Perspectives on Grid Transformation and the Market for Storage

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Major Trends Affecting Grid & Grid Storage

- **Deployment of renewable generation –**
  - Faster than load growth – displacing conventional generation
  - Variable – creating need for flexibility
  - Flexibility -
    - Acquired via markets – double edged sword for storage
      - Creates revenue stream for storage
      - Enables alternatives (e.g. Demand Response)
- **Smart Grid –**
  - Enables new sources of flexibility
  - Enables multiple functions for distributed storage
- **Reliability/Resiliency**
  - High reliability zones
  - Microgrids – Storage a vital component

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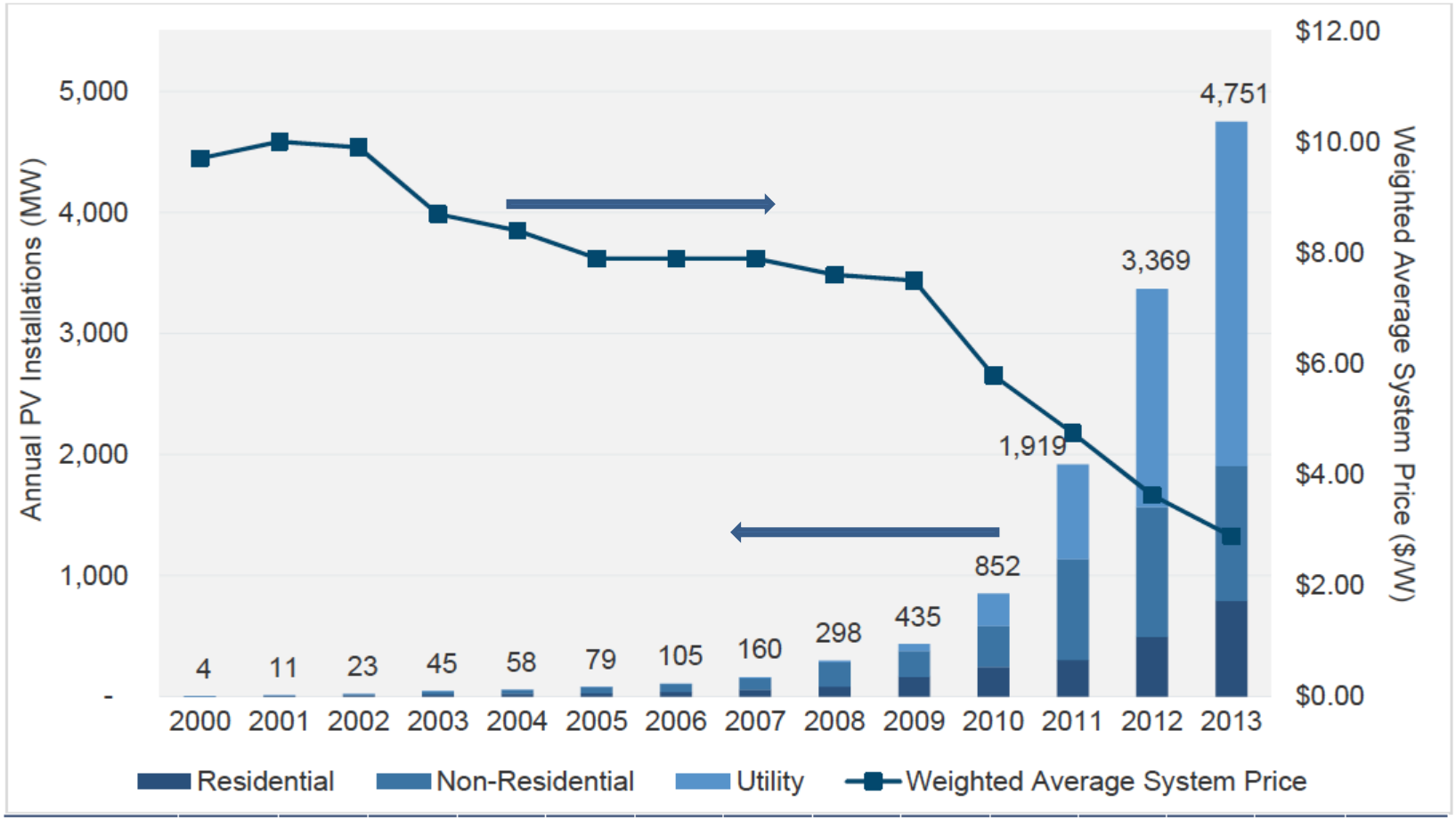
U.S. PV Costs and Deployment

Figure 2.1 U.S. PV Installations and Average System Price, 2000-2013



Source: US Solar Market Market Insight Report 2013, ©Greentech Media Inc and Solar Energy Industry Association

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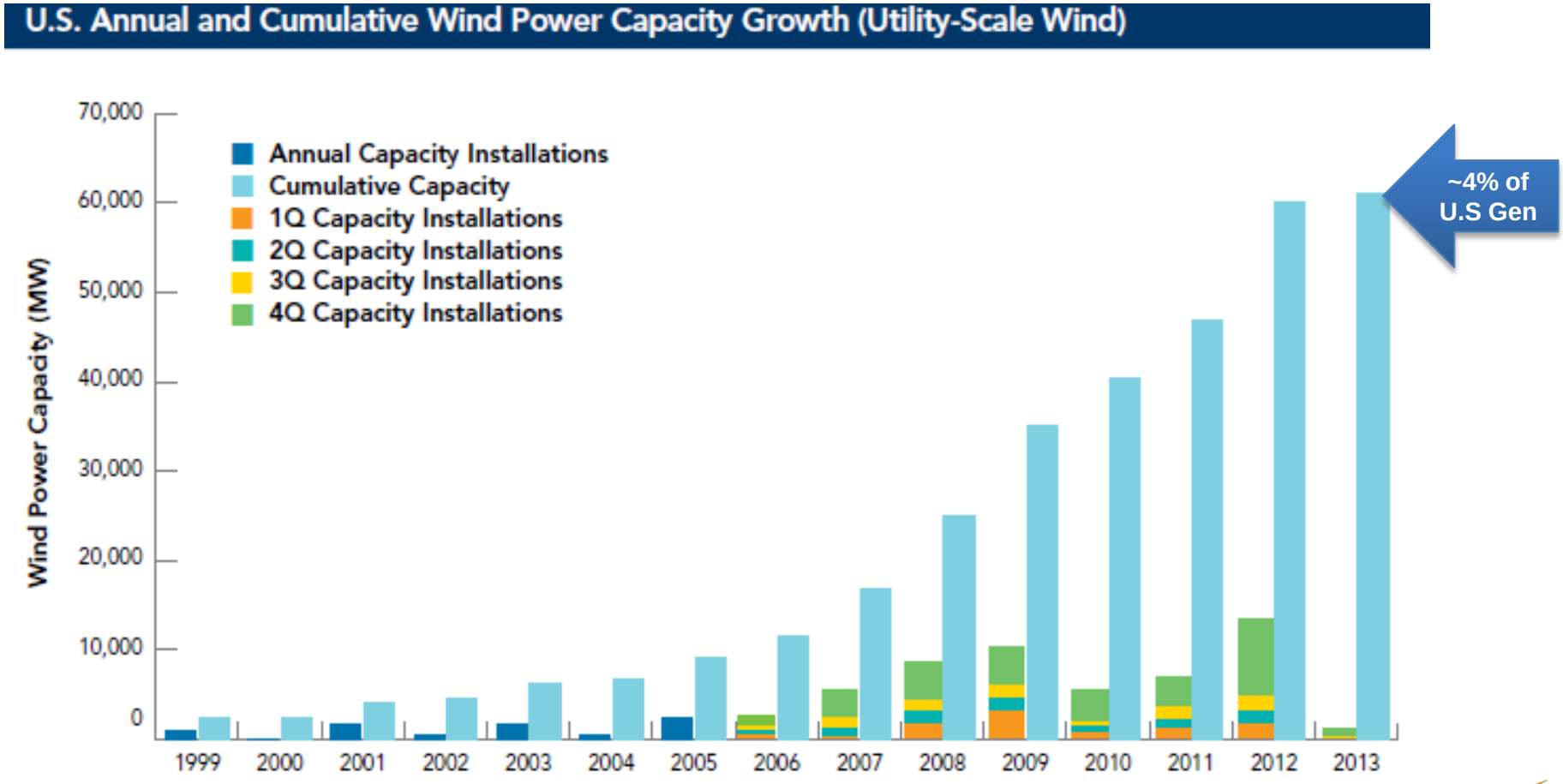
U.S. Wind Generation



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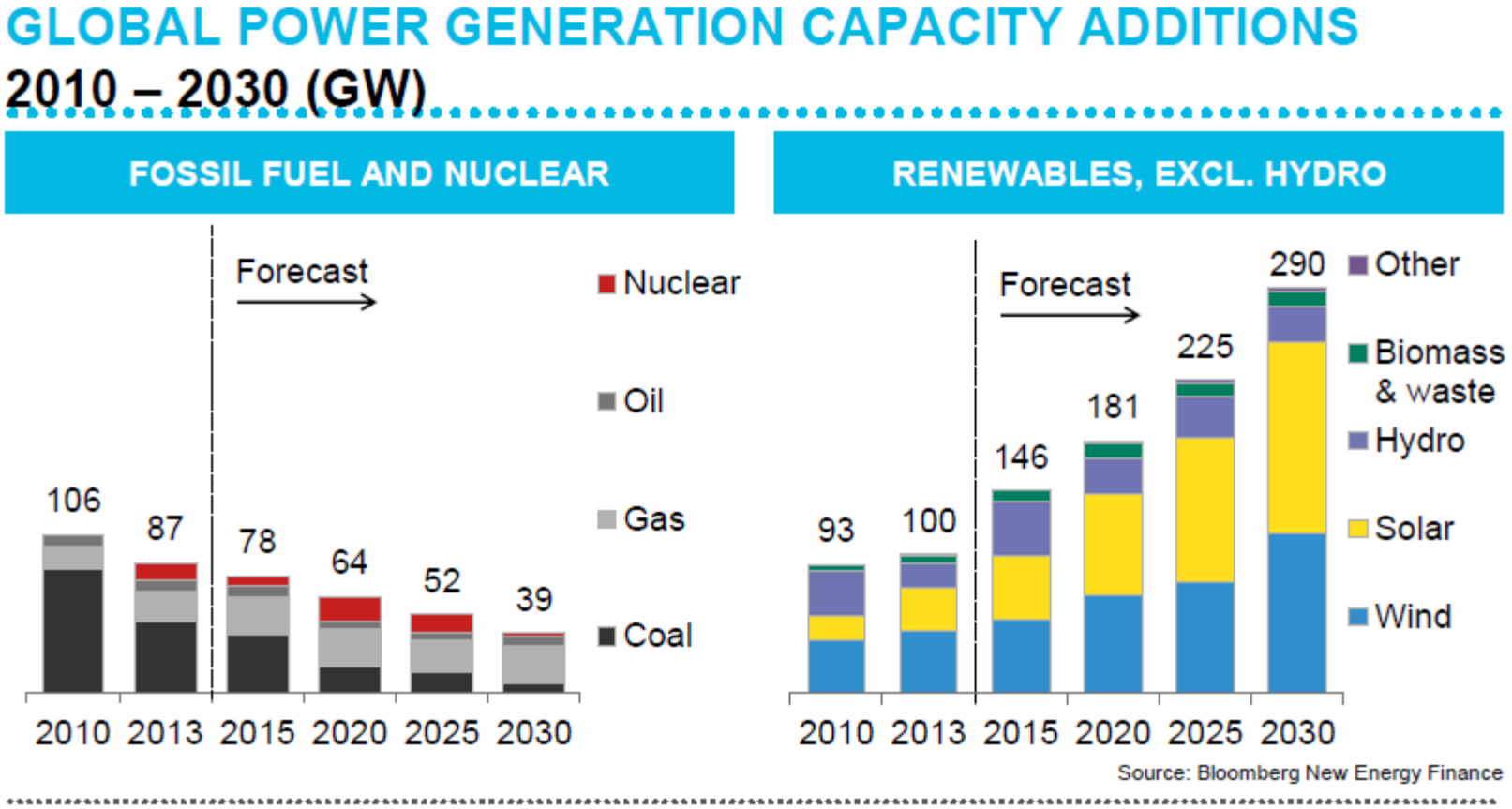
Global Power Generation Forecast



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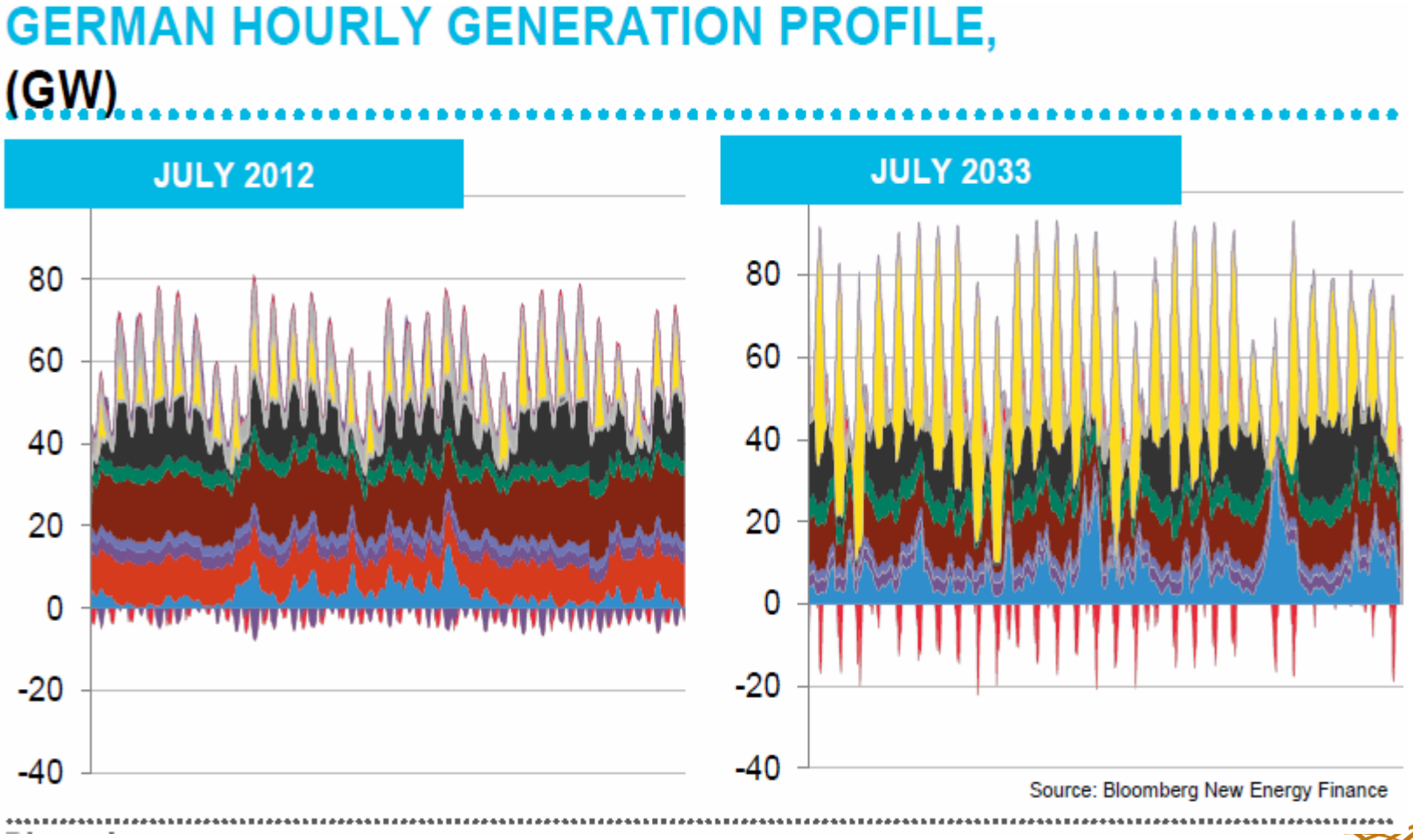
Forecast of German Generation Profile



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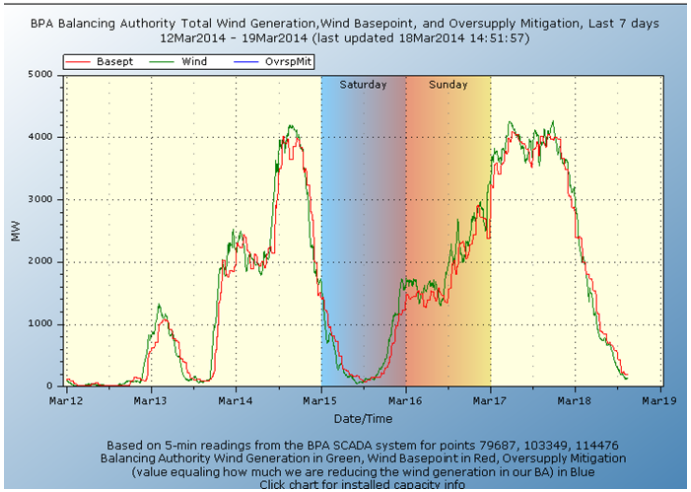
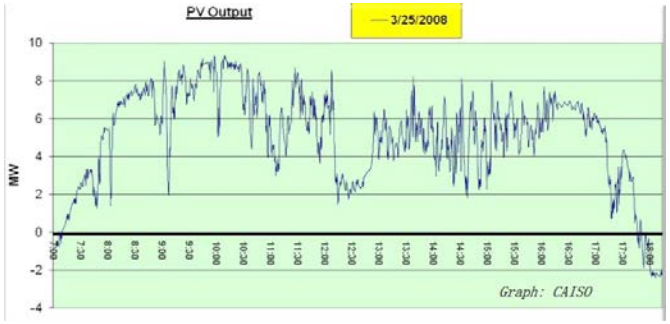
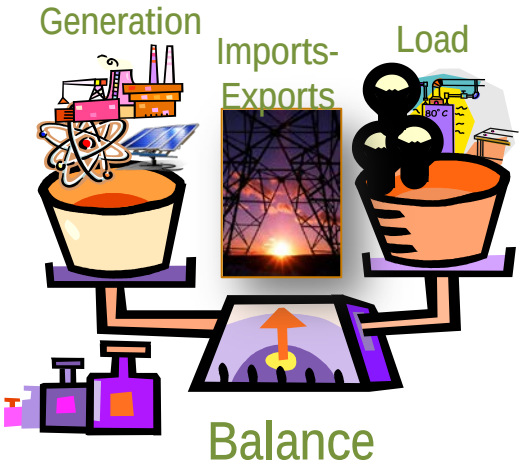
Grid Operations & Stochastic Generation

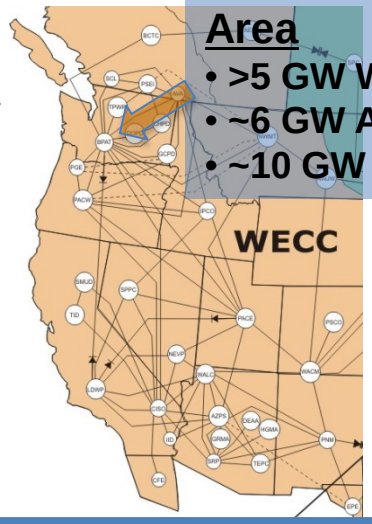


BPA Aggregated Wind (March 12-18, 2014)
Up to 500 MW Forecast error, 1 GW per hour ramp



Intermittent supply of PV for California ISO





BPA Balancing Area

- >5 GW Wind
- ~6 GW Avg. Load
- ~10 GW Peak Load

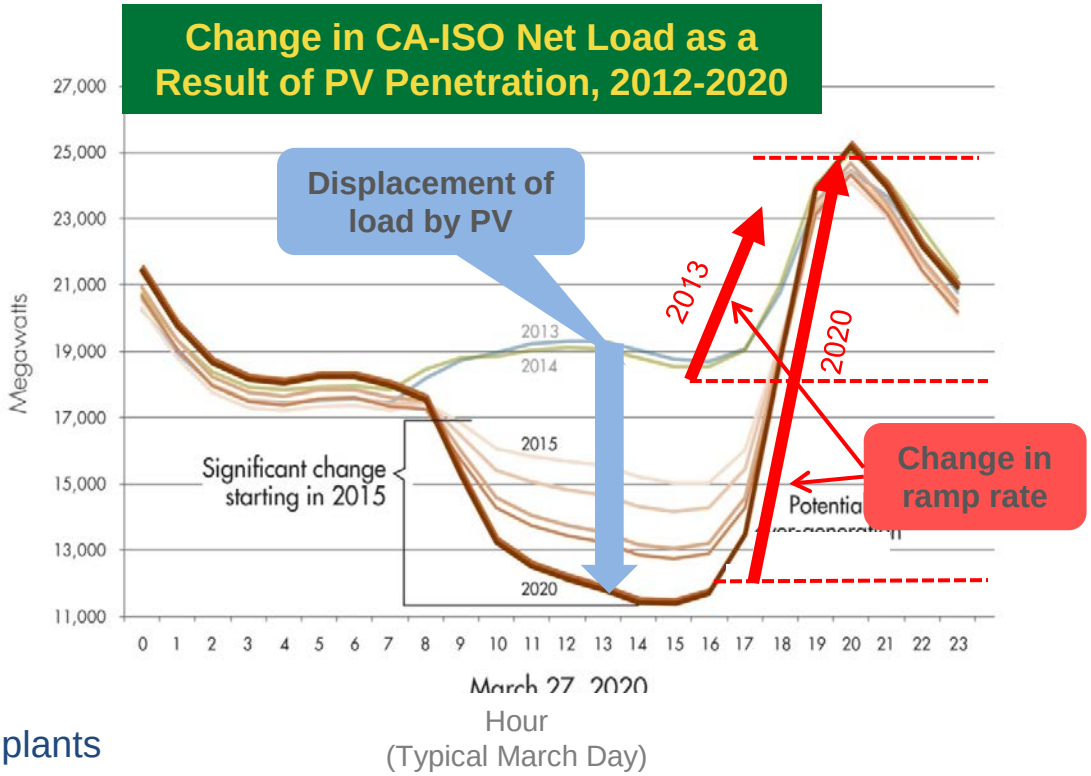
- Over-generation
- Congestion
- Markets for transmission rights
- Frequency ride-through capability
- Impacts on dynamics and stability
- Reactive power generation/voltage
- Coordinating System Protection Schemes,
- System balancing, reserve requirements, and frequency control;
- Dispatch of the remaining conventional units (e.g. more starts and cycling), and
- Transmission cost recovery and allocation

PV Penetration - creating operational challenges

Rapid PV penetration increasingly displaces mid-day loads over time

Challenges presented by PV penetration become barriers under business-as-usual operations

- Ramp rate (load change) at end of day expected to double
  - Rapid swings complicate dispatch – a challenge for reliability
  - Increased costs for more reserve power plants



- Rapid distribution system voltage swings from fluctuations in output (intermittently cloudy days) must be managed
  - Disruptive to electronics; when outside ANSI standard range can damage customer equipment
  - Voltage management gear will wear out – designed for ~10 operations/day now will see 100s
  - Who will pay for the upgrades or storage needed? Regular customers? PV owners?

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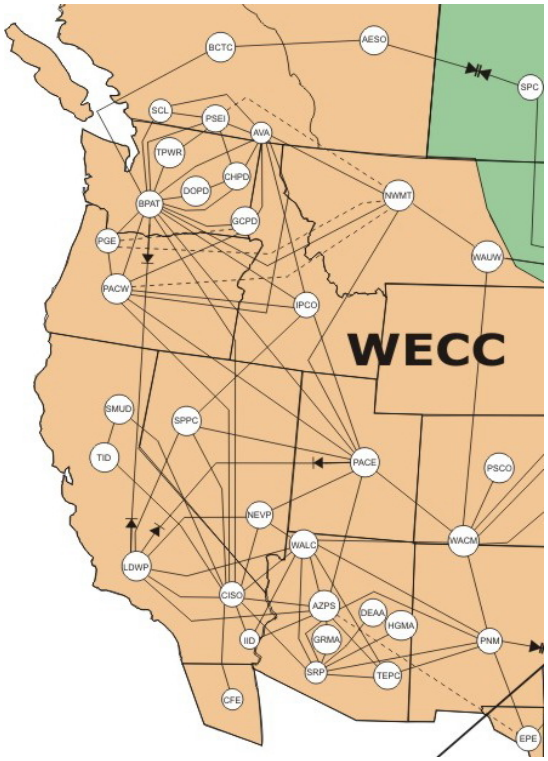
Coordination is Important

There are 37 BAs within the Western Interconnection, as wind and solar penetration in each BA increases, it becomes more challenging to operate individually



		11% Case		33% Case	
		Up	Down	Up	Down
Regulation Capacity, GW	Individual BAs	1.76	-1.82	3.65	-3.78
	CBA	0.74	-0.75	1.05	-1.09
	Savings in %	58%	59%	71%	71%
Regulation Ramp Rate, MW/min	Individual BAs	566	-597	962	-993
	CBA	138	-143	222	-220
	Savings in %	75%	76%	76%	77%
Load Following Capacity, GW	Individual BAs	12	-11	18	-18
	CBA	4.1	-3.9	5.2	-5.0
	Savings in %	64%	66%	70%	72%
Load Following Ramp Rate, MW/min	Individual BAs	356	-357	708	-715
	CBA	186	-190	245	-254
	Savings in %	48%	47%	65%	65%

Consolidation saves over $600M/yr

Simply going to 10 minute scheduling will save over $750M/yr

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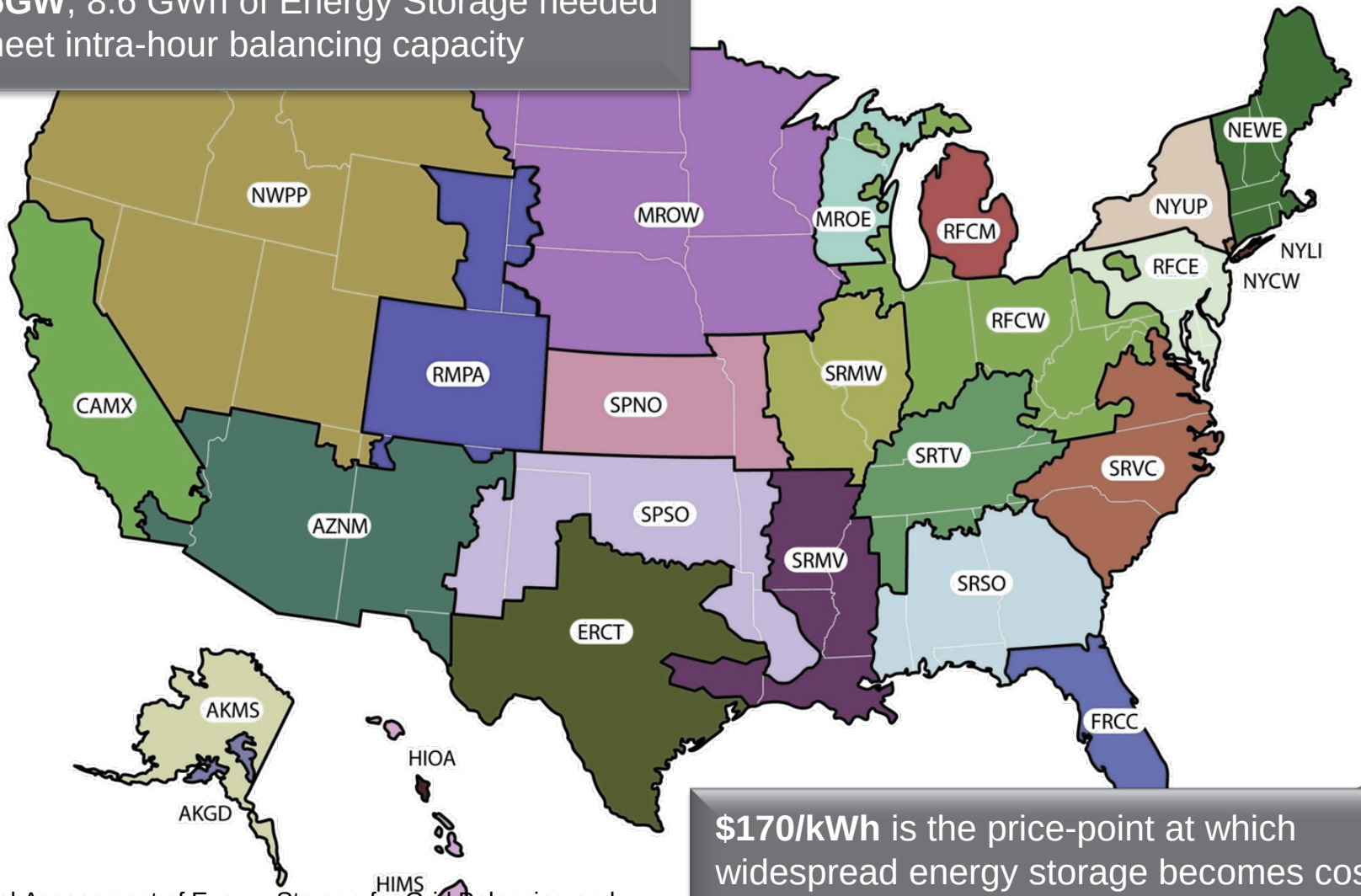
Intra-Hour Balancing
2020 Grid with 20% Renewable Portfolio Stds. (Wind)

18.6GW, 8.6 GWh of Energy Storage needed to meet intra-hour balancing capacity



$170/kWh is the price-point at which widespread energy storage becomes cost effective

National Assessment of Energy Storage for Grid Balancing and Arbitrage, Phase: II: WECC, ERCOT, EIC, Volume 1: Technical Analysis, PNNL-21388

Grid Scale Energy Storage

Smart Grid

Resiliency

Reliability

Asset Utilization

Renewable Integration

EV deployment

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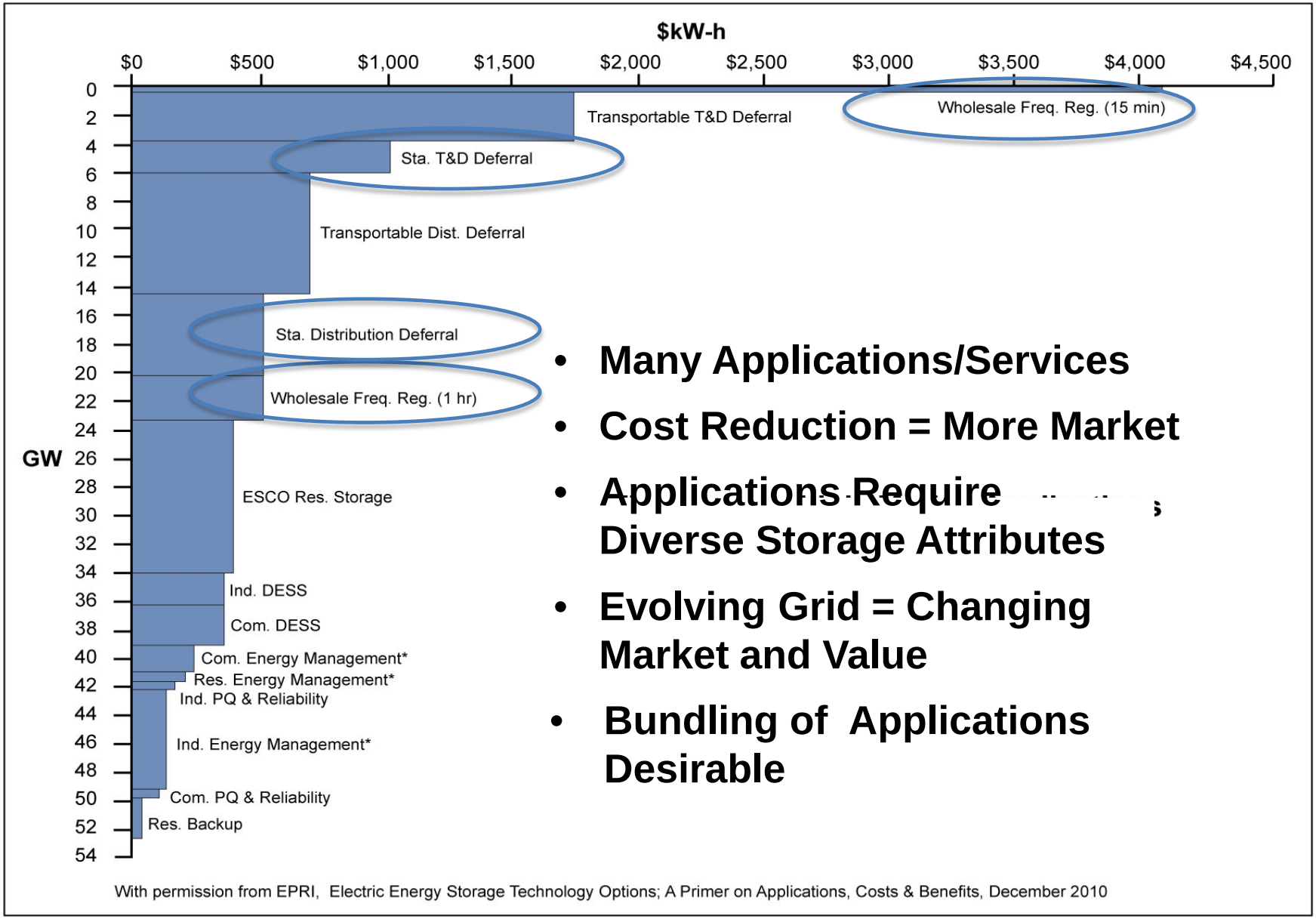
Grid Energy Storage Diverse Markets Encourage Bundling and Cost Reduction



- **Many Applications/Services**
- **Cost Reduction = More Market**
- **Applications Require Diverse Storage Attributes**
- **Evolving Grid = Changing Market and Value**
- **Bundling of Applications Desirable**

With permission from EPRI, Electric Energy Storage Technology Options; A Primer on Applications, Costs & Benefits, December 2010

Bainbridge Island Storage Analysis

Bainbridge Setup:

- 3 Substations
- 2 radial substations supply power for most of the island
- Substations are capacity constrained
- Reliability issues with radial transmission AND distribution

Proposed Solution:

- Add new substation to the island
  - Community opposition

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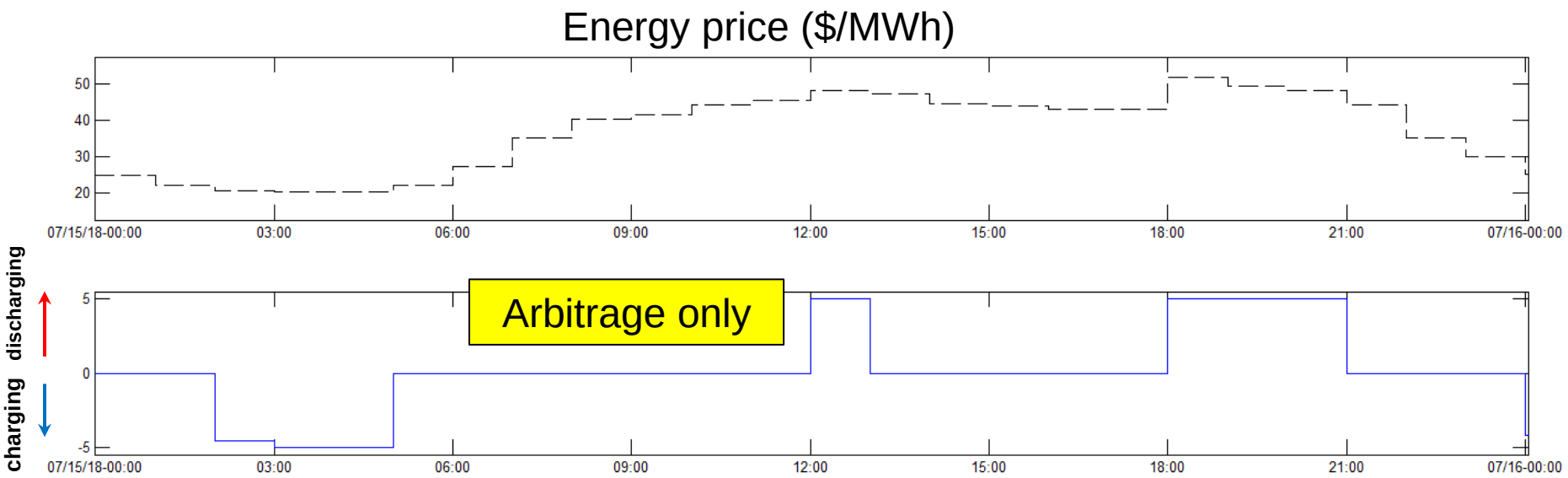
Bundling Services: how to do it optimally?



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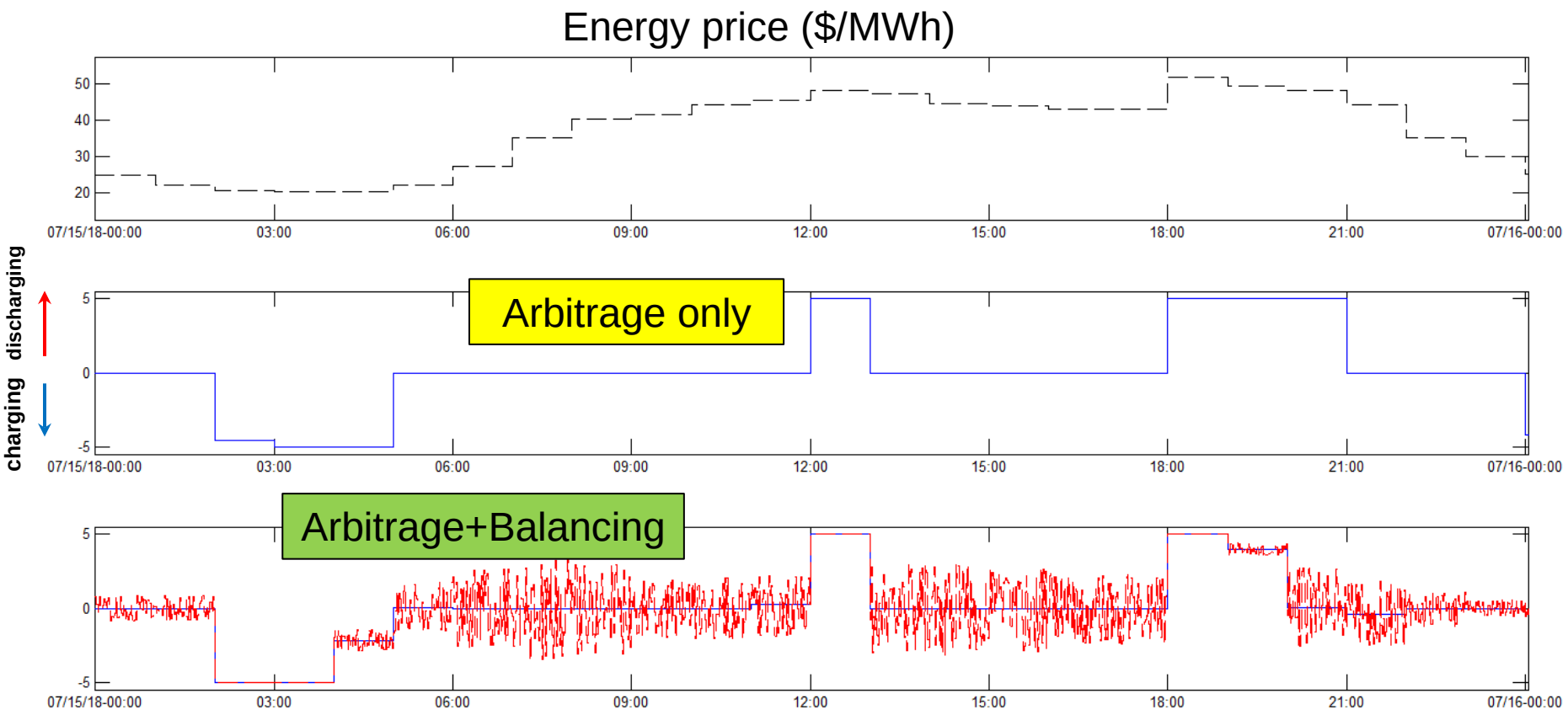
Bundling Services: how to do it optimally?



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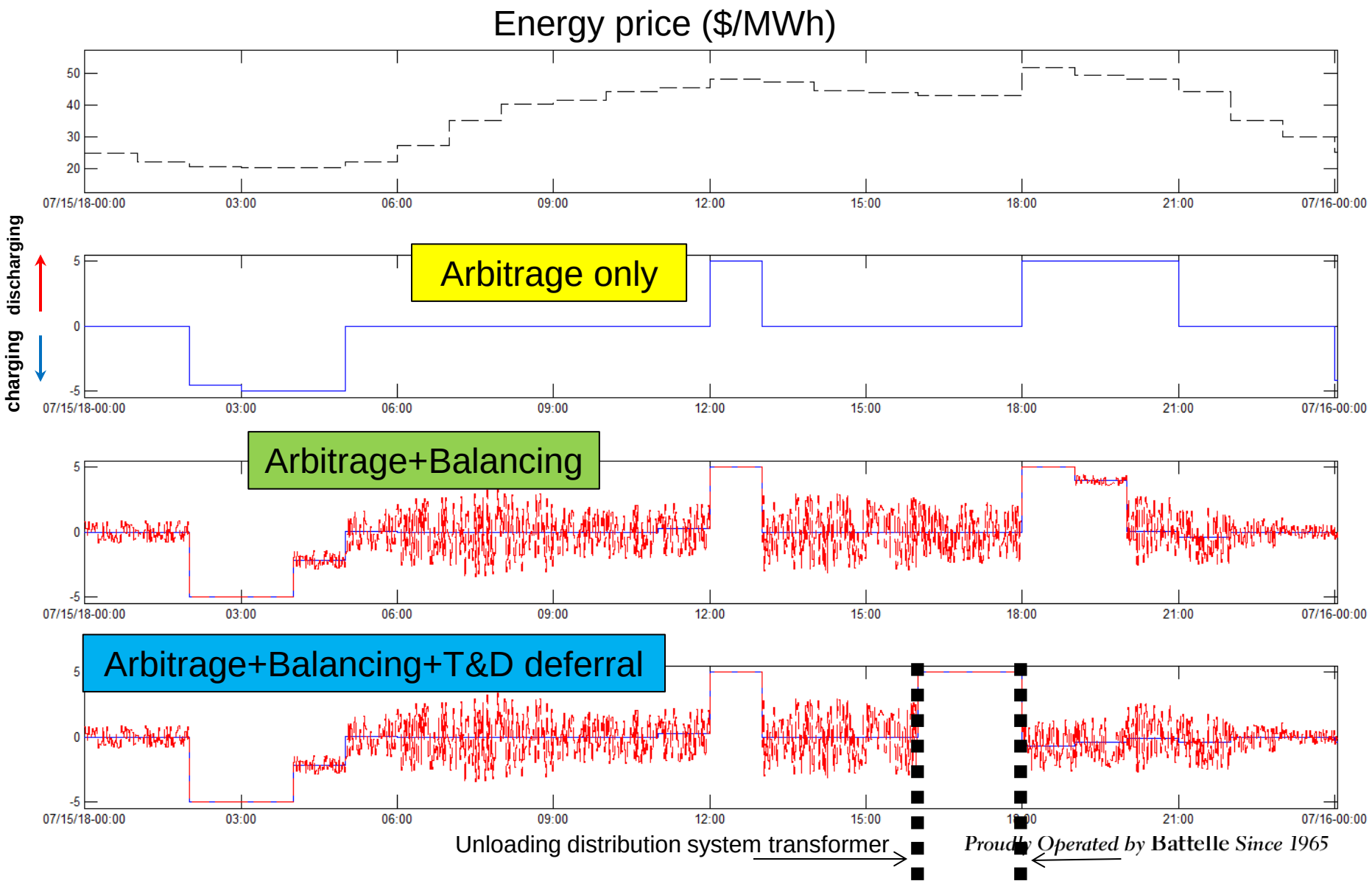
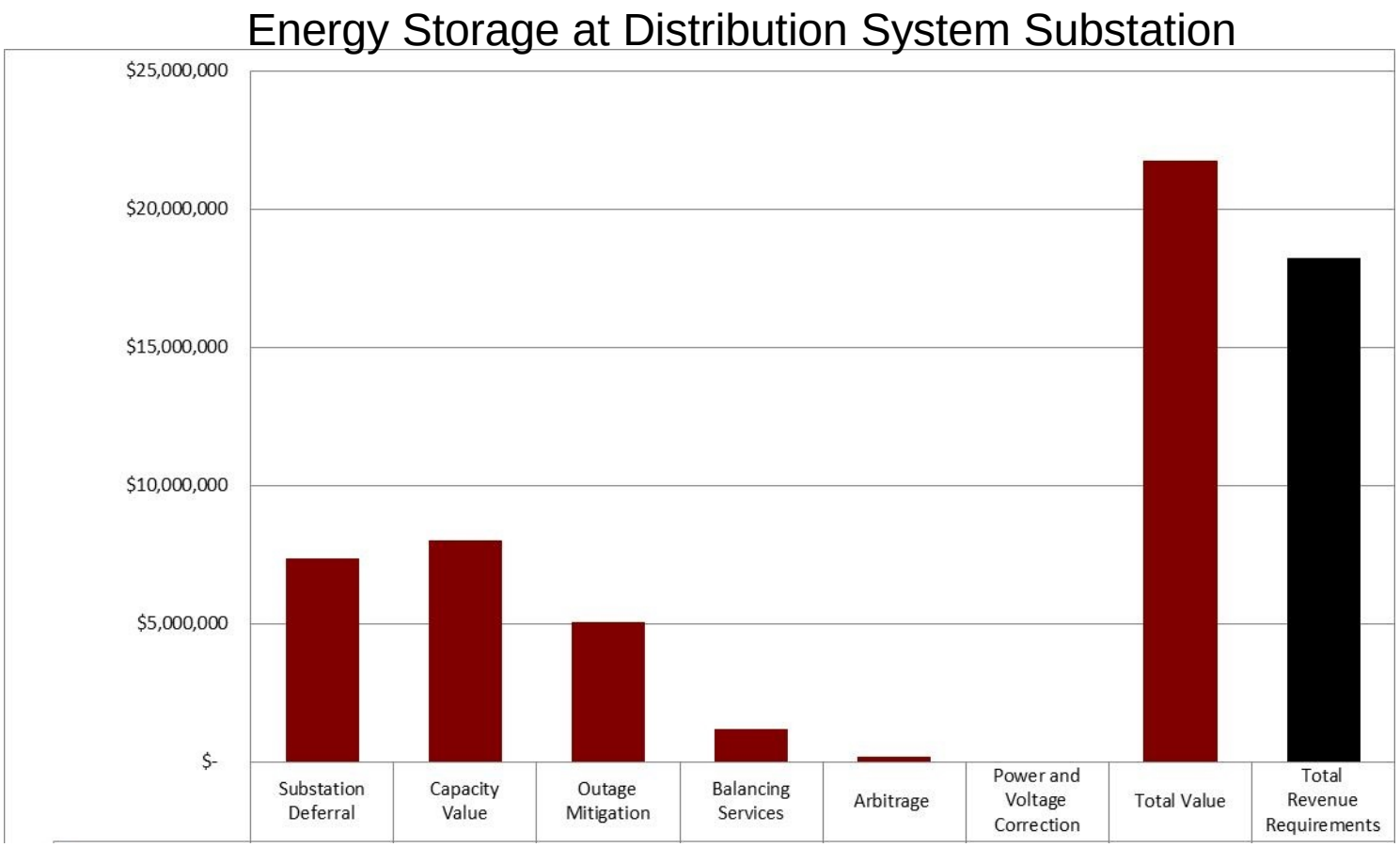
Bundling Services: how to do it optimally?



Total Value of Bundled Values

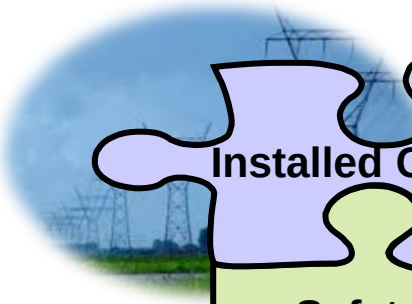


Only when 5 value streams are captured storage can be cost-effective requires: optimized control strategies to avoid double counting of resources

Grid Scale Energy Storage Chellanges

Smart Grid

Resiliency



llenges

- *npetitive storage technologies*
- *Reliability*
- **Validated reliability &**
- **regulatory ment**
- **Industry acceptance**
- *EV deployment*

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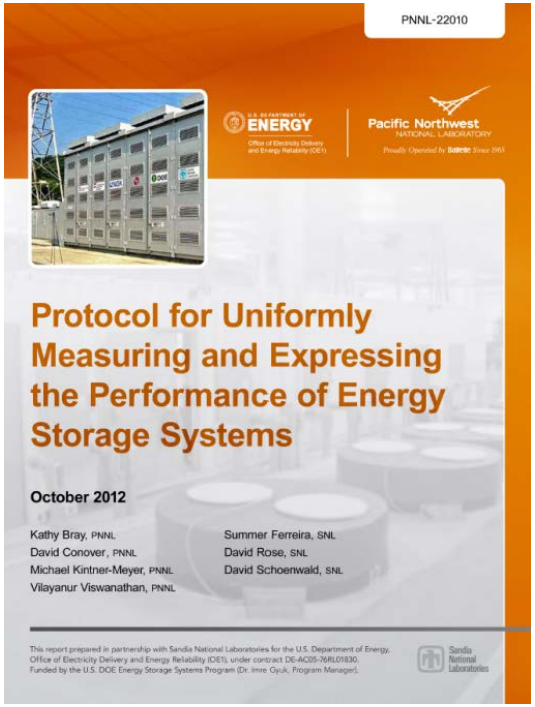
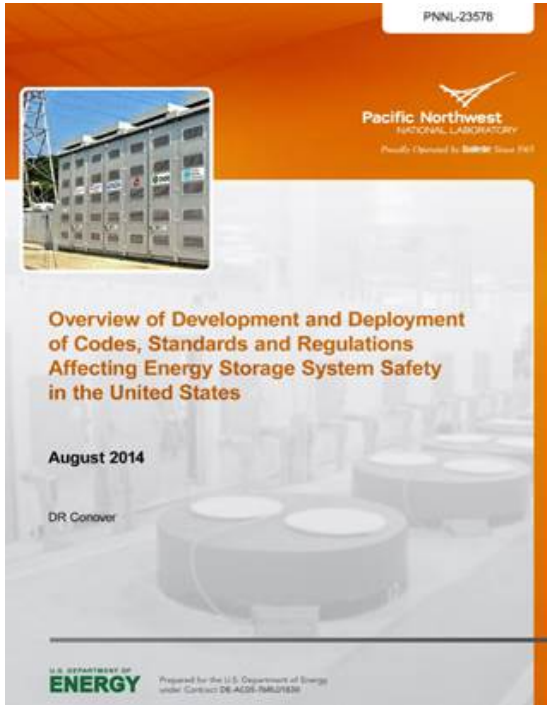
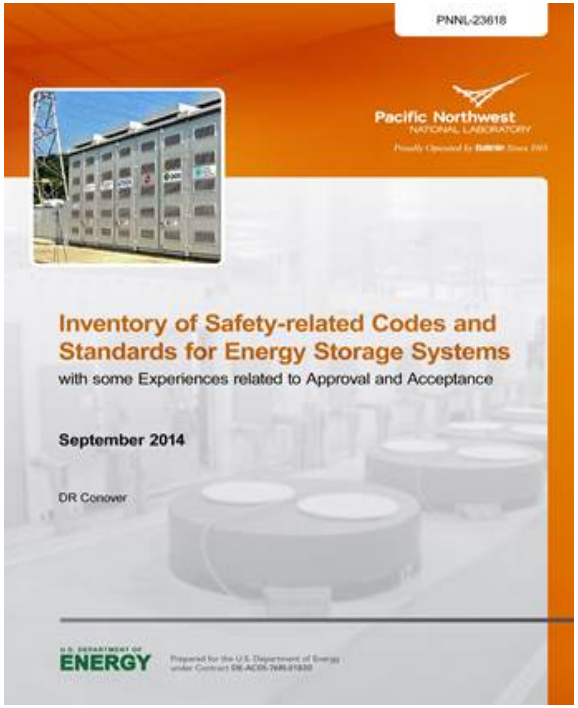
Codes, Standards and Regulations







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Summary

- Deployment of renewables generation increase the need for storage (and other sources of grid flexibility)
- Institutional and markets adapting to provide more flexibility – creating opportunity and challenge for storage
- Market projections for storage are dramatically up
- High storage system costs encourage realization of multiple storage benefits/revenue streams
- A number of challenges face widespread deployment of grid energy storage
- Storage industry and governments are responding to the challenge – new technologies, new incentives, maturing deployment

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