# Progress toward a Resilient, Green Energy Future: Energy Storage to Energy Systems Approaches for Decarbonization

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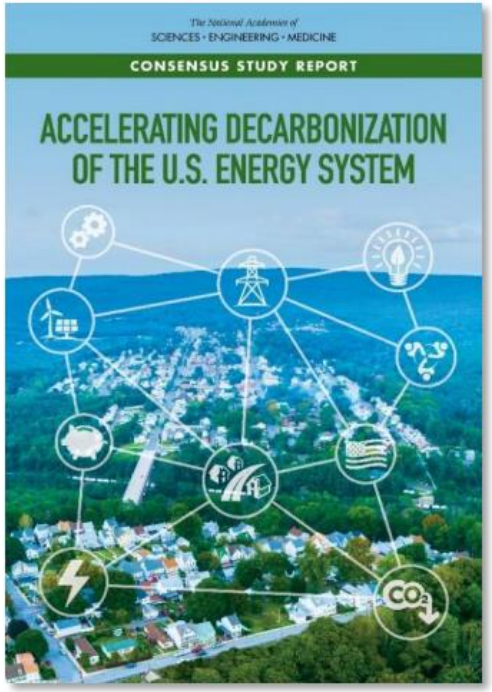
# Decarbonizing the Energy System

## NAP recommendations over next 10 years to achieve net-zero by 2050

- Electrify energy services in transportation, building, and industry
- Improve energy efficiency and productivity
- Produce carbon-free electricity
- Expand the innovation toolkit




nap.edu/decarbonization

## New York's clean energy goals align with Federal direction

*Climate Leadership and Community Protection Act (CLCPA) Goals*

- 85 % reduction in greenhouse gas emission by 2050
- 100% zero-emission electricity by 2040
- 70% renewable energy by 2030

***To achieve the ambitious goals, a multifaceted approach is necessary, integrating energy storage, energy systems, and climate science expertise***

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# Technical Expertise for Decarbonization

## Interdisciplinary Science

### Energy Systems

- Energy efficiency
- Grid modernization

Tom Butcher

Tatiana Pyatina

Rebecca Trojanowski

Meng Yue

Raj Yogarathnam

Peng Zhang

### Energy Storage

- Batteries in action - *operando* studies
- Fast charging electric vehicle batteries
- Science of scalable batteries

Esther Takeuchi

Kenneth Takeuchi

Lei Wang

Lisa Housel

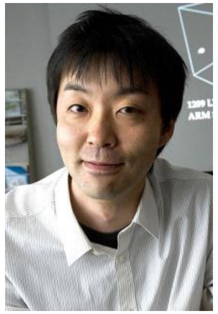
Dave Bock

## Environmental and Climate Science

- Meterology and atmospheric modeling
- Cloud physics

Alison McComiskey

Michael Jensen



Satoshi Endo

# Energy Efficiency: Current Programs

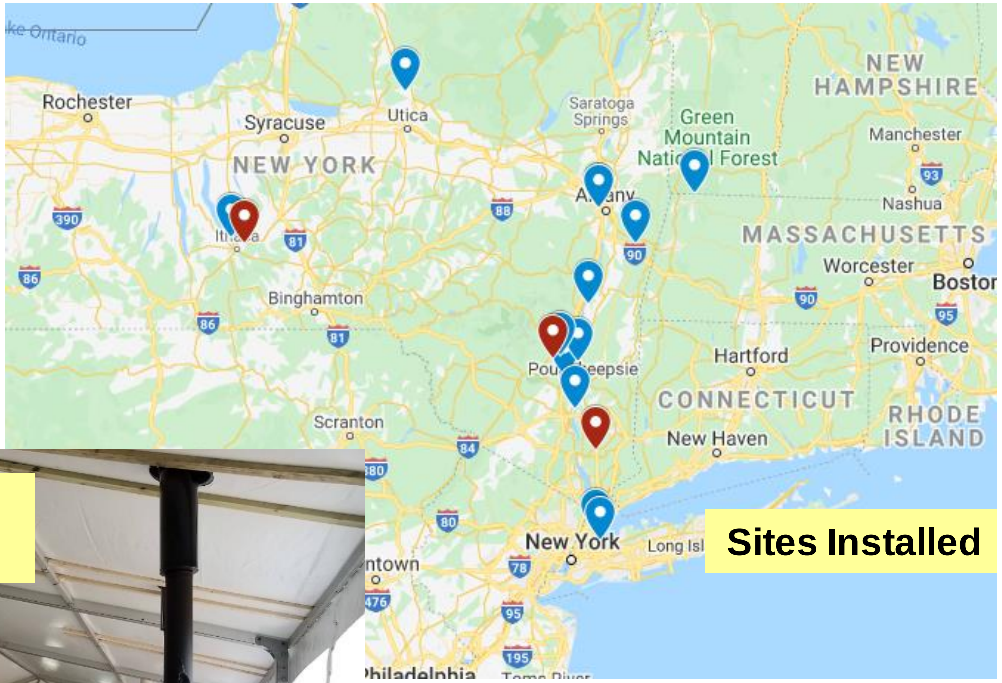
Field study of air-source heat pumps in cold climates

Novel, low-cost methods for evaluating emission and efficiency of advanced wood burning appliances

Development of next generation Certification Test Methods for Wood Heaters.

Development of air pollutant emission factors for emerging fuels.

Solid oxide fuel cells with natural gas and gas/hydrogen blends.






T.A. Butcher, R. Trojanowski, *ACS Omega,* **2021,** *5(44),* 28517-28528.

T. Butcher, J. Am. Oil Chem. Soc., **2021,** *98,* 114.

R. Trojanowski, V. Fthenakis, *Renewable & Sustainable Energy Reviews,* **2019,** *103,* 515-528.

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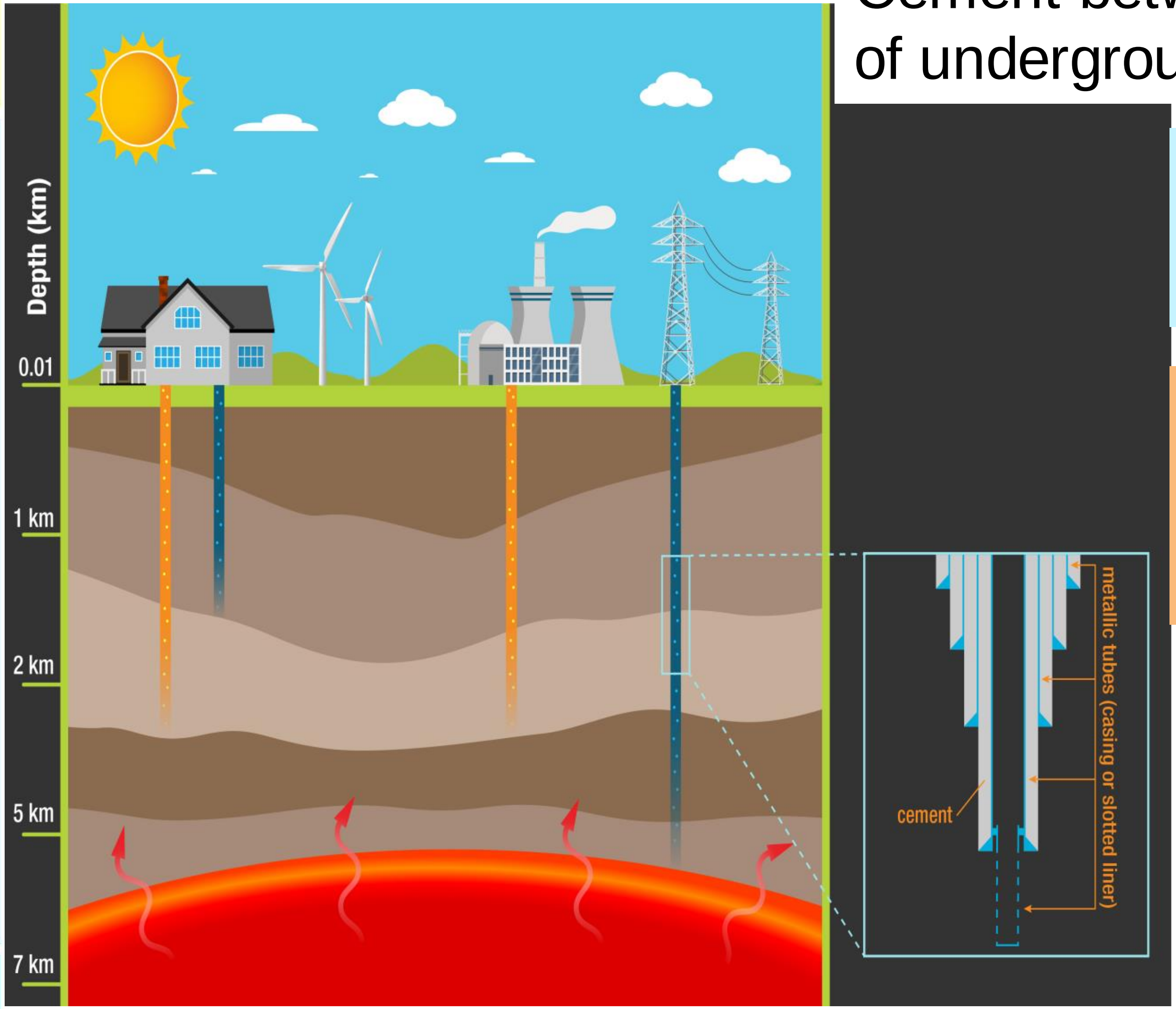
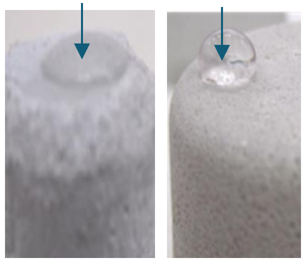
# Geothermal materials

Deep geothermal made with telescopic metallic tubes

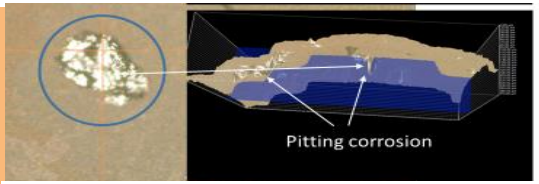
Cement between the tubes and rock prevents mixing of underground fluids and supports well structure.




**Hydrophobic thermally insulating cement (100-250$^{o}$C)** decrease energy losses > 60%

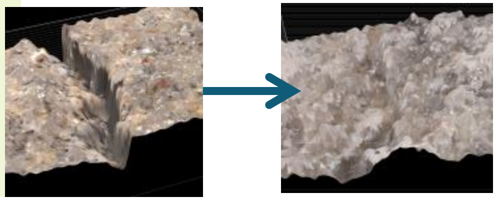



***Cements for super-critical conditions (400-500$^{o}$C) in collaboration with 5 European partners***




Strong pitting superalloy corrosion in super-critical conditions

TSRC crack sealing (3D microscope)



**Thermal Shock Resistant Cement** - self-healing and steel casing re-adhering

U.S. Non Provisional Patent App # 17/494,477.

T. Sugama, T. Pyatina; *Materials*, **2021**, *14(21)*, 6679.

T. Sugama, T. Pyatina. *Geothermics*, **2021**, *96*, 102068.

T. Pyatina, T. Sugama. *Geothermics*, **2020**, *86*, 101840.

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# Grid Modeling: Current Capabilities

## Grid modeling and simulation

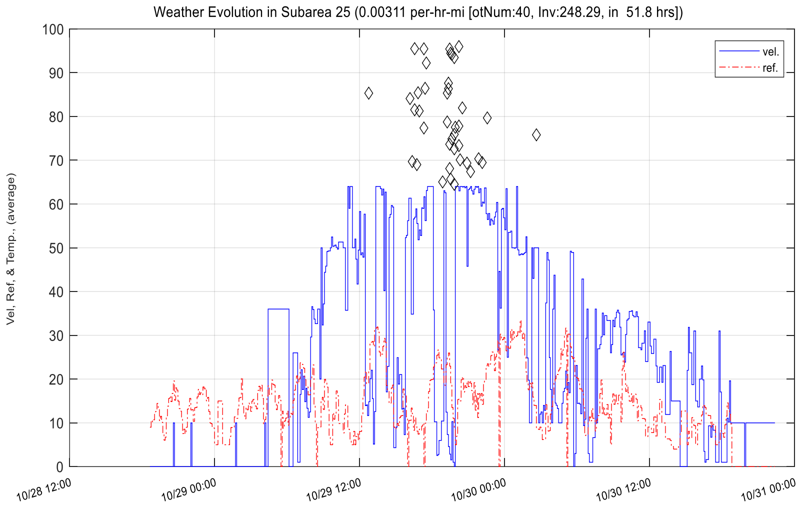
- Steady-state and dynamic impacts of renewables
- Machine-learning and physics-based transient simulator

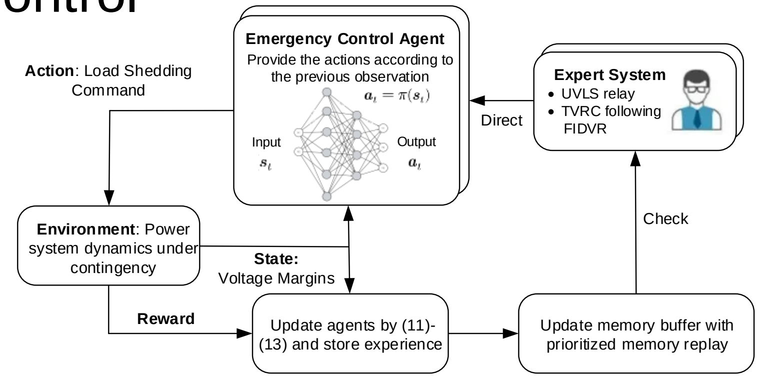
## Data analytics and machine learning applications

- Model-based anomaly detection for cybersecurity
- Damage forecasting under severe weather conditions
- Data-driven stability assessment, trajectory prediction, and control

## Probabilistic risk assessment

- Uncertainty modeling, quantification, and propagation
- Stochastic optimization for energy storage sizing and siting
- Probabilistic damage modeling for forecasting





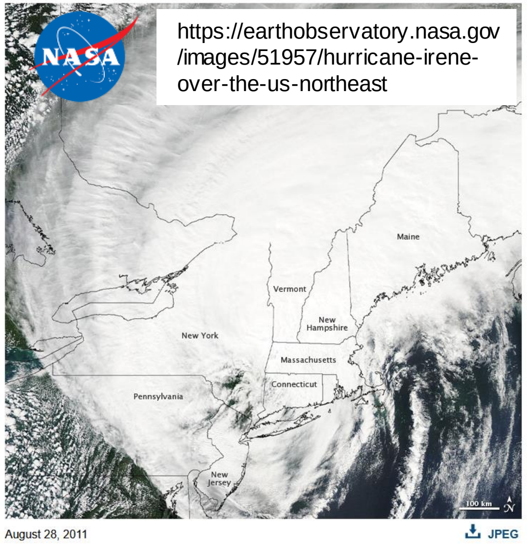
Y. Zhou, P. Zhang, M. Yue, *IEEE Trans. Power Sys.*, **2021,** *36(3),* 2416-2427.

Y. Zhang, K. Tomsovic, S.M. Djouadi, M. Yue. *IET Energy Sys. Integ,* **2020,** *2(3).* 226-234.

M. Cui, J. Wang, M. Yue, *IEEE Trans. Smart Grid,* **2019,** *10(5),* 5724-5734.

# BNL LDRD: Granular Grid-Outage Nowcasting Towards Numerical Weather Prediction Forecasting

Michael Jensen, Environmental and Climate Sciences Department
Meng Yue, Interdisciplinary Sciences Department




Storm-Related Weather: Aug2011

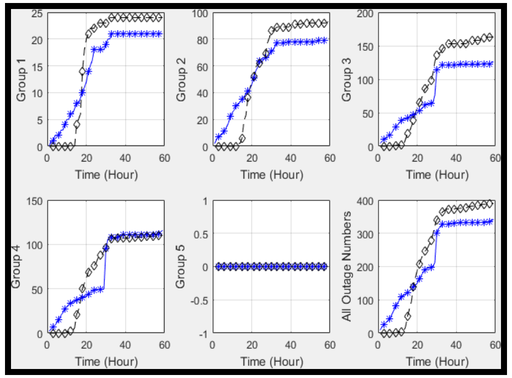
Total outages >400, most are overhead (OH) cable related

Failure rate model calculated for five areas of utility service territory

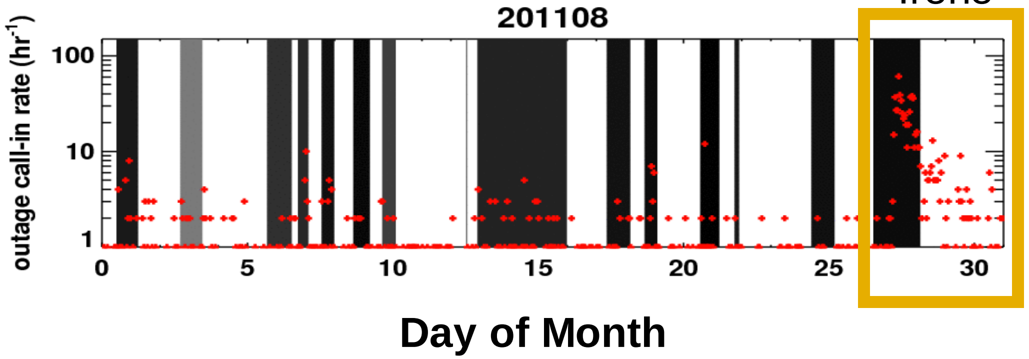
- Inputs: Hourly weather condition data and utility's component inventory.
- Output: Hourly evolution of OH outages in different areas.

Bayesian update in development considering both failure rate model and known outages

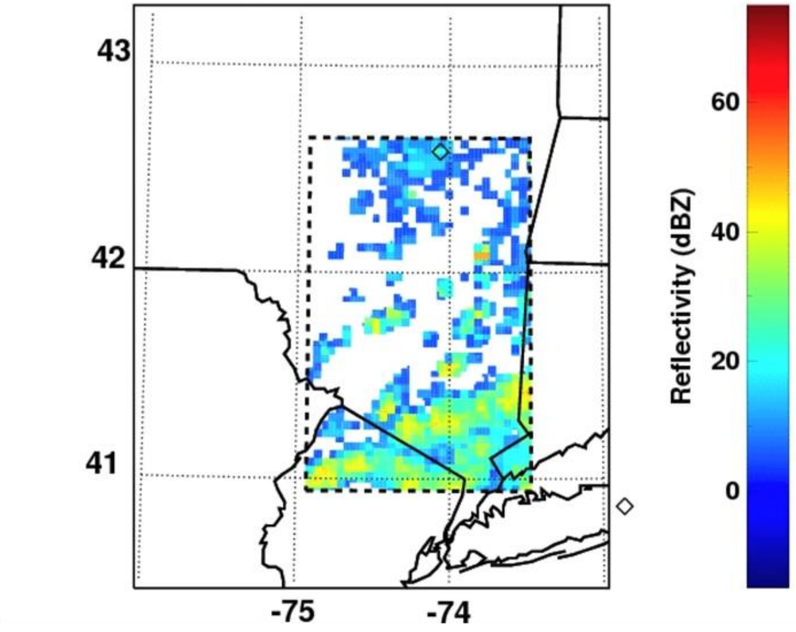
OH Outages (1 h interval): **actual**, calculated




Storm-Related Utility Outages : Aug2011




Shaded areas = storm activity by radar reflectivity
+ = general outage call in rate (hours⁻¹)




Reflectivity: reflects precipitation and wind

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https://electrek.co/2020/05/18/mercedes-benz-introduces-ev-insurance-coverage-to-include-charging-stations/

# Enabling Fast Electric Vehicle Charging via Control of Li Deposition Overpotential

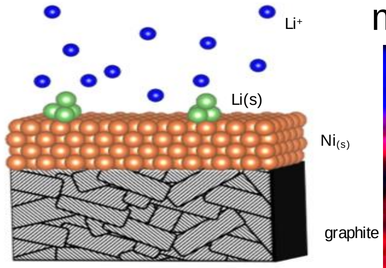
**Challenge:** major technical barrier preventing fast EV battery charging is lithium plating at the graphite anode.

**Approach:** Suppress Li plating via scalable, manufacturable coating of graphite anodes with metallic nanoscale films having high overpotentials for Li metal nucleation.

**Outcome:** Nanoscale films suppress lithium plating by 50%, with ~9% improvement in capacity retention after 500 fast (10 minute) charge cycles

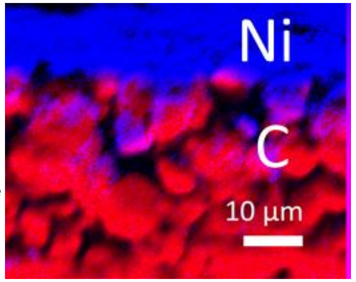
$$E_{neg} - \eta_{neg} \leq E_{Li^+/Li^0} - \eta_{Li^+/Li^0}$$

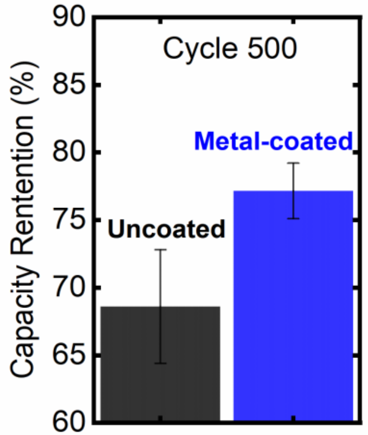
$E_{neg}$ = graphite electrode potential
$\eta_{neg}$ = overpotential for graphite electrode
$E_{Li^+/Li^0}$ = lithium deposition reaction potential
$\eta_{Li^+/Li^0}$ = overpotential for lithium deposition

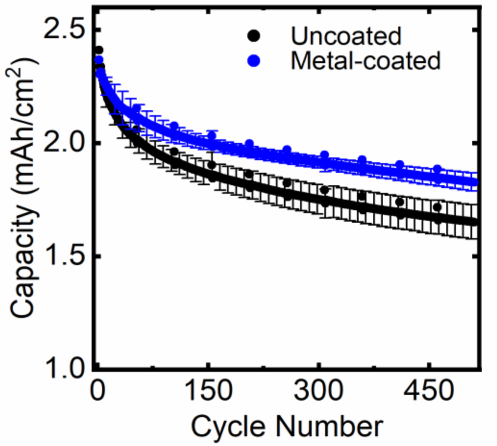


M-graphite electrode

10 nm films via DC magnetron sputtering




Center for Functional Nanomaterials at BNL

Brookhaven National Laboratory

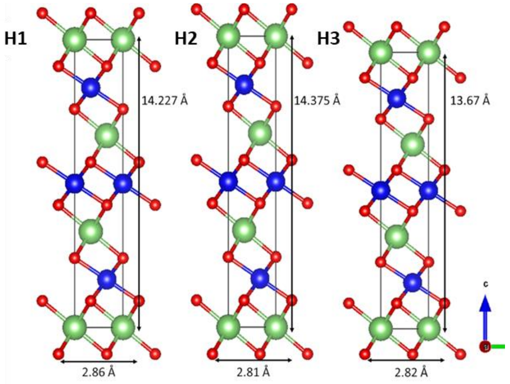
U.S. Patent Appl. No. 62/618,116.

K.R. Tallman, S. Yan, C.D. Quilty, A. Abraham, A.H. McCarthy, A.C, Marschilok, K.J. Takeuchi, E.S. Takeuchi, D.C. Bock, *J. Electrochem. Soc.*, **2020,** *167(16),* 160503.

K.R. Tallman, B. Zhang, L. Wang, S. Yan, X. Tong, J. Thieme, A. Kiss, A.C. Marschilok, K.J. Takeuchi, D.C. Bock, E.S. Takeuchi, *ACS Appl. Mater. Interfac.*, **2019,** *11,* 46864-46874.

# Characterizing Battery Lifetime and Mechanism *Operando*

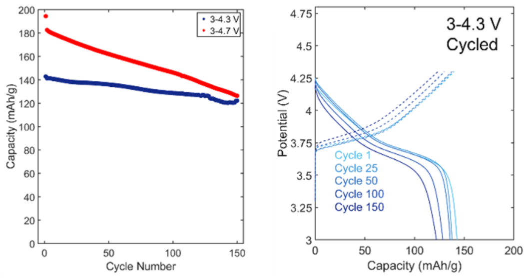
Battery degradation mechanisms were elucidated using *operando* synchrotron based X-ray characterization, scanning probe methods, and microcalorimetry



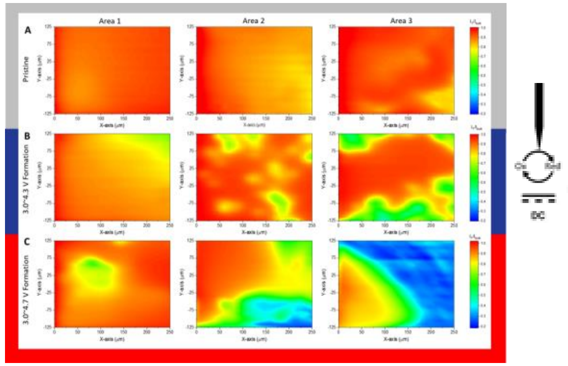

Lithium nickel manganese cobalt oxide (NMC), $LiNi_xMn_yCo_zO_2$

National Synchrotron Light Source II (NSLS-II) at BNL

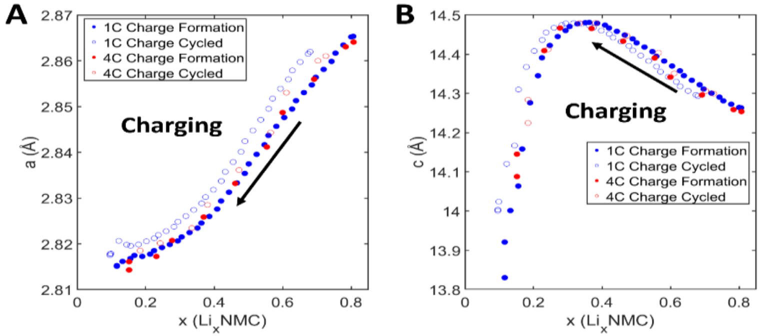
electrochemistry

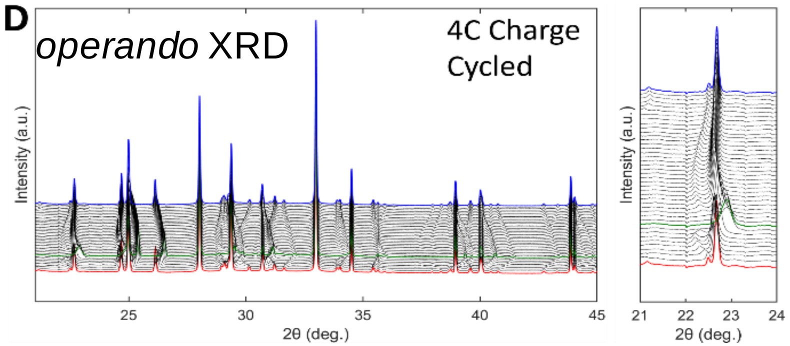



scanning probe analysis



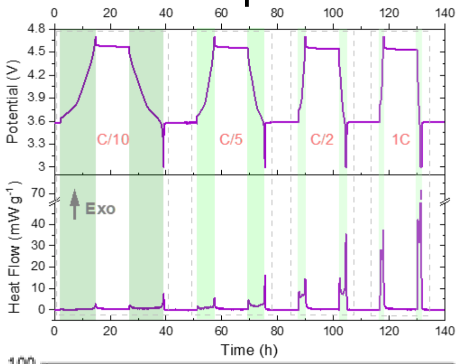

tracking structural change during fast charge

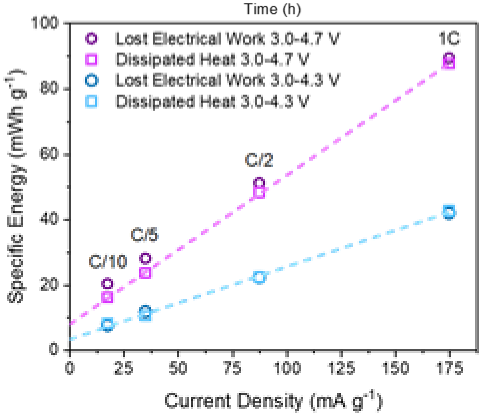



quantifying heat vs work

ΔE = q + w




W. Li, L.M. Housel, G.P. Wheeler, D.C. Bock, K.J. Takeuchi, E.S. Takeuchi, A.C. Marschilok, *ACS Appl. Energy Mater.*, **2021,** *4(11),* 12067-12073.

C.D. Quilty, G.P. Wheeler, L. Wang, A.H. McCarthy, S. Yan, K.R. Tallman, M.R. Dunkin, X. Tong, S. Ehrlich, L. Ma, K.J. Takeuchi, E.S. Takeuchi, D.C. Bock, A.C. Marschilok, *ACS Appl. Mater. Interfac.* **2021,** *13(43),* 50920–50935.

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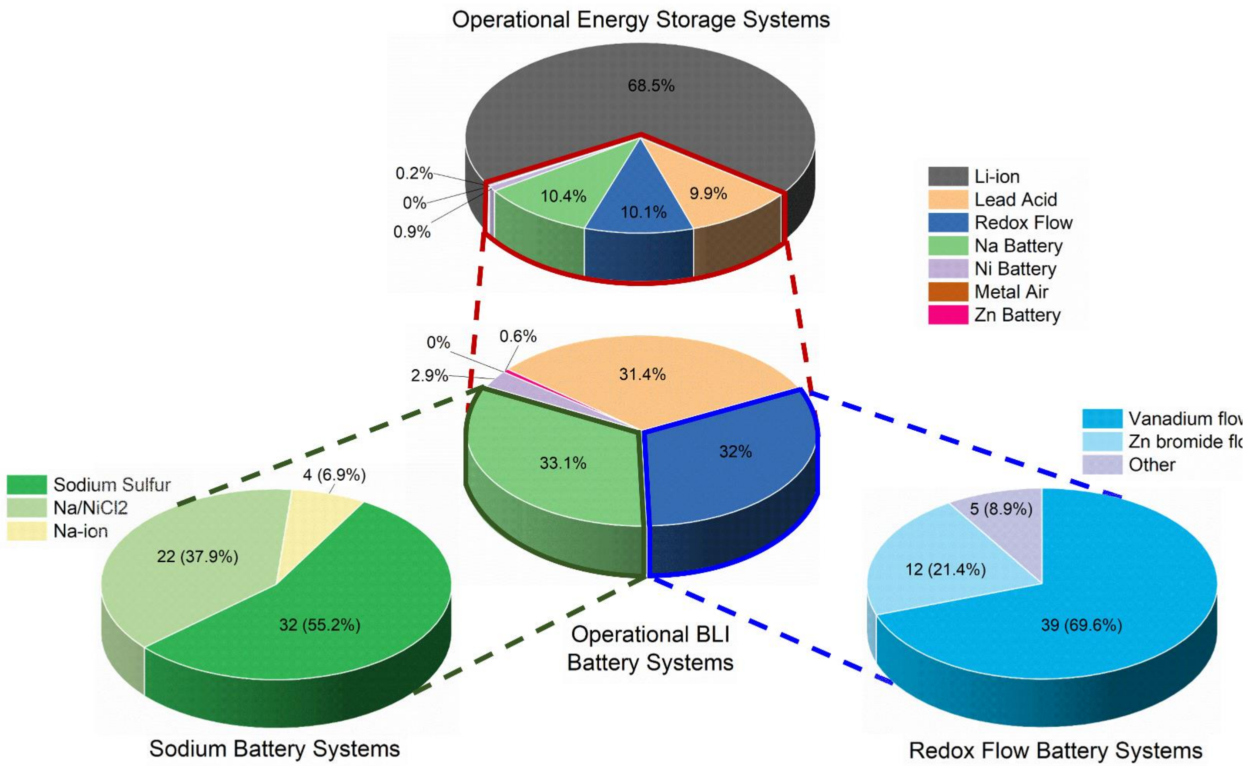
C.D. Quilty, P.J. West, G.P. Wheeler, L.M. Housel, C.J. Kern, K.R. Tallman, L. Ma, S. Ehrlich, C. Jaye, D.A. Fischer, K.J. Takeuchi, D.C. Bock, A.C. Marschilok, E.S. Takeuchi, *J. Electrochem. Soc.*, **2022,** *169,* 020545.

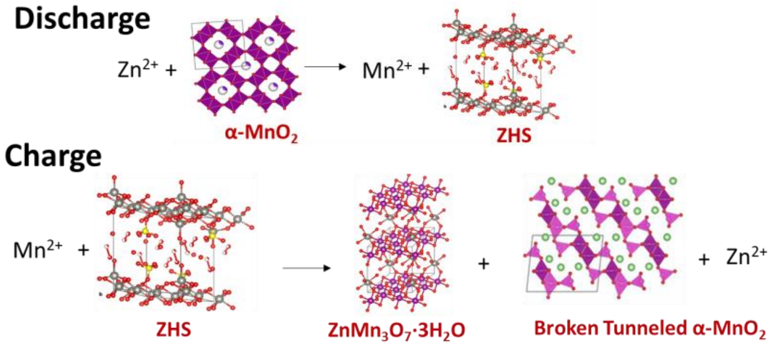
# Aqueous Electrolyte, Low Cost, Environmentally Friendly Batteries

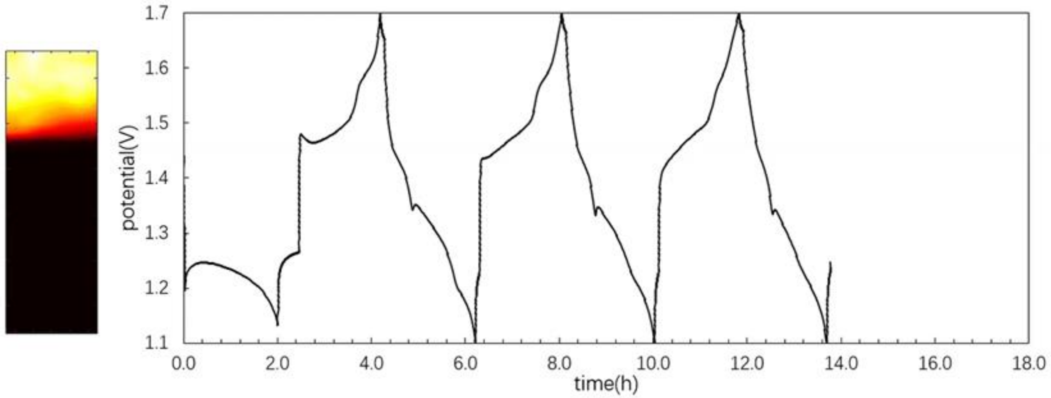
Due to lifetime, safety, and raw material sourcing concerns, alternative technologies to lithium ion battereis are desired for large scale (grid level) energy storage

Investigating new materials and chemistries for next-gen safe, sustainable batteries




Zn/$MnO_2$ Battery




“Beyond Li-Ion Batteries for Grid-Scale Energy Storage,” G.P. Wheeler, L. Wang, A.C. Marschilok, in *Elements in Grid Energy Storage,* Ed. B. Chalamala, V. Sprenkle, I. Gyuk, R. Masiello, R. Byrne, V. Gupta. ***In press.***

D. Wu, L.M. Housel, S-J. Kim, N. Sadique, C.D. Quilty, L. Wu, R. Tappero, S.L. Nicholas, S. Ehrlich, Y. Zhu, A.C. Marschilok, E.S. Takeuchi, D.C. Bock, K.J. Takeuchi, *Ener. Environ. Sci.*, **2020,** *13,* 4322-4333.

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# Integration of Energy Systems and Energy Storage Expertise is Essential to Achieve Decarbonization!

## Interdisciplinary Science

### Energy Systems

- Energy efficiency
- Grid modernization

### Energy Storage

- Batteries in action - *operando* studies
- Fast charging electric vehicle batteries
- Science of scalable batteries

## Environmental and Climate Science

- Meterology and atmospheric modeling
- Cloud physics


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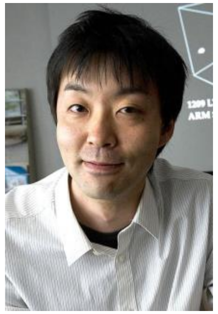
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