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Assigning Value to Services Offered by Fuel Cell Technologies in Multiple Markets

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H2@Scale R&D Consortium Kick-Off / Workshop
Chicago, IL
August 1, 2018

DISCOVERY *in Action*

U.S. DEPARTMENT OF ENERGY

Taxonomy of Energy Storage Services

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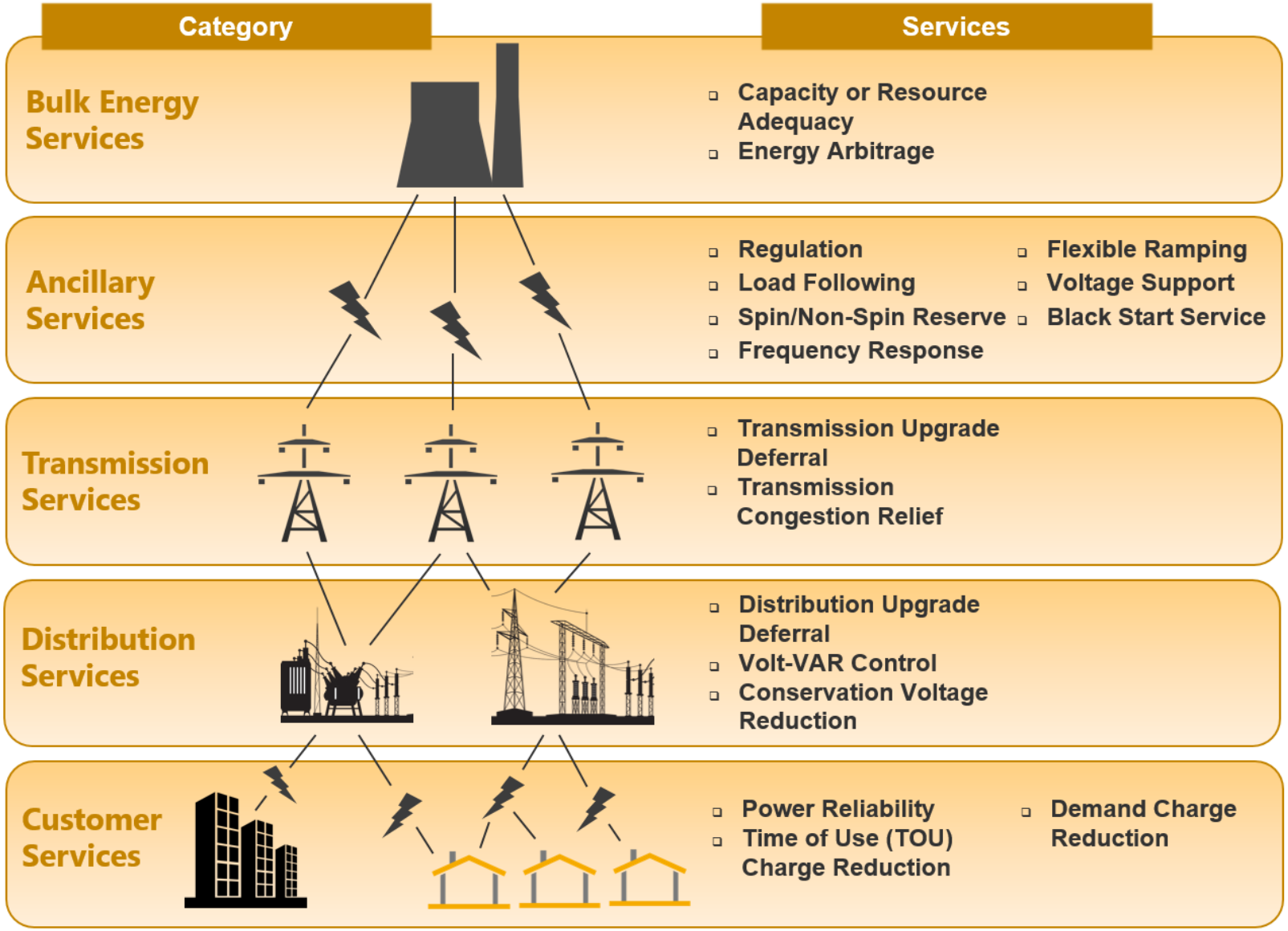

Energy Storage Holds Tremendous Value

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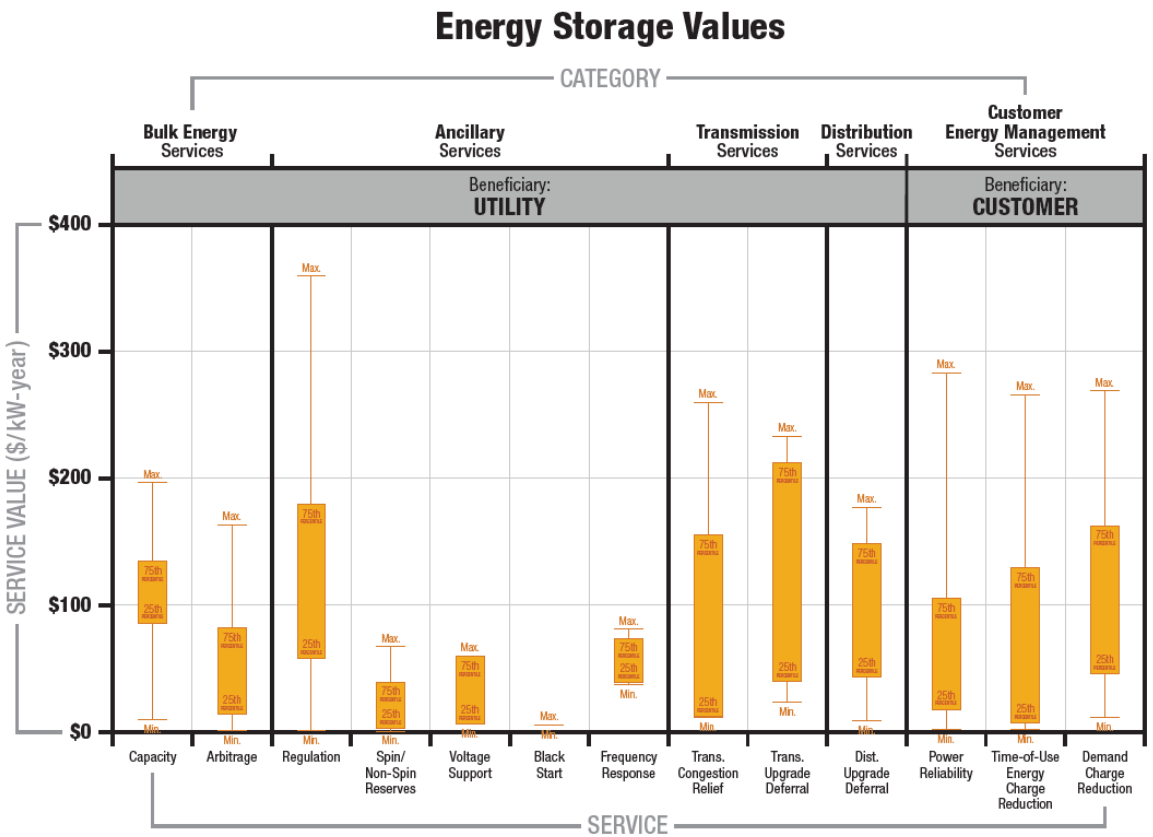
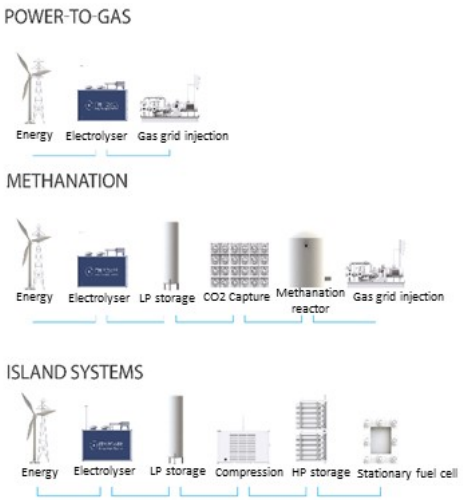


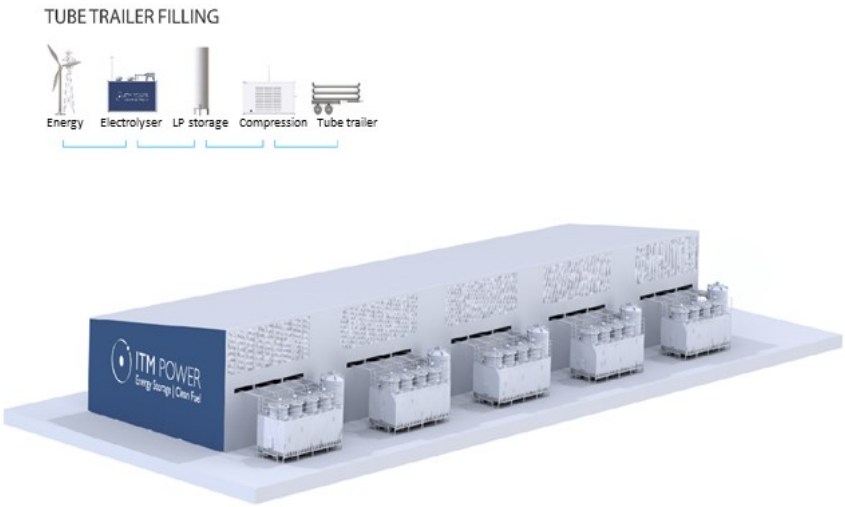
Key Lesson: The value of distributed energy resources accrue at multiple levels of the electric grid and there are no existing tools with all the required features to fully capture these values.

Source: Balducci, P., J. Alam, T. Hardy, and D. Wu. 2018. Assigning Value to Energy Storage Systems at Multiple Points in an Electrical Grid. Energy Environ. Sci., 2018, Advance Article. DOI: 10.1039/C8EE00569A. Available online at http://pubs.rsc.org/en/content/articlelanding/2018/ee/c8ee00569a#!divAbstract.

Defining P2G System, Capabilities, and Use Cases

ENERGY STORAGE SOLUTIONS





- Use Cases
  - Sale of hydrogen as a renewable gas delivered via the natural gas grid
  - Hydrogen as a renewable natural gas component used for the acquisition of renewable energy credits
  - ISO-NE and utility-level demand response
  - Regulation services
  - Fuel for fuel cell electric vehicles
  - Industrial gas

Battery Storage Evaluation Tool (BSET) Used to Perform Optimization

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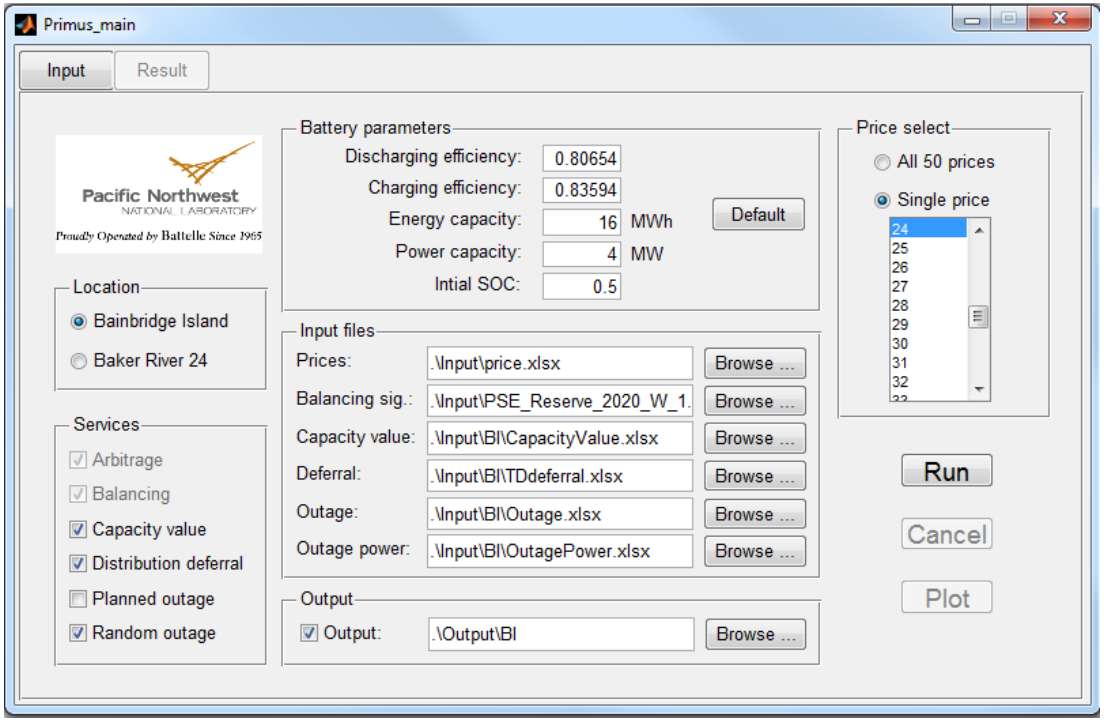
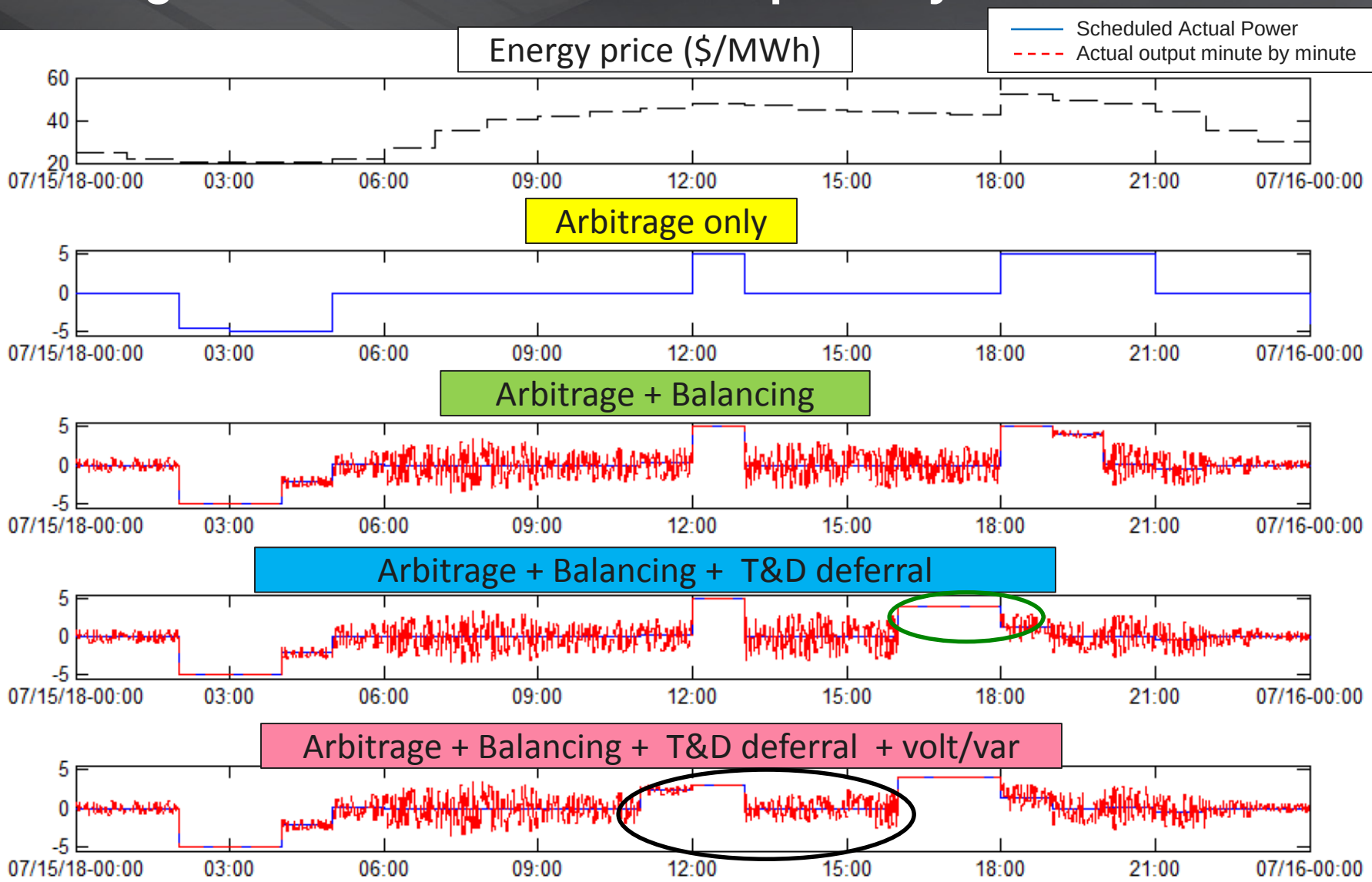


- There are losses associated with charging/discharging operations, which are modeled and considered in the optimal scheduling formulation in order to obtain the maximum obtainable value to the grid or profit

- BSET is used to run a one-year simulation of storage operations
- The formulation considers the different operation modes of the storage system and its operational characteristics
- Increasing discharging power for one energy service decreases the battery's capability for other services
- Data files are linked through a simple interface
- The primary outputs of the model are the value of each service and the optimal number of hours the storage system would be engaged in the provision of each service

Bundling Services: How To Do It Optimally



Example Project - Shell Energy North America (SENA) Small, Modular Pumped Storage Hydro – Market Assessment

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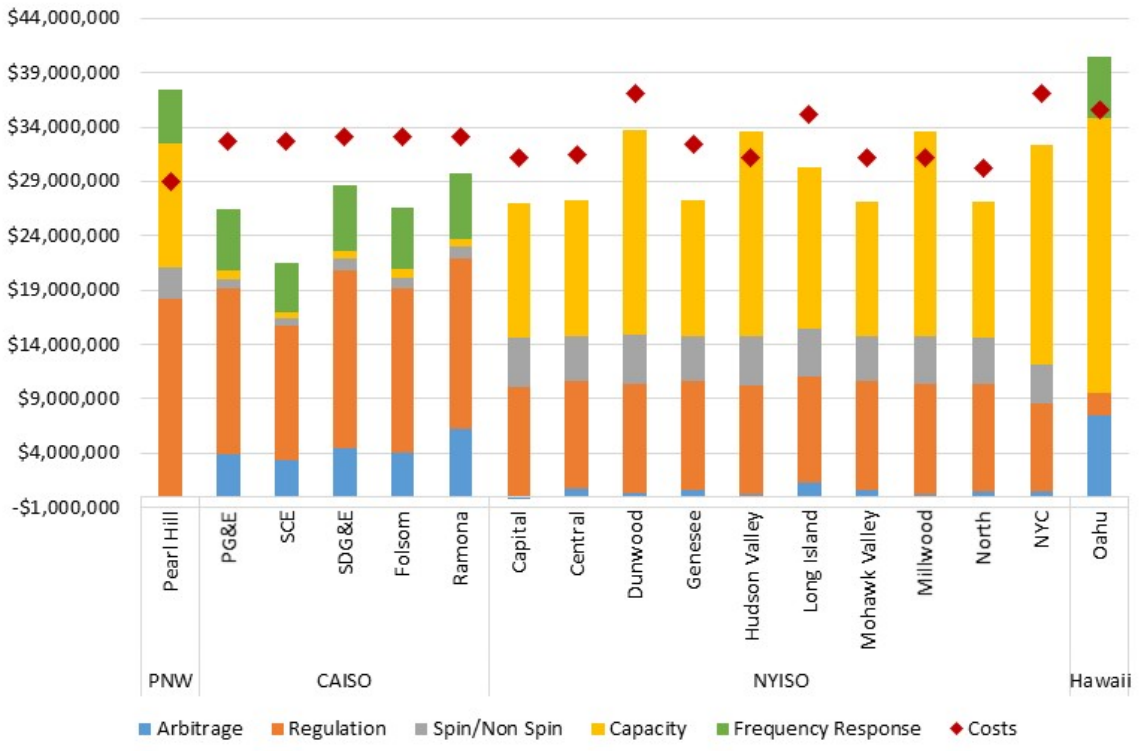
- SENA hydro battery costs are roughly comparable to those in the marketplace for electro-chemical batteries at $743/kWh
- Several hydro battery characteristics outlined by SENA are tremendously valuable
  - the ability to act as load and generation
  - the ability to follow a regulation signal
  - the ability to provide 14 MW of regulation up/down capacity
  - the spinning reserve mode enables grid synching to improve project economics



- Benefits exceed costs under the base case in the Pacific NW, Hawaii, and two NYISO regions. Under the mature cost method, positive benefit-cost ratios are obtained in all regions with the exception of one CAISO sub-region
- Economic viability of the SENA hydro battery is highly dependent on locational factors
- Regulation, capacity, and frequency response are the most valuable use cases

New Tools and Business Models are Required to Monetize and Capture Energy Storage Benefits for Multiple Grid Applications

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- Challenge - Over 3,000 utilities
  - Different grid reliability, resiliency, flexibility, renewable integration challenges
  - Different market structures and cost of electricity
  - Other competing solutions besides energy storage
- What is needed
  - New tools to evaluate services that extend beyond electrical grid services
  - Requires regional and local analysis of deployed storage technologies in diverse markets to develop full understanding of monetized and un-monetized benefits
  - Development of industry standard design tools with fidelity to capture the multi-use value of storage in transmission, distribution, and behind-the-meter applications
  - Development of models to characterize and predict storage system performance, and to assess degradation
  - Development of control algorithms and tools to evaluate dispatch controllers
  - New business models