Energy Storage Trends and Challenges - New Mexico's Numerous Contributions

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Together…Shaping the Future of Electricity

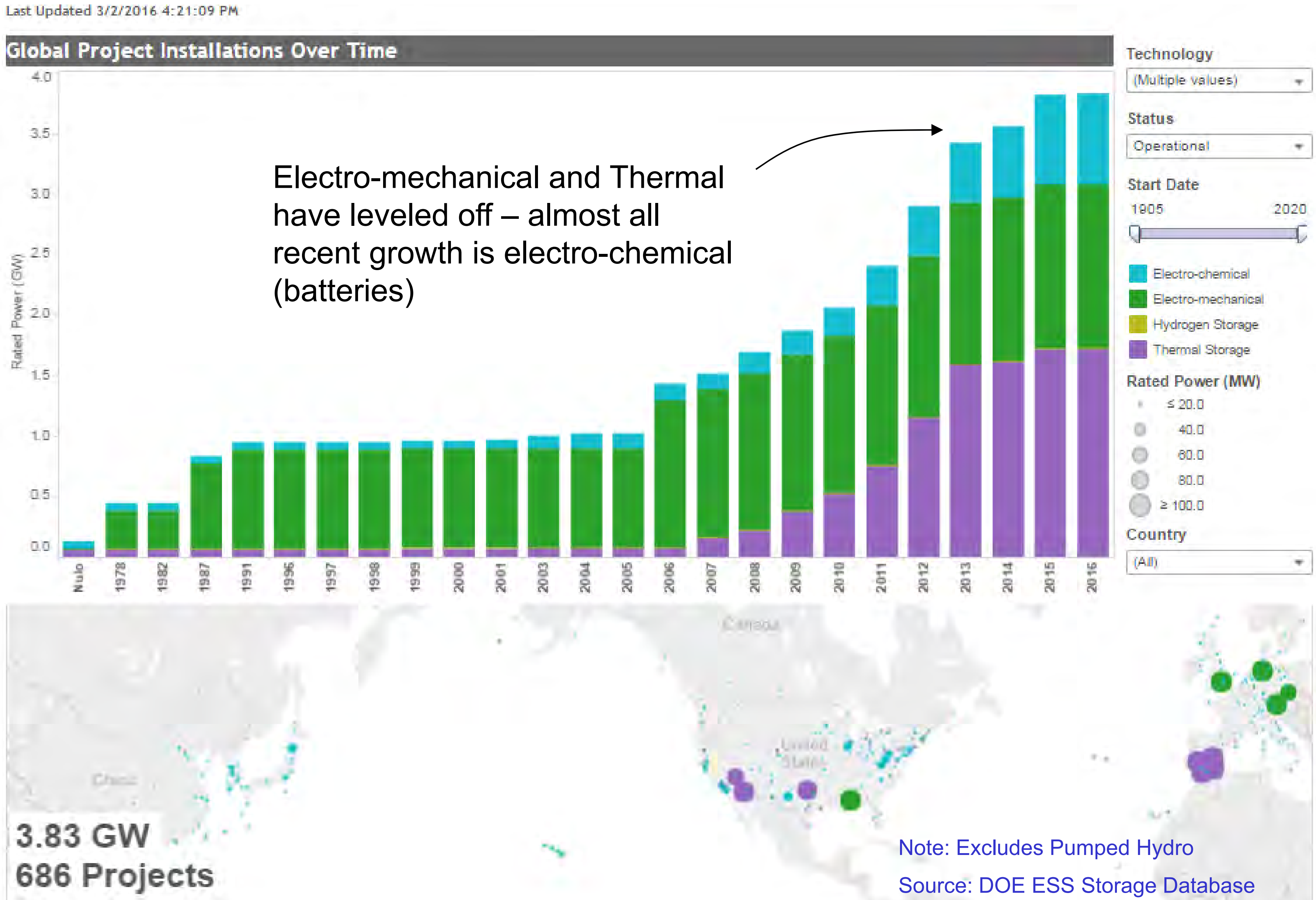
EPRI's Mission

Advancing safe, reliable, affordable, and environmentally responsible electricity for society through global collaboration, thought leadership and science & technology innovation.

Agenda

- Energy Storage Background & Vision
- Grid Integration Issues and Challenges
- Efforts addressing the Challenges
- New Mexico Initiatives that are making a difference

Background - Global Application of Storage



Electro-mechanical and Thermal have leveled off – almost all recent growth is electro-chemical (batteries)

Note: Excludes Pumped Hydro

Source: DOE ESS Storage Database

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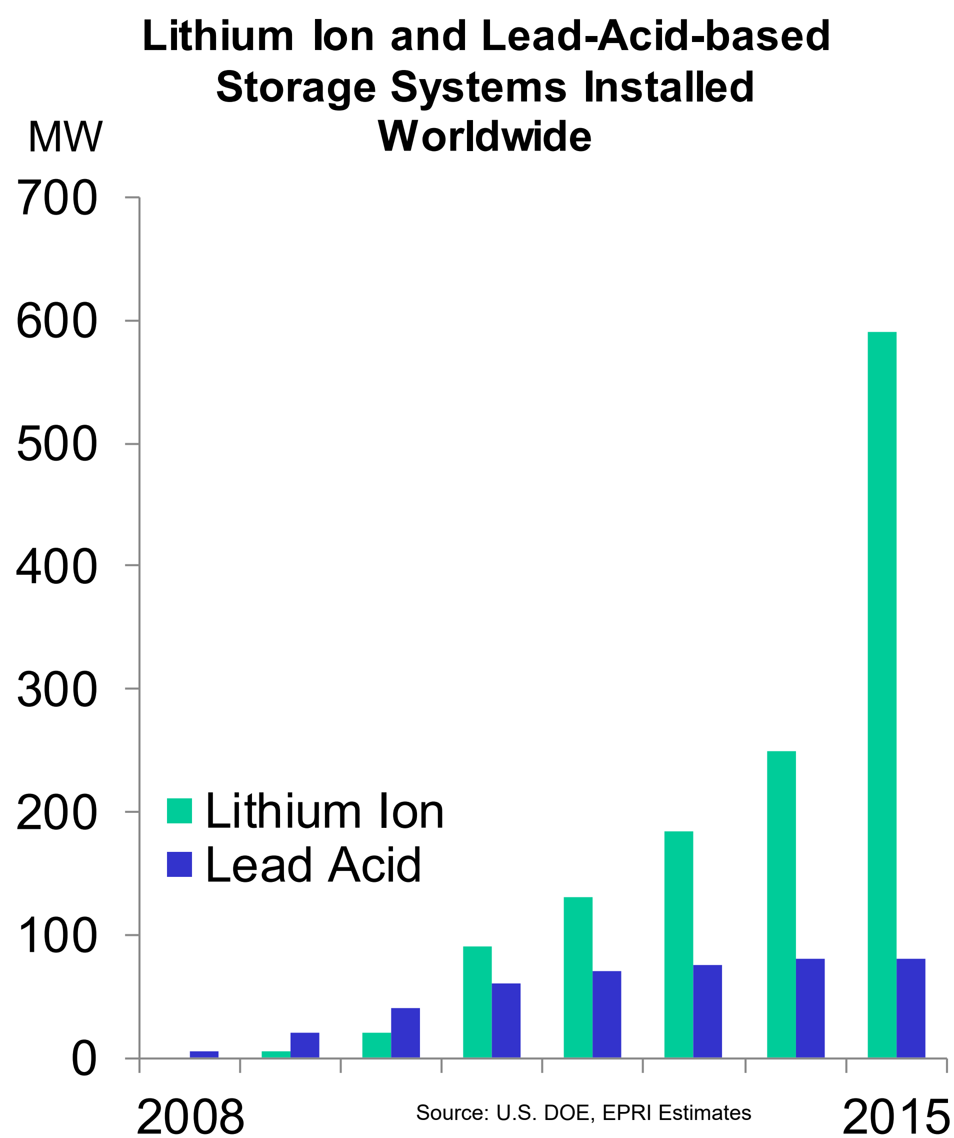
Background - Deployment of Battery Storage to Date

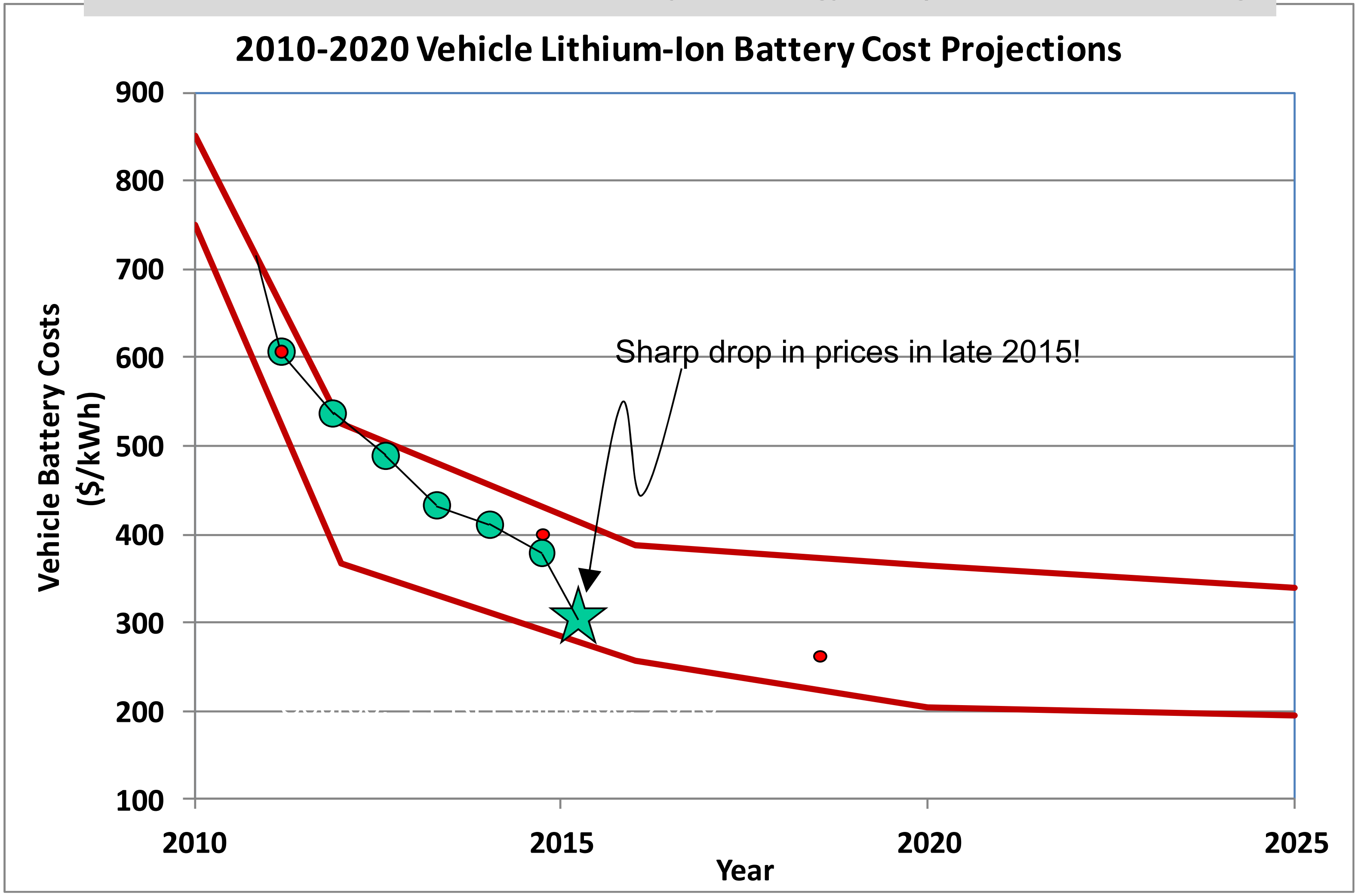
- Investment is still relatively small but rapidly growing
  - IPPs installing storage to provide ancillary services to energy markets
  - Utilities are exploring options at the transmission and distribution level
  - Some developers are installing systems on the customer side of the meter (currently ~10% of installed base
- Many installations are at the demonstration / pilot phase
  - Benefits are understood, but monetization can be difficult
  - Network based, frequency regulation/market systems are being financed
- Lithium ion has become the most popular technology



Source: U.S. DOE, EPRI Estimates

Why is lithium ion so popular?

Lithium ion is now the lowest-cost battery technology, and prices are still declining



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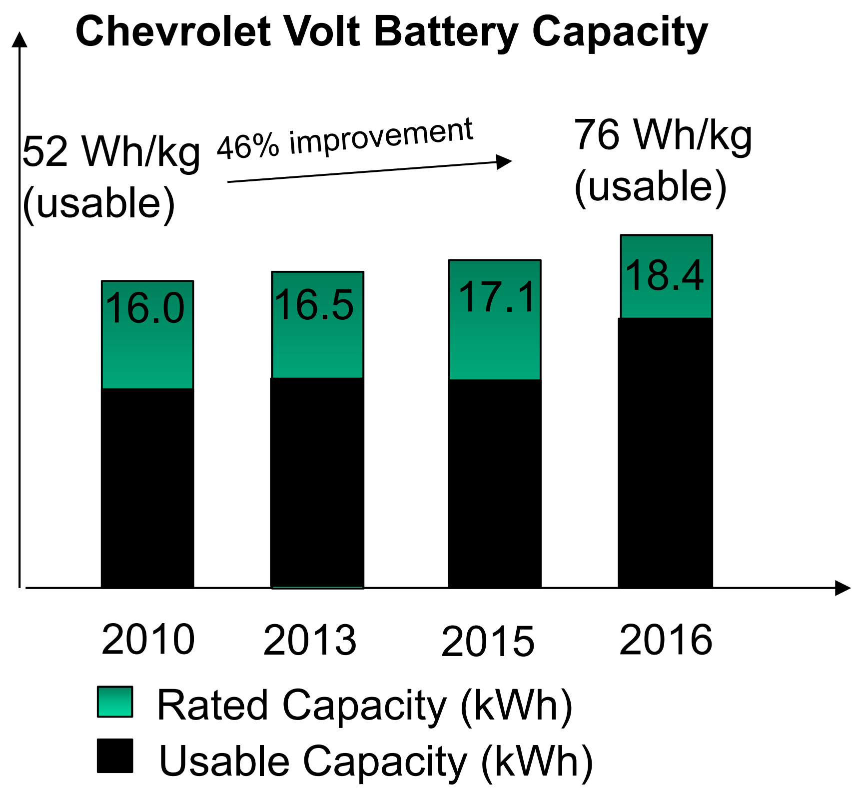
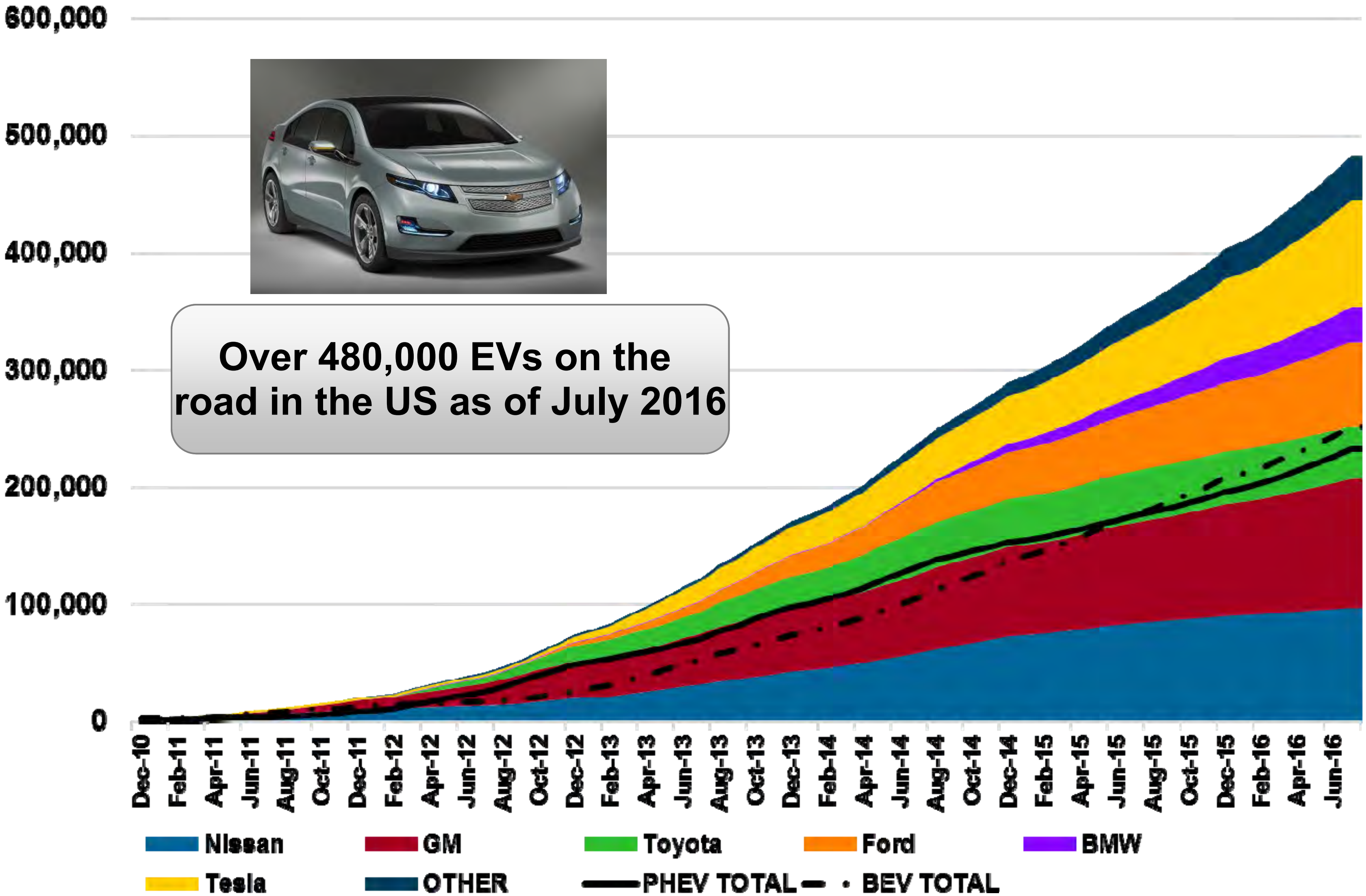
More on Lithium Ion Technology

Significant improvement in real performance (usable Wh/kg)

- 46% improvement in usable capacity
- Largely due to learning curve effects and more confidence in performance
- Improved cell chemistries have resulted in more energy, lower weight



Backing Lithium Ion Growth and Price drop - Electric Vehicle Sales Volume



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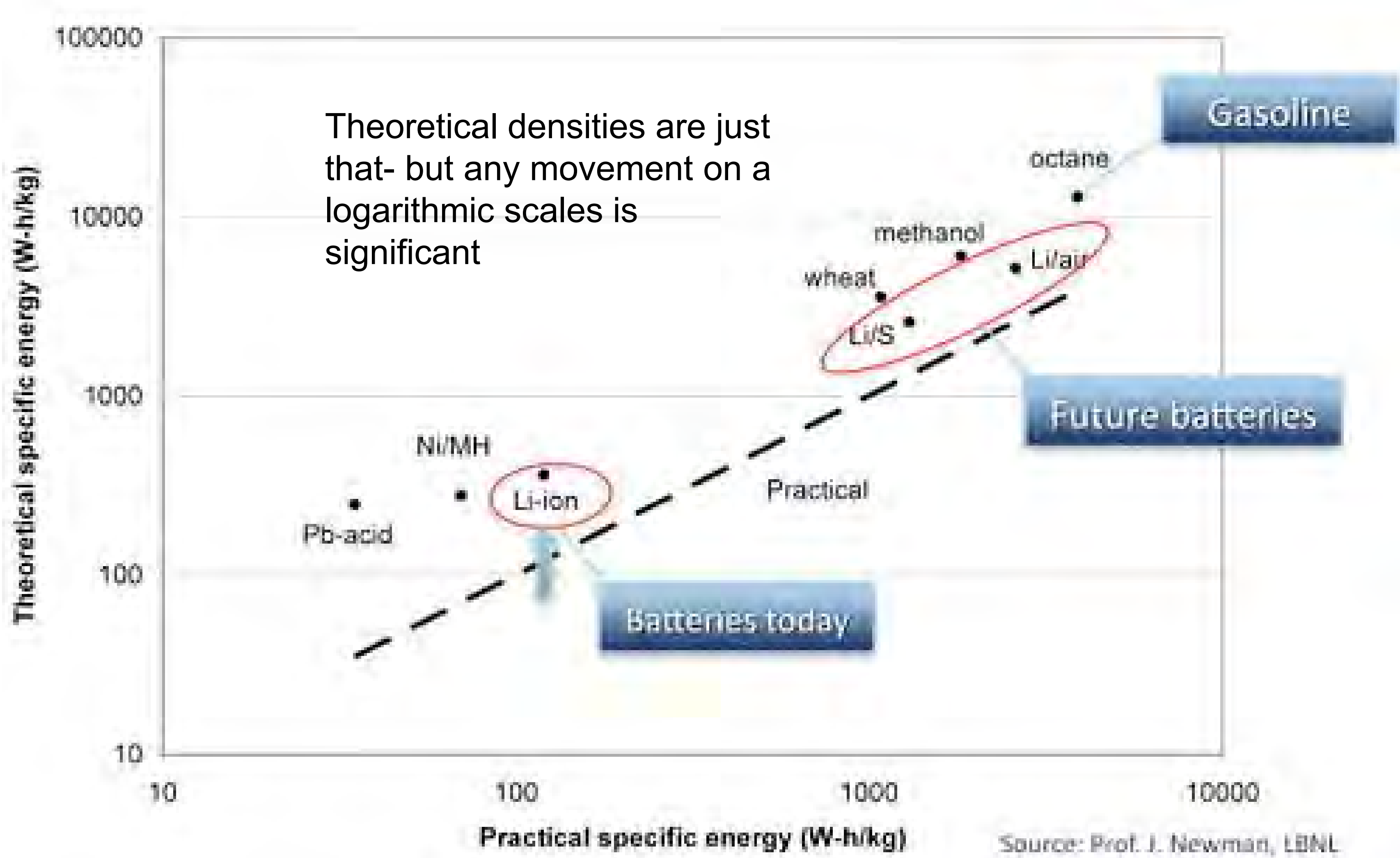
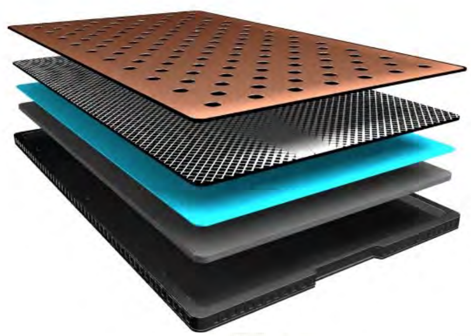
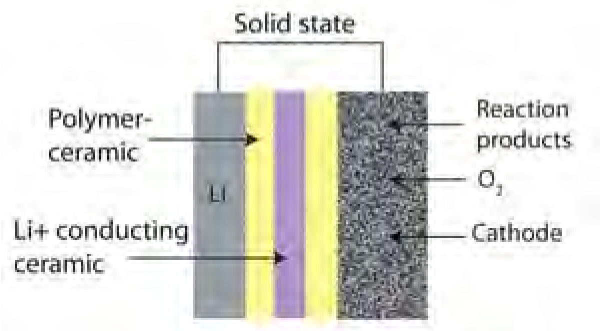
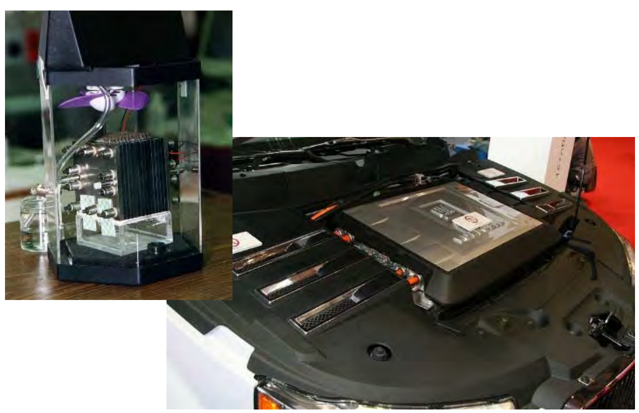
Future Development of Lithium Ion Based Batteries



Other Storage Technologies Experiencing Headwinds







Established technologies

- Lead-acid sales have slowed for stationary market
- High-temperature sodium has seen some vendor attrition
- Flywheels have also experienced vendor attrition

Near to Mid-Term Technologies

- Flow batteries very slowly achieving scale
- Sodium Ion making progress in some markets
- Metal-air (zinc-air, lithium-air) still nascent, though a few vendors claim some deployment

Medium to Long-Term Technologies

- Hydrogen Fuel Cells have experienced huge investment, with mixed results – great progress but still tremendous challenges
- Solid-State Batteries experiencing substantial investment but no products yet

Companies without strong strategic partners may have trouble surviving

Technology Forecast

Rapidly declining costs for lithium ion batteries arising from a combination of scale production, learning curve effects, and vicious competition among players. Most players are counting on supply chain management for further cost reduction

Lithium ion will continue to be the dominant battery technology at least for the next decade and perhaps even beyond 2030. Continuing advances in cathode technologies, high-voltage electrolytes and silicon/graphene anodes may allow for another doubling of energy density without significant changes to the fundamental chemistry or operation.

Future technologies still face major challenges though research continues and revolutionary advance is still possible. Most technologies are awaiting fundamental materials breakthroughs to address challenges; while such breakthroughs are possible and even probable, it is difficult to put a timeline to when they may occur.

Behind the meter storage growth could be robust as some forecasts point to a 30-45% (currently at 10%) market share by 2025 and the virtual power plant concept is gaining traction

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Addressing the Challenges to Storage

Aligning storage to larger grid needs, where very high renewable penetrations are envisioned, requires significant developments in controls, rates and price delivery structures, especially to accommodate customer side storage - *See recent NREL report*

Costs and performance factors of technology solutions must be better understood – *Costs are becoming apparent but many value streams remain challenging to quantify*

Tools for understanding the value and grid impacts of storage are being developed – *EPRI StorageVET – web hosted, publically available this fall*

Ensuring that storage technology solutions are safe, secure, reliable, affordable, and practical – *Broad stakeholder engagement and interaction through EPRI's Energy Storage Integration Council*

Photo courtesy Southern Co.

Create best practices for deployment, integration, operations, maintenance, and disposal – *Huge focus on Smart Grid interoperability (CIM, Wi-SUN FAN), SNL/PNNL Storage Test Protocols*

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Addressing the Challenges to Storage - continued

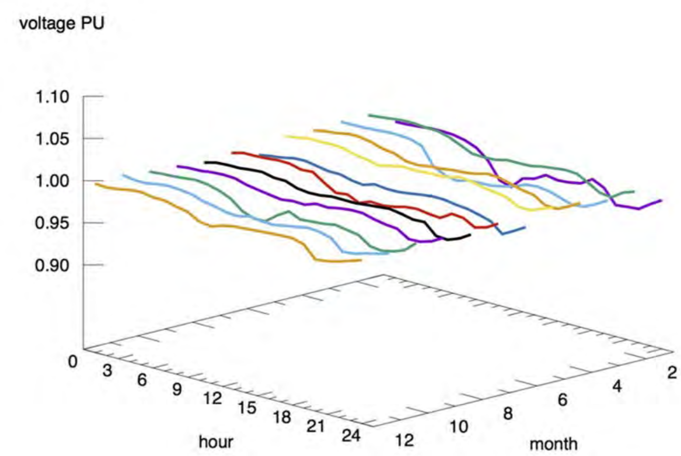
Modeling Storage – currently on a feeder by feeder basis for distribution based storage - *numerous models are now capable of addressing energy based (slow) applications – power based (fast) modeling is being developed*

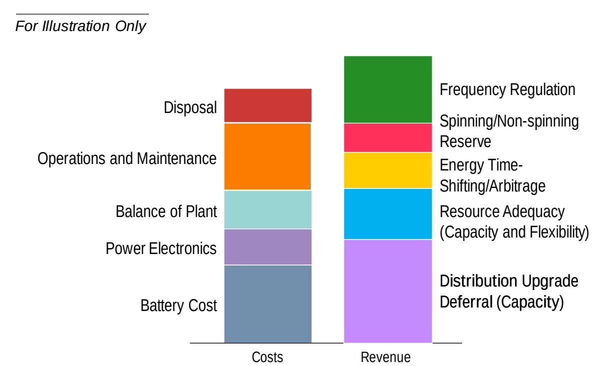
Codes and Standards are emerging but still a slow pace – *Need to foster stakeholder input to code/standard making process*

Operational Data – reliability figures needed to justify future investments – *database needed – similar to PVROM (EPRI/SNL collaboration)*

Costs are still too high – limited B/C >1 ratios for distributed or customer based applications – *costs need to be driven down for all storage components*

Storage value needs clarification – benefit of resiliency/improved reliability =?





* Iterations of this Use Case Performed in "Cost-Effectiveness of Energy Storage in California". EPRI. 2013.

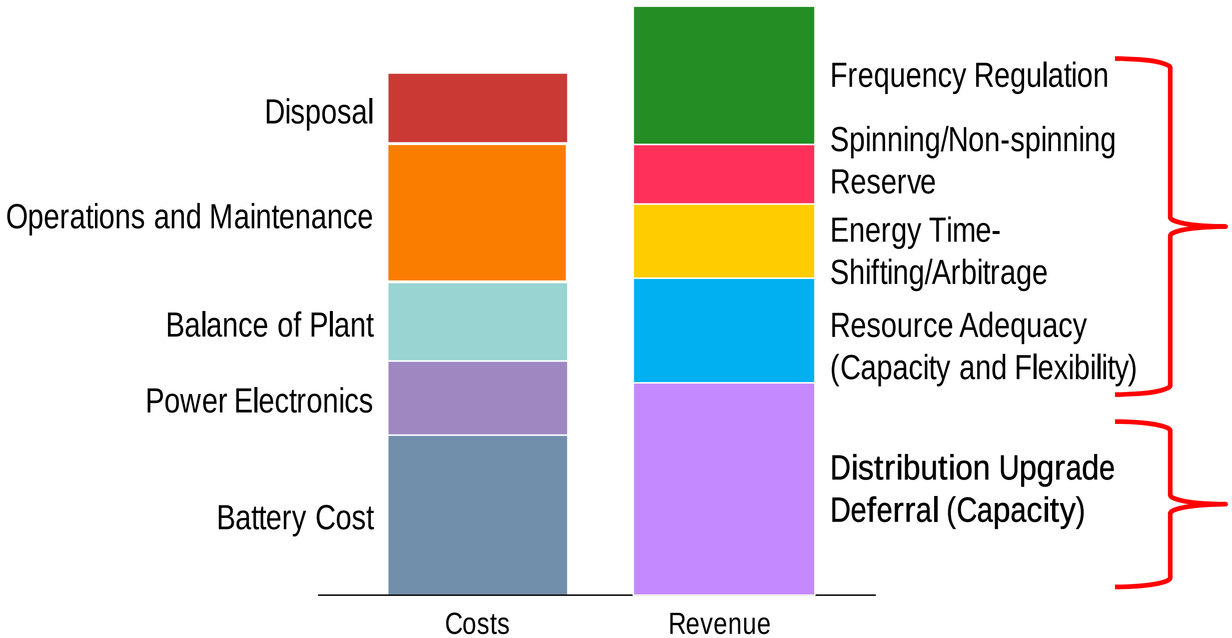
Photo courtesy Southern Co.

Possible Economics for 1MW+ / 4 Hour Storage System

For Illustration Only

Site Costs are becoming apparent *Enterprise controls aren't*

Some benefits are easily quantifiable, some aren't – especially in the case of utility side distribution based storage *Current costs require multiple benefit streams.*



Requires market signal delivery and back office platform (very expensive but typically not embedded in costs)

If no deferral apparent can reliability/resiliency substitute? Difficult to attach $ benefits to this

* Iterations of this Use Case Performed in "Cost-Effectiveness of Energy Storage in California". EPRI. 2013.

Control Integration-*One of the Biggest Challenges*

How to get storage to do what's needed?

- Simple vs sophisticated controls
- Single application vs. multiple applications
- PCS based controls vs. back office controls vs. cloud base

How to control a lot of storage units?

- DMS DERMS – names of very robust back office platforms
- Part of Smart Grid infrastructure

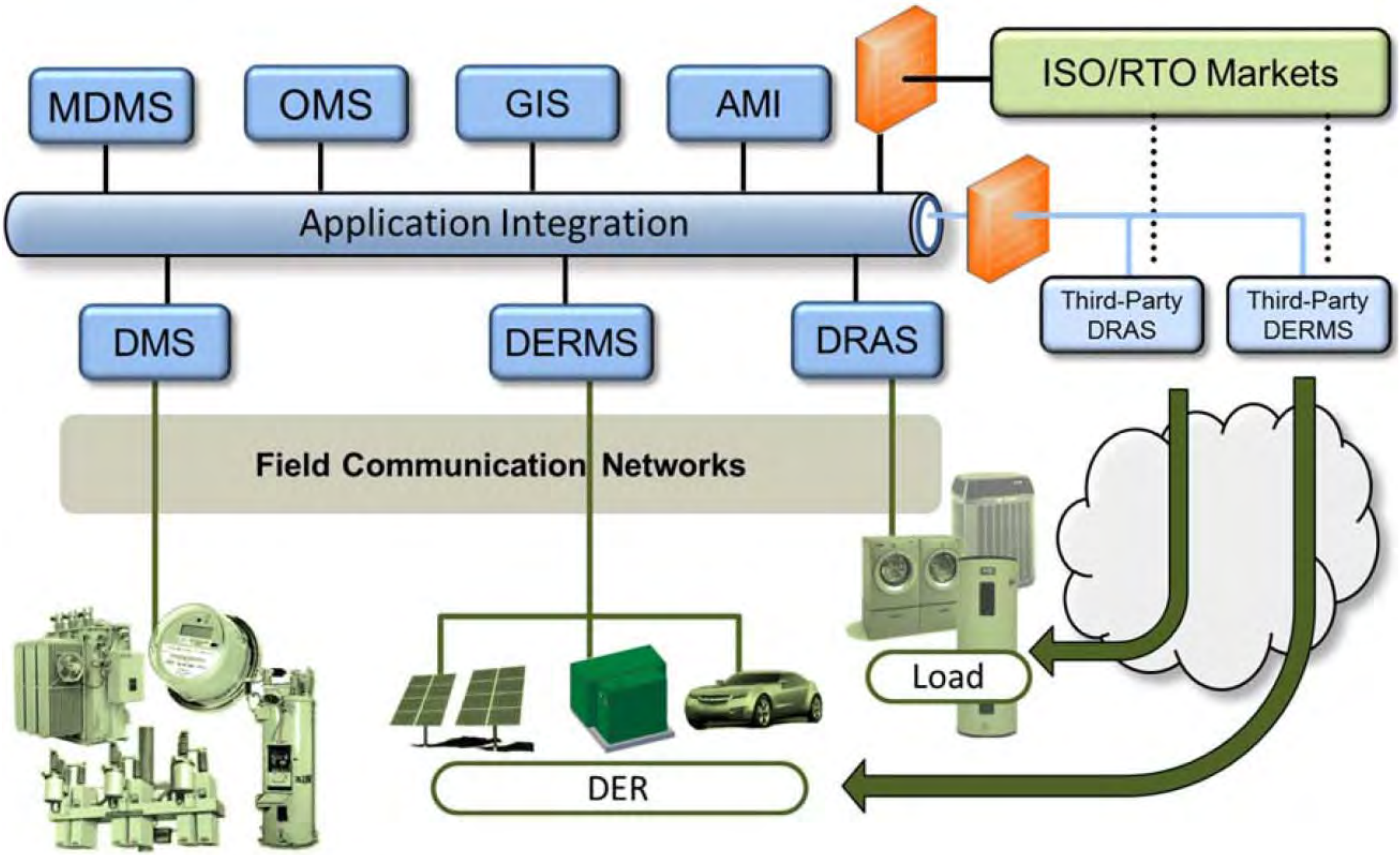
How to talk to storage systems?

- IEEE 2030.2 – guidance on interoperability for storage – making many systems/pieces of equipment talk to each other
- Utility – DNP3 (SCADA protocol) – typically need to translate to:
  - Storage controls – MODBUS/CANBUS
- Emerging standards – Emerging from IEEE, SGIP, CA and other efforts

Cyber security

- Vendor remote access – there may be limits to what is allowed
- Evolving standards and policies – some sites may prevent vendor access

The Back Office Controls Needed for Lots of Distributed Resources



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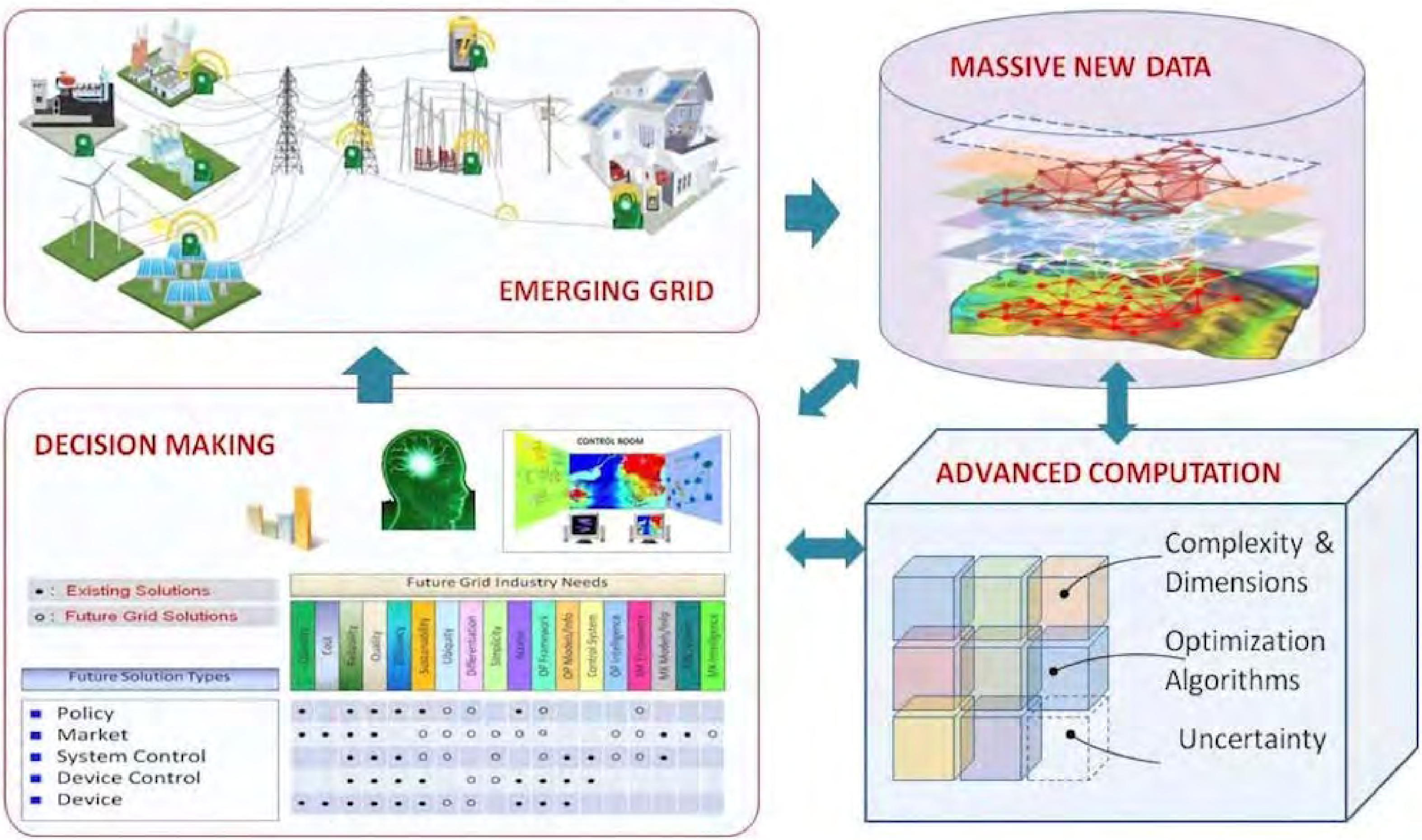
The Future Grid – Far Away from Edison's Pearl Street



DOE Power Systems Engineering Research Center
http://pserc.wisc.edu/Images/Future%20Grid%20Slides/DataNeeds.jpg

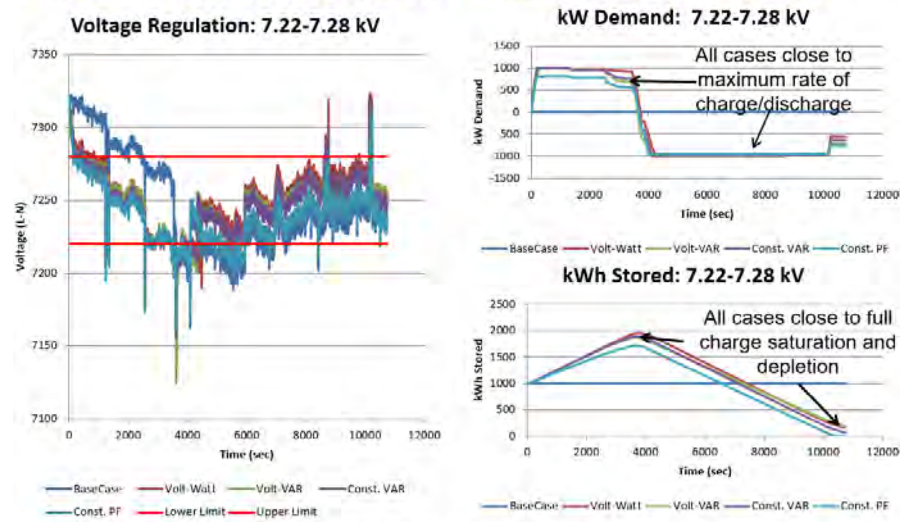
New Mexico Based Initiatives

- DOE/EPRI/NRECA Energy Storage Handbook
- PNM's Prosperity Energy Storage Project
- Mesa del Sol Micro-grid – UNM/ Mitsubishi Research Institute
- EPRI/UNM Model Development
  - DER CAM - Canary Islands, Spain
  - PCS fast acting storage model
  - Applications of Machine Learning to Big Data Using Neural Networks
- EPRI/Sandia Micro-grid Collaboration
- EPRI/SNL – PVROM database
- UNM/Frauenhofer CSE - NSF CRISP (Critical Resilient Interdependent Systems and Processes)

New Mexico Based Efforts – On the Forefront of Meeting the Challenges

PCS fast acting model – showing battery interacting on voltage support

Results: Voltage Regulation + Smart Inverter Controller



The size of storage and inverter determine the extent of voltage regulation capabilities.

DER CAM optimization of island based PV and storage analysis

Matrix of optimization results – annual costs

					location							
					loc7		loc8		loc4		loc11	
	total	fuel	CO2	losses	PV	BESS	PV	BESS	PV	BESS	PV	BESS
Case #	€M	€M	kg	%	€M	€M	€M	€M	€M	€M	€M	€M
0	10.45	8.13	3.69E+07	3.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	9.20	5.98	2.72E+07	3.10	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	9.19	5.95	2.70E+07	3.11	1.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	8.99	5.54	2.52E+07	3.94	0.43	0.00	0.95	0.00	0.00	0.00	0.00	0.00
4	8.99	5.55	2.52E+07	3.71	0.40	0.00	0.98	0.00	0.00	0.00	0.00	0.00
5	8.81	5.26	2.39E+07	4.93	0.41	0.00	0.57	0.00	0.53	0.00	0.00	0.00
6	8.81	5.23	2.38E+07	5.65	0.37	0.00	0.61	0.00	0.55	0.00	0.00	0.00
7	8.80	5.26	2.39E+07	6.28	0.43	0.00	0.27	0.00	0.39	0.00	0.41	0.00
8	8.80	5.26	2.39E+07	6.28	0.43	0.00	0.27	0.00	0.39	0.00	0.41	0.00

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Additional material

Power and Energy Comparison for Storage Technologies

Features

Energy Storage Technology	Energy Density (W-hr/kg)	Power Density (W/kg)	Commercial Availability
Battery Technology			
• Lead Acid	35	300	Available (Mature)
• Nickel cadmium	35	200	Available
• Lithium-Ion	75	180	Available
• Nickel Hydride	50	200	Available
• Sodium Chloride	90	150	Available
• Sodium Sulfur	110	260	Available
• Zinc Bromine	70	75	Available
• Zinc Air	375	175	
Flywheels	10-100	1,000-10,000	Available
Pumped Hydro	---	---	Available
CAES	---	---	Available