



# Eos Energy Storage

Public | February 2013

# Executive Summary

- Eos has developed a safe, reliable, non-toxic, non-combustible, low cost zinc energy storage system for the electric grid that can be sold for **\$160/kWh**, rechargeable over 10,000 cycles (30 years)
- Eos is scaling up battery prototypes in 2013 in preparation for manufacturing and delivery of MW scale systems to customers in 2014
- Eos will develop 100s of MW of energy storage projects through its **Genesis Program** and through strategic partnership with **Convergent Energy + Power**
- While Eos will emphasize grid storage with its Aurora product, Eos seeks to create partnerships to develop automotive and light industrial batteries using Eos technology



# Eos: Energy Storage Solutions Provider

<b>Mission:</b>	<b>Providing the utility and transportation industries with safe, reliable, low-cost energy and power storage</b>
<b>Eos Aurora Grid Product:</b>	<ul style="list-style-type: none"><li>• 1MW/6MWH energy storage system for the electric grid (1 MW optimal power for 6 hours, with surge capability)</li><li>• Safe, non-toxic, stable, reliable, low capital and operating cost</li><li>• Battery price for major orders: \$1000/kW, \$160/kWh</li><li>• 30 year life, 10,000 full cycles*</li><li>• Scaling up battery prototypes (5kW/30kWh units) for initial manufacturing in 2013 and delivery of MW scale systems to first customers in 2014</li></ul>
<b>Vehicle Product:</b>	<ul style="list-style-type: none"><li>• 70kWh battery capable of &gt;350 km range for \$10,000</li></ul>
<b>Value Proposition:</b>	<ul style="list-style-type: none"><li>• Cost competitive with incumbent technology: gas-fired turbines for additional generation capacity and gasoline powered vehicles</li></ul>
<b>Customers:</b>	<ul style="list-style-type: none"><li>• Development cooperation with Convergent Energy &amp; Power</li><li>• Eos Genesis Program for utility early adopters and strategic industry partners</li></ul>



\* One full cycle includes full charge, discharge and additional frequency regulation over the course of one full day.

# The Challenge: Adapting to the Future Grid

- **Energy demand growing** — projected to grow globally by 36% from 2010 to 2035, including energy efficiency increases <sup>1</sup>
- **Aging generating capacity needs to be replaced** — by 2025, most coal-fired plants and by 2030, most nuclear plants, will need to be rebuilt or retired <sup>2</sup>
- **Need for new transmission and distribution** — \$180B of planned US transmission projects <sup>3</sup>
- **Infrastructure driven by peak demand** — 25% of distribution and 10% of generation and transmission assets used less than 400 hours per year <sup>4</sup>
- **Growing renewable generation** that is intermittent leads to grid instability and—in some cases—curtailment or negative pricing <sup>5</sup>



# The Largest Supply Chain in the World Has No Storage



**Total Annual  
Electricity  
Consumption =  
20,000,000 GWh**

**Energy  
Storage =  
1,270 GWh  
(.0064%)**

**Total Annual  
Crude Oil Production =  
4,748,067,825 m<sup>3</sup>**

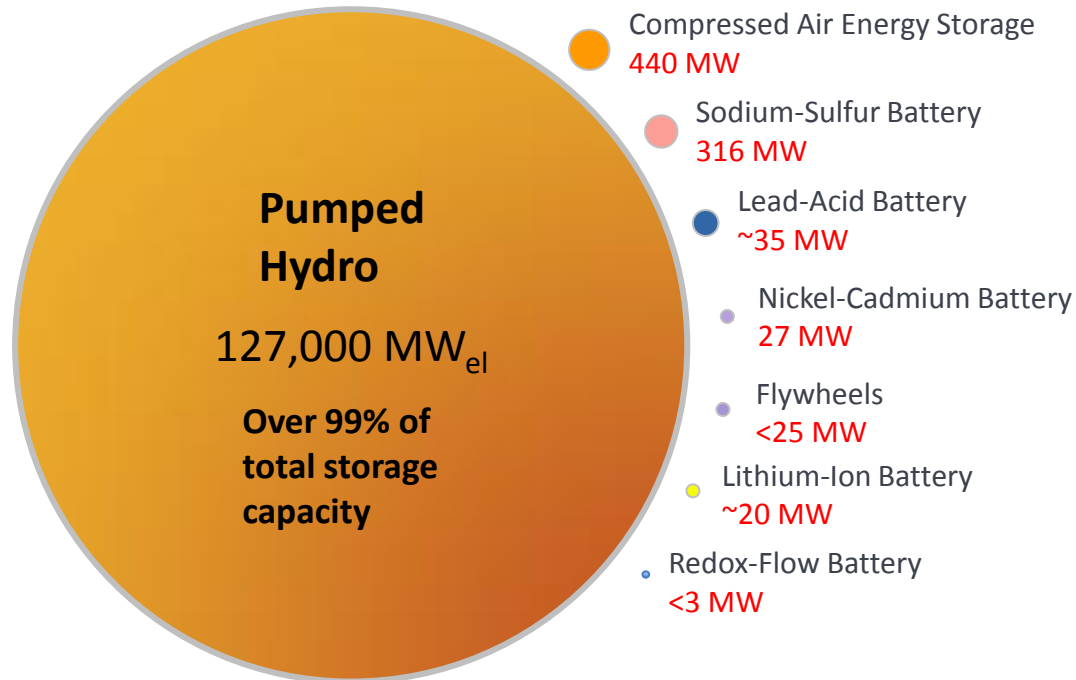
**Oil Storage =  
600,000,000 m<sup>3</sup>  
(12.6%)**



**Oil storage = 46 days  
Electricity Storage = 33 minutes  
A 2000X differential**



# Current World Electric Energy Storage Capacity

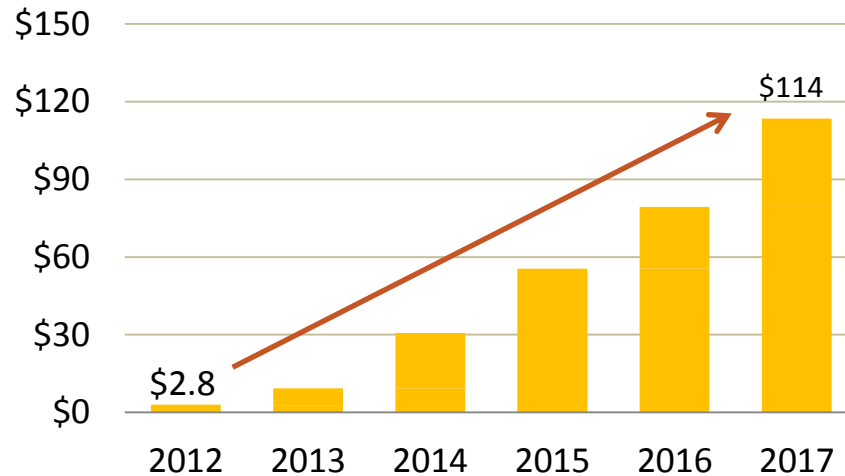


Today's electricity energy storage is almost exclusively pumped hydro



# Energy Storage Market Potential

## Grid-Scale Energy Storage (\$B)

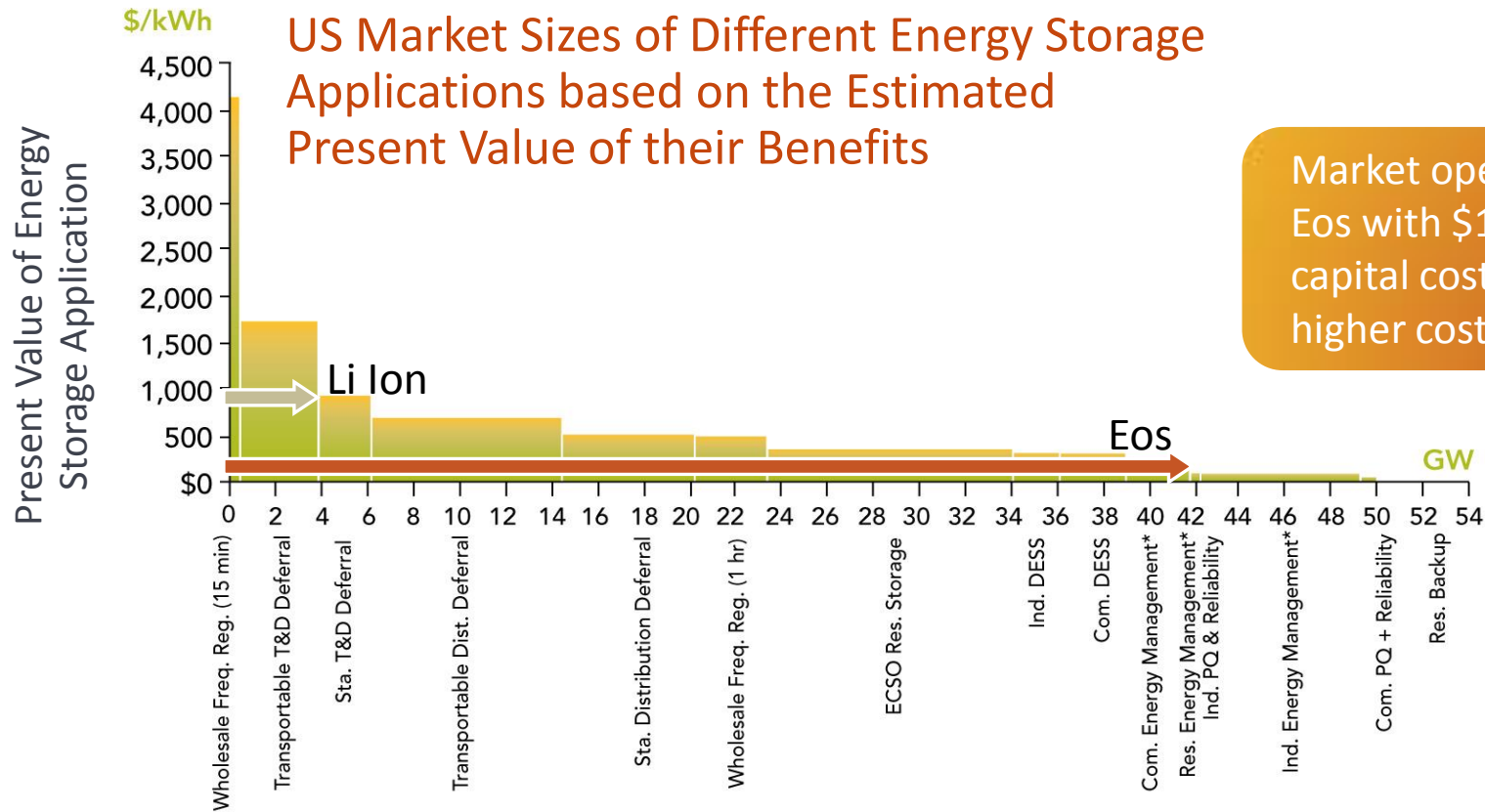


- **Lux Research** – \$114 B by 2017
- **Piper Jaffrey** – \$600 B market over 10-12 years
- **Boston Consulting Group** – \$400 B market by 2020
- **EPRI/DOE** – annual savings of \$50 billion/year via energy storage

Plenty of market potential... for the right product at the right price



# Eos Low Capital Cost Opens US Grid Market



Market opens up for Eos with \$160/kWh capital cost vs other higher cost solutions





# Eos Application Overview

Value is created by energy storage that is less expensive than incumbent solutions



De-link supply and demand to reduce peak infrastructure



Enhance profitability & adoption of renewable generation



Empower electricity consumers to reduce costs



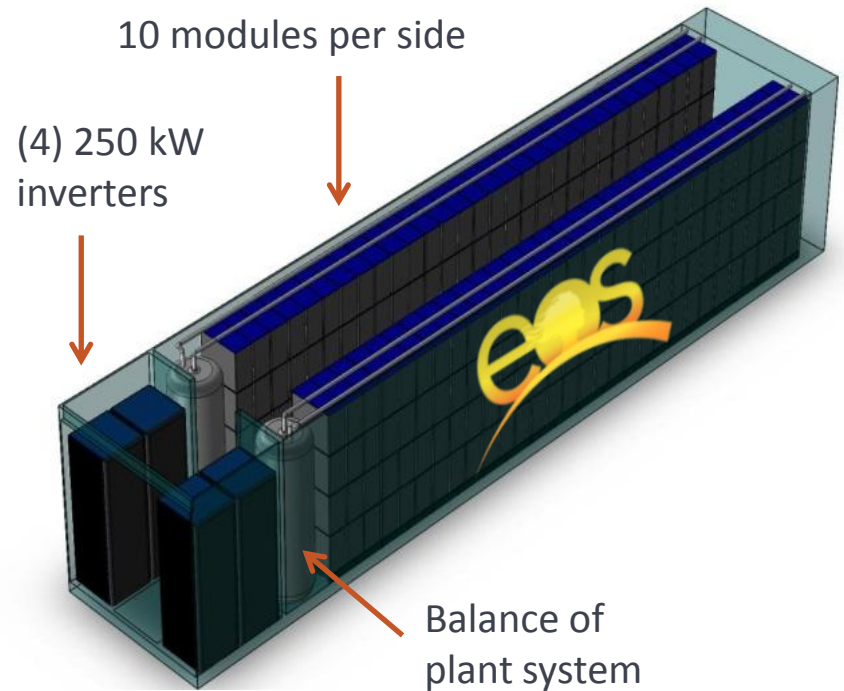
Enable electric vehicles that are cost competitive



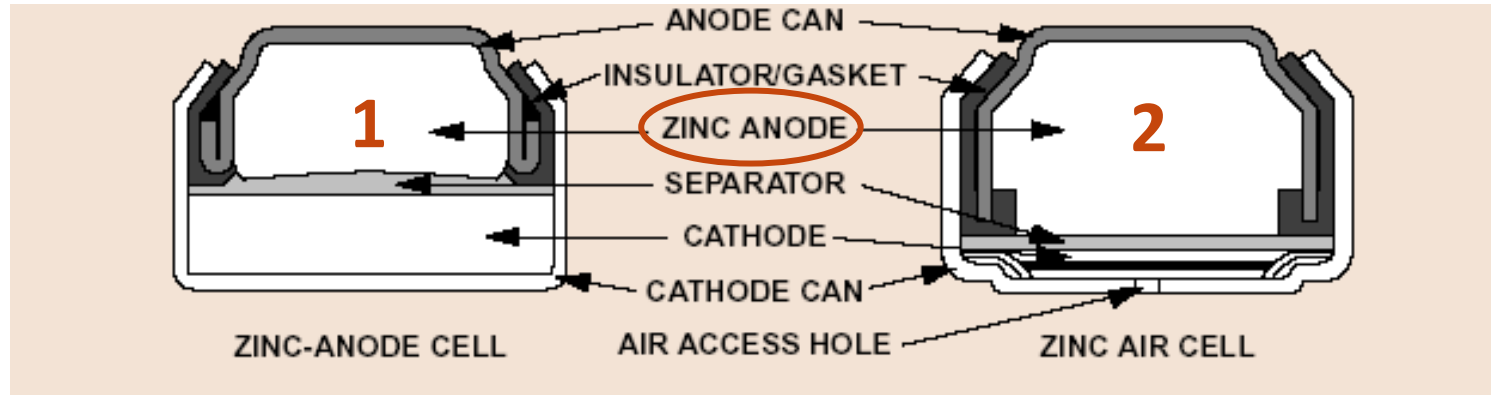
# Eos Aurora 1000 | 6000

Targeted applications define technology characteristics required for profitability

Technology Attributes	
Low-Cost	\$1,000/kW or \$160/kWh
Long Life	10,000 cycles (30 years)
Ample Storage	1 MW for 6 hours = 6MWh in a 40' ISO shipping container
Efficient	75% round-trip efficiency
100% Safe	Non-toxic, non-combustible, no risk of catastrophic failure



# Why Zinc-Air Batteries?



- Increased amount of anode material in the Zinc-air cell enables greater capacity and energy density at lower cost
- Zinc-air batteries use ambient air as the active cathode material—eliminating material that would normally be carried within the battery



Non-metal Air Batteries

Vs



Zinc-Air Battery

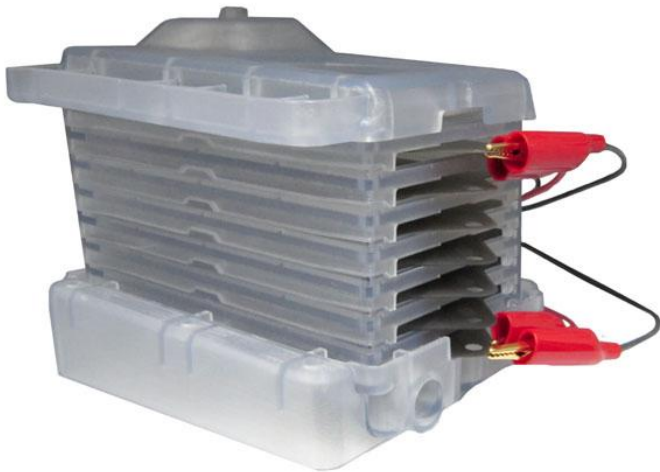
# Eos' Technology Solutions

The Historic Problem	Eos Solution
<ul style="list-style-type: none"><li>• Air electrode clogging due to CO2 absorption</li></ul>	<ul style="list-style-type: none"><li>• Novel aqueous electrolyte with near neutral pH</li></ul>
<ul style="list-style-type: none"><li>• Rupture of ion-selective membrane due to dendrite</li></ul>	<ul style="list-style-type: none"><li>• No membrane, non-dendritic electrolyte</li></ul>
<ul style="list-style-type: none"><li>• Electrolyte drying out over time as oxygen enters</li></ul>	<ul style="list-style-type: none"><li>• Self-healing electrolyte management system</li></ul>
<ul style="list-style-type: none"><li>• Zinc electrode changes shape</li></ul>	<ul style="list-style-type: none"><li>• Inert non-zinc current collector</li></ul>
<ul style="list-style-type: none"><li>• Materials degradation/corrosion over time</li></ul>	<ul style="list-style-type: none"><li>• Treatment of metals for conductivity and corrosion</li></ul>
<ul style="list-style-type: none"><li>• Poor efficiency and kinetics</li></ul>	<ul style="list-style-type: none"><li>• Hybrid reactions with 95% cell efficiency</li></ul>
<ul style="list-style-type: none"><li>• Limited power</li></ul>	<ul style="list-style-type: none"><li>• Enhanced system with surge capability</li></ul>

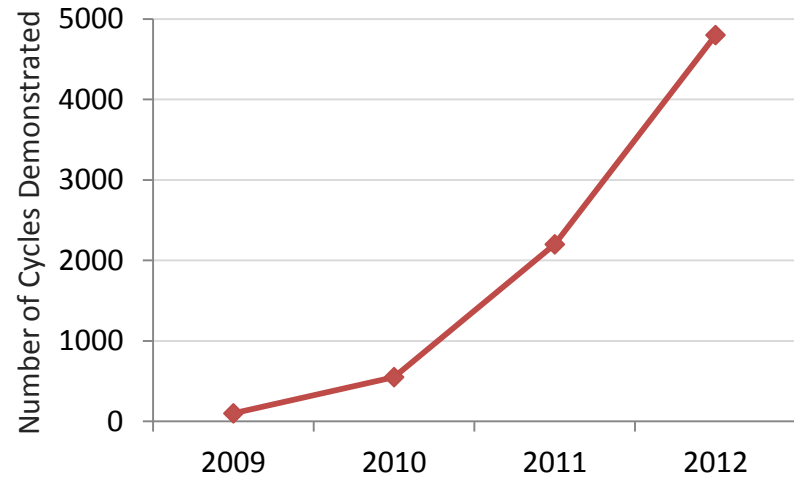


# Eos Progress to Date: >5000 Cycles with No Degradation

Demonstrated  
rechargeability  
of zinc-air



### Cell Cycling Performance Improvement



Cells continue to cycle:  
target 10,000

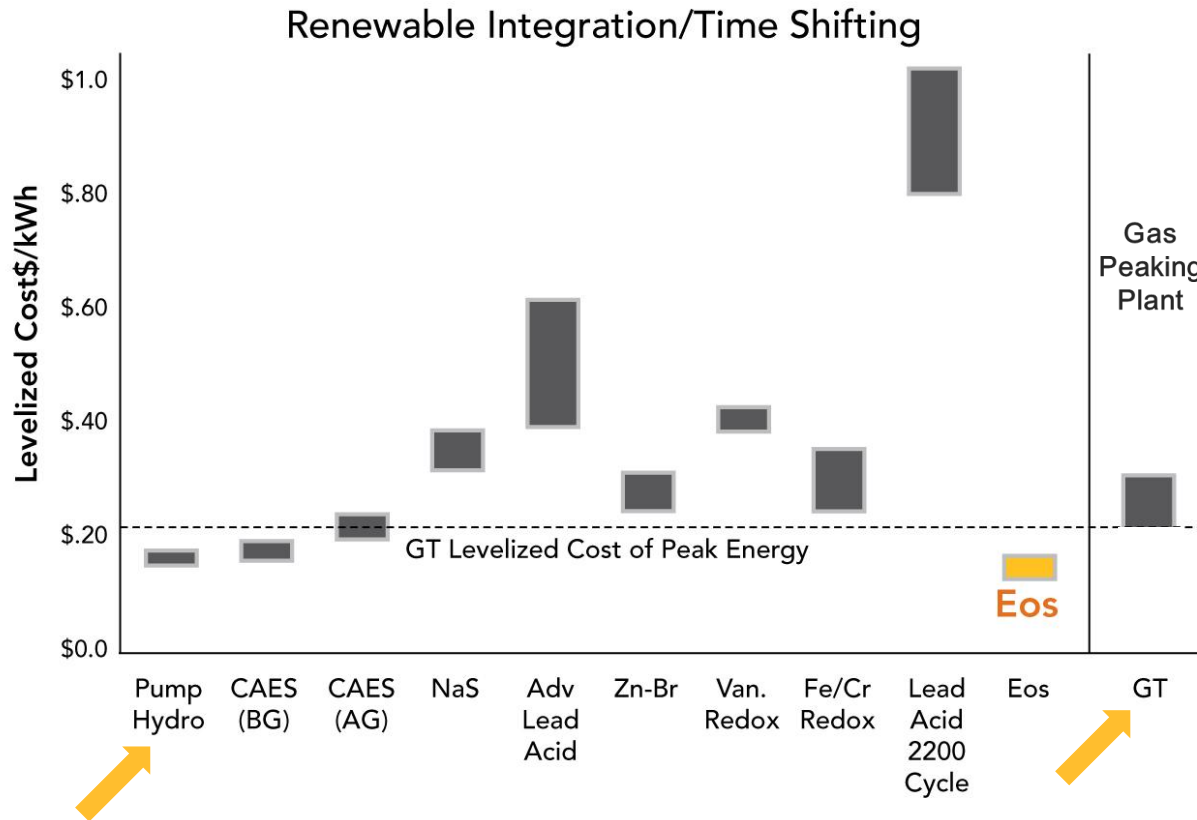


# Competition

- Peak load reduction via energy efficiency and demand response
- Capacity additions from gas peaking plants
- New transmission and distribution spending
- Distributed generators (i.e., fuel cells, diesel gen)
- Other energy storage providers



# Eos Levelized Cost of Peak Energy vs Leaders

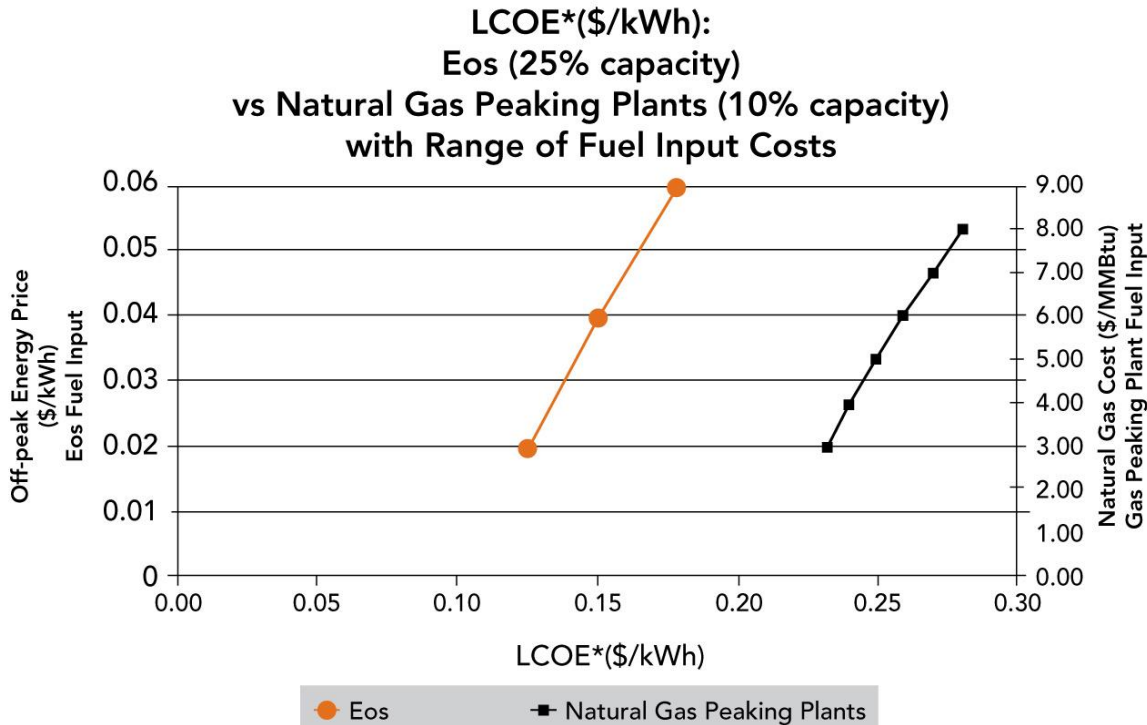


Eos' levelized energy cost is comparable to pumped hydro and gas turbines

\* Non-Eos data source: EPRI, Electricity Energy Storage Technology Options, 2010. Natural gas fuel cost range: \$6.5 -8/MMBtu. Levelized cost of energy includes cap. fix, and var. costs. Gas peaking cost estimate from Lazard, 2009, midpoint of est. range; assumes: 150MW facility, Capital cost \$1,125/MW, Heat rate 10.5 MMBtu/MWh, Cap. factor 10%, Facility Life 35 years, Construction time 25 months. Eos: 2MW plant, 25% cap. factor (6hrs of energy production), Roundtrip efficiency of 75%, Cap. cost for entire system with Eos battery \$1.7/watt, O&M costs: \$20,000/year for a 2MW/12MWh operating costs, Facility Life 30 years.



# Eos Superior to Gas Peaking Plants



Eos utility scale energy storage systems can be cheaper than gas peaking plants when compared at realistic operating conditions



\* Chart Notes: Levelized Cost of Energy included cap. fix, and var. costs. Gas peaking cost estimate from Lazard, 2009, midpoint of est. range. Assump: 150MW facility, Capital cost \$1,125/MW, Heat rate 10.5 MMBtu/MWh, Cap. factor 10%, Facility Life 35 years, Construction time 25 months. Eos: 2MW plant, 25% cap. factor (6hrs of energy production), Round-trip efficiency of 75%, Cap. cost for entire system with Eos battery \$1.7/watt, O&M costs: \$20,000/year for a 2MW/12MWh operating costs, Facility Life 30 years.



# Eos Levelized Cost of Peak Energy vs Leaders

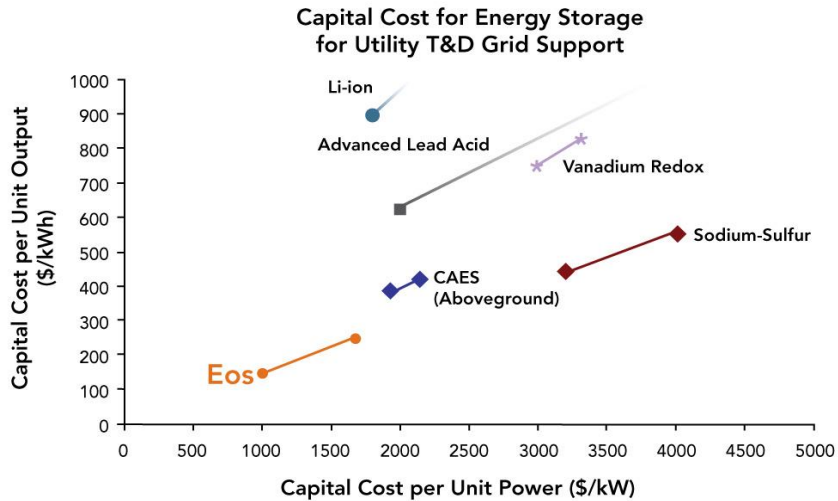
- = Good
- ◐ = Medium
- = Poor

	Eos	Pumped Hydro	CAES-Below Ground	CAES-Above Ground	Sodium Sulfur	Lead Acid	Advanced Lead Acid	Lithium Ion	Zinc Bromine	Vanadium Redox
Low capital cost/kWh	●	●	●	○	○	○	◐	○	◐	○
Large volume of energy storage capacity	●	●	●	●	●	○	○	○	●	●
Long life (high # of life-cycles)	●	●	●	●	◐	○	◐	◐	◐	◐
Quick response time (milliseconds)	●	○	○	○	●	●	●	●	◐	◐
Safe (non-toxic, non combustible)	●	●	●	◐	○	○	○	○	○	○
Flexible to locate (in cities)	●	○	○	○	○	◐	◐	◐	◐	◐
Low O&M costs	●	●	●	◐	◐	◐	◐	◐	◐	◐
In commercial production	○	●	●	◐	●	●	◐	◐	○	○

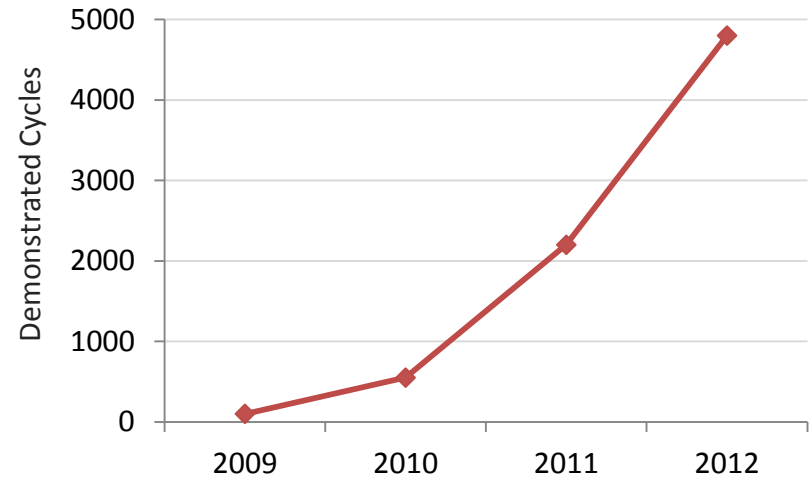


# Eos Competitive Advantages

## Low Cost



## Long life



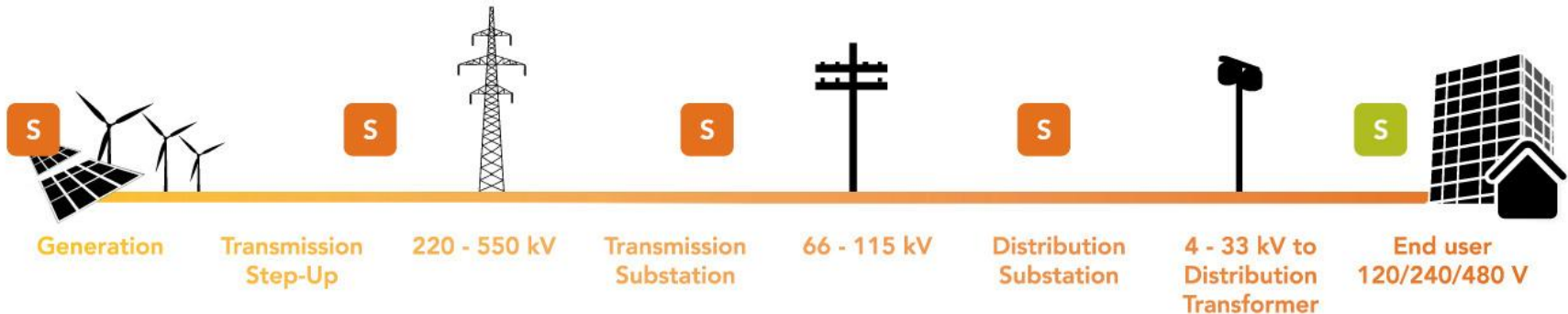
## Energy dense



## Safe



# Value Proposition: Grid and Load Centers



## Grid/Utility Benefits

- Electricity peak shifting (arbitrage)
- Supply of flexible, distributable capacity
- Ancillary services
  - \* Load following
  - \* Frequency regulation
  - \* Voltage support
- Transmission congestion relief / upgrade deferral
- Renewable energy integration support via supply firming and time shift

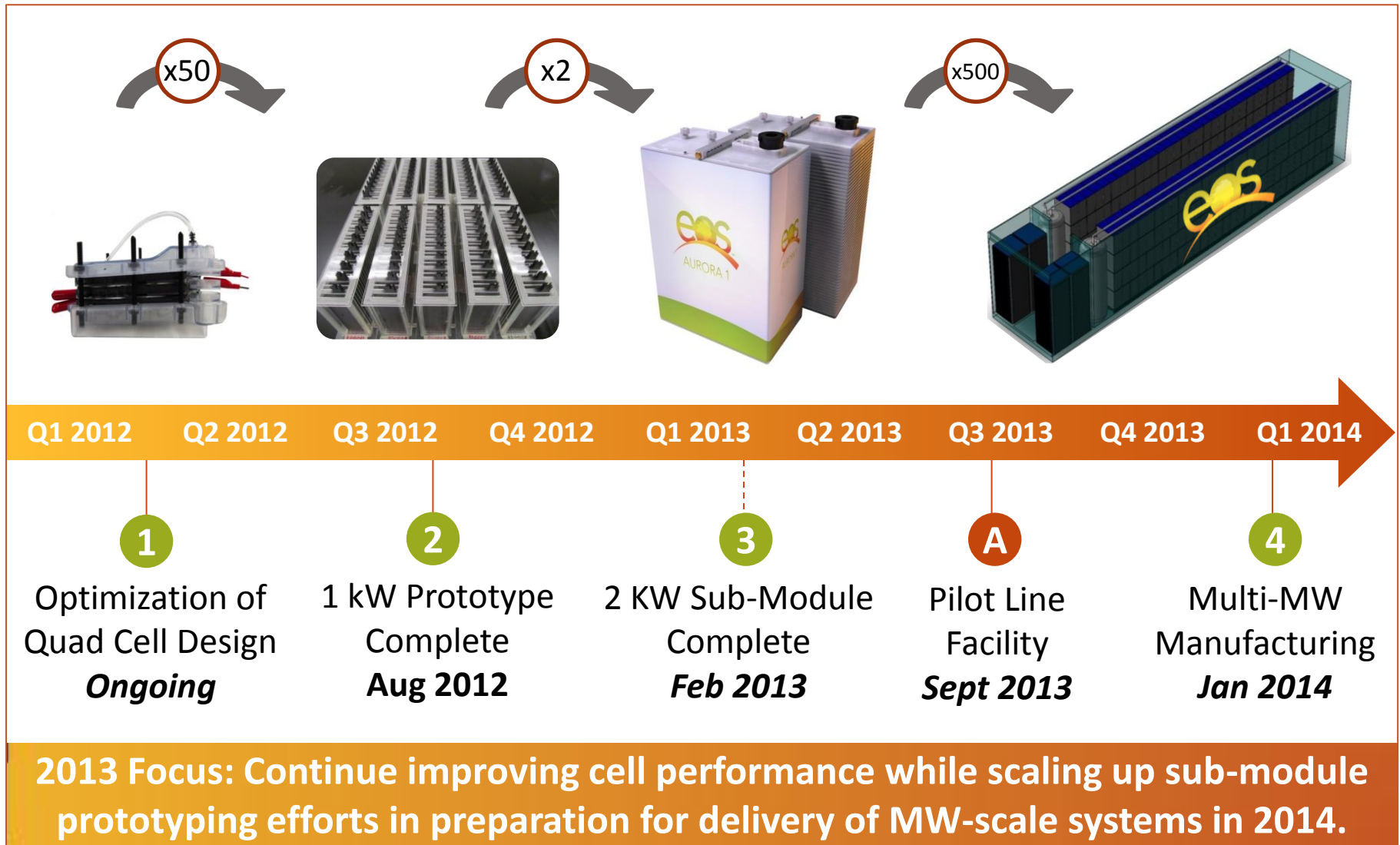
## End User Benefits

- Time of Use (TOU) Energy management (arbitrage)
- Demand charge reduction
- Electricity supply reliability improvement (backup)
- Electricity supply quality improvement

**Eos provides overlapping revenue streams**



# Eos Aurora Milestones



# Grid-Scale Market Entry Strategy

**eos** GENESIS

## Early Adopter Program



## Asset Development Co.

Development partnership with 5 major utilities and end-users	<b>WHAT?</b>	Fully integrated asset developer with evaluation, EPC, financing & operations
Large utilities and end users with strong R&D, interest in early market entry	<b>WHO?</b>	Utilities or end-users that want benefits of storage without risk or investment
2014 pilots followed by full deployment	<b>WHEN?</b>	Immediate with 1 <sup>st</sup> deployments using existing battery technology in 2012
Product customization, preferred pricing, priority access, after-market support	<b>WHY?</b>	Provides value while mitigating tech, construction, and operating risk
Match product to high value applications	<b>HOW?</b>	“Pay-for-performance” service



# Electric Vehicle Challenges

- Today's EV battery costs \$500/kWh
- Goal of \$250/kWh

**Cost?**

**Range?**

- 40-190 mile range today
- Goal of 350 miles

- 7 hrs to charge 24 kWh  
Nissan Leaf

**Fueling  
Time?**

**Safety?**

- Li-ion instability can result in catastrophic incidents



# Mobile Energy Storage Solutions

## Potential EV Configurations:

1

**EV with Eos Zinc-Air  
Range Extender**



- 350 km driving range
- Same cost as ICE vehicle
- \$0.02/mile fuel cost

2

**EV with Eos Zinc-Air  
Battery/Fuel Cell**



- Refuelable in addition to rechargeable
- Lower cost per kWh

*"These are magical distances. To buy a car that will cost \$20,000 to \$25,000 without a subsidy where you can go 350 miles is our goal."*  
- US Energy Secretary, Steven Chu



# Gasoline Car vs Li-ion EV vs Eos EV

	Toyota Camry	EV with Li-ion (Nissan Leaf)*	EV with Eos Zinc-Air Range Extender	EV with Eos Zinc-Air Battery/ Fuel-Cell
Capital Cost of Car	\$25,000	\$33,000	\$25,000	\$25,000
Propulsion System	Internal Combustion Engine	24 kwh Li-ion battery 80 kw motor	Eos Zinc-Air 'range extender' battery paired with Li-ion	Eos Zinc-Air battery/fuel-cell paired with Li-ion
Range (km)	640	120-160	350	350+
Refueling Time	3 mins	5-7 hrs with 220-240V charger	6 hours	3 mins
Cost of fuel/mile at \$4/gal gas	.20	.03	.02	.02
HP (peak)	179 hp	107 hp	175 hp	175 hp



\* <http://www.nissanusa.com/ev/media/pdf/specs/FeaturesAndSpecs.pdf>



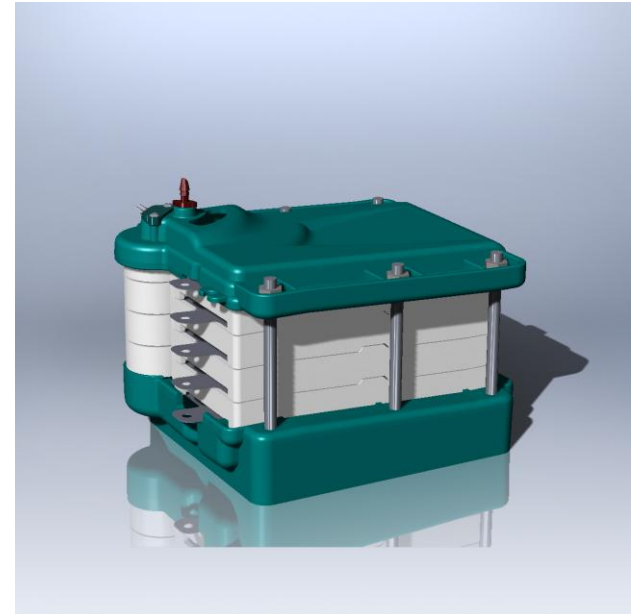
# Eos EV Strategy

Partner with EV industry players	
<b>Goal:</b>	<ul style="list-style-type: none"><li>• Work with existing EV players to jointly develop technology</li></ul>
<b>Eos Offering:</b>	<ul style="list-style-type: none"><li>• IP for two battery configurations that can enable &gt;350 km driving range at \$10,000/70kwh<ol style="list-style-type: none"><li>1. Eos zinc-air range extender</li><li>2. Eos refuelable zinc-air battery/fuel-cell</li></ol></li></ul>
<b>Potential Partners:</b>	<ul style="list-style-type: none"><li>• Battery companies, Tier 1 suppliers, OEMs</li></ul>
<b>Time-frame</b>	<ul style="list-style-type: none"><li>• With right partner, EV battery could be available for prototyping within 24 months</li></ul>



# Eos White Goods Strategy

Development/Manufacturing Partnership	
<b>Goal:</b>	Address market for smaller scale white goods product (1-100 kW)
<b>Applications:</b>	<ul style="list-style-type: none"><li>• Energy management</li><li>• Back-up power</li><li>• Uninterruptible power supply (UPS)</li><li>• On-site renewable integration</li></ul>
<b>Customer:</b>	Commercial, industrial, residential
<b>Time-frame:</b>	24 months



Eos is looking for a strategic retail and manufacturing partner to lead white goods product development



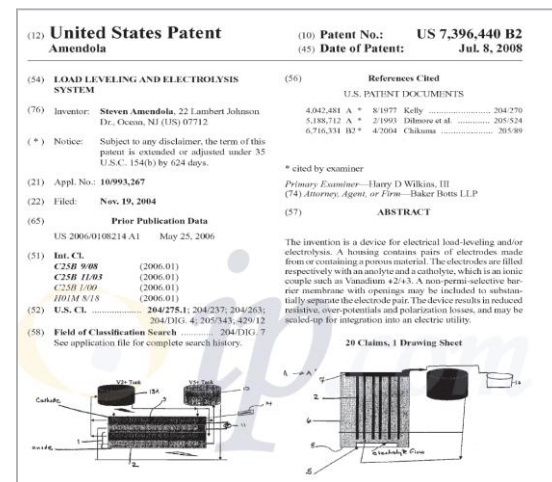
# White Goods Product Characterization

- ✓ **Modular Size** – 1-5 kW or 50 kW building blocks
- ✓ **User Friendly** – easy to install, low maintenance
- ✓ **Inherently Safe** – non-toxic, non-combustible
- ✓ **Compact** – minimal space requirements
- ✓ **Long Duration** – 6 hrs or more of storage
- ✓ **Low-cost** – \$1,000/kW or \$160/kWh
- ✓ **Long Lasting** – 30 year expected lifetime



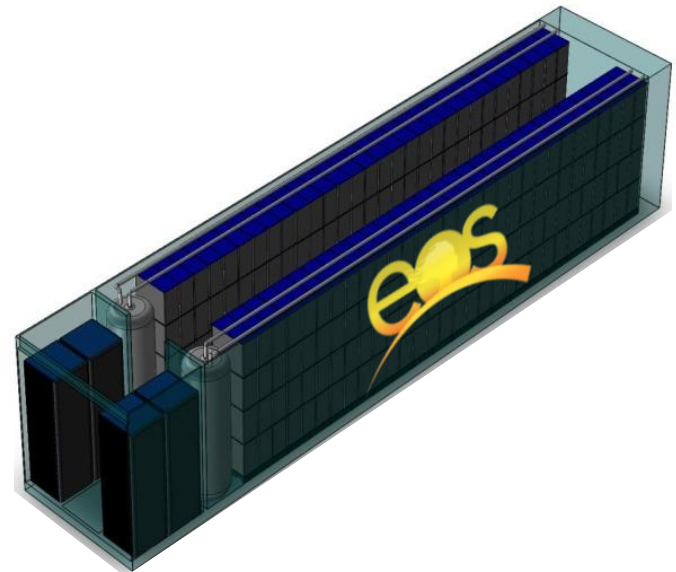
# Eos IP Protection

- Eos has obtained and applied for multi-layer patent protection on key intellectual property
  - ✦ Cell configuration and architecture
  - ✦ Cathode design, materials and catalysts
  - ✦ Electrolyte and additives
  - ✦ System configuration and electrolyte system
- Seven major patents registered and pending in the US and abroad with ~400 separate claims



# Summary

- The Eos Aurora will be a safe, reliable, non-toxic, non-combustible, low-cost zinc-air energy storage system for the electric grid that can be sold for **\$160/kWh**, rechargeable over 10,000 cycles (30 years)
- Superior value proposition to incumbent technology: e.g., gas-fired turbines
- Scaling up battery prototypes in 2013 in preparation for manufacturing and delivery of MW scale systems 2014
- Establishing partnerships for market entry
- Collaboration opportunities for EV and white goods product





[www.eosenergystorage.com](http://www.eosenergystorage.com)



# Corporate Background

- Offices in Edison, NJ and NY, NY
- Incorporated in DE (2008)
- Key invention in 2004
- Employees: >28

## Management Team

### **Michael Oster, CEO, Co-Founder, Eos Investor**

- >20 years experience as an entrepreneur in renewable energy, real estate, and emerging markets
- enXco, Aspect Enterprise Solutions, ATT Pension Fund, AT Kearney, IBM

### **Steve Hellman, President, Eos Investor**

- Founded and built 14 successful companies in energy, shipping, real estate and media
- Energy Advisor to US State Department

### **George Adamson, VP Research and Development**

- >17years experience moving 5 products into manufacturing
- Developed zinc-air and lithium batteries for Zpower, Vitric, Valence, Zinc Air
- Holds 9 patents

### **Steve Amendola, CTO, Inventor, Co-founder**

- Inventor of Eos' patented technology in 2004
- Founder and CTO of RSI (solar grade silicon) and Millennium Cell (sodium borohydride fuel cell)
- >20 US patents in batteries, energy storage, new fuels, turbines, diesel, hydrogen production, silicon manufacture, electrochemistry

### **Phil Black, VP of Engineering, Eos Investor**

- 20 years experience in industrial design, product engineering and manufacturing;
- 2 patents issued
- Six Sigma Manufacturing Green Belt
- PA State Industrial Design Advisory Panel



# Expert Opinions of Eos

*"(Eos') novel non-flow design offers elegant approach to management of prior zinc-air issues."*

- Electric Power  
Research Institute

*"Metal-air batteries contain high energy metals and literally breathe oxygen from the air, giving them the ability to store extreme amounts of energy."*

- US Energy Secretary, Steven Chu

*"I think that EOS is one of the most exciting and promising early-stage ventures in the space,"*

- Steven Minnihan, Lux Research

*"Zinc Air batteries have the highest specific energy and lowest cost of an electric vehicle rechargeable battery technology..."*

- Meridian International Research

*"Metal air batteries... have the potential to be lower-power, long-duration energy storage devices..."*

- SCE, 2011\*

*"Eos has developed a number of improvements for the conventional zinc-air battery to become a viable secondary battery."*

- KEMA Energy Consultants





## The New York Times

*"(Eos') zinc-air batteries will be able to store energy for half the cost of additional generation from natural gas — the method currently used to meet peak power demands.."*



### About Eos Energy Storage



*"(Eos is) developing a zinc-air flow battery for use in electric vehicles, which ... will extend EV range to over 500 kilometres and can be recharged for less than 2 cents per kilometre."*



*"With the right pricing and performance, zinc air batteries may compete not only against other energy storage systems but also grid technologies such as gas turbine plants. The company has an impressive list of product benefits, and investors have been responsive."*

### technology review

Published by MIT

*"Unlike conventional batteries, in which all reactants are packaged within the battery, zinc-air cells draw in oxygen from the air to generate current. Drawing on outside air gives the batteries a higher capacity-to-volume ratio and lowers the material costs. The battery's water-based chemistry also means it isn't prone to catching fire, unlike lithium-ion batteries."*

### Watt Now

*"...zinc-air batteries demonstrate tremendous promise because they have a high energy storage capacity and are relatively inexpensive to produce."*



*"...energy storage giant of the not-too-distant future."*



*"Eos Energy is on a mission to develop a low-cost, high-energy rechargeable zinc-air battery for utility and transportation applications."*



*"...the zinc air batteries being developed by Eos Energy Storage stand apart"*

### greentechgrid

*"...besides being cheap, zinc also packs a wallop of power."*

### Torque News

*"The proposed zinc-air battery tech of EOS Energy Storage would have a much longer range than lithium-ion within the same battery volume..."*