WECC

# Long-duration ES Performance Metrics

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# Key Characteristics and Metrics

- Performance
  - Nameplate Capacity
  - Depth of Discharge and Usable Capacity
  - Cycle Life and Degradation
  - Energy Density / Power Density
  - Storage efficiency and Energy lost in storage/standby
- Cost
  - Cost of Usable Capacity
  - Lifetime Cost of Usable Capacity

# Nameplate Capacities

- Storage capacity (MWh)
- Discharge capacity range – max/min (MW)
  - 100 MW X 4 hours = 400 MWh
  - 50 MW X 8 hours = 400 MWh
- Charge capacity range – max/min (MW)
- Charge rate (MW/hour) – minimum, optimal, maximum
- Operating range (min / max)
- Charge time (hours to charge from min to max)
  - Function of charge rate

# Depth of Discharge (DoD)

- The percentage of the nameplate energy that is being used
- Determined by design parameters and usage recommendations
- Usable Capacity = Nameplate energy X DoD
  - Example:
  - 1000 MWh X 80% DoD = 800 MWh
  - 1000 MWh X 60% DoD = 600 MWh

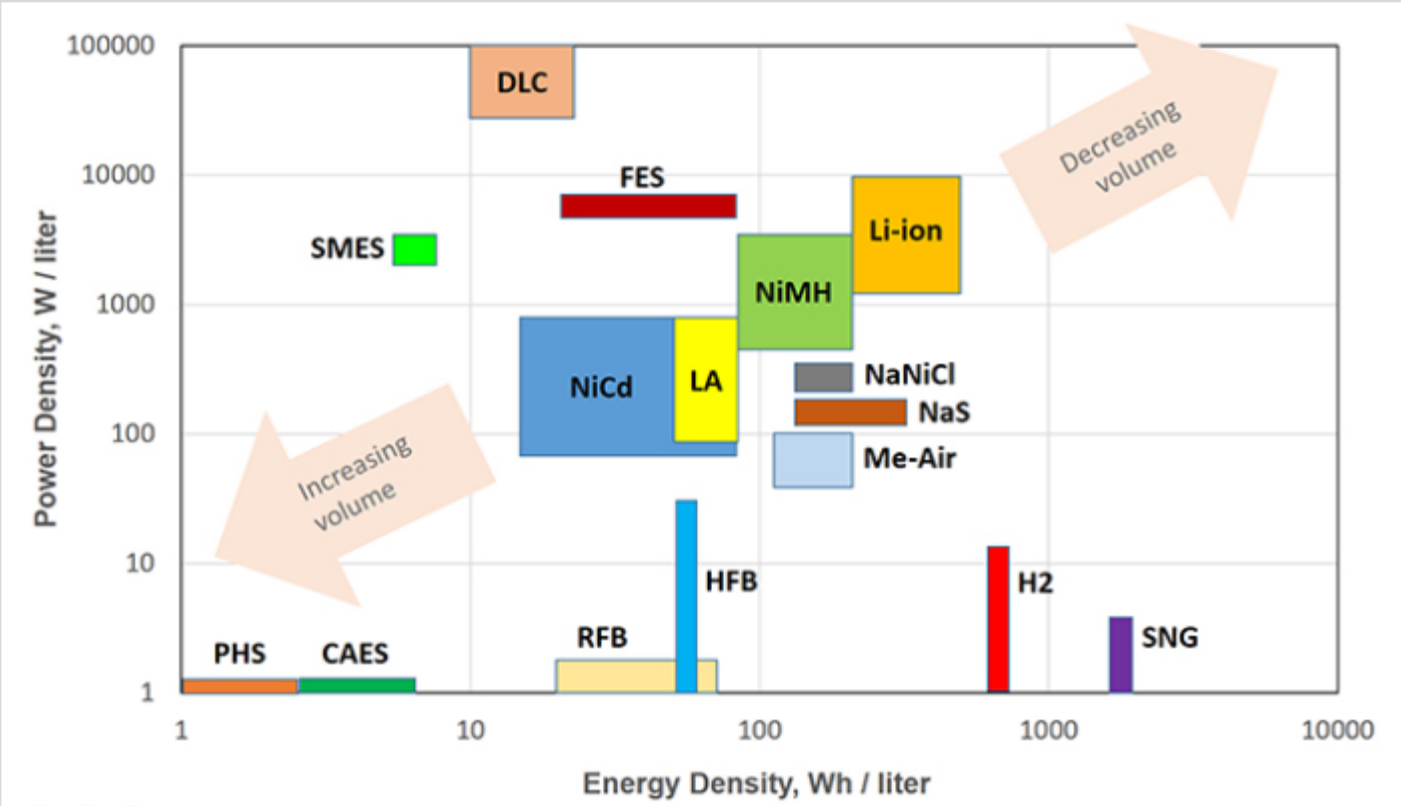
# Cycle Life and Degradation

- Cycle Life
  - The number of times that a storage technology can be charged and discharged over its lifetime
  - Often a function of the depth of discharge
- Degradation
  - The reduction in maximum capacity over time
- Average State of Charge
  - The degradation caused by remaining at a high state of charge over time

# Energy Density / Power Density

- Energy Density
  - Relates the storage capacity to the size or mass of the storage
  - Technologies with higher energy densities will be more compact
- Power Density
  - Indicates how quickly a storage system can release power
  - Measured in watts per kg or watts per liter

# Energy Density vs. Power Density Comparison




**Classification of energy storage systems by energy and power density. Key to abbreviations is provided below.**

*Credit: Mark Fedkin © Penn State based on the data from IES, 2011*

CAES – Compressed Air Energy Storage
DLS – Double Layer Capacitor
FES – Flywheel Energy Storage
H2 – Hydrogen storage
LA – Lead Acid Battery
Li-ion – Li ion Battery
Me-air – Metal Air Battery
NaNiCl – Sodium Nickel Chloride Battery
NaS – Sodium Sulfur Battery
NiCd – Nickel Cadmium Vented Battery
NiMH – Nickel Metal Hydride Battery
PHS – Pumped Hydro Storage
RFB – Redox Flow Battery
SMES – Superconducting Magnetic Energy Storage
SNG – Synthetic Natural Gas

# Storage Efficiency

- The efficiency of the charge – discharge cycle, also called Round-trip efficiency
  - Accounts for losses during each phase of the cycle from charge to storage to discharge
  - Examples: (from Penn State EME 812 - 2011/2012 data)
    - Lead-Acid Battery 75 – 90%
    - Li-ion Battery 85 – 98%
    - Pumped hydro 70 – 80%
    - Compressed Air 41 – 75%
    - Hydrogen 34 – 44%

# Energy Lost in Storage

- Losses after charging and before discharging
- Standby vs. storage losses
- Types of storage losses
  - Station service – cooling, heating,
  - Evaporation
  - Chemical maintenance

# Cost of Usable Capacity

- Installed cost per MWh capacity
  - Cost of Usable Capacity = Installed cost / Usable MWh capacity

# Lifetime Cost of Usable Capacity

- Commonly called Levelized Cost of Energy (LCOE)
  - LCOE = Installed Cost / Lifetime Usable MWh Capacity

- LAZARDS annual study of LCOE
  - Now includes energy storage and hydrogen

# PCM Inputs for Storage

- Maximum and Minimum storage (MWh)
- Initial storage at first hour of study (MWh)
- Efficiency
- Capacity Factor
- Schedule Mode 1 (load curve, price curve)
- Schedule Mode 2 (hourly, daily, weekly)
- Multi-day schedule pattern (storage targets)
- Cost Benefit Ratio
- Charge capacity max/min (MW); Discharge capacity max/min (MW)
- Weekly Energy (MWh) [optional]
- LMP Price to charge ($); LMP Price to discharge ($)
- Ramp up / down rates (MW/hour)
- Reserve contribution (%); Ancillary Services contribution (%)

# PCM Storage Horizon

- GridView is limited to hourly, daily, or weekly
- Would need a work-around to model seasonal storage. WECC will work with vendor on this.

# PCM Costs

- Production cost represents cost to serve load
  - Fixed costs not modeled by WECC; data often confidential
  - Variable costs are modeled using publicly available data
    - Fuel consumption
    - Variable O&M
    - Start-up
    - Carbon tax
    - Wheeling
- Perhaps a different cost-based tool would work better for LDES cost metrics
  - Capital expansion
  - Hybrid

# Future Considerations

- Check with PCDS, PCMS, vendor, National Labs, CEC funded studies (UC Merced), and other industry sme's
- Storage duration of 1 week or more for study
- What level(s) of clean energy? Goal is 100%, but subject to solution success.

WECC

Electric Reliability and Security for the West

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