



Nanophosphate™ for Grid Storage Applications

NICHe Workshop on Materials for Large-Scale Energy Storage

Roger Lin

Director, Product Planning and Marketing

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A123 Systems, Inc.

A123 Systems is a leading U.S. developer and manufacturer of advanced high power, safe and long-life lithium-ion energy storage solutions for next-generation applications in the transportation, electric grid and consumer markets

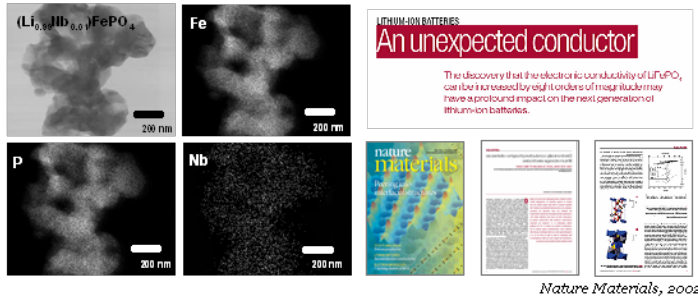
- Corporate headquarters: Watertown, Massachusetts
- 1700+ employees worldwide
- Mass producing millions of batteries per year
- 1,000,000+ square feet of manufacturing facilities in China, Korea and United States



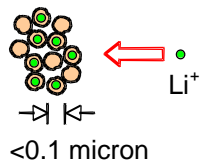
A123's Core Technology – Nanophosphate™

- A123 Systems Nanophosphate™

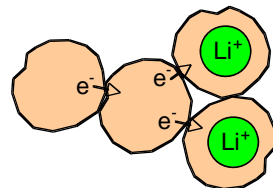
Better battery enabled by new nano-materials [Nature Materials, 2002]



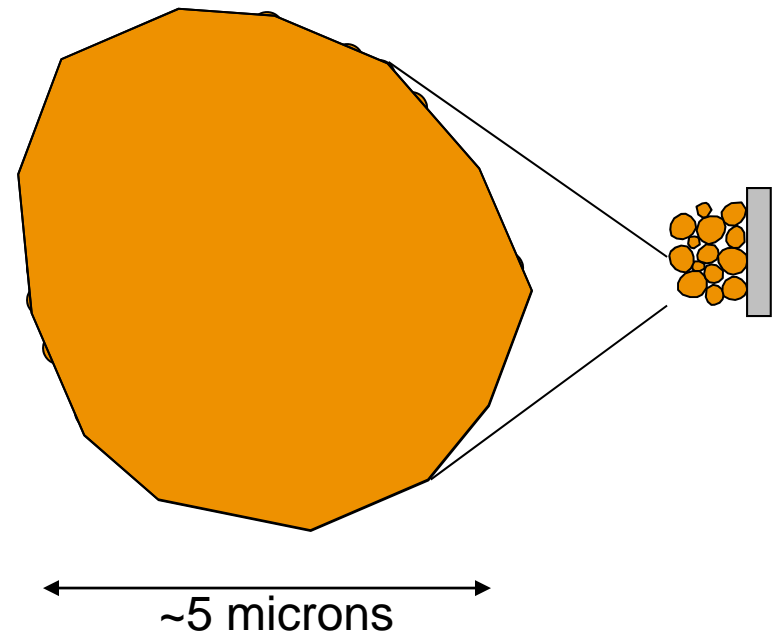
Nature Materials, 2002



Nano particle size = extremely fast diffusion

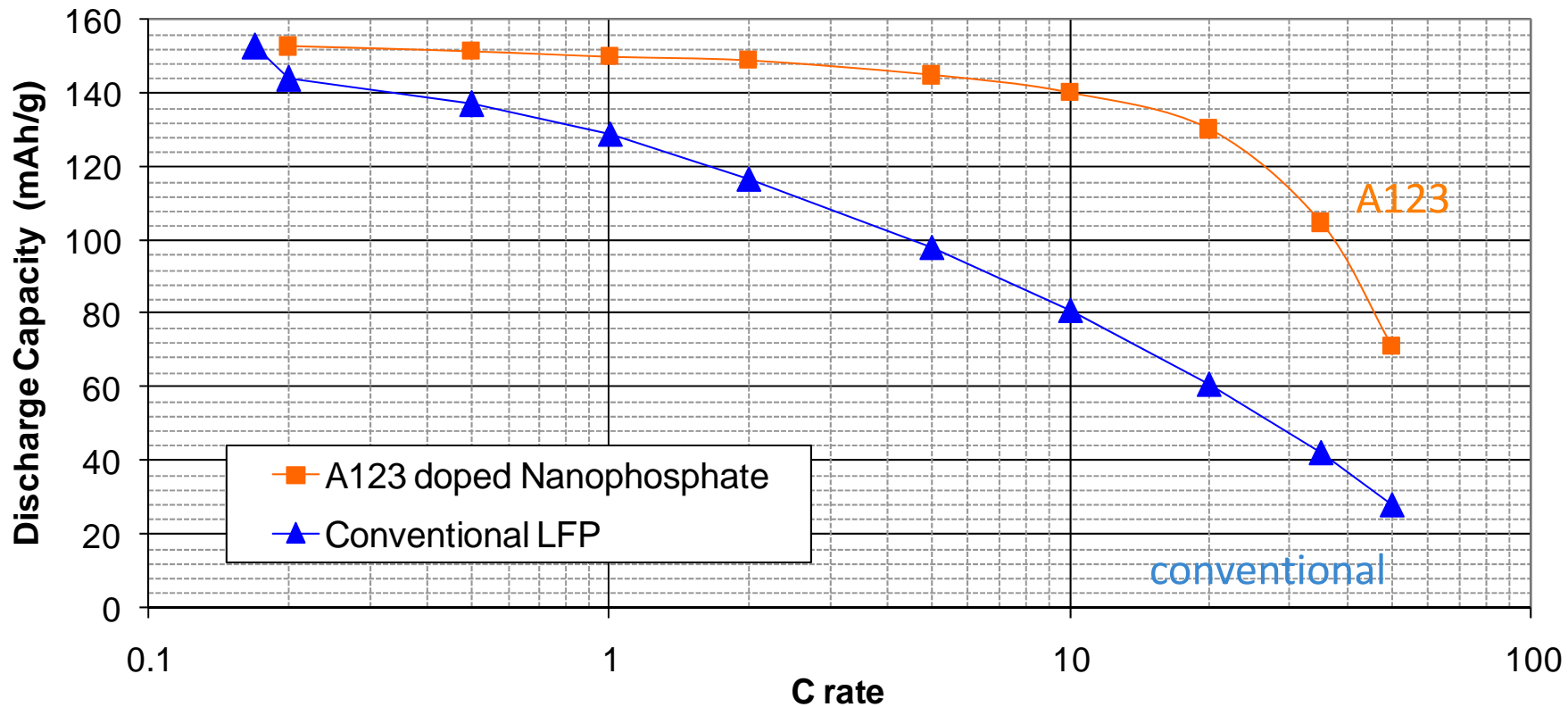


Dopant significantly increases rate capability



- High Contact Area Low Internal Impedance

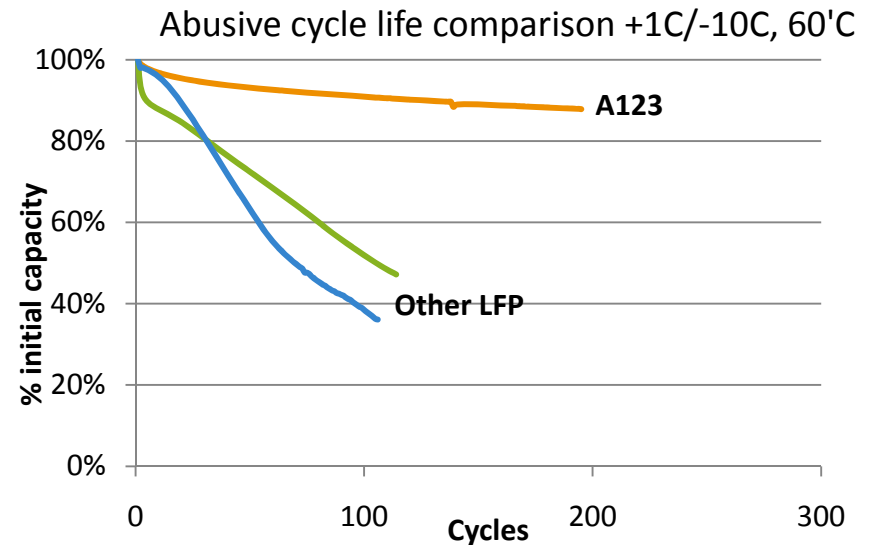
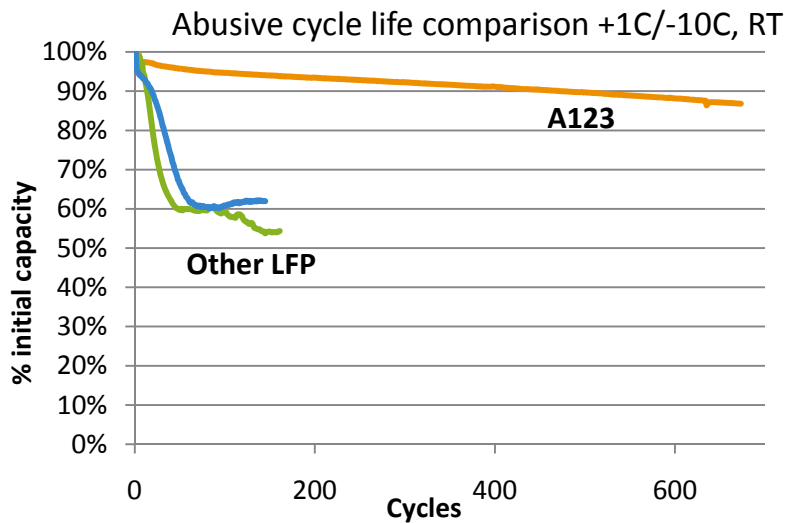
Comparison of A123 doped Nanophosphate and conventional battery grade LiFePO₄



Iron phosphates are not created equal

Comparison with other commercial phosphate products of similar construction

- Nanophosphate™ provides superior cycle life to alternative phosphates
- Superior life evident at low rate. More prominent at high rates, both room and elevated temperature (60°C)



Serial Production in Heavy Duty Hybrid Applications

Daimler Orion VII Series Hybrid

- #1 selling hybrid bus in the world
- Over 2,000 systems deployed with A123 batteries worldwide
- Collecting 4M miles/month
- >45 million miles of revenue service
- Runs 16 hours per day, 365 days per year in numerous cities including Toronto, San Francisco, Houston, Seattle, NYC, and London.



BAE SYSTEMS

DAIMLER

Fisker Announces Selection of A123

A123 to supply battery systems for Karma PHEV

“Fisker is committed to developing environmentally friendly cars that don’t sacrifice style or performance. A123’s technology will ensure the Karma delivers.”

-Henrik Fisker, CEO



Navistar

A123 chosen for development contract for Navistar's EV - a pure electric commercial truck application

NAVISTAR®



EV for the Navistar Modec Electric Vehicle Alliance, Navistar and Modec JV

Wind, The Predominant New Renewable Resource

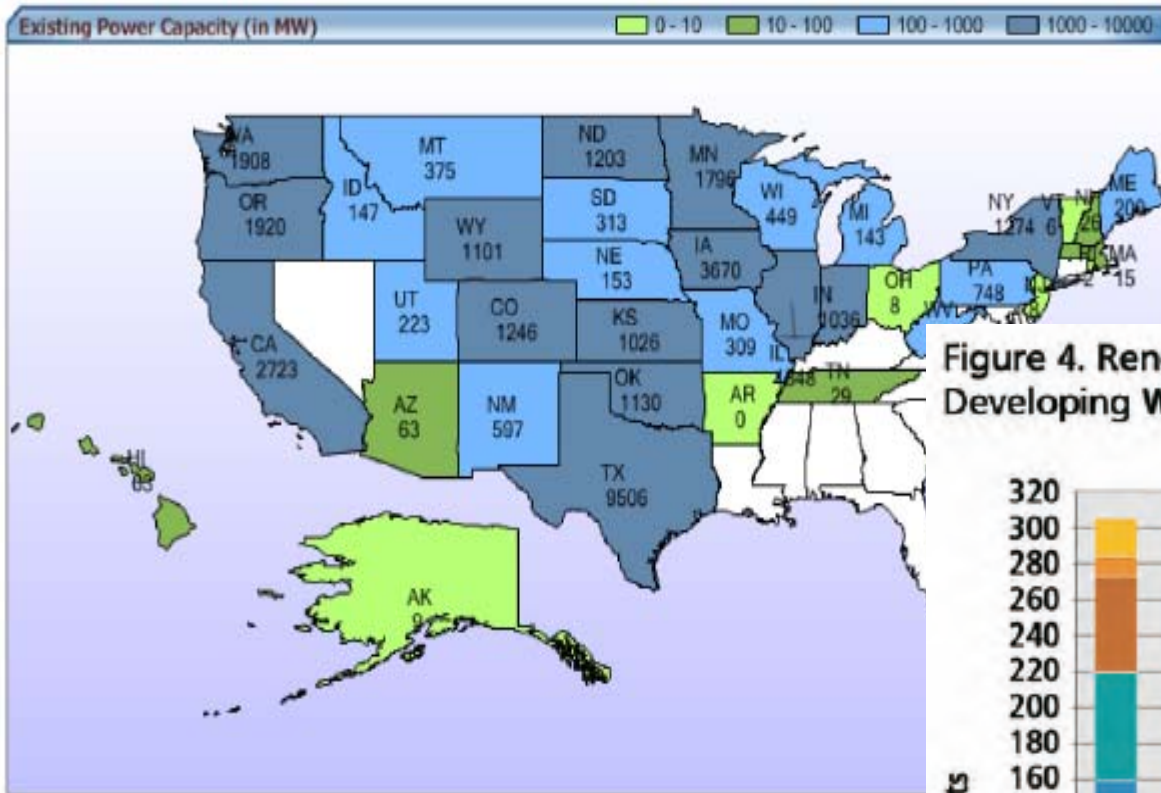
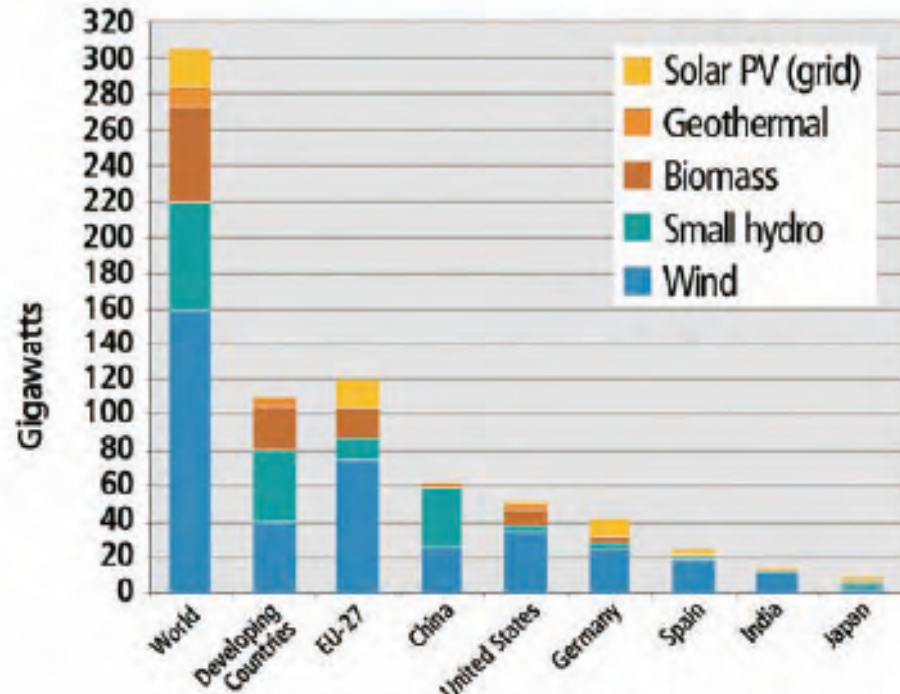


Figure 4. Renewable Power Capacities: Developing World, EU, and Top Six Countries, 2009

National Total Power Capacities (MW)

Existing	Under Construction
35,603	3,779



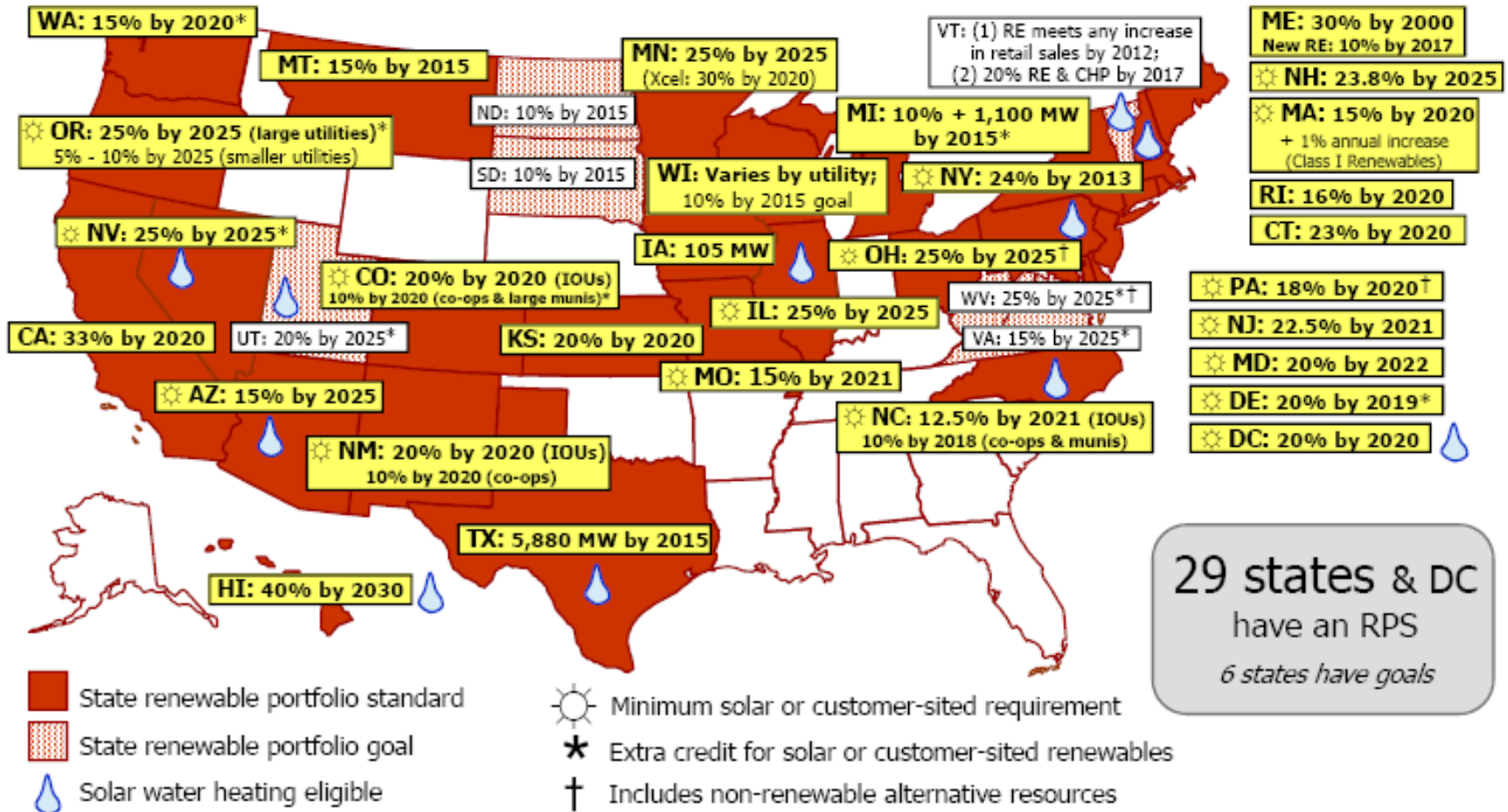
Sources:

www.awea.org/projects/

http://www.ren21.net/globalstatusreport/REN21_GSR_2010_full.pdf

Renewable Portfolio Standards

www.dsireusa.org / October 2009

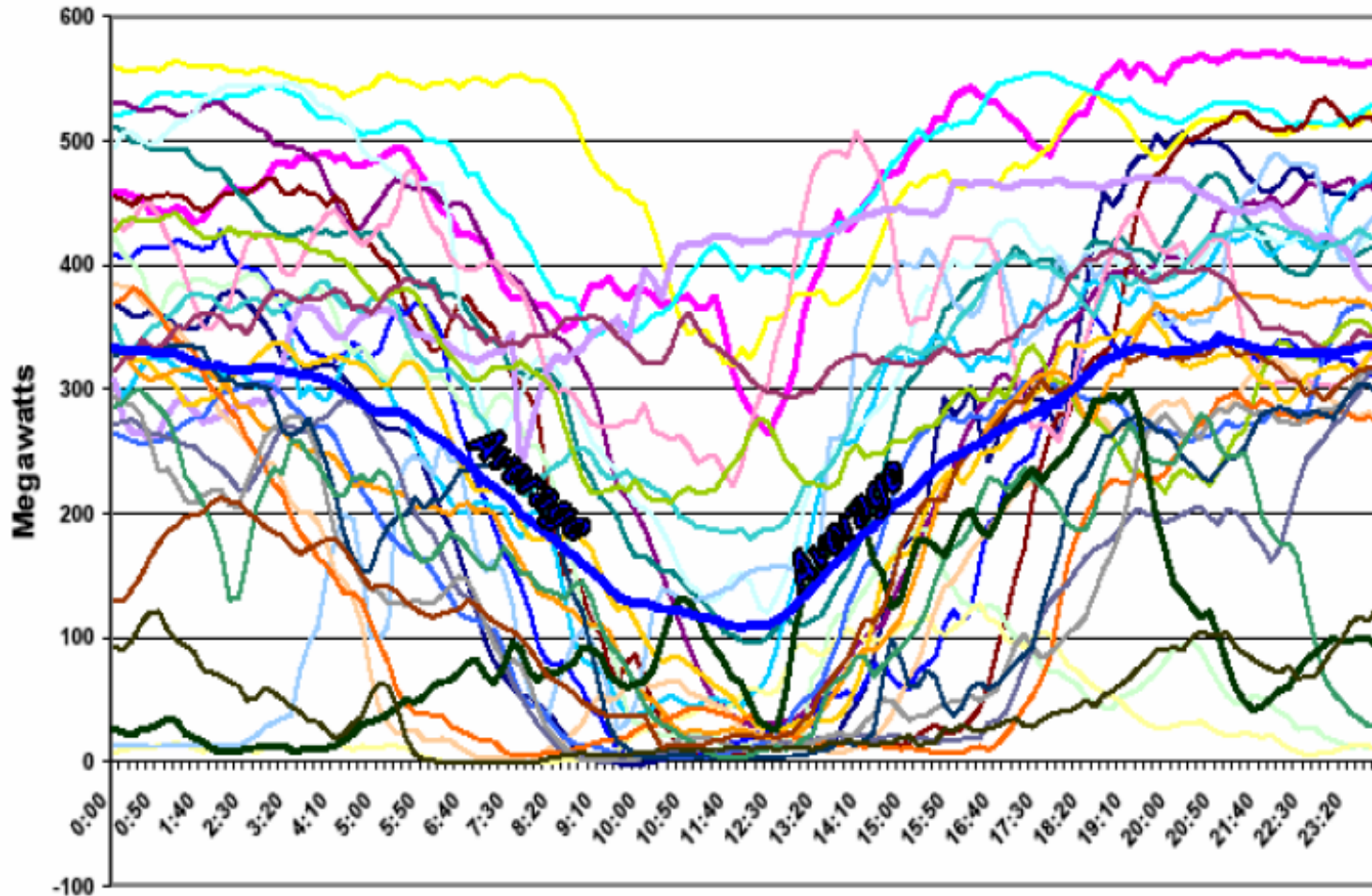


29 states & DC
have an RPS
6 states have goals

Source, <http://www.dsireusa.org/>

Integrating Wind, The Obvious Challenge

Tehachapi - June 2006 Daily Energy Production



Source, "CAISO's Plan for Integration of Renewable Resources", Presentation to NARUC, D. Hawkins, June 20, 2008

Integrating Wind, The Less Obvious but Impactful Transient/Short Term Timeframe Challenges

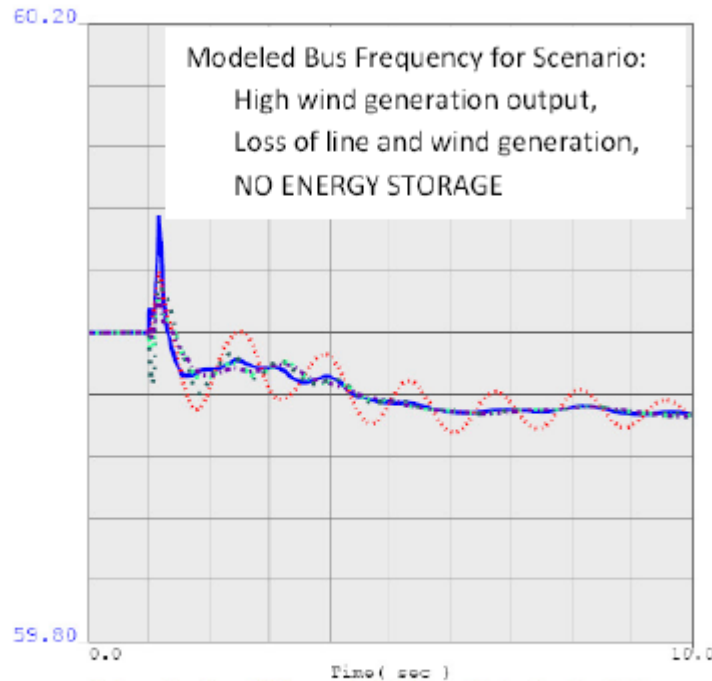


Fig. 5a. Declining bus frequencies in a dynamic simulation run for a high-wind scenario, without storage added to the modeled grid

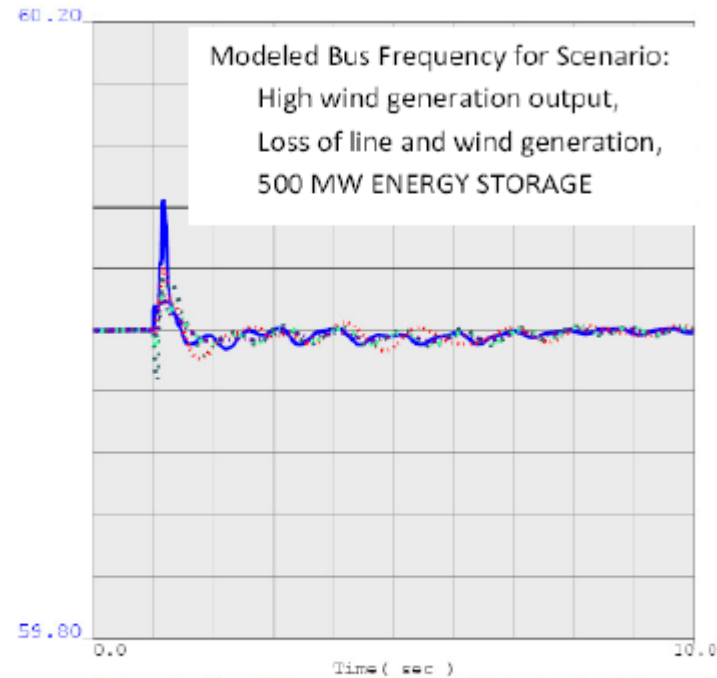


Fig. 5b. Damped and stable bus frequencies in a dynamic simulation run for the same high-wind scenario, but with storage added to the modeled grid

FUTURE STUDIES CAN TEST DYNAMIC STABILITY IMPACT AND MITIGATION:

Growing electrical distances between remote generation and load centers

Increase in import of remote resource output vs local area generator output

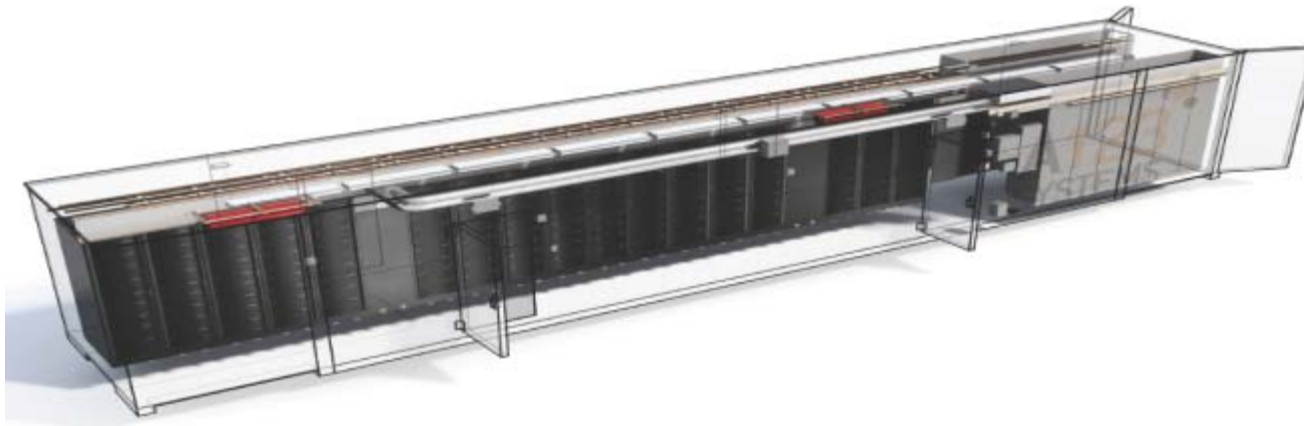
Inertia loss with changing generation asset mix

**ADVANCED ENERGY STORAGE
TECHNOLOGIES WITH ROBUST 4
QUADRANT PCS INTERFACES ARE ONE
CONTRIBUTING WIND INTEGRATION
SOLUTION, BEING DEPLOYED TODAY**



A123's Smart Grid Stabilization System (SGSS™)

Scalable solutions from 50 KW to 100+ MW



Products

- Modular fault tolerant battery systems design
- Integrated cooling system
- Inverters and transformers to connect to the grid
- Communication systems and control algorithms to interface with existing Utility infrastructure, and extend into Smart Grid capabilities and app's

Support

- System modeling
- Commissioning services
- Remote Monitoring

Application: Reserve and Regulation

The Problem:

- Fragile power system increases risk of loss of production for area mines, driving high generation reserve requirement



The Solution:

- 12MW Storage replaced unpaid generating reserve, freeing up this generating capacity for paid energy service. Economics: <3 year payback

Next opportunity in this market

- \$2B in wind plants approved, but at risk due to grid limitations

Tehachapi

- California's largest wind resource
- Massive wind development potential driving grid infrastructure upgrades and expansion
- Facts:
 - + Second largest wind park in the world with ~ 5,000 wind turbines
 - + 660 MW of installed wind energy, with potential for thousands more¹
 - + ~ 350 square miles
 - + ~ 100 miles from major So-Cal load center (LA basin)



1 - 4,500 MW of generation capacity may be available. California Energy Commission, "Renewable Resources Development Report", November 2003

Purpose of DOE Project

- **Tehachapi Wind Energy Storage Project**

Deploy and evaluate an 8 MW / 32 MWh utility-scale lithium-ion battery system and evaluate its ability to improve grid performance and aid in the integration of wind generation into the electric grid.

The project will also evaluate a wider range of applications for lithium-ion batteries that may spur broader demand for the technology, bringing production to a scale that will make this form of large energy storage more affordable.

DoE Storage Demo, Wind Integration, SCE & A123



8MW, 4hr

Dynamic 4-Quadrant PCS/Grid Interface

A123 Prismatic Cells

Tehachapi Wind Farm



Advantages of lithium-ion systems

Large scale lithium-ion based energy storage for grid

Fast response

- Dynamic exchange of real power with the grid
- Inherent sub-20 ms response times

High efficiency

- 90% round trip efficiency

Scalable and Portable

- From several kWh to multi MWh sizes
- Can be sited in many locations

Reliable and Low Maintenance

- Being demonstrated in 12MW Chile installation



Additional advantages of A123 Systems Nanophosphate™

Long cycle life

High power/low impedance

High abuse tolerance for safe failure modes

Lithium-ion in various major applications

The portable electronics industry

- Proxy: The 18650 cell currently down to \$0.20-\$0.25/Wh
- 20 years of process refinement and throughput improvements



The automotive industry

- Larger (20-60Ah) cells, added requirements of durability and reliability on top of cost
- Automotive industry will drive normalized cost to the \$0.20/Wh level



The grid storage opportunity

- Largest cell sizes required
- Requires low cost, and even higher durability and reliability
- Leverage scale of combined Elec and Auto industry

The future of lithium-ion

Material Advances

- Active materials
- Separators
- Electrolytes
- To decrease \$/Wh and \$/Wh throughput, increase safety characteristics, and improve robustness

More Efficient Processing

- Cell design for manufacturing and assembly
- Higher throughput and fully automated for large scale product
- Increase yields and reliability of product for large scale systems

Fundamental Understanding of Cycle Life

- Control laws and algorithms to minimize degradation during use
- Balanced against application goals

Thank you!

