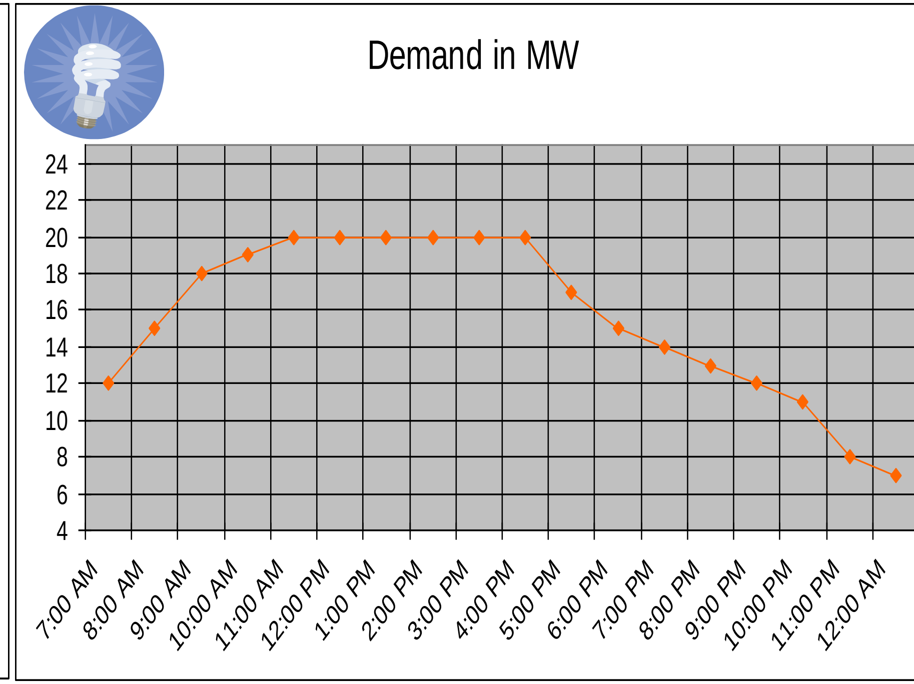
Power consumption
Demand and efficiency with which electricity is used

- The current design practice is to build and support a power network designed the meet the highest peak load of the year



Power consumption
Demand and efficiency with which electricity is used





- **Demand profile 1**
- **Demand profile 2**

- **Demand profile 2 is more efficient**
- **Load Factor Profile 2 > Load Factor Profile 1**

Distributed energy storage

What are the drivers of energy storage?

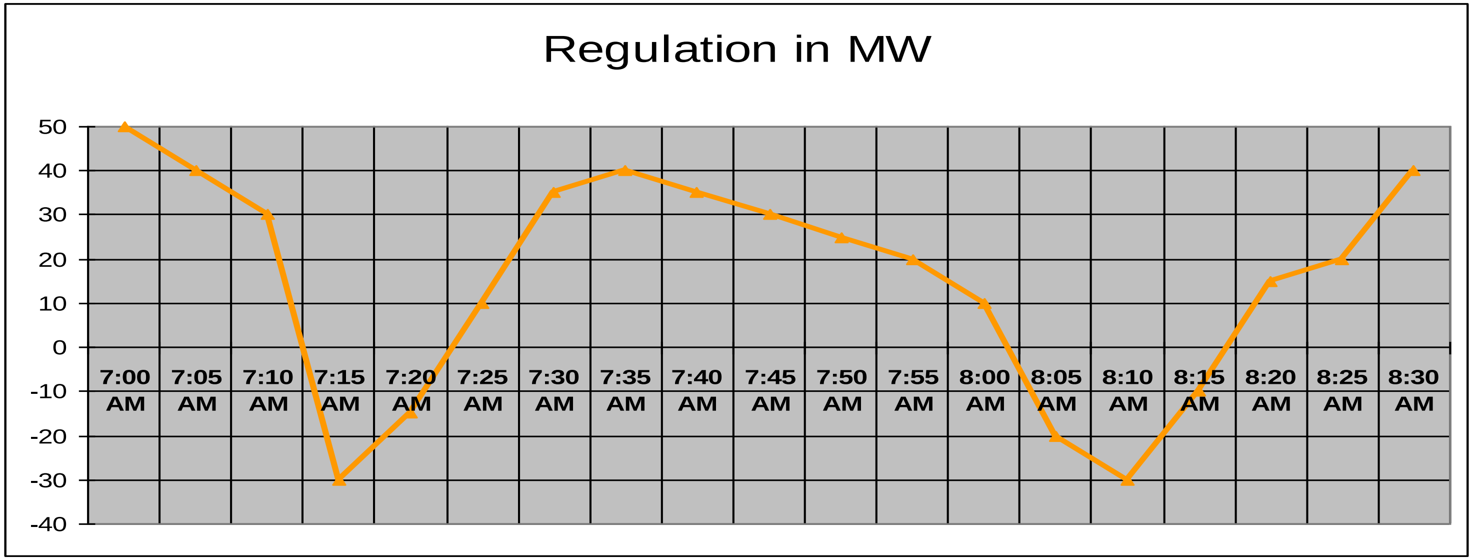
What is driving energy storage? Reliable and fast ancillary services = Service continuity

- Power **system reliability depends upon the ancillary services** to maintain the **balance between generation and consumption**
- Fast response time, cyclical operation and rapidly control unit makes the **Regulation the most expensive ancillary service**

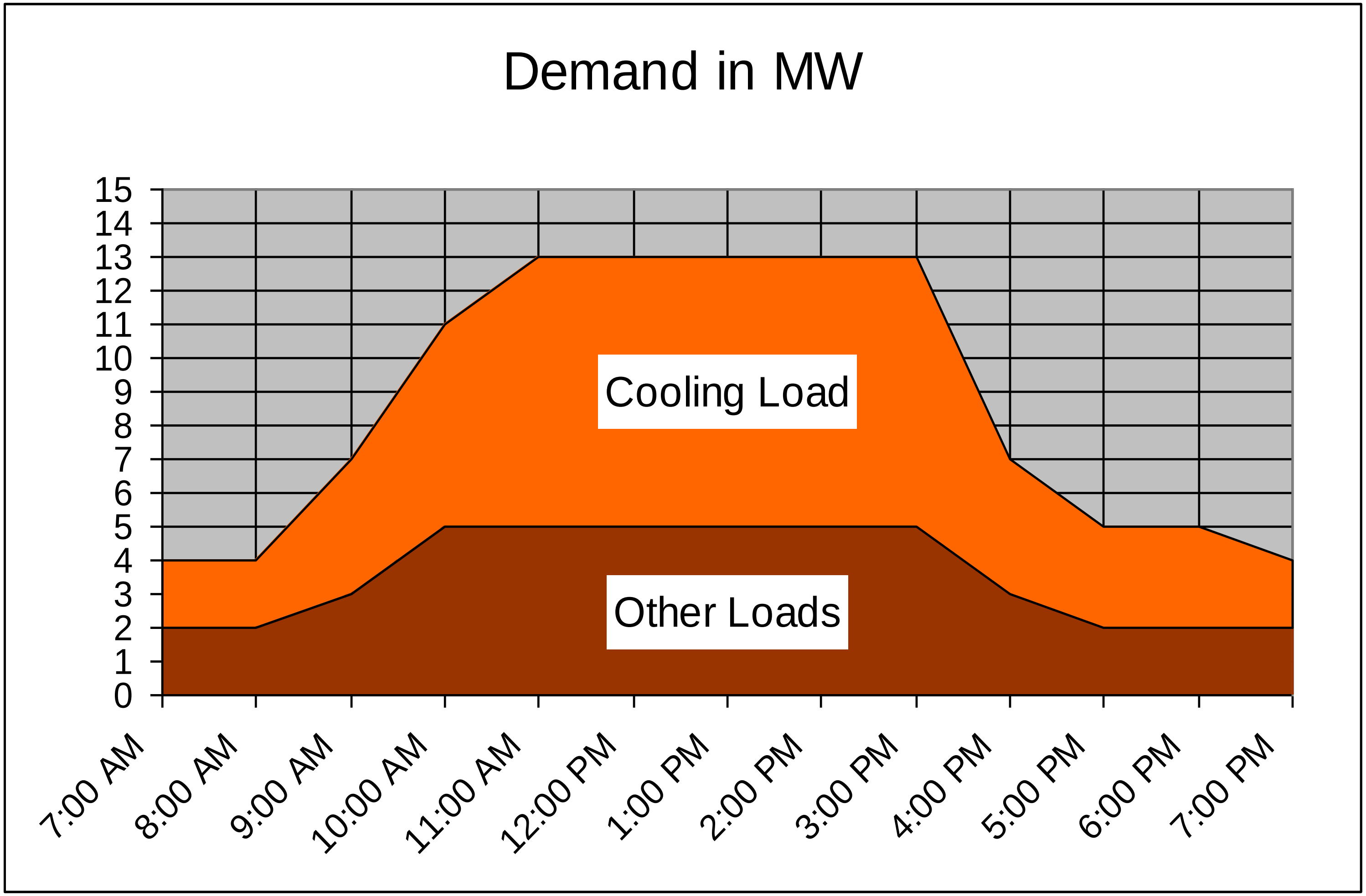
What is driving energy storage? Regulation service: Faster response has greater value to the network

Some **storage technologies can be excellent regulation providers** :

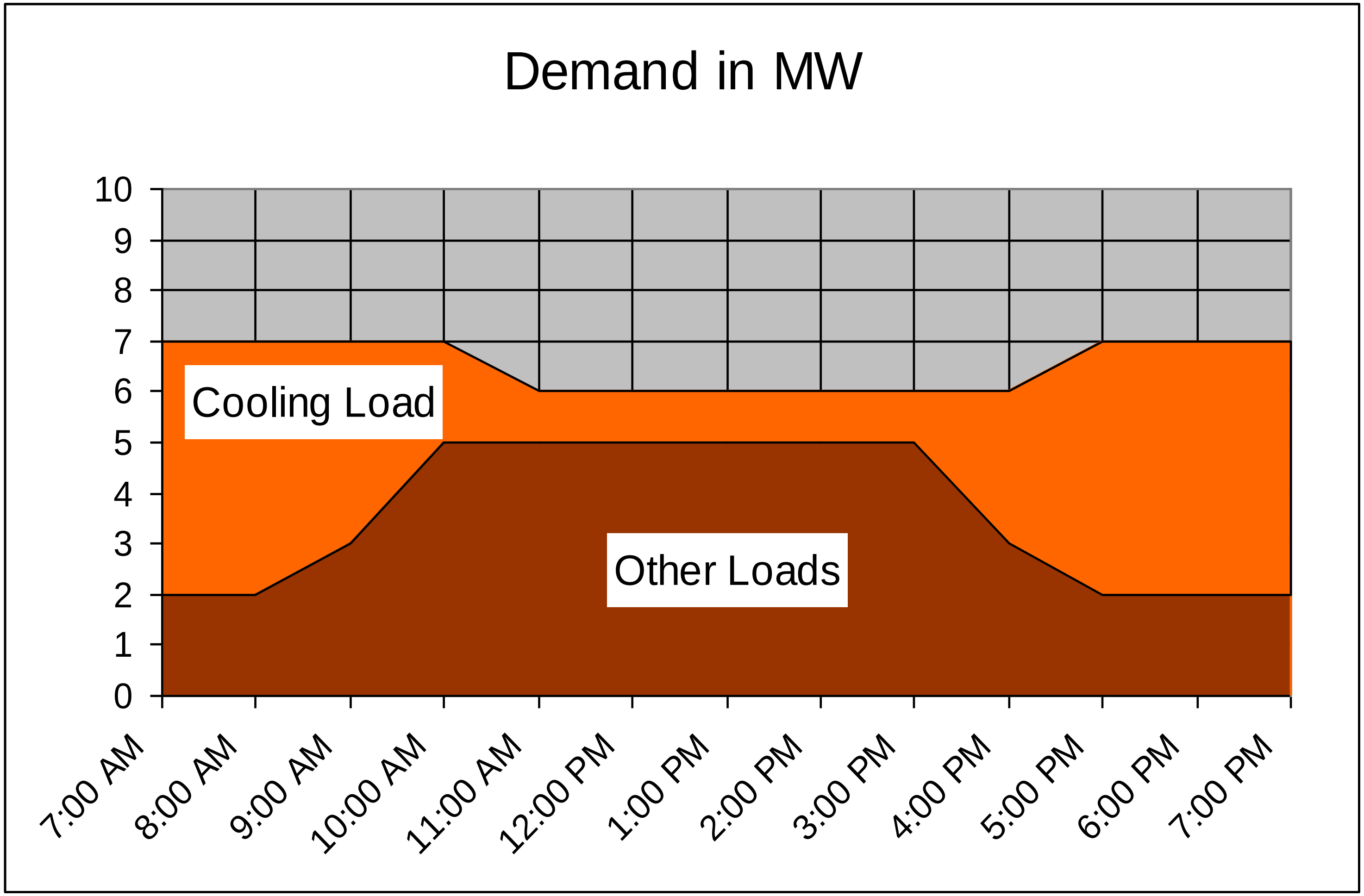
- It matches a zero net energy resource with a zero energy net energy service
- Quick response and precise control
- Technologies that can perform repeated high cyclic storage without affecting the rated performance are the best fir for regulation service



What is driving energy storage?
Efficient use of electrical energy = Demand management



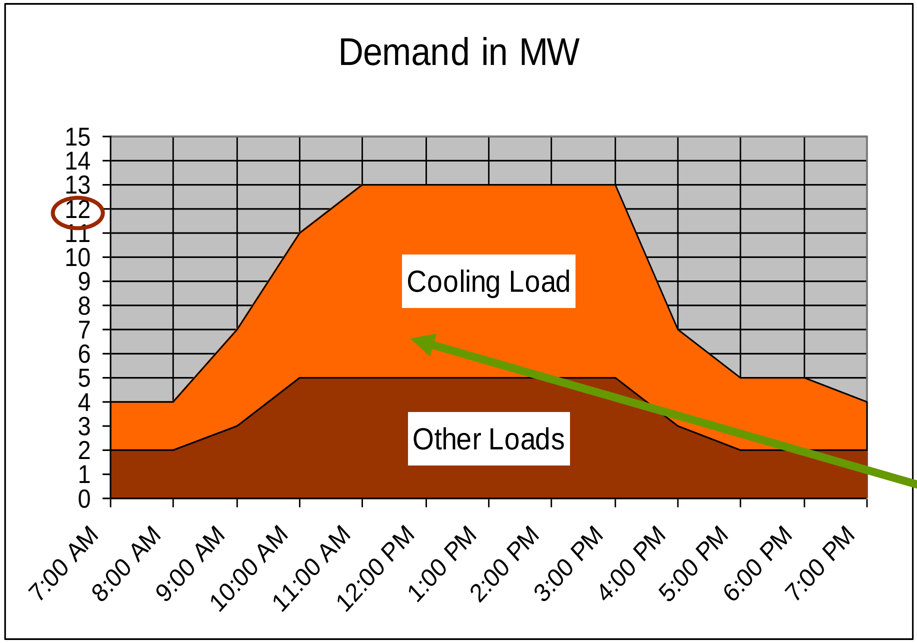
What is driving energy storage?
Efficient use of electrical energy = Demand management



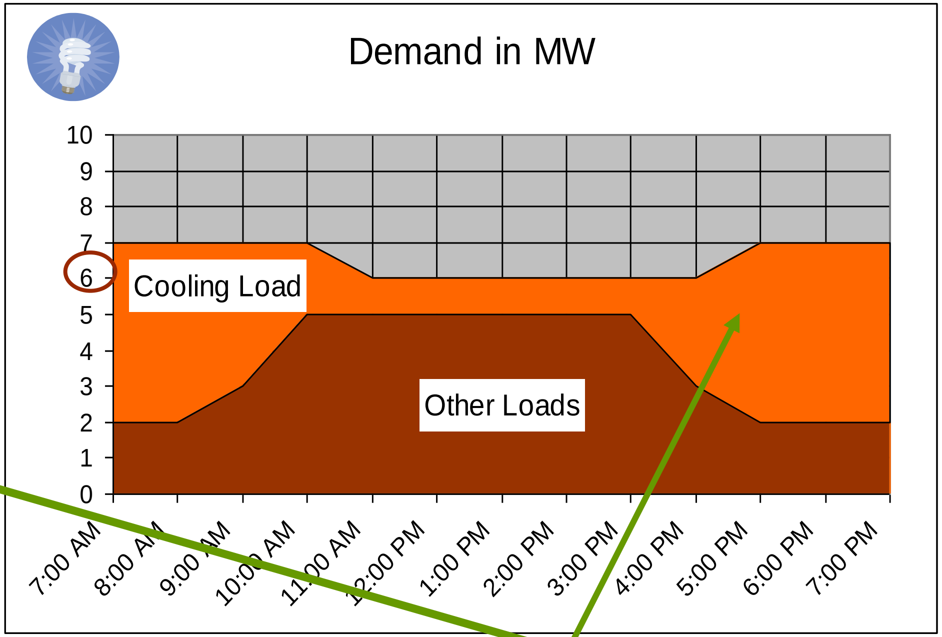
What is driving energy storage?

Efficient use of electrical energy = Demand management

- **Demand profile 1**

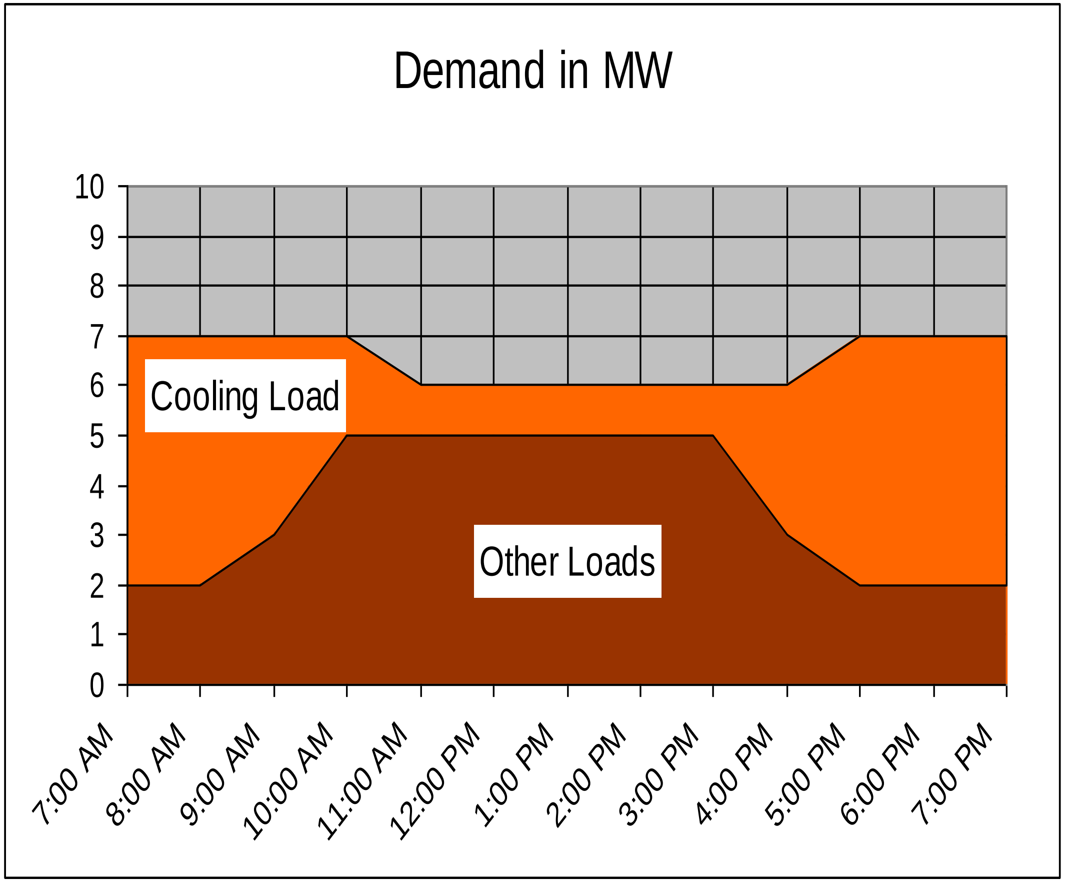


- **Demand profile 2**



- 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 = $\frac{\text{Energy Used in KW-hr / Time (hours in billing period)}}{\text{Maximum Demand in kW}}$
- **Load Factor profile 2 >load factor profile 1**

What is driving energy storage? Efficient use of electrical energy, Smart Grid

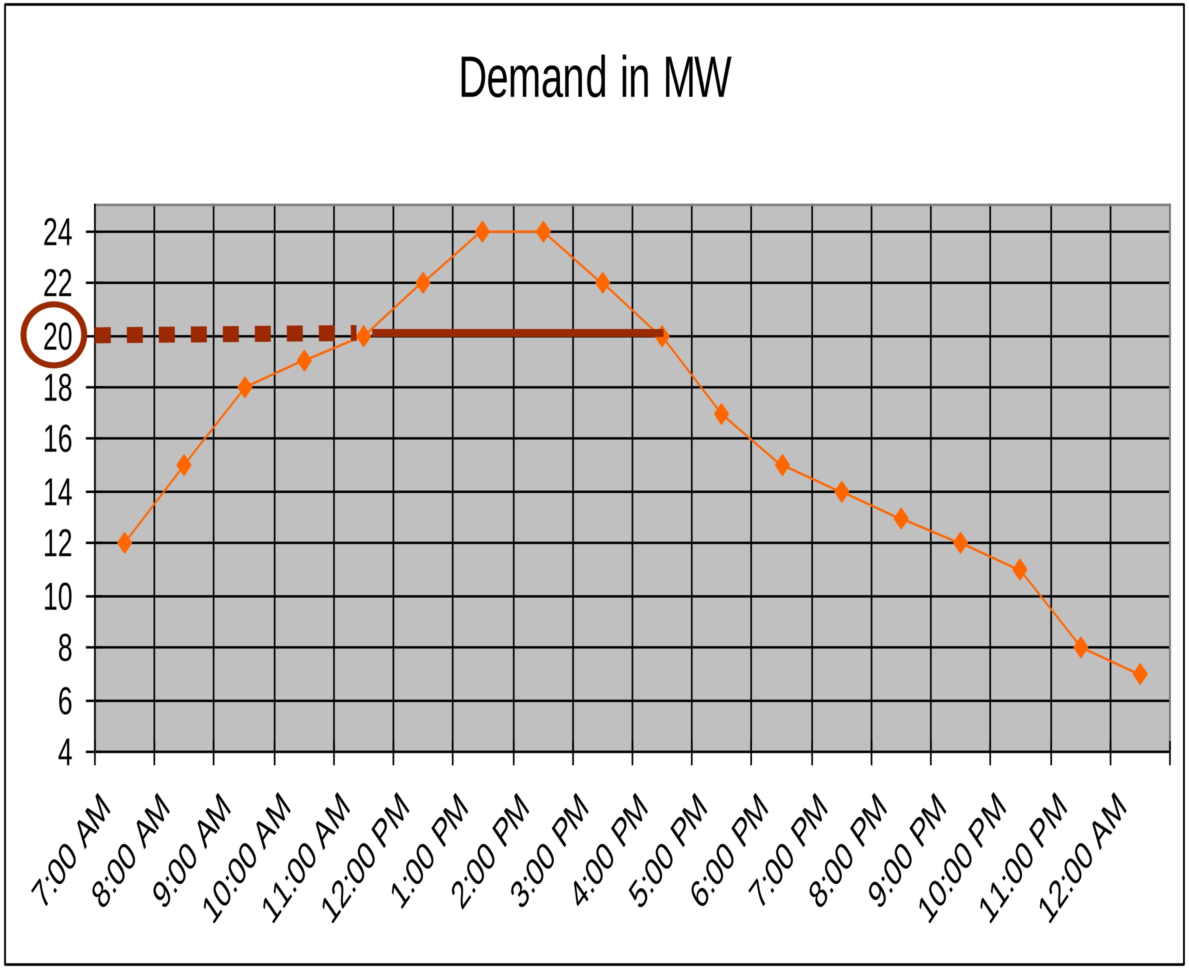


- For utilities this means **lowering the generation cost** and **maximize the assets of the network such as transformers and the power grids**
- For users is to **lower the electrical bills through the management of the energy** consumption and demand

What is driving energy storage?
Efficient electrical energy use = Deferral of Investments

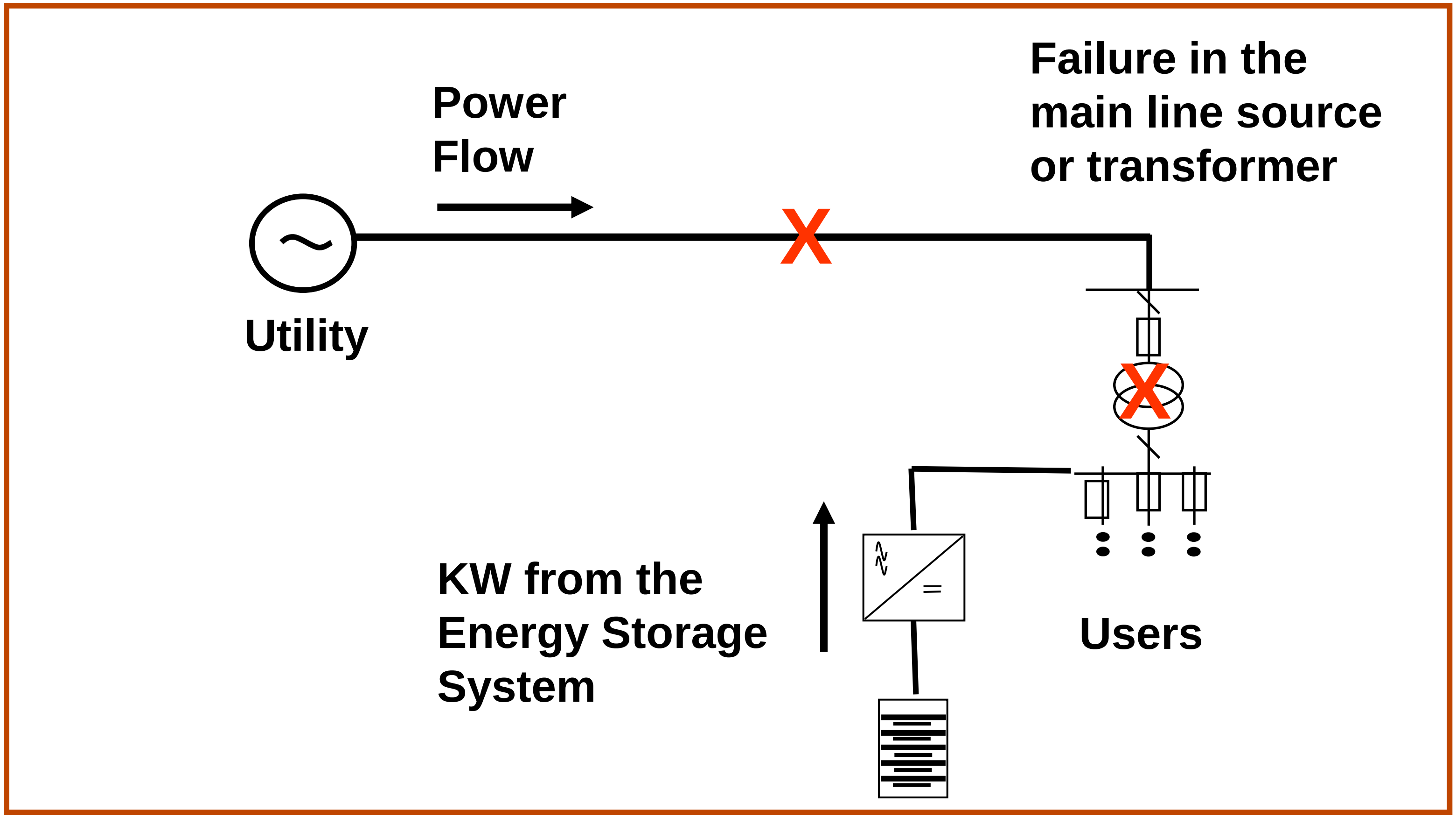
If the demand peaks are shaved > higher load factors:

- Deferral of new generation capacity
- Deferral of new transformer
- Deferral of new distribution and transmission lines
- Reduce fuel use > Increase environmental benefits

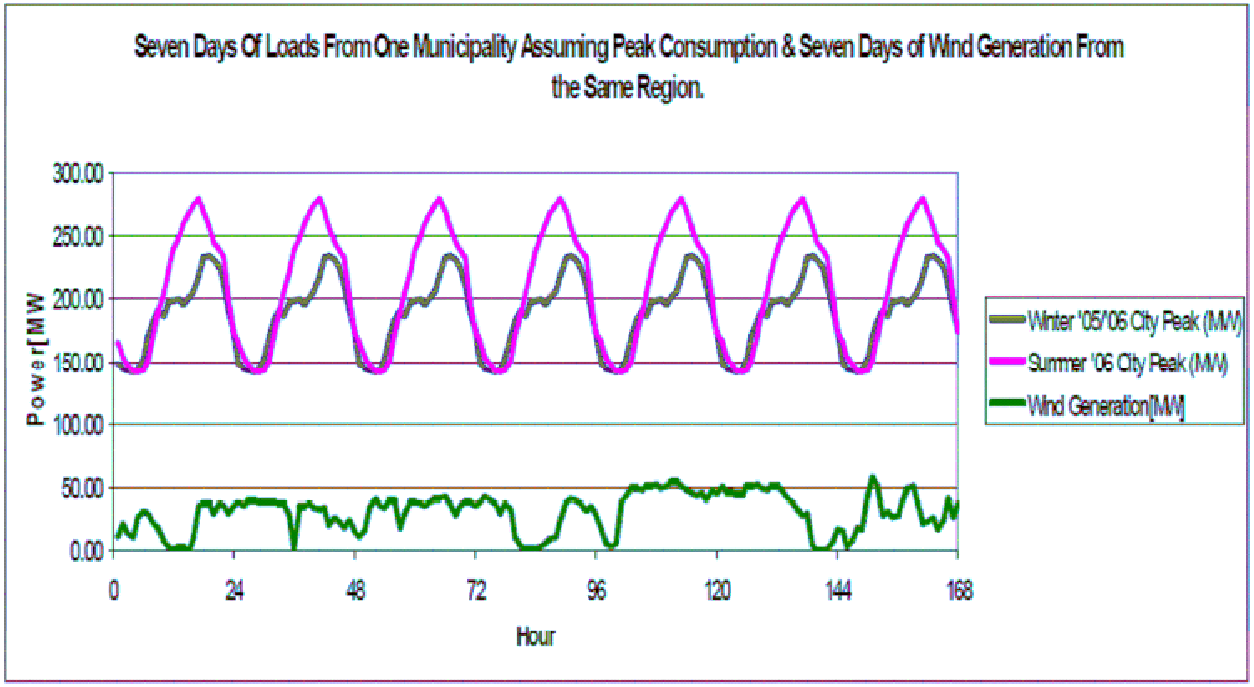


What is driving energy storage? Reliability

- Storage will allow loads to operate through outages



What is driving energy storage?
Proliferation of solar and wind energy sources



"Courtesy of Dr Frank S Barnes - University of Colorado at Boulder"

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**.

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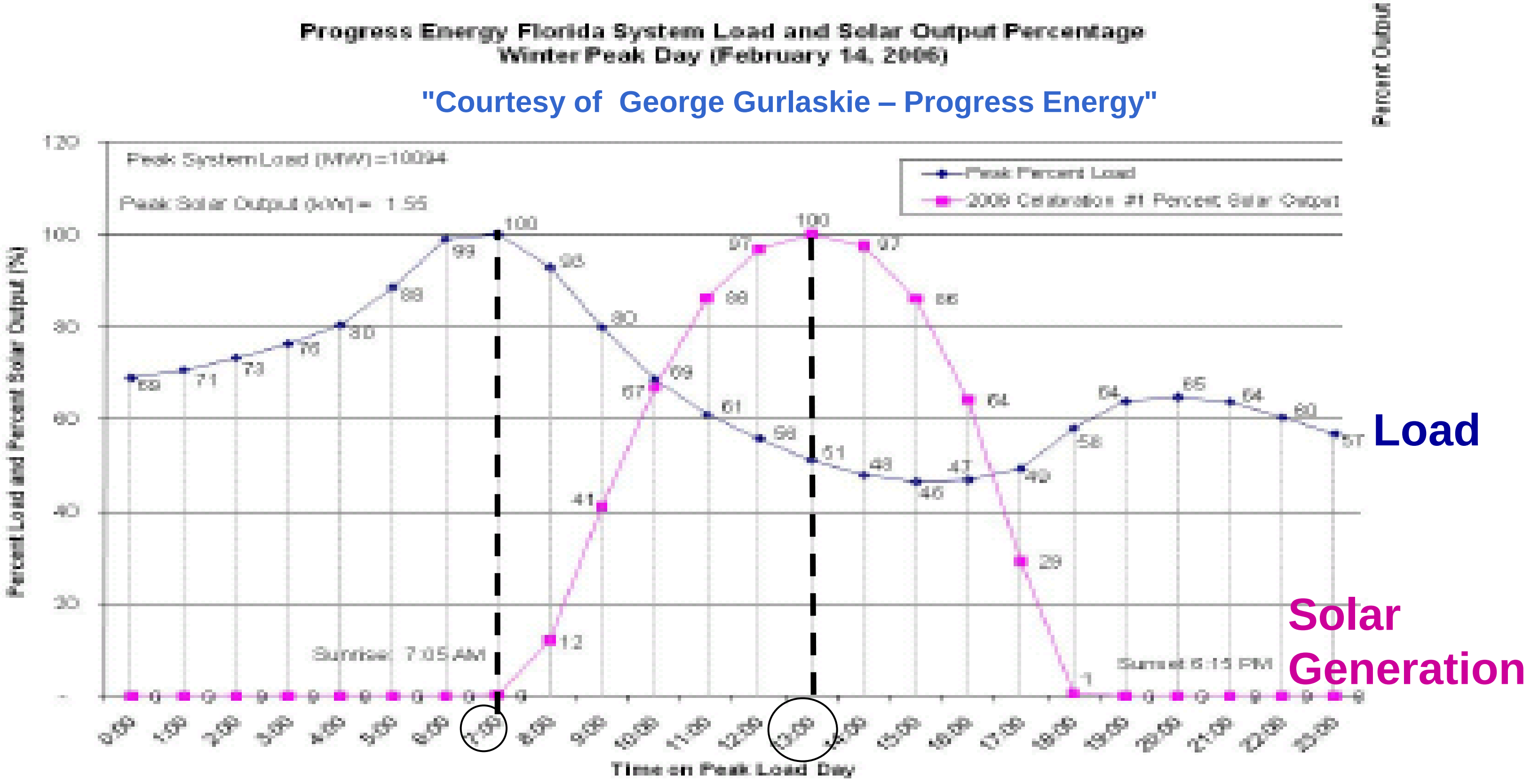
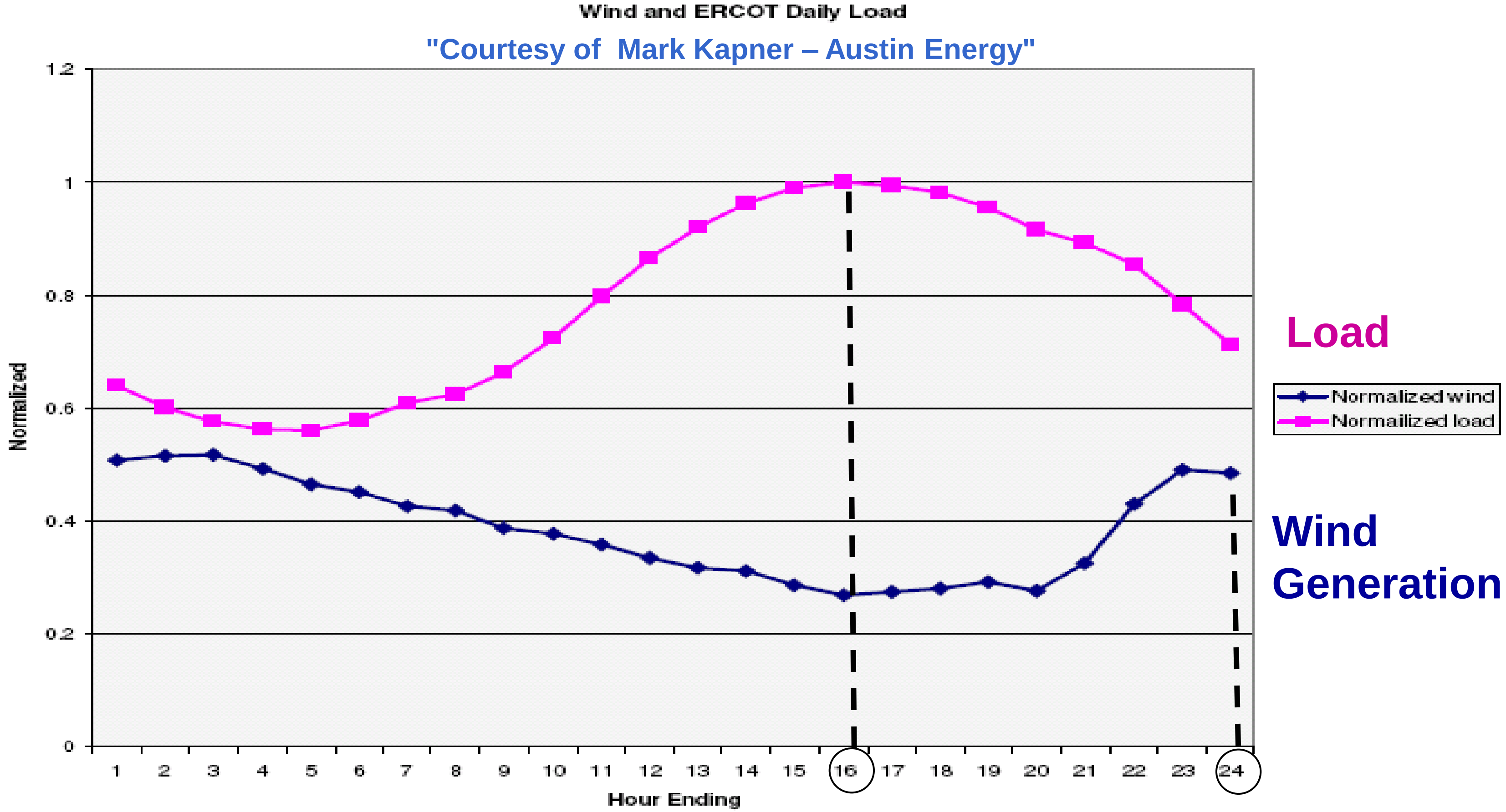
What is driving energy storage?
Solar generation's capacity peak



•Solar generation peak is not aligned with load's demand peak

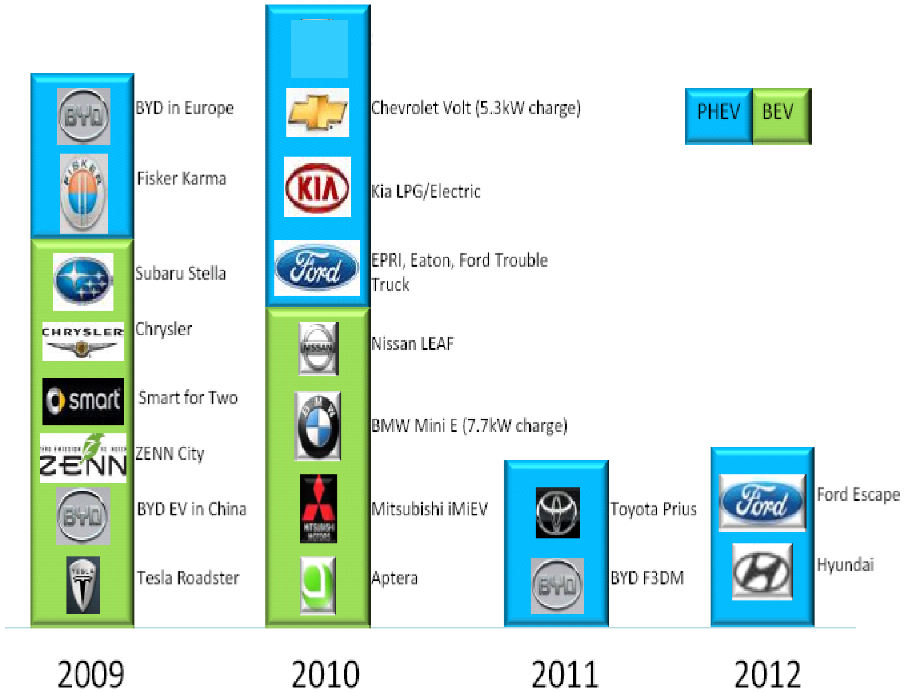
What is driving energy storage? Wind generation's capacity peak

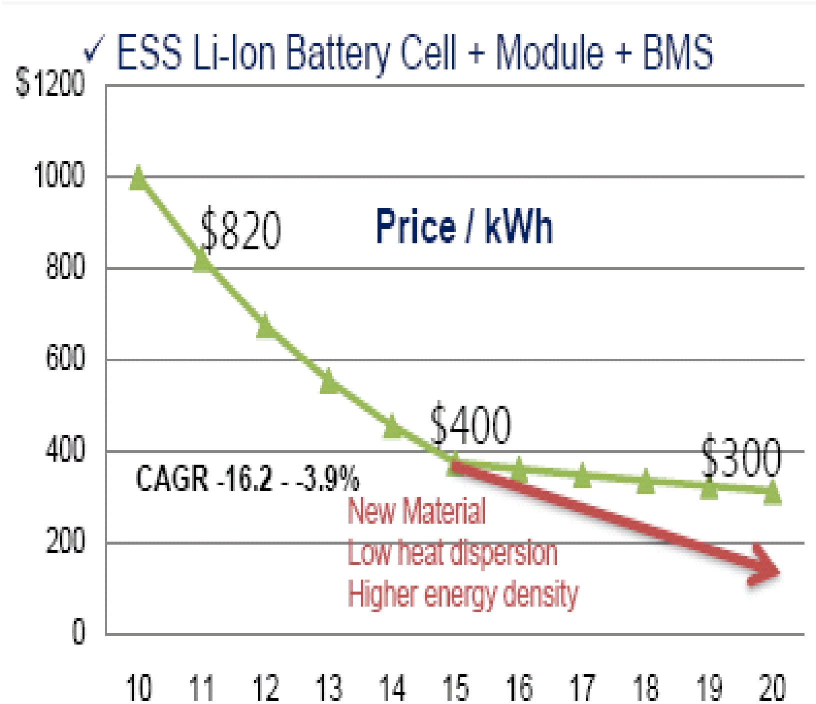


Wind generation peak is not aligned with load's demand peak

- The U.S. Department of Energy (DOE) estimates that, **for every gigawatt (GW) of wind capacity added, 17 megawatts (MW) of spinning reserves must also be built to account for the system's variability.**

What is driving energy storage?
Rollout of Electrical Vehicles (EV)





- •EV charging will stress out the distribution system
- •EV roll out will increase batteries volume and reduce cost

What is driving energy storage?
Rollout of Electrical Vehicles (EV)

The New York Times

September 21, 2010

GM Looks to Give EV Batteries a Life After Cars

By JENNY MANDEL of

General Motors Co. and power electronics company ABB Group will work together to research how used electric car batteries can gain a second life on the nation's power grid, the companies said today.

As electric vehicles creep toward general market readiness, automakers and grid experts are looking for ways to make electrified transportation work seamlessly with power systems. Finding new markets for car batteries that are no longer fit for vehicles could trim the cost they add to auto manufacturing, while also providing energy storage options for utilities.

"The Volt's battery will have significant capacity to store electrical energy, even after its automotive life," said Micky Bly, GM's executive director of electrical systems, hybrids, electric vehicles and batteries, in announcing a research tie-up between the two companies that will focus on GM's all-electric car due out this year. "Our relationship with ABB will help develop solutions that optimize the full life cycle of the Volt battery."

What is driving energy storage?
Incentives

- **AB 2514 -** California Assembly had just passes the bill AB 2514 that set a deadline by 2012 to set objectives for the utilities to invest in energy storage projects (all technologies).

- **Storage act (1091 – pending) –** the storage act will amend tax code to create incentives for energy storage deployment.

- **SGIP** (Self generation Incentive program), provides financial incentives ($ 2/watt) for installation of storage (behind the meter) combined with wind turbines and fuel cells.

What is driving energy storage? Incentives

- **EISA 2007 –** Requires Council to develop a 5 year plan (by Dec 2009) for storage as a tool to manage variability and capacity concerns. Directs DOE to conduct a cost sharing R&D.

- **ACELA (1462) –** Peak demand reduction and load shifting goals with tools like demand response technologies (smart grid technology, dynamic pricing, distributed generation, energy storage).

- **US government (DOE)** has granted (cost shared) USD 585 million for project totalizing 533 MW of energy storage (large batteries, compressed air, frequency regulation, CES).

Distributed energy storage

Components

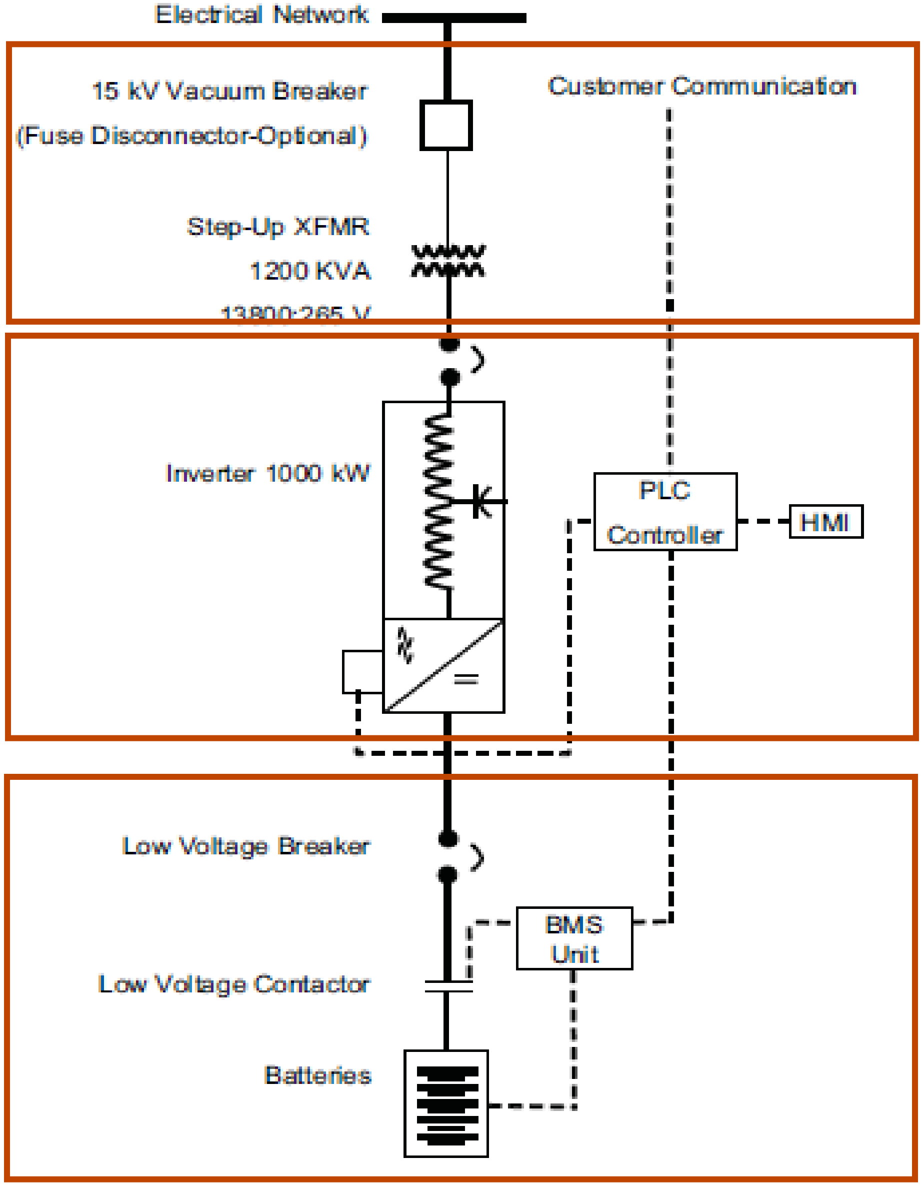
DES components

The energy inverted into AC power can be connected to the electrical network at low (<1000 Volts) or medium voltage(<40.5 kV).

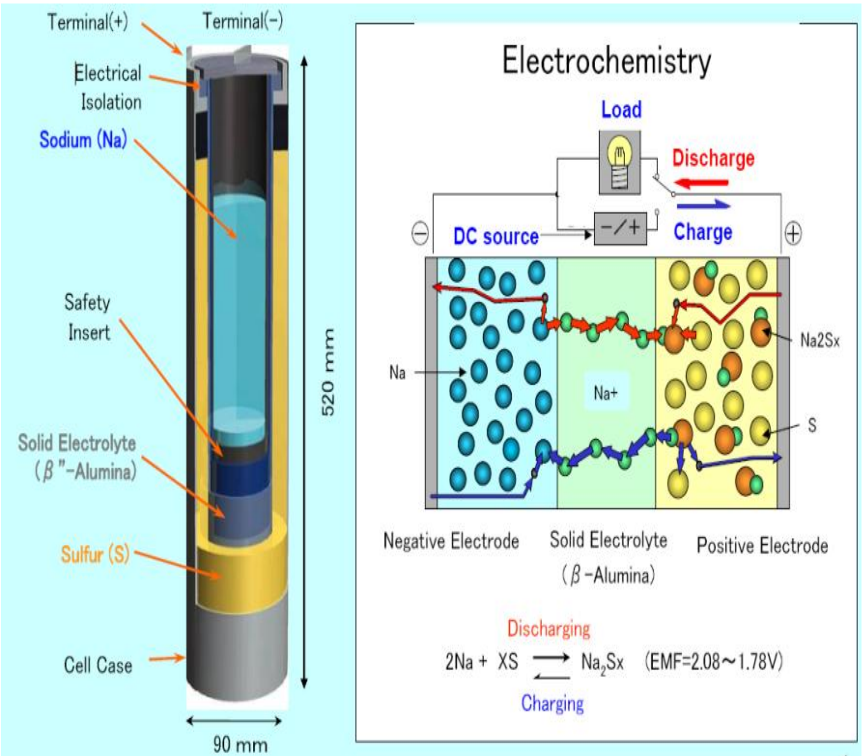
Inverters rectify the AC energy into DC to store in the batteries and then invert the DC energy into AC energy, single or three phase at 50 or 60 Hertz .

Some of the battery types are: Lead-acid, Li-Ion, Ni-Cd, Zinc Bromine, NaCl-Ni among others.

The BMS (**B**attery **M**anagement **S**ystem) measures the battery parameters to control the operation in order to extend the battery life and increase the safety of the system.

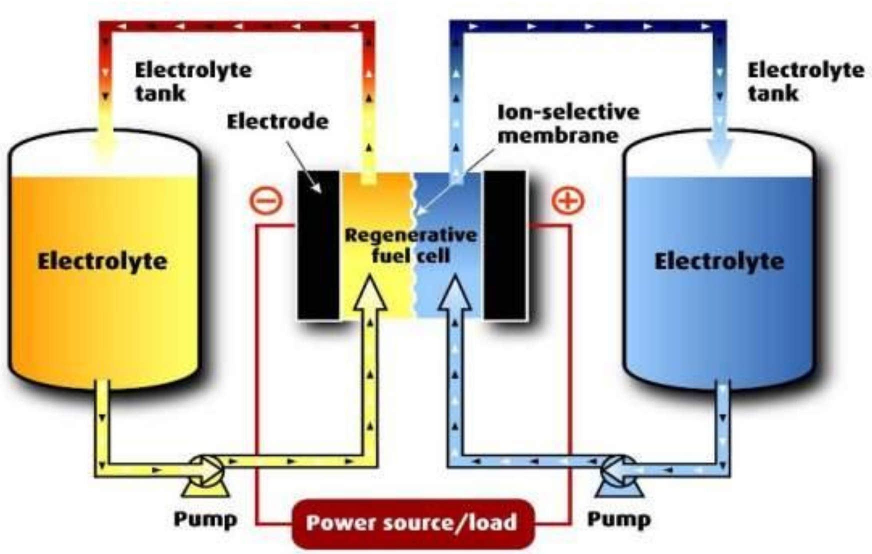


Batteries – Battery technology - NAS



- **Advantages**
  - Abundant and low cost raw materials
  - Proven reliability: > 200 large installations
  - Excellent life time: 15 years, 4500 cycles
  - High energy density of module: 124 Wh/l (same as Li-Ion modules)
  - Battery containers – no need for building
- **Disadvantages**
  - Difficult to produce the high grade ceramics
  - Sole manufacturer is NGK in Japan
  - High temperature: runs at 330°C
  - Only limited cool downs permitted (around 20 times)
  - Low power density of 21 W/l
  - Fast discharge is not possible

Batteries – Battery technology - Flow

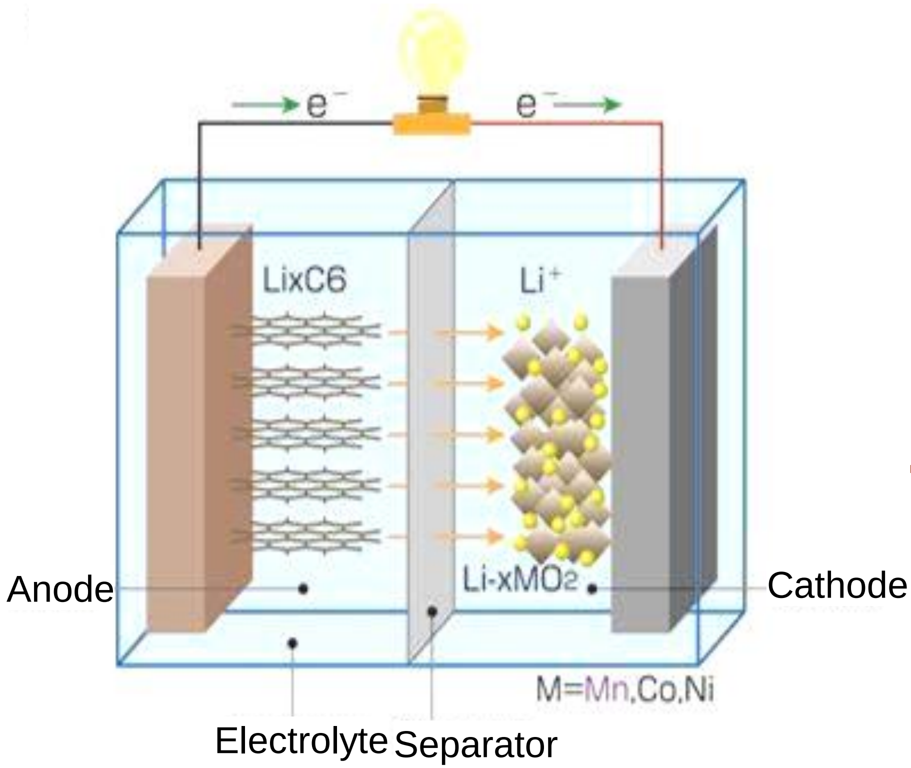


- Relatively new technology
- Efficiency 70%
- Low power density
- Indicative capital cost:
  1.5 – 3 kUSD / kW
- Charge/Discharge time typically up to several hours
- Capacity is given by the Electrolyte volumes (and concentration)
- Power is given by the Electrodes (surface area, structure, material)

Batteries – Battery technology – Li-Ion

Working principle:
Lithium ions move between the electrodes

Electrons flow through the outer loop to compensate the movement of charges



Prof. J. M. Tarascon (Amiens)

- Advantages
  - High specific energy
  - High efficiency (90-95%)
  - Long cycle life (more than 3000 cycles)
  - Low stand-by losses (0.1-1%/month)
  - No maintenance
  - Many manufacturers (especially for EV) / High potential for cost reduction
  - Opportunity for cost reduction
  - Large development potential (many new chemistries)
- Disadvantages
  - Today cost is high (1000-2000$/kWh)
  - Mass manufacturing of large modules is not mature
  - Safety issues for lithium-metal (thermal runaway)
  - More complex battery monitoring system (charging and discharging equilibration)

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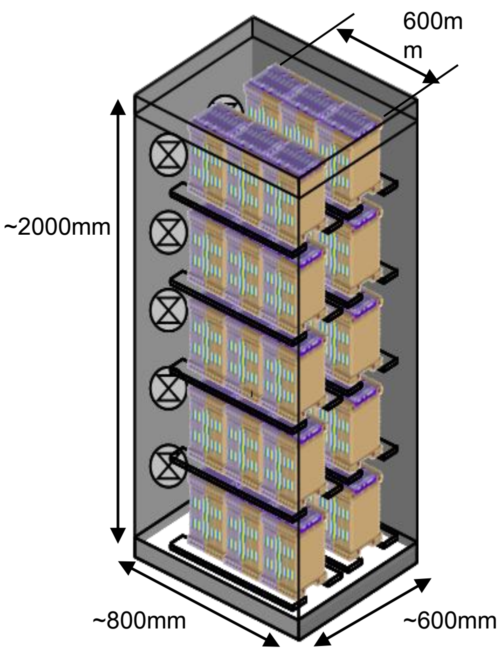
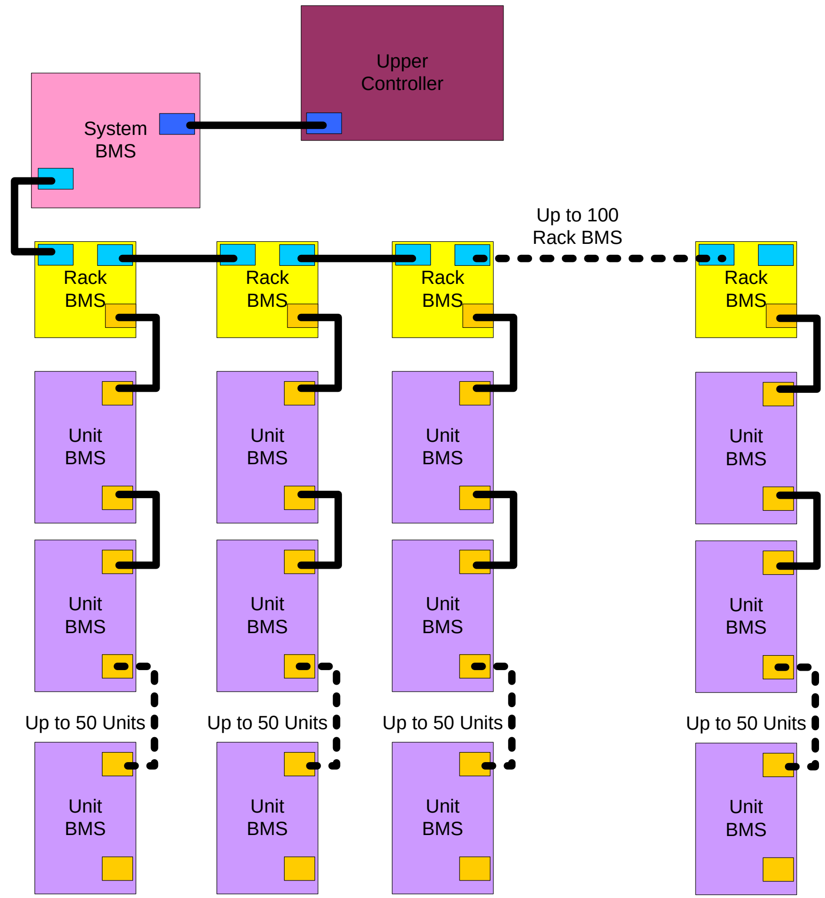
Batteries – Battery technology – Li-Ion

Battery Racks



" Courtesy of LG Chem"

Battery Management System



System BMS

Interface with PCS

Rack Balancing Control

Rack BMS Control

Rack BMS

Interface with System BMS

Rack Voltage, Current, ISO.

SOC,SOH,Power Estimation

Unit BMS Control

Unit BMS

Interface with Rack BMS

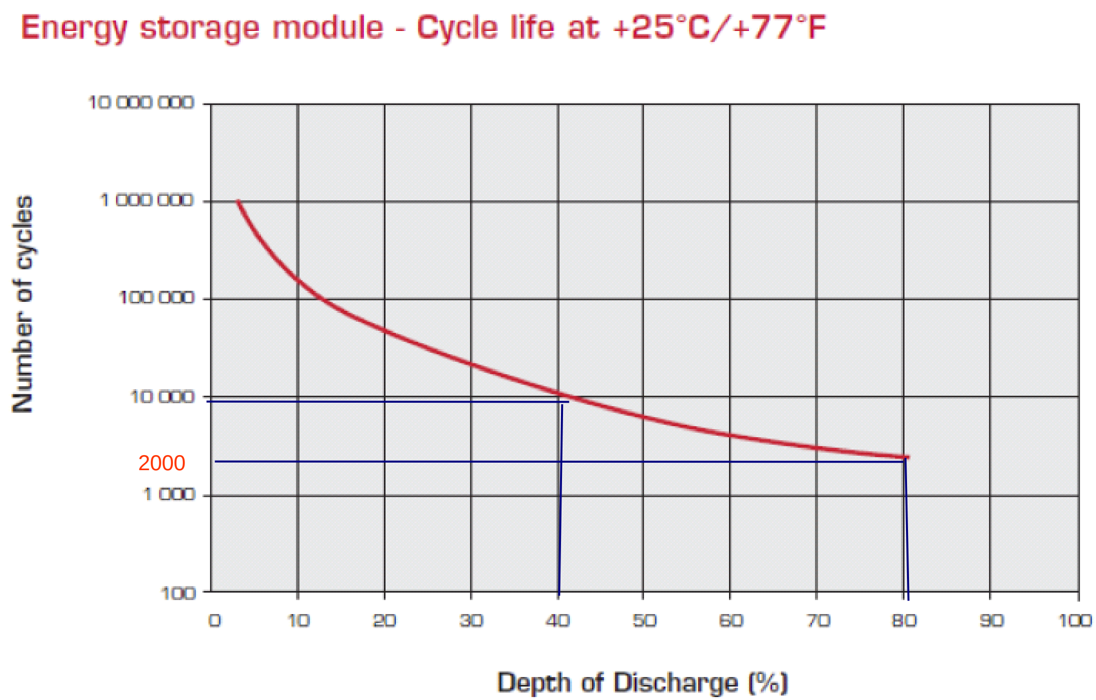
Cell Voltage, Temperature.

Diagnostic, Balancing

2nd Protection

Battery management system (BMS): measures voltage, depth of discharge, temperature in order to extend the battery life and avoid temperature overrun.

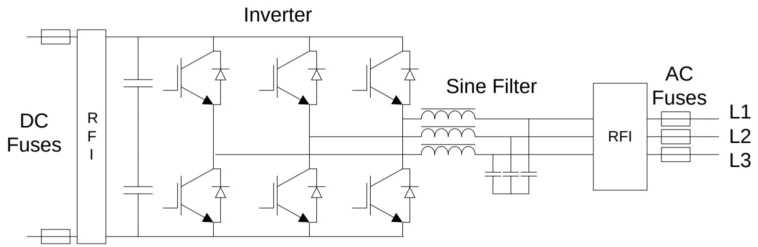
Batteries – Battery technology – Battery Life

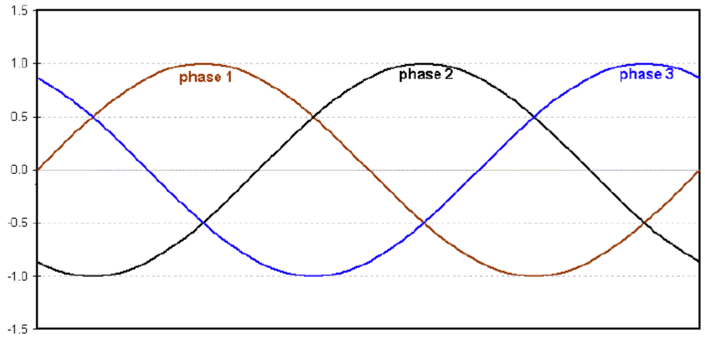


" Courtesy of Saft""

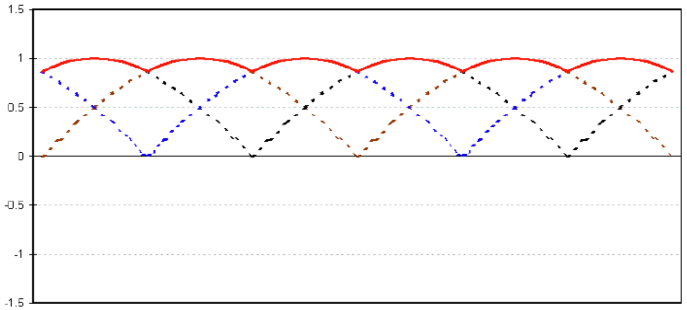
- The battery systems can be designed to fulfill different quantity of cycles modifying the depth of discharge.
- The battery chart shows battery cycle life as a function of depth of discharge,
- Example 1: If we want to design a 100 kW-hr battery to fulfill 2000 cycles, with a remaining capacity of 80 % at the end of life, then we will have to discharge less than 80 % (80 kW-hr) in each cycle
- Example 2: If we want to use a battery system for 10,000 cycles, then we would only be able to discharge less than 40 % (40 kW-hr) in each cycle. Therefore, if we need to fulfill 10,000 cycles of 80 kW-hr, we will need a 200 kW-hr battery.

Converter/Inverter Technology



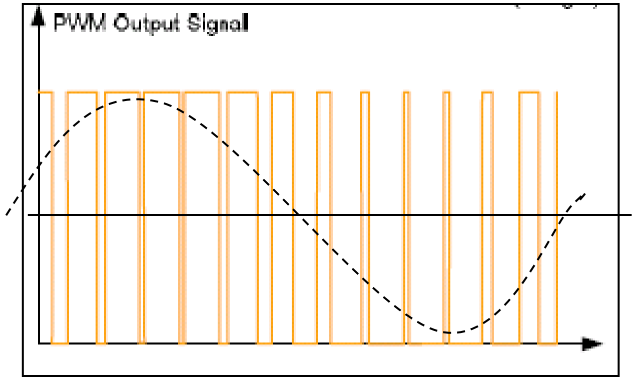


3-PHASE AC



3-PHASE FULL WAVE RECTIFICATION

AC to DC rectifying



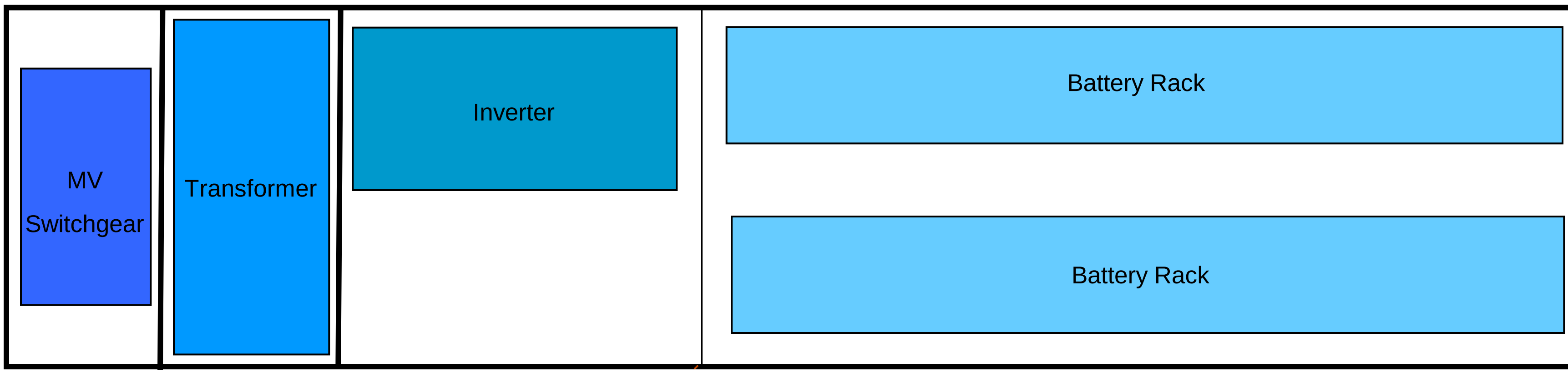
DC to AC inverting

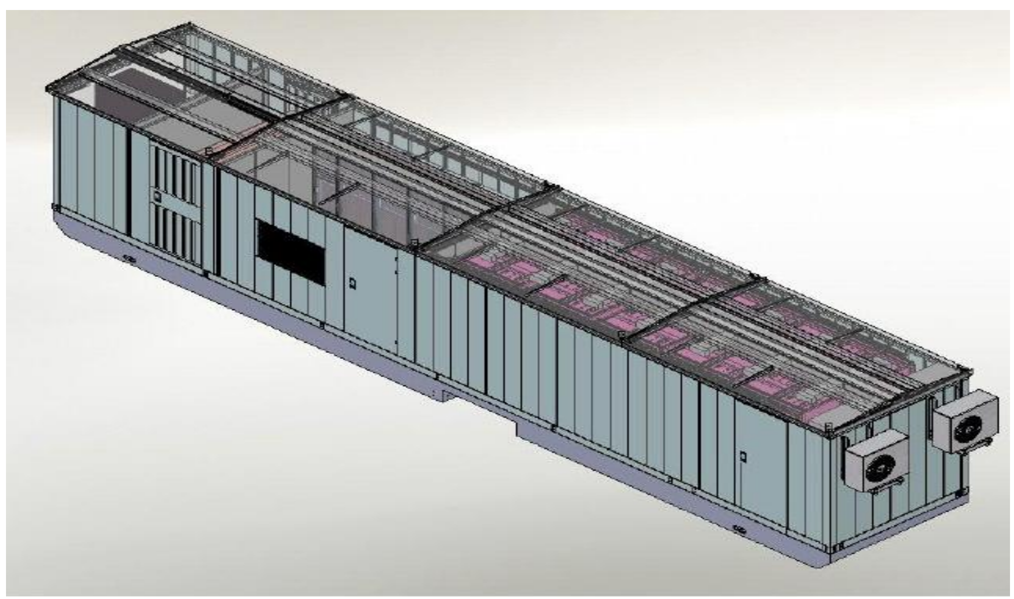
- Converters used in Energy storage are bidirectional
- Converters can inject reactive power into the grid without having to discharge the batteries.

Components: e-house solution

Distributed Energy Storage / Predesigned Unit with outdoor housing

Module for 1000 kW / 250 kW-hr (frequency regulation)





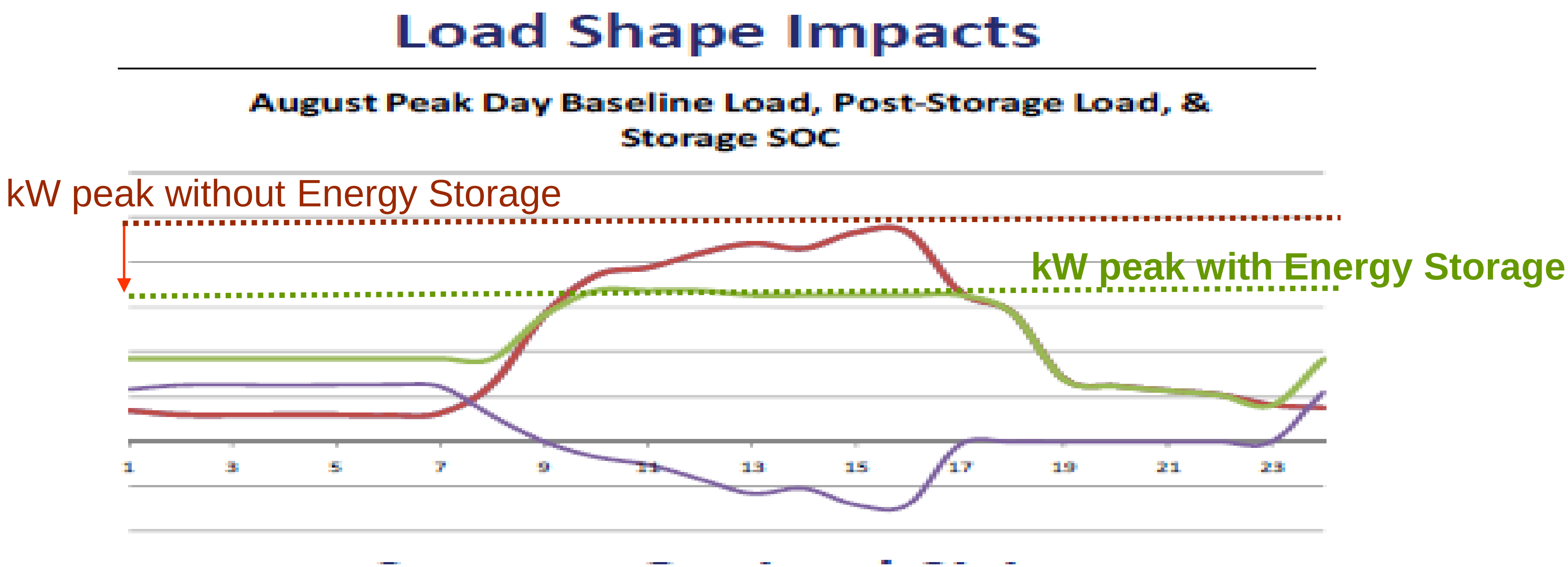
Key Technical parameter to define the Distributed Energy Storage

- Connection voltage, Type of connection (1 or 3 phase)
- Short-circuit power at connection point
- Type of application, Power (KW), energy (kWh) (power/energy rate),
- Quantity of charging/discharging cycles required (based on the remaining capacity required at the end of the cycle life)
- Environmental Temperature, seismic zone
- Space availability
- Accessibility to the site (capacity of performing maintenance)

Distributed energy storage

Applications

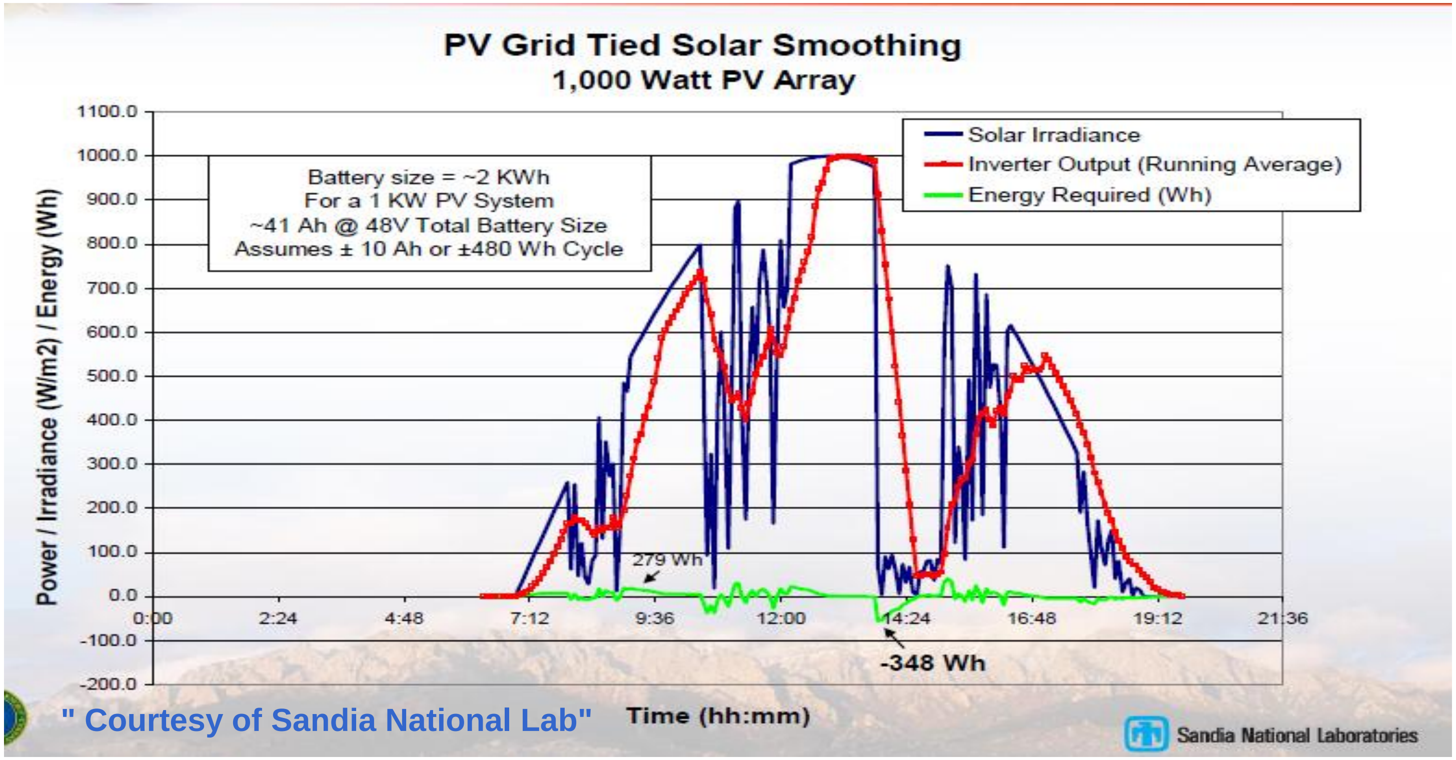
Applications - Load Shifting / Peak Shaving Benefits



- Time shift benefit ($) = ($/kwh$_{peak}$*Sthr-$/kwh$_{off}$*Sthr/eff)*Power
- Peak shaving benefit ($) = Power (kw) * Power fee ($/kw)
- $/kwh$_{peak}$: on peak energy price ($/kwh)
- $/kwh$_{off}$: off peak energy price ($/kwh)
- Sthr: hours of storage (hr)
- Eff: efficiency system (%)

ABB

Applications - Renewable Energy Capacity Firming
Reducing intermittency of renewable sources



- Reduce the intermittency of the renewable generation, by discharging or charging **active power**, making easier the integration of renewables to the grid.
- Distributed Energy Storage (DES) is smoothing the slope of the solar farm power generation variability. The solar farm power is showed in blue, the DES system power in **green** and the smoothed output is showed in **red**.

Distributed energy storage
Real cases

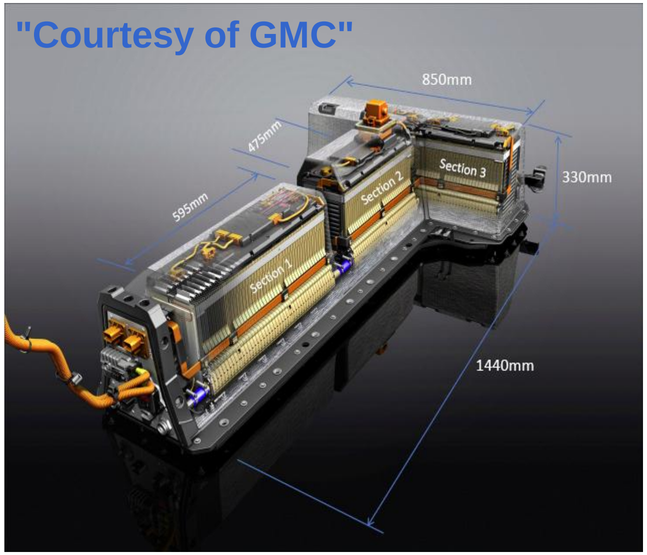
Memorandum of understanding ABB - GM

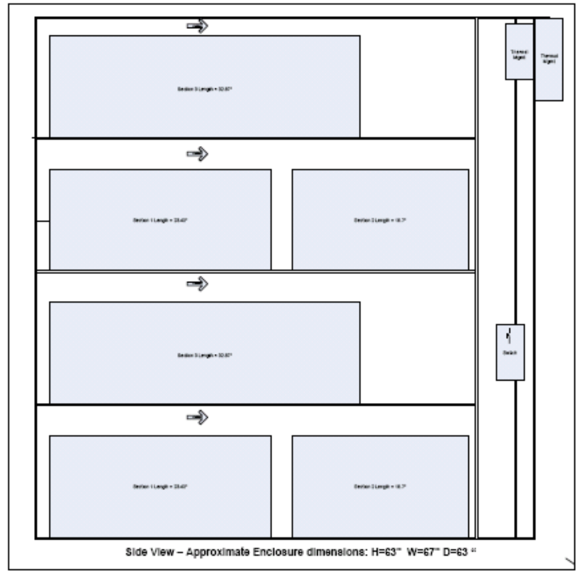
GM and ABB will investigate uses of electric vehicles batteries once their useful life in the vehicle is over.

•1st phase to test subsystem in Raleigh Corporate research Lab. To be finished by Aug/2011

•2nd to install a unit on site. To be completed by Jun/2012

DES – 100 kW-hr GM/ABB padmounted enclosure





- ABB is designing a padmounted enclosure (following MDS padmounted switches), to hold 30 battery sections (100 kw-hr)
- Inverter and protection equipment will be installed in a separate enclosure
- Tbattery pack dimensions are 57" x 34" x 13"
- Battery enclosure dimensions are H=63" W=67" D=63 "
- Inverter enclosure dimensions are H=74.7" W=31" D=32.28"

Battery energy storage system

PCS and Battery Enclosures
500 kW PQ (30 seconds)
&
100 kW (720 kWh) Peak Shaving

Customer needs:

- Demonstration project
- Peak Shaving
- Power Quality

ABB Scope:

- ABB PCS to monitor grid voltages for disruptions, sags and swells. If an out of tolerance voltage event occurs, the PCS will disconnect the load from grid and power from batteries. Reconnect to grid when nominal voltage returns
- NaS Batteries

ABB

BESS – NYPA, Garden City, NY

1MW / 6.5MWHr

Customer needs: Load Leveling and Peak Shaving

- **ABB Scope**
- ABB PCS to work in parallel with local utility during day to power gas compressors and recharge at night when electricity rates are lower.
- Shifts compressor demand to night. Lowers daytime peak demand rates paid by end user.
- Utility benefits by reduction of peak demands on overburdened system
- BESS system provides backup power in a utility interruption.
- NaS Batteries

ABB

World's largest battery – GVEA, Fairbanks, Alaska

Customer needs

- Spinning Reserve

ABB Scope

- ABB PCS to supply power long enough for local generation to come online.
- BESS system to operate in -52C temperatures.
- Ni-Cd Batteries

27 MW / 15 minutes
46 MW / 5 minutes

CERTIFICATE

The Golden Valley Electric Association (USA) Battery Energy Storage System became operational in Alaska, USA in November 2003. On 10 December 2003, during a test of its maximum limit, it was discharged at a rate of 46 megawatts for five minutes. The battery system is designed to prevent power loss to thousands of local residents during interruptions in the main electricity supply

Keeper of the Records
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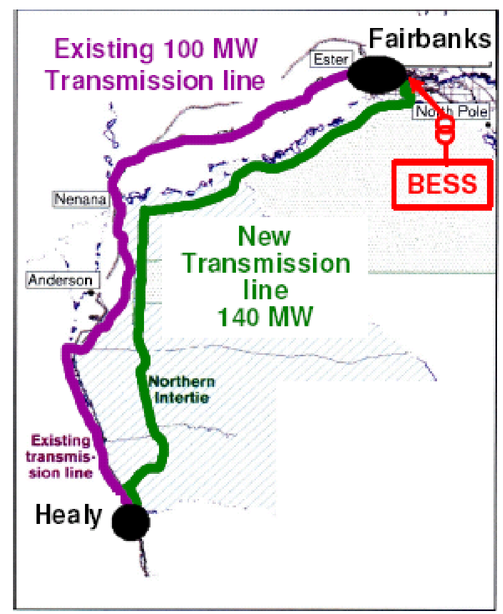

Business case analysis

- ABB can support the users to evaluate the feasibility of distributed energy storage application, considering power and energy charges, installation, maintenance and operation cost among other factors.

Distributed energy storage
Summary

Summary

- Power **system reliability depends upon the ancillary services** to maintain the **balance between generation and consumption. Regulation is the most expensive ancillary service.**
- **Drivers for energy storage are:** high cost of ancillary services, integration of solar and wind sources to the grid, make and efficient use of electricity, and reliability.
- Additional drivers are the rollout of electrical vehicles and government incentives.
- Some of the battery types are: Lead-acid, Li-Ion, Ni-Cd, Zinc Bromine, NaCl-Ni among others.
- Inverters rectify the AC energy into DC to store in the batteries and then invert the DC energy into AC energy, single or three phase at 50 or 60 Hertz.
- Applications for distributed energy storage are: frequency regulation, demand management and peak shaving, investment deferral, and capacity firming of renewable energy sources among others.
- To evaluate an energy storage project the key factor is to consider several applications and stack the benefits.
- Distributed Energy Storage contributes to make the grid efficient and smarter.

Distributed energy storage

Question and answers

Reminders
Automation & Power World 2011

- Please be sure to complete the workshop evaluation
- Professional Development Hours (PDHs) and Continuing Education Credits (CEUs):
  - You will receive a link via e-mail to print certificates for all the workshops you have attended during Automation & Power World 2011.
  - BE SURE YOU HAVE YOUR BADGE SCANNED for each workshop you attend. If you do not have your badge scanned you will not be able to obtain PDHs or CEUs.

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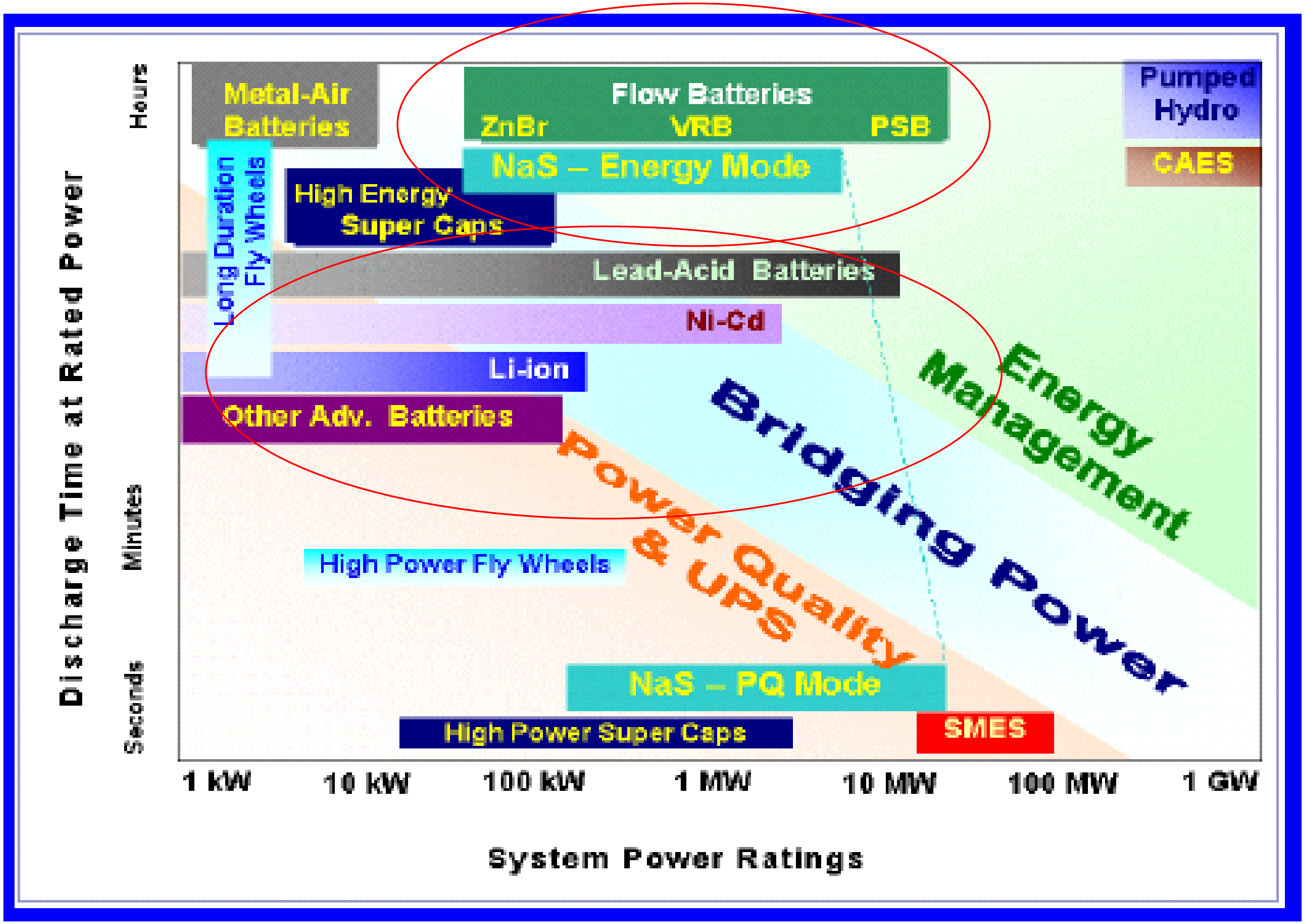
Energy Storage Alternatives



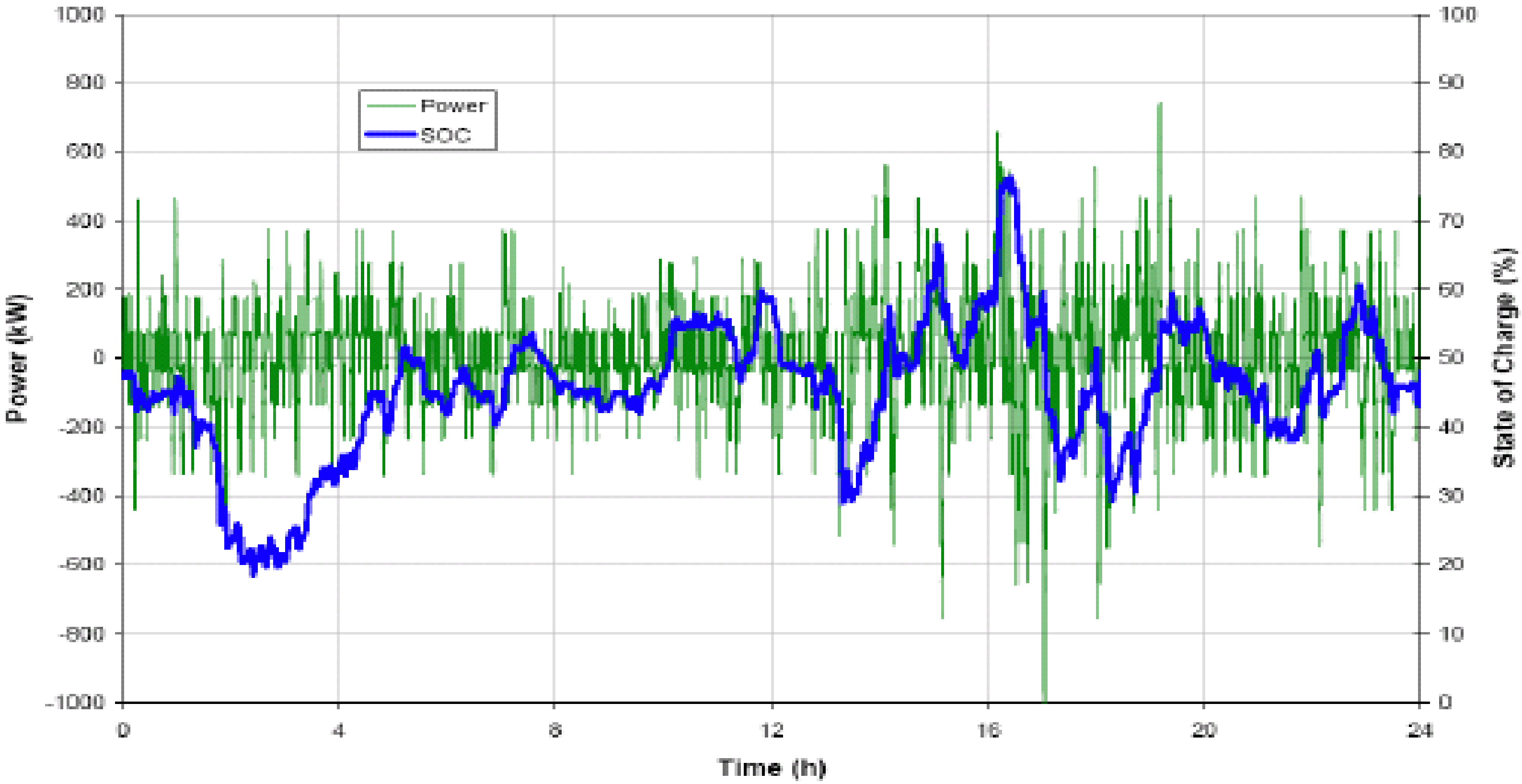
Lead acid is a mature technology, but weight, dimensions and temperature operating range significantly increase the overall cost.

Batteries – ABB Research

	Cells	Modules	Modules	Packs/racks
Where	ABB China	ABB Switzerland	ABB USA	ABB Sweden
How	–Capacity –Lifetime –Charge/discharge	–Capacity –Charge/discharge –BMS –Temperatures –Cell balancing	–CES functionality –Capacity –Charge/discharge –BMS –Cell balancing	–Capacity –Charge/discharge –BMS –Temperatures –Module balancing

- ABB does not manufacture batteries but is investing resources in testing different battery technologies and resources in the Corporate Research Centers in China, Switzerland, Sweden and USA
- The ABB Business Unit uses the knowledge acquired by the Test centers to choose the battery technology for each project

Applications – Frequency Regulation



" Courtesy of Altainano "

- **Battery can give a fast response (40 msec) and be a good alternative (profitable) for system with lack of spinning reserves**
- Several system installed in US for this applications (not pilot projects but investment with a return)

Distributed energy storage (DES) vs UPS

DES can be designed to work as an UPS but generally the functionality is different:

- DES batteries are designed for one charging/discharging cycle at least per day
- DES is connected to the grid so design requires grid interconnection protection functions
- DES speed of response is generally slower than UPS
- UPS batteries are designed to standby and act in case of a fault or disturbance