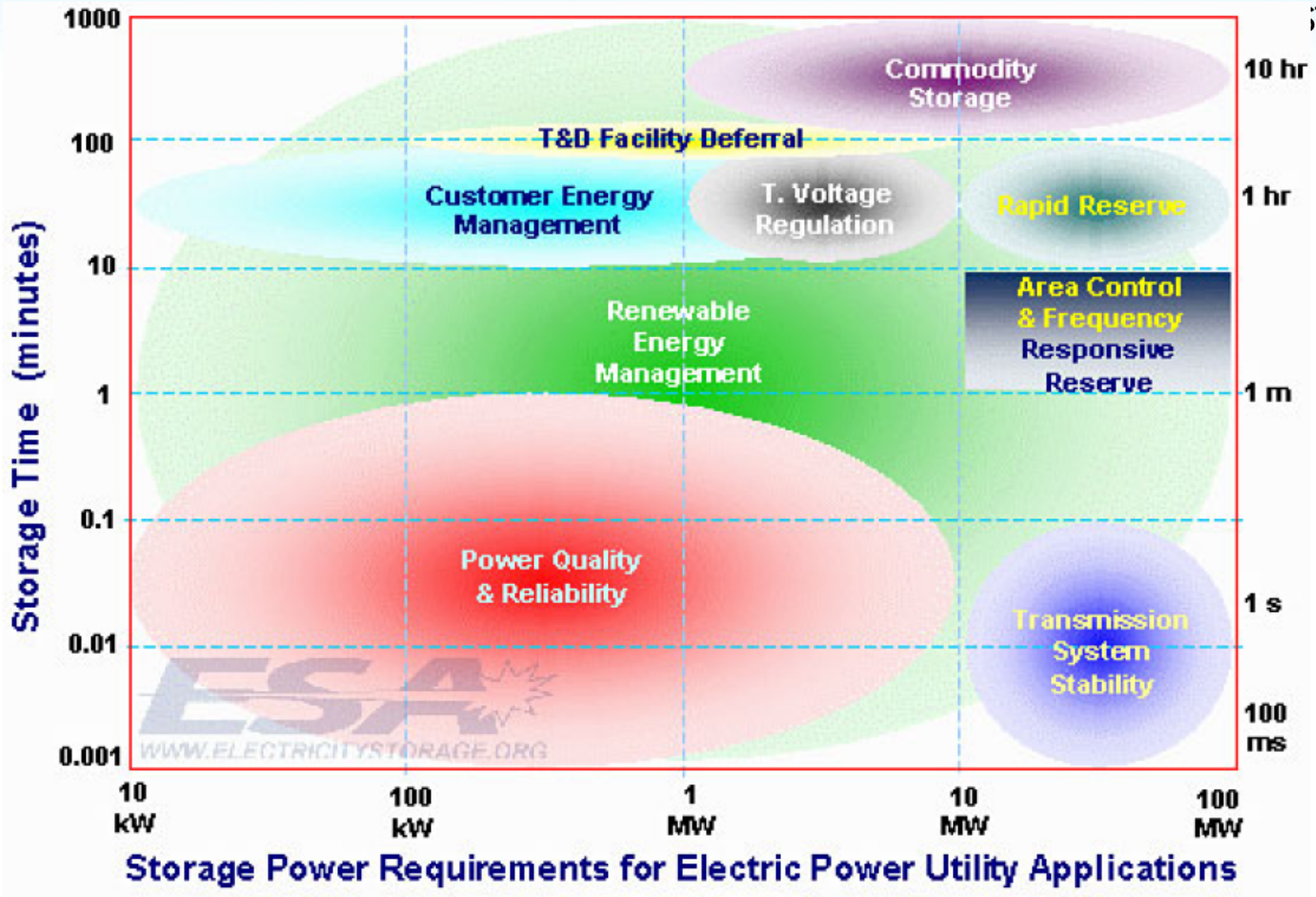
Storage, Storage Interfaces, Frequency Regulation, and Beyond

High MW Electronics – Industry Roadmap Meeting
Challenges to Growth of Grid Connected Electronics

National Institute of Standards & Technology

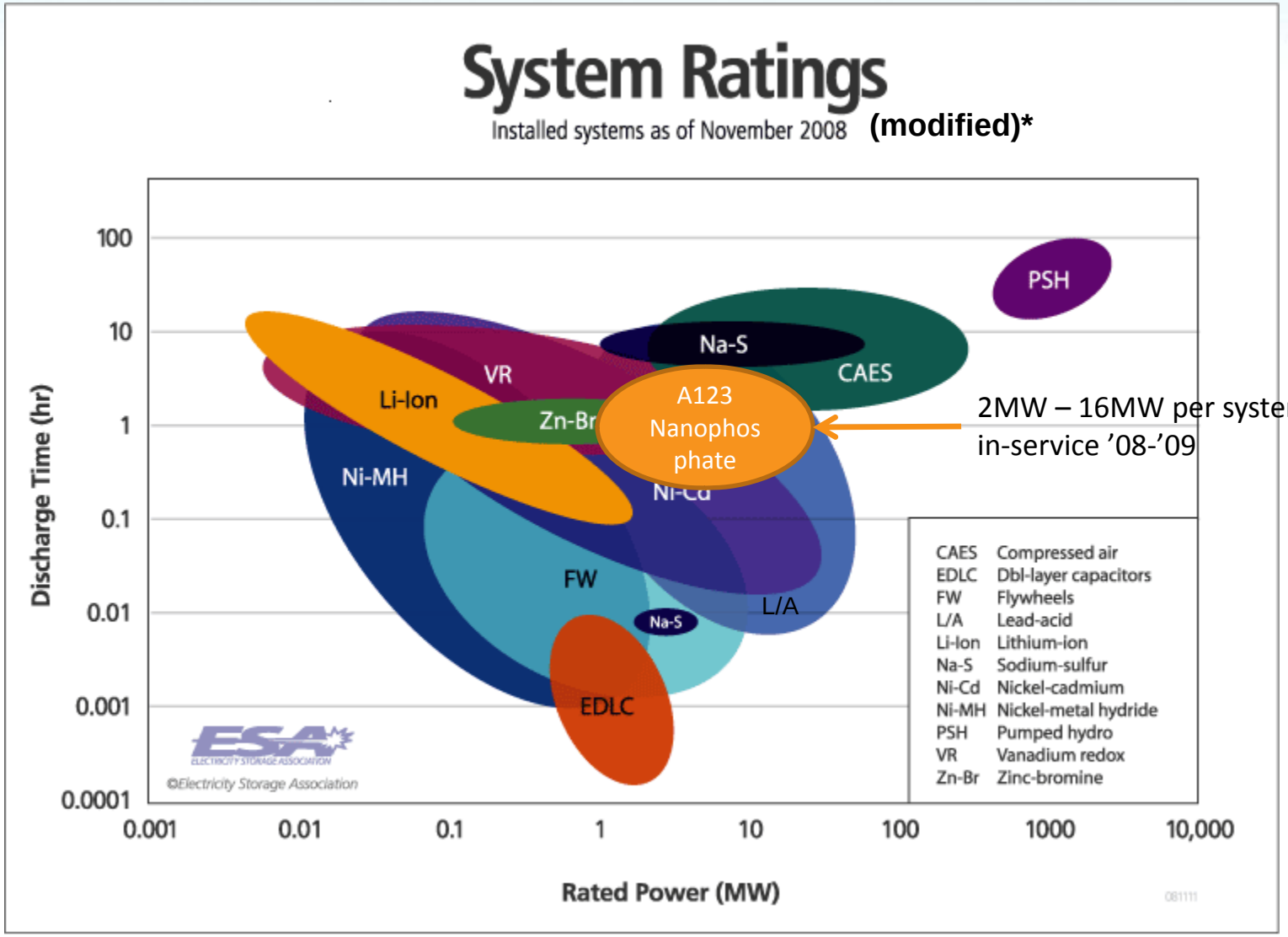
December 11th, 2009

Storage, Grid Applications



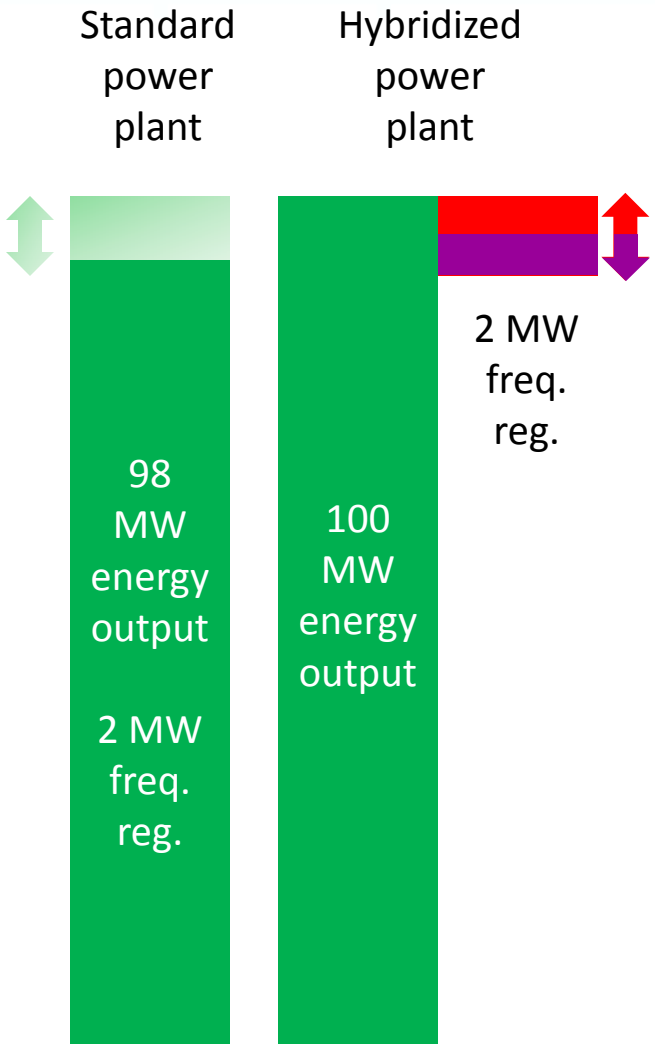
Source: ESA

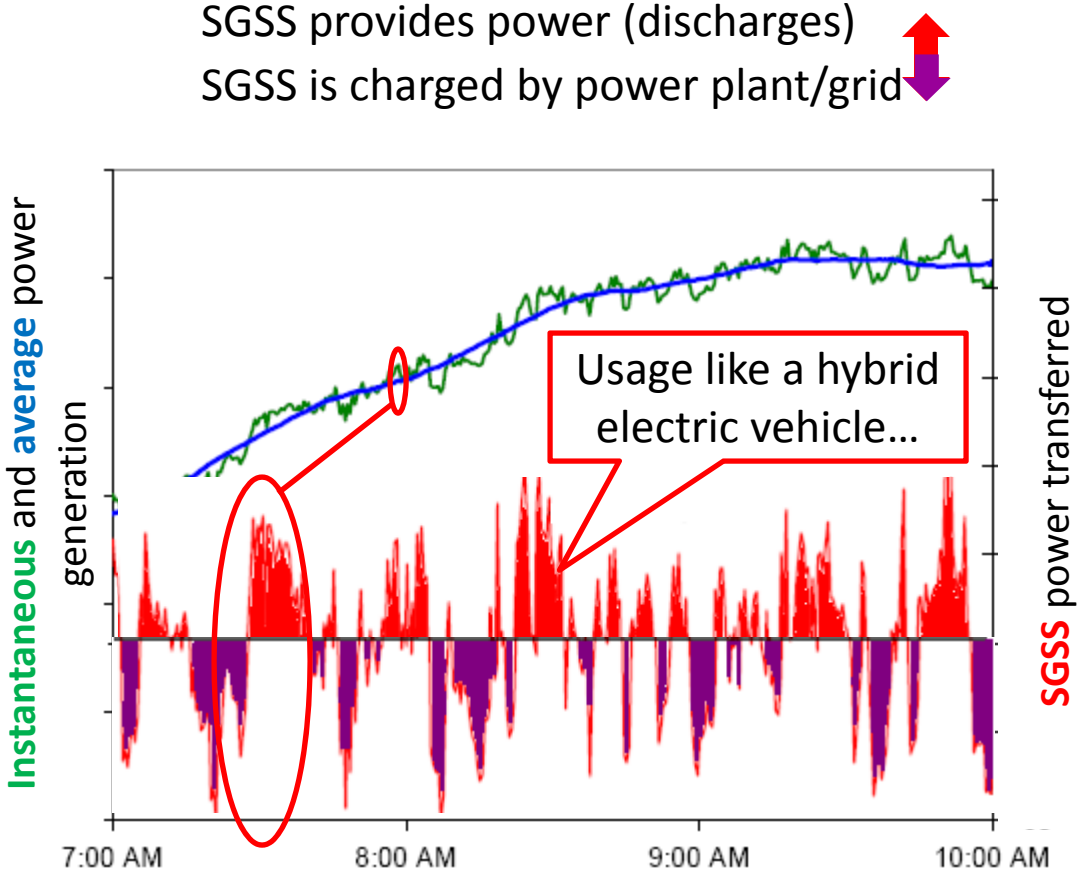
Storage, System Characteristics Comparison



Source: ESA, * **modified** to include A123 in-service and proposed

Frequency Regulation with Storage (SGSS*)





* SGSS is A123's Smart Grid Stabilization System

Frequency Regulation, What's Delivered by PCS? Per CAISO Tariff, Controlled MW Output Level

A 1.2.1.2 the Generating Unit power output response (in MW) to a control signal must meet the minimum performance standards for control and unit response which will be developed and posted by the ISO on its internet "Home Page." As indicated by the Generating Unit power output (in MW), the Generating Unit must respond immediately, without manual Generating Unit operator intervention, to control signals and must sustain its specified ramp rate, within specified Regulation limits, for each minute of control response (MW/minute);

A 1.2.2 **Monitoring:**

the Generating Unit must have a standard ISO direct communication and direct control system to send signals to the ISO EMS to dynamically monitor, at a minimum the following:

A 1.2.2.2 high limit, low limit and rate limit values as selected by the Generating Unit operator; and

A 1.2.2.3 in-service status indication confirming availability of Regulation service.

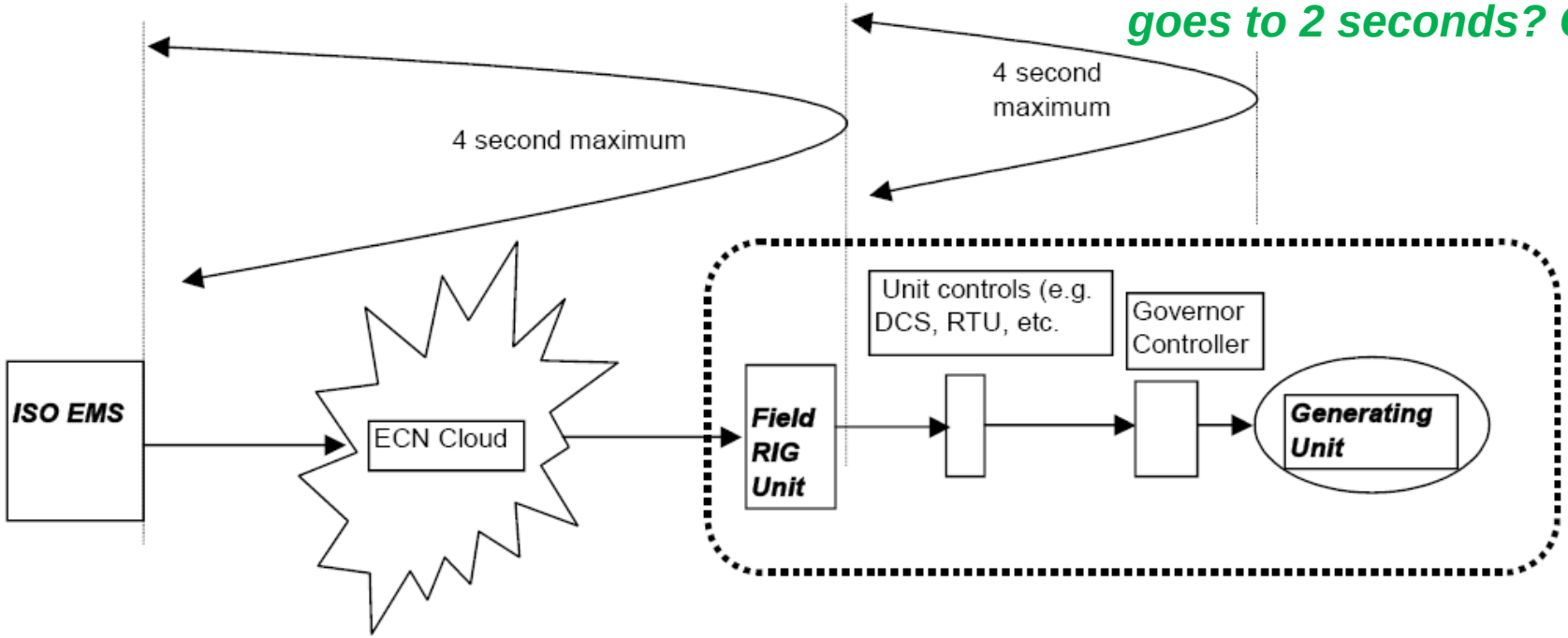
	** Point of Delivery Megavars is not required for AGC Regulation Units. However, it may be required in the future if a voltage market is established.

Delivering the Product, PCS Control and Tempo

California ISO Your Link to Power	Technical Standard	Revision Date Revision No.	2/20/2007 4.6
ISO Generation Monitoring and Control Requirements for AGC/Regulation Units		Print Date	2/26/2007
		Effective Date	11/8/2004

Figure 1 - Timing of Telemetered Data for Generators Providing AGC through the RIG

What happens when tempo goes to 2 seconds? CMU



#1 Driver – Storage F/R Commercially Viable

INDICATIVE COST OF PRODUCTION

42 mills CT Production Cost, 12 mills capacity, 30 mills variable cost

22 mills Battery Production Cost, 12 mills capacity, 10 mills variable cost

MARKET PRICE

10 – 50 mills Frequency Regulation average market clearing price

How can the PCS interface impact the "#1 Driver " for deploying this solution?

Lower cost, increase efficiency, and improve reliability

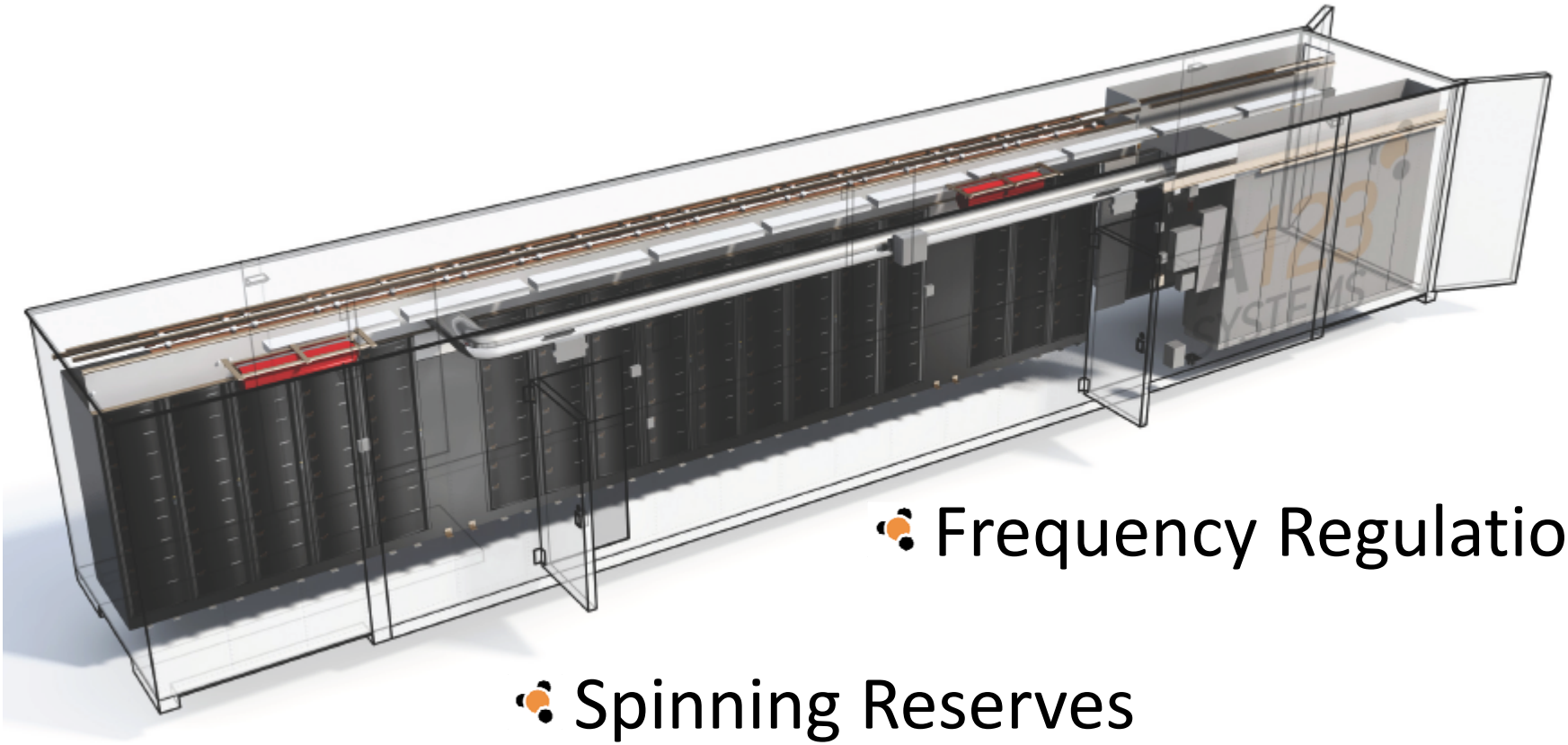
… and also expand compensable capabilities.

But, barrier is not technology, it's lack of investment recovery mechanisms

See Slide 11

Industry research supports additional potential "drivers", including emission reduction, renewable integration, system asset efficiency improvement . Once again, barrier is lack of investment recovery mechanism, not technology gaps.

One Implementation
A123's Smart Grid Stabilization System (SGSS)



- Frequency Regulation
- Spinning Reserves

Grid Deployed SGSS's, Multi-MW Scale

California

Chile

Grid Interface, Parker-Hannifin

AC890PX Power Entry Types

TOP POWER ENTRY/EXIT

BOTTOM POWER ENTRY/EXIT

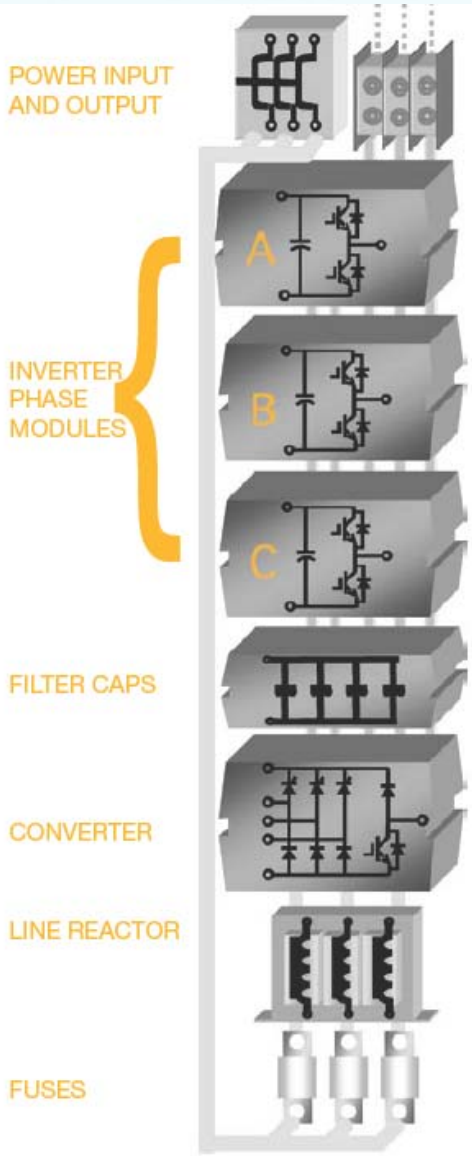
Four Operating Modes

- **Volts/Hertz**
- **Sensorless vector**
- **Full flux vector**
- **Servo (PMAC)**

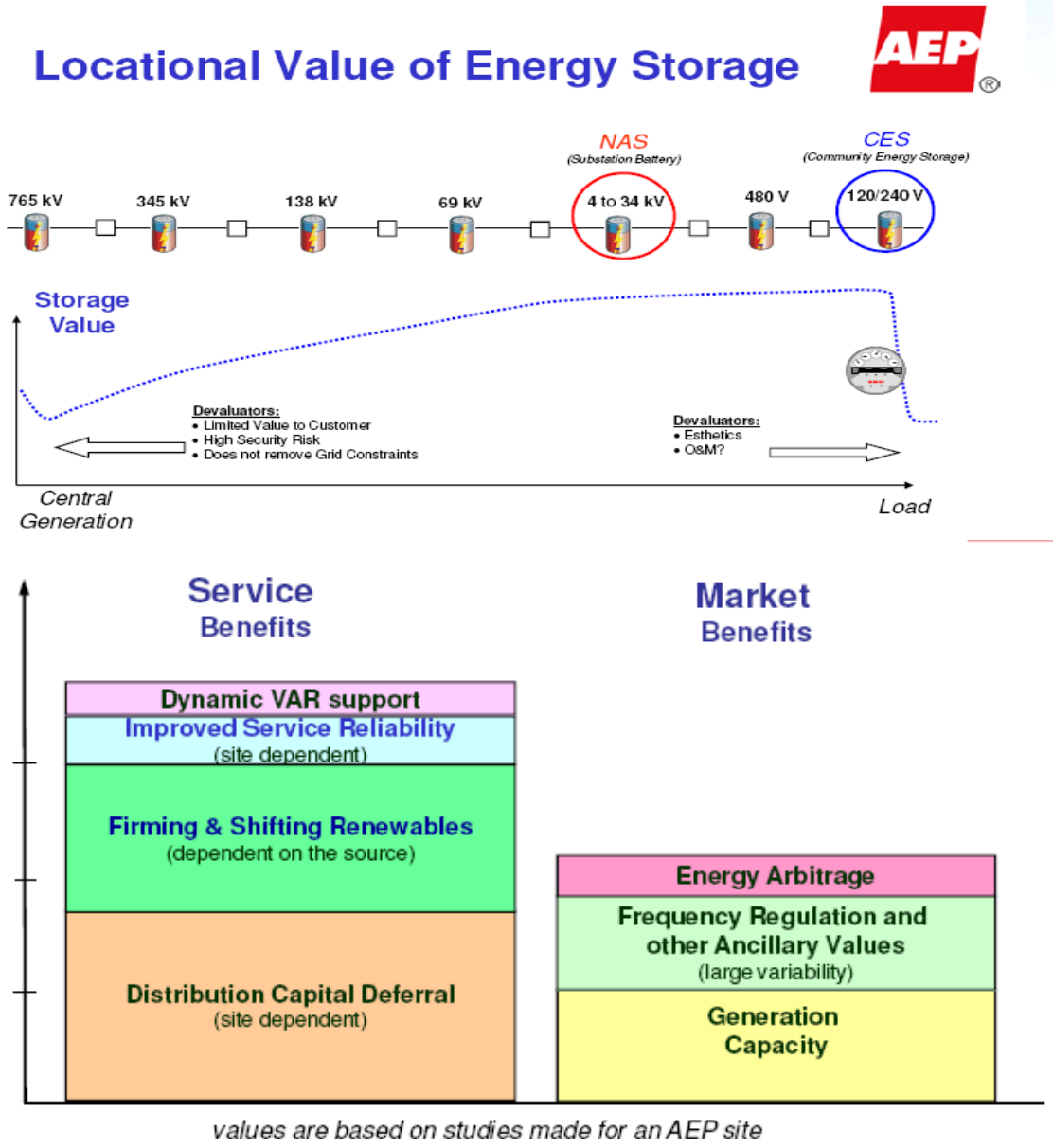
Four Feedback Options

- **Incremental encoder**
- **Sin/Cos encoder**
- **Endat absolute encoder**
- **Resolver**

Runs induction, torque motors, or PMAC Servo



AEP's Vision of Robust Storage Benefits



PCS Capabilities For Full Grid Benefit

Steady State W, power transfer

Plus:

Steady State VAR, *voltage reg.*
Transient W, *a/c stall barrier*
Transient VAR, *sag mitigation*
Dynamic W, *damping, inertia*
Dynamic VAR, *voltage stability*
Islanding, *reliability*

Can this be delivered <$3/watt?
First U.S. Retail Rate Case

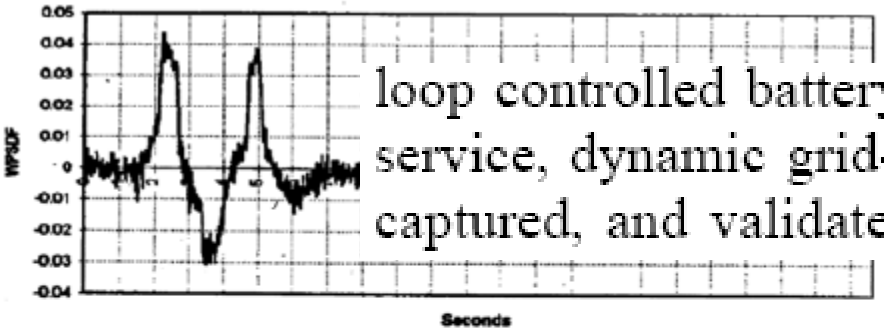
SCE's Utility's Vision of Storage Benefits (FOA 36)

Transmission	1	Provide Voltage Support/Grid Stabilization
	2	Reduce Outage Frequency/Duration (islanding)
	3	Reduce Transmission Losses
	4	Reduce Congestion
	5	Relax Reliability Limits (Defer Load Shed/Provide Generation under N-2 Contingency)
	6	Transmission Access
	7	Defer Transmission Investment
	8	Renewable Energy Transmission
System	9	Provide System Capacity/Resource Adequacy
	10	Renewable Energy Integration (smoothing)
	11	Renewable Energy Integration (daily output shifting)
ISO Markets	12	Provide Frequency Regulation
	13	Provide Spin/Non-Spin/Replacement Reserves
	14	Provide Ramp
	15	Provide Black Start
	16	Energy Price Arbitrage

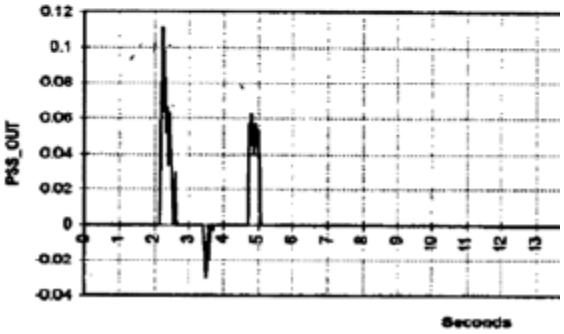
SCE Chino - Back to the Future - SCE Tehachapi

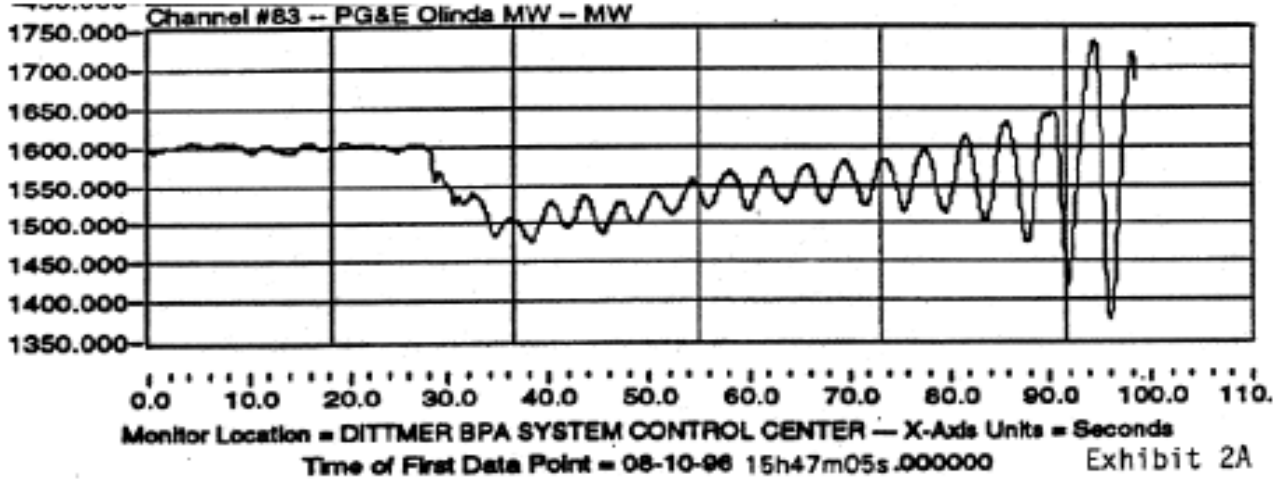
B. Chino Battery Energy Source Power System Stabilizer

In 1994 an Energy Source Power System Stabilizer (ESPSS) was designed and built by GE, and added to the Chino Battery and put into operation by SCE.



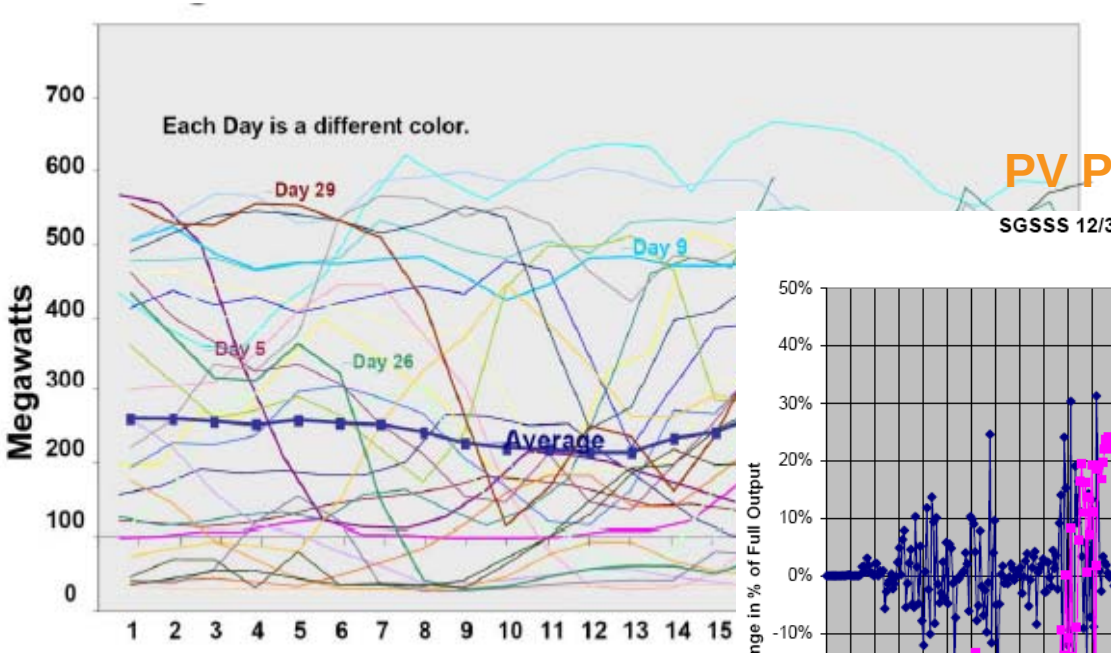
loop controlled battery output. Within two days of going into service, dynamic grid-supportive response by the battery was captured, and validated, through project metering.



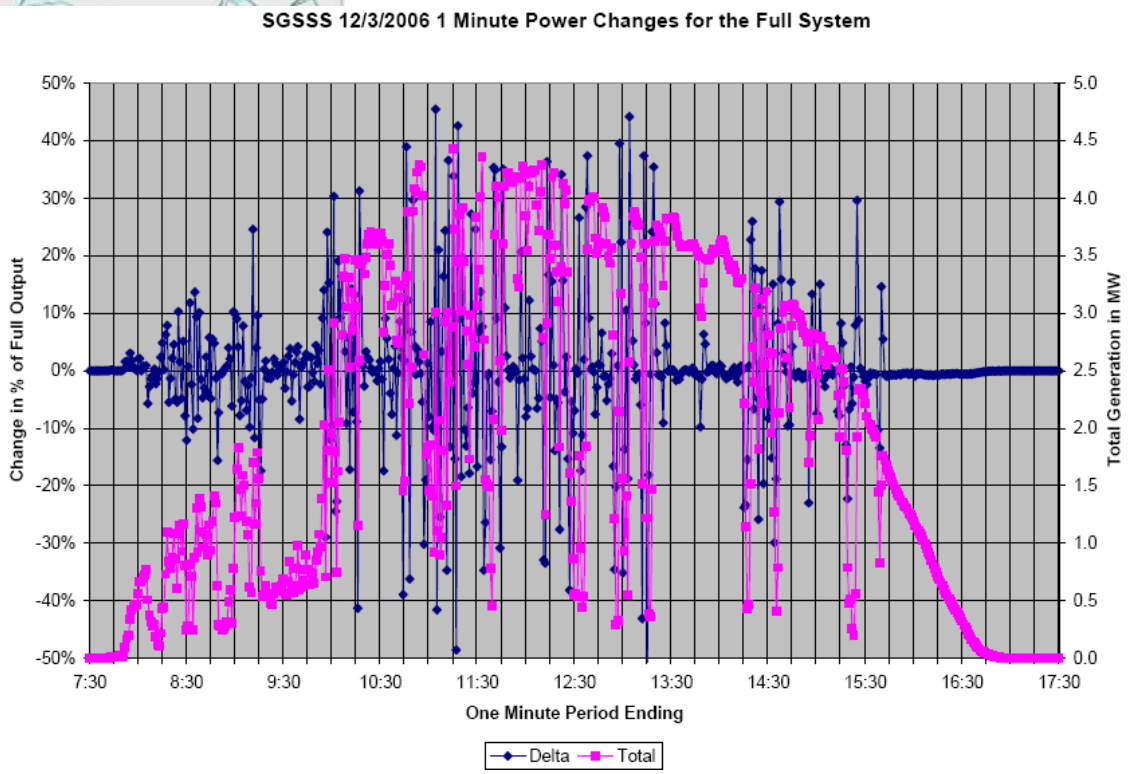


Wind Challenge: Persistent Cycling Intermittency
PV Challenge: Infrequent Intermittency, Local PQ

Wind Production (Tehachapi)



PV Production (Tucson)



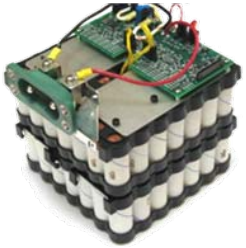
Source: CAISO and TEP

Ideas for Roadmap Development

- Cutting your PCS cost in half and doubling efficiency would be nice, but, wouldn't be a game changer in terms of accelerating significant commercial uptake of advanced-technology grid stabilizing storage; 4,000 MW UK, 10,000 MW US
- Help me map capabilities to grid performance outcomes relevant to grid-access controlling stakeholders.
- Help me characterize of renewable penetration impacts and solutions. Adamant voices want 'business as usual' to 20% penetration. OK, but then what? Stop, or accept higher outage exposure?

BACKUP SLIDES

A123 Core Competencies



- Materials science and development expertise
- Battery design capabilities
- Battery systems engineering and integration expertise
- Vertical integration from battery chemistry to battery system design services
- Industry-leading partners in focused markets
- High-quality, volume manufacturing facilities and proprietary process technologies

A123 Efficiencies for Maximum Value