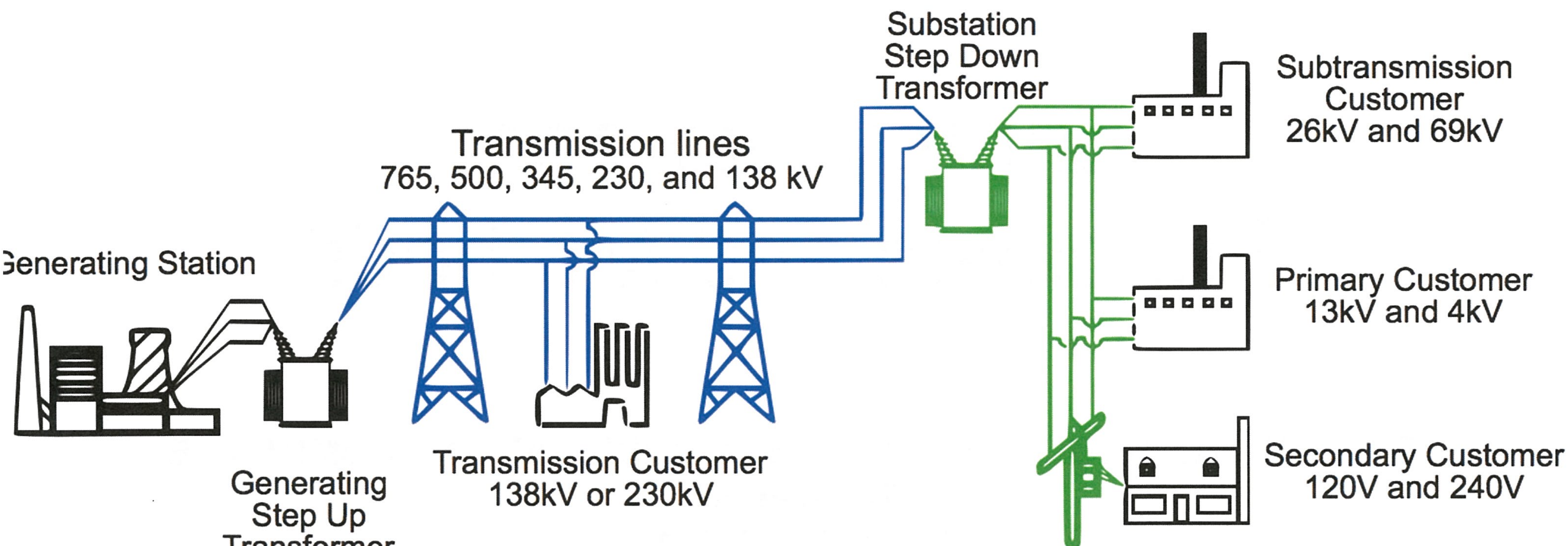
Energy Storage: Principles and Methods

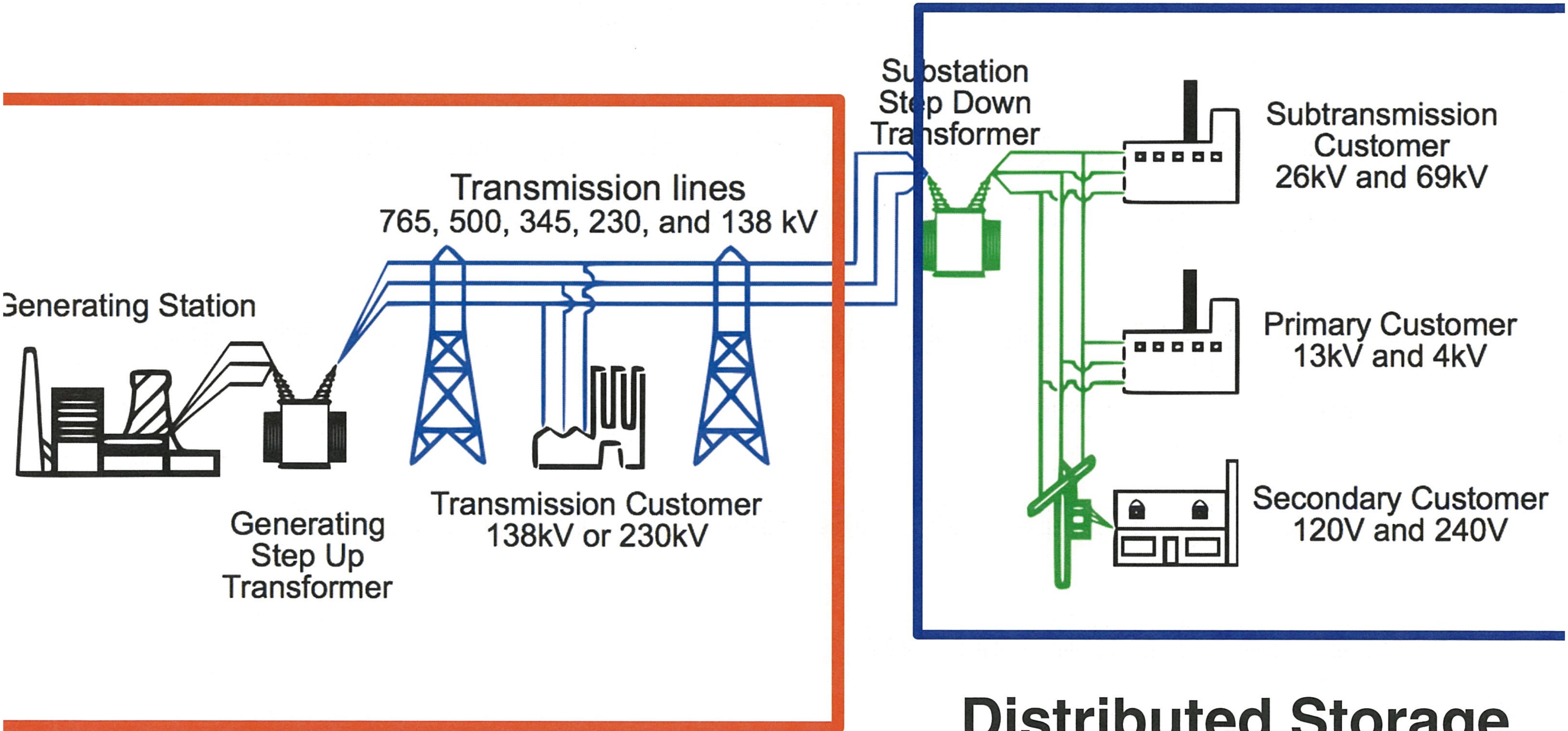
SCIENCE, TECHNOLOGY AND TELECOMMUNICATIONS COMMITTEE
7th Meeting
November 6, 2019

Abbas Akhil

Schematic of the Electric Grid



Flexibility in Using Energy Storage in the Grid



Distributed Storage
3+ kW / 30 sec – 4 hrs

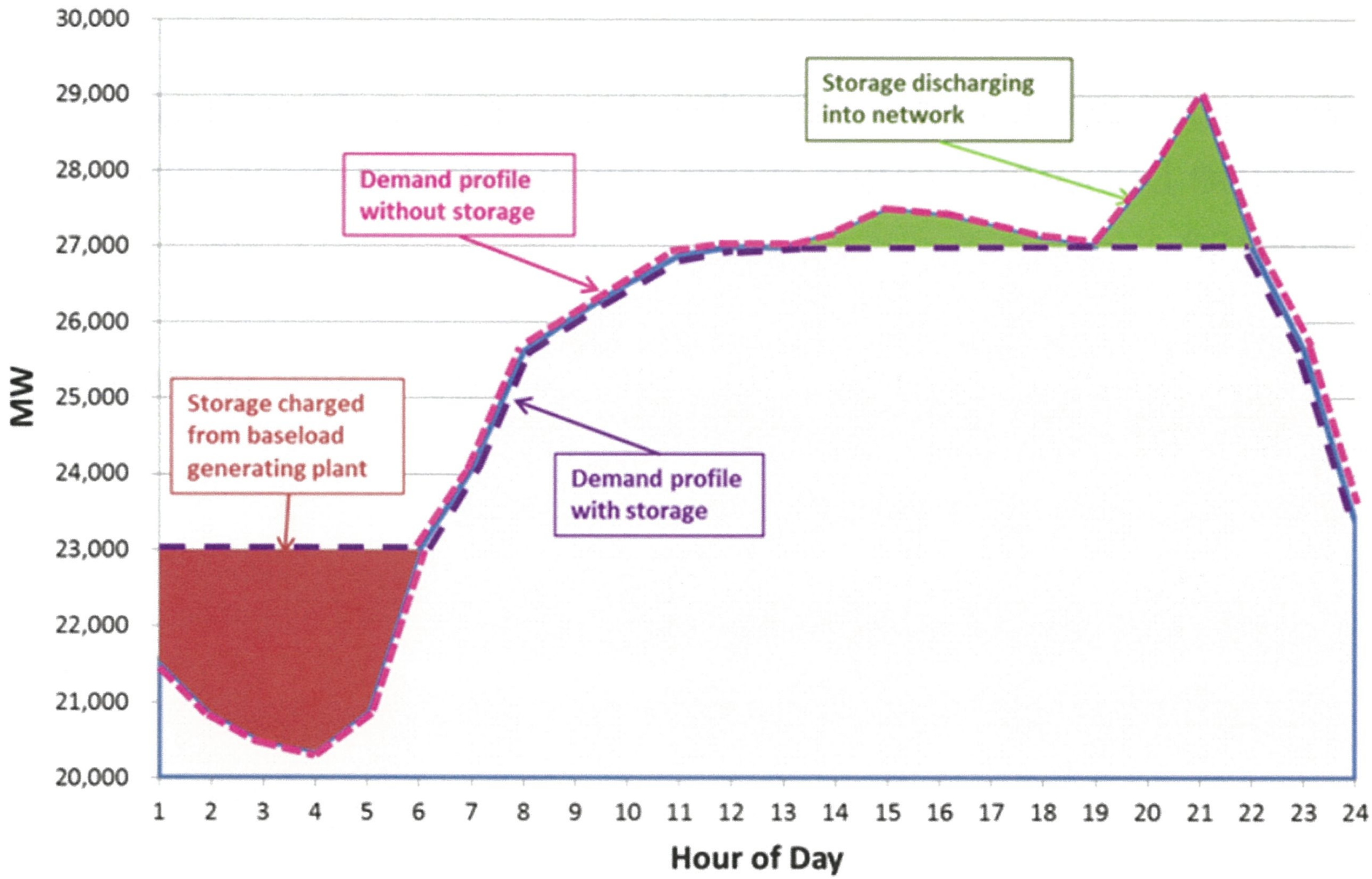
Bulk Storage
10+ MW / 4+ hrs

The Need for Energy Storage in the Electric Grid

- Generation has to match load at all times to maintain voltage and frequency within a narrow band
- Energy storage acts as the buffer - absorbing excess and supplying shortage
- Think of it as a “shock absorber” in the electric grid
- At least 16 different uses

Risk: Intra-hour load management

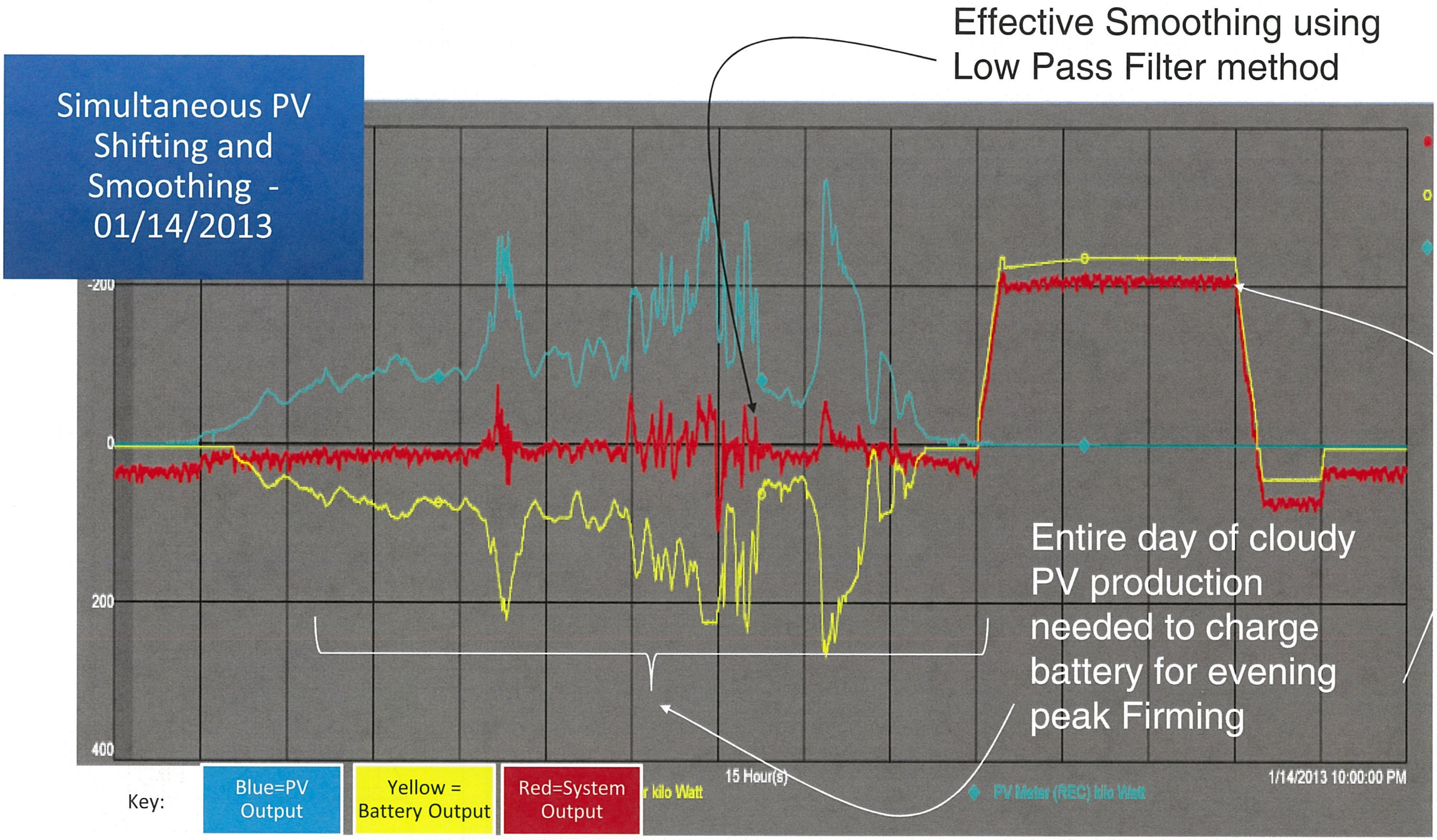
Daily System Load



The Need for Energy Storage with Renewables

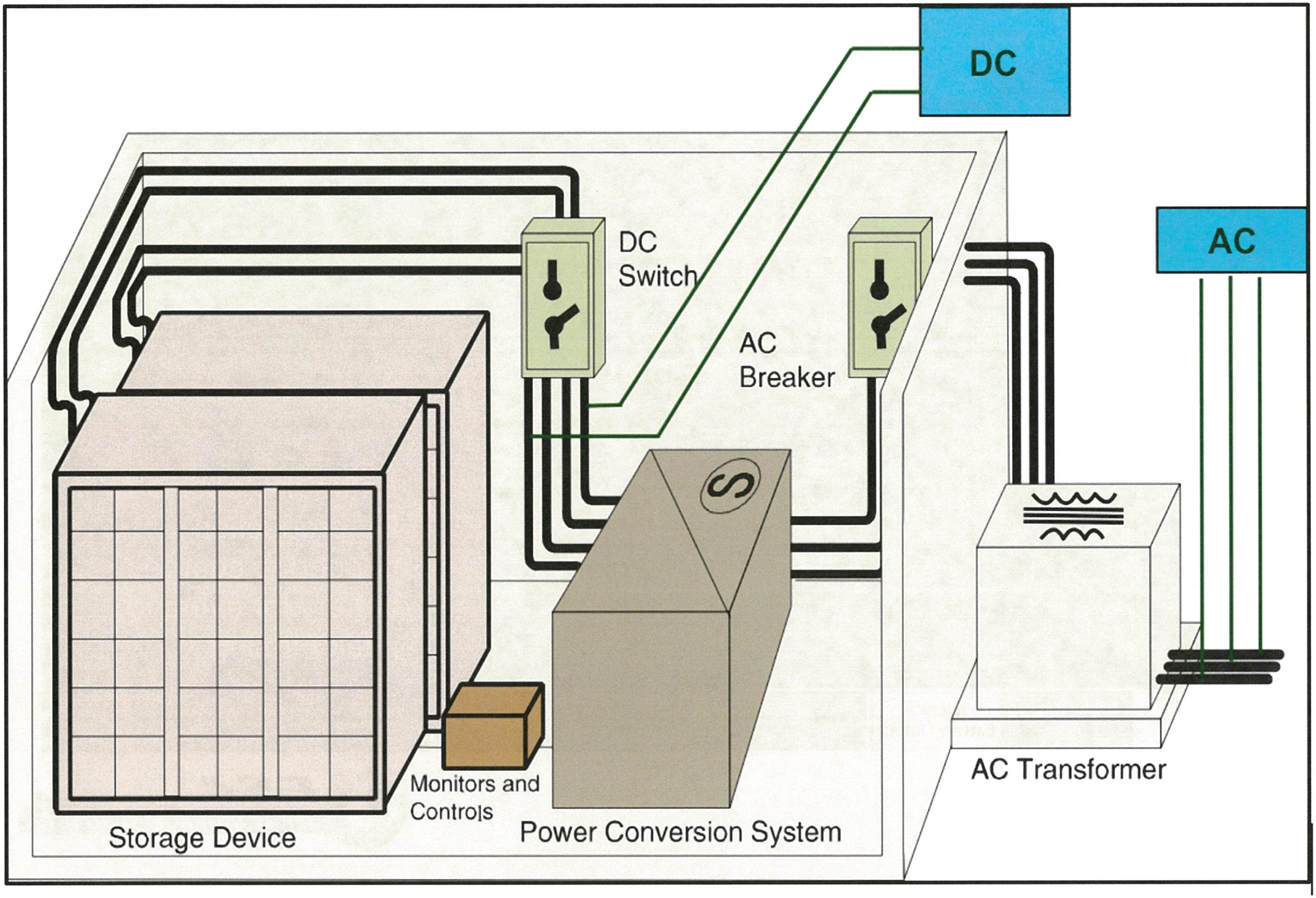
- Wind and solar are intermittent sources and energy storage becomes even more critical to maintain the balance
- Smooths short term fluctuations - cloud cover or wind variability
- “Time shift” solar after sunset

Combined PV Smoothing and Shifting
Maximizing Benefits from Energy Storage



ESA 23rd ANNUAL CONFERENCE
ENERGY STORAGE: TURN IT ON

Components of an Energy Storage System



Energy Storage Units

- Power - expressed in kW, MW or GW
  - Number of homes or businesses can it power

AND

- Energy - expressed in kWh, MWh or GWh
  - Duration of that power

- Units are kW/kWh, MW/MWh or GW/GWh
- Cost is expressed in $/kW (power component) AND $/kWh (energy component)

Relevant Storage Technologies

Short-Duration

Seconds to 1 hour

Fly Wheels
Batteries

Mid-Duration

1 to 4 hours

Batteries
Flow Batteries

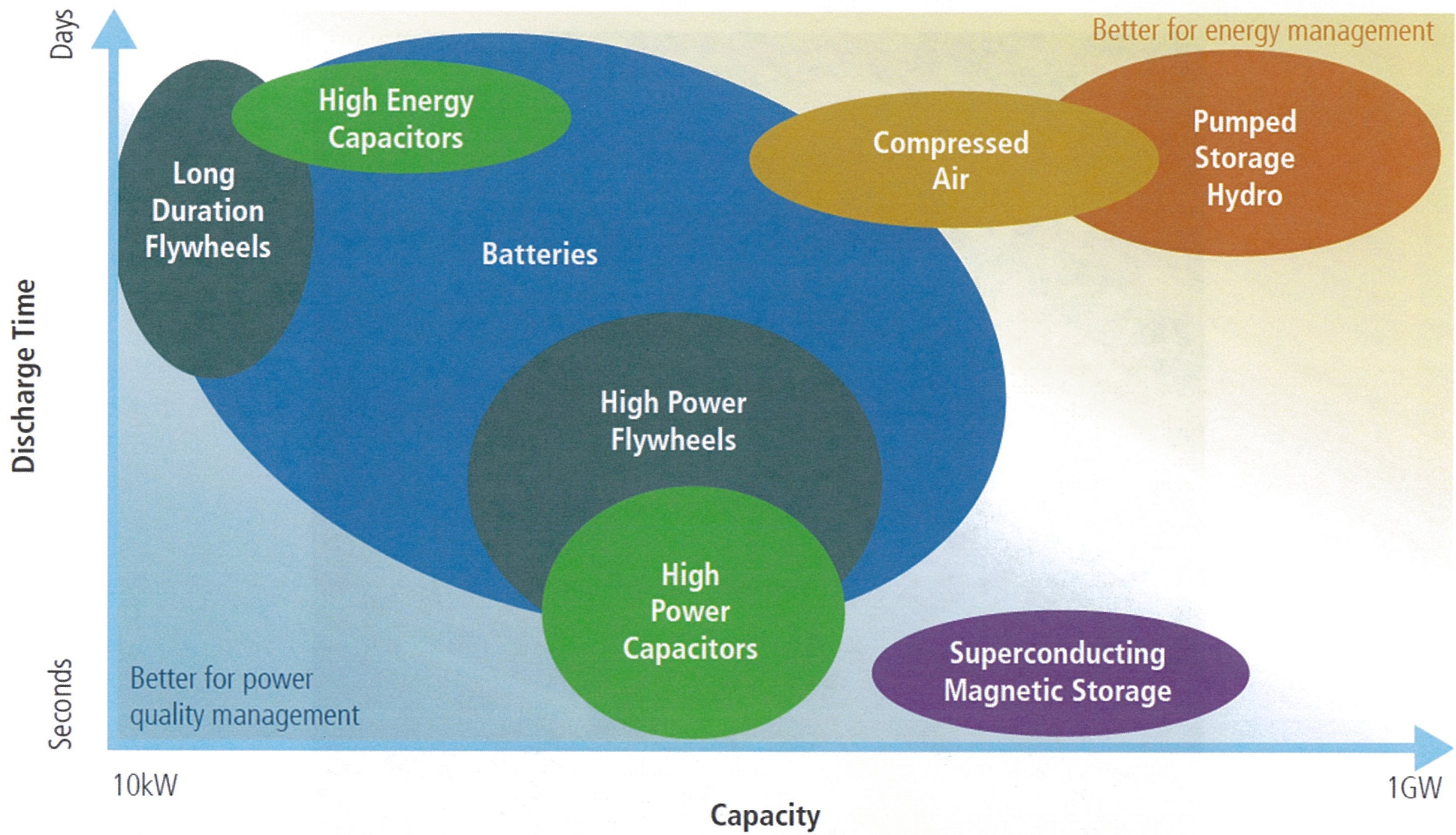
Thermal Energy Storage

Long-Duration

4 to 14 hours

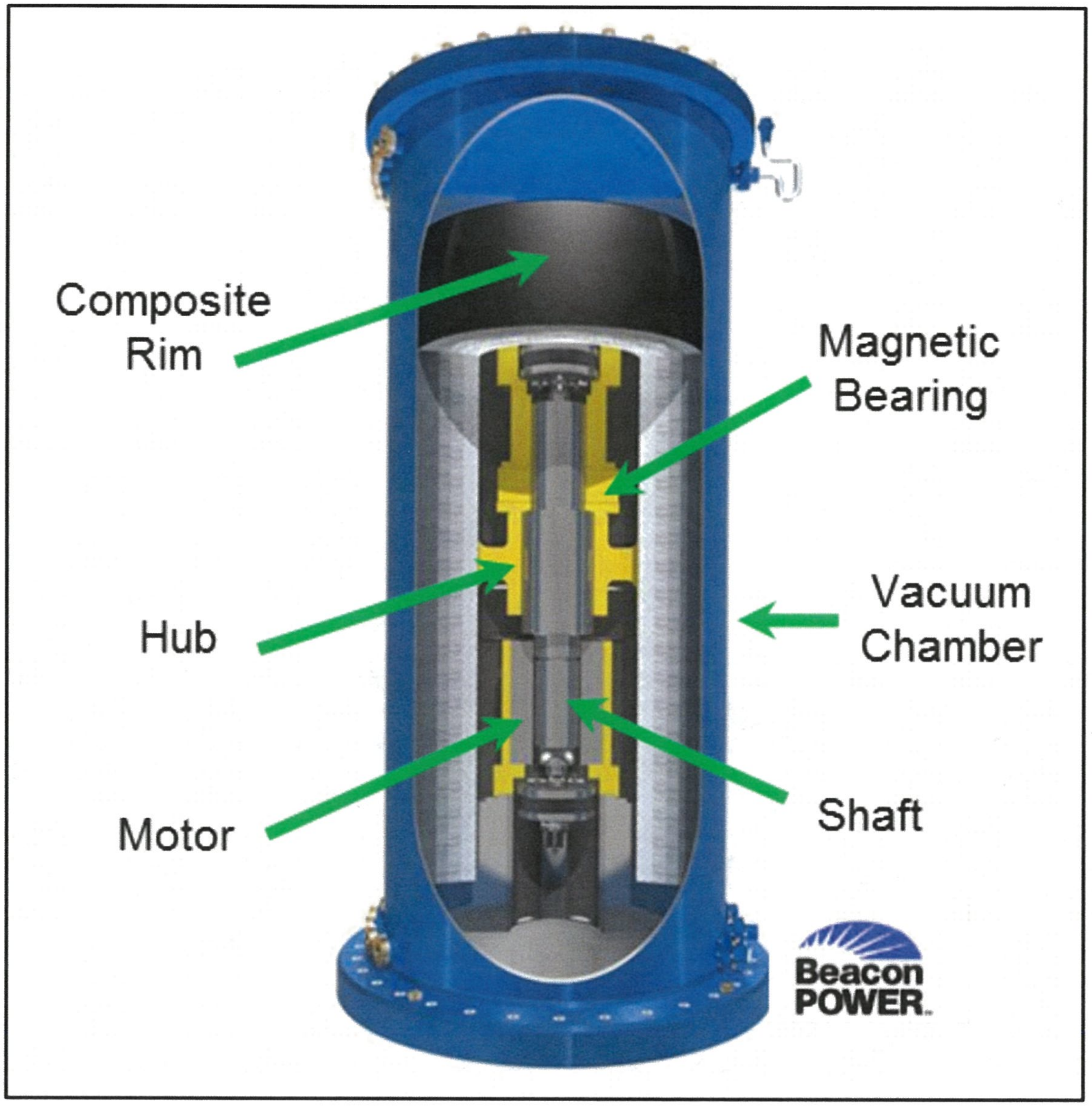
Flow Batteries
Pumped Storage
Compressed Air

Spectrum of Storage Technologies

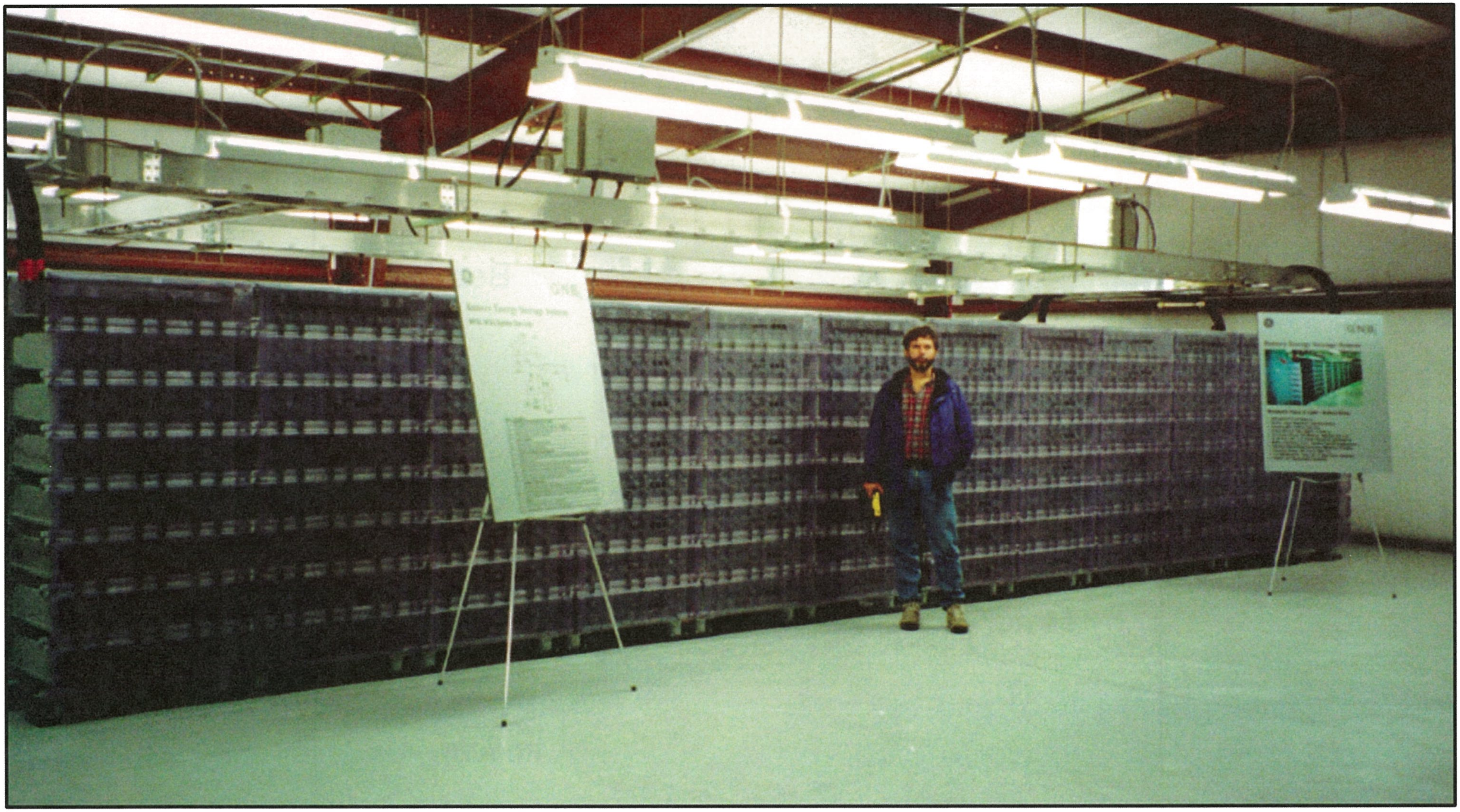


Pumped Hydro Plant

Flywheel Energy Storage



Legacy Lead-acid System



Li-ion Family – Utility Applications

Tehachapi Energy Storage Project
Southern California Edison
8MW/32 MWh, (608,832 cells)

Li-ion Family – Residential Application

Sodium-Sulfur Battery – Similar to Los Alamos system

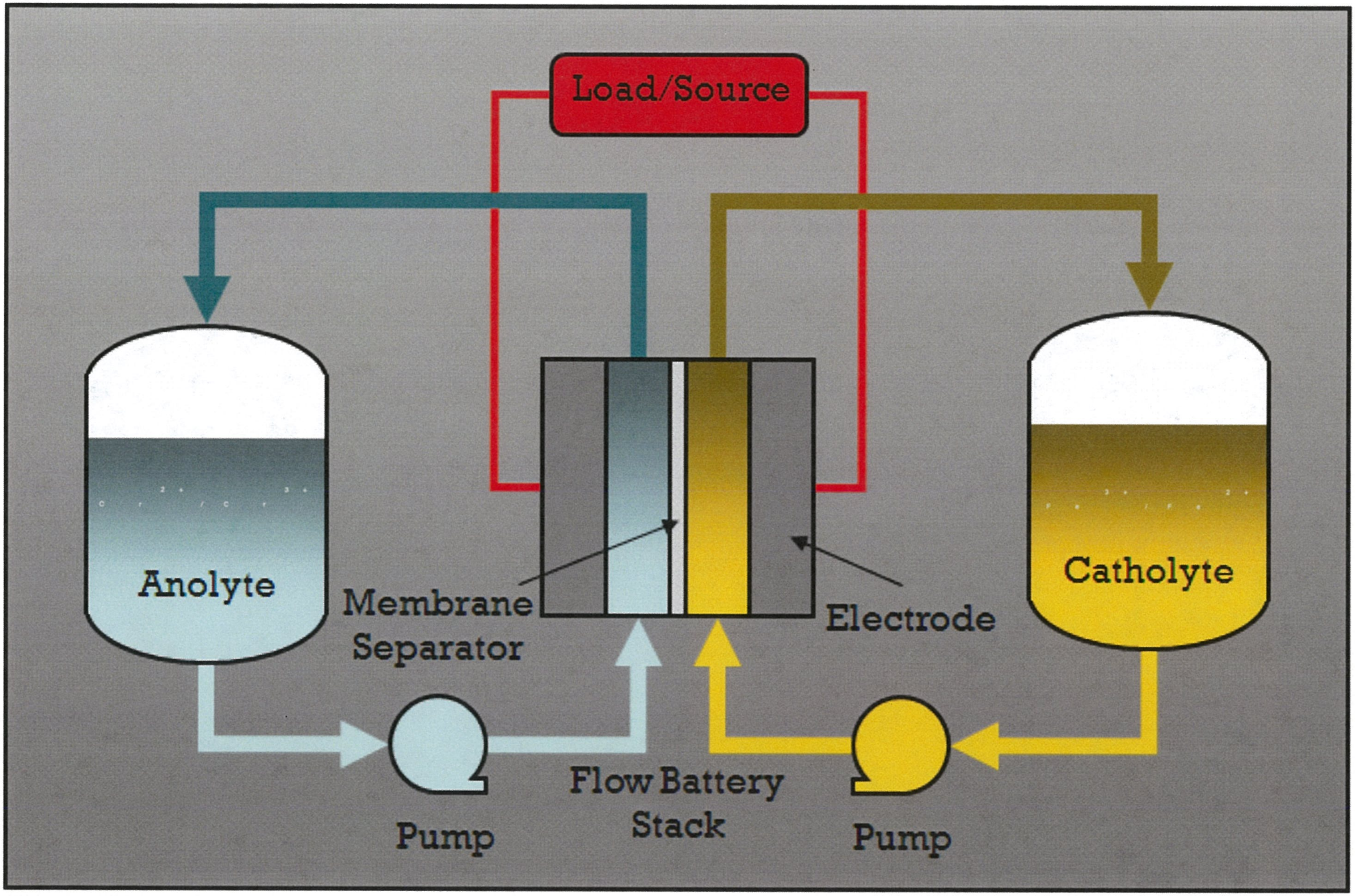
Source: American Electric Power

PNM Prosperity Project

Solar Smoothing & Shifting/Firming

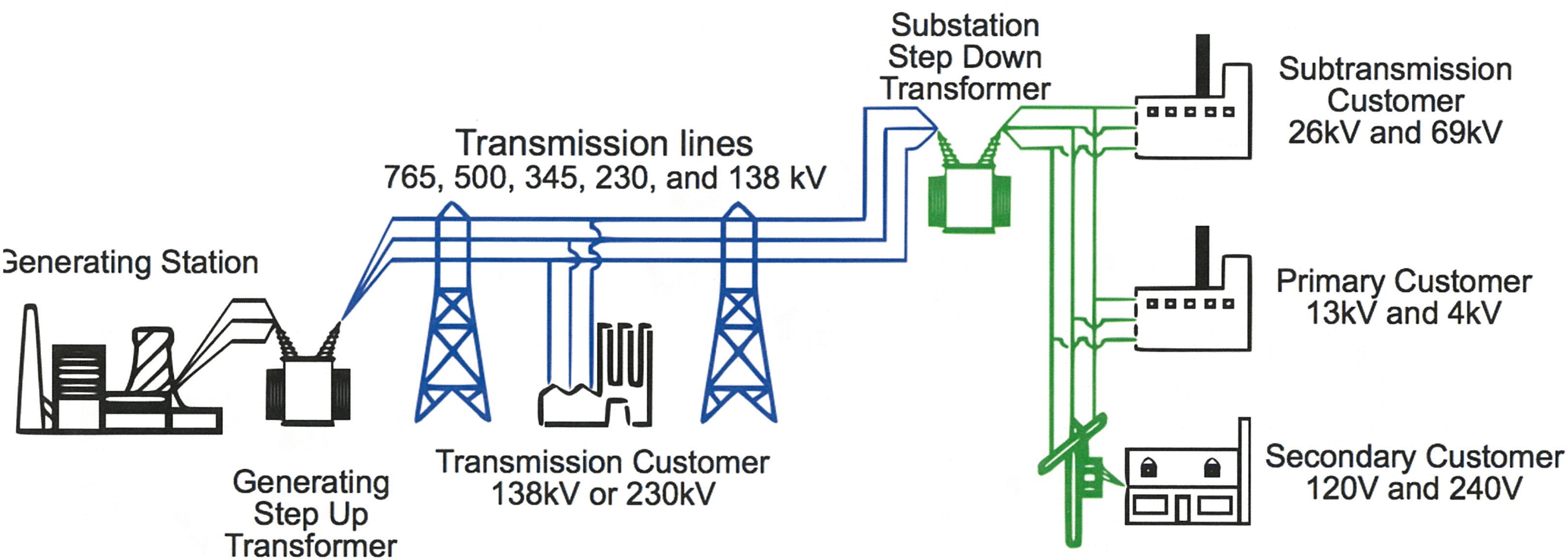
ecoult
energy storage solutions

Flow Battery Schematic

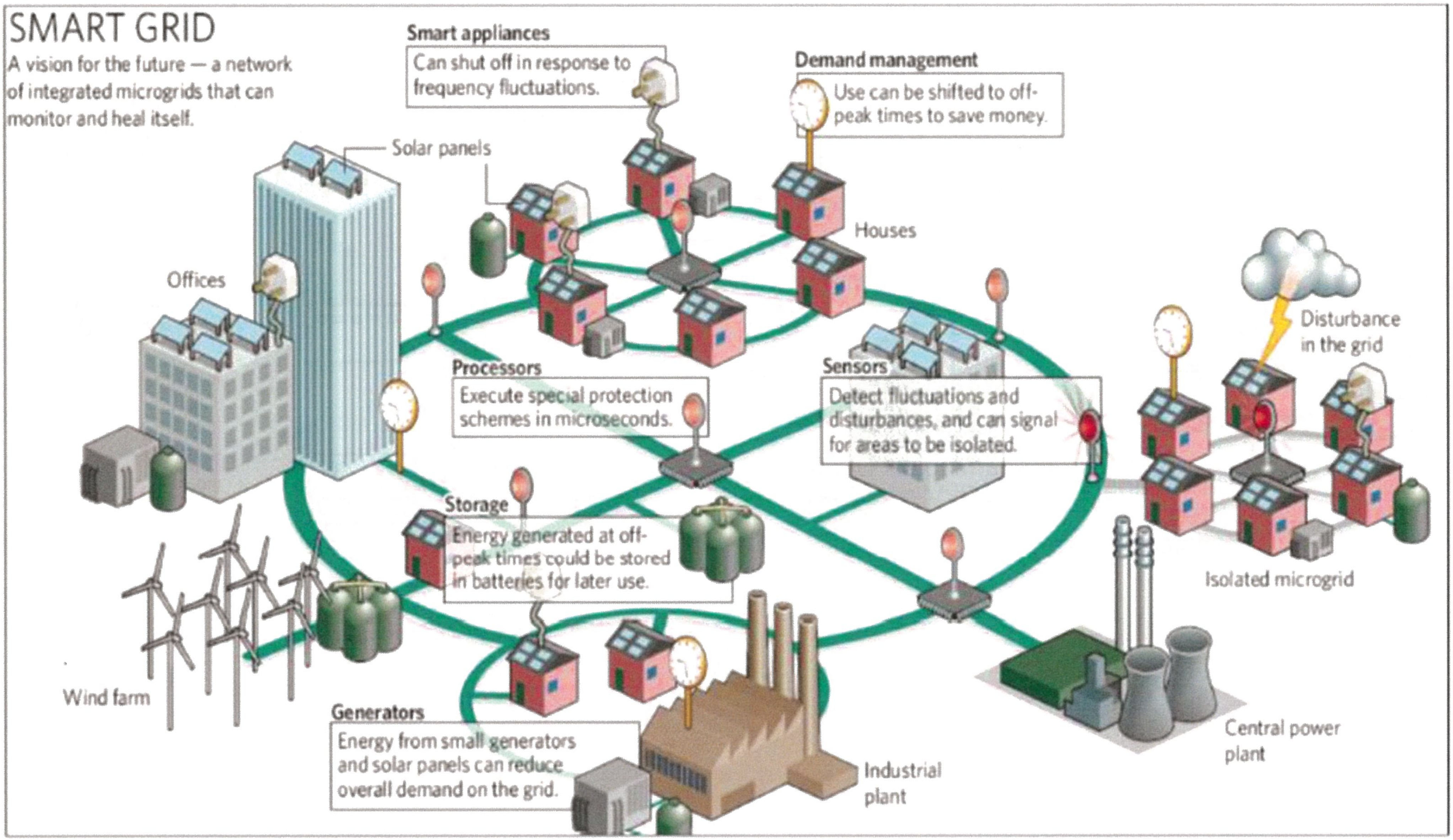


Thermal Energy Storage

Legacy Electric Grid



Future Grid



SMART GRID
A vision for the future — a network of integrated microgrids that can monitor and heal itself.
Smart appliances
Can shut off in response to frequency fluctuations.
Demand management
Use can be shifted to off-peak times to save money.
Solar panels
Houses
Offices
Disturbance in the grid
Processors
Execute special protection schemes in microseconds.
Sensors
Detect fluctuations and disturbances, and can signal for areas to be isolated.
Storage
Energy generated at off-peak times could be stored in batteries for later use.
Isolated microgrid
Wind farm
Generators
Energy from small generators and solar panels can reduce overall demand on the grid.
Industrial plant
Central power plant

A Modern Electric Grid

Electric systems	Traditional Grid	Development Trends and Needs	Future Grid
Generation	• Large centralized power plants • Dispatchable generation • Mechanically coupled • Minimal DER	• Growing role of DER • Energy storage • New planning tools to handle RE • Control coordination • NG replacing coal plants	• Hybrid control architectures • Bidirectional power flows and stochastic loads • Power electronic centric infrastructure across the grid
Transmission	• SCADA for status visibility • Operator-based controls • Aging infrastructure. Low peaking capacity utilization. • Threats/vulnerabilities not well defined	• HVDC transmission • Growing dc loads • Improving EMS • Integrated planning tools • Growing security awareness • Increasing role of storage	• Wide-spread PMU deployment • Coordinated sensing and control infrastructure • System-wide dynamic power flow management • Resilient and self healing
Distribution	• Minimal to non-existent sensing and automation • Radial design and one-way power flows • Aging distribution infrastructure	• Deployment of ADMS • FACT/inverter enabled voltage regulation • Early adoption of storage in distribution systems	• Truly bi-directional power flows and large scale DG • Pervasive sensing and communications • Local, autonomous coordination • Asynchronous networks
Consumption	• Regional, location and customer specific rate structure • Uniformly high reliability • Predictable behavior based on historical needs and weather • Reliable, yet inflexible	• Customer-determined reliability/power quality • Real time pricing, time of use rates, demand charges • Improved utility communications • Behind-the-meter storage	• Autonomous microgrids • Advanced EMS • Widespread DERs and transactive energy • Pervasive sensor environment
Operation/Market structure	• Vertically integrated utilities, wholesale markets	• Market reform to compensate for services provided	• Diversity of energy products and services

DOE Electricity Storage Handbook – 2013 ed.

- PDF format only, 12 MB file size
- Downloaded over 2,700 times during first month
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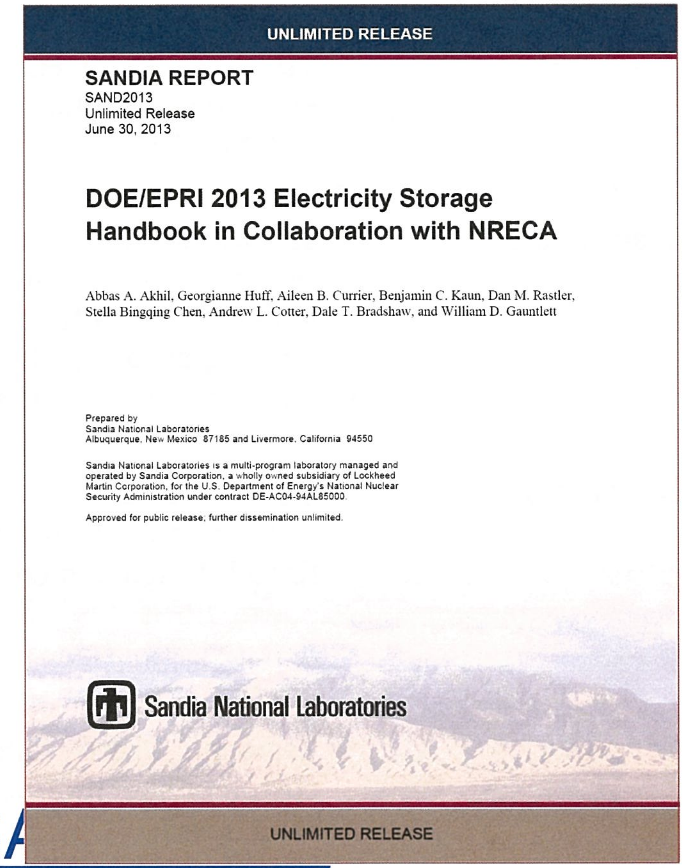
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SANDIA REPORT
SAND2013
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June 30, 2013

DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA

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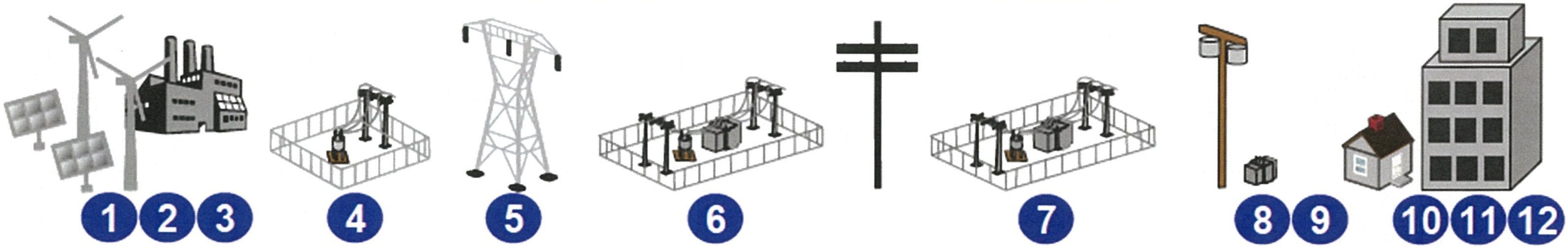
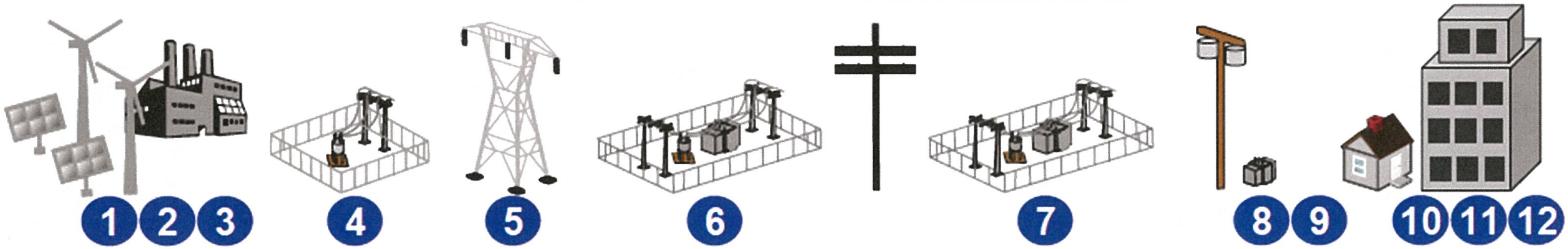
Application Location on the Grid



	Application	Description
1	**Off-to-on peak intermittent energy shifting & firming**	Charge at the site of off-peak renewable and / or intermittent energy sources; discharge "firmed" energy onto grid during on-peak periods.
2	**On-peak intermittent energy smoothing & shaping**	Charge / discharge seconds-to-minutes to smooth intermittent generation, and / or charge / discharge minutes-to-hours to shape energy profile.
3	**Ancillary service provision**	Provide ancillary service capacity in day-ahead markets and respond to ISO signaling in real time.
4	**Black start provision**	Unit sits fully charged, discharging when black start capability is required.
5	**Transmission infrastructure**	Use an energy storage device to defer upgrades or other technology on the transmission system.
6	**Distribution infrastructure**	Use an energy storage device to defer upgrades or other technology on the distribution system.
7	**Transportable distribution-level overload mitigation**	Use a transportable storage unit to provide supplemental power to end users during outages due to short-term distribution overload situations.

Source: Moving Energy Storage from Concept to Reality: Southern California Edison's Approach to Evaluating Energy Storage

Application Location on the Grid



8	**Peak load shifting downstream of distribution system**	Charge device during off-peak downstream of the distribution system (below secondary transformer); discharge during 2-4 hour daily peak period.
9	**Variable distributed generation integration**	Charge / discharge device to balance local energy use with generation. Sited between the distributed generation & distribution grid to defer otherwise necessary distribution infrastructure upgrades.
10	**End user time-of-use rate optimization**	Charge device when retail time-of-use prices are low, discharge when high (and / or to avoid demand response curtailment periods / charges).
11	**Uninterruptible power supply**	End user deploys energy storage to improve power quality and / or provide back-up power during outages.
12	**Micro grid formation**	Energy storage is deployed in conjunction with local generation to separate from the grid, creating an islanded micro-grid.

Source: Moving Energy Storage from Concept to Reality: Southern California Edison's Approach to Evaluating Energy Storage