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Energy Storage Fundamentals

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U.S. DEPARTMENT of ENERGY BATTELLE

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What is energy storage?

Not quite generation nor load.

Any system designed to capture generated or transmitted energy and hold that energy until it is ready to be dispatched for later use.

Horn Rapids Solar, Storage & Training Project: Richland, WA

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What is energy storage?

Not quite generation nor load.

There are many different storage technologies:

- Mechanical
  - Flywheels
  - Compressed Air
  - Pumped Storage
- Chemical
  - Fuel Cell
- Electrochemical
  - Battery
- Thermal
  - Hot or cold reservoir

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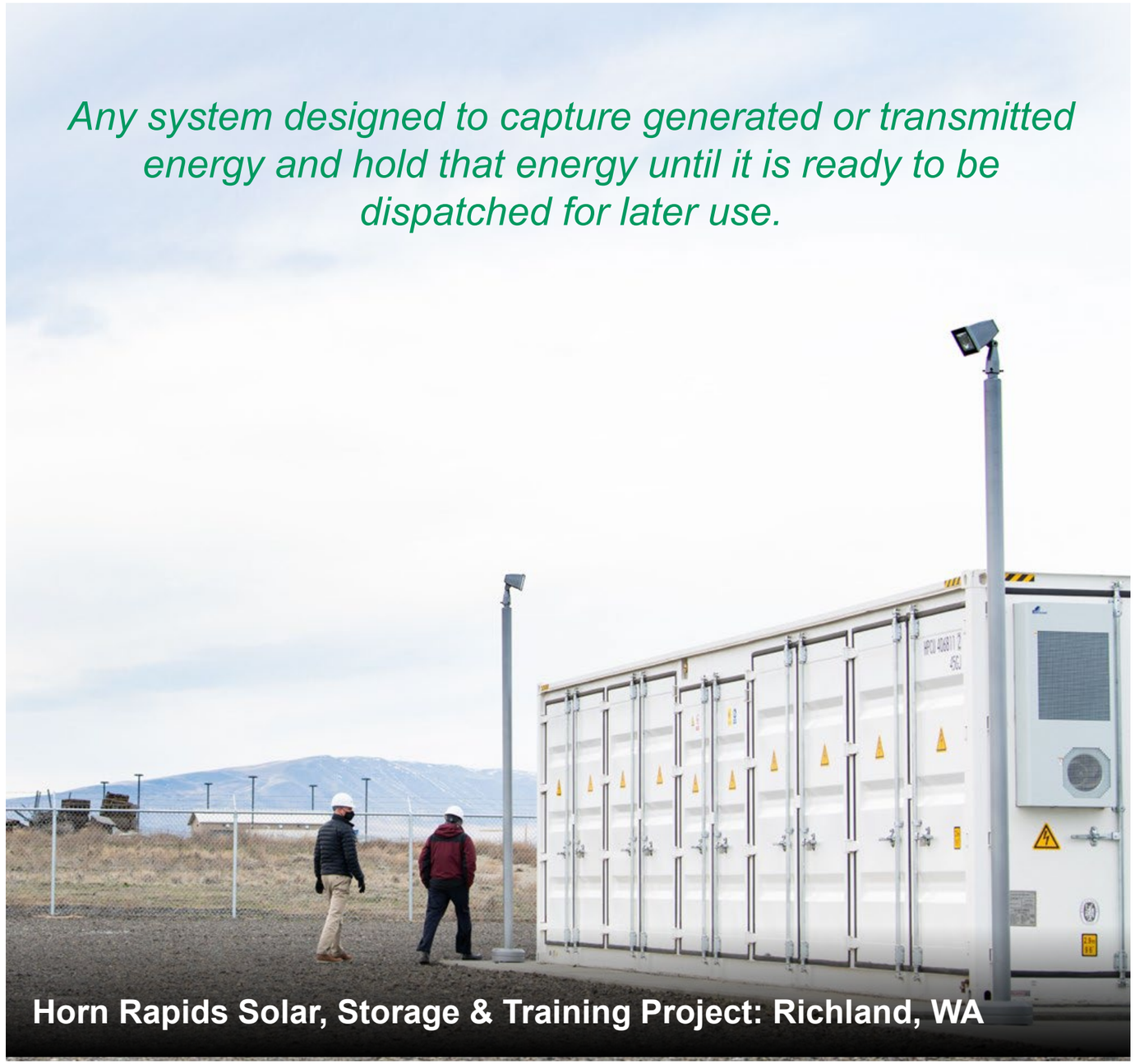

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Types of Batteries

Lithium-Ion batteries make up the largest market share and will be our focus during this workshop.

Abrv.	Battery Chemistry	Operating Characteristics	Common Applications
LCO	Lithium Cobalt Oxide	High energy, lower power	Cell phones, laptops, cameras
LMO	Lithium Manganese Oxide	High power, lower energy	Power tools, medical devices
NMC	Lithium Nickel, Manganese, Cobalt	High power and energy, less stable	Electric vehicles, e-mobility devices, industrial applications
NCA	Lithium Nickel, Cobalt, Alumina	High energy, less stable	Tesla EVs, medical and industrial applications
LFP	Lithium Iron (Fe) Phosphate	High cycle life and stability, lower energy	Vehicles (combustion and electric), stationary energy storage

Power versus Energy

Concept	Definition	Metric	Units
Energy	How much energy is stored	Capacity	kilowatt-hours (kWh)
Power	How quickly that energy can be dispatched	Rating	kilowatt (kW)

What's the difference?

***Time**.*

$$Power = \frac{Energy}{Time}$$

*The **duration** of a battery is given by providing both the **energy** and **power** of a battery. For example:*

a 4 kW / 16 kWh battery

has a 4-hour duration

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What can energy storage do?

It depends on…

- Grid Location
- Energy Markets
- Policy and Regulatory Mechanisms
- Capacity

Energy Storage Applications

Bulk Energy Services
- Resource Adequacy
- Energy Arbitrage

Ancillary Services
- Regulation
- Load Following
- Spinning and Non-Spinning Reserve
- Frequency Response
- Flexible Ramping
- Voltage Support
- Black Start

Transmission & Distribution Services
- Congestion Relief
- Volt-Var Control
- Infrastructure Update Deferral

Customer Services
- Bill Management (time-of-use, demand charges)

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How do you know if energy storage is economically feasible?

Value stacking –

designing energy storage to provide multiple services and maximizing its potential utilization

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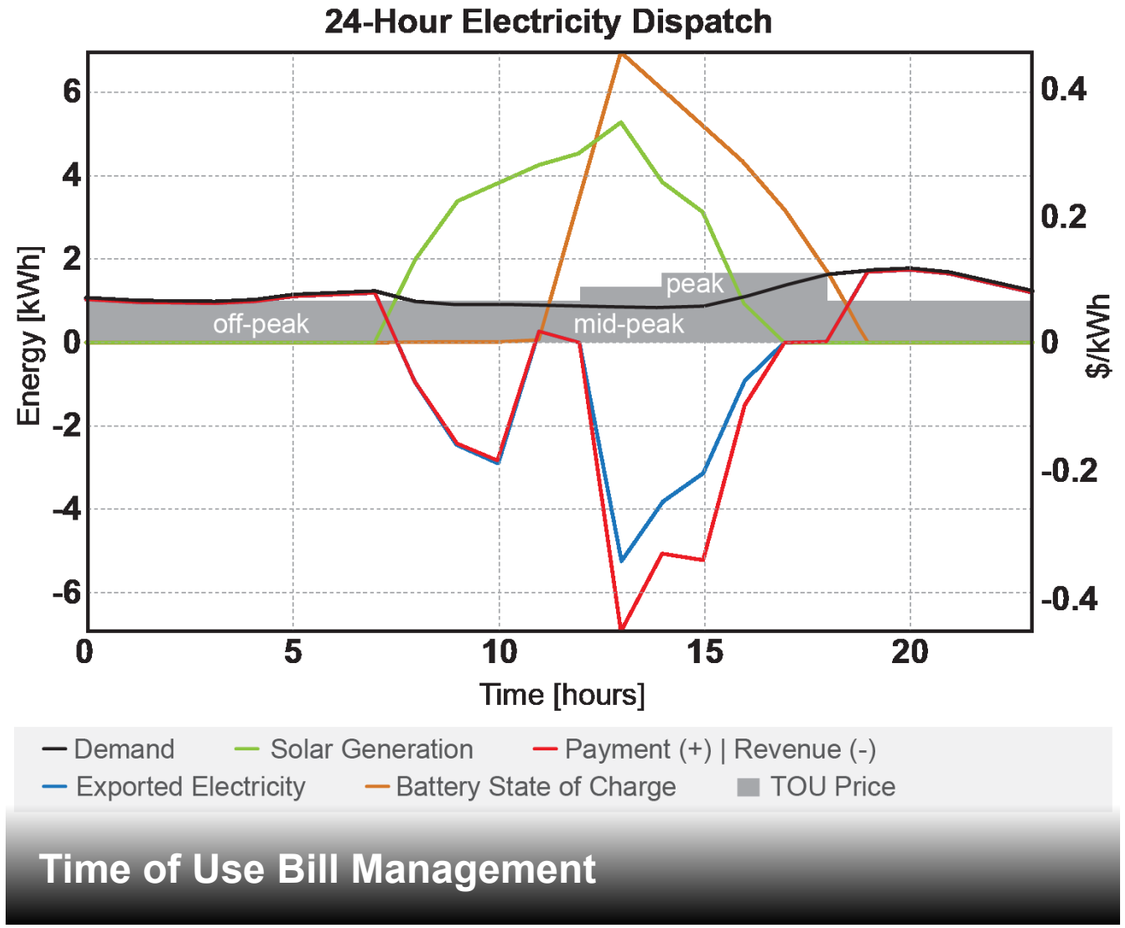
How do you configure energy storage to enable value stacking?



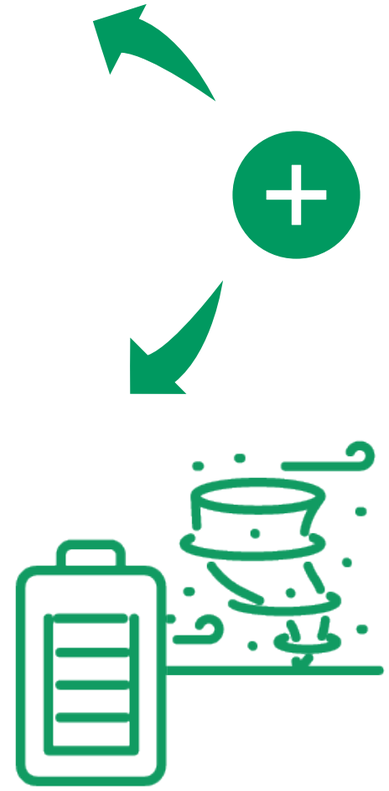
Time of Use Bill Management

Operating Profile –

the charge/discharge strategy of the battery

The operating profile of an energy storage device can be designed to

- *increase onsite consumption of local generation,*
- *run on a schedule (time of use bill management),*
- *respond to grid or market signals (ancillary services),*
- *prepare for potential outages (manually or responding to an alert), or*
- ***practically any combination of these services.***

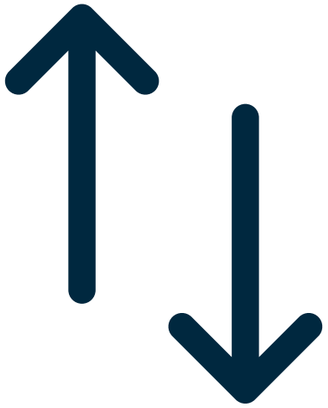


Resilience

Does the operating profile impact the lifetime of the battery?

Calendar Life

Expected lifetime of a battery due to the aging of its components

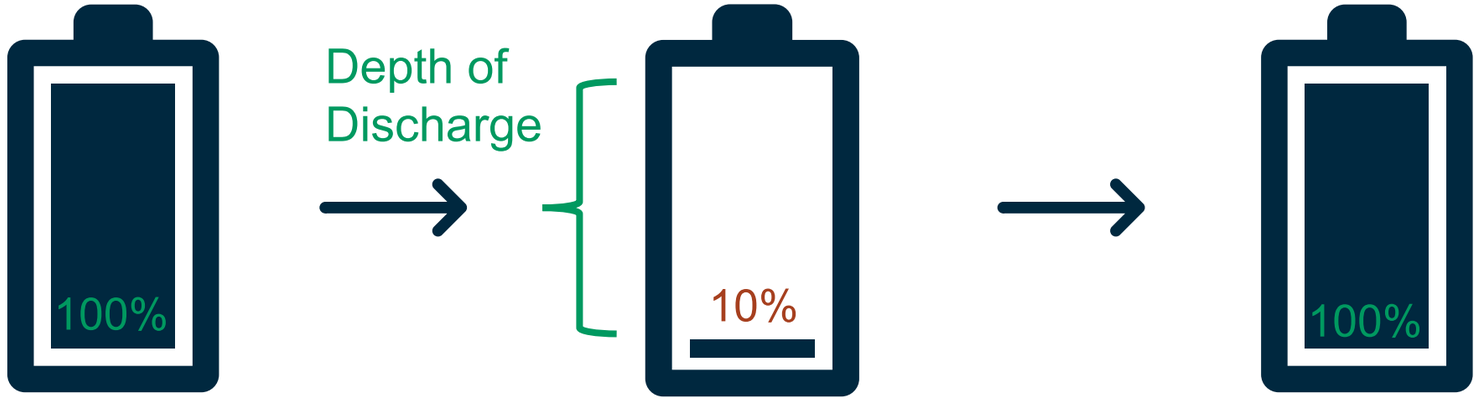


Cycle Life

Number of cycles (charge/discharge) a battery is expected to achieve before its capacity falls below usable levels

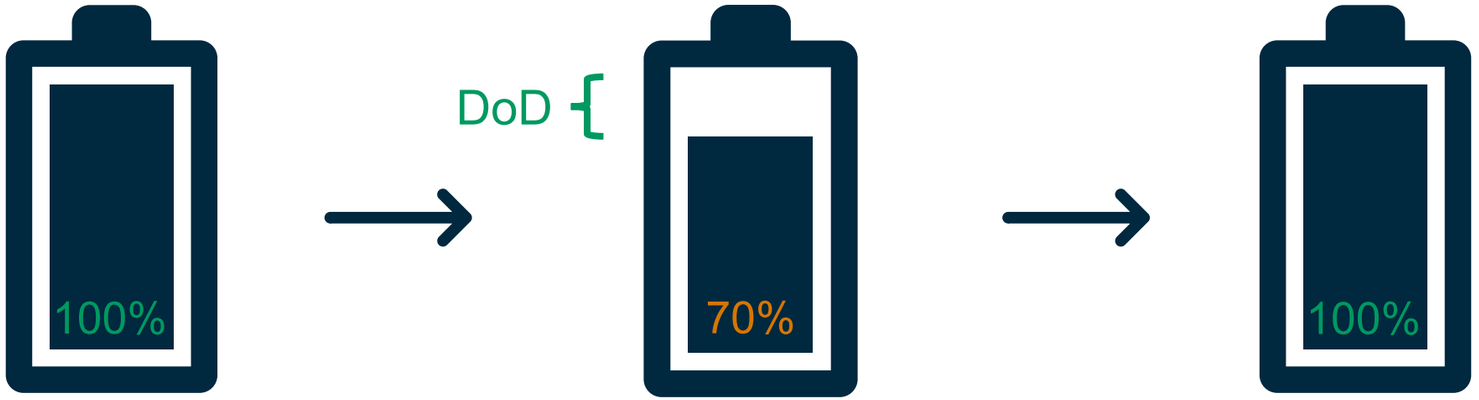
The battery operating profile impacts the cycle life of the battery.

What do we mean by “cycle”?



“Deep” Cycling
Large DoD

“Shallow” Cycling
Small DoD



*Both the depth of discharge (**DoD**) and how quickly batteries are charged and discharged (**C-rate**), impact the cycle life of the battery.*

How do you properly maintain a battery?

- Physical Security
  - Shield from exposure to elements
  - Protect against tampering
- Stable Temperatures
  - Proper ventilation
  - Adequate Insulation
- Operating Scheme
  - Follow manufacturer’s specifications
  - Select battery chemistry best-suited to application
- Preventative Maintenance
  - Update Battery Management System (BMS) firmware regularly
  - Stable charge if stored long-term

How do you measure the benefits of energy storage?

Access: provides access to on-demand electricity; supports energy independence when paired with local generation.

Affordability: reduce the cost of electricity by increasing consumption of locally generated electricity as well as bill management.

Improved Air Quality: reduce reliance on backup fuel-powered generators, improving local air quality during an outage.

Resilience: dispatches stored electricity during grid outages, providing uninterrupted electricity access for critical infrastructure, such as hospitals and community gathering spaces.

Social Impact: Energy storage paired with local generation sources can serve as a community asset, not only providing energy independence, but community ownership and wealth creation.

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So then why isn't energy storage everywhere?

*The inherent flexibility of energy storage has historically made it difficult to articulate and measure both its **benefits** and **impacts to the grid…***

***…**slowing adoption and creating additional barriers to widespread deployment.*

High upfront cost

Large Physical Footprint

Complex Siting and Permitting Requirements

Lack of Community Buy-In

Perception of Risks

Lack of Standards

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Questions?

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