CHARGES Program Overview

B. PROGRAM OVERVIEW

ARPA-E has invested a significant amount of funding in novel, electrochemical-based electrical energy storage technologies for stationary applications. However, widespread adoption of new storage technologies has been hindered by a lack of proven performance, economic benefit, and long term reliability. In this program, applicants will quantify the value of storage devices, develop realistic duty cycles for storage devices on a microgrid[1], and test emerging battery storage systems in both a controlled environment and under realistic microgrid operating conditions. This program aims to accelerate the commercialization of electrochemical energy storage systems developed in current and past ARPA-E-funded research efforts by giving those battery development teams a clear understanding of value-driven performance requirements that allow for evaluation of their technology early in the development cycle. The performance data that is generated will provide potential end-users of energy storage systems with validated information from a trusted third-party about the performance and value of novel grid storage technologies that are currently in development.

BACKGROUND

Advanced energy storage promises to play a key role in the modernization of our nation's electricity grid. While relatively little storage is deployed on today's grid, tomorrow's grid is likely to have widespread energy storage that improves the grid's operating capabilities, enhances reliability, enables the cost effective integration of ever-increasing amounts of renewables, allows deferral of infrastructure investments, and provides backup power and grid stabilization during emergencies. In a recent assessment of stationary storage[2], US DOE identified four principal challenges to widespread adoption. These challenges include:

1. Development of cost competitive energy storage technology
2. Validation of grid storage technologies' reliability and safety
3. Development of an equitable regulatory environment that enables storage adoption
4. Fostering industry acceptance of new storage technologies

Since 2009, ARPA-E has focused on the first challenge, funding over $85M in research and development of breakthrough stationary storage technologies[3]. These technologies have the potential for very low capital cost (<$150/kWh), enabling widespread deployment to serve a variety of applications on the grid. Many of the ARPA-E technologies have successfully matured, but most still have not proven their performance, reliability, and safety in real grid applications during extended usage. Due to the lack of long term performance and reliability data, end users of stationary storage have difficulty estimating the lifecycle costs and operating requirements of these systems, which is essential to establishing the value of energy storage on the grid. Electric utilities, independent power producers (IPPs), and end users are interested in new storage technologies, however they are reluctant to invest and deploy such systems until there is more comprehensive data related to economic based performance and reliability data under real-world conditions.

Since 2009, DOE's Office of Electricity Delivery and Energy Reliability (DOE-OE) has worked actively with end users to demonstrate storage technologies on the electric grid, including 16 deployments included as part of the Smart Grid Energy Storage Demonstration Program (SGDP)[4]. The SGDP program has generated important findings regarding the development, deployment, and operation of grid storage systems under "real world" conditions. However, the scope of the DOE-OE program is not on emerging battery technologies. For example, only half of the technologies demonstrated in the

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[1] ARPA-E uses the definition of "microgrid" that was developed by the Microgrid Exchange Group (MEG) and adopted by DOE's Smart Grid R&D Program. It defines a microgrid as "a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode." Under this definition, a microgrid may include a privately-owned electric network or a portion of a utility grid that can be operated independently in islanded mode.

[2] US DOE's grid storage strategy is outlined in the December 2013 publication *Grid Storage,* available at http://energy.gov/oe/downloads/grid-energy-storage-december-2013.

[3] Descriptions of active ARPA-E grid storage projects can be found at http://arpa-e.energy.gov/?q=projects/search-projects by selecting Technical Category "Stationary Storage: Grid-Scale Batteries."

[4] For more information, see *Smart Grid Regional and Energy Storage Demonstration Projects*, available from: http://energy.gov/oe/downloads/smart-grid-regional-and-energy-storage-demonstration-projects-awards

SDGP program were electrochemical systems, and many of the batteries that were included were mature chemistries, such as lithium-ion and lead-acid batteries, rather than early-stage electrochemical storage technologies like those supported by ARPA-E.

In addition, most existing storage demonstrations (including those in the SGDP program) focus on storage that is interconnected to the utility grid. As the deployment of microgrids accelerates worldwide, another important opportunity for stationary storage technologies is emerging. While only a limited number of microgrids are currently operational, microgrid capacity is forecast to grow rapidly. Navigant Research, for example, forecasts that worldwide microgrid capacity will increase 5X to 4,100MW by 2020, with North America as the largest market for microgrid systems.[5] Interest in microgrids is growing due to their potential to enhance the efficiency, reliability and resiliency of the electric power system. Yet microgrids present unique technical challenges, including the need to accommodate large amounts of renewable generation and to maintain system stability during islanding[6]. Stationary storage can help to address these challenges, and storage deployments are expected to grow as the number of microgrids increases. To facilitate this growth, additional data is needed on the performance, reliability, and safety of new stationary storage technologies under actual microgrid operating conditions.

C. PROGRAM TASKS

To accelerate commercialization of stationary storage technologies, ARPA-E is initiating the CHARGES program, which focuses on valuing and validating the performance of new stationary storage technologies and fostering industry acceptance of these systems. The CHARGES program includes evaluation of emerging ARPA-E funded stationary storage systems through both controlled laboratory testing as well as under real-world conditions on a microgrid, with substantial participation from future adopters of energy storage systems. This program structure will help ensure that owners of power systems assets have reliable information about the performance characteristics, operating requirements, and life expectancy of emerging stationary storage technologies as those systems are developed. The structure of the CHARGES program differs from previous ARPA-E programs; CHARGES awardees[7] will not develop new technologies, but rather will provide facilities and expertise to teams with existing or past ARPA-E funding who are developing new grid storage technologies. CHARGES awardees will assist ARPA-E-funded battery developers[8] in analyzing, scaling, and testing new battery and flow battery systems, and will also provide a conduit into a potential buyer of grid storage devices, such as a utility, IPP, microgrid operator, or commercial end user.

ARPA-E WILL DETERMINE WHICH STORAGE TECHNOLOGIES ARE TESTED AT THE APPLICANT'S FACILITY. APPLICANTS SHOULD NOT PROPOSE SPECIFIC TECHNOLOGY VENDORS AS PARTNERS IN THIS PROGRAM. APPLICANTS WILL PROVIDE UNBIASED ANALYSIS AND TEST SERVICES IN THIS PROGRAM, AND MUST AGREE TO MAINTAIN STRICT CONFIDENTIALITY REGARDING THE TECHNICAL DETAILS OF THE SYSTEMS BEING TESTED AND THE RESULTS THAT ARE GENERATED.

Awardees in the CHARGES program will conduct the following tasks:

1. Economic Valuation of Grid Storage: In this task, the awardee will select a combination of applications (or application "stack") to be served by the storage device. At a minimum, the application stack should include functions that enable the operation of the microgrid in islanded mode, such as frequency and voltage regulation. The application stack may also include functions necessary for operating the microgrid in grid-connected mode, such as minimizing the cost of energy import from the utility grid at the point of common coupling (PCC). In addition, the awardee may also choose to include one or more applications related to wholesale power services for the utility grid, such as area regulation or ramping support, that the storage device can provide when the microgrid is operating in grid-connected mode. Since not all applications can be adequately served by a single storage device simultaneously, the awardee also will demonstrate that the chosen applications can be combined in a technically feasible manner.

The awardee will assess and quantify the economic benefits associated with each application, and will select an application stack that maximizes the economic value that is expected from the storage device during its operation.

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[5] See Navigant Research report *Microgrids* published in Q4 2013, available from http://www.navigantresearch.com/research/microgrids

[6] For a summary of technical challenges and emerging research and development topics for microgrids, see the US DOE's *Summary Report: 2012 DOE Microgrid Workshop.*

[7] The terms "applicant" and "awardee" use throughout this FOA can refer to a single entity or a team.

[8] "ARPA-E battery developers" includes teams from industry, academia, and national laboratories who received funding from ARPA-E in the past to develop new grid storage technologies.

While methods to value grid storage are developing rapidly, challenges remain in assessing the benefits provided by storage devices, and no standard methodology yet exists.[9] In addition, much of the current financial analysis assumes storage devices will be interconnected to utility grids and generate value through participation in wholesale power markets; fewer studies have examined the financial value of storage devices on microgrids, where they can enhance transient stability and provide other essential services when the system is operating in islanded mode. The awardee will quantify the value the storage device provides during at least one year of future operation at a specific interconnection point on the awardee's microgrid. As part of this process, the awardee must simulate the operation of the storage device under future microgrid operating conditions. This simulation will consider not only how the physical microgrid network may change over time (for example, when additional generation capacity is added), but also how key economic parameters will change in the future, including microgrid operating costs, retail electricity rates, and wholesale power prices. At the conclusion of this task, the awardee will present an application stack, and will deliver simulation results confirming that a single storage device operating on the awardee's microgrid can simultaneously meet the combination of applications. The awardee will also provide a detailed analysis of the economic value delivered by the device, and will present key assumptions about the device and its performance, including system size (power and energy), ramp rates, dwell times, etc.

In the proposal for this effort, the applicant should discuss the general approach for conducting this task, including the applications that will be considered, how combinations of applications will be explored, how technical feasibility of the chosen combination will be confirmed, and how economic value of the application stack will be assessed. The applicant should demonstrate a sound understanding of state-of-the-art methods in economic assessment of grid storage, but also should discuss what new techniques will be applied to assess the value of the services provided by storage on the microgrid operating in both islanded and grid-connected modes. In addition, the applicant should discuss what simulation methods and tools will be employed to simulate operation of the storage system in the future. Applicants should leverage existing datasets (for example, wholesale electricity prices, retail rate schedules, microgrid operating costs, etc.) when possible, and discuss how this data will be obtained. Applicants that choose to include grid-connected applications should discuss the physical location of their microgrid PCC and which utility grid node will be used for pricing information. Applicants should also discuss the process for developing forecasts of how operating costs and market prices are expected to evolve during the period of operation, and clearly outline assumptions about current and future microgrid and utility grid conditions. Finally, applicants should also highlight how their own past microgrid operating experience will be leveraged in the forecasting effort.

2. Test Protocols: In this task, the awardee will simulate the operation of the battery system and develop detailed duty cycles and test procedures that reflect how the battery system must operate to serve the application stack selected in Task 1. The test protocols will be utilized during controlled testing of the battery systems in Task 3, and should encompass the full range of demands that will be placed on the battery during one representative year of operation. Depending on the applications selected and simulation results, the awardee will define 1-3 daily (24-hour) duty cycles. For example, the awardee may choose to have one duty cycle for winter weekdays, another for summer weekdays, and a third for weekend operation to account for the diverse operating conditions that occur throughout a single year. However many duty cycles are developed, each must define the battery system's operational state (charging, discharging, float, offline) as well as the power required from the system at regular intervals. The applicants should propose an appropriate resolution (for example, 1-second intervals) for the duty cycle depending on the application stack that is proposed.

In conjunction with the ARPA-E Program Director, the awardee will also determine the parameters that will be measured as the battery systems follow the duty cycles, as well as the test procedures and equipment that will be used in measurement. Sample battery performance parameters include the battery's ability to deliver the power and energy required in the duty cycle, as well other factors such as capacity retention, energy efficiency, and system temperature during cycling. The awardee will propose measurement procedures and an appropriate sampling rate for acquisition of these parameters. The test protocol, therefore, will outline the specific duty cycles that will be used for testing, the performance metrics that will be measured, how this measurement will be conducted, and how often measurement will occur for each performance parameter. The test protocol (in particular, the duty cycle and performance parameters) may also be reviewed by the awardee's commercial partner (see Task 4). At the conclusion of this task, the awardee will deliver a test protocol in a format so it can be used by ARPA-E battery developers in single-cell battery testing at their own facilities. The protocol will also be used by the awardee to test single and multi-cell systems in Task 3. In addition, the awardee will present key requirements for the storage device to execute the

[9] For a sample valuation methodology, see Byrne, et. al. (2012) *Methodology to Determine the Technical Performance and Value Proposition for Grid-Scale Energy Storage Systems.* SAND2012-10639.

protocols, including system size (power and energy), ramp rates, dwell times, cycle life, capacity utilization, etc. as described in Task 3.

In the proposal for this effort, the applicant team should discuss its general approach to developing the duty cycles and test protocols in this task. The applicant should also discuss how the duty cycles will be validated to confirm that they closely adhere to the operational simulation conducted Task 1. The applicant should demonstrate a sound understanding of existing protocols and state-of-the-art methods in protocol development,[10] and should discuss the tools and methods that will be used in this effort. The proposal should also discuss how the applicant's past experience will be leveraged in this effort, including modification and re-use of existing protocols (if applicable). The applicant should also discuss how the protocols will be presented and what documentation will be provided to ensure that they are "user friendly" and can easily be implemented by ARPA-E performers during single-cell testing.

3. Battery Testing and Analysis: In this task, the awardee will assist ARPA-E-funded battery developers in analyzing, scaling, testing new battery and flow battery systems. The battery developers will conduct initial cell and system testing in their own facilities using the protocol developed in Task 2. The awardee will work collaboratively with ARPA-E technical staff to review the results from this initial testing, and to select systems that are ready for further testing and analysis at the awardee's facility. The awardee then will test energy storage units at varying stages of readiness, from individual cells with a capacity of < 10Wh up to multi-cell systems with a capacity >10 kWh. Regardless of size or technology readiness level (TRL), all storage units will be measured using the same performance parameters. The awardee will develop an appropriate set of performance parameters, and will also propose an appropriate collection rate and measurement procedure for each parameter. At a minimum, the parameters should include:

Charging

- Duration of charge time ,
- Voltage and Amperage input for each cycle
- V_{max} cut-off;
- Power input profile for each cycle (W/kg and W/L on a cell basis and/or system basis, as agreed upon with the ARPA-E Program Director for each test)
- Energy input profile for each cycle (Wh/kg and Wh/L on a cell basis and/or system basis, as agreed upon with the ARPA-E Program Director for each test)
- System temperature

Discharging:

- Duration of discharge time
- Voltage and Amperage output for each cycle;
- V_{max} cut-off;
- Power output profile for each cycle (W/kg and W/L on a cell basis and/or system basis, as agreed upon with the ARPA-E COTR for each test);
- Energy output profile for each cycle (Wh/kg and Wh/L on a cell basis and/or system basis, as agreed upon with the ARPA-E COTR for each test)
- System temperature

Float and Offline:

- Capacity retention (given as a function of percentage of current capacity retained over time at a given state of charge) at points defined during individual cycling;
- System Temperature;

Overall Performance:

- Name Plate Rated Capacity of the System, given as total weight of the cell or system, and its largest possible energy capacity. C-Rate of this optimal case should be disclosed if applicable;
- Duty cycle rated Round trip efficiency, given as a percentage of energy input / energy output at a given power rating. At a minimum, these data should be reported for the highest and lowest rated charge and discharge rates within a given protocol.

[10] For example, see Ferreira, et. al. (2013) *Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems.* SAND2013-7084.

- Overall round trip efficiency of the System, given as the average round trip efficiency over the full range of conditions tested in the agreed upon protocol

At regular intervals during this task, the awardee will report to ARPA-E on the status and performance of the storage systems being tested. The awardee will also share test results with the developers of the systems being tested, providing insights that guide cell/system modifications and improvements. The awardee will develop a plan to manage the data generated in this task, and a process to determine how a particular system progresses from single cell to multi-cell testing. In addition to performance testing, the awardee will work collaboratively with ARPA-E funded battery developers to characterize selected systems, including analysis of fundamental cell or module characteristics such as area specific resistance, electrode kinetics, and limiting current values. In this task, the awardee will be expected to work with up to ten systems from different battery developers simultaneously.

In the proposal for this effort, the applicant should discuss its team's past experience testing and qualifying energy storage units of varying sizes for customers, such as electronics or automotive manufacturers, utilities, hospitals, or other storage customers. Where possible, specific examples should be cited in the applicant's proposal that show the applicant's full breadth of experience in battery testing and analysis, including the protocols used for testing. The applicant should also discuss the facility and physical capability for storage system testing and data acquisition maintained at the applicant's facility, such as number of testing channels and their capacity, maximum safe capacity testing, voltage and current ranges. In addition, the applicant should discuss how cell/system data will be managed and protected, and the process that will be used to share performance data between members of the applicant's team and with ARPA-E battery developers and the ARPA-E technical team. The applicant should describe a plan for assuring confidentiality of test results and for management of intellectual property that may be generated in the collaborative research and development that occurs in this task.

4. Microgrid Testing of Storage Systems: In this task, the awardee will interconnect up to five 1-10kW storage devices provided from ARPA-E battery developers to the awardee's microgrid and operate these devices for up to 24 months. The objective is to assess performance of these devices under actual microgrid operating conditions, as well as to collect initial data on calendar life. Not all systems that are tested in Task 3 will be included in Task 4. The awardee will work collaboratively with ARPA-E technical staff to determine if and when a particular system is ready to proceed to testing on the applicant's microgrid. While some systems may progress rapidly from single cell testing to 1kW system validation, others may move more slowly as performance or durability challenges are identified during Task 3.

In this task, the awardee will provide battery management systems (BMS) for each of the 1-10kW storage systems that are deployed on the awardee's microgrid. The awardee will work collaboratively with ARPA-E battery developers to set key BMS control parameters, such as minimum and maximum voltages during charge and discharge. The awardee will also provide power conversion systems (PCS) for each of the battery systems in this effort. In addition, the awardee will provide appropriate housing for the storage systems, and will interconnect storage systems to the awardee's microgrid. Devices provided from ARPA-E battery developers for testing will be emerging storage technologies that have not been UL-listed or received other safety certifications. Therefore, the awardee will develop a clear process that highlights the steps that are required (including any certification and/or permitting) in order to interconnect this type of new technology safely and quickly to the awardee's microgrid.

Once a storage device is connected to the awardee's microgrid, the awardee will operate the device for up to 24 months. The awardee will implement a system to control dispatch of the storage devices, which will serve the application stack defined in Task 1.[11] The awardee will define key usage parameters and track these parameters during the period that a storage device operates. Sample usage parameters include power delivered/absorbed (with power factor), state of charge, and ambient temperature. The awardee will also define key performance parameters, such as capacity retention, energy efficiency, and system temperature, and track these performance parameters over time as the storage system is operating. Periodically during this task, the awardee will report to ARPA-E on the usage and performance of the storage systems being tested. During the test period, the awardee also will compare the actual operating cycle of the device with the duty cycle(s) developed in Task 2 to confirm that the controlled testing conducted earlier accurately simulated actual conditions on the microgrid. In this task, the awardee will be expected to host up to five systems from different battery developers simultaneously.

[11] While the devices will serve the combination of applications that was selected in Task 1, the actual operating cycle of the battery may differ from the duty cycle(s) that were developed in Task 2.

In the proposal for this effort, the applicant should describe the microgrid that will be used for testing, including system size (average and peak load), types of loads served, types and sizes of generation sources, and tools that will be used for data acquisition, analysis, and control of the microgrid or utility grid. If the applicant's microgrid or utility grid currently has interconnected storage devices, the applicant should describe these devices, how they are operated and controlled, where they are located on the system, how they are connected (including bus voltage, power conversion system, and switchgear), and how they are housed (outdoors, indoors, in portable shipping container, etc.) The applicant should also address the same topics for additional storage devices that will be added to the microgrid in this project, including where future storage devices will be located and how they will be connected to the microgrid. Applicants should also discuss how the storage devices will be housed, describe the infrastructure that will be available for heating/cooling storage systems, and discuss the anticipated conditions (temperature, humidity, etc.) for storage devices in this location. Applicants should also describe any site preparation or system upgrades that will be needed in order to accommodate additional storage units.

Applicants also should discuss previous experience in BMS development and configuration, and propose a BMS (or commercial off-the-shelf solution) that provides sufficient monitoring of key parameters (such as cell voltage and temperature) to ensure safe system operation and to allow for accurate state-of-health and state-of-charge measurements. The applicant should also discuss previous experience in PCS development and configuration, and propose a PCS design (or commercial off-the-shelf solution) that allows for simplified interconnection with the microgrid and interface with control systems. The applicant should also describe the control strategies that are currently in use for existing storage devices on the applicant's microgrid (if applicable), and discuss how the control algorithm will be developed for the storage devices in this effort.
Because devices provided from ARPA-E battery developers for testing will be emerging storage technologies that have not been UL-listed or received other safety certifications, applicants should discuss the procedures that will be used to safely connect and operate these systems on the microgrid, as well as any certification and/or permitting that must be completed before interconnection can occur. The applicant should estimate the time that will be required for interconnection, and should also include "lessons learned" from previous interconnection and operation of storage devices on the applicant's microgrid.

5. Commercial Deployment Pathway: In this task, the awardee will collaborate with at least one potential buyer of stationary storage technologies, such as an electric utility, independent power producer (IPP), or other owner of grid assets. While few of these entities currently operate microgrids, some may elect to operate microgrids with storage in the future, while others will deploy stationary storage on the utility grid. Systems that successfully complete extended testing on the applicant's microgrid will be attractive candidates for scaling, pilot demonstration, and eventual procurement by utilities, IPPs, and end-users. The objective of this task is to ensure that consistent information exchange between storage developers and potential grid storage users occurs throughout this program. The awardee will review and validate key deliverables in this project with a commercial partner; these deliverables include the proposed application stack (Task 1), duty cycle and performance parameters (Task 2), results from controlled testing (Task 3), and results from microgrid testing (Task 4). In order to ensure transparency while also protecting key aspects of ARPA-E battery developers' technologies, the awardee will develop a data management plan that defines the types of data that will be shared with commercial partners and the processes that will govern this data disclosure.

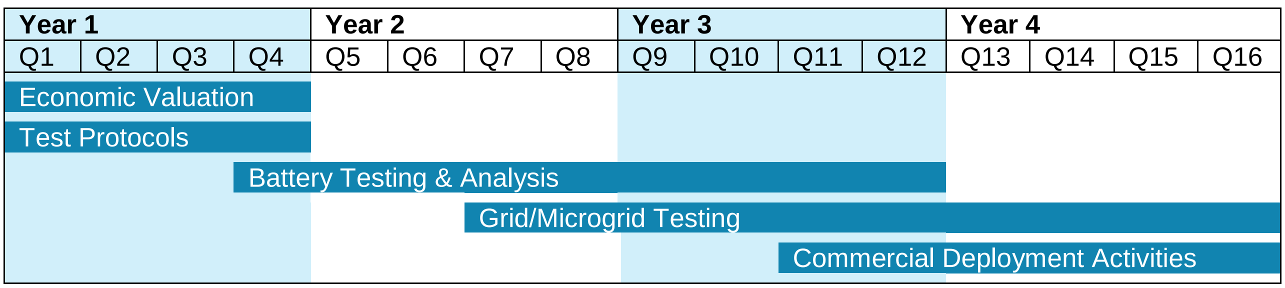
ARPA-E recognizes that the systems tested in this program offer modest amounts of power and energy (5-50kWh). Yet many microgrid applications will require storage systems capable of delivering hundreds of kilowatt-hours, and utility grid applications will demand even larger amounts. Clearly, additional scaling will be required for systems that are successful in this program before they can be widely deployed on microgrids or utility grids. In addition, storage buyers are also likely to require further pilot testing of the scaled systems to confirm their performance is consistent with previous results, as well as to secure the necessary safety certifications. The goal of the CHARGES program is not to deliver a fully-proven storage solution that is ready for deployment. Rather, this program aims to resolve key performance issues before scaling occurs by incorporating real use cases and user requirements early in the development process, giving battery development teams a clearer understanding how these systems will need to perform if they are eventually deployed on a microgrid or utility grid. In addition, potential buyers of energy storage systems will receive validated information from a trusted third-party about the performance of emerging grid storage technologies.

In the proposal for this effort, the applicant should discuss partnerships with electric utilities, IPPs, microgrid or utility grid operators, or other owners of grid assets and discuss how these partnerships will be leveraged in this effort. The applicant should discuss how information exchange will be facilitated between battery development teams and potential buyers of grid storage, and how the data management plan will be developed. The applicant should also discuss how requirements from electric utilities or other end users will be incorporated into test procedures or other aspects of the program. In addition, the applicant team should also discuss its past experience in transitioning advanced technologies (including energy storage) into commercial use on microgrids and/or utility grids, including the process used to validate performance of the new technology and the type of performance data that was required by the customer before the transition could occur.

D. PROJECT STRUCTURE

Timeline: ARPA-E anticipates that the proposed project will proceed according to the timeline shown in Figure 2, with delivery of systems from ARPA-E battery performers beginning in Q4 of the project period. Applicants may propose project timelines that differ from the one shown below, provided the revised timeline is adequately explained and justified, and that it contains all of the key deliverables from the five required tasks. The applicant must address all five tasks outlined in Section C.

Figure 1: Anticipated Project Timeline



Deliverables: The following table outlines key tasks and deliverables that ARPA-E anticipates will be completed during each year of the project. Applicants may propose additional deliverables and/or a revised timeline, provided that the revisions are adequately explained and justified.

Year	Tasks	Deliverables
1	▪ Define application stack ▪ Analyze financial value provided by storage device serving application stack on team's microgrid ▪ Develop use cases for selected application stack ▪ Define test protocols ▪ Initiate analysis and testing of single-cell and multi-cell battery systems from ARPA-E battery developers in controlled testing	▪ Description of final application stack ▪ Accounting of expected financial benefits from storage device serving application stack on team's microgrid ▪ Test protocol, including use case(s) and performance parameters, with sufficient documentation to enable use of the protocol by ARPA-E battery developers in the initial stage of testing ▪ Initial performance results from controlled battery testing and analysis
2	▪ Continue analysis and testing of single-cell and multi-cell battery systems from ARPA-E battery developers in controlled testing ▪ Collaborate with ARPA-E technical team to select systems for testing on microgrid or utility grid ▪ Initiate testing of pilot battery systems (1-10kW) on microgrid or utility grid for 12-24 months	▪ Performance results from controlled battery testing and analysis ▪ Performance results from microgrid or utility grid testing

	▪ Share performance data with potential grid storage system buyers	
3	▪ Continue analysis and testing of single-cell and multi-cell battery systems from ARPA-E battery developers in controlled testing ▪ Collaborate with ARPA-E technical team to select systems for testing on microgrid or utility grid ▪ Continue testing of pilot battery systems (1-10kW) on microgrid or utility grid for 12-24 months ▪ Share performance data with potential grid storage system buyers	▪ Performance results from controlled battery testing and analysis ▪ Performance results from microgrid or utility grid testing
4	▪ Continue testing of pilot battery systems (1-10kW) on microgrid or utility grid for remaining 12 months ▪ Share performance data with potential grid storage system buyers	▪ Performance results from controlled battery testing and analysis ▪ Performance results from microgrid or utility grid testing