U.S. DEPARTMENT OF ENERGY

Energy Storage Grand Challenge

Policy & Valuation

JULY 16, 2020

U.S. DEPARTMENT OF ENERGY

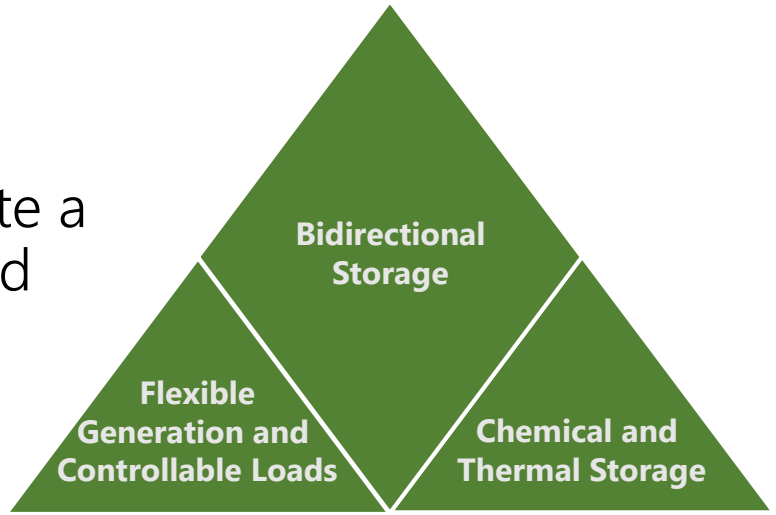
ESGC Vision, Mission, and Scope

Vision

By 2030, the U.S. will be the world leader in energy storage utilization and exports, with a secure domestic manufacturing supply chain independent of foreign sources of critical materials

Mission

The ESGC will focus resources from across the DOE to create a comprehensive program to accelerate the development and commercialization of next-generation energy storage technologies and sustain U.S. global leadership in energy storage, through the following objectives:

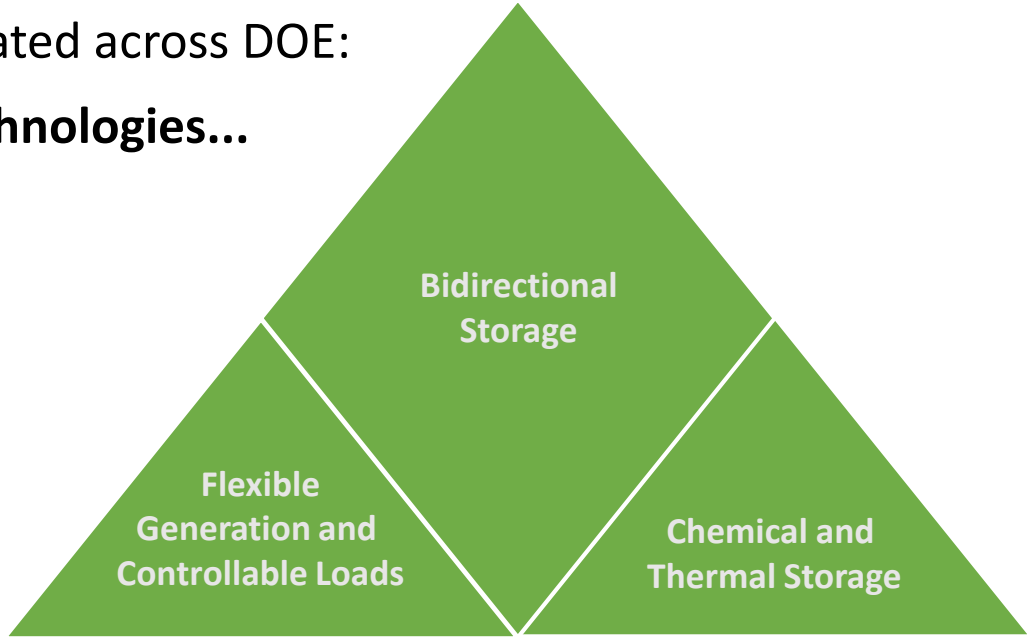


ESGC Coordination

DOE-wide strategy to accelerate US leadership in energy storage technologies

Coordinated across DOE:

technologies...



...offices...

- Office of Electricity
- Energy Efficiency and Renewable Energy
- Office of Science
- Office of Technology Transitions
- Nuclear Energy
- Fossil Energy
- ARPA-E
- Loan Programs Office

...and functions

ESGC Focus Areas

How to achieve "Innovate Here, Make Here, Deploy Here"

Technology Development	Technology Transition	Policy and Valuation	Domestic Manufacturing and Supply Chain	Workforce Development
•Establish ambitious, achievable performance goals, and a comprehensive R&D portfolio to achieve them.	•Accelerate the technology pipeline from research to system design to private sector adoption through rigorous system evaluation, performance validation, siting tools, and targeted collaborations.	•Develop best-in-class models, data, and analysis to inform the most effective value proposition and use cases for storage technologies.	•Design new technologies to strengthen U.S. manufacturing, recyclability, and reduce dependence on foreign sources of critical minerals.	•Train the next generation of American workers to meet the needs of the 21st century grid and energy storage value chain.

Getting Policies and Regulations Right

Policies are limited by incomplete understanding of:

- **What can storage do?** Technical capabilities and lifecycle costs
- **What is it worth?** The value of different services under different conditions
- **How to integrate, operate, and pay for it?** Planning, operation and compensation of storage in the power system

Who does this affect?

PUCs	**ISO/RTOs**	**States**	**Utilities**
Developers	**Consumers**	**Manufacturers**	**DOE**

What is the result? Rules and policies that limit value, compensation, and storage deployment.

Policy & Valuation: DOE's Role

DOE has the analytical capabilities, data and computing resources, and institutional credibility to inform more effective and cost-effective policy and regulatory decisions.

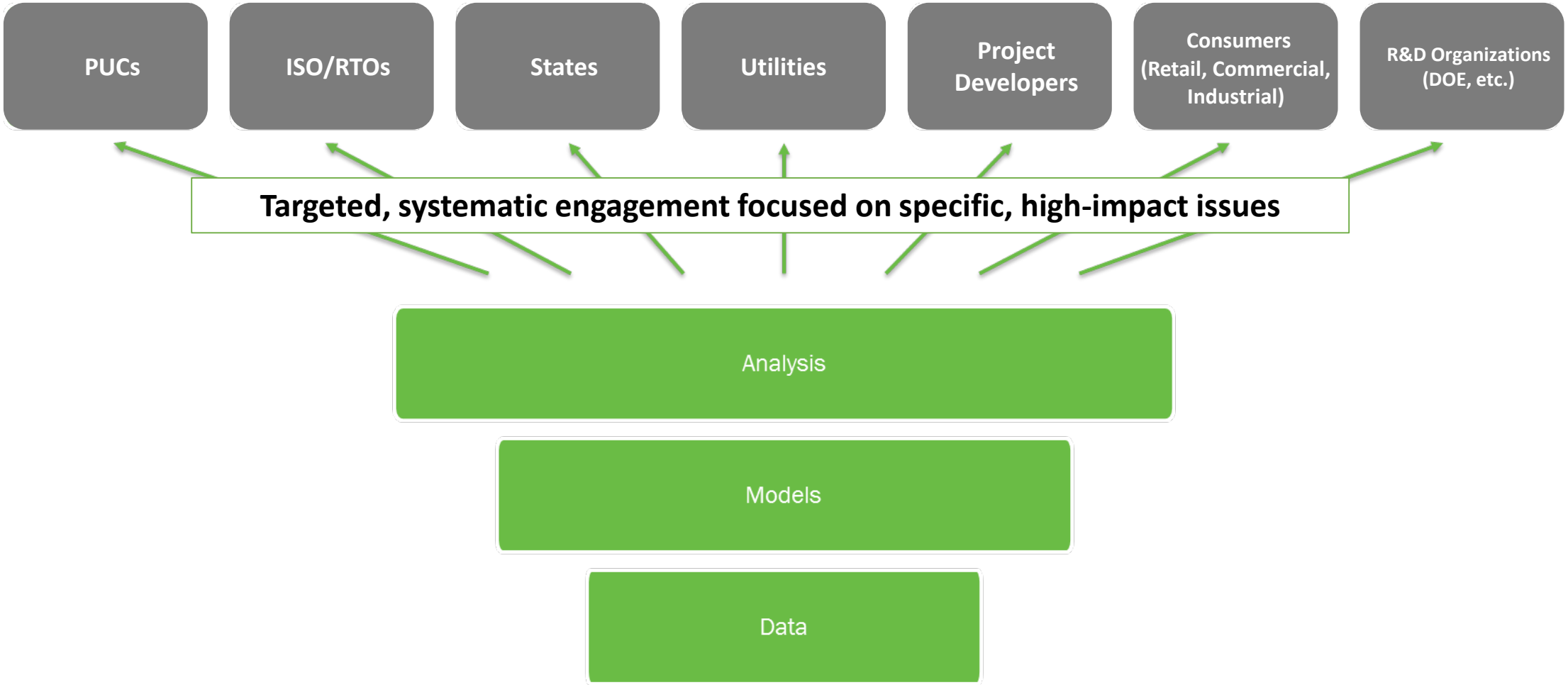
Caveat: DOE does not make policy, but offers policymakers the tools to most effectively meet their own policy and regulatory goals.

But in order to be effective, DOE policy and valuation support must be:

- **Targeted** at the most pressing policy barriers or regulatory challenges, and the specific information gaps that prevent them from being addressed
- **Systematic** in proactively working with decision-makers to identify and provide all the information needed to enable effective decisions, rather than ad hoc support for targets of easiest opportunity
- **Coordinated** across relevant offices in DOE, to ensure the right areas of expertise are applied to a given question and avoid conflicting information on a given topic
- **Informed and objective,** with support to decision-makers closely linked to the analysis informing it and avoiding any appearance of supporting one technology or office's mission over another's

Policy and Valuation: Delivery

How can these products be delivered? Systematic policy support and technical assistance to critical organizations, supported by best-in-class analysis based on up-to-date data and improved models



Existing DOE Work (Examples)

Implementation: DOE has many efforts that can help address these challenges:

OE Storage Regulatory Engagements and TA

- Informational workshop and technical assistance to states evaluating energy storage deployments.
- TPTA Technical Assistance Program

OE Storage Analysis

- Analytic tools for utilities and regulatory agencies to facilitate planning and implementation of energy storage in transmission and distribution infrastructure.

GMLC Analysis and Institutional Support

- Institutional support framework for PUCs, ISOs/RTOs
- Framework for valuation of grid services, grid architecture
- Demonstration of storage contribution to black-start (Plum Island)

EIA

- Improved representation of storage in capacity expansion models
- Annual Energy Outlook

EERE Strategic Programs (SPIA) Analysis

- Improved representation of storage in capacity expansion models
- Evaluation of long duration storage, hybrid systems • Storage futures study • Annual Technology Baseline

Individual EERE Offices

- Solar: Solar + storage for resilience; Integration costs of BTM storage + PV; SHINES demo projects
- Hydro: Storage data (w OE); valuation guidelines/tool for PSH; storage in power models; hydro in micro-grids, hydro + batteries;
- Fuel Cells: H2@scale for grid storage; • Wind: grid services from grid and utility-scale wind + storage • OWIP: State Energy Program

Policy & Valuation: Key Issue Areas

Resilience

Defining resilience and measuring energy storage technologies' ability to improve system and end-use resilience accounting for different threat types, probabilities, outage durations, costs, and system/facility characteristics

Power System Operations

Improving the representation of storage technologies (including hybrid configurations) in power flow, system stability, and optimal dispatch tools. Enhance tools' and planning processes' ability to capture interactions between the bulk-power, distribution, and transportation assets

Energy System Planning

Identifying how much, where, and what duration future DER, bulk-power, transmission, non-wire-solutions, and transportation-related storage investments are needed given potential generation mixes, infrastructure constraints, weather conditions, technology costs/availability, etc.

Transportation & Cross-Sector

Determining how can transportation-related energy storage systems (electric and fuel cell vehicles) provide services to the grid and or other end-users? How can other types of energy storage (H_2, CH_4, etc.) be valued, especially if they have end-use applications, interactions, and interdependencies across sectors?

Policy & Valuation: Foundational Needs

Markets, Policy, and Utility Operations Information

How will different federal, state, and local policies and regulations impact how storage is deployed and valued? What are near-, medium-, and long-term market issues for vertically integrated utilities and competitive power markets that can impact storage (interconnection processes, participation models, asset classes, planning requirements, etc.)?

Model & Tool Improvements

Improve geographic and temporal resolution, dynamic representation of operational characteristics, ability to represent hybridized configurations, stochastic optimization, use of open-source code and publicly available data.

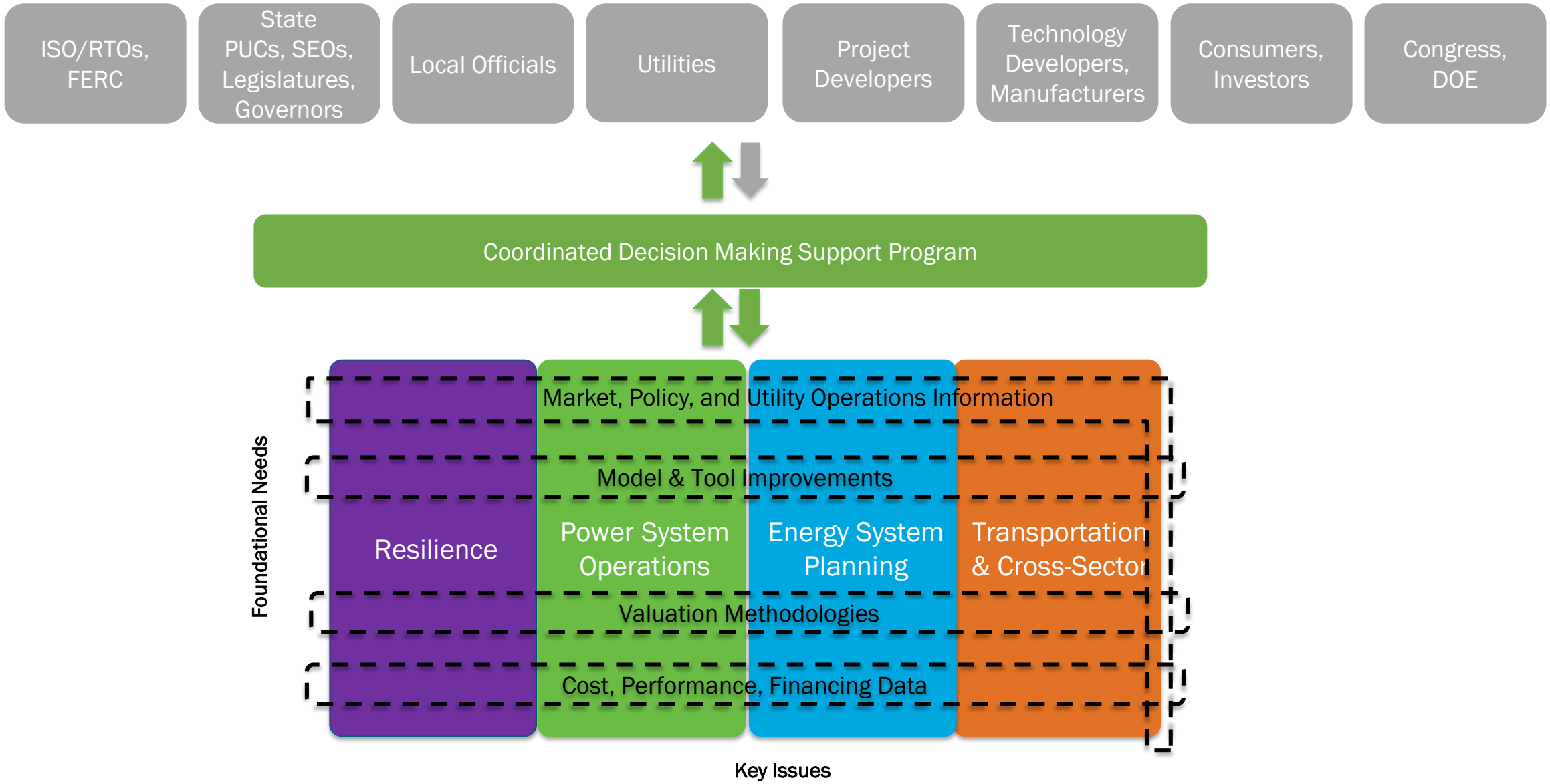
Valuation Methodologies

Consistently classify what services and other non-monetized benefits different stationary and transportation-related energy storage technologies can provide and their value given system, infrastructure, and market characteristics.

Cost, Performance, Financing Data

Track and validate technologies' current capital, O&M, and financing data given associated system size and resource quality; provide transparent future cost projections given uncertainty; and identify storage technologies' attributes and how duty-cycles can have non-linear impacts on long-term performance and degradation.

Delivering on Key Issues & Foundational Needs



Energy Storage Cost and Performance Database

Foundational Need: Data

Key Issue Area: Energy System Planning, Power System Operations

Description:

- Develop an online cost and performance database with both historic data and future cost trajectories (out to 2030) for batteries, PSH, CAES, ultracapacitors, combustion turbines, and hydrogen broken down category (CapEx vs. OpEx) by component type (ESS, BOP, EPC).
- Database will serve as a baseline for internal research targets and provide easy access to verified data for external stakeholders looking to develop, finance, manufacture, or make policy/regulatory decisions affecting storage.
- Data will be updated and published annually. Future iterations will include a wider range of storage technologies.

Performer: PNNL

Timeline: First version is expected in fall 2020.

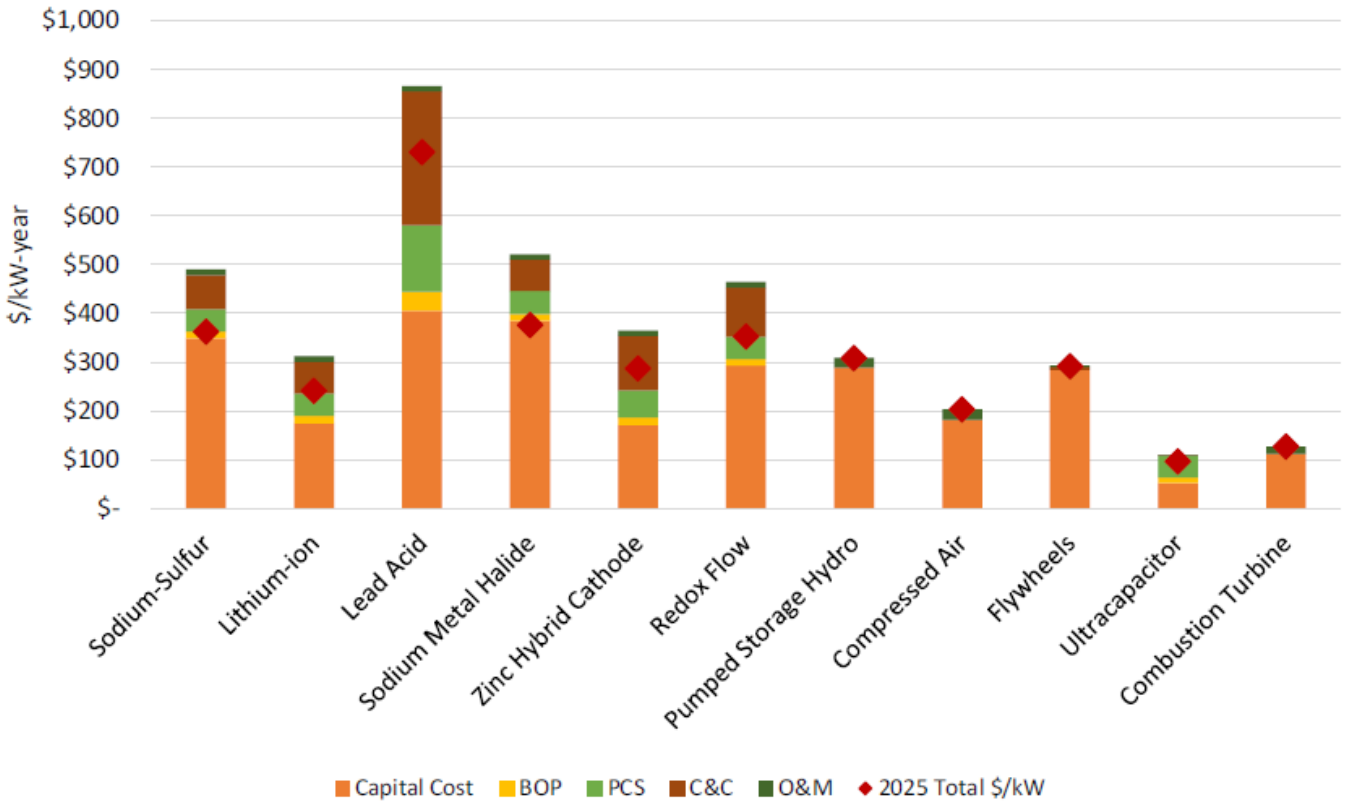


Figure 5.5. Annualized $/kW cost of all technologies.

Source: HydroWIRES Energy Storage Cost Characterization (2019)

Energy Storage Policy Database

Foundational Need: Market, Policy, and Utility Operations Information

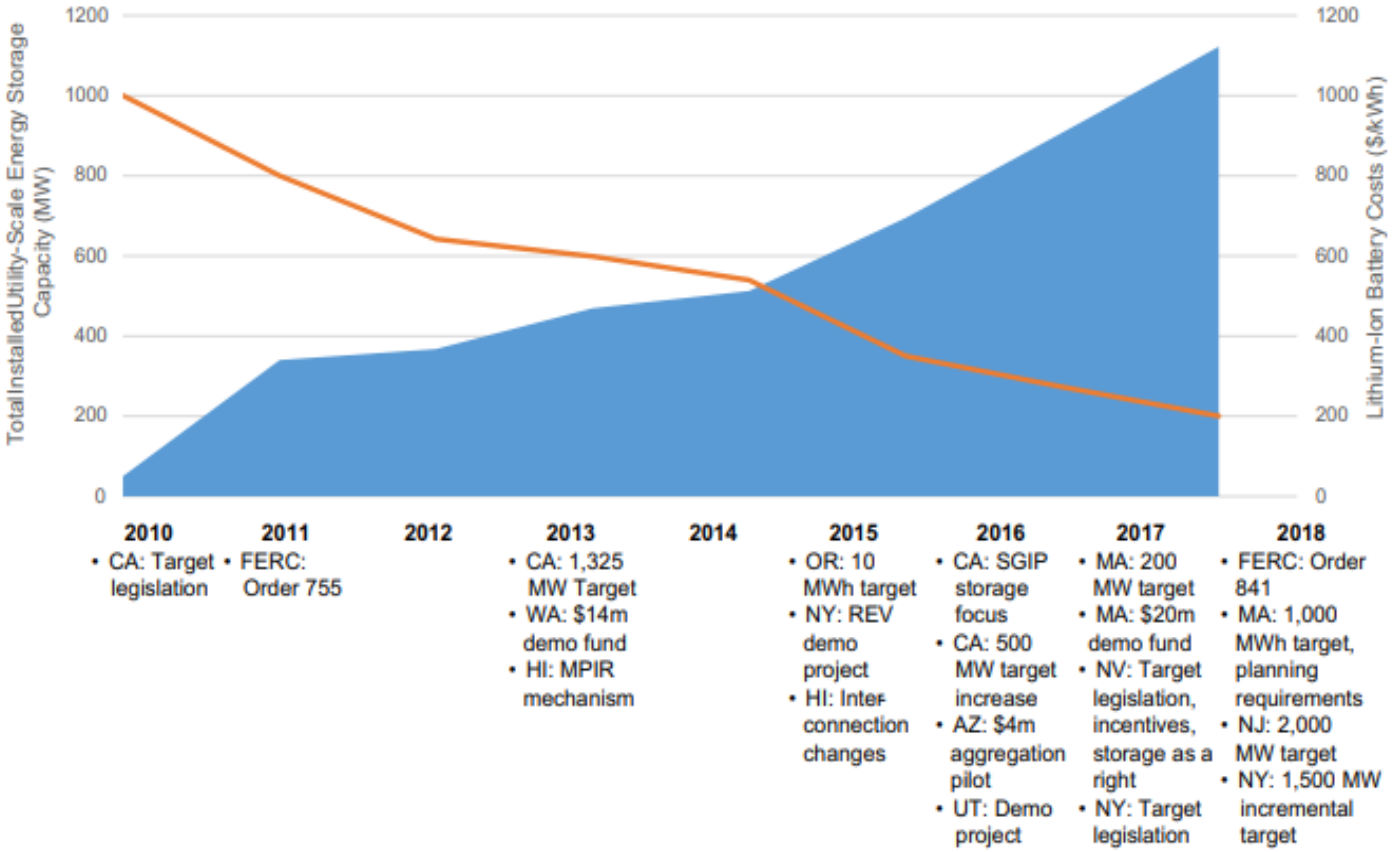
Key Issue Area: Energy System Planning, Power System Operations

Description:

- Develop an online database to track state-level energy storage procurement targets, regulatory requirements, demonstration programs, financial incentives and consumer protections.
- Create a storage primer for policy makers that is an overview of storage technologies, applications in the electricity and transportation sector, policy and market barriers, and policy options
- Provide additional trainings, workshops, and webinars to ensure state policy makers and the public understand the policy landscape and potential available options.

Performer: NCSL, PNNL

Timeline: Winter 2020



Source: *A Review of State-Level Energy Storage Policies* (2019)

Hybrid System Analysis and R&D Opportunities

Foundational Need: Data, Valuation Methodologies, Tools, Market, Policy, and Utility Operations Information

Key Issue Area: Energy System Planning, Power System Operations

Description:

- Create an taxonomy for hybrid energy systems that can be overlaid with past and existing work to identify where current R&D and analysis opportunities exist
- Develop a methodology to value different hybrid configurations and their operational characteristics
- Build representations of hybrid systems in capacity expansion (ReEDS) and production cost models (PLEXOS)
- Assess the value and deployment of hybrids systems over a range potential future scenarios
- **Performer**: NREL, LBNL, EPRI
- **Timeline**: Fall 2020

Table 2. Expected impacts and evaluation methods for our proposed hybrid categories

	Virtual Hybrid:	Colocation Hybrid:	Full Hybrid:	**Key Tools and Methods [and select examples from the literature]:** Recommendations for representing hybrid renewable energy systems
Changes in Costs, Relative to Multiple Independent Systems				
Component Capital Costs	More sophisticated control systems could increase costs	Negligible change, due to the lack of shared components	Competing effects of shared components and more sophisticated control systems	**Bottom-up engineering models [15,70]:** consider shared components and necessary component upgrades
Balance-of-System (BOS) Costs	Potential cost savings from avoided integration charges	Potential cost savings from shared BOS costs and avoided integration charges	Potential cost savings from shared BOS costs and avoided integration charges	**Balance-of-system (BOS) cost models [135]:** consider opportunities for shared permitting, overhead, interconnection, engineering, labor, and land costs
Operations and Maintenance (O&M) Costs	Negligible change, due to the lack of a locational linkage	Potential cost savings from shared crews	Potential cost savings from shared crews, but unknown directionality for impacts of co-optimized operations	
Changes in Values, Relative to Multiple Independent Systems				
Energy Value	Co-optimized energy production from constituent technologies could increase energy value	Sub-optimal siting for one of the constituent technologies could reduce energy value	Competing effects of co-optimized energy production and sub-optimal siting for one of the constituent technologies	**Geographic information system models [136]:** consider hybrid-specific land-use constraints and resource complementarity **Resource adequacy models [137,138]:** represent technology interactions **Performance simulation [139] and economic dispatch models [140,141]:** represent changes in efficiency, engineering constraints, and multiple energy pathways in hybrids that link renewable energy generation and energy storage technologies
Capacity Value	Depends on market-specific criteria for the provision of capacity services	Largely unchanged due to the lack of shared components	Competing effects from sub-optimal siting for one of the constituent technologies, shared components, and technology interactions	
Ancillary Services and Other Values	Depends on market-specific criteria for the provision of ancillary services and policy compliance [142]	Largely unchanged (due to independent operations), but depends on market-specific criteria [142]	Depends on market-specific criteria for the provision of ancillary services and policy compliance [142]	

Source: NREL *Forthcoming*

Compensation in Hypothetical Future Market Systems (Proposed)

Foundational Need: Market, Policy, and Utility Operations Information, Tools

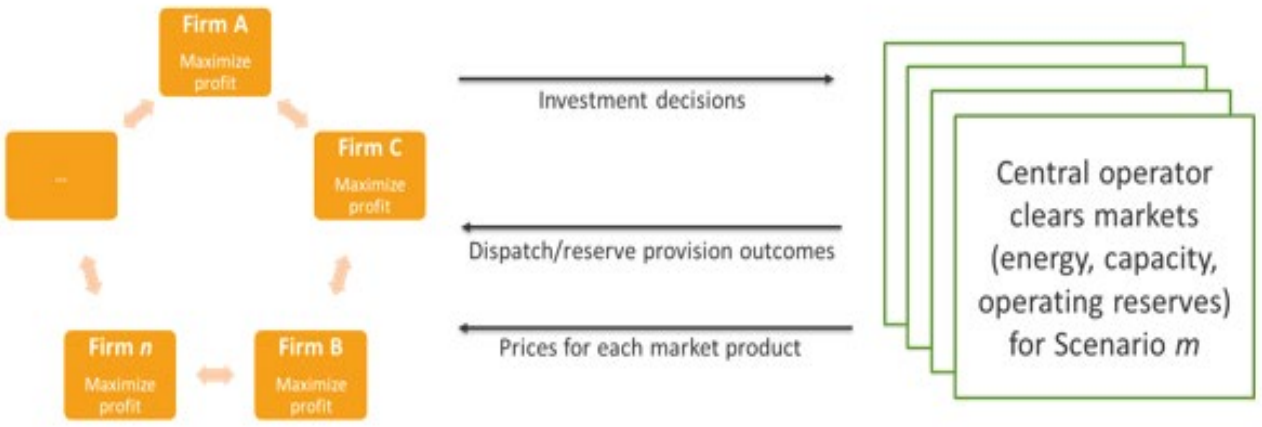
Key Issue Area: Power System Operations, Energy System Planning, Resilience

Description:

- Assess methods and tools to analyze future markets that support universal participation, are flexible to changing system conditions, and ensure reliability at the lowest possible cost.
- Areas of consideration:
  - Market operation with high penetration of zero marginal cost renewables
  - Aggregation and control of distributed, demand-side, and virtual resources
  - ISO and DSO coordination
  - Sufficient incentives for long-term capacity investment, and avoiding stranded assets
  - Trade-offs in energy only vs. energy and capacity markets
  - Optimization of multiple objectives: cost, reliability, resilience, emission
  - Generator behavior, e.g. avoiding market power, collusion

Performer: Lab, Universities, ISO/RTOs, Technical Experts

Timeline: 2021



	Multiple Firms				Physical System		
	Strategic Behavior	Heterogenous Financing Parameters	Heterogenous Risk Tolerance	Heterogenous Beliefs about Future	Unit Commit-ment	Operational outcome uncertainty	Multiple Project Phases
Idealized Competitive Equilibrium	No	No	No	No	Yes	Yes	Yes
Agent-Based Simulation	Indirect	Yes	Yes	Yes	In market clearing	Yes	Yes
Approximate Strategic Equilibrium	Approximate	Yes	No	No	In training data	No	No

Source: NREL *Forthcoming*

Integrated Energy System Planning (Proposed)

Foundational Need: Market, Policy, and Utility Operations Information, Tools, Valuation Methodologies Data

Key Issue Area: Power System Operations, Energy System Planning, Transportation & Crosscuts, Resilience

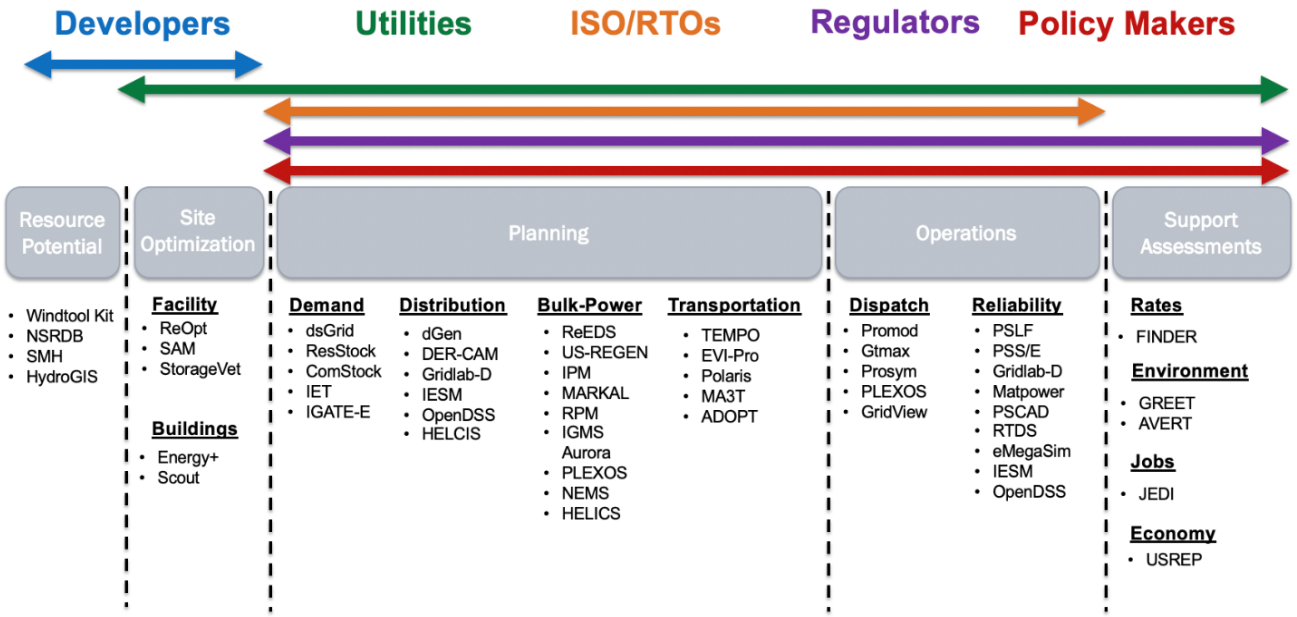
Description:

- Survey stakeholders to determine how stakeholders currently use data, tools, and analysis to make decisions
- Assess the limitations and trade-off associated with different tools and processes used evaluate emerging cross-sectoral planning issues, e.g. higher EV penetration or large-scale hydrogen buildout.
- Identify opportunities and work with stakeholders to help them implement and better coordinate planning processes that are integrated and optimized across multiple sectors

Performer: Lab, Universities, ISO/RTOs, Technical Experts

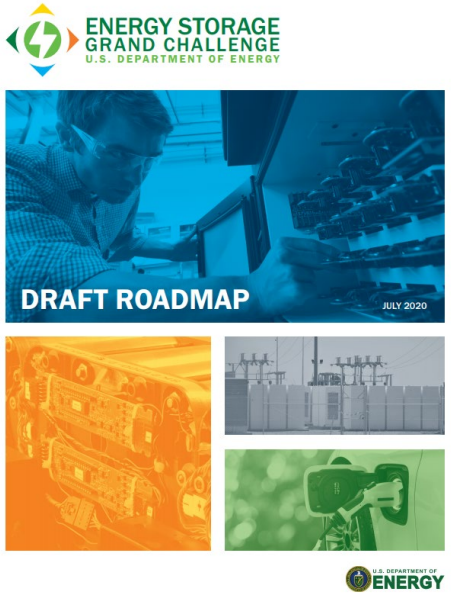
Timeline: 2021

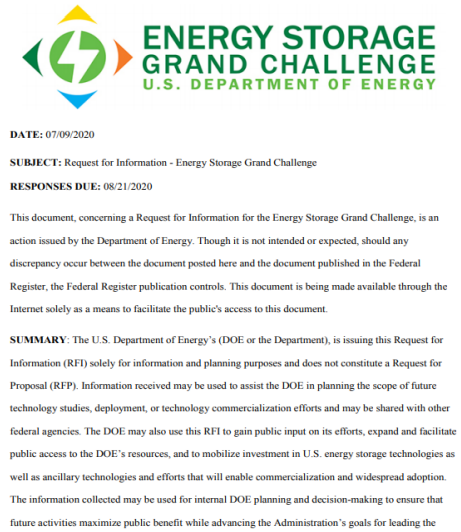
Different Tools Available to Energy Decision Makers



Source: *Forthcoming*

ESGC Draft Roadmap & Request for Information





ENERGY STORAGE GRAND CHALLENGE
U.S. DEPARTMENT OF ENERGY

DATE: 07/09/2020

SUBJECT: Request for Information - Energy Storage Grand Challenge

RESPONSES DUE: 08/21/2020

This document, concerning a Request for Information for the Energy Storage Grand Challenge, is an action issued by the Department of Energy. Though it is not intended or expected, should any discrepancy occur between the document posted here and the document published in the Federal Register, the Federal Register publication controls. This document is being made available through the Internet solely as a means to facilitate the public's access to this document.

SUMMARY: The U.S. Department of Energy's (DOE or the Department), is issuing this Request for Information (RFI) solely for information and planning purposes and does not constitute a Request for Proposal (RFP). Information received may be used to assist the DOE in planning the scope of future technology studies, deployment, or technology commercialization efforts and may be shared with other federal agencies. The DOE may also use this RFI to gain public input on its efforts, expand and facilitate public access to the DOE's resources, and to mobilize investment in U.S. energy storage technologies as well as ancillary technologies and efforts that will enable commercialization and widespread adoption. The information collected may be used for internal DOE planning and decision-making to ensure that future activities maximize public benefit while advancing the Administration's goals for leading the

- The Draft Roadmap describes what activities and issues areas each of the Grand Challenge's five tracks (Technology Development, Policy & Valuation, Manufacturing & Supply Chain, Workforce Development, and Technology Transfer) will work on.
- The Request for Information (RFI) will be used as a formal mechanism to receive stakeholder feedback on the roadmap, critical areas to focus on, and other storage-related activities.
- The Draft Roadmap and RFI can be downloaded: https://www.energy.gov/energy-storage
- Responses to this Request for Information must be submitted electronically to rticstorage@hq.doe.gov no later than August 21, 2020.
- We also welcome informal feedback about the Roadmap, RFI, or any other energy storage related issues at any time through whatever mechanism is most convenient to you.

Extras

Power System Operations

Markets Policy Analysis

- **Integrated Planning –** what are the benefits associated with integrating operations planning for the distribution and bulk-power system, are there enabling policies that need to be implemented, e.g. communications protocols, etc.
- **Interconnection Processes –** are there benefits to standardizing interconnection requirements for stand-alone and hybrid storage technologies
- **Market Participation Models** – can markets introduce artificial constraints that impact the operation of storage systems
- **Storage as an Embedded Asset –** if storage was already include in the grid and its costs were socialized how would that change operations

Tools

- **Improving Storage Representation in Reliability Models –** PSS/E, PSLF, etc.
- **Storage Representation in Dispatch Models –** PLEXOS, PROMOD, PROSYM, GridView, etc. adding technology attributes, EMS, market constraints
- **Increase Temporal Resolution –** to capture ability to provide short duration products (fast frequency response, inertia, etc.)
- **Power System Resolution –** ability co-simulate or co-optimize distribution and bulk-power systems. (HELICS, IESM)
- **Geographic Resolution** – accurate representations of localized conditions like congestion, generation mix are needed to accurately value storage
- **Storage System Configurations -** storage dispatch parameters, especially if attached to generation as a hybrid

Valuation Methodology

- **Optimizing Energy Storage System vs. the Power System –** tradeoff between optimizing storage for revenue vs. operation for maximizing grid services
- **Methodology to Value Resources that Impact both Distribution and Bulk-Power Systems –** If DERS provide both local distribution services as well as wholesale services how does that impact the operation of the storage system and impact the broader grid's operations
- **Measuring Storage's Ability to Reduce O&M costs on Distribution Infrastructure –** validate storage's impact on distribution impacts
- **Taxonomy of Grid Services –** what actions are grid operators asking generators to take in order to maintain system reliability

Data

- **Energy Storage Cost & Performance** – Duration, round trip efficiency theoretical response time, achieved response time (limited by inverter), life cycle at 80% depth of discharge. Non-linear relationship between performance and duty cycle
- **Validation –** What is the best way to validate data and work with OEMs to ensure IP safety
- **Distribution Equipment –** need virtual representations of feeders and other infrastructure accurately understand potential distribution impacts
- **Spatial and Temporal Electricity Demand –** location and time of demand will drive storage operation

Storage technologies' dynamic performance characteristics need to be incorporated into operational planning tools so developers, utilities, and other planners can assess behind-the-meter, utility-scale, and transportation-related storage technologies' ability to improve dispatch and power flow while minimizing system costs.

Energy System Planning

Markets Policy Analysis

- **FERC 841 and 845 –** are current market participation rules effective, what improvements could be made
- **T&D Deferral and Congestion Relief –** is storage an effective means to accomplish this, are there market barriers (storage as a transmission asset)
- **State-Level RPS and Storage Mandates –** state policy is driving storage deployment, will this continue and are there long-term implications
- **Storage ITC –** if incentives were introduced, how would they impact deployment and the incremental value of storage under different scenarios
- **Improving IRP Processes and Integrating Other Sectors**

Tools

- **Capacity and Transmission Expansion Models –** ReEDS, US-REGEN, etc. need to have greater representation of storage technologies, and must be flexible enough to rapidly change underlying assumptions. Also increase spatial and temporal resolution, and incorporate market structures
- **DER Adoption Models –** dGen, DER-CAM
- **Broad Range of Scenarios -** assess how different generation mixes, fuels and technology availability, infrastructure buildouts, and changing weather/resource quality to determine how much storage will be needed, where, and at what duration
- **Buildings & Demand Side Solutions –** storage technologies must be compared to other sources of flexibility, these options must be included in tools

Valuation Methodology

- **Valuing Long-Duration Storage Technologies –** how should long-duration storage projects be valued since they may be able to provide a broad range of services over a long lifespan (PSH), is there an optimal duration for given market types or generation mixes
- **Incorporating Other Factors Like Resilience into Planning Processes –** increase ability of the energy system to be resilient to future uncertainty
- **Single Metrics Probably are No longer Sufficient –** while things like LCOE or LCOS are useful, are there more useful metrics that should be adopted

Data

- **Future Cost and Performance Trajectories –** need consistent trajectories of storage technology cost declines and performance improvements given different levels of potential R&D success
- **Temporal and Spatial Demand Forecasts –** need to know what subsectors will experience energy demand growth, and when and where that growth or decline will occur (e.g. how could increased transportation electrification impact capacity requirements)

Understanding how much, what types, and the locational value of stationary and transportation-related energy storage in future scenarios requires the full variety of behind-the-meter and utility-scale storage technologies to be included and accurately represented in long-term planning tools.

Resilience

Market Policy Analysis

- **Would resilience or microgrid procurement mandates be effective?**
- **Do IRPs and other planning processes need to be restructured to account for resilience?**
- **What analysis could help utilities make effective resilience investments?** Estimate potential savings under hypothetical scenarios? Best Practices?
- **Codes and Standards (safety, fire, cybersecurity)?** What can DOE do to provide useful information

Tools

- **Do you need a resilience specific model or should existing power sector tools be augmented?** System Simulation [NAERM or SIIP], Capacity Expansion [ReEDS], Outage Cost Calculator [ICE] Facility Optimization [ReOpt], Building [ResStock]
- **What are essential metrics for the models to capture?**
- **How do we layer models to assess different aspects of resilience? –** a especially if storage is inserted in multiple levels of the energy system
- **Response to Different Event Types** - a relationship between advanced notice and recovery time could be represented endogenously—through a model parameter that relates advanced notice with recovery time, accounting for changes in planning costs
- **Scenarios** – extreme weather, cyber attack, etc. what should they look like what parameters should be captured in planning tools

Valuation Methodology

- **Locational Value** – based on surrounding infrastructure and generators, what are the specific attributes of technology that enhance resilience
- **Willingness-To-Pay** – duration arc, infrastructure/network interdependencies, intersection with other health and economic impacts
- **Duration Dependent Value of Lost Load** - location of the bus, time of day of the event, and duration of the event
- **Impacts to Other Critical Services** – can energy storage solve short-term problems that enable authorities to have a more effective response

Data

- **Definition?** Ability to mitigate and recover from low probability, high-impact natural and man made events
- **Where do you draw the line between reliability and resilience? -** level of predictability
- **Metrics? -** load not served (kWh), avg. # of % of customers experiencing an outage, same metrics for critical customers, # and type of critical entities without power, critical locations without power for longer than X hours of duration, time to recovery, loss of utility revenue, cost of grid damages ($), cost of recovery, avoided outage costs, cost of lost assets and perishables, business interruption costs

Quantifying energy storage's value requires assessing each technologies' ability to improve system and end-use resilience accounting for different threat types, probabilities, outage durations, costs, infrastructure, and system/facility characteristics.

Transportation & Cross-Sectoral Issues

Markets Policy Analysis

- **Clean Vehicle Procurement Mandates** – to date, state mandates have driven market growth, new policies will dictate size of market
- **Charging/Refueling Rate Structures & Communication Protocols –** rates will either encourage or discourage charging that benefits grid operations
- **Cross-Sectoral Policies** (H_2 pipelines & safety) – H_2 can only become more ubiquitous policies support the safe installation of new infrastructure
- **EV Warrantees for V2G** – in order to provide grid services, EV warrantees need to be changed

Tools

- **System Simulation/Mobility Models** (POLARIS) – simulations of entire transportation systems to optimize flow, infrastructure, and assess costs
- **Transportation, Electricity, and Fuel Demand Models** (TEMPO) – Increased geographic and temporal resolution of energy and electricity demand
- **Charging/Fueling Infrastructure Models** (EVI-Pro) – need to not only find optimal location for customer convenience/range but also distribution system
- **Connection Transportation and Power Sector Models** – need higher resolution in distribution models to optimize charging and upgrades,
- **Cross Sectoral General Equilibrium Models** – inform how fuels use across sectors may impact price and subsequent adoption/fuel switching, e.g. H_2
- **Fuel production models for H_2, NH_3, CH_4** – how cost effective are different storage mediums/fuels to produce under different system scenarios

Valuation Methodology

- **Valuing Cross-sectoral Storage Interactions** – mobile storage can provide power system benefits and stationary storage can enable EV integration
- **Value of Managed EV Charging –** can coordinated EV charging provide an effective demand side flexibility option, how should value be allocated
- **V2G Methodologies: value, duty-cycle, and degradation** – what services can EVs provide to the grid and how will V2G impact vehicle lifespan
- **Value of new fuels (H_2, NH_3, etc.) Methodologies** – how should energy mediums/fuels be valued especially if they provide benefits to multiple sectors
- **Industrial Storage Application Methodologies** – how can storage be incorporated into industrial processes to improve efficiency and productivity

Data

- **Technology Penetration –** how many EVs and FCEVs do we expect to be on the road in the future, where are they located
- **Charging/Fueling Infrastructure Characteristics –** what are the operational constraints and grid impacts of charging/refueling infrastructure
- **Spatial and Temporal Charging/Fueling Demand –** where does charging occur and what times
- **Cost & Performance –** of vehicle subcomponents (batteries, fuel cells), how do they interact with stationary applications cost and performance
- **Fuel Production Costs –** what are the lifecycle costs of making different energy mediums/fuels, what is efficiency of each process
- **Consumer Behavior –** what factors impact vehicle adoption and participation in managed charging or V2G programs, driving behaviors

Developing methodologies and tools that can quantify the potential value that transportation-related storage assets (EVs, fuel cell vehicles, etc.) provide the grid is crucial if we want to maximize the value of existing storage assets and diversify the types of storage available to grid.