Energy Storage Systems Analyses

Challenges and Complexities

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What is Systems Analysis (SA)

Boundaries define the system, methodology defines the analysis

What is Systems Analysis?

"A system is a cohesive conglomeration of interrelated and interdependent parts that is either natural or man-made. Every system is:

- delineated by its spatial and temporal boundaries
- surrounded and influenced by its environment
- described by its structure and purpose or nature
- expressed in its functioning
- can be more than the sum of its parts if it expresses synergy or emergent behavior

Changing one part of the system usually affects other parts and the whole system, with predictable patterns of behavior."

Systems Science—an interdisciplinary field that studies the nature of systems

Systems Analysis—the branch of systems science that analyzes systems, the interactions within those systems, and/or the interactions with environments

INCOSE | WSRC Western States Regional Conference

Source: Drewien, Celeste A., Osborn, Thor D., and Hess, Marguerite Evelyn. Systems Analysis Overview.. United States: N. p., 2019. OSTI Identifier 1641663

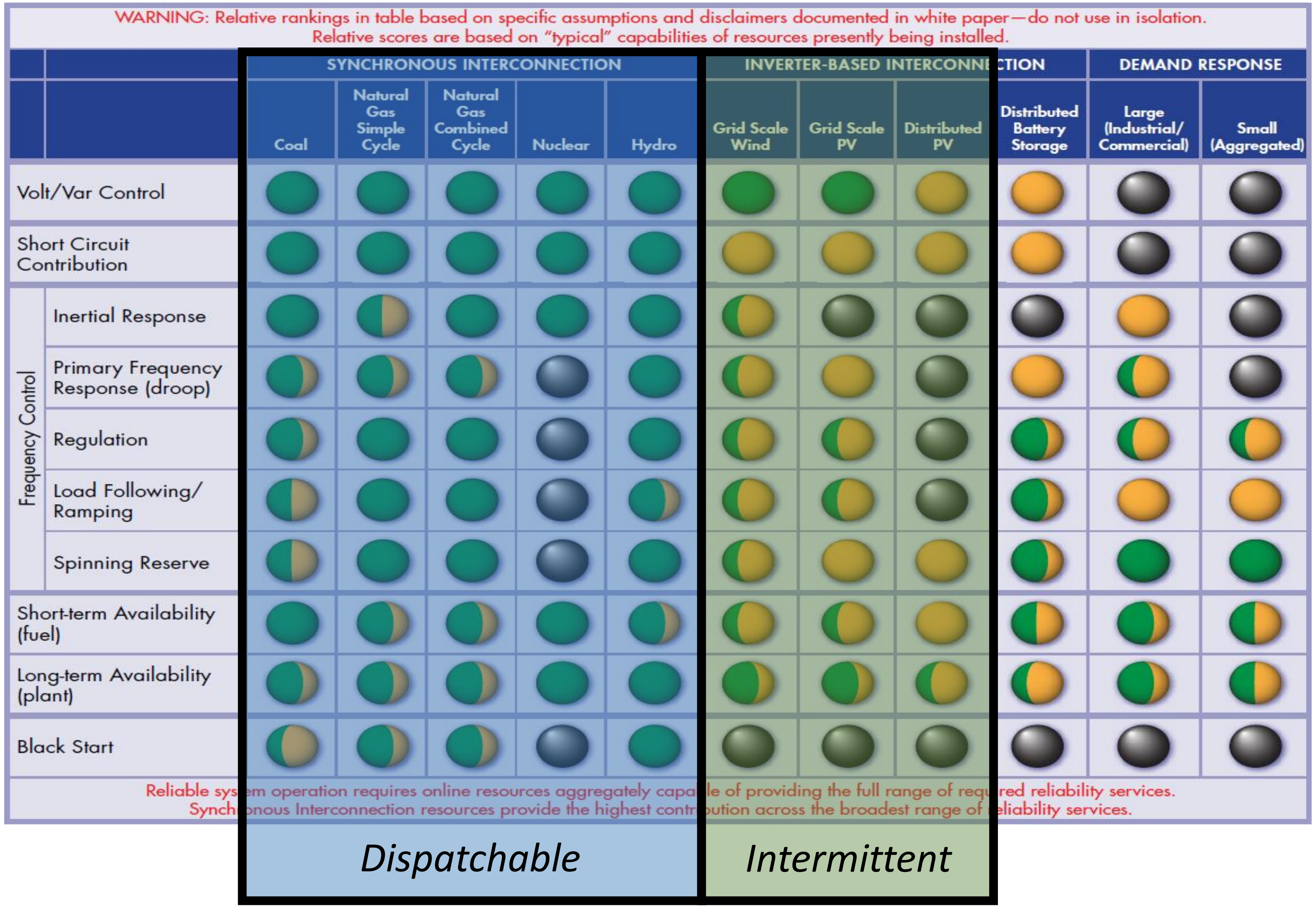
SA of Energy Storage (ES) Concepts

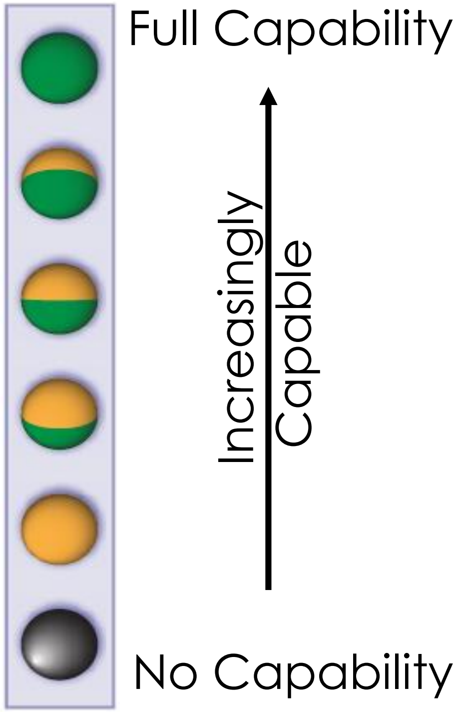
Objectives are often a matter of Use Case and stakeholder perspectives

- **Storage System Owner**
  - Generate revenue
    - Energy arbitrage
    - Expanded/enhanced service menu
  - Enhance the value of existing assets
    - Increased operational flexibility
    - Decreased production costs
- **Bulk Power System**
  - Address changing nature of generator base
    - Increasing replacement of dispatchable with intermittent resources
  - Maintain necessary level of critical grid services
    - Reduction of existing base due to retirement of conventional generating resources
    - Compensate for limitations in the "service menu" provided by asynchronous generating technologies

Illustration of Varied "Service Menus"

Conventional dispatchable resources provide a "fuller" menu





SA Scope a Function of ES Use Case

System boundaries and parameter granularity are key considerations

- **Unit-Level**
  - Stand-alone electricity storage system
  - Integrated energy storage system
    - Operationally integrated
    - Physically integrated
- **Bulk Power System-Level**
  - Grid
    - Stand-alone
    - Integrated
  - Grid+ (i.e., Bulk power system plus co-product markets)

The more relevant the desired analysis outcome, the higher the analysis complexity.

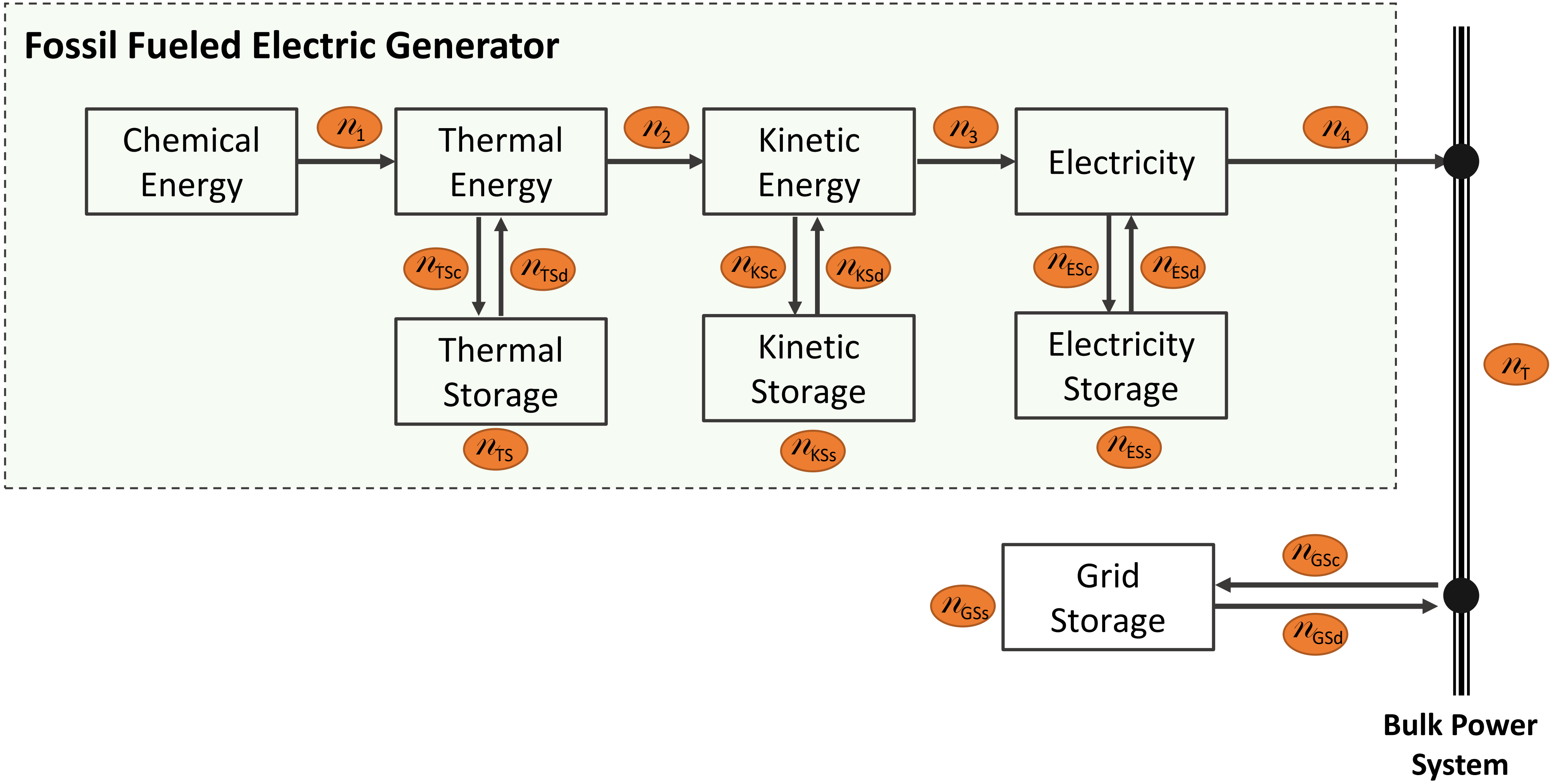
For any analysis outcome to be meaningful, sufficient consideration must be given to determine the appropriate resolution/granularity of:

- *Process performance*
- *Capital and operating costs*
- *Products/services evaluated*
- *Locational specificity*
  - *Supply (including competition) and demand (including alternatives)*
  - *Supply chain*
- *Timescale*

And more than likely many others …

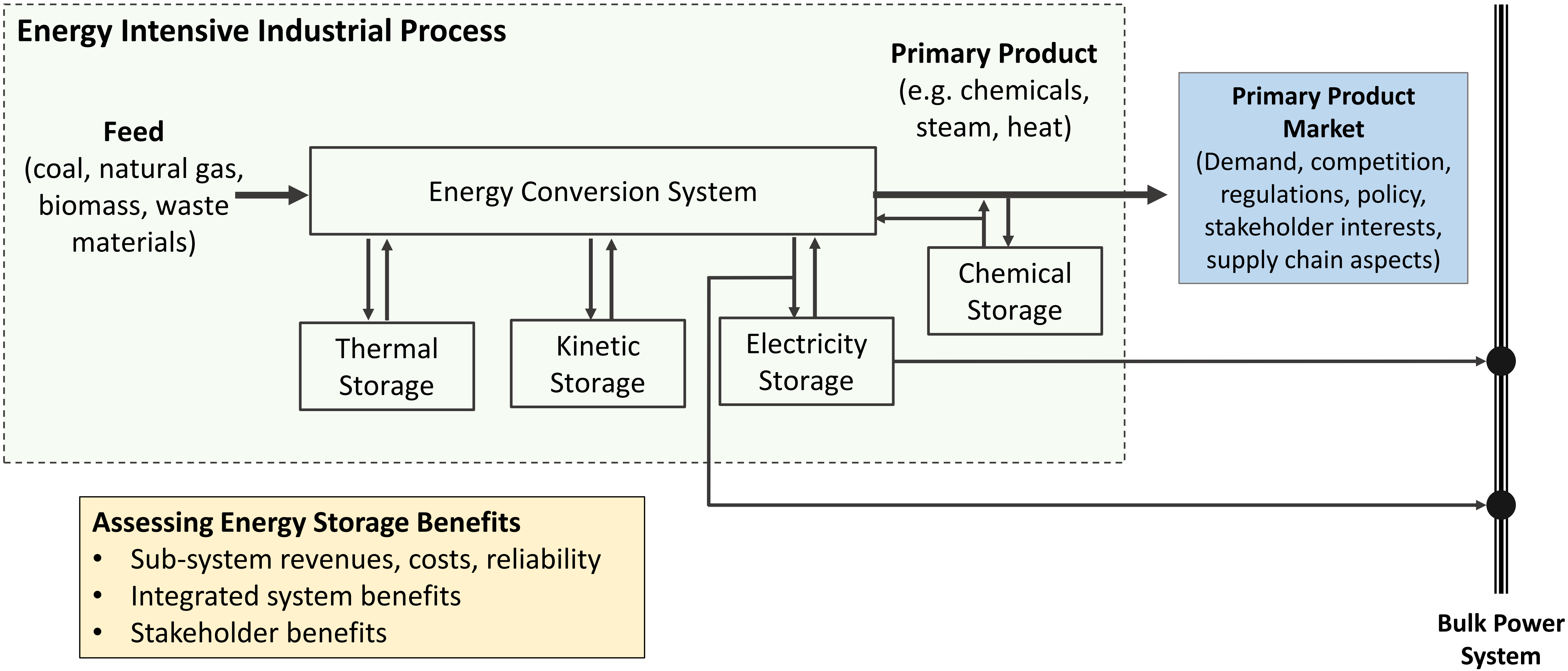
ES Integrated w/ Fossil-Fueled Power Plant

Energy intensive processes provide multiple ES integration pathways



Energy Intensive Industrial Processes

Industrial processes offer similar (and maybe more) integration opportunities



Assessing Energy Storage Benefits

- Sub-system revenues, costs, reliability
- Integrated system benefits
- Stakeholder benefits

Integration Options for Fossil Energy Systems

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"Other than electricity" ES pathways for fossil energy

Thermal Energy Storage

Integration of thermal storage at power plants for improved operations and/or increased power output during high-demand periods

Pilot projects underway for some technologies (e.g. concrete TES); Material testing and assessment of integration schemes necessary

Chemical Energy Storage

Integration of chemical storage with grid connected co-production (e.g., power & hydrogen) providing greater operational flexibility

Multiple product pathway options; e.g. H_2; bulk storage and distribution in early development

Kinetic Energy Storage

Fossil or nuclear energy conversion paired with mechanical energy storage options

Standalone CAES has been commercialized, but not widely deployed; Other technologies are currently being developed (e.g. gravity-based options)

Operational Flexibility as Storage

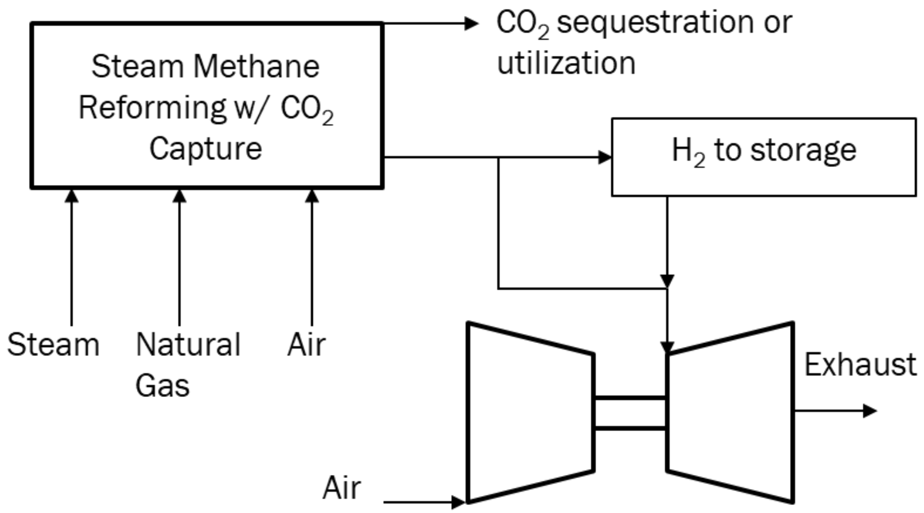
Flexibility in facility operations to leverage energy stored within the system redirected to support the bulk power system

CCS technology demonstrated; flexible system design, control and optimization needed

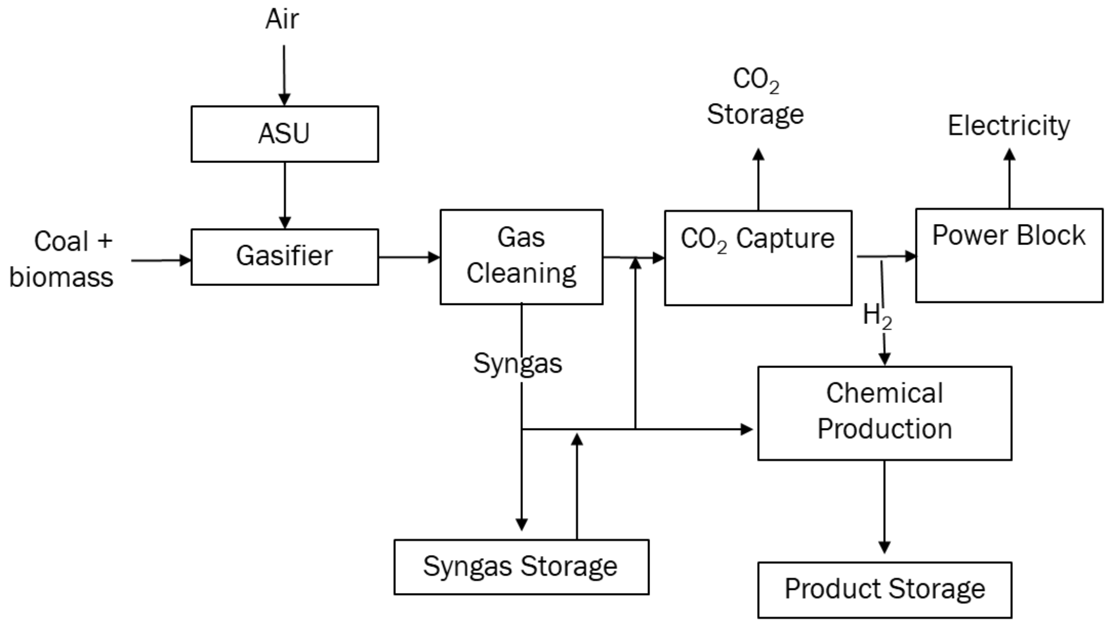
Low-Carbon Fossil Enabled Via Chemical ES

Fossil based H_2 production with carbon capture and storage

Co-production of Power and Hydrogen from Natural Gas

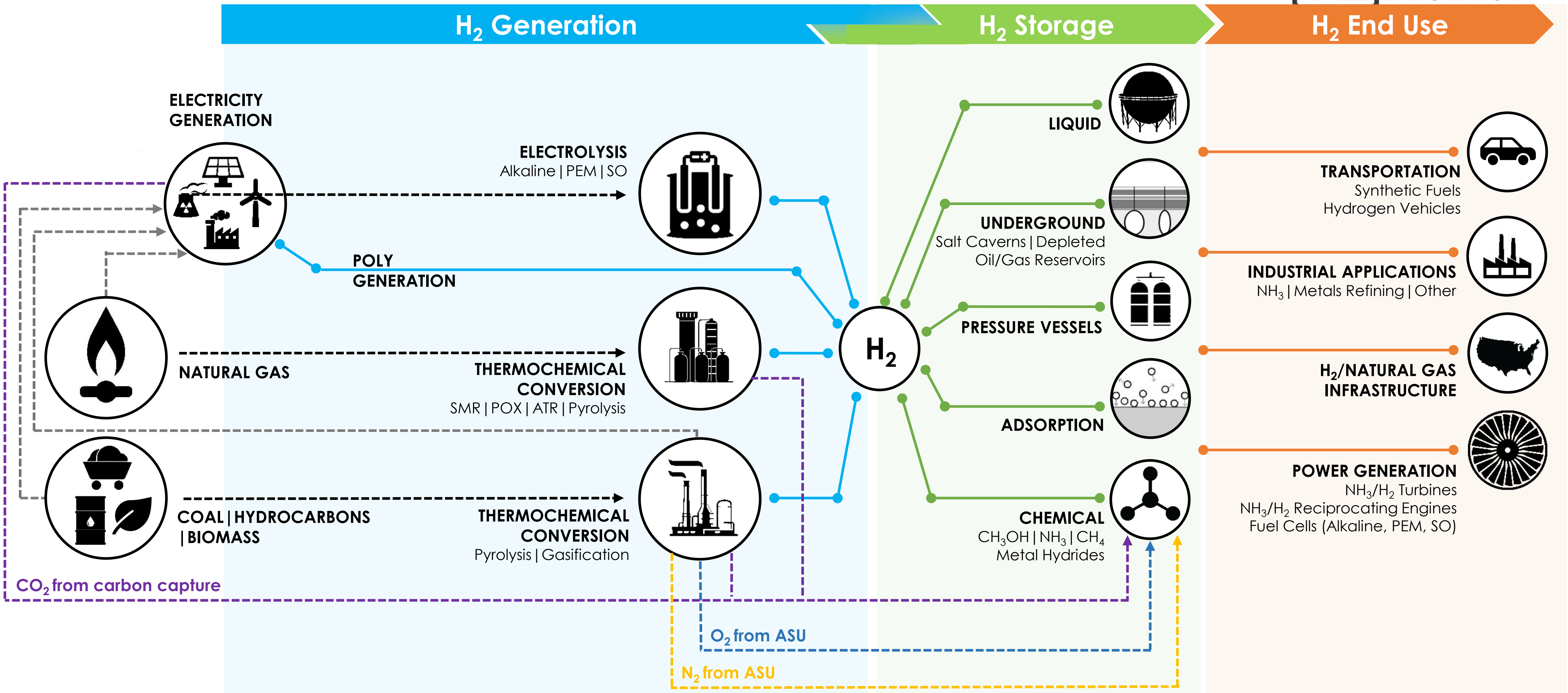


Co-production of Power and Chemicals using Coal Gasification



Operational flexibility of CO_2 capture system provides access to energy "stored" within the system

Hydrogen Energy Storage is Highly Versatile



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Energy Storage Valuation Conundrum

Value is amorphous and ever changing

- The value of pairing energy storage (ES) with generation is less about the product(s) that it provides and more about the flexibility it enables
- Application dependent – ES enables/enhances flexibility attributes differently

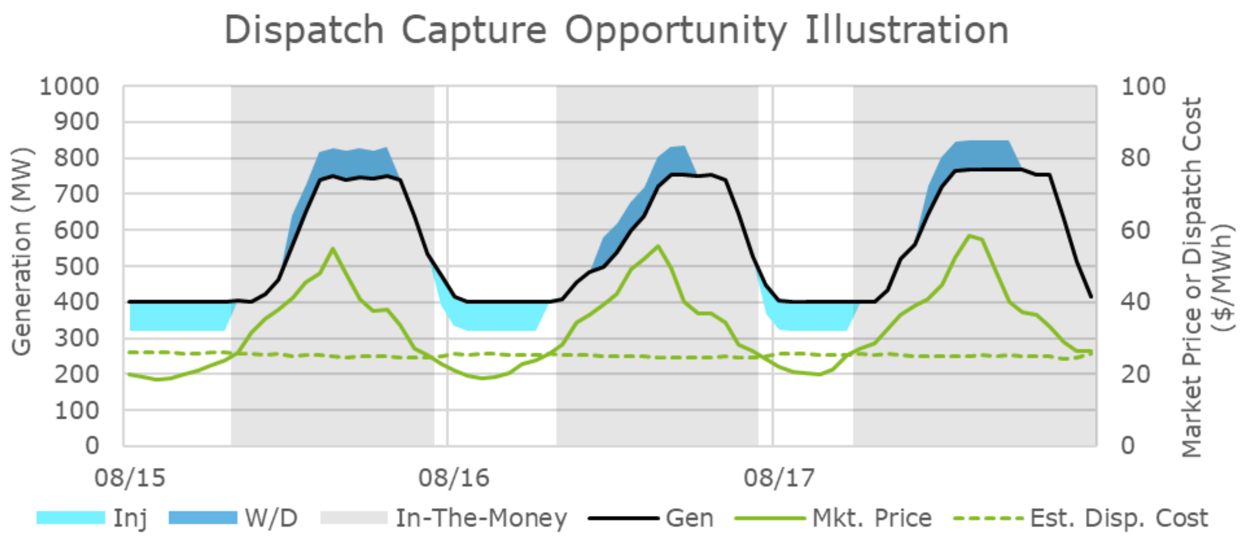
Fossil Fueled EGU Attribute Enhancement	Enhancement Opportunity
Energy arbitrage	Low to High
Lower production cost and/or improved energy conversion efficiency	Moderate to High
Expanded product slate	Low to Moderate

- Spatially and temporally dependent – Heterogeneity of how energy is produced, delivered and consumed dictates the demand for and value of flexibility attributes
    - Value Here ≠ Value There
    - Value Now ≠ Value Then

Quantifying Economic Benefits of Integrated ES

ES offers a range of improvements, many of which are difficult to quantify

- **Integrated ES Offers Improved Unit-Level Economics Via**
  - Lower variable production cost leading to enhanced dispatch capture
  - Decreased losses due to out-of-the-market sales
    - ES-enabled energy arbitrage
    - Lower (or avoided) costs associated with taking unit off-line
  - Lower maintenance costs due to decreased cycling of process components

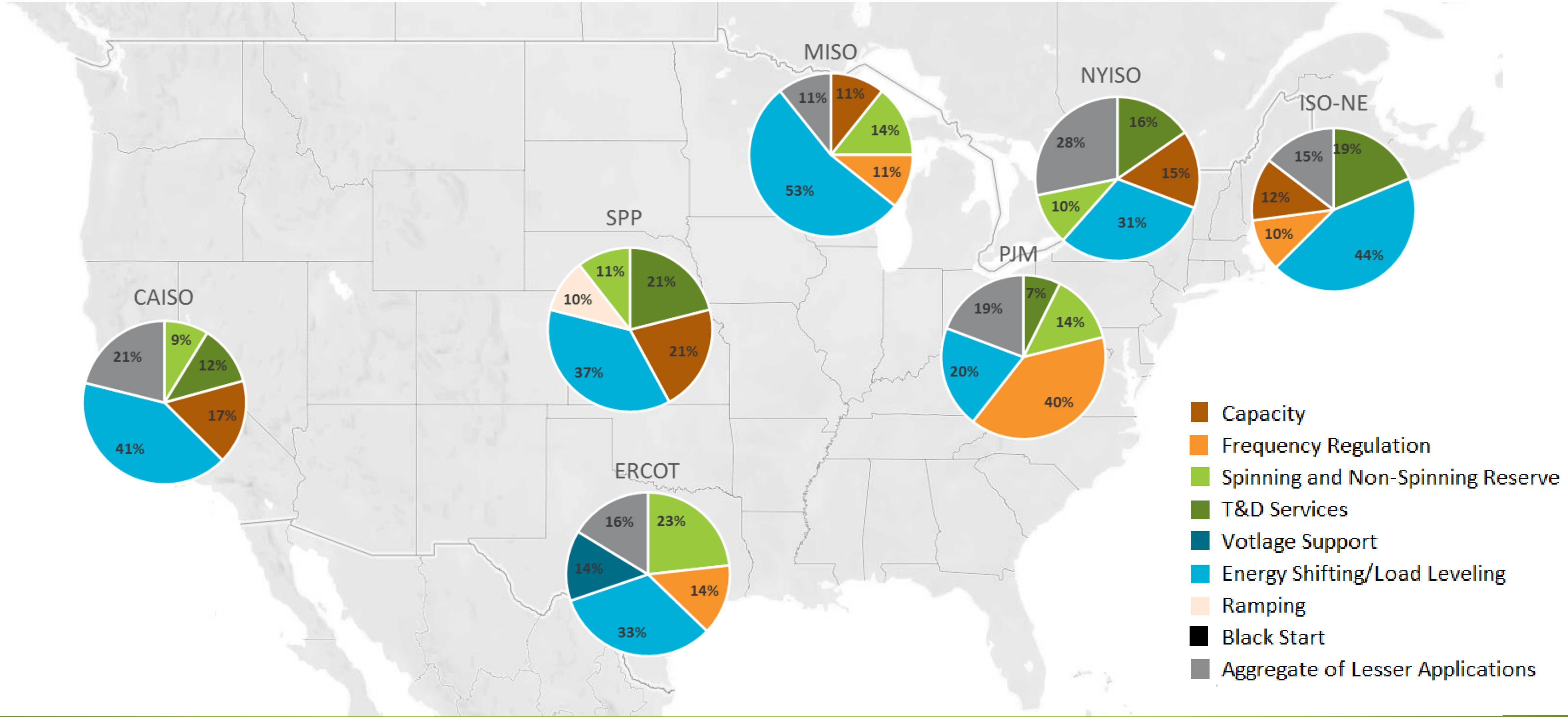


Potential dispatch capture from coupling storage with generation could accrue by avoiding out-of-the money sales (and losses) and instead releasing the energy during more valuable periods. The example assumes 10% of unit capacity in coupled storage and energy total storage equivalent to 8 hours.

Source: Estimated dispatch cost and chart compiled by NETL

Primary Energy Storage Applications

In-front of the meter applications for select RTOs/ISOs



Source: Sandia National Laboratories, "DOE Global Energy Storage Database," Department of Energy, 2018. [Online]. Available: https://www.sandia.gov/ess-ssl/global-energy-storage-database/ [Accessed April 2020].