The STG Lecture Series

Electric Industry Perspectives on Storage

Presented by
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March 21, 2013

About the Lecturer…

- Richard Fioravanti is a graduate of the University of Southern California
- Vice President of DNV KEMA Electricity Storage Practice for the "Americas"
- On the Board of the NY-BEST organization (www.ny-best.org)
- Previous worke in advanced aerospace and distributed generation applications
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Game Changing Technology?

An old political perspective:

U. S. Congressional Record, 1875

- A new source of power... called gasoline has been produced by a Boston engineer.
- Instead of burning the fuel under a boiler, it is exploded inside the cylinder of an engine. The dangers are obvious. ….
- The menace to our people of vehicles of this type …would call for prompt legislative action.
- In addition, the development of this new power may displace the use of horses, which would wreck our agriculture.

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Game Changing Technology?

- Storage is a potential game changing technology – but at this stage of its market cycle, the technology is proving itself in some niche applications and revealing gaps in others

- Efforts in understanding the technology often reveal a complex mix of opportunities, applications weighed against both traditional and advanced storage devices

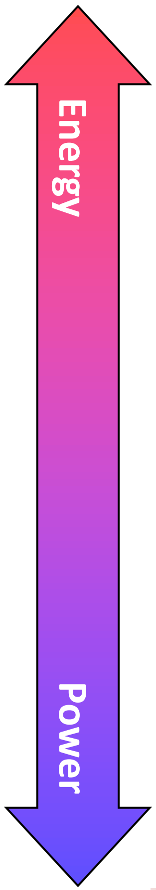
- This current state provides a variety of perspectives on the technology and how to utilize it for different markets.

- Presentation will try to clarify the different perspectives and impacts of those perspectives on "storage."

Agenda

- Summary of Electricity Storage
- Global Markets & Perspectives
- Perspective of Key Stakeholders
- Mapping of Technologies to Applications
- Conclusions

Storage Trends - Technologies



- **Compressed Air Energy Storage** – will be utilized for “centralized” applications
- **Above Ground CAES** – Gen II, projected as 5MW, above ground
- **Sodium Sulfur (NaS) battery** – Long duration, Transmission back-up
- **Vanadium Redox Battery** – Long duration, flow battery, used for back-up applications
- **Advanced Lead Acid Batteries** – 1 to 4 hours, used for renewable integration
- **Sodium Nickel Chloride Battery** – Targeting vehicles and small backup (Telecom)
- **Li-ion – High Energy** – Used for CES, renewable integration, maybe regulation
- **Li-ion – High Power** – used for frequency regulation, renewable integration
- **Flywheels** – 15 minute, many cycles, used for frequency regulation

Today, no single storage technology does it all…

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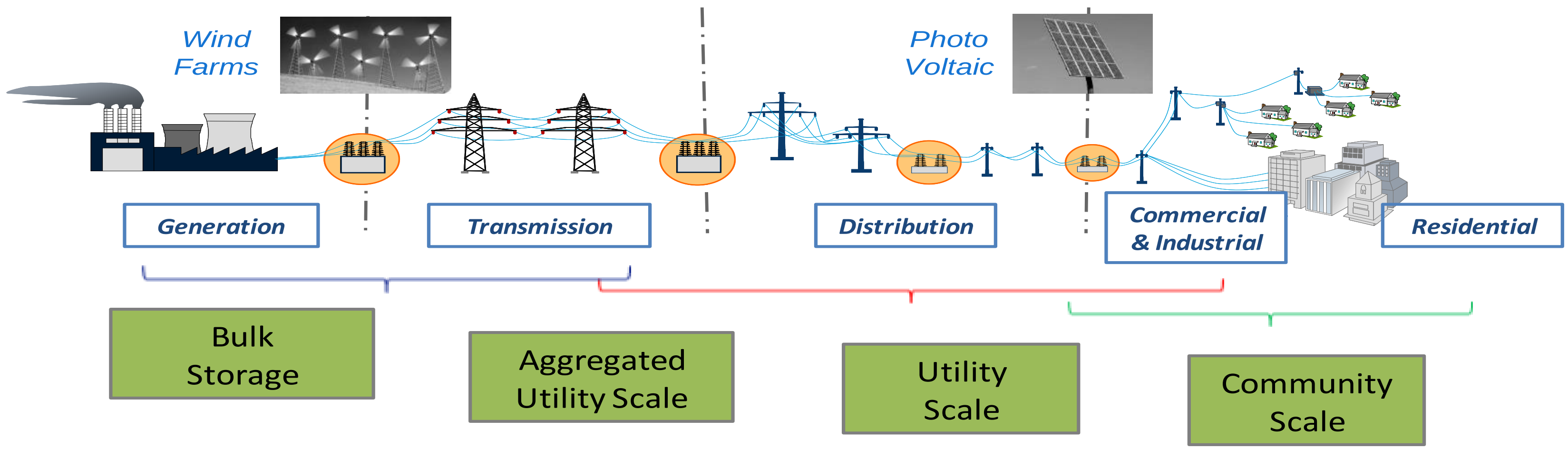
Storage Trends - Technologies



- The chart above shows how storage can play a role at every segment of the grid, as part of generation support through to end use utilizations
- There are tendencies in industry to generalize and categorize devices…but it is clear that there are a variety technologies, performance characteristics, and locations where the device can be sited…

….it is important not to look at one application area and make assumptions across the entire industry

A Range of Possible Applications

Application	Discharge Duration Low	Discharge Duration High	Capacity Low	Capacity High
Large Renewable – Grid Int. – Long Duration	1 hr	6 hr	500kW	500 MW
Large Renewable – Grid Int. – Short Duration	10 sec	15 min	500kW	500 MW
Electric Energy Time Shift	2 hr	6 hr	1 MW	500 MW
Electric Supply Capacity	4 hr	6 hr	1 MW	500 MW
Large Renewables Energy Time Shift	3 hr	5 hr	500kW	500 MW
Large Renewables Capacity Firming	2 hr	4 hr	500k	500 MW
Load Following	2 hr	4 hr	1 MW	500 MW
Area Regulation	15 min	1 hr	1 MW	50 MW
Electric Supply Reserve Capacity	1 hr	2 hr	1 MW	500 MW
Voltage Support	15 min	1 hr	1 MW	10 MW
Transmission Support	2 sec	5 sec	10 MW	100 MW
Transmission Congestion Relief	3 hr	6 hr	1 MW	100 MW
T&D Upgrade Deferral	3 hr	6 hr	250kW	5 MW
Demand Charge Management	5 hr	11 hr	50 kW	10 MW
Time of Use Energy Cost Management	4 hr	6 hr	1 kW	1 MW
Electric Service Reliability	5 min	1 hr	.2 kW	10 MW
Electric Service Power Quality	10 sec	1 min	.2 kW	10 MW
Small Renewables Energy Time Shift	3 hr	5 hr	1 kW	500kW
Small Renewables Capacity Firming	2 hr	4 hr	1 kW	500kW
Small Renewable – Grid Int. – Long Duration	1 hr	6 hr	1 kW	50 kW
Small Renewable – Grid Int. – Short Duration	10 sec	15 min	1 kW	50 kW
Substation on-site Power	8 hr	16 hr	1.5 kW	5 kW

Aggregated Utility Scale (Large Renewable – Grid Int. – Long Duration through Area Regulation)

Utility Scale (Load Following through Transmission Congestion Relief)

Community Scale (Demand Charge Management through Small Renewable – Grid Int. – Short Duration)

- This complexity is seen in the simple list of potential application areas that storage systems could perform
- Couple this with the knowledge that some of these technologies can be bundled together, enabling the storage device to preform multiple roles

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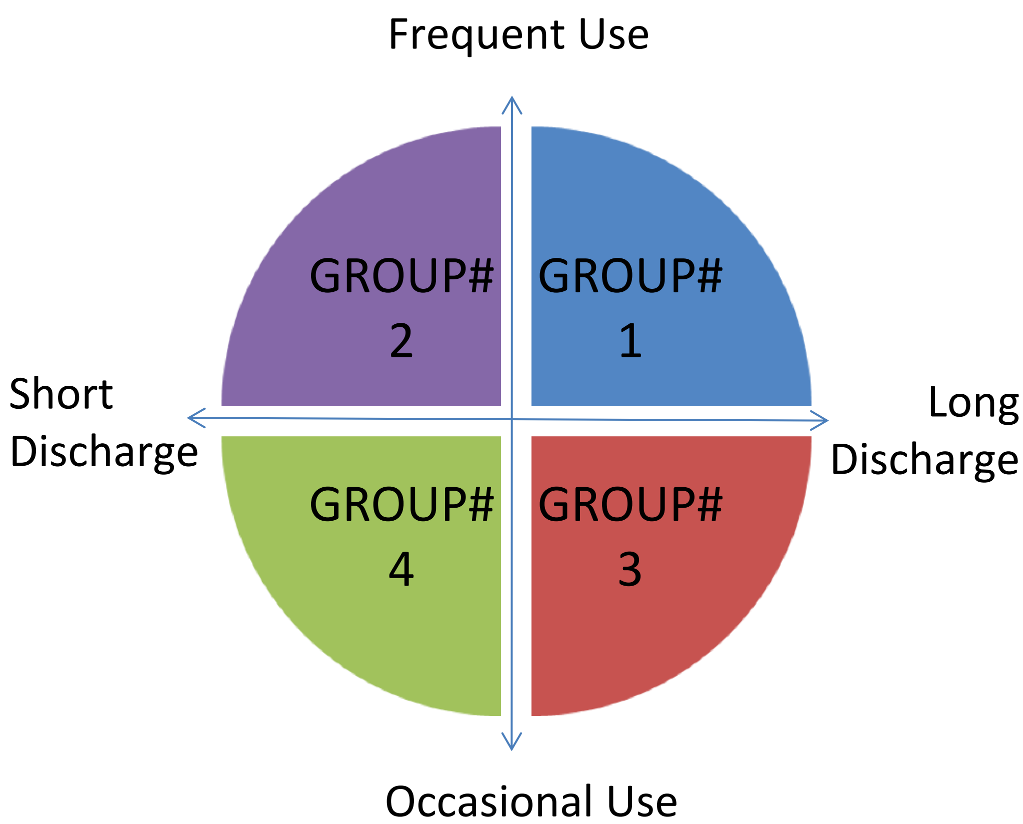
How to Map Technologies to Applications



- Chart on the left shows basic steps that need to be taken in order map a technology to an application
- This type of approach is also used when “bundling” different applications and packaged into a single storage system – ensuring that “like characteristics” are mapped to “like” applications

Cost of Storage Technologies

- Impact of cost on electricity industry perspectives
  - Cost has to be considered as a major driver to how storage is examined across the Globe
  - Most studies today focus on the potential along with the assumption that cost parity of the technology will be achieved
  - If Technology fails to deliver on this "implied" promise, then for the electricity industry the recent trends deployment will reverse back traditional systems and application
    - Lead acid
    - Pumped Hydro

- It can be proposed that the gains that the device are making will fade or even reverse if the technology cost stagnates at current Levels

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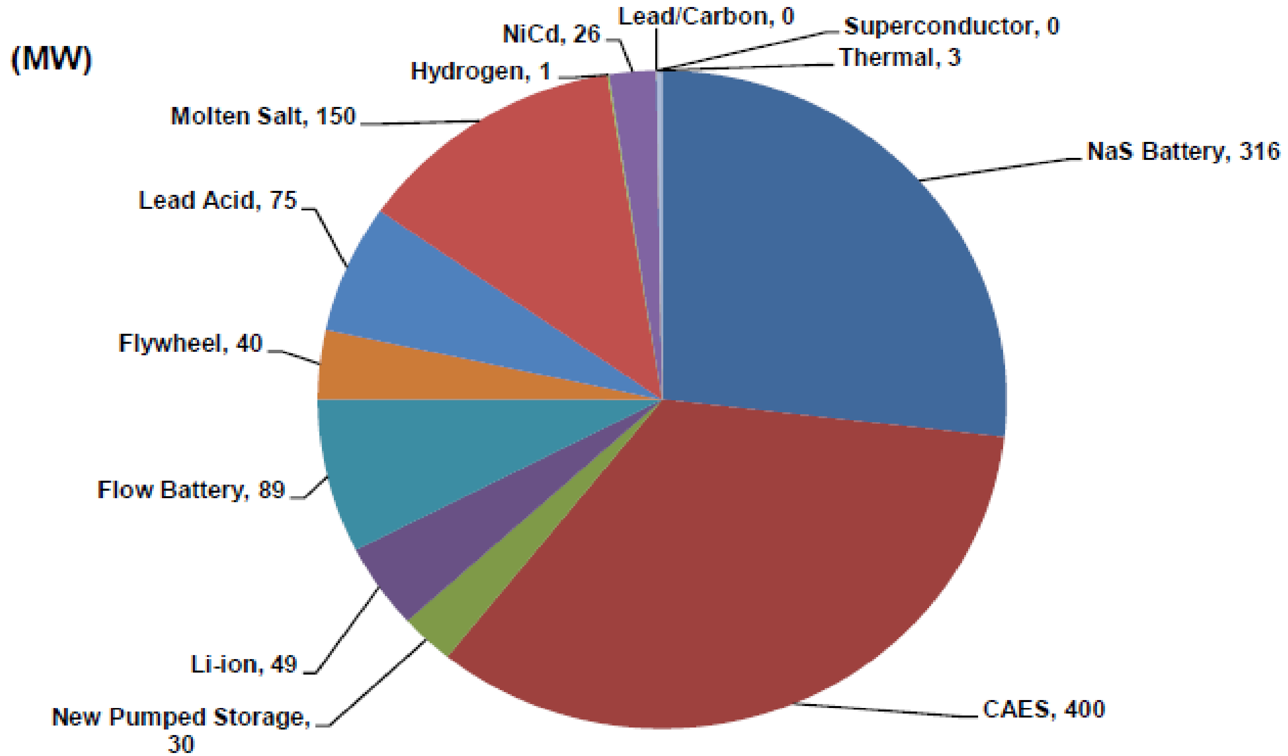
Global Markets MWs Deployed Globally by Technology

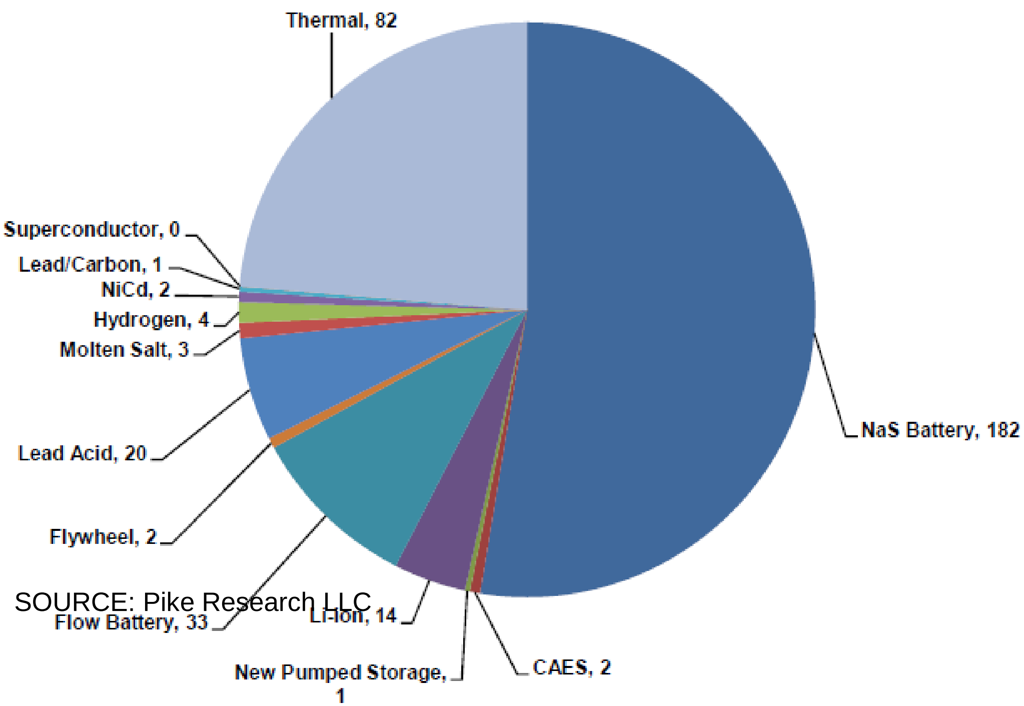
Global Energy Storage Capacity (MW) by Technology, Excluding Pumped Hydro, Q2 2012



SOURCE: Pike Research LLC

Global Markets: Storage Installations by Technology

Number of global storage projects EXCLUDING pumped hydro



SOURCE: Pike Research LLC

Number of Global Storage Installations by Region 2012

Technology	Global	North America	Western Europe	Asia Pacific	RoW
CAES	2	1	1	0	0
Flow Battery	**33**	11	2	19	1
Flywheel	2	1	0	1	0
Hydrogen	4	2	2	0	0
Lead Acid	**20**	19	1	0	0
Lead / Carbon	1	0	0	1	0
Lithium ion	**14**	6	1	5	2
Molten Salt	3	0	3	0	0
NaS Battery	**182**	8	3	171	0
NiCd	**1**	1	0	0	1
Pumped Storage (new)	1	0	0	1	0
Pumped Storage (traditional)	134	29	40	65	
Superconductor	0	0	0	0	0
Thermal	**82**	68	4	9	1

Source: Pike Research Energy Storage Tracker Q2 2012

U.S Trends: Initiatives Shaping the U.S. Storage Market

Initiative	Description	Market Impact / Timeframe
ISO/RTO Ancillary Service Markets Open to Storage	Five open-bid ancillary services markets are now (or shortly will be) directly accessible to energy storage: PJM, NYISO, ISO-NE, MISO and CAISO	***Current to near-term*** • Creates large-scale markets for storage-based regulation
FERC Final Rule (RM11-7-000; Final Order No. 755)	Clarifies frequency regulation compensation for fast-response storage in organized markets (Oct. 2011)	***Near-term*** • Increased revenues for storage-based regulation due to value of fast response
ERCOT Ancillary Services for Storage	ERCOT is considering new rules for storage participation in the ancillary services markets. (In process as of 2011)	***Mid-term*** • Expands market for regulation; pending
California State Law (AB 2514)	Sets energy storage procurement targets in the State of California (Enacted 2010)	***Near to Mid-term*** • Increased awareness of storage capability and benefit
U.S. STORAGE Act of 2011 (S.1845)	Legislation would provide tax incentives for grid storage as well as for on-site and residential applications. (Introduced Nov. 2011)	***Mid to Long-term?*** • Would accelerate growth of national market by defraying initial investment
Renewable Portfolio Standards (29 states)	State-driven RPS mandates and goals to increase renewable generation. Targets from 10% - 40%	***Current to Long-term*** • Greater need to mitigate intermittency
FERC Order 1000 Enacted Jul. 25, 2012	States that energy storage should also be evaluated as a potential solution for applicable T&D issues	***Current to Long-term*** • Opens door to storage solutions for T&D
FERC Declaratory Order; Western Grid Development LLC Approved Jan. 2012	FERC determined that the batteries will operate as wholesale transmission facilities and granted Western Grid the advanced transmission incentives subject to California ISO transmission planning	***Current to Long-term*** • Opens door to rate base storage for T&D; basis point and other incentives may apply for advanced technology

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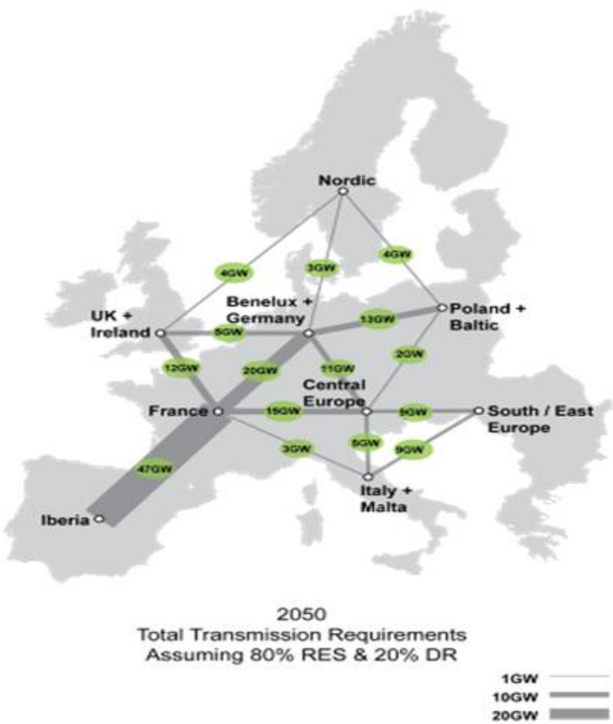
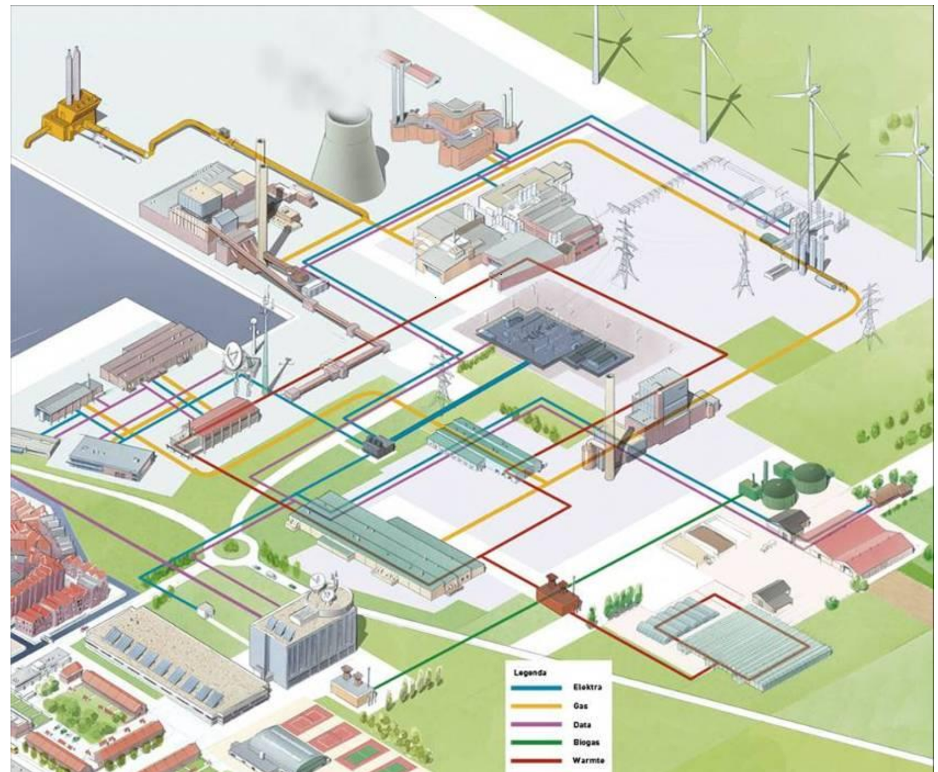
Example US Storage Projects ≥ 2 MW: 2007 – 2012

SPONSOR	PROJECT & STATE	MW/ MWh	APPLICATION	SUPPLIER & TECHNOLOGY	TARGET DATE	CO-FUNDING
Primus Power	Modesto Irrigation, CA	25 / 75	WS, LS, AS	Primus Power, RFB	2012	ARRA grant
First Wind	Kaheawa Wind Power II, HI	10/ 20	WS	Xtreme Power, ALA	2012	Private
Duke Energy	Notrees Wind Storage, TX	36 / 24	WS, AS, AR	Xtreme Power, ALA	2012	ARRA grant
SCE	Tehachapi Wind ES Project, CA	8 / 32	WS, E	A123, LI	2012	ARRA grant
East Penn Mfg.	Ancillary Services, PA	3 / 1-4	AS	Ecoult, ALA	2012	ARRA grant
Kodiak Electric	Pillar Mountain, AK	3 / 2	WS, AS	Xtreme Power, ALA	2012	Private
A123	Alternative Technology Regulation , MA	2 / .5	AR	A123, LI	2012	Private
Premium Power	Peak Demand Reduction, CA	3.5 / 3	D	Premium Power, Flow	2011	ARRA grant
Beacon Power	Stephentown, NY	20 / 5	AR	Beacon Power, FW	2011	DOE loan
AES Energy Storage	Laurel Mountain , WV	32 / 8	WS	A123, LI	2011	Private
First Wind	Kahuku Wind Project , HI	15 / 10	WS	Xtreme Power, ALA	2011	DOE loan
AES Energy Storage	Johnson City, NY	8 / 2	AR	A123, LI	2010	Private
AEP	Presidio/TX	4 / 25	T&D	NGK, NAS	2010	Rate base
AEP	Bluffton, OH	2 / 14	T&D	NGK, NAS	2007	Rate base
AEP	Balls Gap/ WV	2 / 14	T&D	NGK, NAS	2007	Rate base
AEP	Churubusco/ IN	2 / 14	T&D	NGK, NAS	2007	Rate base

European Trends: Energy transmission and distribution will change radically

Huge investments in interconnection and smart grids are needed





European Trends: Summary of Applications

Market Segment	Germany	UK	Spain	Netherlands	France	Italy	Market Start-up
Frequency Regulation & Spin Res							Long Term
PV-ESS System	✓✓	✓	✓	✓	✓	✓	Near term
Community Energy Storage		✓			✓	✓	Mid Term
C&I Back-up, Grid interactive UPS							Mid Term
Substation support		✓		✓	✓		Mid Term
Home Systems							

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Asia Markets

- Interest and Activity remain high across Asia due to the utilization of the NaS battery in heavy manufacturing capability in China and Korea
- Renewable Integration
  - Continues to be a major driver for storage but mechanisms outside of government initiatives to propel the deployments in unclear….
  - Though need parallels that of North America, no "best in practice" plan or approach to get storage deployed with renewables.
- Manufacturing
  - Larger industrial firms and Korean and Japan continue to invest in and promote advanced battery technologies
  - Companies still appear to be targeting North American markets but are clearly deploying in Asia

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Key Applications for Storage

Before focusing on the perspectives of key stakeholders, let’s review the major global applications …

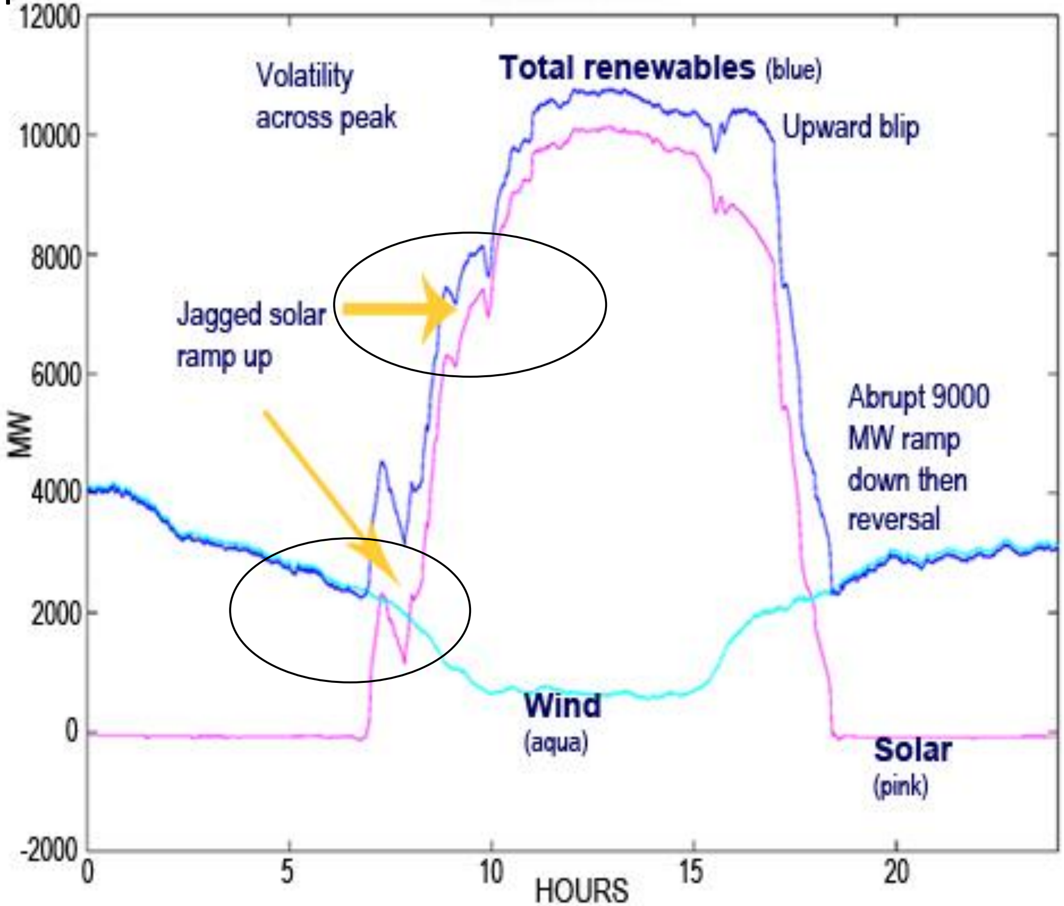
- Regulation – Ancillary Services
- Renewable Integration
- End Use Back Up “Plus”
- End Use Grid Resiliency
- Community Energy Storage
- Micrgrids

Summary of Ancillary Services Application

- In some markets, Regulation is a fee based service tailored to a fast-response device such as storage
- In U.S., ISO (Independent System Operators) and RTOs (Regional Transmission Organization) are creating market rules to utilize fast response storage.
- Bottom picture from AES shows an application being used for regulation and wind integration

Summary of Issues around Renewable Integration

- Covers the short term fluctuations of the renewable resource and maintaining operation
- Issue 1: Chart shows challenges of solar and wind MW production during 24 hours in July
    - Some swings in diagram represent up to 3,500 MW
- Issue 2: Wind often blows in "off peak" hours when there is no load to accept it
- Solution not about advanced batteries only, pumped hydro, CAES as well



source: DNV KEMA

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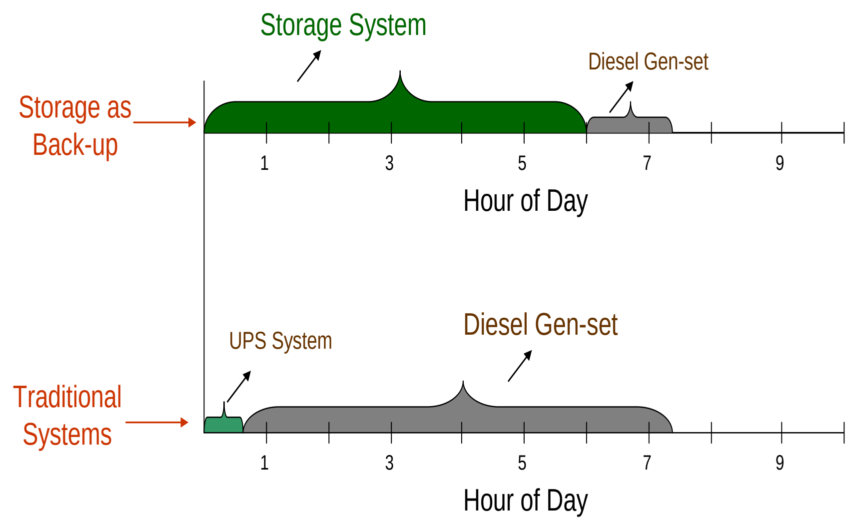
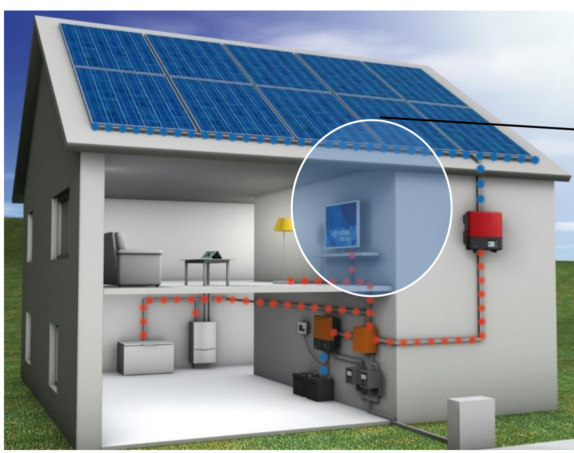
Summary of End-Use, Back-Up "Plus"

- Back-up Systems are common at all facilities
  - Typically a combination of a lead-acid battery with a diesel generator
- This solution replaces the battery with advanced system
  - Multi-cycle capability of the of the battery is used to both reduce the size of the diesel generator
  - And accesses additional revenues such as regulation or demand response programs



Summary of Grid Resiliency – Storage Applications

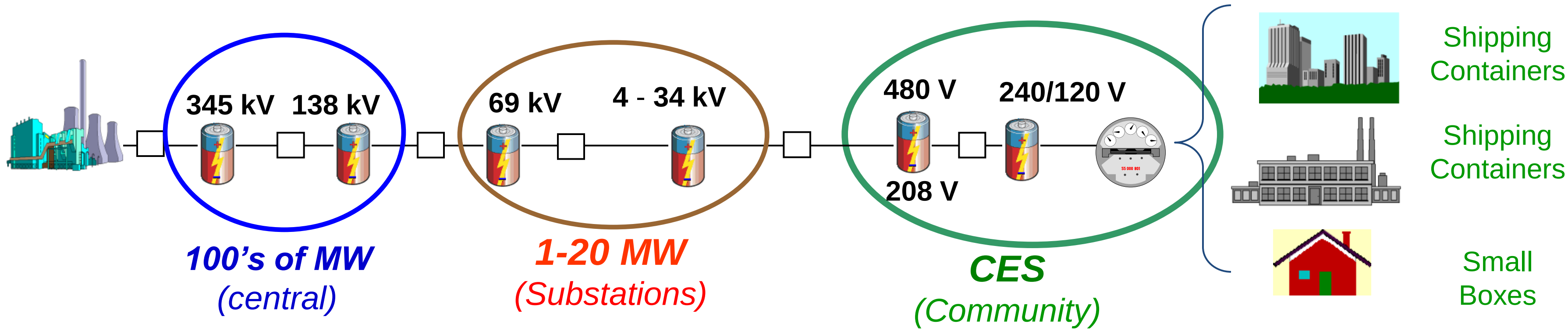
- Long term weather related outages revealed that if not set up to island, solar systems will not function during the outage
- Solutions are being advanced to allow for critical loads to be powered by the solar device
- Issue that is being addressed for residential PV as well as grid-scale storage

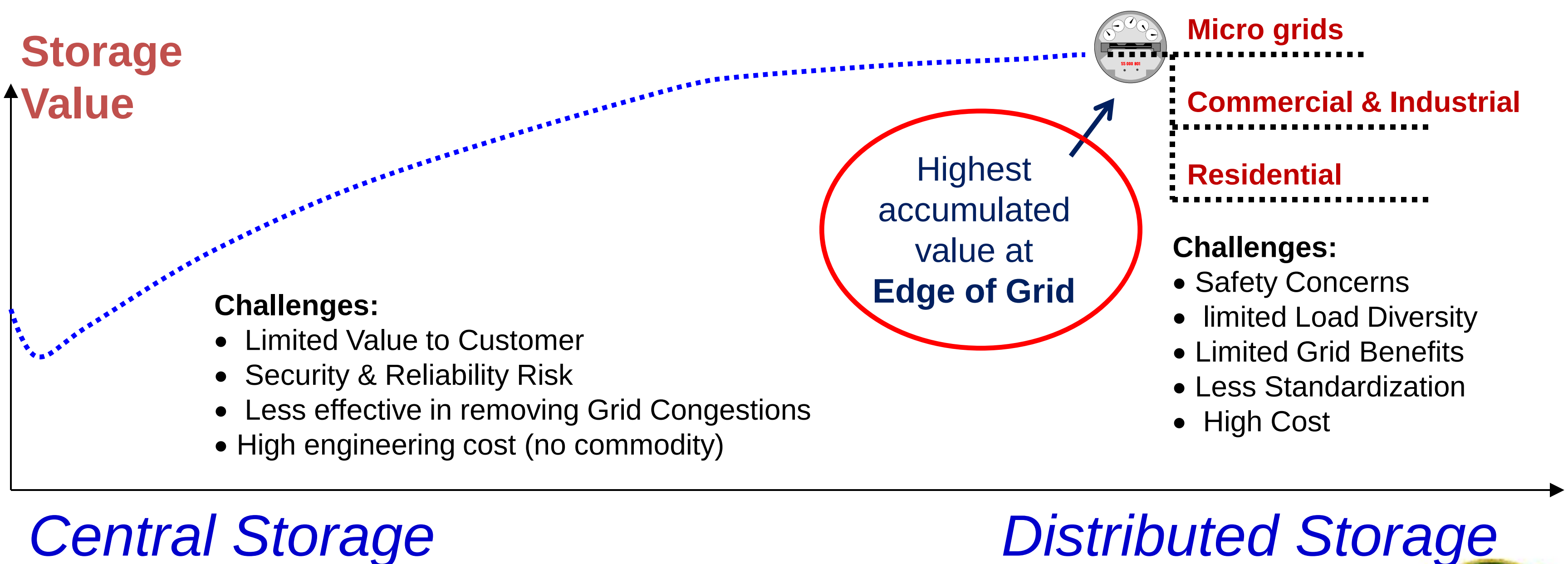


Source: Sunny Backup by SMA

Source: Sunny Backup by SMA

Summary of CES – Community Energy Storage





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CES – Multiple benefits increase the total value

A flexible balance between local and system needs

3- Grid Benefits

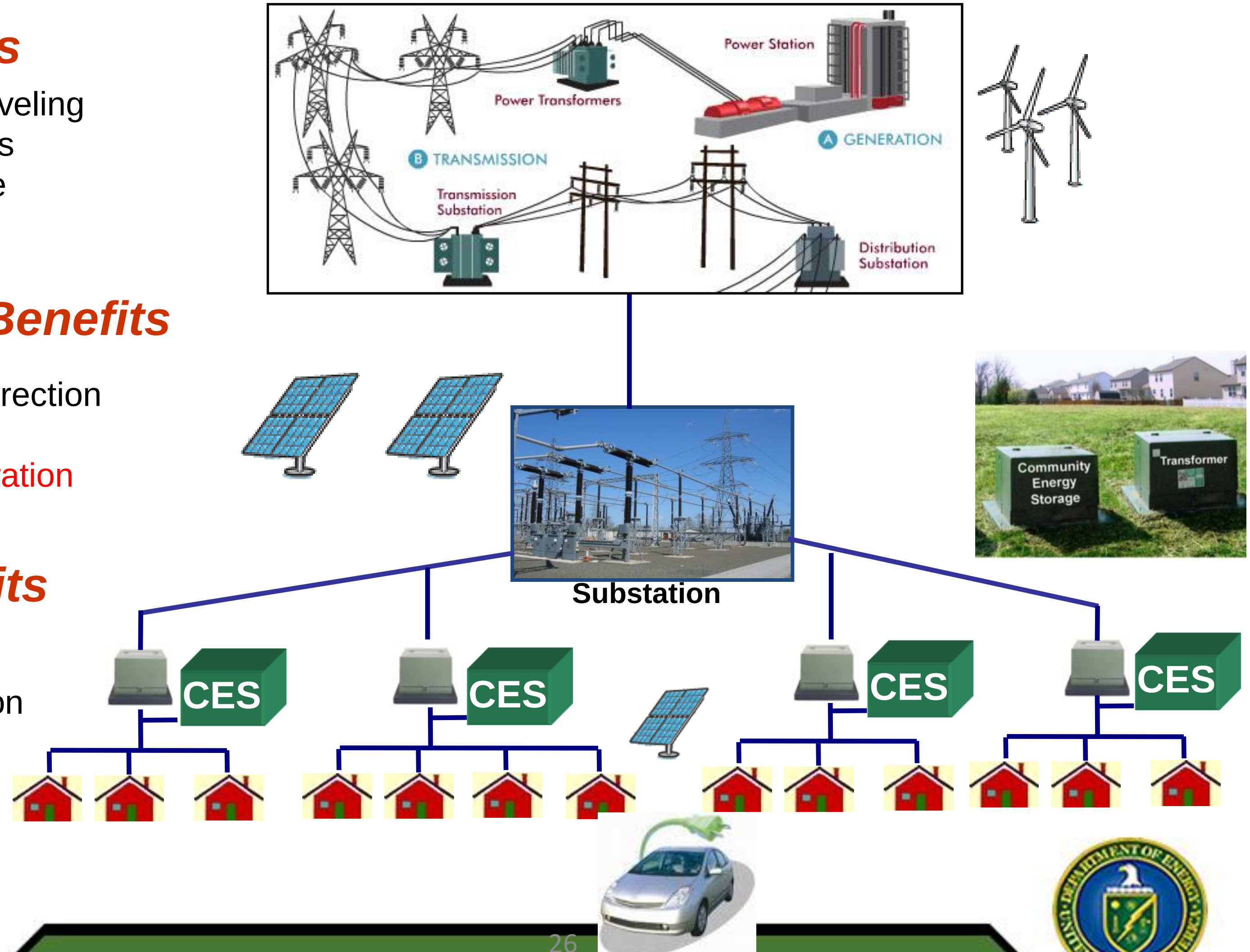
- System Load Leveling
- Ancillary services
- Spinning reserve

2- Substation Benefits

- T&D Deferral
- Power Factor Correction
- Reliability
- Renewable Integration

1- Local Benefits

- Backup power
- Voltage correction
- EV buffer
- PV buffer



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Summary of Microgrid Applications

Storage isn't consider the core component of every microgrid, but the technology is part of microgrid designs

Institutional / campus MicroGrid
Single owner, typically colleges, hospitals, airports, etc.

Military MicroGrids
Supports remote base operations with and w/o connection to local/regional power grid

Remote MicroGrids
"Off-grid" remote locations without super-grid infrastructure

Community / utility MicroGrid
Tied to the larger utility grid infrastructure

Commercial / industrial MicroGrid
May have multiple owners

Conceptual Image of a Microgrid

Source: DNV KEMA

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Perspectives - Manufacturers

- Manufacturer Characterization
  - Many startups but global manufacturers are entering the game:
    - GE, Johnson Controls, Applied Materials, Siemens, ABB, Mitsubishi, Samsung, Panasonic, etc.
  - Different roles for manufacturers, suppliers and system integrators
    - Smaller firms focused on finding right partners
    - Larger firm tend to target a global market
- View on Storage Applications
  - Unique issue with pre-commercialized technologies is trying to both sell and, at the same time, continue to invest in lower costs

Perspectives - Developers

- Developer Characterization
  - Group includes large wind, solar developers and independent power producers
    - Wind and solar developers that are looking to interconnect their systems
    - Independent Power Producers IIPPs) that are looking to participate in potential ancillary services markets, capacity markets, or as transmission alternatives

- View on Storage Applications
  - For developers of wind and solar, storage is viewed as a potential benefit and potential hurdle.
    - It is acknowledged that as renewable systems increase penetration above 20% levels, variable generation devices can present problems in maintaining grid operation. Utilization of storage can potentially allow increase penetration of systems – a great benefit
    - However, if the burden of paying for the storage device fall s solely to the developer, then it can be problematic in getting the system to achieve profitable returns – a hurdle
    - …Hence, wind and solar industry accept the benefits but try to make the issue of wind on the grid a “grid” problem
  - For developers, the focus is on regulations to clear paths for owners of storage to have mechanisms to get compensated for services they provide

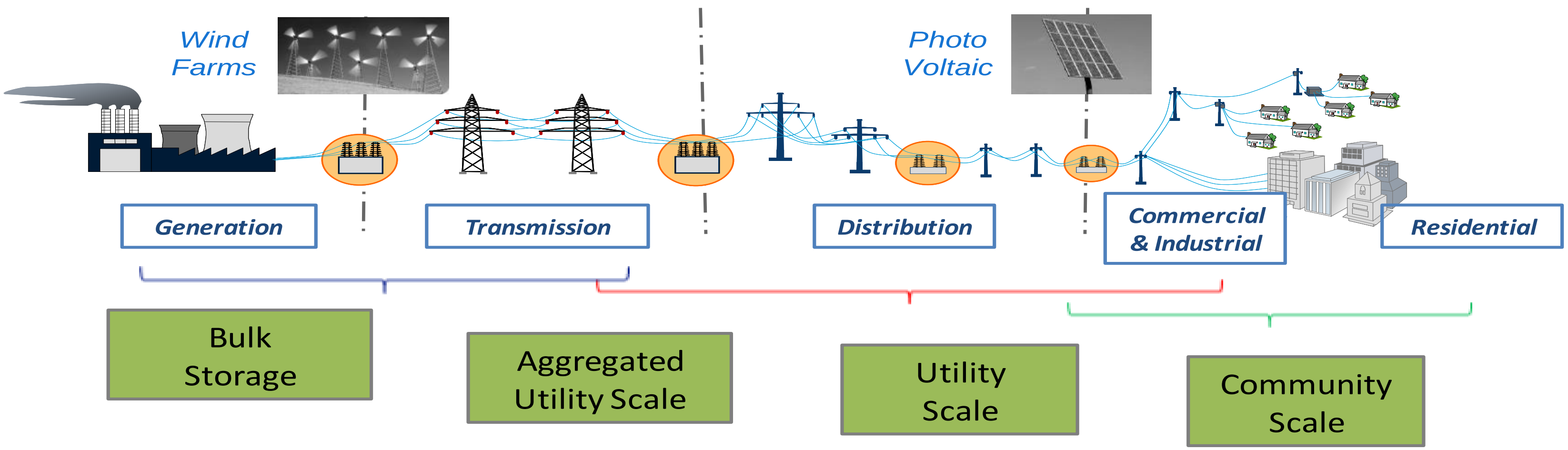
Perspectives - Developers

- Developer Characterization
  - Large wind, solar developers
    - looking to interconnect their systems
  - Independent power producers (IPPs)
    - looking to participate in potential ancillary services markets, capacity markets, or as transmission alternatives

- Wind & Solar Developers' View on Storage
  - Potential benefit and potential hurdle.
    - Potential when renewable exceeds 20% levels
    - Hurdle if the burden of paying for the storage device fall s solely to the developer,
    - The focus is on regulations for owners of storage to get compensated

Perspectives - Utilities

- For utilities, the diagram below shows the storage can provide benefits from the site of generation through to end use
- Utilities also vary in structure from vertically integrated, transmission, distribution, municipality – all with slightly different motivations



Perspectives – Utilities (Continued)

- Utility Characterization
  - Group includes vertically integrated to segmented entities, some under jurisdiction of State utility commissions and some under jurisdiction of cities…
    - In all cases, charters are commonly focused on providing safe, reliable energy to end users at a reasonable cost
    - This charter often makes utilities resistant to adopting new technologies – at least resistant to adopting new technologies quickly

- View on Storage Applications
  - Utilities tend to have a good understanding of the potential benefits storage can offer in improving reliability, demand response, deferral of upgrades, or a potential mitigation device for PV on their system.
  - However, utilities understand their charters and will look to adopt new technologies when there is a clear cost-benefit in favor of the technology.
  - Hence, utilities understand "potential" benefits of storage but MUST have the technology prove itself through concepts, business cases, and performance

Perspectives – Grid Operators

- Grid Operator Characterization
  - Group includes organizations that are responsible for maintaining grid operations such as ISOs (Independent System Operators), RTO (Regional Transmission Organizations) or utilities meeting their own regulation requirements
    - Grid operators understand the benefits of some storage technologies (fast systems and pumped hydro) and are looking to adopt the technology
    - Like utilities, operators are governed by cost of services…they look to improve the system but not to increase the overall cost of system operation

- View on Storage Applications
  - Grid Operators have a solid understanding of the potential benefits that storage systems can offer and are following FERC (Federal Energy Regulatory Commission) to adopt tariffs and control algorithms to take advantage of the characteristics of some of the technologies
  - Because the process involves a series formal request, notifications, responses, assessments typical of rule-making processes, the path to compensation for owners of storage is not fast.

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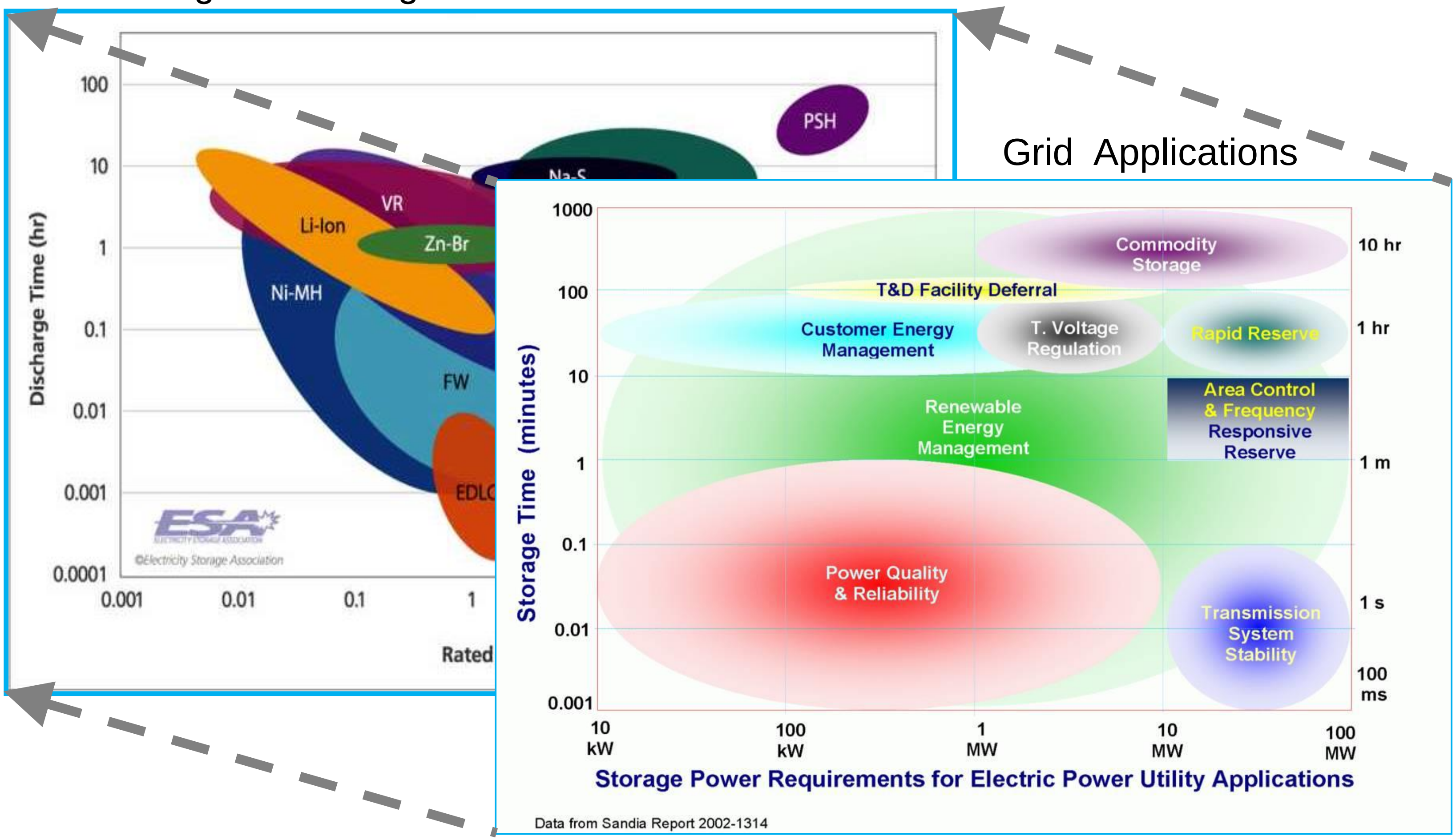
Mapping Storage Technologies to Applications

Storage Technologies

Grid Applications



It looks simple but has many practical challenges & hurdles to overcome !

Mapping Storage Technologies to Applications

- Understanding "storage" can be complex for the following reasons
  - Multiple Applications at various segments of the grid mean benefits can accrue to different stakeholders
  - Multiple technologies with that vary in efficiency, durations, speed, cost, and level of technology readiness
  - Ability to perform multiple of "Bundled" applications as opposed to single tasks

- For these reasons, DNV KEMA tends to utilize a matrix approach to assessing how a particular technology fits rates in a specific application

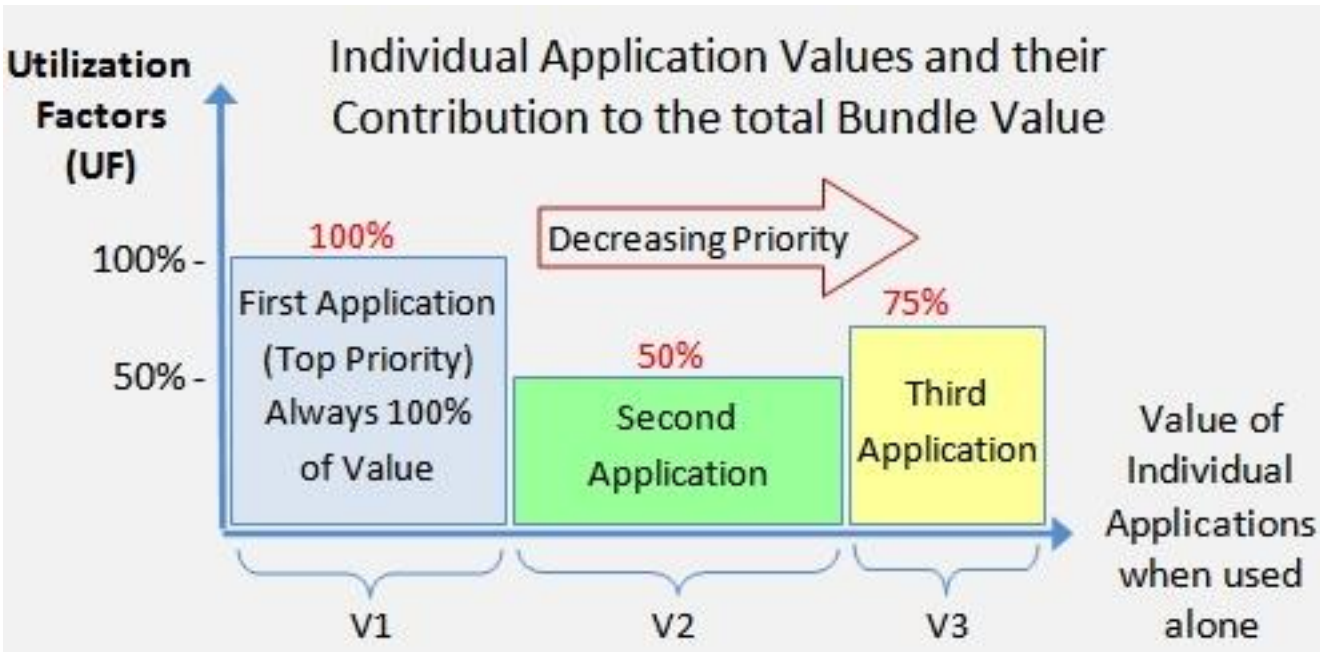
Example of How a Matrix is Used to Map Storage Technologies to Applications

Application	Application Requirements			Commercial / Traditional Systems							
	Discharge Duration (hours)		Frequency of Use	Advanced lead acid	Lithium-ion: High energy	Lithium-ion: High power	Sodium nickel chloride (NaNiCl)	Sodium sulfur (NaS)	Thermal: Ice	Vanadium redox flow battery	Zinc bromine
	Low	High									
Microgrid / Islanded Systems											
Supply spinning reserve	0.3	1	Occasional	Yellow	Yellow	Red	Green	Red	Yellow	Yellow	Yellow
Load following	2	4	Frequent	Yellow	Yellow	Red	Green	Red	Green	Yellow	Yellow
Peak shifting / Energy time shift	3	7	Frequent	Yellow	Yellow	Red	Green	Red	Green	Yellow	Yellow
Uninterruptible Power Supply (UPS)											
Service reliability (customer backup)	0.5	2	Occasional	Yellow	Yellow	Red	Green	Red	Red	Yellow	Yellow
UPS			Occasional	Green	Green	Green	Yellow	Yellow	Red	Yellow	Yellow
Large renewable											
Renewables time shift	3	6	Frequent	Yellow	Yellow	Red	Green	Red	Green	Yellow	Yellow
Renewables capacity firming	2	3	Frequent	Yellow	Yellow	Red	Green	Red	Red	Yellow	Yellow
Grid Support											
Frequency regulation / fast regulation	0.3	0.5	Frequent	Yellow	Yellow	Green	Yellow	Red	Red	Yellow	Yellow
Voltage regulation	0.3	1	Frequent	Yellow	Yellow	Green	Yellow	Red	Red	Yellow	Yellow
Demand response / Demand charge management	5	8	Frequent	Yellow	Yellow	Red	Green	Red	Green	Yellow	Yellow
Infrastructure (T&D) deferral	3	6	Occasional	Yellow	Yellow	Red	Green	Red	Yellow	Yellow	Yellow

Lessons from Perspectives

- Each stakeholder group appears to understand the benefits of storage
- There are identified applications today where storage can be applied and add value
- The path to adoption of storage is not completely clear
- The hurdles preventing mass adoption may be more technical than a “bias”
  - Devices still have not truly proven themselves in the field
  - Cost of the devices
  - Incidences with storage systems….XtremePower in Hawaii, APS, the Boeing 787 to name a few

Combining Multiple Storage Applications



Total Bundle Value = 100% V1 + 50% V2 + 75% V3

Where V1, V2 and V3 are the individual application values and the percentage factors are Utilization Factors (**UF**) estimated with the ES-Select bundling algorithm.

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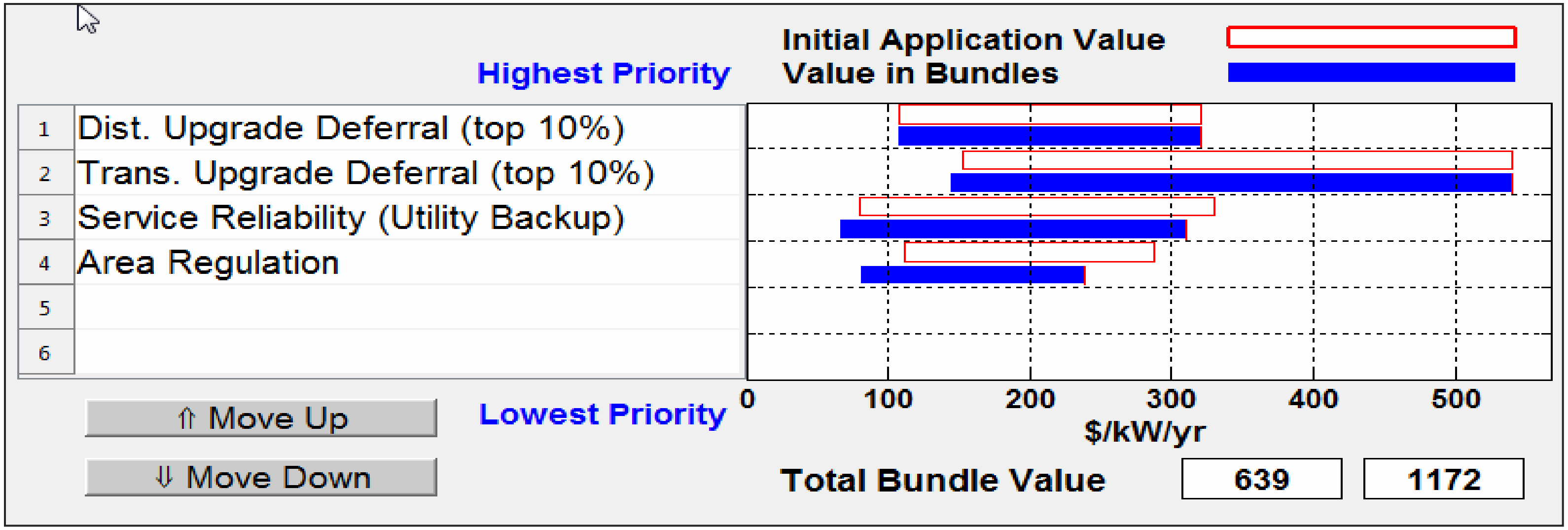
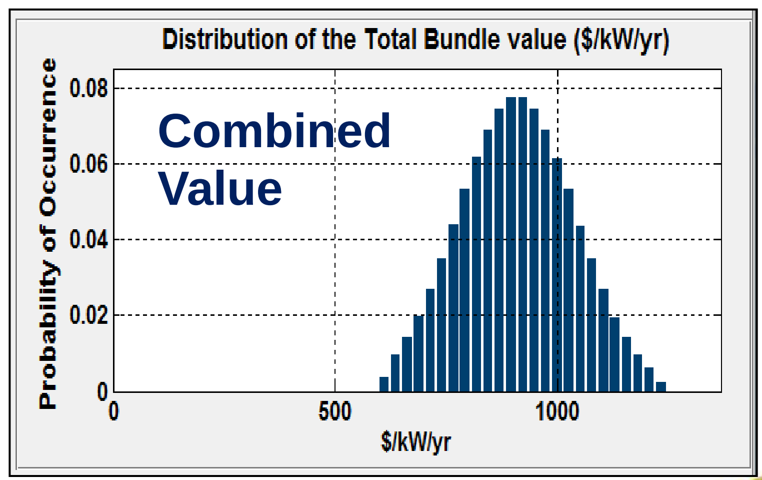
Bundling Applications using ES-Select™



ES-Select™ is a free tool to identify the most feasible storage options for any grid application.

It is available from the website of the Sandia National Lab:

www.sandia.gov/ess



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Conclusions

- Compared to a decade ago, there is a clear excitement and significant increase in recognition of the storage value for the grid

- Storage cost is still high and efforts are being made to reduce it:
  - Reduction of manufacturing cost
  - Cost-effective plug-n-play packages
  - Standardization of storage modules
  - Development of more advanced technologies

- Efforts are being made to bundle applications for higher value