EaglePicher™
Technologies, LLC
An GMG Company

Energy Storage:

Current landscape for alternative energy storage technologies and what the future may hold for multi-scale storage applications

Presented by:

Dave Lucero, Director
Alternative Energy Storage

September 22, 2010

Agenda

EaglePicher™ Technologies, LLC
An OMG Company

- Background
- Industry initiatives
- Technology
- Energy Storage Market
- EaglePicher initiatives
- Summary

EaglePicher (EPT) Business Units

EaglePicher™ Technologies, LLC
An OMG Company

EaglePicher Technologies, LLC

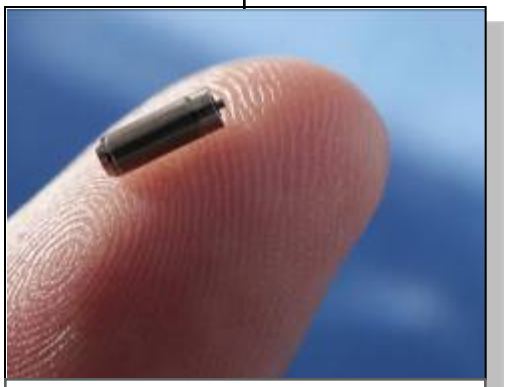
Randy Moore, President

Aerospace Systems

Satellites
Aircraft
Commercial
Alternative Energy

Defense Systems

Missiles
Infantry Support



Medical Power

Implantable Devices

Leader in Batteries, Battery Chargers & Energetic Devices for Defense, Space, Commercial, and Medical Applications

- HQ in Joplin, Missouri
- 11 Plants
  - Joplin, Missouri
  - Seneca, Missouri
  - Pittsburg, Kansas
  - Plano, Texas
  - Vancouver, B.C.
  - Rothenbach, Germany (JV)
- Expertise in >25 Chemistries

Headquarters - Joplin, Missouri

INTERTEK AS9100 • ISO 9001

ANAB ACCREDITED

Trusted Power ♦ Reliable Power ♦ Innovative Power

EPT Heritage

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1843	The Eagle-White Lead Company Formed in Cincinnati, OH
1874	The Picher Lead Co. Began Mining in Joplin, MO
1922	EaglePicher Initiates Research into Storage Battery Technology
1944	First Special Purpose Battery Contract Awarded to EaglePicher
1947	Bell Labs Used EaglePicher Germanium for 1st Transistor
1970	Apollo 13 Safely Returned to Earth on EaglePicher Batteries
1990	Patriot Anti-Missile System and Tomahawk Cruise Missiles Powered by EaglePicher Batteries
1997	Columbia Shuttle Battery Experiment with EPT Sodium/Sulfur
2007	New State-of-the-Art Battery Facilities in Pittsburg, KS and Joplin, MO
2009	New State-of-the-Art Battery Facility in Plano, TX
2010	EaglePicher Achieves 1.4 billion cell hours in Space
2010	OM Group, Inc. purchases EaglePicher Technologies, LLC
2010	EaglePicher awarded ARPA-E Sodium beta battery technology development program


EaglePicher Mine – Picher, OK


EaglePicher Ge & Ga Factory


EaglePicher Germanium at Bell Labs


EaglePicher Battery Brings Apollo 13 Home


Hubble Telescope 19th Birthday Original EP Batteries

Rich Past ♦ Bright Future

EPT Product / Market Overview

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Medical Power:

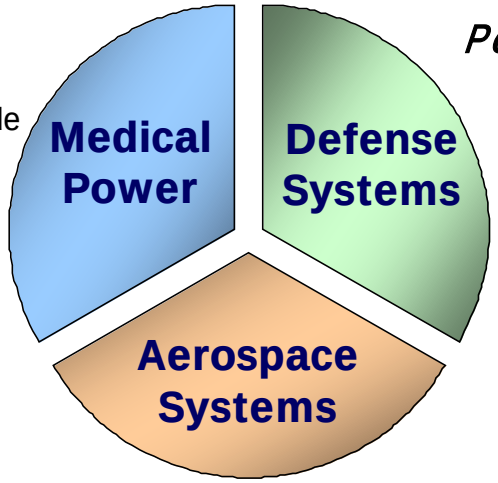
- Lithium Ion
- Lithium Manganese Dioxide
- Lithium Carbon Monofluoride
- Lithium Thionyl Chloride
- Microcell

Missiles:

- Thermal
- Silver Zinc
- Energetic Devices
- Lithium Oxyhalide
- Custom Packaging

Distributed Products:

- Sealed Lead Acid
- Lithium Thionyl Chloride



Portable Power:

- Lithium Sulfur Dioxide
- Lithium Manganese Dioxide
- Lithium Carbon Monofluoride
- Lithium Thionyl Chloride

Engineering Services:

- Chargers
- Analyzers
- Test Systems
- Custom Battery Packaging
- Battery Management Systems

Launchers:

- Silver Zinc
- Lithium Ion

Space:

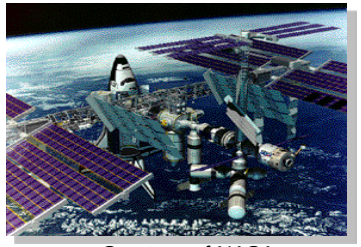
- Nickel Hydrogen
- Lithium Ion

Alternative Energy

- Hybrid Power Storage Systems
- Technology development

Aircraft:

- Lithium Ion
- Nickel Cadmium
- Primary Lithium
- Energetic Devices



Energy Storage – Why?

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- Increased global energy demand
- Enable renewable energy sources such as wind and solar
  - Reduce consumption of fossil fuel & GHG
  - Reduce dependency on foreign supply
- Introduction of smart grid concept
- Provide assistance to PHEV/EV integration

Utility Grid

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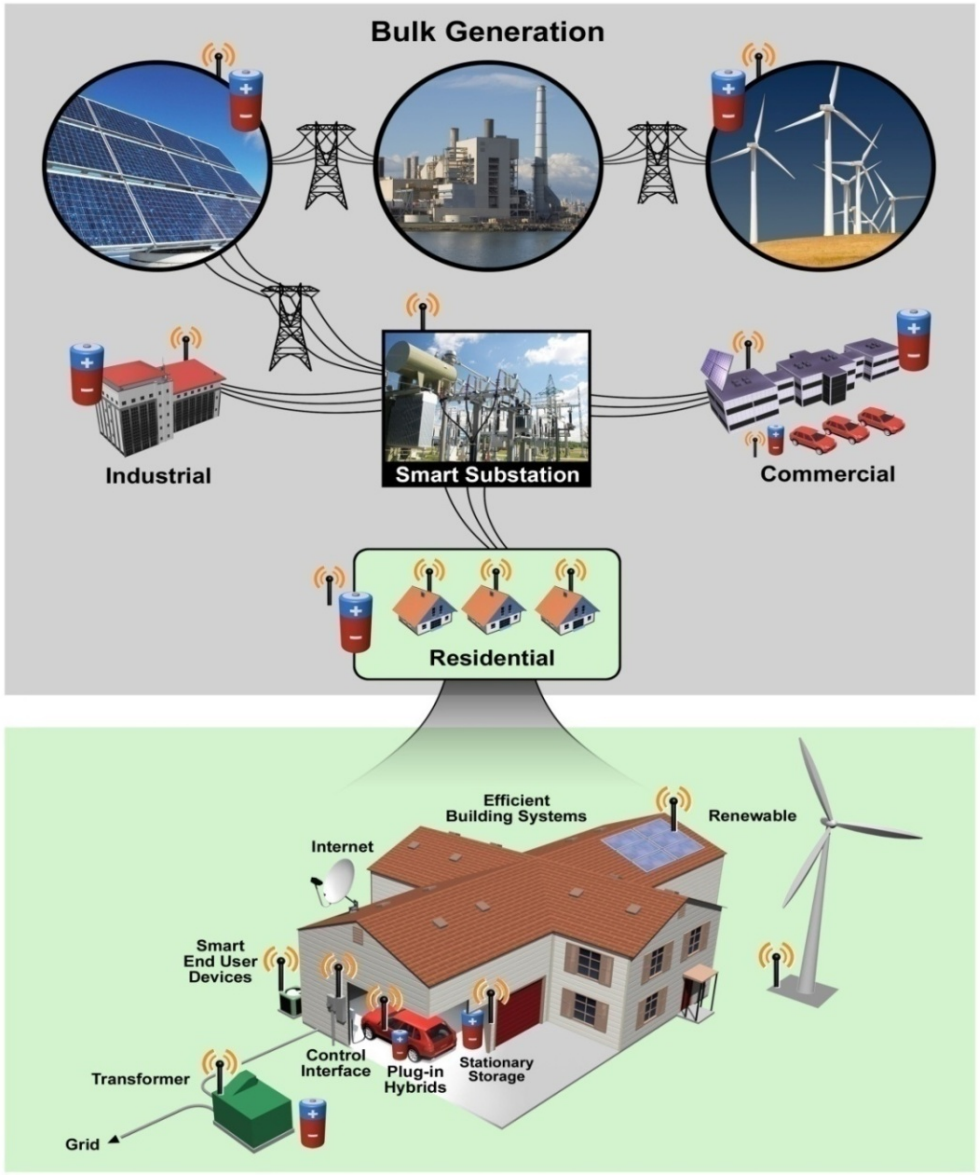

U.S. Incentives

- ARRA (“Stimulus”) Projects – Department of Energy
- Federal Carbon Tax
- Smart Grid Standards Development for Storage – NIST
- Individual ISO Market Tariffs & Experiments
- State Incentives –
  - Renewable Portfolio Standards
  - California legislation (AB 2514) mandating energy storage equal to 5% of demand by 2014

Value Proposition – Energy Storage

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- Utilities can address deficiencies in electricity grid
- Utilities can deploy energy storage resources as needed in generation, transmission or distribution
- Energy storage can delay or avoid capital investment in systems upgrade
- Provides the ability to integrate renewable energy sources

Energy Storage Categories

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- Community Scale (Community Energy Storage)
  - Typically 25-100 kW devices
  - Diurnal storage, Peak-load shaving, Backup supply, Power quality
- Utility Scale
  - Typically 250 kW-10 MW devices
  - Ancillary Services and Renewables
- Bulk Storage
  - Typically 100 MW and larger
  - Compressed Air and Pumped Hydro are only alternatives at this scale

Energy Storage Benefits

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Customers

- Improved Reliability
- Emergency Backup
- Reduction in demand costs

Utility

- Improved Power Quality
- Reduced Peak Generation
- Reduced Spinning Reserve

System Operator

- Improved Grid Reliability
- Ancillary Services
- Security

Society

- Reduced GHG emissions
- New industry for employment
- Less dependence on fossil fuel generation

Key Drivers for Energy Storage Growth

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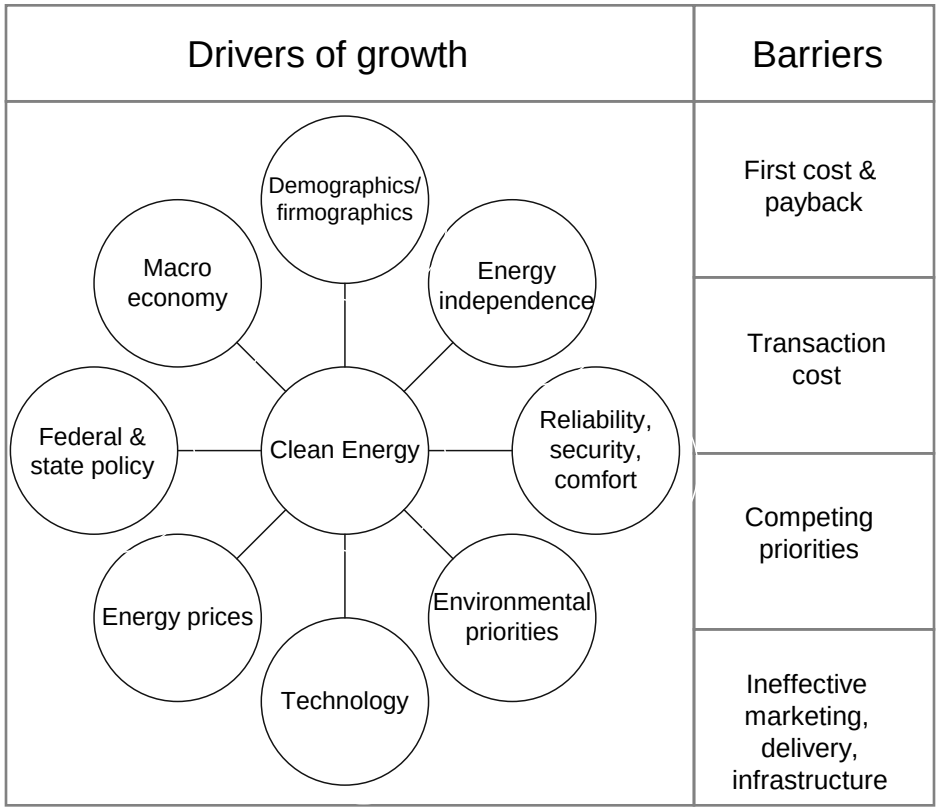
- Renewables Integration
- Peak Load Growth
- System Constraints
- GHG emission reduction
- Smart Grid

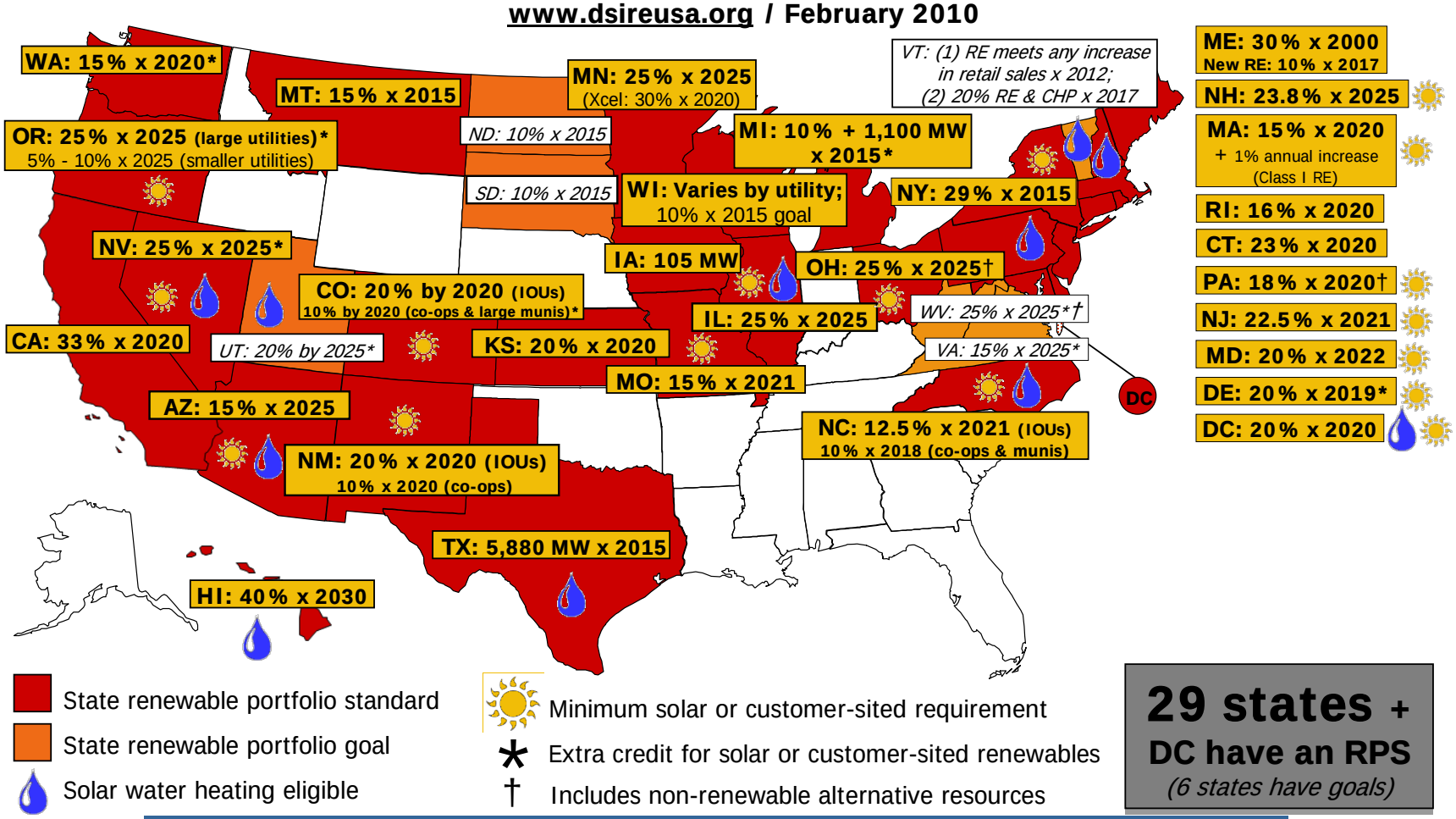
Renewable Energy Drivers



- Rapid evolution of technology, rising investment & declining costs
- Growing subsidies & mandates for energy efficiency and renewables
- Carbon constraints inevitable

Source: KEMA

Renewable Portfolio Standards



Drives Need for Alternative Energy Storage

Technology Overview

- Pb-Acid Batteries
  - Flooded & VRLA
  - Limited Cycle life make insufficient for utility application
- Nickel Batteries
  - Vented & Sealed
  - Good high rate capability
  - Good energy density
  - Cost profile not the best fit
- Sodium Sulfur Batteries
  - High energy density, high efficiency and long cycle life
  - Most promising technology for utility-grid application
- Advanced Li-ion Batteries
- Flow Batteries (Vanadium & Zinc Bromide)

Technology Overview (con't)

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- Pumped Hydro (hydroelectric storage)
- CAES – Compressed Air Energy Storage
- Flywheels
- Superconducting Magnetic Storage
- Super-capacitors/Ultra-capacitors

Key Cost & Performance Characteristics

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	Lead-Acid	Sodium Sulfur	Lithium-Ion	Zinc Bromine	Vanadium Redox
System Costs ($/kWhr)	$170	$2,000	$1,500	$400	$780
Cycle life (cycles)	> 500	2,500	> 1,000	> 2000	12,000
Efficiency (%)	~ 80	> 85	~ 95	> 75	> 65
Specific energy (Wh/L)	> 35	~ 370	> 300	60	33
Self discharge (per month)	< 5%	< 1%	~ 1%	< 1%	< 3% per day

Each battery storage technology has its own unique benefits, but each system has drawbacks that limit its widespread adoption.

Energy Storage Today

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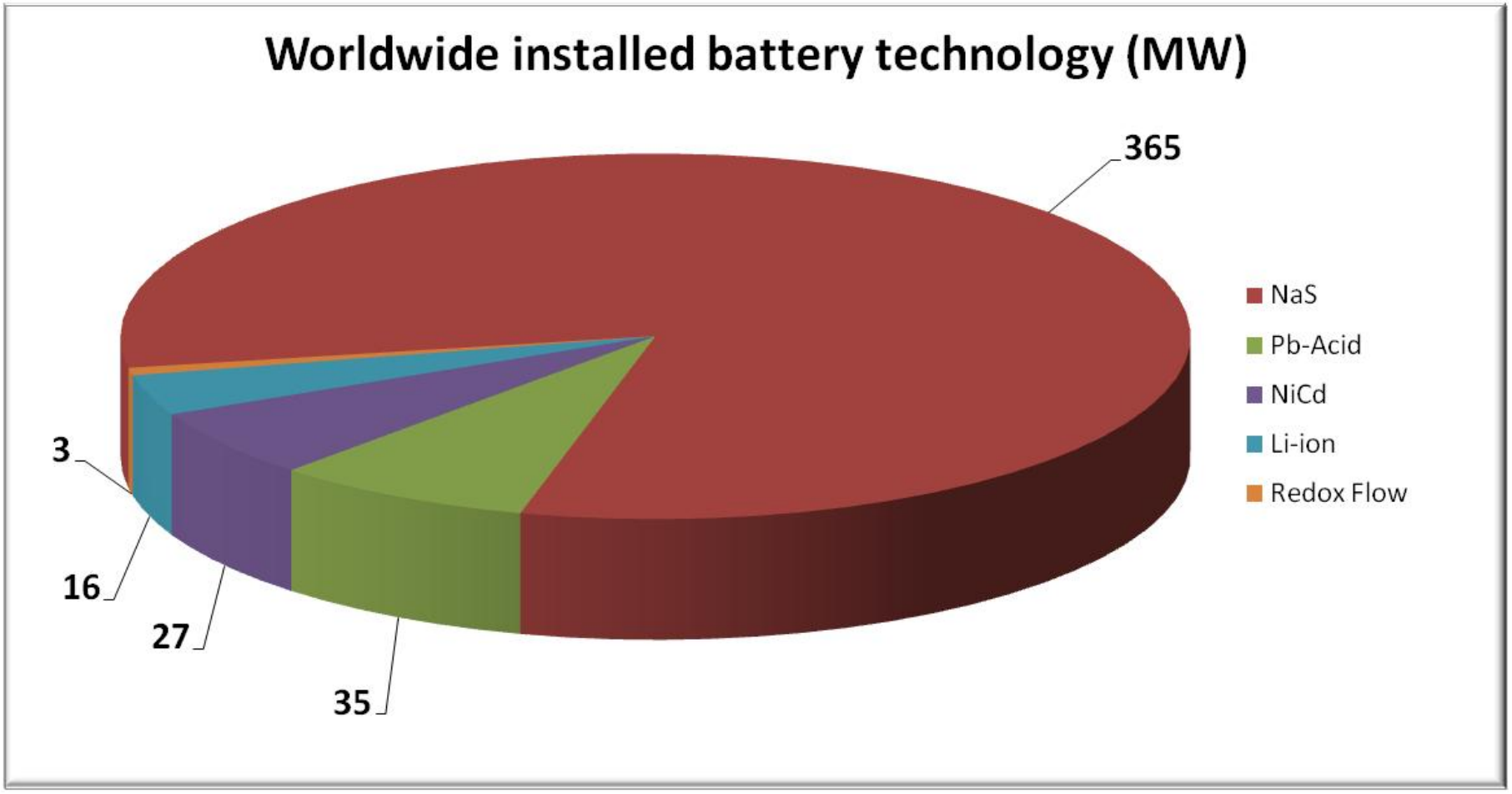
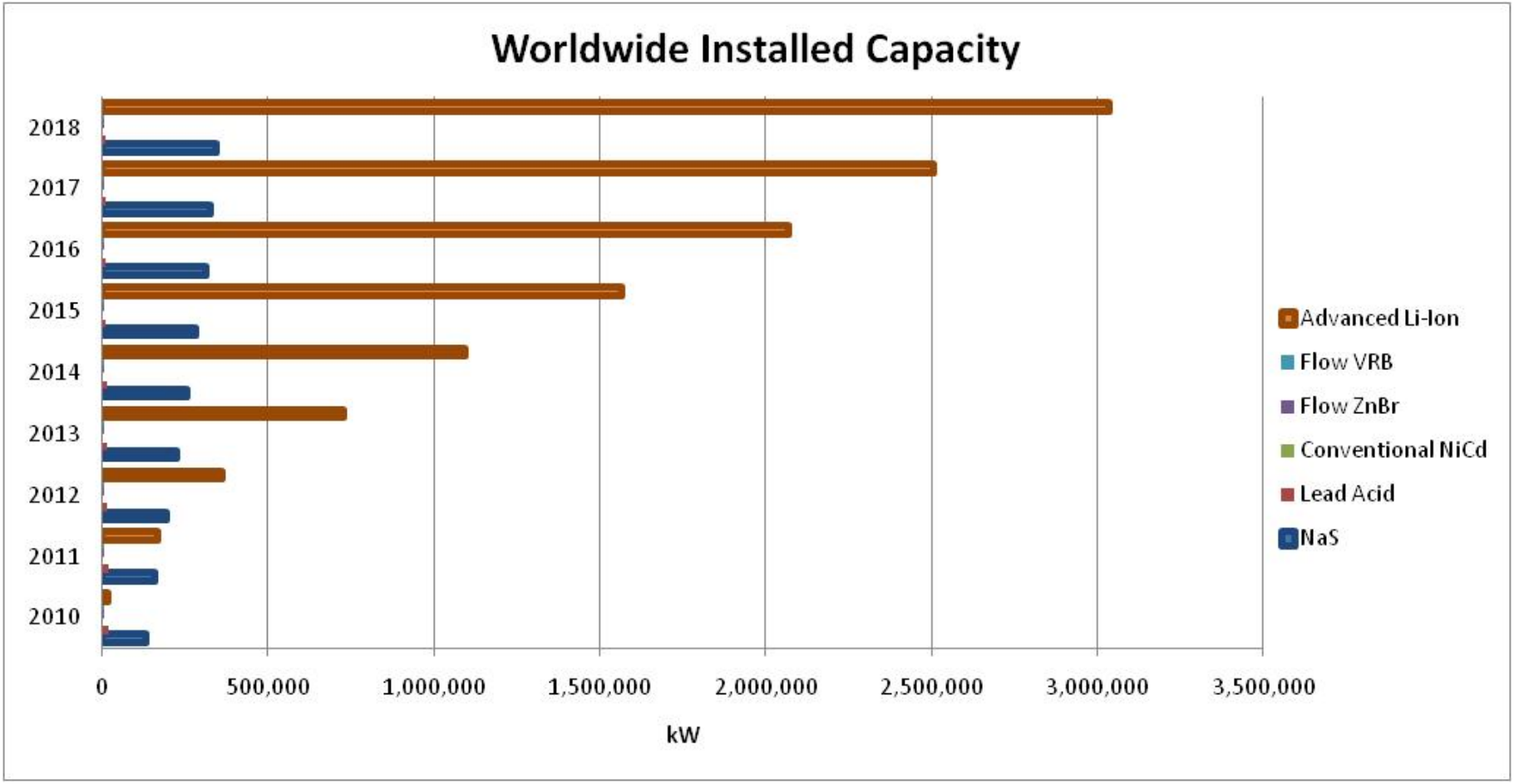


Source: Pike Research

Projected Market



Source: Pike Research

Projected Revenues

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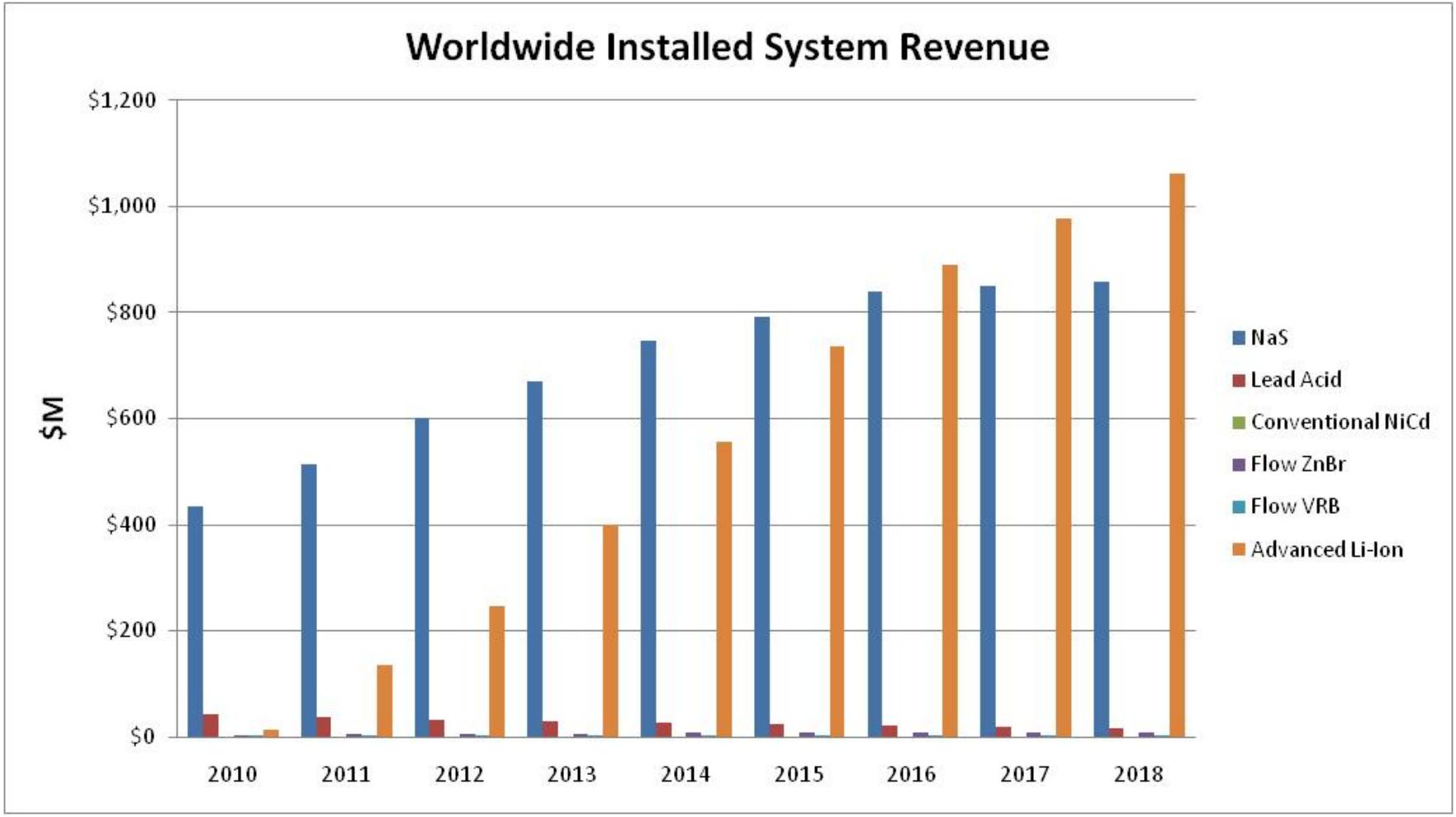

Source: Pike Research

Energy Storage Policy

- No policy governs the use of storage technology
- FERC
- Incentive structure for utilities is non-existent
- Generation, Transmission, Distribution
- Policy will play strong role in market growth

"New Generation Na-Beta Batteries for Renewable Integration & Grid Applications"

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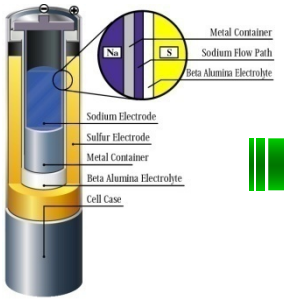
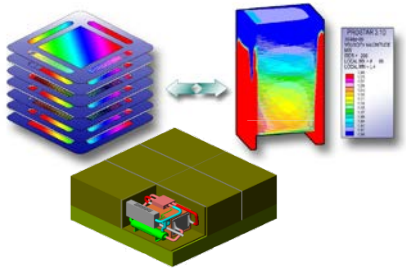
Proposed Technology vs. State of the Art





SOA Tubular Na-beta Design

Leverage US National Lab Tech

Proposed Planar Na-beta Design

- **Energy Density Increase**
- **Cost Reduction**
- **Temperature Reduction**
- **Transformational Changes**

ARPA-E Mission Area Impact

- **Renewable Energy Storage With Improved Na-beta battery reduces CO_2 emissions by 150 Million Tons/Year**
- **Improves/maintains US energy storage leadership**

Transition Strategy

Proof of Concept | Commercialization

PNNL Research and Development

Tech Transfer & IP

EaglePicher R&D and Production

3 Yr

One Team: Concept Thru Production

No Tech Transfer Lag

No IP Transfer Lag

EaglePicher
Full Scale Development

2 Yr

EaglePicher
Establish Large Scale Production

2 Yr

Program Summary

Period of performance:
36 months

ARPA-E funds:	**$7.2M**
Cost-share:	**$1.8M**
Total budget:	**$9.0M**

Annual Schedule Milestones

- Improved Na-beta cell demonstration & initial system model complete
- PNNL electrolyte & seal technology transfer complete & demonstration of multi-cell battery
- 5kW-20kWh battery model demonstration & system model complete

Sodium-Beta Evolution

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- Sodium Sulfur Batteries first developed by Ford Motor Co. in 1960's
- Sodium Metal Halide Batteries first developed by Zeolite Battery Research Africa project (ZEBRA) in 1980's
- Present Day Players in Sodium Beta are:
  - CoorsTek
  - General Electric
  - NGK Insulator, ltd

EPT's Sodium-Beta Experience

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- 1952: Molten Salt Battery Development
- 1973: Argonne National Laboratory Contract on Rechargeable Batteries for Electric Vehicles
- 1986: Air Force Contract to Develop Tubular Na/S for Satellites
- 1988: Beta" Electrolyte Development
- 1990: Planar Sodium/Sulfur*
- 1992: Sodium/Nickel Chloride
- 1997: Space Shuttle Flight Experiment
- 2010: Planar Sodium/Metal Chloride

* EPT Patent # US4894299A Cell Having Dome-Shaped Solid Ceramic Electrolyte

EPT/PNNL Na-Beta Project

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- Domestic Supply
- Energy Dense Storage
- Improved Power/Energy Ratio over Tubular
- Moderate Initial Cost
- Long Installed Life (low life cycle cost)
- Site Independent Use
- Near Term Availability

EPT's Power Pyramid™ = Energy Storage

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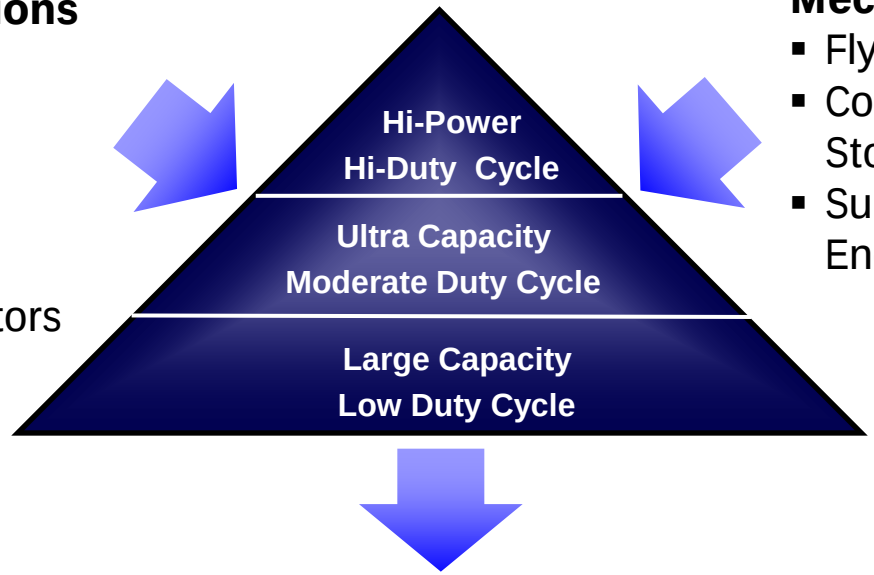
Energy Storage Options

Electrochemical Solutions
- Lithium-ion
- Lead Acid
- Sodium Sulfur
- Redox Flow Batteries
- Nickel Cadmium
- Electrochemical Capacitors



Mechanical Solutions
- Flywheels
- Compressed Air Energy Storage (CAES)
- Superconducting Magnetic Energy Storage

Benefits of Hybrid Approach
- Optimize Cost
- Leverages Existing Technologies
- Adaptable to Technology Improvement
- Balances Variability with Variable Power Sources
- Smoothes/Levels Supply to Grid
- Represents "Spinning" Capacity

Why the Power Pyramid™ Works?

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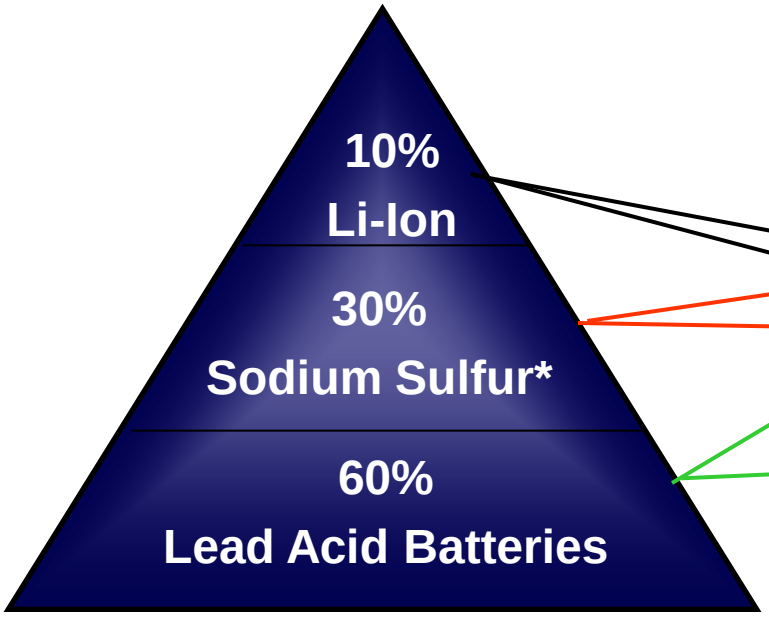
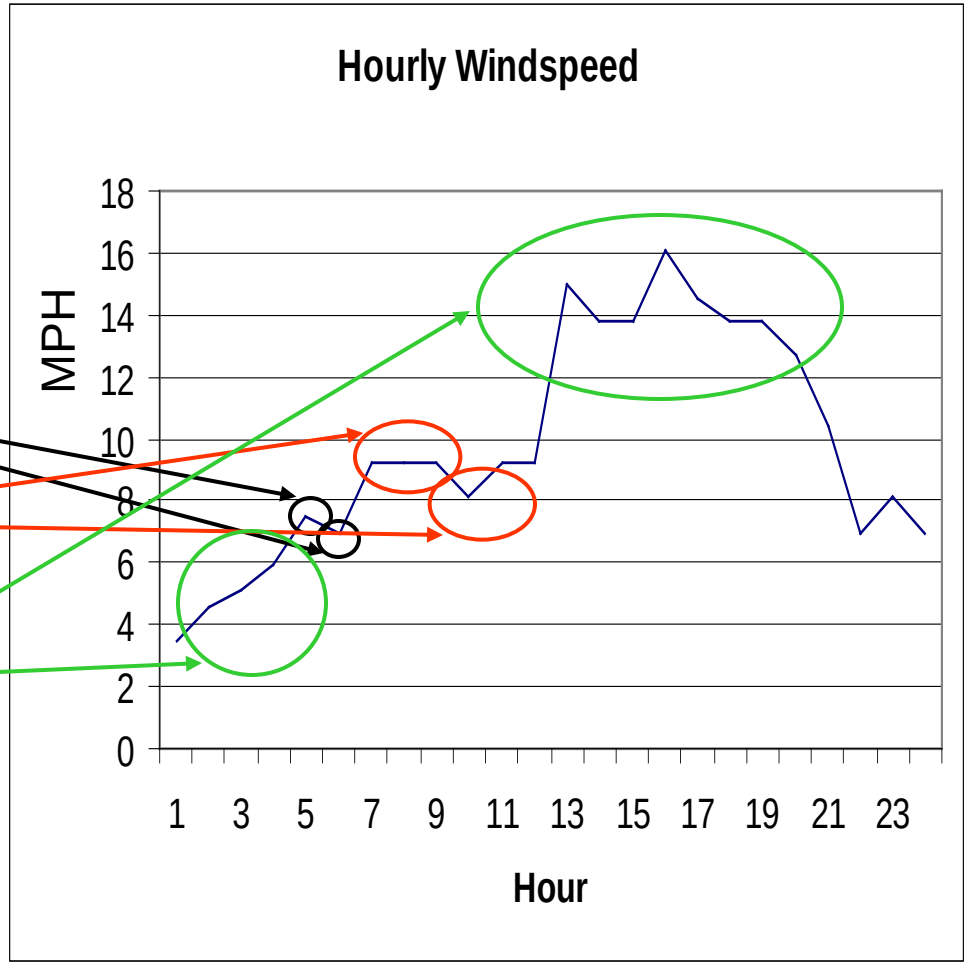
POWER PYRAMID™



(PowerPyramid Example)



Managing Variability with Variability

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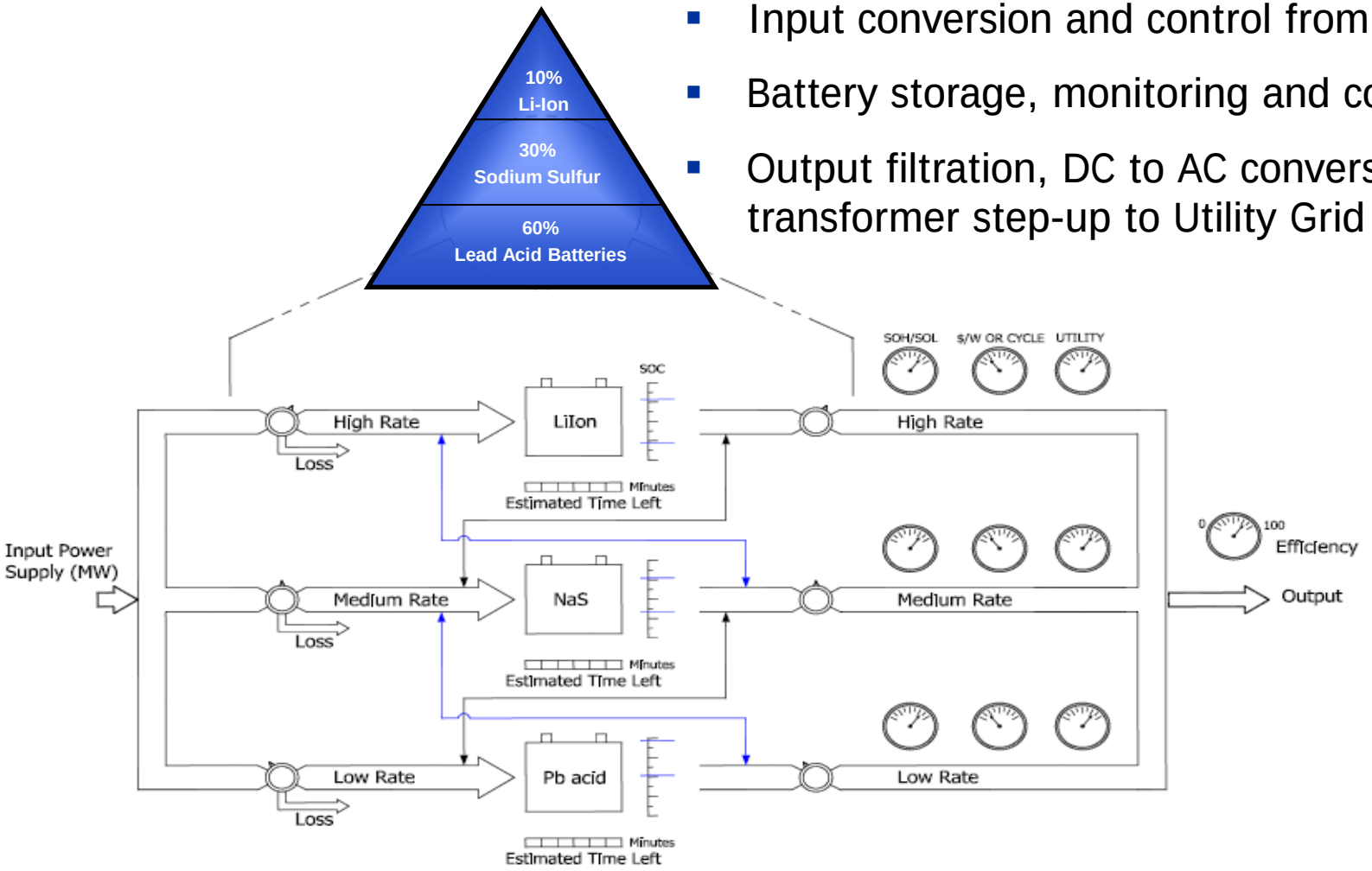
The Power Pyramid™ provides:

- Input conversion and control from Utility Grid
- Battery storage, monitoring and control
- Output filtration, DC to AC conversion and transformer step-up to Utility Grid



Battery Management System (BMS)

- EaglePicher's BMS technology has been successfully demonstrated through multiple space, defense and aerospace applications - 1.4 billion cell hours in space without mission failure gives testimonial to the integrity of these robust systems.
- Power Pyramid™ BMS features include:
  - Over and under voltage sensing
  - High and low temperature sensing
  - Over current and short circuit protection
  - Equalization time limit
  - State-of-Charge, State-of-Health

- In addition, the Power Pyramid™ BMS control algorithms will monitor and provide:
  - Battery cycle cost and estimated life
  - Overall Storage System power costs and efficiencies
  - Utility definable metrics to help optimize Battery Storage System reliability

Power Pyramid™ Storage Example

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- Lithium Ion Technology
  - Very high energy to weight ratios
  - EP can choose cathode and electrolyte materials to influence energy capacity, cycle life and safety.
  - EP has battery management experience to maximize the performance of Lithium Ion batteries while ensuring their safety under all conditions.
  - EP's knowledge of specialized charging techniques may improve depth of discharge and cycle life of Lithium Ion batteries.
- Sodium Sulfur Technology
  - EP is uniquely qualified to handle temperature management to maintain at elevated temperatures.
  - Molten salt batteries operate at ~350^{o}C.
  - No self-discharge
  - Efficiency > 85%, including heat losses
  - Lower weight and smaller size than lead acid batteries
- Lead Acid Technology
  - Low cost, high reliability
  - EP experience in thermal management needed

Alternative Energy Storage - Summary

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- World has changed- technology advancements, geopolitical agenda and U.S. driven stimulus funding have combined in a “perfect storm” for energy storage
- Renewable sources (wind/solar) will be an important component of our grid, but they are unreliable
- State mandates for increasing the Renewable Portfolio Standard (RPS) will provide a large market for AES
- California is leading with legislation (AB 2514) mandating energy storage equal to 5% of demand by 2014
- Batteries provide reliability to Renewable sources at a fraction of the cost of new capacity
- EPT has the capability to engineer and build battery storage capacity for renewable energy storage