Long Duration Storage Value in Electricity Markets

Operations and Planning for High Renewable Futures

Aidan Tuohy, PhD
EPRI Grid Operations and Planning R&D Group
Lead, Bulk System Renewable Integration

ARPA-E Long Duration Storage
Dec 7-8, 2017

Title and Content

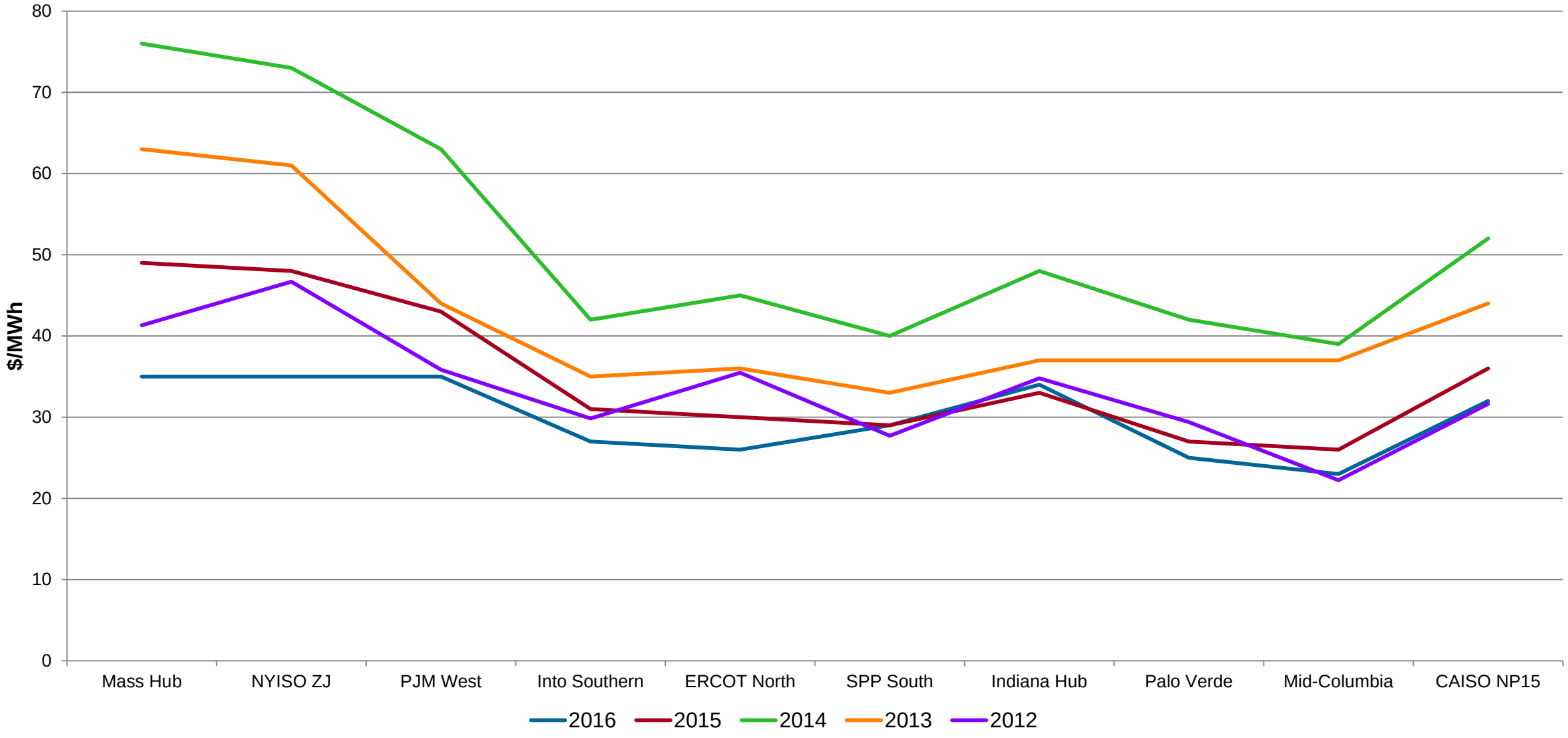
- Wholesale Electricity Markets and Energy Storage
  - Wholesale market operations
  - Current sources of value and remuneration
  - How markets operate energy storage
- Challenges with high penetrations of renewables
  - Need for flexibility
  - Market participant challenges
- Value of storage in future system
  - Modeling challenges
  - Survey of recent studies

Wholesale Market Operations and Energy Storage

Wholesale Markets – Common Functions

- Day Ahead Markets
  - Day Ahead Security Constrained Unit Commitment
  - In US: Nodal markets used in all ISOs
  - Procure Ancillary Services as Well as Energy (next slide)
- Hour Ahead Security Constrained Unit Commitment
  - Update based on new information
  - Quick starting generation can come online
- Security Constrained Economic Dispatch
  - Sometimes done hour ahead
  - Real time – 5 minute intervals
- Financial Transmission Rights
  - Form of hedging to ensure transmission congestion can be managed
  - Firms purchases financial rights to injection/consumption points
  - Longer time horizon – months or years
- Capacity markets
  - Not in all ISOs
  - Forward market for energy

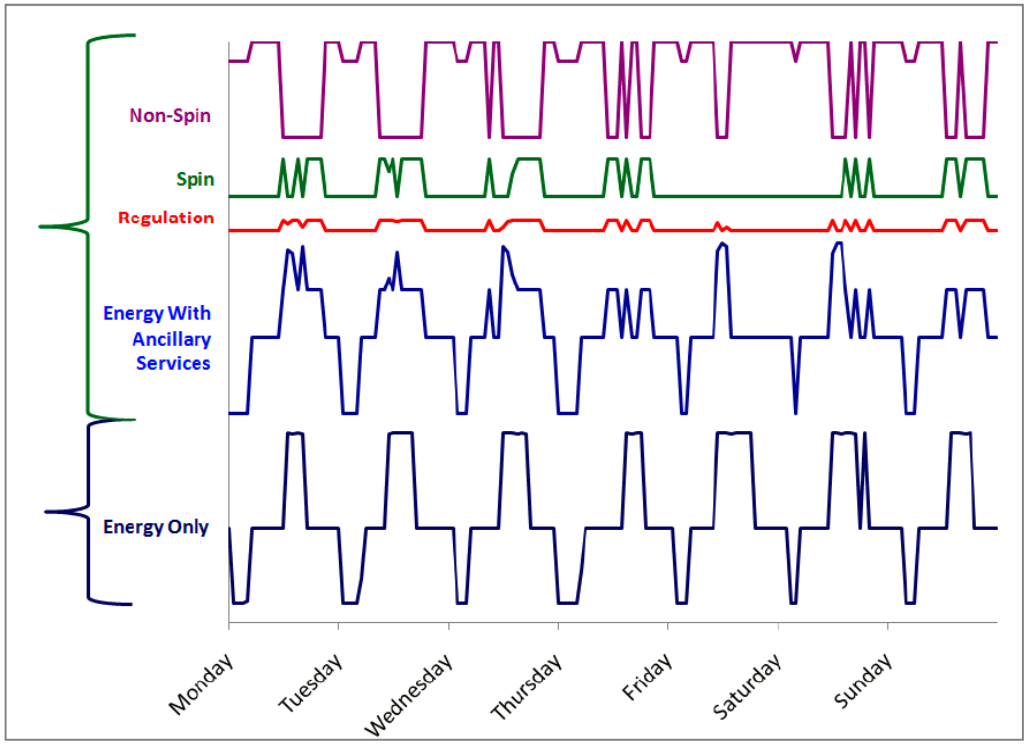
Wholesale market prices are decreasing



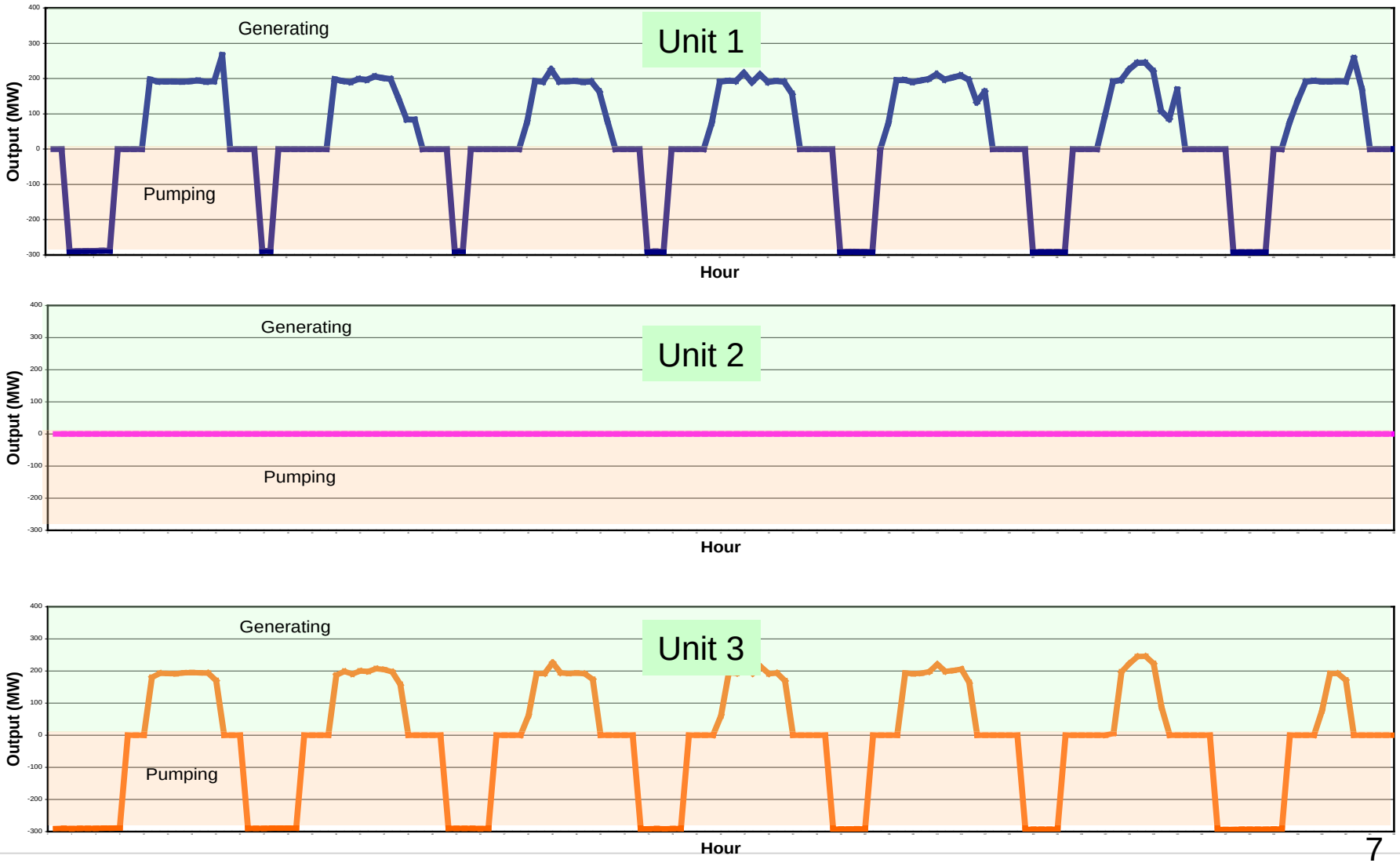
EPRI ELECTRIC POWER RESEARCH INSTITUTE

Energy storage in ISO markets - state of the art

- Most areas with pumped storage have ways that pumped storage can participate in various markets
  - Bid as a load resource to consume energy and provide non-spin reserve when in pump mode
  - Bid as a generator (similar to thermal plant) to provide energy, regulation, spin as a generator
  - Typically cannot bid as both in same hour
- Some areas have or are proposing/developing storage optimization models for pumped storage
  - PJM hydro optimizer, NYISO TEC, ISO-NE DARD pump
  - PJM is most advanced and implemented in DA market
  - Previous EPRI work showed increase in profits by of up to 80% if optimized versus fixed schedule
- Current discussions, including recent FERC Notice:
  - Are the current models for pumped storage sufficient?
  - Can the advanced pumped storage models be applied to limited energy storage (batteries), and if so what changes are required?
  - When is ISO management of SOC warranted
  - How can limited energy storage participate in other markets beyond regulation?



Helms Operation – Typical 1990-2010 Summer Week

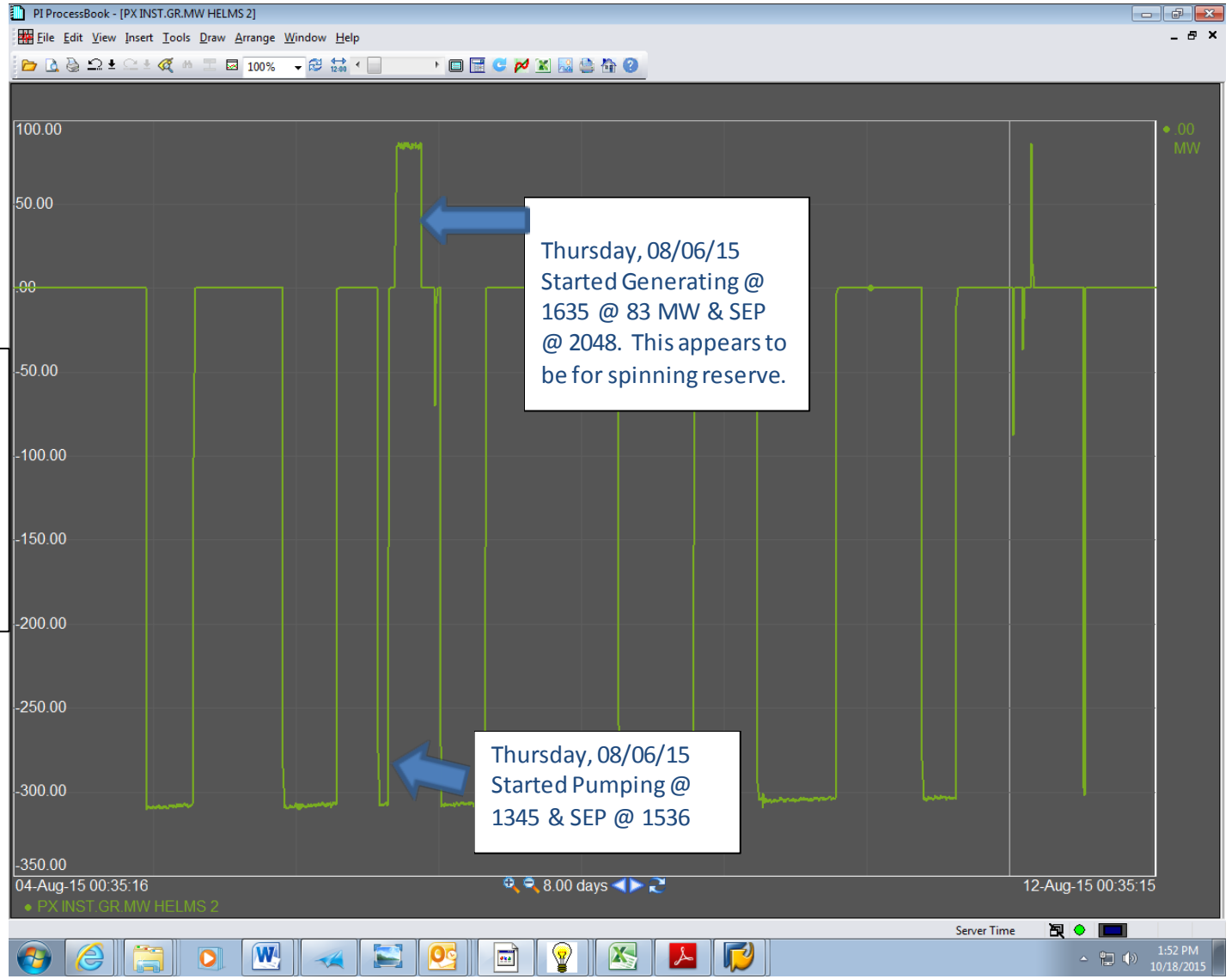


Courtesy PG&E

7

Preview of future - Helms Operation - Pumping Mid-day is Now Common

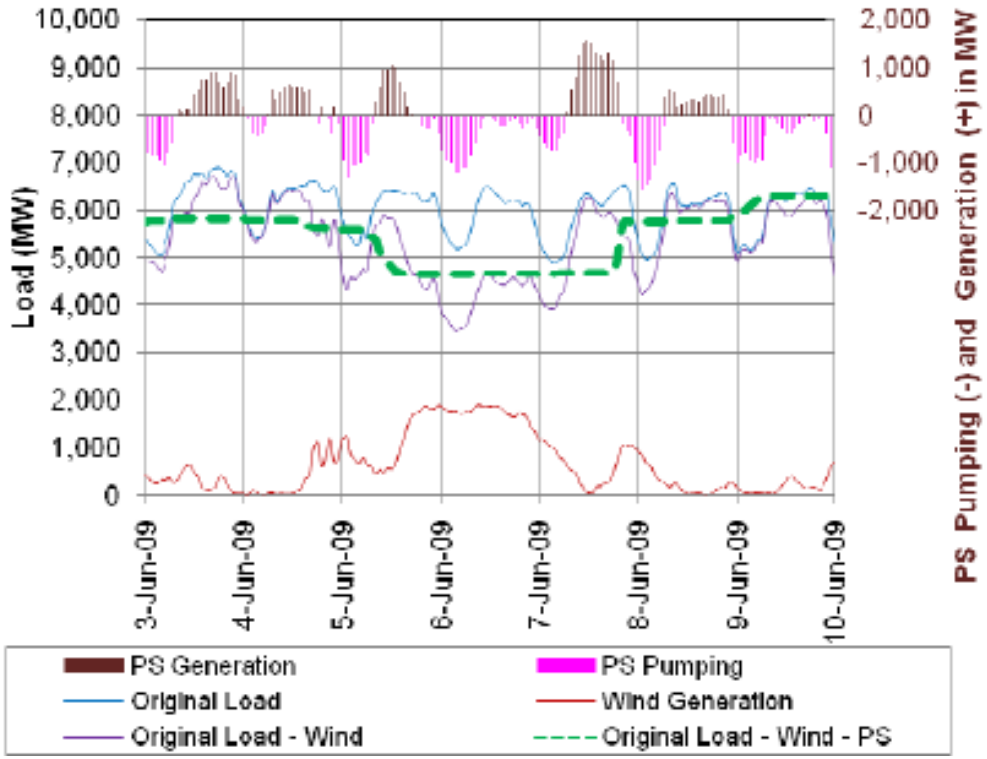
August 2015, Fresno area temp's in 90's



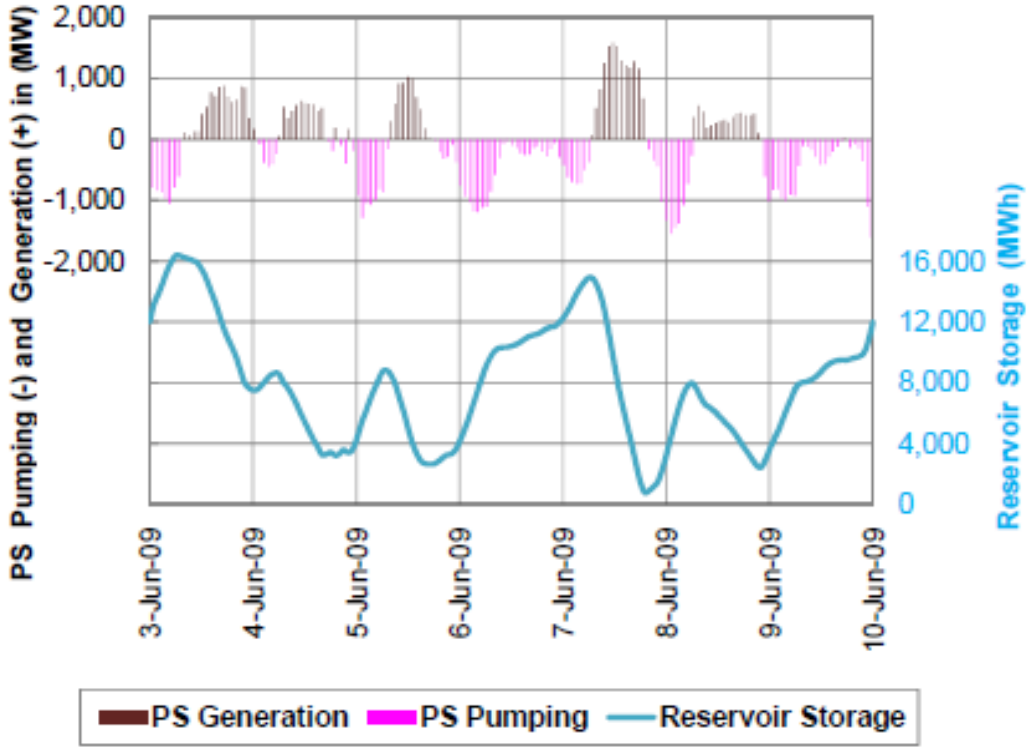
8

High Wind Penetration and Impact on Storage Operations

Pacific NW – one week of actual wind and load



Storage reservoir when managing wind



From “Technical Analysis of Pumped Storage and Integration with Wind Power in the Pacific Northwest: Final Report” by MWH Americas

Potential Changes in How Storage Is Treated in Markets and Operations

DOE-EPRI Hydro Value Project Recommendations

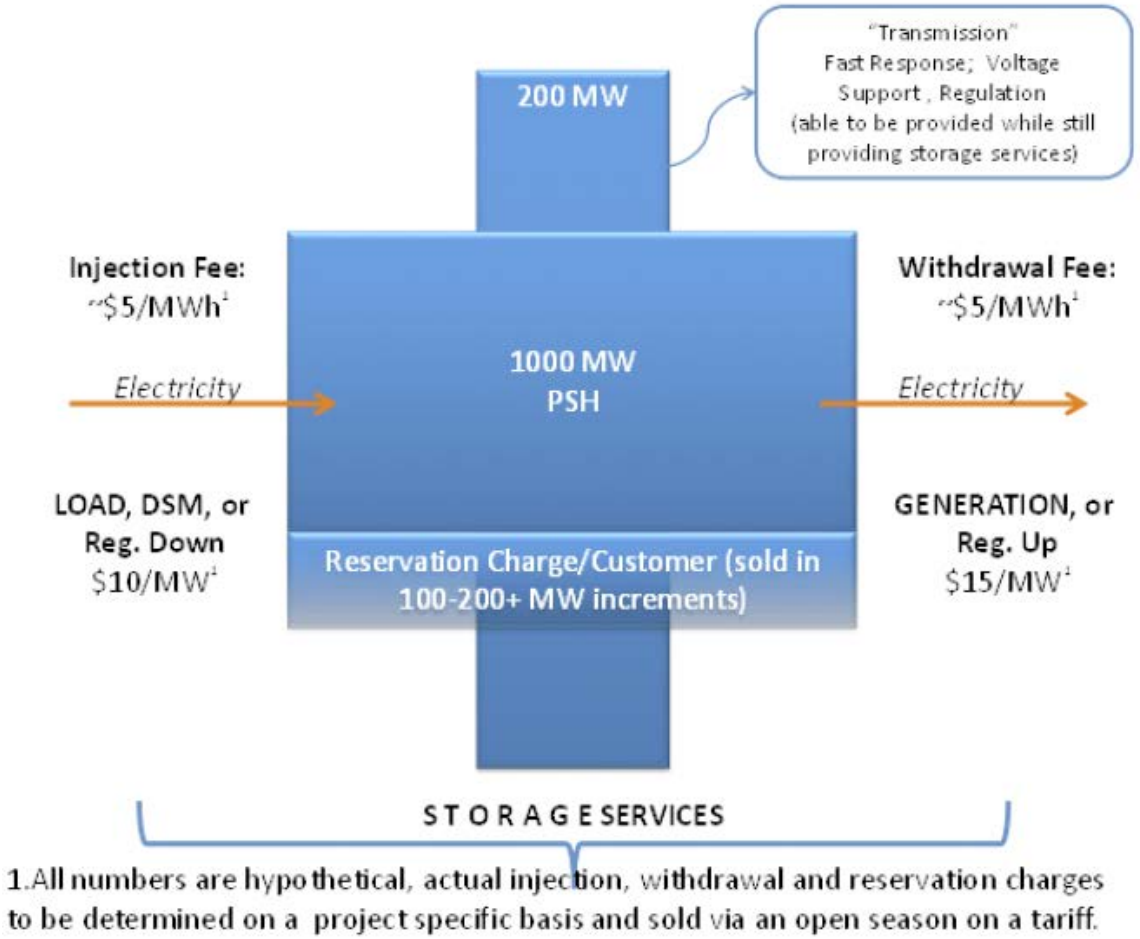
Operations

1. Identify and make efficiency improvements by modifying unit operations
2. Use hydro to address system variability, providing flexible reserves, reducing wear and tear on thermal fleet, and increasing efficiency
3. Recognize hydro for allowing generation diversity/options, enhancing energy security and maintaining reliability

Markets

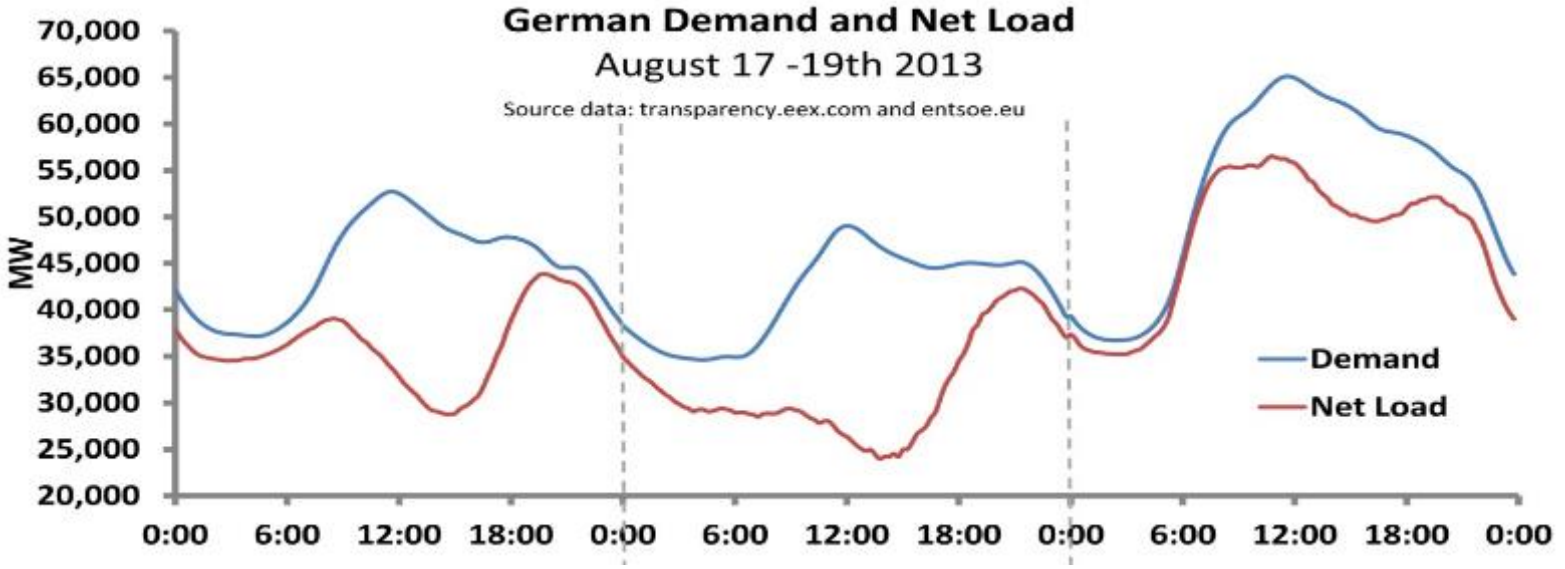
4. Settle energy markets sub-hourly, increasing arbitrage opportunities
5. ISO scheduling of hydro to co-optimize resources
6. Treat pumped storage as a storage asset class

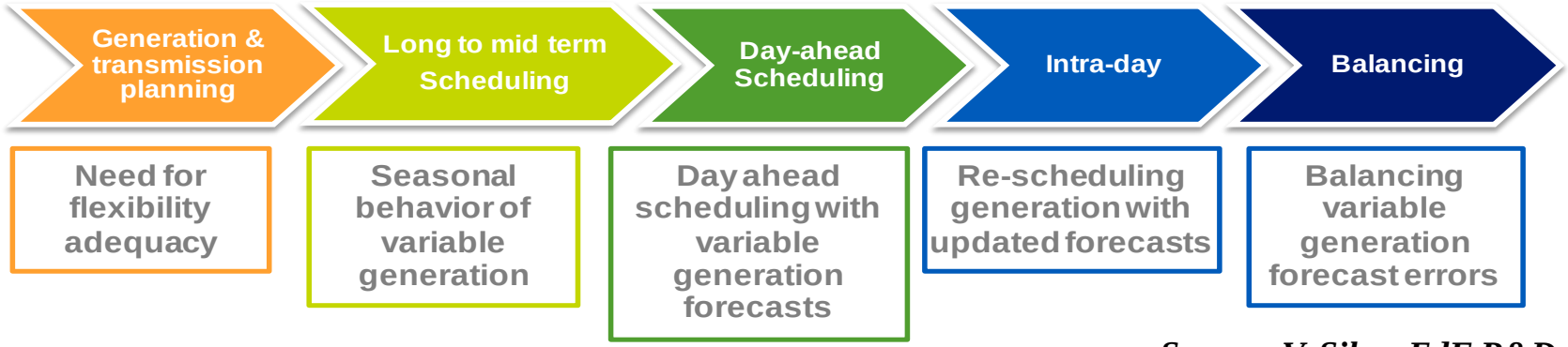
Potential Storage Asset Class



High Renewable Challenges

When do we need flexibility?



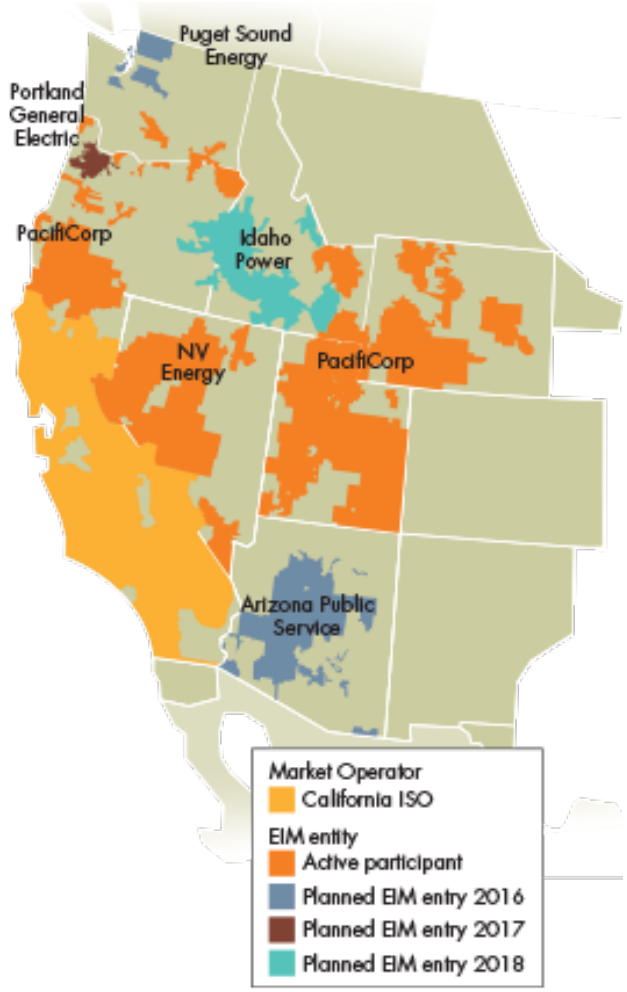


Source: V. Silva, EdF R&D

Need ramping capability for variability and uncertainty over multiple time periods
Both physical and institutional sources of flexibility are important

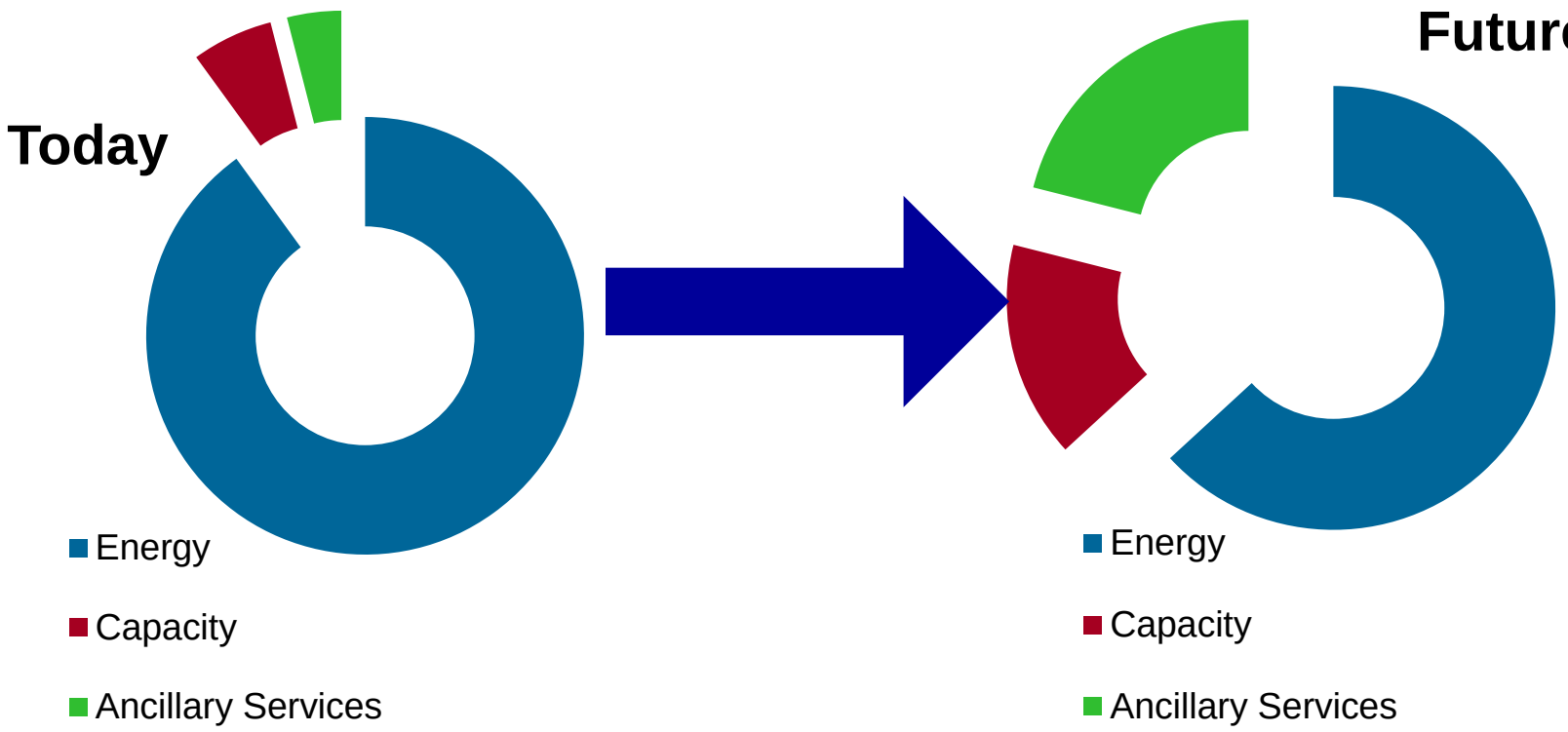
Impact of Variable Energy Resources on Electricity Markets

- Energy Markets
  - Low variable cost can reduce the average prices, and increase occurrences of zero or negative prices
  - Increased variability in energy prices - price spikes due to insufficient capacity or ramp
  - Greater disparity between prices of forward markets (DA) and real-time markets
- Ancillary Services
  - Increase the amount of operating reserve required and potential new reserves (flexible ramping)
  - Requirements change day to day, hour to hour, and forward to real-time
  - Appropriate valuation of essential reliability services will become increasingly important
- Uncertain power flows affecting financial transmission rights markets
- Increased coordination and cooperation → SPP, MISO, Western Interconnection, Europe
- Capacity markets may see increased value, particularly incentivizing flexibility



Significant changes in how markets value energy, capacity and ancillary services

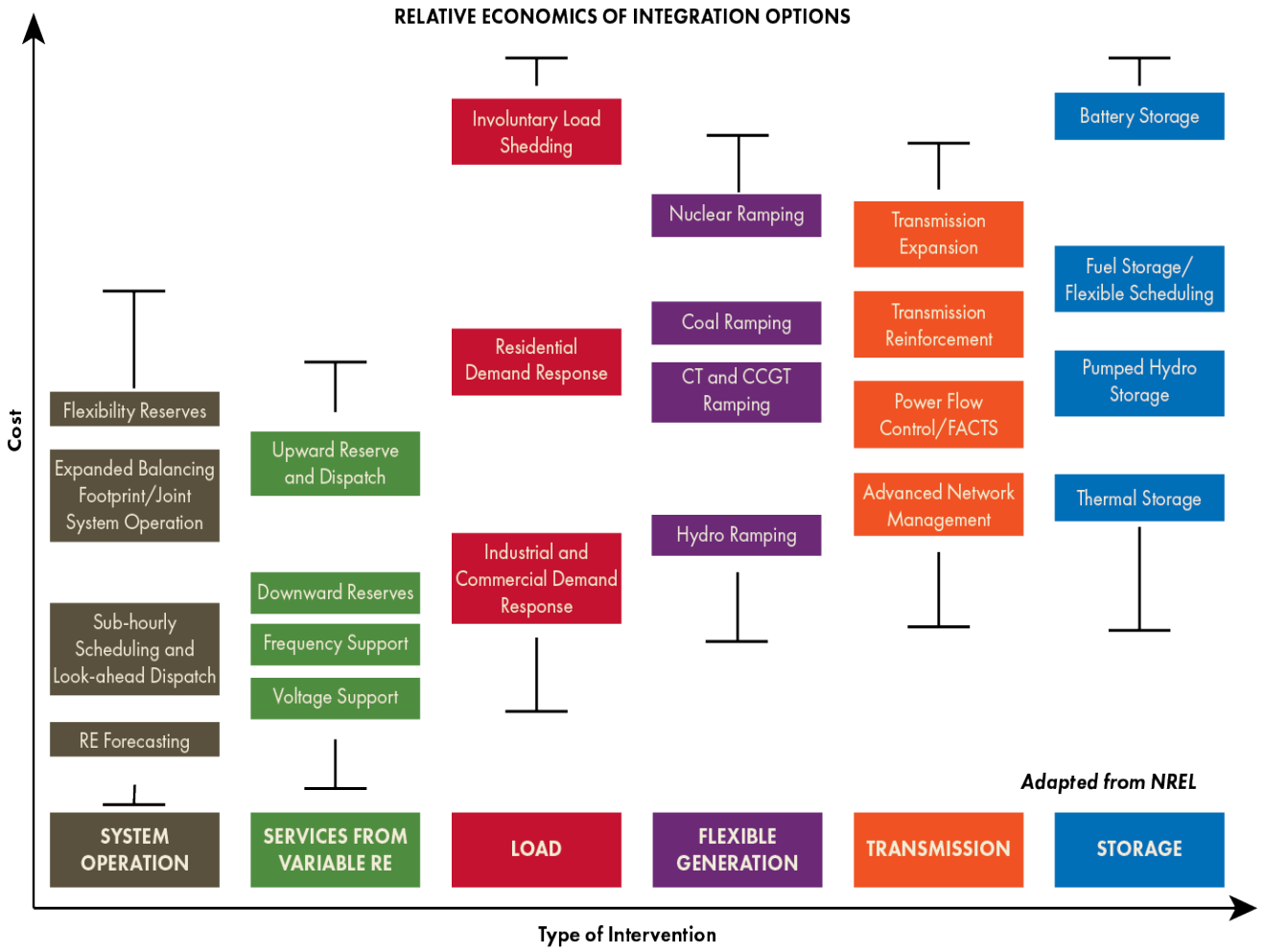
Market Evolution



Electric Power Research Institute, *Capacity and Energy in the Integrated Grid*, EPRI, Palo Alto, CA: 2015 Product 3002006692, Available: https://www.epri.com/#/pages/product/000000003002006692/

Flexibility Will Become More Valuable

- Increasing variability and uncertainty will require flexibility on all time scales and at different spatial scales
- Different resources may contribute
  - DER, storage and inverter based resources may provide some of the needed flexibility services
  - Retrofits and altered operational practices



Flexibility from storage, in whatever form it takes, can provide significant value

Long-term forecasts – major factors affecting storage value

- Long term energy future scenarios
  - Load forecast
  - Natural gas and coal fuel prices, possibly emissions costs
  - Penetration of renewable energy
  - Penetration of storage and other flexible resources

- Energy, capacity and ancillary services needs are all impacted and need to be considered

- EPRI surveyed a large number of storage simulation studies and categorize them:
  - Low penetration – less than 5% of peak demand
  - Medium penetration – 5% to 10% of peak demand
  - High penetration – greater than 10% of peak demand
  - White paper in early 2018

- These vary by whether storage capacity is developed endogenously in the simulation or added exogenously

Penetrations vary across regions → most studies analyze low/medium penetration

Potential Economic and Curtailment Benefits of increased duration of energy storage

- "California Energy Systems for the 21st Century" project on flexibility needs
  - Led by PG&E and SDG&E with EPRI, Astrape, LLNL
  - Study on California system using probabilistic production cost tool
  - Detailed modeling of operations
    High renewable penetration case (50% energy)

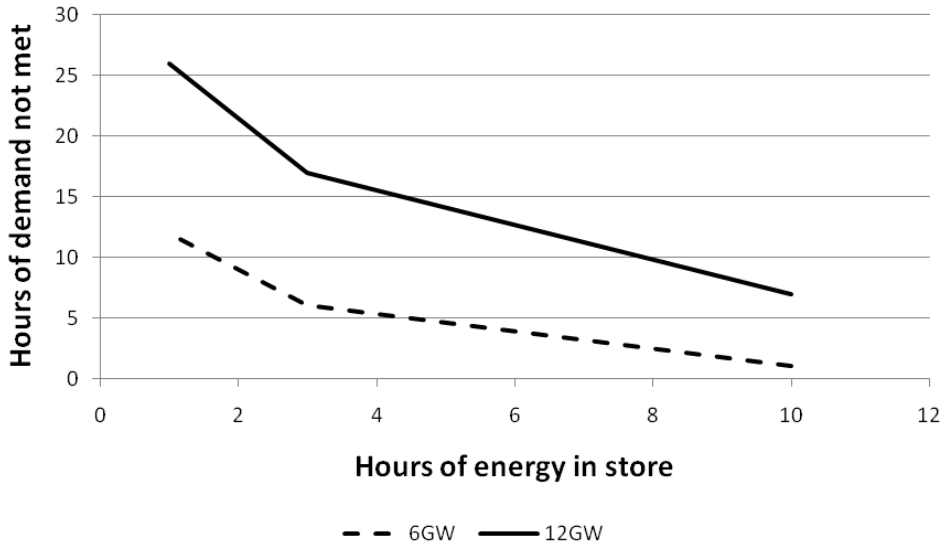
- With increasing storage capability (same capacity of storage), economic benefit decreases

- Shows potential value of flexibility may decrease with more energy storage – may have a 'sweet spot' that varies by system

- Previous work in Ireland showed benefits for system capacity when increasing hours of energy

Economic Sensitivity Studies[1]	Marginal Economic Benefit ($/kw-yr per incremental MWh of storage capacity)[2,3]	Marginal Curtailment Benefit (MWh curtailment reduction per incremental MWh storage capability)
0→2 HR Storage	24	133
2→4 HR Storage	16	103
4→6 HR Storage	8	58
6→8 HR Storage	2	6

1. Studies constructed by adding 1,000 MW of each duration type to the 50% RPS CES-21 Reference Case
2. Does not include any resource cost
3. Includes CAISO production cost benefits, net purchase cost benefits, and the economic scarcity rent.

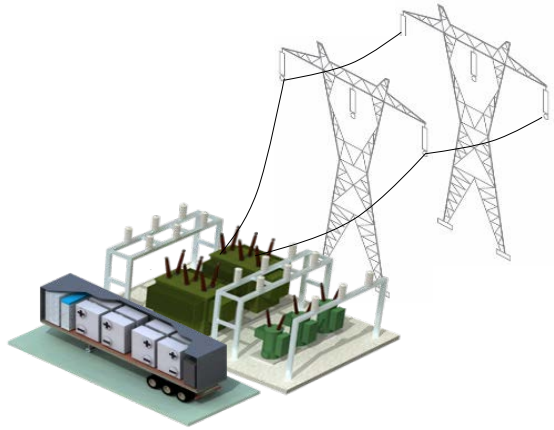


Source: "Pumped Storage in Systems with Significant Wind Penetration", Tuohy and O'Malley, Energy Policy, 2009

Energy Storage Integration Council (ESIC) Mission

To advance the integration of energy storage systems through open, technical collaboration

Currently ~1000 participants from utilities, energy storage suppliers, regulators, and the research community



Guided by EPRI's Public Benefit Vision…Practical Needs for Real Deployment

Started in 2013, by sponsorship of funders and advisors of EPRI's Energy Storage Program

More info on products and enrollment at www.epri.com/esic

ESIC Process and Work Products

Goal: Develop publicly-available guidelines and tools through industry collaboration

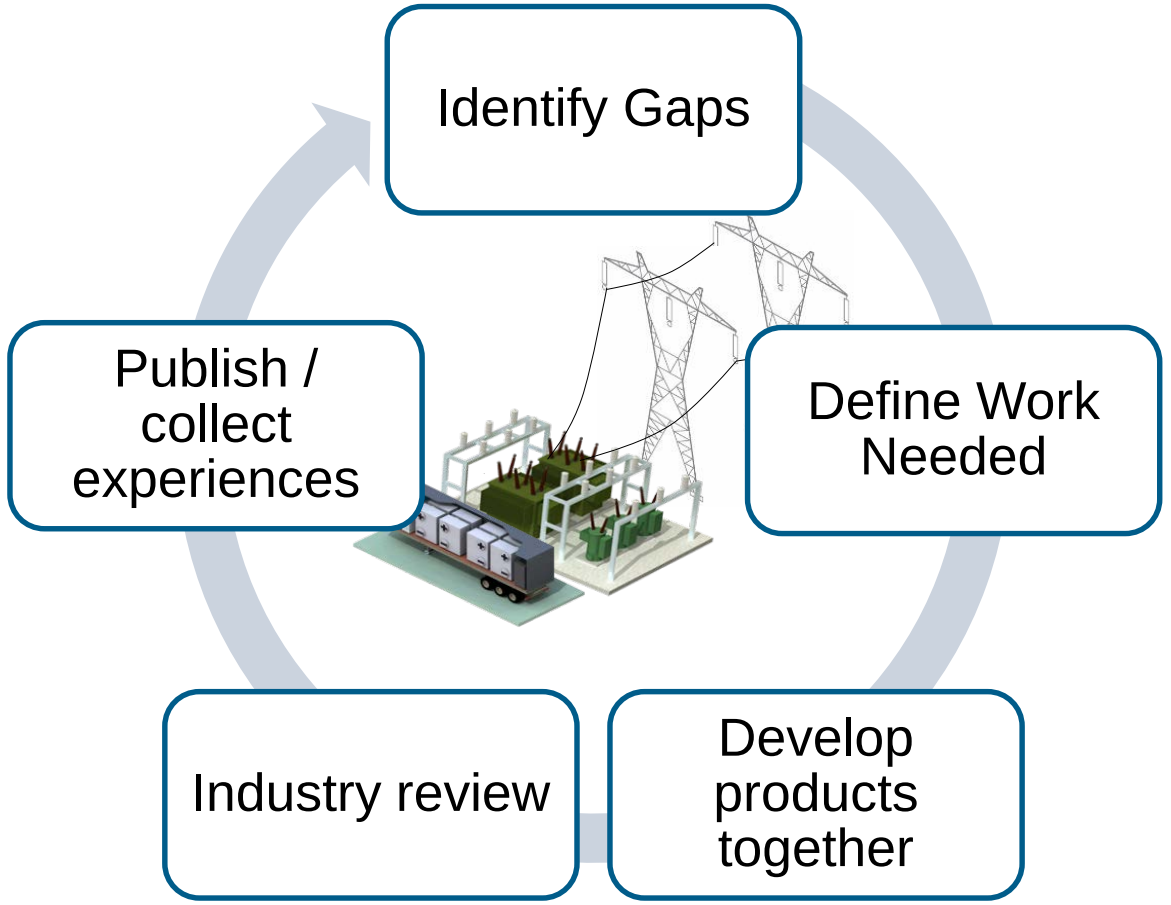
ESIC Published Resources

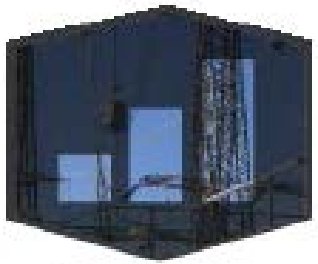
Energy Storage Cost Template and Tool: 3002006072

Energy Storage Safety: 2016 3002008308

Integration Guidelines for Energy Storage: 2015 3002006074

Seven (7) published products at ESIC website: www.epri.com/esic





Working Group 1

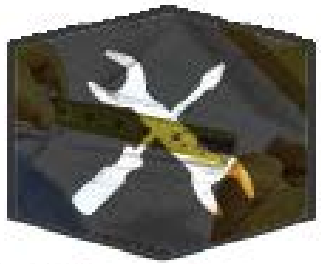
Grid Services and Analysis:

How to quantify value, cost and impacts

Working Group 2

Testing and Characterization:

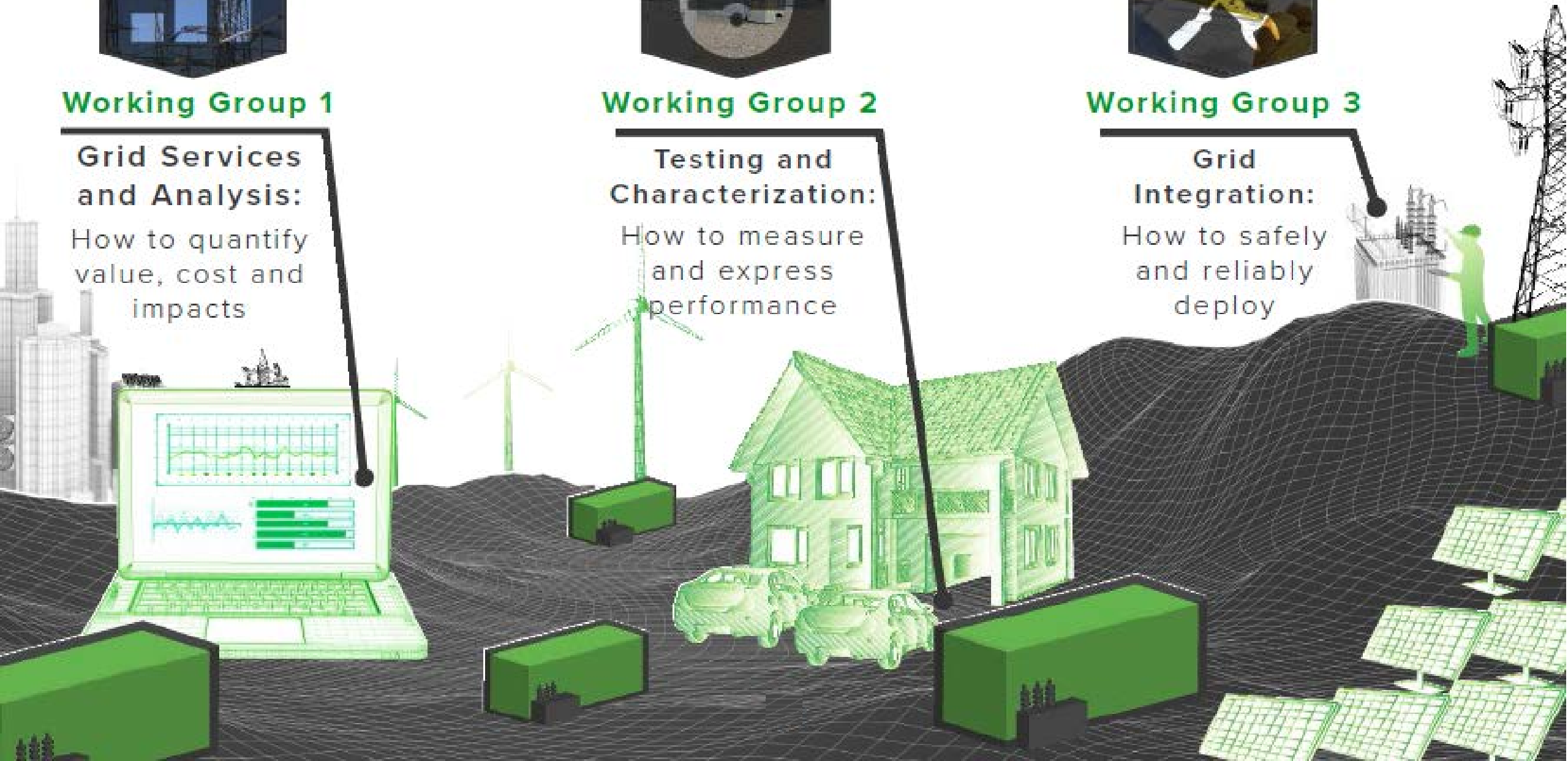
How to measure and express performance



Working Group 3

Grid Integration:

How to safely and reliably deploy



Summary and Conclusions

- Large range of potential value streams for long duration storage in wholesale markets, with significant experience in pumped hydro
- Most current markets moving towards recognizing the value and more efficiently integrating storage, but many don't optimize storage
- Some value for longer duration currently, but mostly due to portfolio/utility operations rather than direct market value
- High renewable penetrations will increase value of flexibility → at first in short time scales, but longer time scales will eventually see increased value
- Capacity contribution of long duration storage to help during periods of low wind/solar may have significant value

EPRI white paper with detailed survey on current and future storage value – Q1 2018

Together…Shaping the Future of Electricity

References

- *Quantifying the Value of Hydropower in the Electric Grid: Final Report.* EPRI, Palo Alto, CA: 2013. 1023144.
- *Energy Storage in Planning, Operations and Wholesale Markets,* EPRI, Palo Alto, CA: forthcoming (Q1, 2018)
- *Technical Analysis of Pumped Storage and Integration with Wind Power in the Pacific Northwest: Final Report.* MWH Americas, August 2009
- *Helms Pumped Storage Project,* David Moller, Pacfici Gas and Electric Company, Oct 2015
- *Energy Storage in Systems with Significant Wind Penetration,* Tuohy and O'Malley, Energy Policy, 2010
- *Wholesale Electricity Market Design Initiatives in the United States: Survey and Research Needs.* EPRI, Palo Alto, CA: 2016. 3002009273.
- *Metrics for Quantifying Flexibility in Power System Planning.* EPRI, Palo Alto, CA: 2014. 3002004243