OAK RIDGE National Laboratory

Next Generation Energy Storage Materials: From Electric Mobility to Smart Grid

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And

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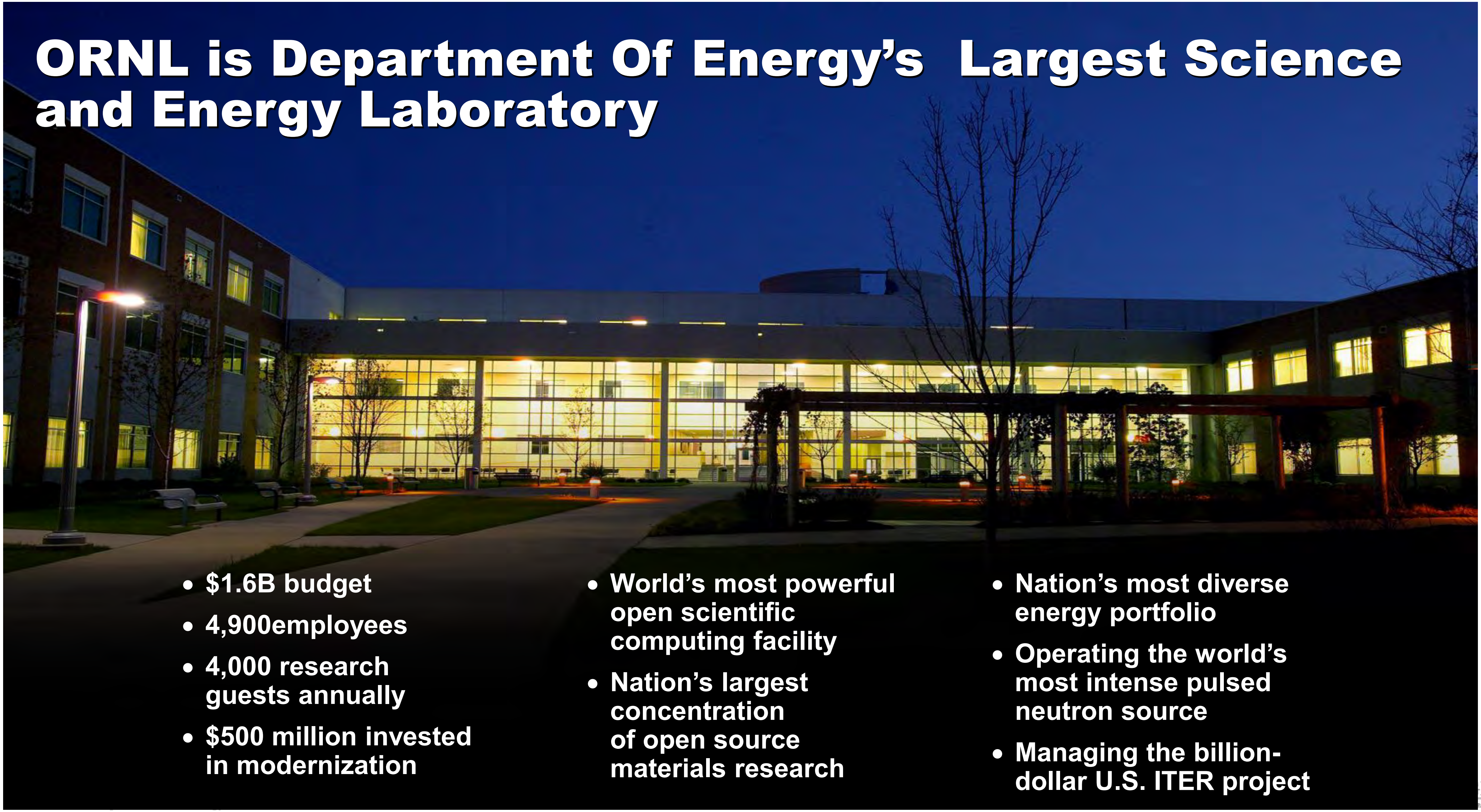


ORNL is Department Of Energy's Largest Science and Energy Laboratory

- $1.6B budget
- 4,900employees
- 4,000 research guests annually
- $500 million invested in modernization

- World's most powerful open scientific computing facility
- Nation's largest concentration of open source materials research

- Nation's most diverse energy portfolio
- Operating the world's most intense pulsed neutron source
- Managing the billion-dollar U.S. ITER project

ORNL today:
Focused on national priorities

Science to solutions

World-leading neutron science capability	World's most powerful scientific computing complex	Nation's largest advanced materials research program	Focused resources for systems biology and environmental sustainability	Nation's largest and most diverse energy R&D portfolio	Unique capabilities in nuclear science and technology

Biomass economy	Climate change	Electric grid	Energy storage	Nuclear energy	Solar energy	Sustainable mobility

The Global Scale in the Future

- 50M vehicles per year x 200 kg ~ 2.5 TWh ~ 10 M tons of batteries produced annually in ~ 100 “gigafactories” current annual production of Si – 8M tons; Al – 63M tons

- Grid backup may need ~ hundreds of TWh presumably this is not going to be the same technology likely need to explore electrochemical conversion (hydrogen, methane)

- Electrochemical technologies for ammonia, hydrogen, will be part of decarbonizing the last third of the economy (after generation, transport).

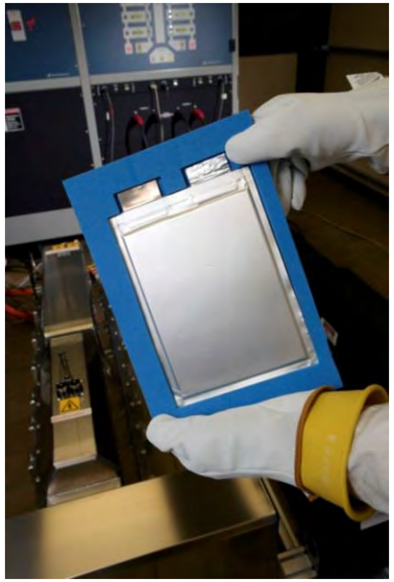
NH_3 production via the Haber-Bosch process consumes 5% of natural gas supply, 1% of world’s energy consumption, and releases abut 1.5% GHG emissions

Courtesy : Peter Littlewood, Univ. of Chicago and ANL

Batteries: From Volta to Chevy Volt
Has anything fundamentally changed ?

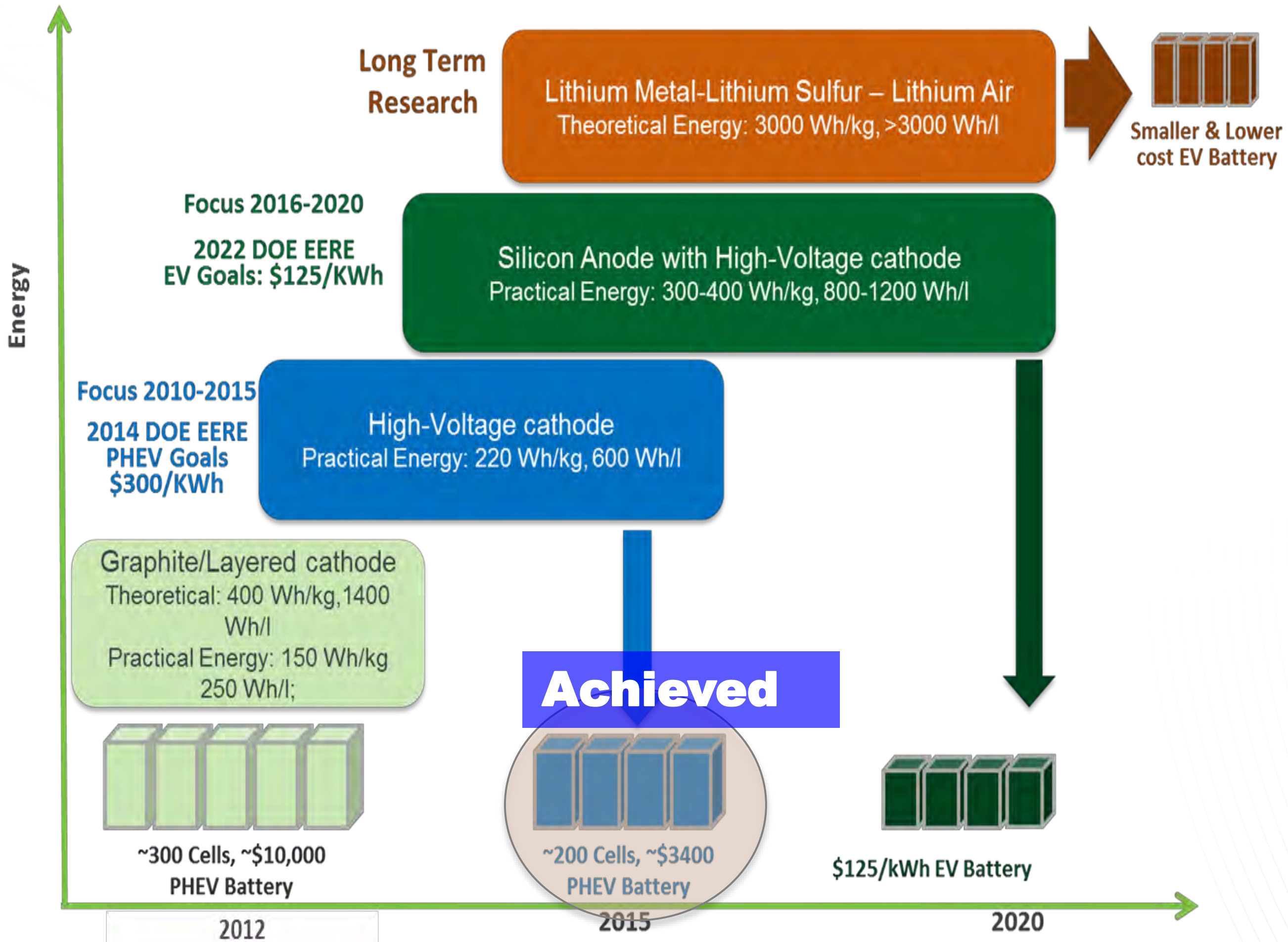
1800 AD

Chevy Volt
Nissan Leaf



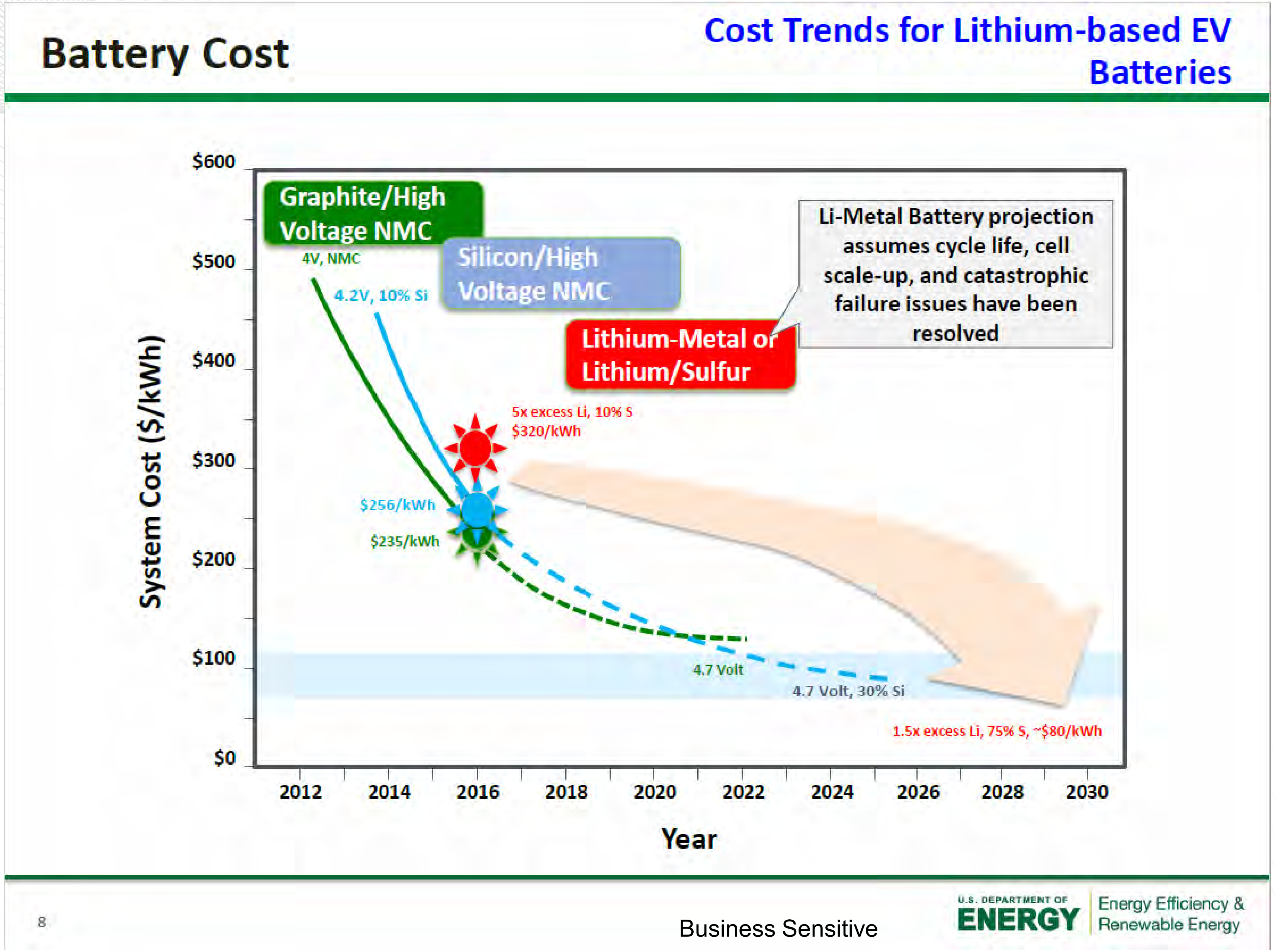
Research Roadmap for Electric Vehicles - DOE

Current emphasis: The development of high voltage cathodes and electrolytes coupled with high capacity metal alloy anodes. Research to enable Lithium Metal-Li Sulfur systems.



Courtesy : Dave Howell and Brian Cunningham, EERE-VT

Cost per KWh for lithium batteries is rapidly decreasing



Courtesy
David Howell, VTO-DOE

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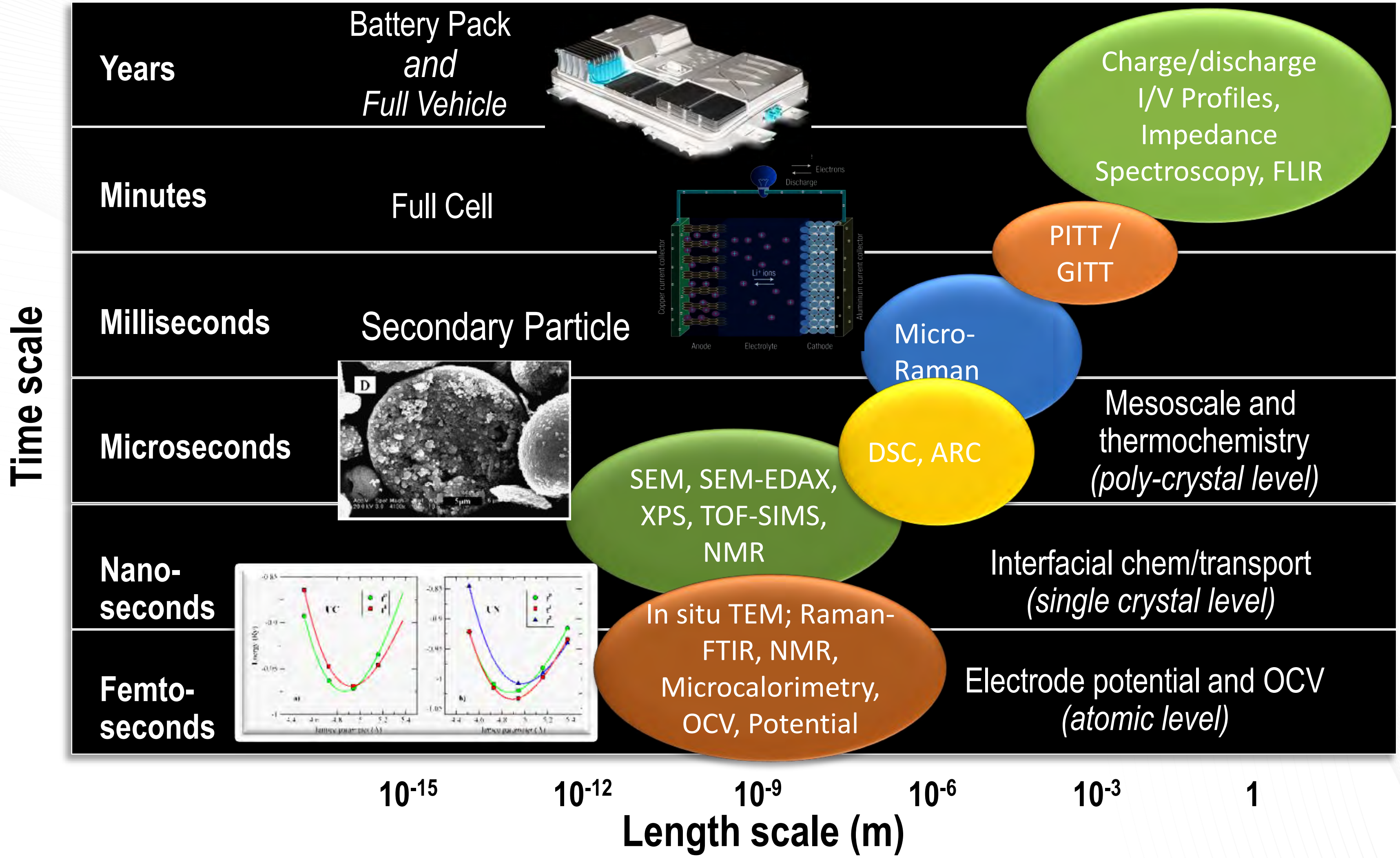
A battery is a complex multiscale device



Various electrochemical and transport process in multiple length and time scales

Business Sensitive

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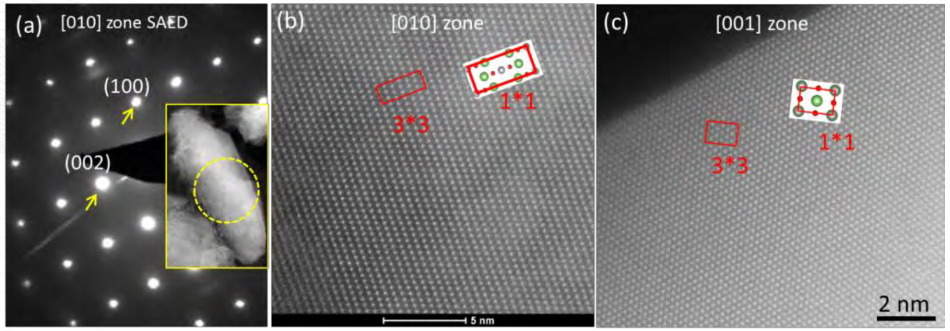
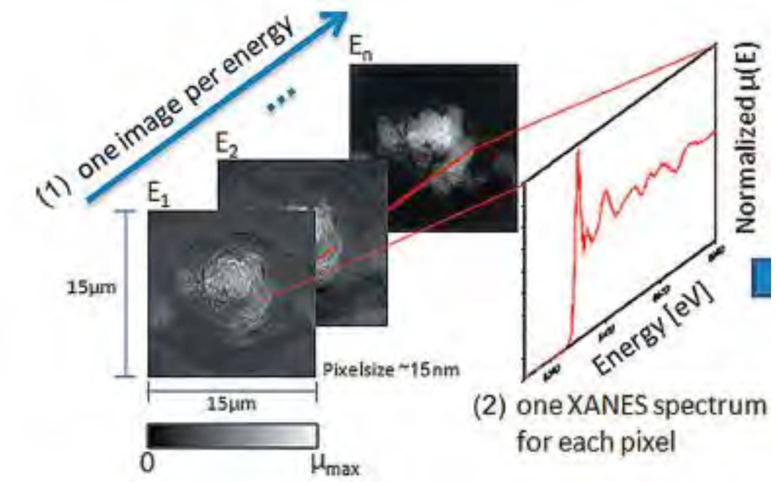
Bridging Material and Electrode Length Scale with Imaging and Microscopy Techniques

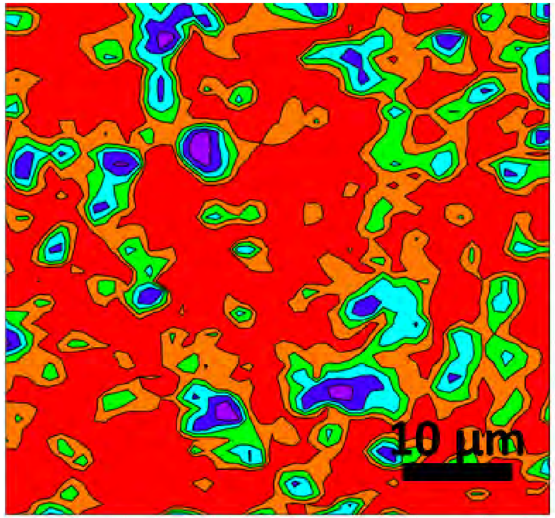


Atomic/Molecular : Electron Microscopy-HRTEM, EELS

ACS Nano 9, 2530.(2015)
Chem Mater. 227, 6746 (2015)
ACS Nano *8* (12), 12710 (2014)
J. Mater.Chem 1, 5587 (2014)
Nature Nanotech. 7(3), 16 (2012)

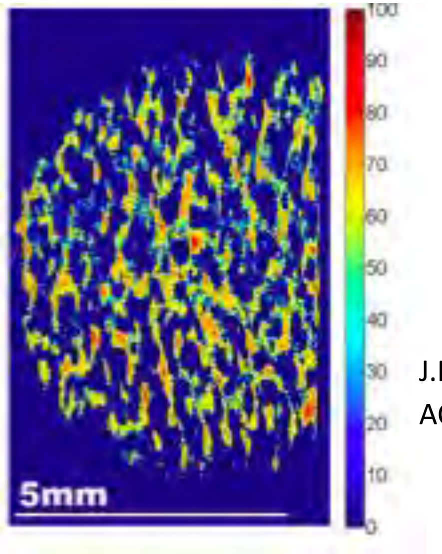


Transmission X-ray Microscopy + X-ray Absorption Near Edge Spectroscopy (TXM-XANES) - Mesoscale



Micro-Raman/SERS/TERS
(10's nm-submicron-micron)

Adv.Func.Mater, 21, 3282 (2011)
J.Phys.Chem C 119,18022 (2015)
J. Electrochem.Soc 162 (1) A1-A5 (2015)



Chem Mater. 29, 6818 (2017)
Chem Mater. 227, 6746 (2015
Nano Letts. 14, 4334 (2014)

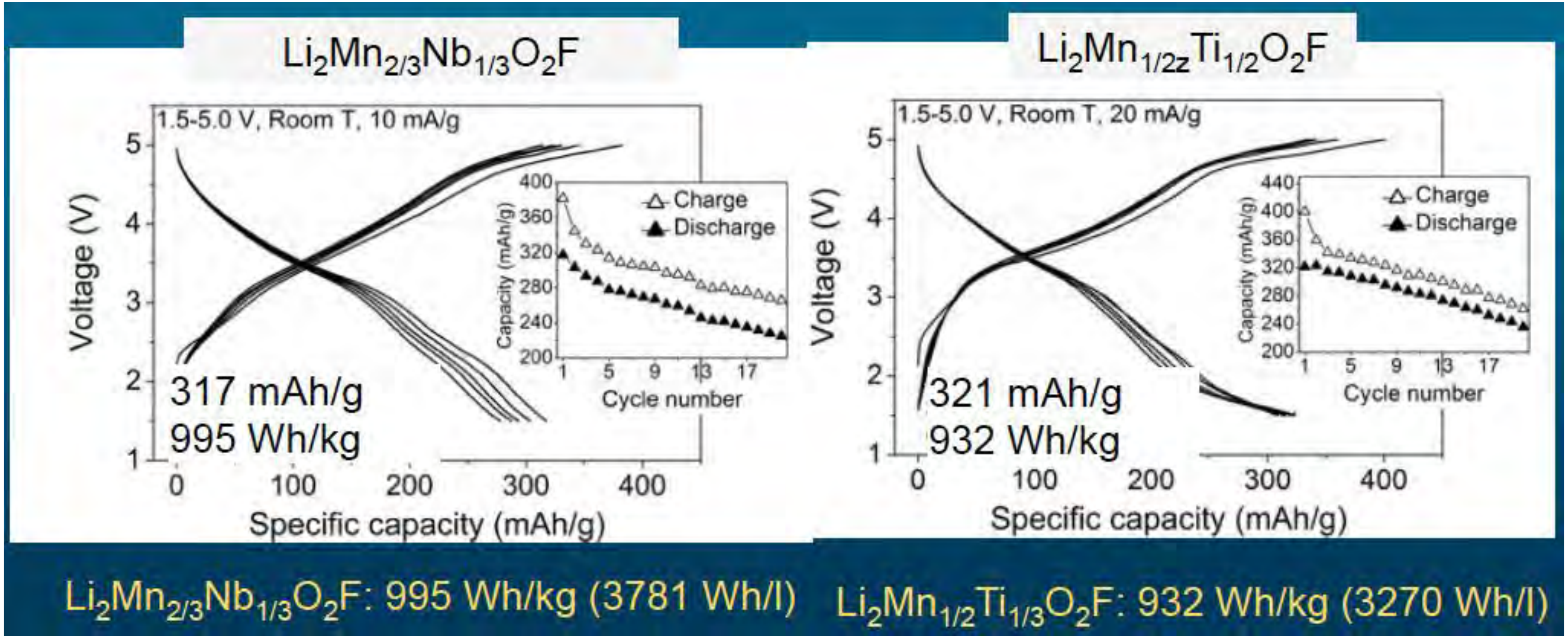
Neutron Imaging
10's of Micron

J.Phys.Chem C 116, 8401 (2012)
ACS Energy Lett 1, 981–986 (2016).

Disorder cathode design based on effective charge compensation : An example

(i) Lower the redox active TM (such as Mn) by high valent substitution – Nb^{5+}, Ti^{4+} Mo^{6+}

(ii) Lower the anionic charge by replacing O^{2-} with F^{-1}



Lee , Ceder et al. Nature 2018

Mediated Redox Flow Batteries for Grid Storage

Demand for long duration storage is growing for different markets

Military Bases

Remote Islands and Off-grid

Backup power for data center

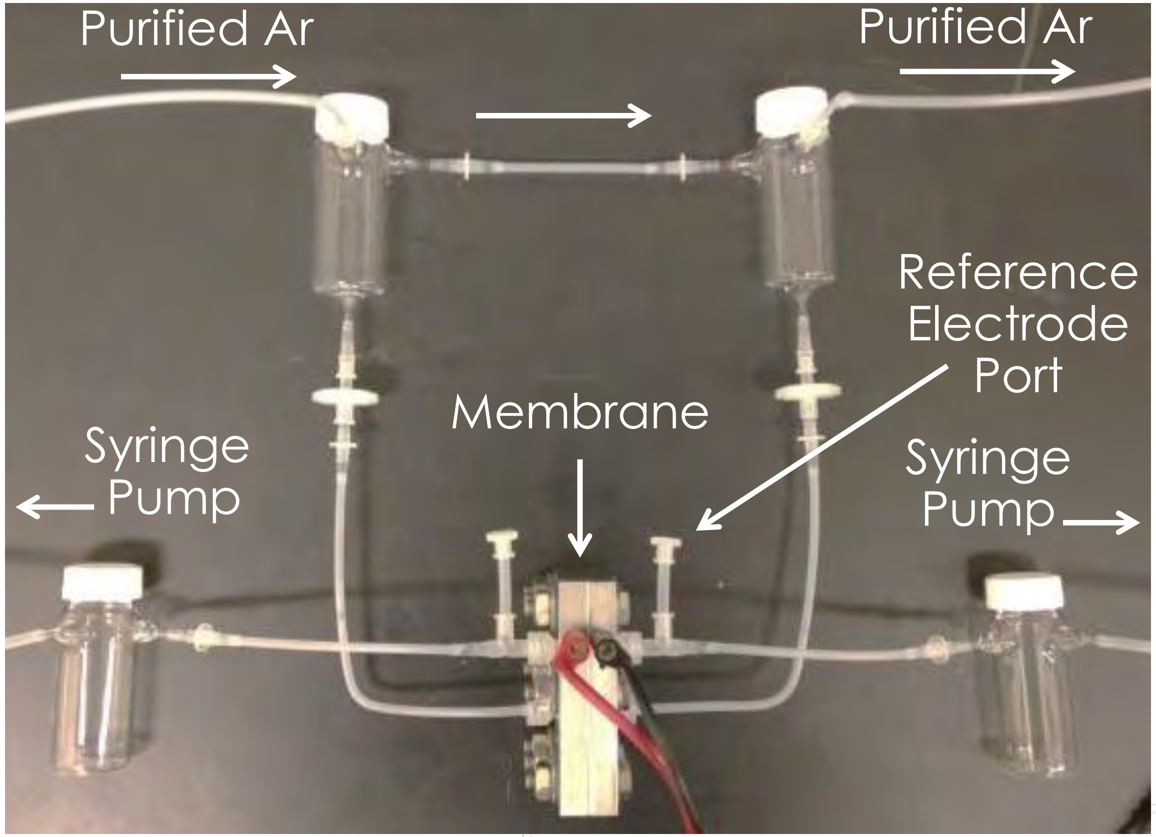
Increased renewables (solar & wind) penetration to the grid

A custom redox flow cell was designed to demonstrate a mediated red phosphorus anode

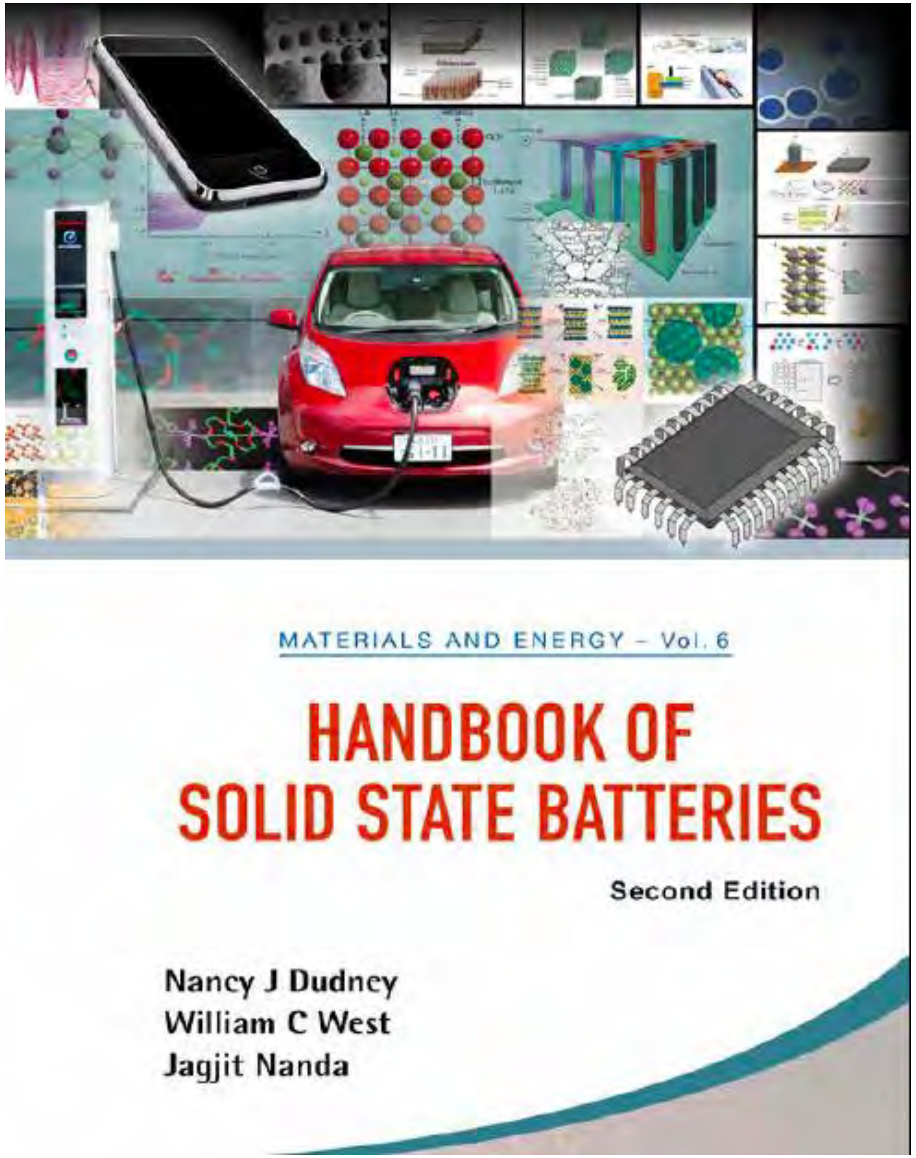
Cell Components:

- Working/Auxiliary Electrodes: Porous Ni foam
- Reference Electrode: Na in 1 m NaTFS (TEGDME)
- Membrane: $Na^{+}\beta''$ Al_2O_3 Ceramic (Ionotec, 45 x 45 x 1.5 mm^3)

Serpentine Flow Channels



Flow Cell (connected to potentiostat)



Beyond Lithium-ion XII
June 25th-27th 2019
Venue : National Renewable Energy Laboratory, Golden

http://events.r20.constantcontact.com/

Acknowledgements

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