U.S. DEPARTMENT OF ENERGY

Energy Storage Grand Challenge

Technology Development Use Cases

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ESGC Technology Development Use Cases

The Energy Storage Grand Challenge (ESGC) will accelerate the development and commercialization of next-generation energy storage technologies through the five focus areas as shown in Figure 1. The ESGC technology development focus area will develop a roadmap to solidify the United States' leadership in energy storage. A series of diverse and innovative use cases are being assembled to help guide this roadmap. These use cases, derived from high-level energy or infrastructure goals of communities, businesses, regions, or other stakeholders, will be translated into a set of technology-neutral functional requirements. These broad specifications will help identify new and augmented research and development paths for a portfolio of energy storage and flexibility technologies that meet emerging needs.

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.

Figure 1: Energy Storage Grand Challenge Focus Areas

0 Introduction to the ESGC Use Case Framework

A use case family describes a set of broad or related future applications that could be enabled by much higher-performing or lower-cost energy storage. Each use case family can contain multiple specific instances that represent scenarios ranging from early high-value projects to high-quantity mass adoption.

The use case families are intended as guidepost examples to facilitate stakeholder discussions that envision future ways (i.e., 2030 and beyond) in which energy storage can benefit end users. The ESGC will seek to identify specific use case examples in each family to help validate the needs and technical requirements for future energy storage systems.

The U.S. Department of Energy (DOE) notes that the use cases presented are not final and may continue to develop prior to the launch of the roadmap.

0.1 Process

To assemble the initial set of use case families, DOE offices and national labs were invited to submit future scenarios that could be enabled through a significant cost or performance improvement in storage technologies. These scenarios were then sorted into use six broad use case families presented in this document. Stakeholders are now invited to provide feedback on these use cases, specifically:

- How can these use cases support the energy or infrastructure goals in your region?
- What can be added to or modified in these use cases to improve their applicability?
- How can these use cases inform the strategies in the other ESGC focus areas?

0.2 Structure and Connections to Technology Roadmaps

Each use case is divided into three sections: introductory discussion of need and scope, high-level vision statement of success for the use case, and identification of stakeholders and beneficiaries. As the use cases are fully developed, each will also include preliminary discussions of technical requirements and examples of enabling technology pathways.

A separate document (under development, based on Appendix B of the Report to Congress on the "Potential Benefits of High-Power, High-Capacity Batteries"[1]) will outline the technology pathways that can contribute to the objectives of the ESGC. As the ESGC strategy development continues, specific technology pathways will be mapped to each use case. DOE envisions that each use case family will have multiple supporting technology pathways and each technology pathway can contribute to multiple use cases.

1 Use Case: Facilitating an Evolving Grid[2]

1.1 Introduction and Scope

The ability of the U.S. electric power system (i.e., the electric grid) to reliably meet customer demand is crucial to our economy and national security. The increasing adoption of variable renewable energy (VRE) and dynamic changes in customer demand, as well as stresses from weather, physical, and cyber threats, are creating the need for enhanced grid flexibility to ensure the continued reliability, resilience, and security of the electric power system.[3] These evolving opportunities and risk factors require an expanded set of storage and flexibility solutions.[4]

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1 **https://energy.gov/sites/prod/files/2020/02/f71/Potential_Benefits_of_High_Powered_Batteries_Report.pdf**

2 Use case development participants included Max Wei (LBNL, coordinator), Katrina Krulla (NETL), Avi Shultz (DOE/EERE/SETO), Nathan Weiland (NETL), Anthony Burrell (NREL), Vikram Linga (EIA), Steve Eglash (SLAC), Jaffer Ghouse (NETL), Hayden Reeve (PNNL), Robert Podgorney (INL), Ryan Wiser (LBNL), Andrew Mills (LBNL), Cyndy Wilson (DOE/OP), Tina Kaarsberg (DOE/EERE/AMO), and Tom Tarka (NETL).

3 Text from U.S. DOE, "Potential Benefits of High-Power, High-Capacity Batteries," January 2020, **https://www.energy.gov/sites/prod/files/2020/02/f71/ Potential_Benefits_of_High_Powered_Batteries_Report.pdf**

4 This use case considers system-level (i.e., front of the meter) vs. facility-centric (behind the meter) effects of Facility Flexibility. For threat and change vectors, this use case considers the changes that can be reasonably foreseen (or happen with sufficient frequency to be incorporated) in current planning or investment processes, as opposed to the disaster resilience/dependent network infrastructure cases, which deal with vectors that happen too rarely or suddenly to guide investment decisions.

1.1.1 Success Statement

If the Facilitating an Evolving Grid use case is successful, grid owners, operators, planners, and users will have access to cost-effective storage, flexibility, and enabling technology solutions to maintain and enhance the provision of electricity services to end users as the grid increases in complexity and diversity.

1.1.2 Beneficiaries

Primary use case beneficiaries (i.e., entities that would procure, operate, and maintain the solution) include utilities, balancing authorities, and commissions in the localities, states, or regions with high carbon-free electricity mandates or facing increasing external threats (i.e., extreme weather events).

Secondary beneficiaries (i.e., entities that benefit when a primary entity implements the solution) include: all grid customers (including vulnerable communities and critical facilities) as well as original equipment manufacturers.

2 Use Case: Serving Remote Communities[5]

2.1 Introduction and Scope

Up to a billion people in the world do not have access to electricity. Island, coastal, and remote communities that are disconnected from the bulk power system pay a premium for electricity due to fuel logistics and maintenance associated with diesel generation. In remote communities subject to extreme weather conditions, fuel supply disruptions are a major risk factor.

2.1.1 Success Statement

If the Serving Remote Communities use case is successful, remote communities will have access to clean, resilient, and cost-effective storage and flexibility solutions to provide electricity for critical and beneficial public services.

2.1.2 Beneficiaries

- Isolated communities without current electrical infrastructure
- Remote communities with electrical power provided by diesel generators, and where connecting to a bulk power system is impractical or economically unfeasible
- The entire United States/world as development of low-cost, robust microgrids can be also incorporated into grid-connected regions to improve local resiliency and flexibility
- Remote Department of Defense locations

[5] Use case development participants included Michael Ropp (Sandia, co-lead), Hugh Ho (DOE/OP), Steve Bukowski (INL), Andre Pereira (DOE/OE), John Vetrano (DOE/BES), Vincent Sprenkle (PNNL, co-lead), Paul Syers (DOE/EERE/AMO), Richard Tusing (NREL), Eric Miller (DOE/EERE/FCTO), and Michael Starke (ORNL).

3 Use Case: Resilience and Recovery[6]

3.1 Introduction and Scope

Sectors that provide critical services include the defense industrial base sector, emergency services sector, government facilities sector, and health care and public health sector. An extended loss of power to facilities in these sectors could lead to unacceptable public health and safety risks, especially following disaster-related power outages. Similarly, non-public companies or manufacturers have a need to resume and maintain operations in the event of an extended outage. The importance of these services reinforces the need to provide sufficient energy supplies to these facilities during an extended outage.

3.1.1 Success Statement

If the Resilience and Recovery use case is successful, critical public service providers will have access to cost-effective storage solutions that maintain critical services for a sufficient duration following extended power outages.

3.1.2 Beneficiaries

Primary use case beneficiaries, (i.e., entities that would procure, operate, and maintain the solution) include:

- End users relying on life safety systems
- Military bases (require longer-duration storage than currently exists)
- Emergency services (FEMA) and first responders
- Government facilities
- Health care facilities

Secondary beneficiaries (i.e., entities that benefit when a primary entity implements the solution) include:

- States, municipalities, islands, and remote communities that suffer from frequent environmental stresses or threats
- Residents and businesses relying on critical services

6 Use case development participants included Cliff Ho SNL (coordinator), Venkat Srinivasan (ANL), Murali Baggu (NREL), Imre Gyuk (DOE/OE), Scott Litzelman (DOE/ARPA-E), Babu Chalamala (SNL), Adam Weber (LBNL), Travis McLing (INL), and Jun Liu (PNNL).

4 Use Case: Electrified Mobility[7]

4.1 Introduction and Scope

Transportation of people and goods is transitioning to increased electrification. To facilitate this transition, there is a need for large-scale, reliable, high-power, and cost-effective charging infrastructure that enables charging times equivalent to that of refueling at a traditional gas station. Because high-power DC fast charging can stress the delivery capacity of the local distribution grid, this new charging infrastructure should minimize any negative grid impact and optimize operations with the grid and other end uses, including buildings. This infrastructure should be planned to account for population, transportation, and grid evolutions. This use case also considers the specific cases of electrified mobility under stress scenarios such as weather-related emergency evacuation needs, and the stationary adaptation of batteries originally developed for vehicles.

Beyond charging infrastructure, energy storage systems will also be necessary for the electric vehicles themselves. Lower manufacturing costs and improved performance of domestically produced electric vehicle batteries can facilitate widespread adoption and further establish American leadership in energy storage.

4.1.1 Success Statement

If the Electrified Mobility use case is successful, transportation and electricity providers will have access to clean and cost-effective storage solutions that facilitate a large-scale adoption of electric vehicles while maximizing beneficial coordination with the power grid.

4.1.2 Beneficiaries

Primary beneficiaries include owners/operators of electric vehicles, electric vehicle supply equipment, or associated power grid infrastructure. Examples of these beneficiaries include:

- Fleet owners (Department of Defense, delivery companies, logistics operators, emergency and first responders)
- Electric utilities, by enabling easier distribution planning
- End consumers, by lowering costs of electrified vehicles and by integrating charging with other beneficial activities
- Charging station operators, by supporting new business models that integrate stationary and mobile storage, providing grid services, or developing new multipurpose functionality of existing assets

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[7] Use case development participants included Madhu Chinthavali (ORNL, co-coordinator), Seth Snyder (INL, co-coordinator), Michael Starke (ORNL, co-coordinator), Claus Daniel (ORNL), Michael Kintner-Meyer (PNNL), John Farrell (NREL), Ralph Muehleisen (ANL), Sam Baldwin (OE/EERE), Vince Battaglia (LBNL), Vinod Siberry (DOE/OE), Stan Atcitty (SNL), Tien Duong (OE/EERE/VTO), Rima Oueid (DOE/OTT), and Stephen Hendrickson (DOE/OTT).

Secondary beneficiaries include:

- States, localities, or communities that suffer from environmental stresses
- Electric truck manufacturers
- Transportation hubs (i.e., Port Authority of New York and New Jersey)
- Entrepreneurs (new business opportunities)

5 Use Case: Interdependent Network Infrastructure[8]

5.1 Introduction and Scope

The operation of the electric grid depends on other infrastructure sectors, including natural gas, communications, information technology, water, and financial services. Loss of function and service within this infrastructure due to energy delivery disruption can have far-reaching impacts and costs for end users. These interdependencies elevate the importance of sustaining the normal operations of critical infrastructure amidst short-term disruption of energy inputs.

5.1.1 Success Statement

If the Interdependent Network Infrastructure use case is successful, critical interdependent infrastructure stakeholders will have access to cost-effective storage solutions that sustain and enhance normal operations amidst short-term disruptions of energy inputs.

5.1.2 Beneficiaries

Primary use case beneficiaries (i.e., entities that would procure, operate, and maintain the solution) include owner-operators of critical infrastructure equipment and systems (and their state and national consortia).

Secondary beneficiaries (i.e., entities that benefit when a primary entity implements the solution) include:

- End users of critical infrastructure products and services
- Municipal, state, regional, and Federal agencies relying upon critical infrastructure
- Commercial and non-profit institutions that rely upon critical infrastructure
- Local, regional, and national planning organizations that make assumptions about the sustainability and growth of critical infrastructure systems
- Vendors of products and services that comprise or sustain critical infrastructures
- Insurers of infrastructure equipment and owner-operators; and insurers of infrastructure-dependent businesses

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8 Use case development participants include Brennen Smith (ORNL, co-coordinator), Kunal Thaker (INL, co-coordinator), Stewart Cedres (DOE/OE), Sumanjeet Kaur (LBNL), Rolf Butters (DOE/EERE/AMO), and Al Hefner (DOE/EERE/AMO).

6 Use Case: Facility Flexibility, Efficiency, and Value Enhancement[9]

The Facility Flexibility, Efficiency, and Value Enhancement use case includes the optimization of processes, behaviors, or value within the boundaries of a facility (i.e., the non-utility side of a revenue or customer meter). Recognizing the significant differences in the nature and intensity of energy flows both across and within specific energy-relevant sectors, this use case family considers two specific sub-families, which will be covered separately in this section:

- **Sub-family 1:** Flexibility for Commercial and Residential Buildings
- **Sub-family 2:** Flexibility for Energy-Intensive Facilities (including Electric Power Generation and Industrial Process Applications)

6.1 Introduction and Scope—Flexibility for Commercial and Residential Buildings

The Flexibility for Commercial and Residential Buildings use case sub-family seeks to leverage opportunities to optimizing energy production and usage in facilities, including commercial and residential buildings. Optimized integrated processes can utilize high-performance, low-cost energy storage technologies to enhance the overall facility value to the owner, operator, and ultimately the end consumer.

6.1.1 Success Statement

If the Flexibility for Commercial and Residential Buildings use case sub-family is successful, building owners, operators, and occupants will have access to storage and flexibility solutions that deliver net benefits, including energy expenditures, comfort, and functionality.

6.1.2 Beneficiaries

Direct beneficiaries include commercial and residential building owners, operators, and occupants.[10] Indirect beneficiaries include utilities and other suppliers to these facilities.

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[9] Use case development participants included Jeff Hoffmann (NETL, coordinator), Susan Babinec (ANL), Joe Cresko (DOE/EERE/AMO), Paul Denholm (NREL), Roderick Jackson (NREL), Robert Kostecki (LBL), Robert Podgorney (INL), Karma Sawyer (DOE/EERE/BTO), Erik Spoerke (Sandia), Michael Starke (ORNL), Paul Syers (DOE/EERE/AMO), Nathan Weiland (NETL), Briggs White (NETL), and Rigel Woodside (NETL).

[10] **https://www.nrel.gov/docs/fy20osti/75470.pdf**

6.2 Introduction and Scope—Flexibility for Energy-Intensive Facilities

The Flexibility for Energy-Intensive Facilities use case sub-family seeks to leverage opportunities to integrate energy storage within a range of electric power generation and energy-intensive industrial facilities. This sub-family is characterized by significantly higher energy flows and in forms not characteristic of the commercial/residential buildings sector. The nature of how energy is converted and transported in the processes associated with energy-intensive facilities optimization offers potential opportunities for improvement in economics, flexibility, and market diversity.

6.2.1 Success Statement

If the Flexibility for Energy-Intensive Facilities use case sub-family is successful, industrial, generator, and other large-scale facilities will have access to storage and flexibility solutions that maximize the total value obtained from the process of interest.

6.3.2 Beneficiaries

Primary beneficiaries are entities that directly benefit from operations of EGU (electric generating units) or energy-intensive industries, including:

- Utility plant owners, operators, and shareholders
- Industry plant owners, operators, and shareholders
- Locally based service providers and/or equipment providers
- Local communities and surrounding regions

Secondary beneficiaries are entities that benefit through reliable, affordable electricity or energy services and/or reduced infrastructure investments, including:

- Electric utility customers (benefit from increased reliability)
- System operators
- Equipment and service provider industry
- Relevant trade and/or training organizations

7 Appendix: Use Case Cross-Referencing

To cross-reference the use case families against previous efforts, Figure 2 maps the connections between use case families and the 16 critical infrastructure sectors listed in PPD-21.[11]

Facilitating an Evolving Grid	Serving Remote Communities	Electrified Mobility	Facility Flexibility, Efficiency, and Value Enhancement	Resilience and Recovery	Interdependent Network Infrastructure
• Dams Sector • Energy Sector ▪ Bulk Power System	• Energy Sector ▪ Energy production and delivery (esp. liquid fuels) • Emergency Services Sector	• Energy Sector ▪ Bulk power system • Emergency Services Sector • Transportation Systems Sector	• Commercial Facilities Sector • Energy Sector ▪ Bulk power facilities • Chemical Sector • Critical Manufacturing Sector • Nuclear Reactors, Materials, and Waste Sector	• Defense Industrial Base Sector • Emergency Services Sector • Government Facilities Sector • Healthcare and Public Health Sector • Food and Agriculture Sector	• Energy Sector ▪ Energy production and delivery (esp. natural gas) • Communications Sector • Financial Services Sector • Information Technology Sector • Water and Wastewater Systems Sector

Figure 2: Coverage of PPD-21 Sectors by Use Case Family

11 Presidential Policy Directive (PPD) on Critical Infrastructure Security and Resilience, February 12, 2013