Grid-Scale Energy Storage:
The 'State of Play' in a Game-Changing Sector

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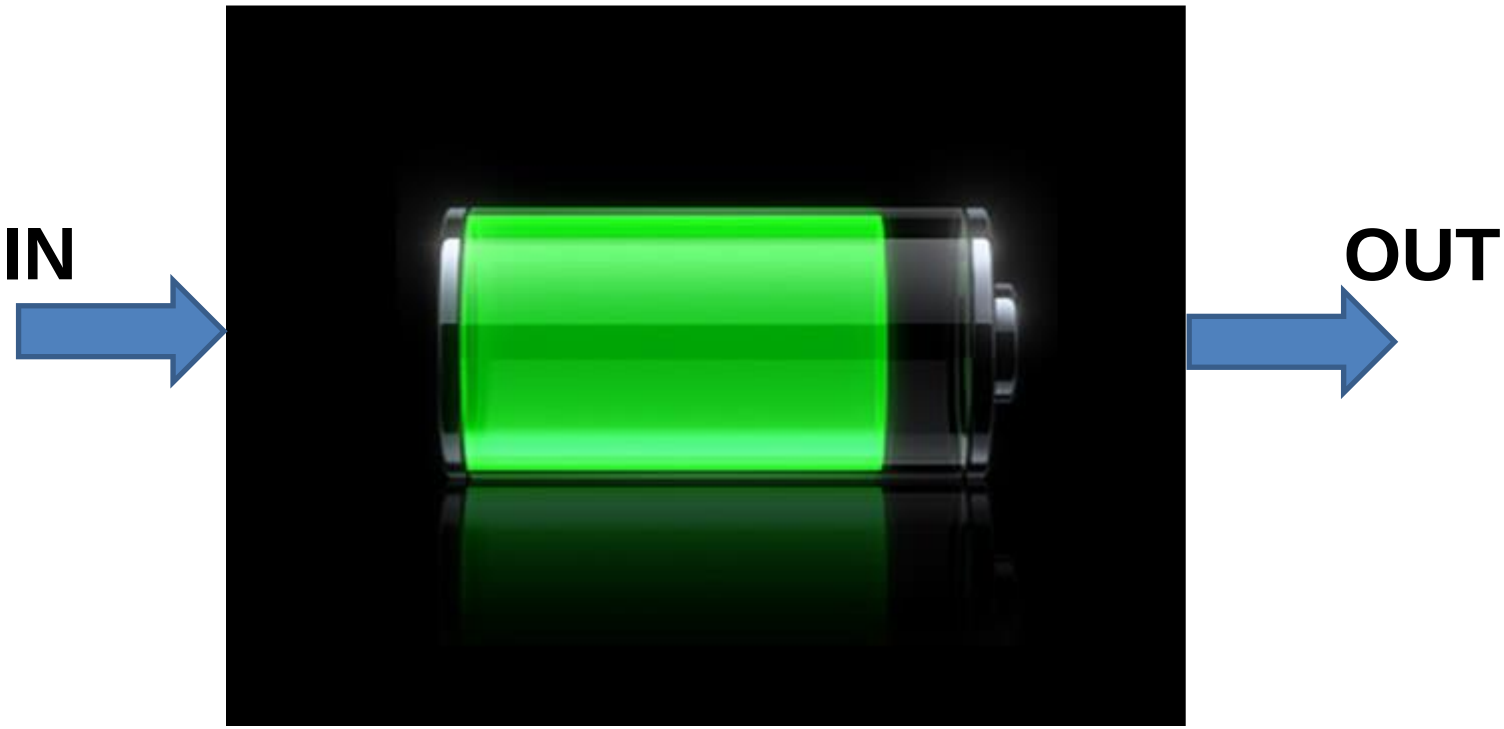
Energy Storage



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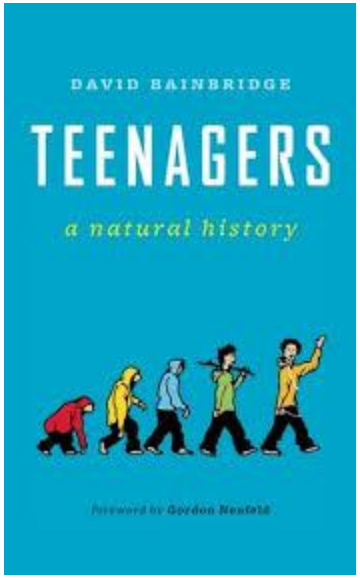
Pearl Street & Energy Storage

- Energy Storage quickly became a focus on Pearl Street's consulting practice when it began in 2001
- Executive Director – Energy Storage Council 2001-2005
- Executive Director – Coalition to Advance Renewable Energy through Bulk Storage (CAREBS) 2008-2012
- Co-organizer or conference program chair for several energy storage conferences
- More than a dozen presentations at industry events covering grid impacts, technologies, legislative activities
- Advisor of record for $5-million capital raise for ultra-cap storage firm, IOXUS Inc
- Numerous clients engagements focused on technology evaluations, business positioning, economic drivers, and engineering/system assessments for clients ranging from venture-level firms to Fortune 500 firms
- Recently completed an engagement with FC Intelligence for the industry report, *Energy Storage Cost & Performance Report: Analysis of Life Cycle Costs of Energy Storage Technologies*

Everybody's talking…but why?

Technologies maturing…



Shortened response times…

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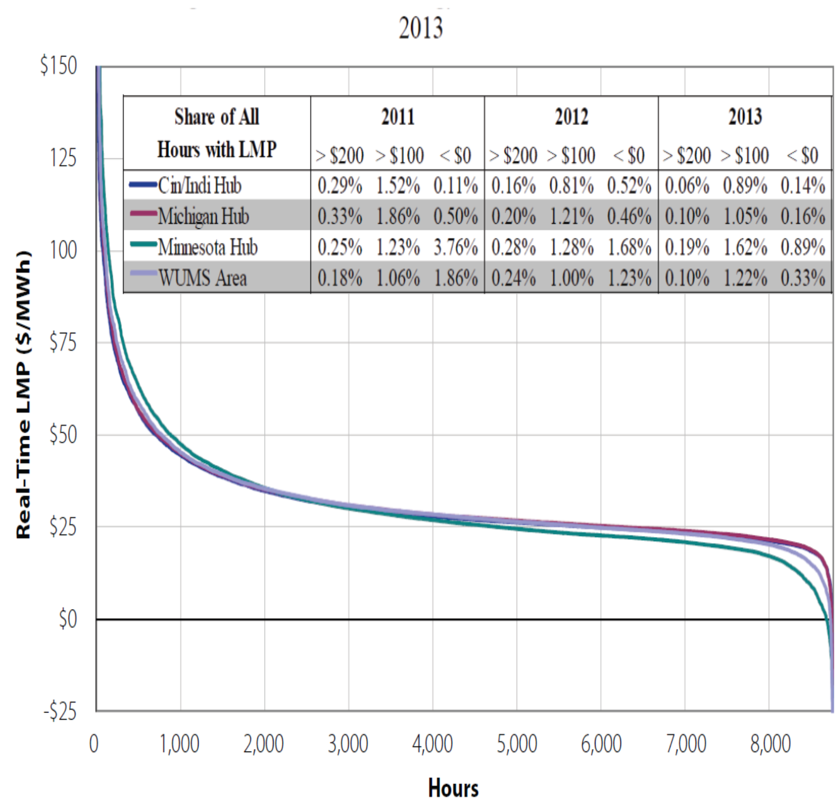
Everybody's talking…but why?

Grid stability issues…

Evolving market price signals…



Share of All Hours with LMP	2011			2012			2013		
	> $200	> $100	< $0	> $200	> $100	< $0	> $200	> $100	< $0
Cin/Indi Hub	0.29%	1.52%	0.11%	0.16%	0.81%	0.52%	0.06%	0.89%	0.14%
Michigan Hub	0.33%	1.86%	0.50%	0.20%	1.21%	0.46%	0.10%	1.05%	0.16%
Minnesota Hub	0.25%	1.23%	3.76%	0.28%	1.28%	1.68%	0.19%	1.62%	0.89%
WUMS Area	0.18%	1.06%	1.86%	0.24%	1.00%	1.23%	0.10%	1.22%	0.33%

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The core value propositions…

- The latest energy storage technologies offer **response times faster than traditional means** of responding to grid disturbances – from near-instantaneous to better than cycling fossil plants or deploying peaking gas turbines

FASTER **BETTER** **CHEAPER?**

The core value propositions…

- Storing large quantities of electricity for periods lasting a few minutes to seasonally changes the grid from a **"just in time" inventory operation to something similar to every other energy commodity** (e.g., oil, natural gas, coal, etc)

FASTER **BETTER** **CHEAPER?**

The core value propositions…

- Energy storage allows the electricity industry to become **more transactional in real time** with less risk of reliability impacts

FASTER **BETTER** **CHEAPER?**

Recent Headlines, Comments…

- We are "waiting on the flood of storage opportunities" – *Texas utility executive*
- "Energy Storage: Poised for Growth" – *Power Engineering*
- "How battery storage costs could plunge below $100/kWh" – *Reneweconomy.com*
- "Battery storage payback takes only a few years in PJM, S&C Finds"

Recent Headlines, Comments…

- "Tesla is going to build its huge battery factory in Nevada [$5-billion]" – *Time.com*
- "From Ashes to Energy: $1-billion Alevo battery factory surges on the scene" – *Renewable Energy World*
- "The world's biggest battery is being built for southern California's grid [100 MW, 400 MWh]" – *Greentechmedia.com*

Is It Time To Drink the Kool-aid?

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Some Reality Checks…

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…From a commercial viewpoint

Q. When is a new technology or system ready for widespread deployment in the electricity industry?

A. When the PUC approves cost recovery
B. When regulators mandate an outcome for which the system or technology can potentially meet
C. When costs are in line with competing options
D. When the system has little to no impact on grid reliability
E. When there are several such systems in operation at scale performing as intended or expected (No one wants to be first)
F. When there are three deep pocket suppliers who will compete for the owner/operator or developer's RFQ under familiar warranty and performance guarantees
G. All of the above

Keeping this in mind…

- There are few fully "utility-grade" commercial options available today
- Most of the commercial opportunity is in California (but it is a huge potential market!) but it is a legislated opportunity
- The current excitement is around Li-ion technology
- More traditional means of providing the same functions as storage exist and may be "good enough" for now

Keeping this in mind…

- It is exceedingly difficult to monetize the value of storage
- The regulatory frameworks outside California are still evolving
- There is little convergence regarding where in the grid (transmission, distribution, behind the meter, etc.) storage provides the best value

The basic options…

- Pumped hydroelectric storage (PHS)
- Compressed Air Energy storage (CAES)
- Lead Acid Batteries
- Thermal Energy Storage
- Lithium Ion Batteries (Li-ion)
- Sodium-sulfur batteries (Na-S)
- Flywheels
- Flow Batteries

California is, uh, different…

- But it's also the ninth largest economy on the planet!

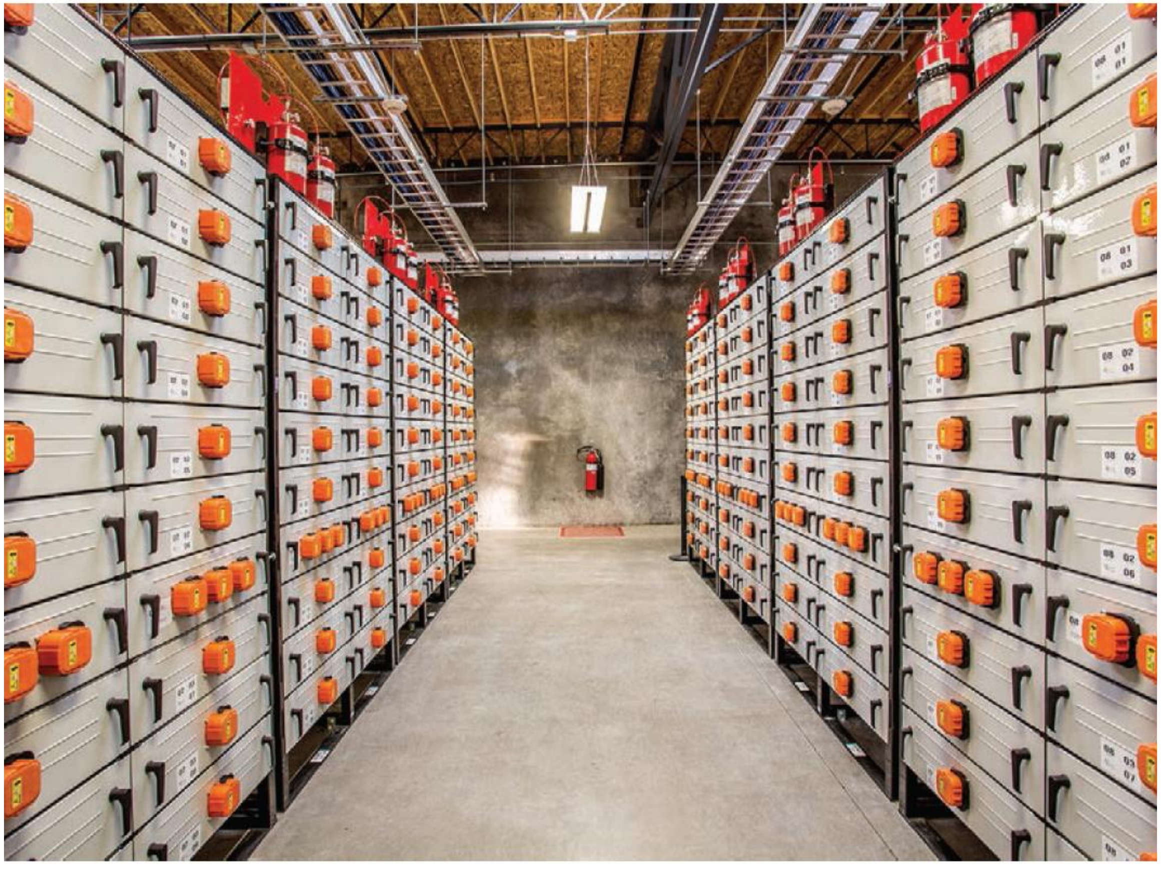
The *legislated* California Clean Energy Economy…

- **California Clean Energy Strategy**
  - Supply destruction creates capacity replacement
  - 12,000 MW of distributed generation
  - 8000 MW of large scale renewable energy
  - 33% RPS by 2020 (75% in-state bundled flows)
  - AB2514, the storage "mandate" (but really "targets") for up to 1500 MW, utility inertia

The *legislated* California Clean Energy Economy…

- **California Clean Energy Strategy**
  - State carbon cap and trade
  - San Onofre (nuclear) retirement
  - AB 1318 (thermal discharges), AB32 (GW Solutions Act), etc., force 15,000 of fossil out
  - Electric vehicle programs
  - Transmission bottlenecks

DO THE MATH! Policy-driven paradigm shift



Where the real excitement lies

5-MW Li-ion Battery Facility at Portland General Electric's Salem Smart Power Center

The new kid on the block…Li-ion

- Battery systems up to 100 MW/400 MWh being installed and evaluated
- Numerous deep-pocket suppliers and ambitious project developers
- Substantial manufacturing capacity being added in the USA
- Significant cost reduction curve playing out
- Progressive operating experience with larger and larger systems
- Appears to be applicable throughout the electric supply and delivery chain – sub 1 MW to 100+MW
- Suppliers willing to mitigate technical risk for customers through warranties, service contracts, partnership, etc.

OVER 70% OF RECENT DEPLOYMENTS ARE LI-ION

Traditional options…

Traditional	$/kW	Typical applications
New peaking GT (small peakers are high $/kW)	$800-$1,400	Capacity, non-spinning reserve, spinning reserve, black start (with appropriate starter package)
Peaking GT with clutch added	$30-$50 (adder for the clutch only)	Load following, reactive power, voltage support, frequency regulation (a clutch allows a GT to add power to the grid and take power, or serve as "load", also called a synchronous condenser)
Conversion of fossil power unit to synchronous condenser	$25-$50	Reactive power, load shedding, area regulation, voltage support
Control system modifications to achieve fast-start GT	<$5	Non-spinning reserve, spinning reserve, area regulation, voltage support
TurboPhase addition to GT	$350-$400	Capacity, frequency regulation, spinning reserve, non-spinning reserve, voltage support
Cycling existing (usually smaller) fossil units	Cannot be expressed as $/kW, but cost penalty for "aggressive" cycling exists	Capacity, load following, renewable firming (fossil units on-line can typically 'cycle' from 10-100% of load and can put capacity on or take capacity off the grid at rates of $10-$25 MW/min
Reciprocating engine/gen sets	$1,000-$1,500	Load following, capacity, frequency regulation, area regulation, wind firming
Static compensators and dynamic volt-ampere reactive (VAR) compensations	$1,000/MVAR (similar to a MW in context of cost)	Transmission and substation-level solutions for proving reactive power capabilities

Monetizing the value…

Driving forces

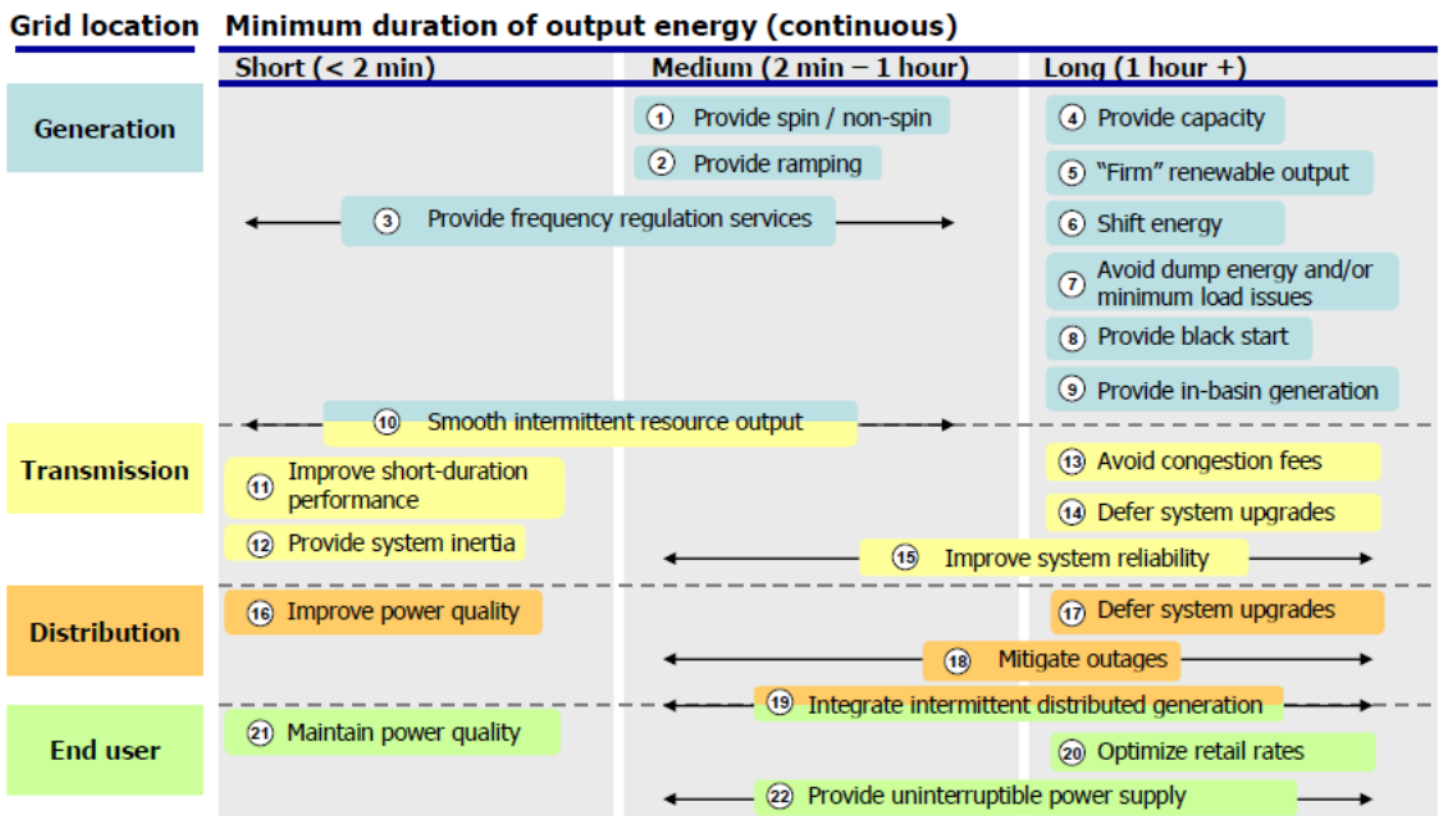
- Ancillary services price signals in select organized markets, e.g., PJM, MISO, CAISO – "pay for flexible performance"
- California legislated targets
- High renewable energy penetrations (Hawaii, Iowa)
- Microgrids and resiliency

Risks

- Life cycle costs
- Catastrophic events
- Ancillaries market small (all of PJM = 1 combined cycle)
- Traditional options compete
- Dynamics of electricity pricing – storage has to be charged and discharged
- Sub-hourly production cost modeling inadequate to validate returns

Location, time, volume…

POTENTIAL OPERATIONAL USES FOR STORAGE SYSTEMS



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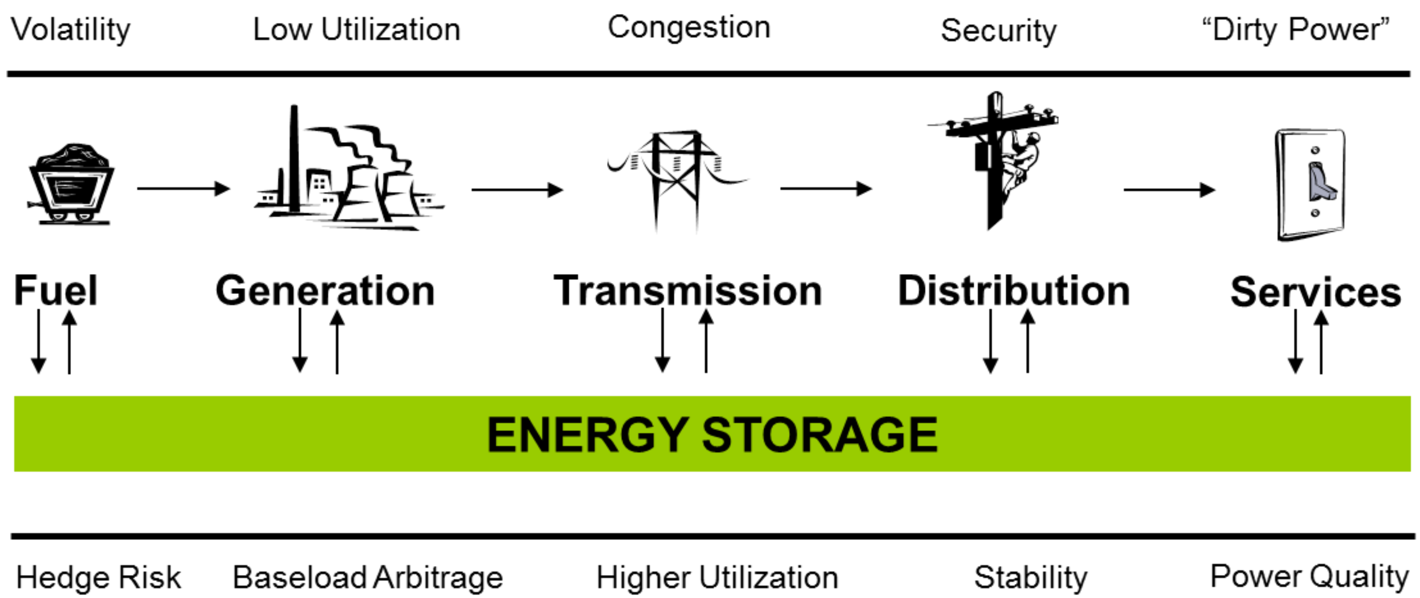
Location, location, time, time… Disaggregated value



The State of Play…

- Energy storage – a new asset class going beyond traditional PHS
- "Mandate" on California IOUs driving the market, but virtually all other CA utilities (municipals, cooperatives) found no economic benefit
- Li-ion – costs falling, progressing beyond the demonstration phase, wide potential applicability
- Monetizing benefits still difficult – RD&D activities addressing

The State of Play…

- Markets beyond California limited by lack of appropriate price signals, regulatory framework, or size
- Deployments too limited to confidently extrapolate life-cycle costs and performance
- Active merchant/IPP approaches shifting risk from utilities
- Functional flexibility of contending systems still in question
- Storage options may be faster, better than traditional options but in most areas, traditional options are still “good enough.”

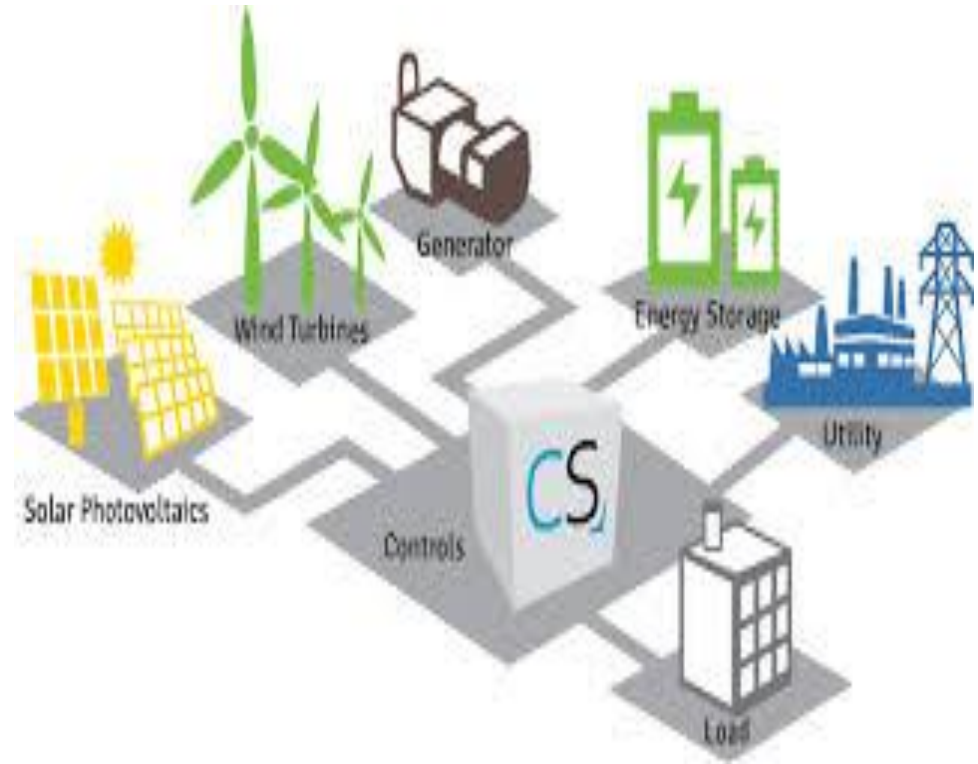
The State of Play…

Maybe not gulp Kool Aid…

But time to sip…

The real threat – behind the meter

Traditional centralized “big iron” yielding to distributed architecture?



Critical challenges remain…

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Issues to ponder…

- The “Tesla” factor – Monetizing your stock value, reminiscent of an “earlier stock bubble”
- Catastrophic events – most scaled up battery technologies have experienced them (but this isn’t unusual – anyone remember boiler explosions early part of last century?)
- Some “proven” storage technologies have been struggling for two and three decades to gain a commercial foothold
- Costs of cycling of traditional units, important to storage economics, are not transparent or well-quantified
- In many ways, storage is a bet in the “electricity casino”

System and technical challenges…

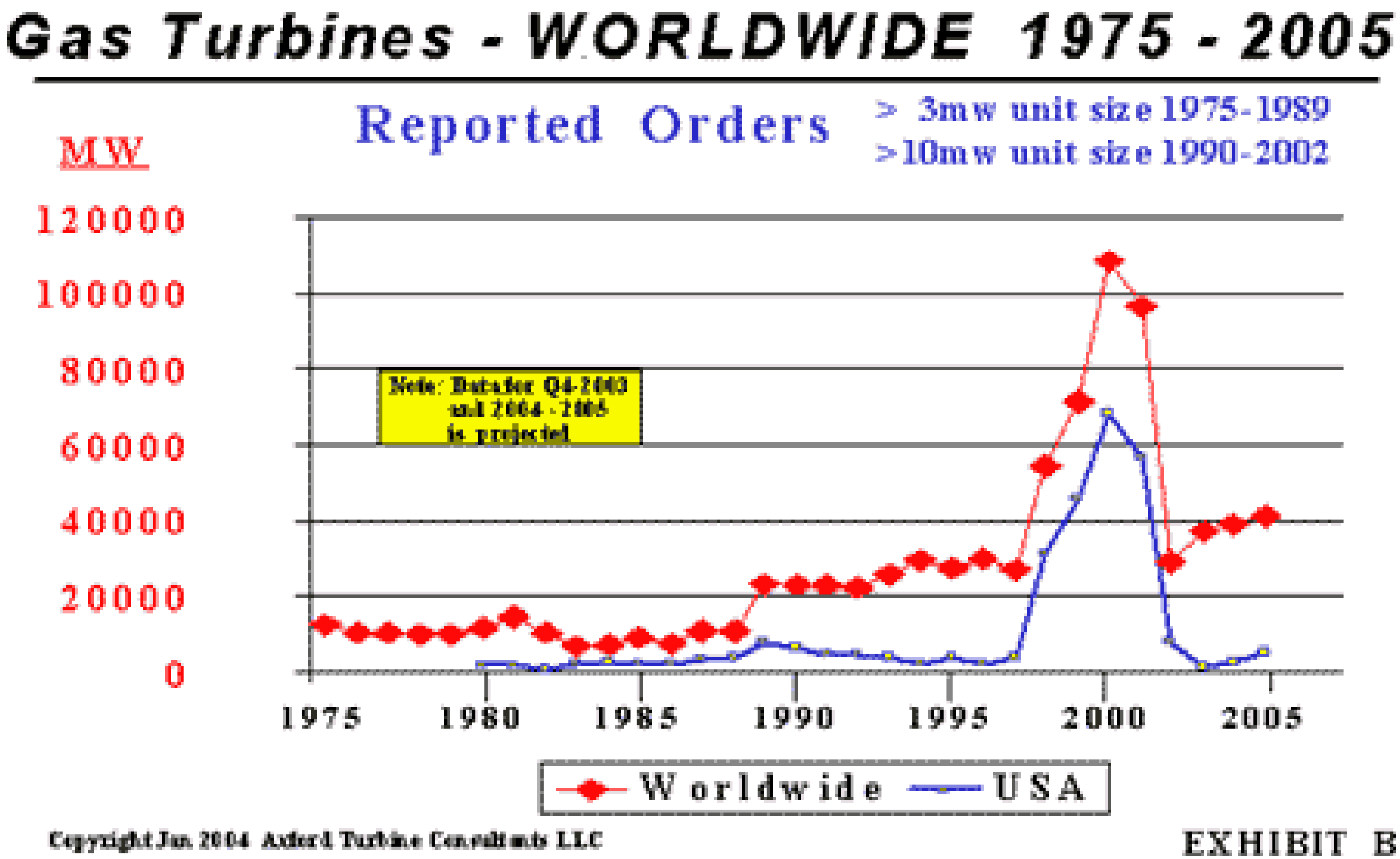
- System integration – subsystems (battery, PCS, BOP, Grid Intertie, Control Systems)
- Codes and standards development lagging
- Fire and thermal runaway events
- Insurability – mitigating early technical risk
- Decommissioning and disposal – Li-ion recycling infrastructure not in place
- Round trip efficiency – not all of the electricity comes back
- Real operating experience difficult to obtain

Multiple forms of storage will come into widespread use over the coming decades

- More bulk storage – PHS, CAES, and/or large scale batteries – regional grid management
- The next few years will determine whether Li-ion will dominate the space
- Distributed storage – distribution substations, microgrids, networks of microgrids serving business parks, neighborhoods, commercial facilities, etc. Distribution-oriented utilities especially interested!
- On-site and behind the meter storage – resiliency, renewables firming

Storage adds a new dimension for grid operations, management, and optimization/balancing of existing generation, transmission, and distribution assets

Remember this trend line?



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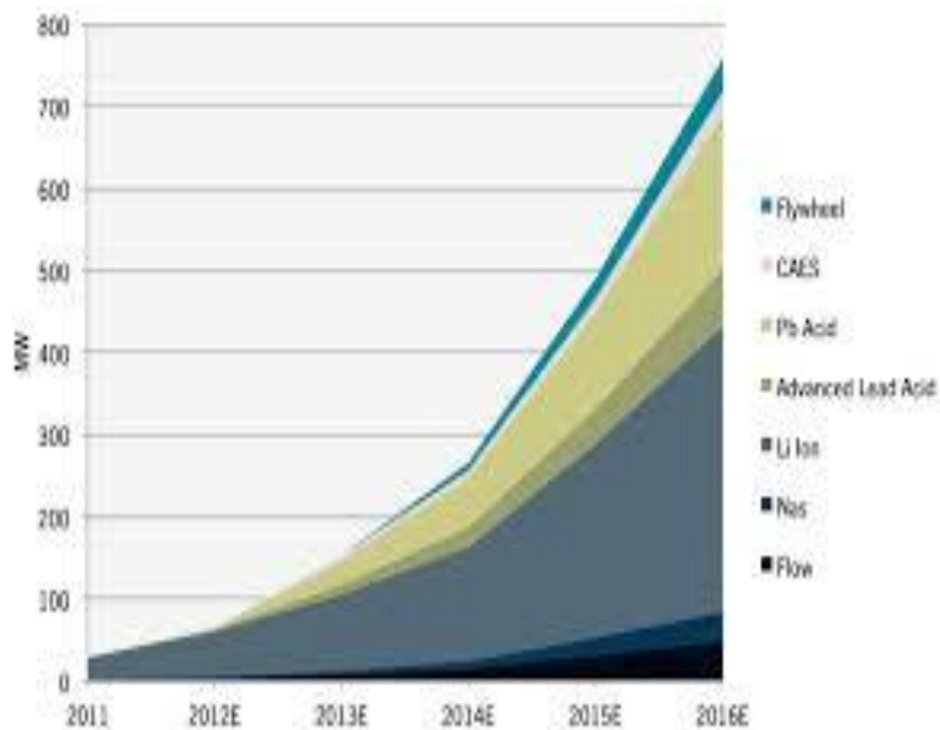
Anyone want to predict the coming grid-scale storage boom/bust?

Sixth Dimension of the electricity supply and delivery chain…!

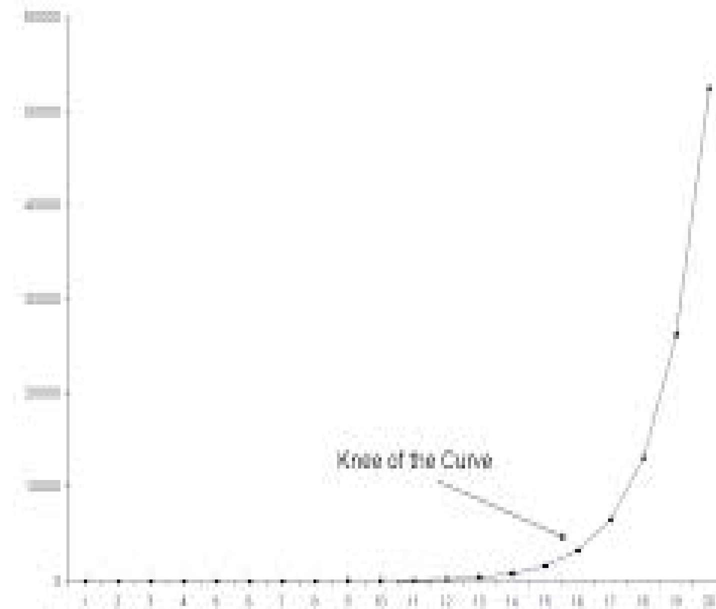
One forecast from 2011…



But…

Li-ion has broken away from the pack…

Over the next few years, we should know if it can become the 'dominant' grid scale storage technology



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Thank you!

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