



PNNL OE Energy Storage Review

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PNNL is operated by Battelle for the U.S. Department of Energy



Summary of FY19 OE Energy Storage Accomplishments at PNNL

- Delivered impactful S&T advances in OE's four strategic thrust areas for Energy Storage

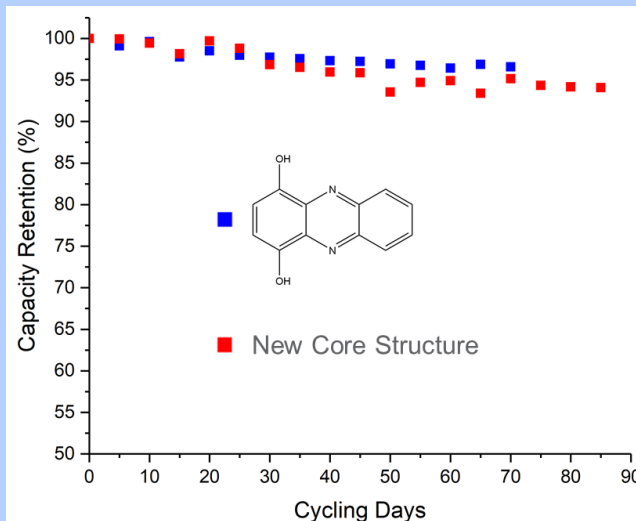
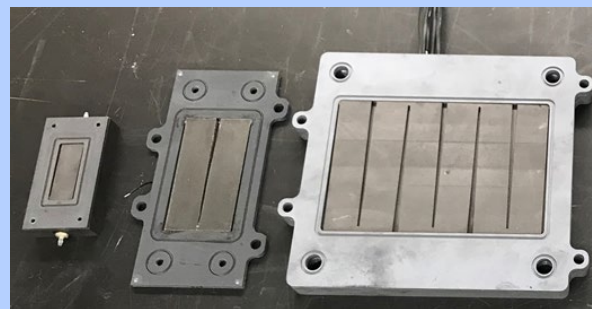
- 1) **Cost Competitive Technologies (David Reed/Wei Wang)**
- 2) **Safety and Reliability (David Reed)**
- 3) **Regulatory Engagement (Jeremy Twitchell)**
- 4) **Industrial Acceptance (Patrick Balducci)**

1.) Cost Competitive Technologies

- continued focus on 3-pillar technologies

Redox Flow Batteries

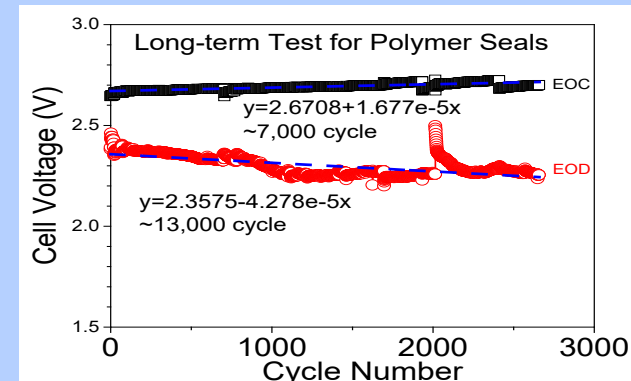
Novel Aqueous Soluble Organic (ASO) chemistry that can enable additional 50% cost reduction over V/V technology.



Sodium Batteries

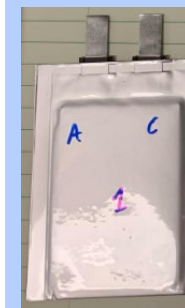
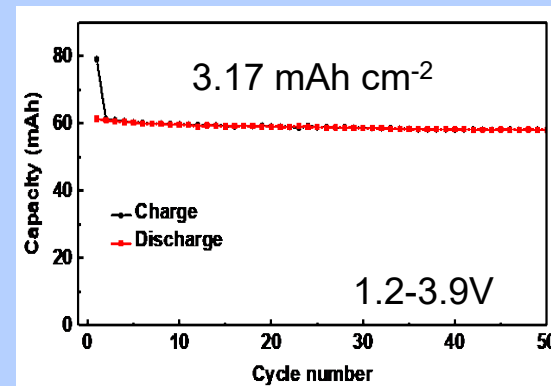
1.) Sodium Metal

- 190°C, > 2500 cycles, polymer seals



2.) Sodium-ion

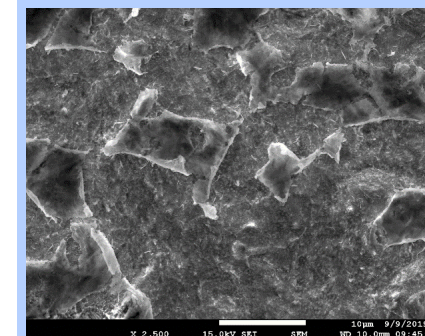
- NMC/Carbon Analog in larger format



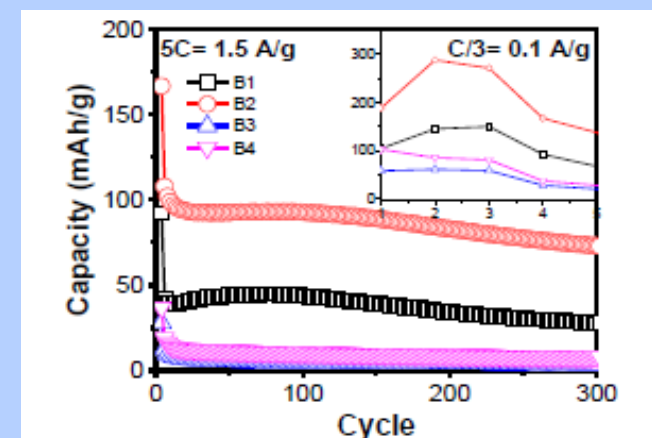
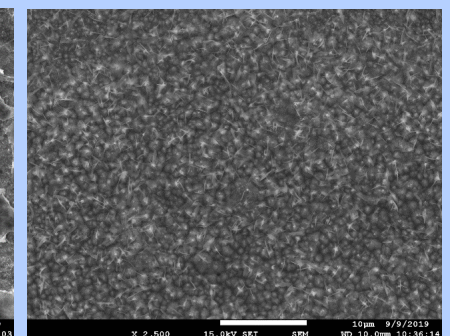
Zn-MnO₂

Neutral pH Zn-MnO₂

Cycled Zn Film



Cycled Zn_xCu_{1-x}





- Moving from cells to module investigations

Safety

Codes Standards Outreach



Cells



Systems



V/V Flow



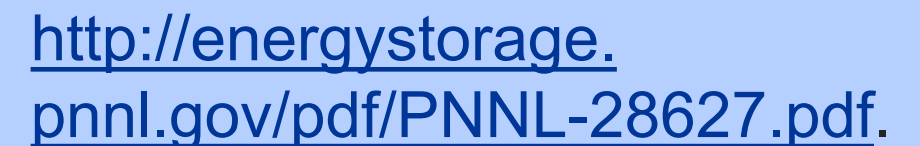
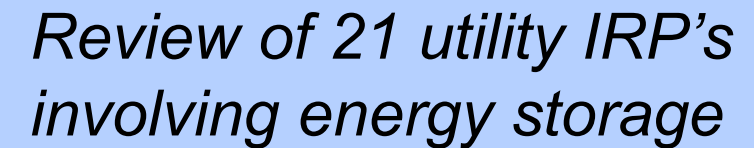
Pb-acid





State ESS Policy Database/ Policy Reviews

Storage and IRP process



4.) Industrial Acceptance

- *Developing tools to better inform economic deployment*

WA CEF I Completion

Utility	Site	Chemistry	Rated Power (MW)	Rated Energy (MWh)	Energy-to-Power Ratio (E/P)
Avista	Pullman	All vanadium mixed acid flow	1,000	3,200	3.2
SnoPUD	Everett MESA2	All vanadium mixed acid flow	2,200	8,000	3.6
SnoPUD	Everett MESA1	Lithium-ion LMO & NMC cathodes	2,000	1,000	0.5
PSE	Glacier	LiFePO4	2,000	4,400	2.2



SnoPUD MESA 2



PSE Glacier



SnoPUD MESA1

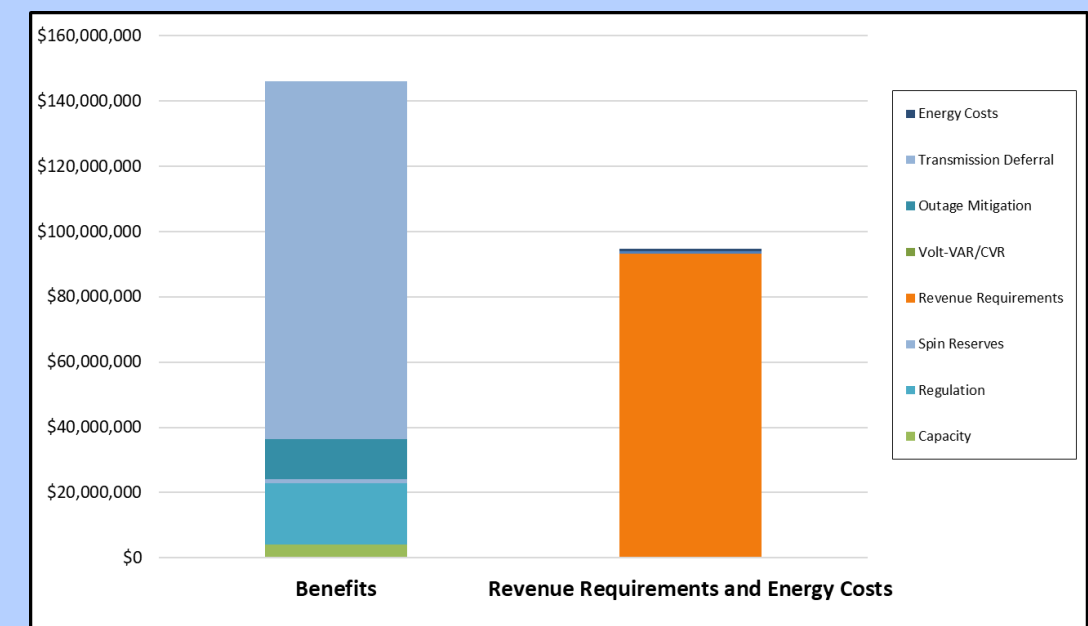


Avista Turner BESS

Enabling integration of field deployed ESS performance parameters into economic optimization tools.

Nantucket Island ESS

- Benefit-cost ratio (BCR) of 1.55 for the energy storage system.
 - 75% Transmission Deferral
 - 13% Regulations Services



Benefits of Local and Market Operations (Base Case) vs. Revenue Requirements

Summary of FY19 Technical Output

- **12 peer reviewed Journal Articles published.**
 - *Including ACS Applied Energy Materials, Advanced Materials, Nanoscale, ChemSusChem, ...*
- **10 PNNL Technical Reports issued**
 - *WA CEF installation, Nantucket, Hawaiian Electric, ...*
- **> 100 presentations**
 - *MRS, ECS, ACS, IEEE, Beyond Li-ion, ESA, State Energy and Utility Commissions, World Bank, US-Korea Clean Energy Policy Summit, ...*
- **Professional Societies**
 - *Organized (2) 2018 MRS Fall symposium on ES Technologies*
 - *Organized ECS Symposium on Flow Batteries*
 - *Organized International Collation Energy Storage*
 - *Co-chair IEEE Energy Storage Collaboration Team (ESCT), ...*

Energy Storage

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Program Areas

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Grid Energy Storage Reports

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2019

- [Nantucket Island Energy Storage System Assessment](#)  Patrick Balducci, Jan Alam, Tom McDermott, Vanshika Fotedar, Xu Ma, Di Wu, Bilal Bhatti, Kendall Mongird, Bishnu Bhattarai, Alasdair Crawford, and Sumittra Ganguli. 2019. PNNL-28941, Pacific Northwest National Laboratory, Richland, WA.
- [Energy Storage Seminar for Western State Regulatory Commission Staff - Report on Proceedings](#)  JB Twitchell, RS O'Neil, K Mongird. 2019. PNNL-28060, Pacific Northwest National Laboratory, Richland, WA.
- [Hawaiian Electric Companies Demand Response Tool](#)  Y Yuan, P Balducci, K Mongird, V Fotedar, D Wu, D Bhatnagar. 2019. PNNL-28956, Pacific Northwest National Laboratory, Richland, WA.
- [Puget Sound Energy Glacier Energy Storage System - An Assessment of Battery Technical Performance](#)  Crawford A, V Viswanathan, C Vartanian, K Mongird, J Alam, D Wu, P Balducci. 2019. PNNL-28379, Pacific Northwest National Laboratory, Richland, WA.
- [Avista Turner Energy Storage System - Assessment of Battery Technical Performance](#)  Crawford A, V Viswanathan, C Vartanian, J Alam, P Balducci, D Wu, T Hardy, K Mongird. 2019. PNNL-28480, Pacific Northwest National Laboratory, Richland, WA.
- [Energy Storage Technology and Cost Characterization Report](#)  K Mongird, V Viswanathan, P Balducci, J Alam, V Fotedar, V Koritarov, B Hadjerioua. 2019. PNNL-28866, Pacific Northwest National Laboratory, Richland, WA.
- [Energy Storage in Integrated Resource Plans](#)  AL Cooke, JB Twitchell, RS O'Neil. 2019. PNNL-28627, Pacific Northwest National Laboratory, Richland, WA.
- [Snohomish Public Utility District Mesa 2 - An Assessment of Battery Technical Performance](#)  Crawford A, V Viswanathan, J Alam, P Balducci, D Wu, C. Vartanian, K Mongird. 2019. PNNL-28478, Pacific Northwest National Laboratory, Richland, WA.