FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

ADVANCED RESEARCH PROJECTS AGENCY – ENERGY (ARPA-E)
U.S. DEPARTMENT OF ENERGY

PERFORMANCE-BASED ENERGY RESOURCE FEEDBACK, OPTIMIZATION, AND RISK MANAGEMENT (PERFORM)

Announcement Type: Modification 01
Funding Opportunity No. DE-FOA-0002171
CFDA Number 81.135

Funding Opportunity Announcement (FOA) Issue Date:	September 19, 2019
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, October 18, 2019
Submission Deadline for Concept Papers:	9:30 AM ET, October 28, 2019
Second Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, TBD
Submission Deadline for Full Applications:	9:30 AM ET, TBD
Submission Deadline for Replies to Reviewer Comments:	5 PM ET, TBD
Expected Date for Selection Notifications:	TBD
Total Amount to Be Awarded	Approximately $30 million, subject to the availability of appropriated funds.
Anticipated Awards	ARPA-E may issue one, multiple, or no awards under this FOA. Awards may vary between $250,000 and $10 million.

- For eligibility criteria, see Section III.A of the FOA.
- For cost share requirements under this FOA, see Section III.B of the FOA.
- To apply to this FOA, Applicants must register with and submit application materials through ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/Registration.aspx). For detailed guidance on using ARPA-E eXCHANGE, see Section IV.H.1 of the FOA.
- Applicants are responsible for meeting each submission deadline. Applicants are strongly encouraged to submit their applications at least 48 hours in advance of the submission deadline.

For detailed guidance on compliance and responsiveness criteria, see Sections III.C.1 through III.C.4 of the FOA.

Questions about this FOA? Check the Frequently Asked Questions available at http://arpa-e.energy.gov/faq. For questions that have not already been answered, email ARPA-E-CO@hq.doe.gov (with FOA name and number in subject line); see FOA Sec. VII.A. Problems with ARPA-E eXCHANGE? Email ExchangeHelp@hq.doe.gov (with FOA name and number in subject line).

Mod. No.	Date	Description of Modifications
01	10/22/2019	• Updated corrupted hyperlinks throughout document

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REQUIRED DOCUMENTS CHECKLIST

For an overview of the application process, see Section IV.A of the FOA.

For guidance regarding requisite application forms, see Section IV.B of the FOA.

For guidance regarding the content and form of Concept Papers, Full Applications, and Replies to Reviewer Comments, see Sections IV.C, IV.D, and IV.E of the FOA.

SUBMISSION	COMPONENTS	OPTIONAL/ MANDATORY	FOA SECTION	DEADLINE
Concept Paper	• Each Applicant must submit a Concept Paper in Adobe PDF format by the stated deadline. The Concept Paper must not exceed 4 pages in length and must include the following: ○ Concept Summary ○ Innovation and Impact ○ Proposed Work ○ Team Organization and Capabilities	Mandatory	IV.C	9:30 AM ET, October 28, 2019
Full Application	[TO BE INSERTED BY FOA MODIFICATION IN DECEMBER 2019]	Mandatory	IV.D	9:30 AM ET, TBD
Reply to Reviewer Comments	[TO BE INSERTED BY FOA MODIFICATION IN DECEMBER 2019]	Optional	IV.E	5 PM ET, TBD

I. FUNDING OPPORTUNITY DESCRIPTION

A. AGENCY OVERVIEW

The Advanced Research Projects Agency – Energy (ARPA-E), an organization within the Department of Energy (DOE), is chartered by Congress in the America COMPETES Act of 2007 (P.L. 110-69), as amended by the America COMPETES Reauthorization Act of 2010 (P.L. 111-358) to:

"(A) to enhance the economic and energy security of the United States through the development of energy technologies that result in—
(i) reductions of imports of energy from foreign sources;
(ii) reductions of energy-related emissions, including greenhouse gases; and
(iii) improvement in the energy efficiency of all economic sectors; and
(B) to ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies."

ARPA-E issues this Funding Opportunity Announcement (FOA) under the programmatic authorizing statute codified at 42 U.S.C. § 16538. The FOA and any awards made under this FOA are subject to 2 C.F.R. Part 200 as amended by 2 C.F.R. Part 910.

ARPA-E funds research on and the development of high-potential, high-impact energy technologies that are too early for private-sector investment. The agency focuses on technologies that can be meaningfully advanced with a modest investment over a defined period of time in order to catalyze the translation from scientific discovery to early-stage technology. For the latest news and information about ARPA-E, its programs and the research projects currently supported, see: http://arpa-e.energy.gov/.

ARPA-E funds transformational research. Existing energy technologies generally progress on established "learning curves" where refinements to a technology and the economies of scale that accrue as manufacturing and distribution to develop drive down the cost/performance metric in a gradual fashion. This continual improvement of a technology is important to its increased commercial deployment and is appropriately the focus of the private sector or the applied technology offices within DOE. By contrast, ARPA-E supports transformative research that has the potential to create fundamentally new learning curves. ARPA-E technology projects typically start with cost/performance estimates well above the level of an incumbent technology. Given the high risk inherent in these projects, many will fail to progress, but some may succeed in generating a new learning curve with a projected cost/performance metric that is significantly lower than that of the incumbent technology.

ARPA-E funds technology with the potential to be disruptive in the marketplace. The mere creation of a new learning curve does not ensure market penetration. Rather, the ultimate value of a technology is determined by the marketplace, and impactful technologies ultimately become disruptive – that is, they are widely adopted and displace existing technologies from

the marketplace or create entirely new markets. ARPA-E understands that definitive proof of market disruption takes time, particularly for energy technologies. Therefore, ARPA-E funds the development of technologies that, if technically successful, have the clear disruptive potential, e.g., by demonstrating capability for manufacturing at competitive cost and deployment at scale.

ARPA-E funds applied research and development. The Office of Management and Budget defines "applied research" as an "original investigation undertaken in order to acquire new knowledge…directed primarily towards a specific practical aim or objective" and defines "experimental development" as "creative and systematic work, drawing on knowledge gained from research and practical experience, which is directed at producing new products or processes or improving existing products or processes."[1] Applicants interested in receiving financial assistance for basic research should contact the DOE's Office of Science (http://science.energy.gov/). Office of Science national scientific user facilities (http://science.energy.gov/user-facilities/) are open to all researchers, including ARPA-E Applicants and awardees. These facilities provide advanced tools of modern science including accelerators, colliders, supercomputers, light sources and neutron sources, as well as facilities for studying the nanoworld, the environment, and the atmosphere. Projects focused on early-stage R&D for the improvement of technology along defined roadmaps may be more appropriate for support through the DOE applied energy offices including: the Office of Energy Efficiency and Renewable Energy (http://www.eere.energy.gov/), the Office of Fossil Energy (http://fossil.energy.gov/), the Office of Nuclear Energy (http://www.energy.gov/ne/office-nuclear-energy), and the Office of Electricity Delivery and Energy Reliability (http://energy.gov/oe/office-electricity-delivery-and-energy-reliability).

B. PROGRAM OVERVIEW

1. MOTIVATION

Affordable and reliable electricity is a fundamental component for any advanced society; there is a strong correlation of a country's gross domestic product (GDP) with its electric energy consumption.[2] The significance of the grid is illustrated by the National Academy of Engineering (NAE) choosing the electric power grid as the greatest engineering achievement of the twentieth century.[3] Today's challenge is to maintain the affordability and reliability of the existing grid, essential to the U.S. economy, while transitioning to a modern, clean, and sustainable electric power sector. As emerging technologies are increasingly deployed,

[1] OMB Circular A-11 (https://www.whitehouse.gov/wp-content/uploads/2018/06/a11_web_toc.pdf), Section 84, pg. 3.
[2] United Nations Development Programme, "Human Development Report 2007/2008: Fighting Climate Change: Human Solidarity in a Divided World," Online. Available: http://hdr.undp.org/sites/default/files/reports/268/hdr_20072008_en_complete.pdf
[3] National Academy of Engineering, "Greatest Achievements," Online. Available: http://www.greatachievements.org/?id=2949

management systems must leverage all capabilities of these emerging assets[4] to maintain an economical and reliable grid.

2. PERFORM PROGRAM SUMMARY

Optimal utilization of all grid assets[5] requires a fundamental shift in grid management rooted in an understanding of asset risk and system risk. ARPA-E seeks innovative management systems that (i) represent the relative delivery risk[6] of each asset and (ii) balance the collective risk of all assets across the grid. A risk-driven paradigm will allow operators to fully understand the true likelihood of maintaining a supply-demand balance and system reliability; this is critical for all power systems and is essential for grids with high levels of stochastic resources.[7]

Existing management practices were designed for a grid consisting of and fully reliant on conventional generation assets.[8] Present operational and planning practices do not acknowledge or leverage the true capabilities and associated challenges of emerging assets. A risk-driven paradigm will allow emerging assets to be trusted and relied upon to provide the critical products and services necessary to maintain an efficient and reliable grid, thereby breaking the persistent reliance on conventional generation technologies.

Through the **Performance-based Energy Resource Feedback, Optimization, and Risk Management** (PERFORM) program, Applicants will propose methods to quantify and manage risk at the asset level and at the system level. At the asset level, ARPA-E envisions the design of a risk score or measure that clearly communicates the physical delivery risk of an asset's offer, similar to the role a credit score plays in determining the creditworthiness of an individual.[9,10] At the system level, ARPA-E envisions the design of grid management systems that endogenously capture uncertainty and evaluate and hedge the system risk position to meet or exceed a baseline system risk index.[11,12] The anticipated outcome of PERFORM is a transformative and disruptive risk-driven grid management paradigm that optimally utilizes all assets (including emerging technologies) to reduce costs and improve reliability.

ARPA-E expects PERFORM awardees to build on existing practices and expertise from the finance, insurance, and actuarial science communities, which have a long history of defining, quantifying, and hedging risk. Applicants should pursue partnerships with these communities along with domain-specific experts (e.g., engineers, operations researchers, and market

[4] Emerging assets include bulk renewable resources, bulk storage, and distributed energy resources (DER).
[5] Assets include: bulk renewables, bulk storage, distributed energy resources (DER), and conventional generation technologies (e.g., fossil-fuel units, nuclear power, hydro power, and other power generation technologies).
[6] Delivery risk is defined as the likelihood and impact as to whether the asset delivers on its obligations.
[7] Stochastic resources are variable and uncertain in nature: wind, solar, and particular types of distributed energy resources.
[8] Conventional generation assets refer to fossil-fuel units, nuclear power, hydro power, and other traditional bulk technologies.
[9] U.S. Government, "Credit Reports and Scores," Online. Available: https://www.usa.gov/credit-reports
[10] See Section I.D.2 and Section I.D.4 of the FOA for the asset-level technical discussion.
[11] See Section I.D.3 and Section I.D.4 of the FOA for the system-level technical discussion.
[12] A baseline system risk index will be proposed, designed, and developed by PERFORM awardees.

designers) to achieve technically relevant innovative solutions. PERFORM is targeting all power sectors: (i) bulk and distribution systems, (ii) centralized and decentralized paradigms, and (iii) vertically integrated utilities, markets, and peer-to-peer transactive energy systems.

Applicants are strongly encouraged to visit the ARPA-E PERFORM Workshop website to review prior presentation material and supplemental background information.[13] Applicants are referred to the Glossary in Section IX of the FOA.

3. EXISTING PRACTICES

Today's grid relies on conventional, bulk power plants to provide the essential flexibility to operate the system reliably. These assets are dispatchable and can guarantee their available capacity, except in rare events. The existing risk management strategy is to protect against those rare events: the loss of a single bulk asset (i.e., a generator asset or a transmission asset). This is referred to as N-1 reliability and is mandated by the North American Electric Reliability Corporation (NERC).[14] There are additional methods to assess system reliability: N-k reliability[15], N-1-1 reliability[16], loss of load expectation[17], loss of load probability[18], the one day in ten years criterion, as well as others.[19,20] Existing risk management practices align well with conventional technologies but must be reassessed due to the impending dramatic shift in resource mix. Levelized cost of energy (LCOE) is decreasing substantially for emerging assets. When combined with aggressive renewable portfolio standards (RPS)[21], stochastic resources are expected to achieve higher penetration levels in the future.[22,23,24,25] Figure 1 provides an overview of predicted levels of stochastic resources by 2030. Existing RPS goals focus only on overall

[13] U.S. DOE ARPA-E, "PERFORM Workshop," Online. Available: https://arpa-e.energy.gov/?q=workshop/performance-based-energy-resource-feedback-optimization-and-risk-management. Applicants are encouraged to review the presentations and supplemental ARPA-E material at the end, which includes an overview of PERFORM based on the Heilmeier questions.
[14] North American Electric Reliability Corporation, "Reliability Concepts," Online. Available: https://www.nerc.com/files/Reliability%20Assessment%20Guidebook%203%201%20Final.pdf
[15] N-k is defined as the loss of k bulk elements simultaneously.
[16] N-1-1 is defined as the loss of a bulk element followed by the loss of another bulk element some time later; N-1-1 reliability assessment is used to analyze whether the system can recover from the first event and regain N-1 reliability within the time requirements established by NERC (e.g., 30 minutes).
[17] Loss of load expectation: the expected number of days per year (or other time period) during which (for one or more intraday time intervals) there is insufficient generation capacity available to serve the demand.
[18] Loss of load probability: The probability that the system demand will exceed the available generation capacity at a given time.
[19] North American Electric Reliability Corporation, "Standard TPL-001-4 – Transmission System Planning Performance Requirements," Online. Available: https://www.nerc.com/files/TPL-001-4.pdf
[20] North American Electric Reliability Corporation, "Probabilistic Adequacy and Measures: Technical Reference Report," 2018. Online.
[21] U.S. Energy Information Administration, "Updated Renewable Portfolio Standards Will Lead to More Renewable Electricity Generation," Online. Available: https://www.eia.gov/todayinenergy/detail.php?id=38492
[22] U.S. Energy Information Administration, "US Battery Storage Market Trends," Online. Available: https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf
[23] IHS Markit, "PJM Solar Forecast 2018: Forecasts," October 29, 2018. Online. Available: https://www.pjm.com/-/media/committees-groups/subcommittees/las/20181127/20181127-item-06a-ihs-markit-pjm-solar-forecasts.ashx
[24] K. Ardani, J. J. Cook, R. Fu, and R. Margolis, "Cost-Reduction Roadmap for Residential Solar Photovoltaics (PV) 2017-2030," National Renewable Energy Laboratory, Online. Available: https://www.nrel.gov/docs/fy18osti/70748.pdf
[25] U.S. Department of Energy, Office of Efficiency & Renewable Energy, "2017 Wind Technologies Market Report," https://www.energy.gov/sites/prod/files/2018/08/f54/2017_wind_technologies_market_report_8.15.18.v2.pdf

renewable energy production and do not acknowledge the long list of services that are required to achieve a functioning and reliable grid.

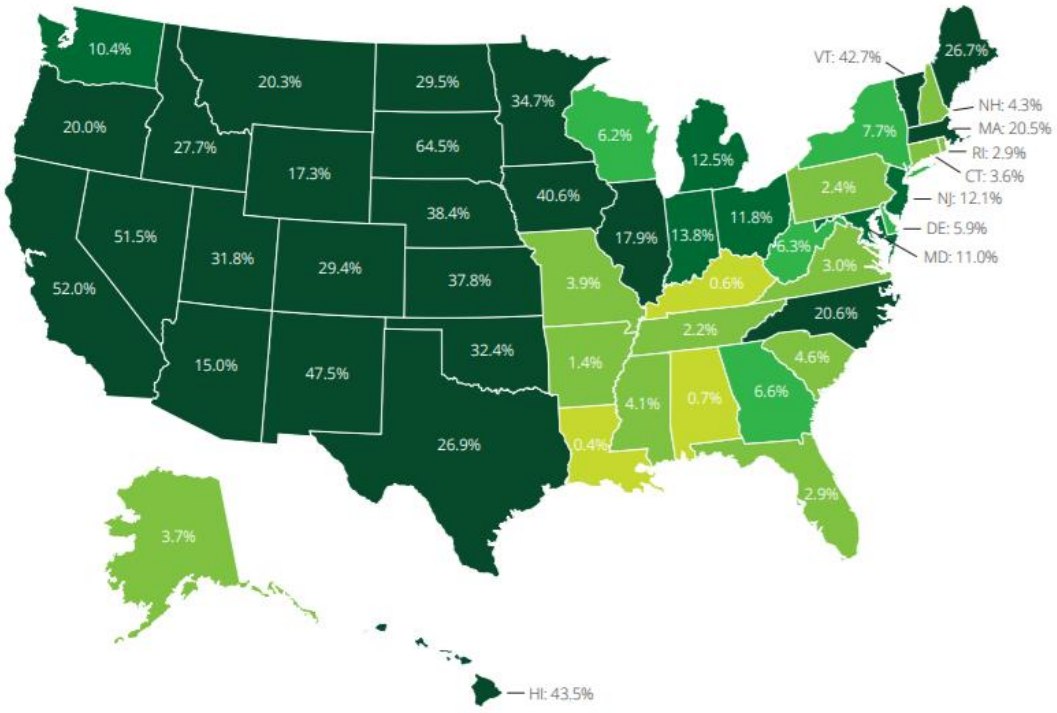

Figure 1. Stochastic Resource Penetration Predicted for 2030[26]

As the portfolio of grid assets evolves, operational challenges are shifting. Existing practices were designed decades ago to manage fleets of conventional power plants. Antiquated grid management systems can only leverage resources that fit this classical definition. These decision support tools do not leverage the capabilities of new technologies because they lack a mechanism to quantify asset delivery risk relative to conventional resources.
Furthermore, existing grid management strategies assume that zero marginal cost assets, like wind and solar, should inject as much power into the grid as possible. While these assets have a zero marginal operational cost, they may also impose a non-zero marginal risk on the system. Existing practices force conventional generation technologies to compensate for the variability and uncertainty introduced by these assets. One famous case is the California Duck Curve, which emphasizes ***variability*** caused by solar assets.[27,28] This variability causes sharp, but foreseeable, changes in net load, such as the loss of rooftop solar production in the evening. In 2012, California predicted 13,000MW ramp events over a three hour period, by 2020 (see Figure 2); operational occurrences are already exceeding these predictions (see Figure 3).

[26] J. McCue, M. Motyka, S. Sanborn, K. Sharma, A. Slaughter, and D. V. Shah, "Managing Variable and Distributed Energy Resources: A New Era for the Grid," Deloitte Center for Energy Solutions, 2016. https://www2.deloitte.com/content/dam/Deloitte/us/Documents/energy-resources/us-er-grid-integration.pdf
[27] California Independent System Operator, "What the Duck Curve Tells Us about Managing a Green Grid," Online. Available: https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf
[28] U.S. Department of Energy, Office of Energy Efficient & Renewable Energy, "Confronting the Duck Curve: How to Address Over-Generation of Solar Energy," Online. Available: https://www.energy.gov/eere/articles/confronting-duck-curve-how-address-over-generation-solar-energy

In the existing operational paradigm, variability is managed by strategies rooted in antiquated grid management practices. California handles the challenge of steep ramping events by relying on flexibility from its conventional generation technologies and on substantial flexibility from neighboring states. This can be seen by the negative correlation of the swing of net imports relative to the overall renewable production, as shown in Figure 4.

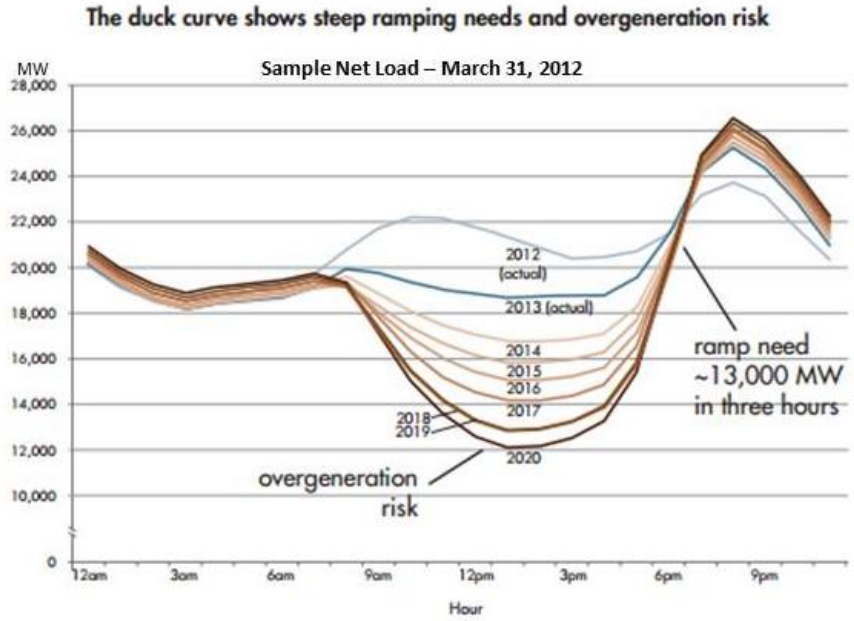

Figure 2. The California Duck Curve

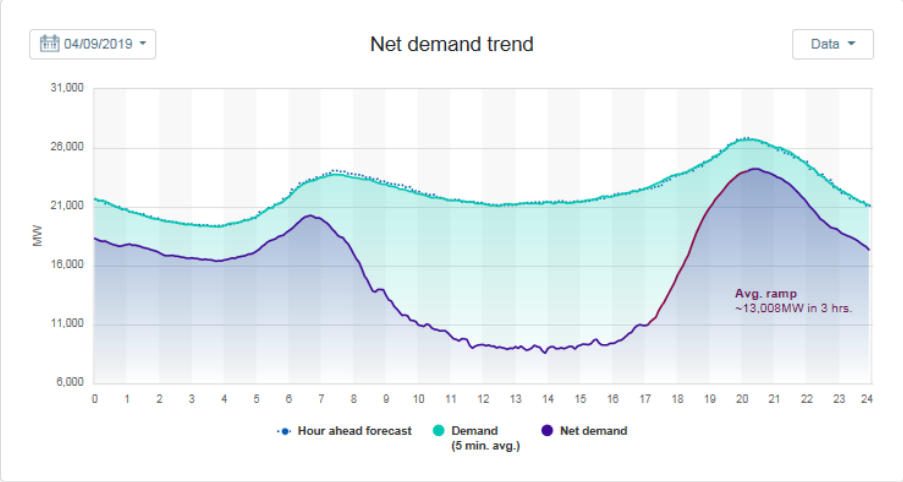

Figure 3. California Independent System Operator (CAISO) Total Load and Net Load: April 9, 2019.[29]

[29] California Independent System Operator, "Today's Outlook," Online. Available: http://www.caiso.com/TodaysOutlook/Pages/default.aspx

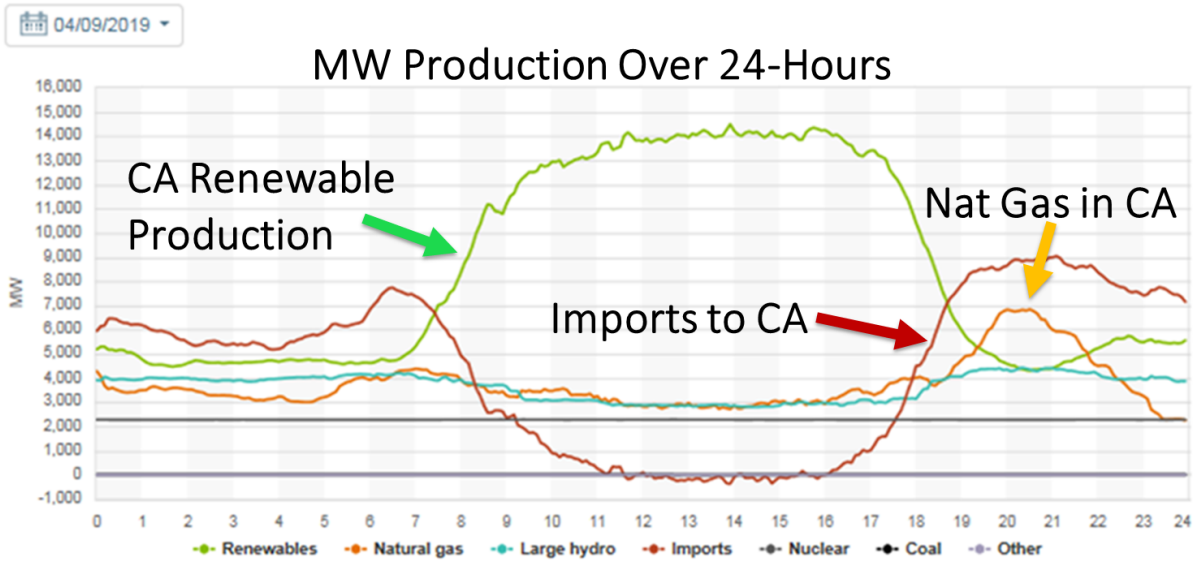

Figure 4. California Independent System Operator (CAISO) Production by Resource Type and Net Imports: April 9, 2019[30]

There are also challenges in managing ***uncertainty***. On June 26, 2019 at 2:00pm, the Midcontinent Independent System Operator (MISO) anticipated 4,000MW of renewable energy production during its day-ahead operational planning stage, as shown in Figure 5. In real-time, only 1,000MW was actually produced. This 73% forecast error had to be balanced in real-time to maintain system operations. Existing practices manage such mismatches between a forecast and the actual delivery based on management strategies designed around (i) conventional thermal technologies and (ii) single point forecasts.[31] System operators rely on conventional resources and conservative quantities of ancillary services because uncertainty is not characterized and risk is not quantified. Ignoring uncertainty complicates operations, increases overall costs, and exposes the system to unnecessary risks.

[30] California Independent System Operator, "Today's Outlook," Online. Available: http://www.caiso.com/TodaysOutlook/Pages/supply.aspx

[31] Existing management systems are incapable of jointly optimizing over distributional forecasts or including a stochastic model within the optimization engine. Instead, it is assumed that the amount of ancillary services, which are estimated offline, will be sufficient to cover any error in the single point forecast.

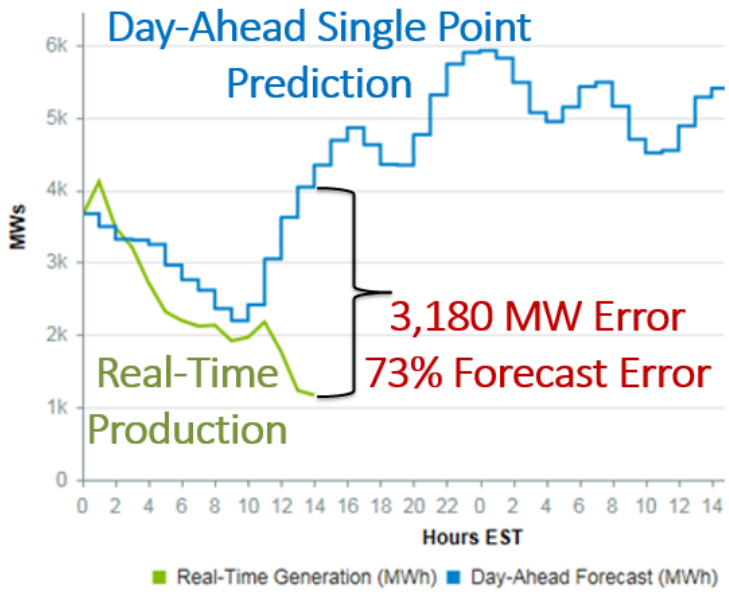

Figure 5. The Midcontinent Independent System Operator (MISO) Day-Ahead Renewable Forecast versus the Real-Time Renewable Production: June 26, 2019[32,33]

It is critically important to acknowledge, quantify, and evaluate asset variability and uncertainty along with ***correlation*** across assets, especially for systems dominated by stochastic resources. To illustrate the importance of acknowledging correlation across stochastic resources, consider the following events in MISO. On July 29, 2018, MISO had an instant where only 1 MW of renewable power was present when the system was in an operational state that was close to its peak load of 100GW. On the previous day, MISO had roughly 128MW of renewable power produced over the course of an hour.[34] MISO had over 18GW of renewable capacity in 2018. It is essential to also consider ***negative correlation*** across stochastic resources such that extreme events (e.g., when very little renewable production is present) can be minimized.

The Independent System Operator of New England (ISONE) partially addresses the challenge of managing wind and solar resources with do-not-exceed (DNE) limits.[35,36,37] The DNE limits specify the vulnerability of the system relative to deviations in injected power at a particular location for a given operational state. The DNE limits do not distinguish based on the type of asset at the location; there is no acknowledgement of asset delivery risk. Innovative

[32] Midcontinent Independent System Operator, "MISO Real-Time Displays," Visited: June 26, 2019. Online. Available: https://www.misoenergy.org/markets-and-operations/real-time--market-data/real-time-displays/

[33] Note that on June 26, 2019, ARPA-E visited MISO's website and observed this event occurring live, which is why the real-time production does not extend across the entire 24 hours.

[34] Midcontinent Independent System Operator, "MISO 2018 Summer Assessment Report," pp. 4, September 2018. Online. Available: https://cdn.misoenergy.org/2018%20Summer%20Assessment%20Report283263.pdf

[35] Do-not-exceed (DNE) limits specify the range in which a stochastic resource's production will not threaten the reliability of the system; DNE limits reflect a worst-case situation for a particular operational state.

[36] Independent System Operator of New England, "Do Not Exceed Dispatch (DNE) Project," Online. Available: https://www.iso-ne.com/participate/support/customer-readiness-outlook/do-not-exceed-dispatch

[37] J. Zhao, T. Zheng, and E. Litvinov. "Variable Resource Dispatch Through Do-Not-Exceed Limit," *IEEE Transactions on Power Systems*, vol. 30, no. 2, pp. 820-828, March 2015.

management practices, which quantify delivery risk, will enable higher penetration levels of these resources while also achieving improvements in costs, curtailment, and emissions.[38]

Misclassification of emerging assets dictates how the assets are managed and utilized, which depresses their value proposition.[39] Consider that renewable resources are often referred to as and treated as negative load. System operators rely on conventional operational paradigms, operator intuition, and rule-of-thumb approaches where the net load must be managed by conventional power plants.[40] Storage is often treated interchangeably as a generation asset, a load, or even as a transmission asset[41,42] rather than as storage, which is a risk-mitigating asset. Forcing emerging assets into the operational characteristics of the most similar conventional technologies is problematic at best. Emerging assets will continue to be under-utilized until modern management systems accurately capture asset flexibility and delivery risk.

Grid entities are beginning to acknowledge the capabilities of new asset classes. MISO has two classifications for stochastic renewable resources: (i) intermittent resources (IR) and (ii) dispatchable intermittent resources (DIR).[43] Intermittent resources provide only energy and DIR may provide energy and regulation down reserves.[44] First Solar has conducted a joint study with the California Independent System Operator (CAISO) and the National Renewable Energy Laboratory (NREL) to demonstrate that photovoltaic (PV) solar resources, combined with existing technologies (e.g., monitoring devices, controls, and power electronics) can provide essential ancillary services, such as voltage support and frequency regulation.[45,46] Asset owners are acknowledging the services that storage can provide and are working towards capturing the

[38] E3, TECO, First Solar Report, "Investigating the Economic Value of Flexible Solar Power Plant Operation," October 2018. Online. Available: https://www.ethree.com/wp-content/uploads/2018/10/Investigating-the-Economic-Value-of-Flexible-Solar-Power-Plant-Operation.pdf

[39] E. Gimon, "How Market Rules Are Holding Back Energy Storage," Green Tech Media, January 24, 2019. Online. Available: https://www.greentechmedia.com/articles/read/energy-storage-wholesale-market-rules

[40] U.S. Energy Information Administration, "Increased Solar and Wind Electricity Generation in California are Changing Net Load Shapes," December 9, 2014. Online. Available: https://www.eia.gov/todayinenergy/detail.php?id=19111

[41] California Independent System Operator, "Storage as a Transmission Asset," Online. Available: http://www.caiso.com/informed/Pages/StakeholderProcesses/StorageAsATransmissionAsset.aspx

[42] B. Cassell, "AEP Texas sees Battery Energy Storage as Alternative to Grid Upgrades," September 19, 2016. Online. Available: https://www.elp.com/articles/2016/09/aep-texas-sees-battery-energy-storage-as-alternative-to-grid-upgrades

[43] Midcontinent Independent System Operator, "Dispatchable Intermittent Resources (DIR) Modification (MR040)," Online. Available: https://www.misoenergy.org/stakeholder-engagement/issue-tracking/dispatchable-intermittent-resource-dir-modification/

[44] Midcontinent Independent System Operator, "Allow Dispatchable Intermittent Resources (DIR) to Provide Regulation Service (MR069)," Online. Available: https://www.misoenergy.org/stakeholder-engagement/issue-tracking/allow-dispatchable-intermittent-resources-dirs-to-provide-regulation-service/

[45] C. Loutan, P. Klauer, S. Chowdhury, S. Hall, M. Morjaria, V. Chadliev, N. Milam, C. Milan, and V. Gevorgian, "Demonstration of Essential Reliability Services by a 300-MW Solar Photovoltaic Power Plant," Online. Available: https://www.nrel.gov/docs/fy17osti/67799.pdf

[46] M. Morjaria, "Grid Services from Solar: Challenges and Opportunities," First Solar. June 17, 2019. Online. Available: https://arpa-e.energy.gov/sites/default/files/04_Grid%20Services%20from%20Solar%20--%20Challenges%20and%20Opportunities_Morjaria.pdf

potential flexibility and reliability benefits.[47] System operators are also working towards including storage and DER into their market management systems.[48]

Even with these advances, existing practices classify whether an asset is allowed to provide a service based on meeting a single performance threshold.[49] This binary policy is a replacement for quantifying the delivery risk directly and provides no middle ground. More fluid asset risk assessment and management approaches are needed for systems with stochastic resources. Until the relative risk that all assets impose on the grid can be accurately quantified and evaluated in operational and planning systems, management practices will remain captive to conventional technologies.

Industry acceptance and adoption risk is important to acknowledge, especially for a mature, entrenched industry. The electric power sector originally resisted deregulation and was hesitant to accept spot markets and locational marginal prices (LMP); these are now fundamental constructs in industry. The new challenge and the impending transition is now risk: (i) the acknowledgment of risk, (ii) the acceptance that assets impose risk on the system, and (iii) the need for innovative asset risk assessment, system risk assessment, and overall risk management. Lessons from the past will smooth the transition to a risk-based paradigm. ARPA-E seeks to leverage expertise from communities that have a history of managing risk.

4. LEVERAGING PRACTICES FROM FINANCE AND ACTUARIAL SCIENCE

The finance community has a long history of articulating, quantifying, balancing, and integrating the tradeoffs between individual asset risk and return versus aggregated asset risk and return. This community has developed concepts and complex mathematics over many decades; these approaches and thought processes may be translated for the power sector to quantify delivery risk. One possible approach is the interplay of individual assets versus the aggregated assets or a portfolio of assets. In the finance world, modern portfolio theory is rooted in the fundamental understanding that diversification across individual assets allows investors to maximize expected return while minimizing risk exposure by understanding asset price correlation across a portfolio.[50,51] In fact, portfolio management strategies have a variety of risk measures that can be minimized including variance, value-at-risk, and conditional value-at-risk, which are indicators of the probability and magnitude of expected loss.[52] These methods mainly address

[47] Edison Electric Institute, "Leading the Way: U.S. Electric Company Investment and Innovation in Energy Storage," October 2018. Online. Available: https://www.eei.org/issuesandpolicy/Energy%20Storage/Energy_Storage_Case_Studies.pdf
[48] M. Almono, "How Power Market Structures are Driving Demand for Energy Storage Investment," American Council on Renewable Energy, April 25, 2019. https://acore.org/market-structures-storage-investment/
[49] PJM, "Performance Scoring: Regulation Market Senior Task Force," Online. Available: https://www.pjm.com/~/media/committees-groups/task-forces/rmistf/20160413/20160413-item-02-performance-scoring.ashx
[50] H. Markowitz, "Portfolio Selection," *The Journal of Finance*, vol. 7, no. 1, pp. 71-91, March 1952. https://www.math.ust.hk/~maykwok/courses/ma362/07F/markowitz_JF.pdf
[51] W. F. Sharpe, "Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk," *The Journal of Finance*, vol. 19, no. 3, September 1964. https://onlinelibrary.wiley.com/doi/full/10.1111/j.1540-6261.1964.tb02865.x
[52] R. T. Rockafellar and S. Uryasev, "Optimization of Conditional Value-at-Risk," *Journal of Risk,* 2000. https://pdfs.semanticscholar.org/0df3/ccfb652189488337202933d4151fc20ac31d.pdf

idiosyncratic, diversifiable, or residual risks due to microeconomic factors. These methods do not address systemic risk (exogenous/event shock) or market/systematic risk due to macroeconomic factors, the latter of which may be partially hedged occasionally. In financial markets, idiosyncratic risk accounts for most of the variability in uncertainty surrounding individual assets over time, rather than market risk; by extension, ARPA-E anticipates most of the variability in uncertainty modeling to be associated with the individual grid assets.

Aggregate portfolio performance can be represented either mathematically or graphically. In its simplest graphical form, a risk/return analysis of an asset portfolio can be modeled as an efficient frontier plot indicating how far the asset portfolio is from an optimum risk/return profile. If a portfolio is suboptimal, i.e., operating below the efficient frontier, then either returns need to be increased or the risk decreased to achieve a Pareto improvement in performance.[53] As a result, factors that influence a portfolio's risk/return profile can be used strategically to anticipate the impact of an added asset on the portfolio's overall performance. Furthermore, such methods as economic value added[54] can be used to understand the impact of (i) capital investments in grid assets and (ii) operational management of grid assets.

The insurance industry is built upon the evaluation and socialization of risk and the assessment of the likelihood of rare events occurring.[55] At its core, insurance is based on actuarial science. Actuarial science is used to build the mathematical and statistical models used to guide decisions on how to assess and value risk in the insurance and finance sectors.[56]

Actuarial science usually groups individuals with specific cohorts of common quantifiable attributes together. Although it is difficult to predict a single entity's default or occurrence rate with certainty, a large collection of individuals with similar attributes will have statistically significant, quantifiable behavior. For example, creditors assess the risk (creditworthiness) that individual debtors will default on a loan relative to the average for that cohort.[57] When extended financial credit is not appropriately reflective of the likelihood of default[58] or when default risk is not transparent or is intentionally hidden behind complicated derivatives, significant problems can occur. Such a scenario is what precipitated the bank initiated subprime mortgage crisis of 2006-2008 where risk due diligence was not performed on loan applicants.[59]

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[53] R. C. Merton, "An Analytic Derivation of the Efficient Portfolio Frontier," *Journal of Financial and Quantitative Analysis,* vol. 7, no. 4, pp. 1851-1872, September 1972. https://www.jstor.org/stable/2329621?origin=JSTOR-pdf&seq=1#page_scan_tab_contents

[54] L. Mocciaro, A. Destri, P. M. Picone, and A. Minà, "Bringing Strategy Back into Financial Systems of Performance Measurement: Integrating EVA and PBC," *Business System Review*, vol. 1, no. 1, pp. 85–102, 2012.

[55] F. Ewold, "Chapter 10: Insurance and Risk," *The Foucault Effect: Studies in Governmentality*, Edited by: G. Burchell, C. Gordon, and P. Miller, The University of Chicago Press. pp. 197-210, 1991. http://lchc.ucsd.edu/cogn_150/Readings/ewald/ewald.pdf

[56] E. W. Frees, R. A. Derrig, and G. Myers, "Predictive Modeling Applications in Actuarial Science: Volume I: Predictive Modeling Techniques," Cambridge University Press. 2014.

[57] Consumer Financial Protection Bureau, "Credit Reports and Scores." Online. Available: https://www.consumerfinance.gov/consumer-tools/credit-reports-and-scores/

[58] Default is the inability to cover obligations.

[59] C. M. Reinhart and K. S. Roghoff, "Is the 2007 US Sub-Prime Financial Crisis So Different? An International Historical Comparison," *American Economic Review: Papers and Proceedings*, vol. 98, no. 2, pp. 339-344, 2008. https://pubs.aeaweb.org/doi/pdf/10.1257/aer.98.2.339

In the electric power sector, there is no real mechanism that tracks the marginal risk that any individual asset imposes on the system; instead, it is assumed that prior fulfillment practices, which worked well in the past, will continue to be sufficient. Actuarial science evolved from deterministic models to stochastic actuarial models combined with modern financial theory;[60] grid management systems are at a stage where there is a need to embrace a similar transition. Such a shift should be supported based on innovation in operations research and, in particular, decision making under uncertainty[61,62] combined with electric power engineering.

C. PROGRAM OBJECTIVES

The overall objective of PERFORM is to develop innovative technologies and approaches to quantify and manage risk for electric power systems. Risk management includes: (i) asset-level assessment to reflect an asset's ability to deliver on its energy and ancillary services obligations[63] and (ii) system-level risk-driven operations and planning to optimally manage the cost and the risk of serving electricity demand given a portfolio of grid assets.

At the asset level (Thrust 1, see Section I.D.2 and Section I.D.4 of the FOA), the goals are to:

- model the asset capability (e.g., characteristics, limitations, control technologies, dependability, flexibility, and maturity/vintage)
- ***quantify*** asset delivery risk (i.e., likelihood the asset delivers on its obligations) at look-ahead time stages in a ***transparent***, ***agreeable***, and ***verifiable*** manner[64]
- design methods to track asset performance supported by *existing data streams*
- identify *new data streams* and collection methodologies necessary to support innovative risk assessment and management
- develop and validate asset risk and performance measures[65]
- design tools to quantify asset performance and delivery risk both spatially and temporally
- define procedures for updating asset risk assessment beyond historical performance (e.g., technology upgrades)

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[60] E. W. Frees. "Stochastic Life Contingencies with Solvency Considerations," *Transactions of the Society of Actuaries,* vol. 42, pp. 91–148, January, 1990. http://library.soa.org/library/tsa/1990-95/TSA90V427.pdf

[61] A. Shapiro, D. Dentcheva, and A. Ruszczyński, "Lectures on Stochastic Programming: Modeling and Theory," *Society for Industrial and Applied Mathematics,* 2009. Online. Available: https://epubs.siam.org/doi/book/10.1137/1.9780898718751

[62] W. B. Powell, "A Unified Framework for Stochastic Optimization," *European Journal of Operational Research,* vol. 275, pp. 795-821, 2019. https://castlelab.princeton.edu/wp-content/uploads/2019/02/Powell-A-Unified-Framework-for-Stochastic-Optimization-EJOR.pdf

[63] Ancillary services cover a wide spectrum of additional flexibility and reliability products and services that are required to ensure synchronized, stable, and reliable grid operations.

[64] See Section I.D.2 of the FOA for further information.

[65] The FOA uses ***measures*** to describe a risk or performance tracking mechanism proposed by Applicants for industry adoption; this could be a risk score or a quality of service ***measure*** used in industry in a risk-driven paradigm. The FOA uses ***metrics*** to reference the quantifiable targets proposed by the awardee and agreed upon by ARPA-E for project evaluation during the three-year funded PERFORM program. Note that a ***measure***, which is proposed by an Applicant for industry implementation, may also be used as a ***metric*** during the project term for evaluation.

At the system level, (Thrust 2, see Section I.D.3 and Section I.D.4 of the FOA), the goals are to:

- target innovative decision making under uncertainty and risk management approaches for steady-state operations and operational planning[66]
- design modern grid management systems centered on risk analysis that acknowledge the stochastic nature of intermittent assets, asset interdependency (i.e., correlation), and the collective system risk while balancing computational complexity and market design complexity (if applicable) relative to the decision-making time stage
- design scalable algorithms capable of solving complex mathematical programs
- capture ***both*** the marginal cost ***and marginal risk*** that assets impose on the system
- quantify the operational system risk given asset mix and corresponding risk measures
- demonstrate reliability of operational decisions produced by grid management tools (at least maintain existing quality of service)
- design ***dynamic*** reliability and flexibility requirements relative to system risk position[67]
- develop and validate system-level risk measures
- demonstrate ability to match or outperform the proposed system risk index
- design and develop an incentive-compatible risk management paradigm that accounts for system-level risk and counterparty risk[68]

In order to leverage the flexibility of all assets, proposed approaches should:

- develop risk and performance measures, for both the asset level and the system level, which account for and include asset flexibility, dependability, and delivery risk
- demonstrate the benefits of an enhanced, risk-aware strategy for integrating and valuing (monetizing) assets by beating the proposed system risk index
- design grid management systems that acknowledge asset risk and obligations for grid services based on system risk position and relative risk associated with asset availability

In order to achieve a performance-based and risk-based asset-level valuation and a risk-based system-level assessment, proposed approaches should:

- develop new grid products (financial and physical) that assist in mitigating system risk to ensure grid reliability, which will open new revenue streams in an evolving power sector
- replace the existing reliance on operator intuition and rule-of-thumb approaches supported by conventional generation technologies with holistic approaches that quantify and optimally manage risk while reducing overall costs
- design grid management systems that acknowledge and utilize storage as a risk-mitigating asset to extract its true value

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[66] Applicants may propose approaches that advance stability analysis packages if the approaches are aligned with the PERFORM program goals of a risk-driven grid management paradigm; however, ARPA-E is placing a priority on decision making under uncertainty for steady-state operations and operational planning.

[67] ***Dynamic*** reliability and flexibility requirements are operational state dependent, i.e., the requirements are endogenously determined within the scheduling process. The requirements are naturally a reflection of and functionally dependent on the system risk position. This can be achieved by a variety of approaches including, but not limited to, stochastic optimization.

[68] Counterparty risk is defined as the risk an asset or market entity imposes on other asset owners or market entities. For instance, peer-to-peer transactive energy system concepts should propose a solution for counterparty risk.

- reward high performing assets with appropriate compensation and hold risky assets financially responsible for the risk they impose on the grid

D. TECHNICAL CATEGORIES OF INTEREST

1. PERFORM PROGRAM TIMELINE, SCOPE, AND THRUSTS

ARPA-E is engaging with industry and researchers to collect synthetic[69] and real data; see Section I.F of the FOA for more information. To emphasize the importance of technology transition and industry adoption (subject to the success of the PERFORM R&D phase and approval of funds), ARPA-E anticipates launching pilot projects (see Section I.G of the FOA). **This FOA covers the PERFORM R&D Program, which spans three years as shown in Figure 6; this FOA does not cover the PERFORM Data Plan and PERFORM Pilot Projects.** Applicants are strongly encouraged to describe how their proposed approach will impact industry practices and how their approach may fit within a pilot project to achieve near-term adoption while also pursuing long-term transformational benefits. ***Industry entities interested in the data pursuits of ARPA-E to support the PERFORM R&D Program or interested in the pilot projects are encouraged to contact ARPA-E directly: ARPA-E-CO@HQ.DOE.GOV.***

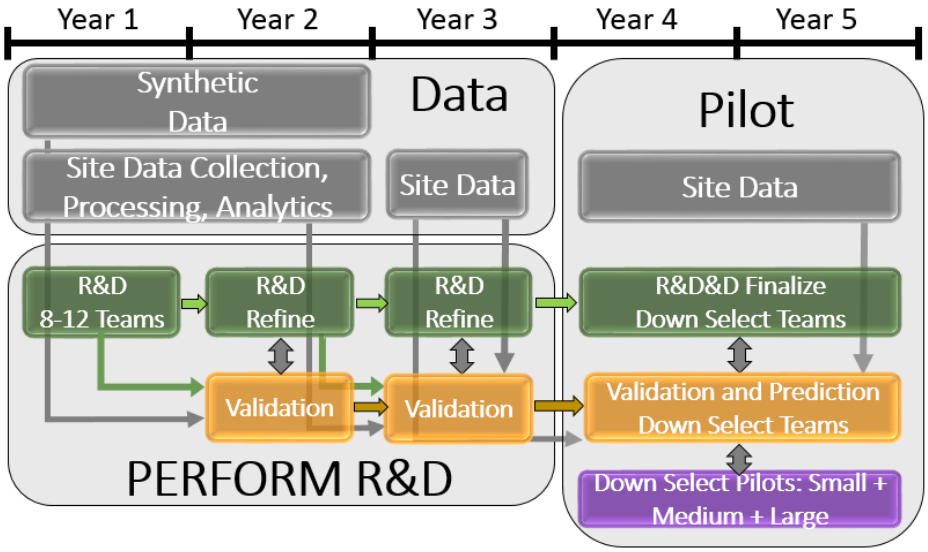

Figure 6. PERFORM Timeline and Anticipated Pilot Projects[70,71]

[69] Note that ARPA-E has the GRID DATA program, which has a similar goal by making power grid data publicly available. There are two repositories: BetterGrids (https://bettergrids.org/) and DR POWER (https://egriddata.org/).

[70] Note that the anticipated pilot projects are tentative, subject to the success of the PERFORM R&D program and are subject to approval of funds.

[71] Visit the ARPA-E PERFORM Workshop website, https://arpa-e.energy.gov/?q=workshop/performance-based-energy-resource-feedback-optimization-and-risk-management, and the presentation: PERFORM_Mod.ppt at the bottom of the website for additional information.

The PERFORM program is structured to understand and quantify risk at both the asset level and the system level within electric power grids. To this end, ARPA-E has structured PERFORM to have two main thrusts with accompanying technology-to-market efforts, as shown by Figure 7.

Applicants should develop approaches that are innovative in risk quantification and management at the asset level (Thrust 1), at the system level (Thrust 2), or at both the asset level and the system level (combination of Thrust 1 and Thrust 2).[72] All projects are required to include a significant technology-to-market focus to align with the ARPA-E mission of developing high-impact projects that bring transformational and disruptive change to industry. More details of the program thrusts are contained within in the subsequent discussion. If an Applicant has a qualified (i.e., impactful and tractable) alternative methodology for risk assessment for electric power grids that falls outside of the defined PERFORM program thrusts, the Applicant has the option to propose an alternative approach to ARPA-E. The Applicant must sufficiently justify that the proposed alternative methodology is innovative, highly impactful, transformative and disruptive, capable to achieve industry adoption, and applicable to the scope of PERFORM. Please refer to Section III.C.3 of the FOA for topics specifically not of interest.

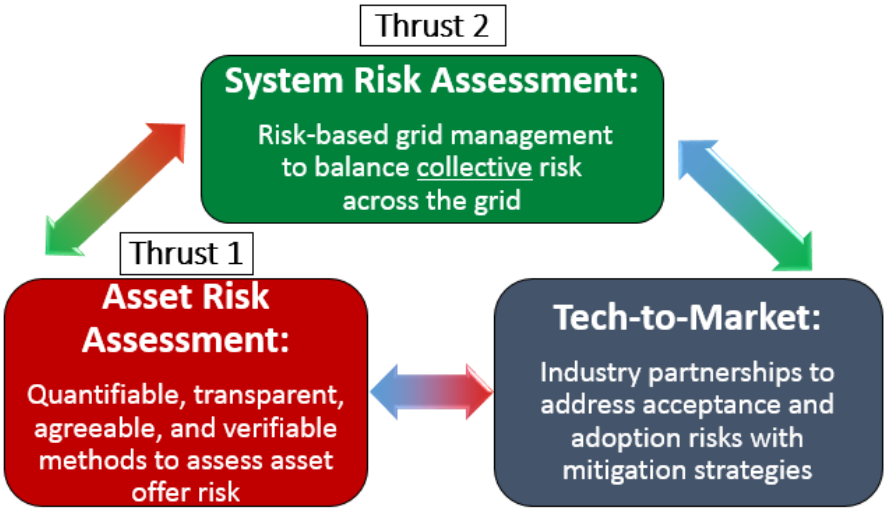

Figure 7. Program Structure Overview[73]

2. THRUST 1: ASSET RISK ASSESSMENT AND MANAGEMENT

The goal of Thrust 1 is to develop methodologies to assess and manage risk at the asset level. Thrust 1 projects will quantify delivery risk: whether an asset will default on its energy and ancillary services obligations. Applicants should articulate the key attributes that are required

[72] Applicants that innovate in Thrust 1 must also include a representation of the system level. Likewise, Applicants that innovate in Thrust 2 must also include a representation of the asset level. See Section I.D of the FOA for further guidance.
[73] Visit the ARPA-E PERFORM Workshop website, https://arpa-e.energy.gov/?q=workshop/performance-based-energy-resource-feedback-optimization-and-risk-management, and the presentation: PERFORM_Mod.ppt at the bottom of the website for additional information.

to conduct the asset risk assessment, e.g., a combination of asset characteristics, asset data, offer strategy, historical data, the look-ahead time stage, and forecast confidence (see Figure 8). PERFORM seeks innovative risk assessment methodologies that can quantify and account for the asset delivery risk (Thrust 1) within the system-level procurement process (Thrust 2).[74]

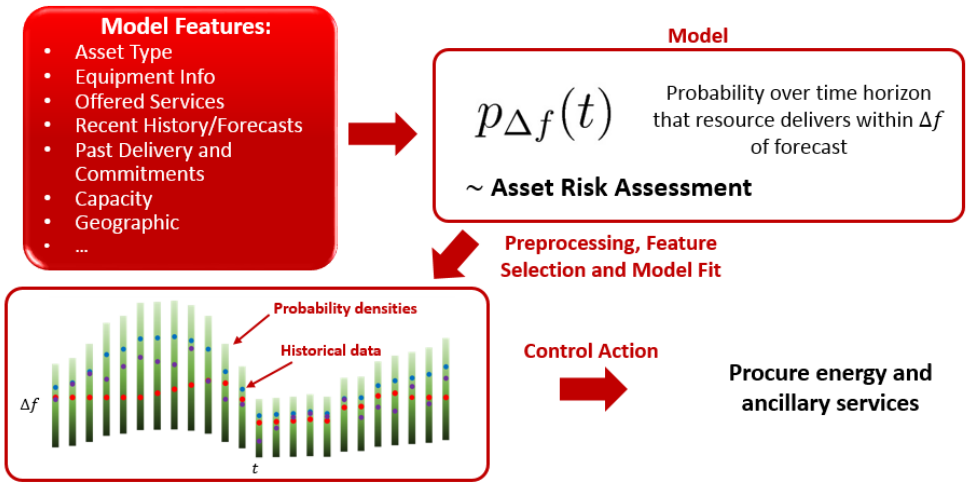

Figure 8. Asset Risk Assessment Example[75]

Applicants should define model features to include in their proposed asset risk assessment. An Applicant may decide to develop a multi-dimensional risk score (or another mechanism, e.g., a stochastic model) to convey the risk of an asset's ability to deliver on its obligations or on its offer stack.[76] This score would inform system operators in regards to asset dependability. Applicants should design a common framework that quantifies performance risk across all asset types, including emerging technologies. Furthermore, proposed risk assessment frameworks should be *quantitative, transparent, agreeable,* and *verifiable. Quantitative* frameworks should be measurable with well-defined and clear performance targets. *Transparent* methodologies will respond rationally to performance enhancements or offer defaults. For example, a risk assessment framework should respond rationally to a resource that continues to default on its obligations by producing a lower performance rating. Likewise, it is anticipated that the co-location of a risk-mitigation technology (e.g., storage) alongside a stochastic resource will improve that asset's overall performance, which a risk assessment framework should accurately reflect. *Agreeable* methodologies will achieve consensus that the resulting risk assessment is appropriate and reflective of an asset's ability to deliver on its obligations. *Verifiable*

[74] Applicants may wish to describe whether their proposed operational risk-driven paradigm can be well paired with a market design that is incentive compatible as to how risk is managed, shared, valued, and who bears the financial responsibility for the risk imposed on the system by the asset. Preference will be strongly given to applications that focus on the need for innovative operational risk-driven paradigms, not applications focused solely on market design and incentive compatible mechanisms.

[75] Visit the ARPA-E PERFORM Workshop website, https://arpa-e.energy.gov/?q=workshop/performance-based-energy-resource-feedback-optimization-and-risk-management, and the presentation: PERFORM_Mod.ppt at the bottom of the website for additional information.

[76] Offer stack is meant to refer to the collection of grid products and services a power sector entity has offered: (i) to another entity such as a market operator or (ii) through a bilateral contract. The power sector entity's obligation is then what is cleared, procured by the market or the final agreement of the contract.

methodologies should hold under a rigorous validation process. Applicants are expected to clearly articulate how their approach addresses all required features.

Applicants should address the effects of look-ahead scheduling on risk assessment.[77] Confidence in forecast accuracy increases closer to real-time operations, which should be captured within the risk assessment framework.

Applicants may construct methodologies to define offers relative to delivery risk. For example, an asset may wish to tranche its offer based on confidence in deliverability relative to the hierarchy of product quality (e.g., an analog might be the ability to tranche either the quality or the seniority of the return). Therefore, an asset confident in its deliverability may offer a high percentage of its forecasted availability as a high-quality product (e.g., firm energy).[78] Similarly, an asset may offer MWs considered to be "high risk" as lower quality products that are unlikely to be called upon (e.g., non-firm replacement reserves). The strategic construction of an asset offer could be used as a risk-mitigation technique resulting from a better understanding of delivery risk and an incentive compatible market design, see Figure 9.

Figure 10 provides an example of a framework for Thrust 1 and the potential interaction between the asset level and the system level. Applicants are not required to follow the framework in Figure 10. Applicants are required to describe their approach (e.g., information flow, core modules, decisions, and interactions between the asset level and the system level).

[77] Typical time stages include day-ahead (noon), day-ahead (midnight), 6 hours ahead, hour ahead, and 15 minutes ahead. However, Applicants may choose to redefine time stages, in which case Applicants will need to justify their chosen time stages.
[78] The construct of firm and non-firm energy and reliability/flexibility product offers does not exist in the existing operational paradigm but may be considered by Applicants.

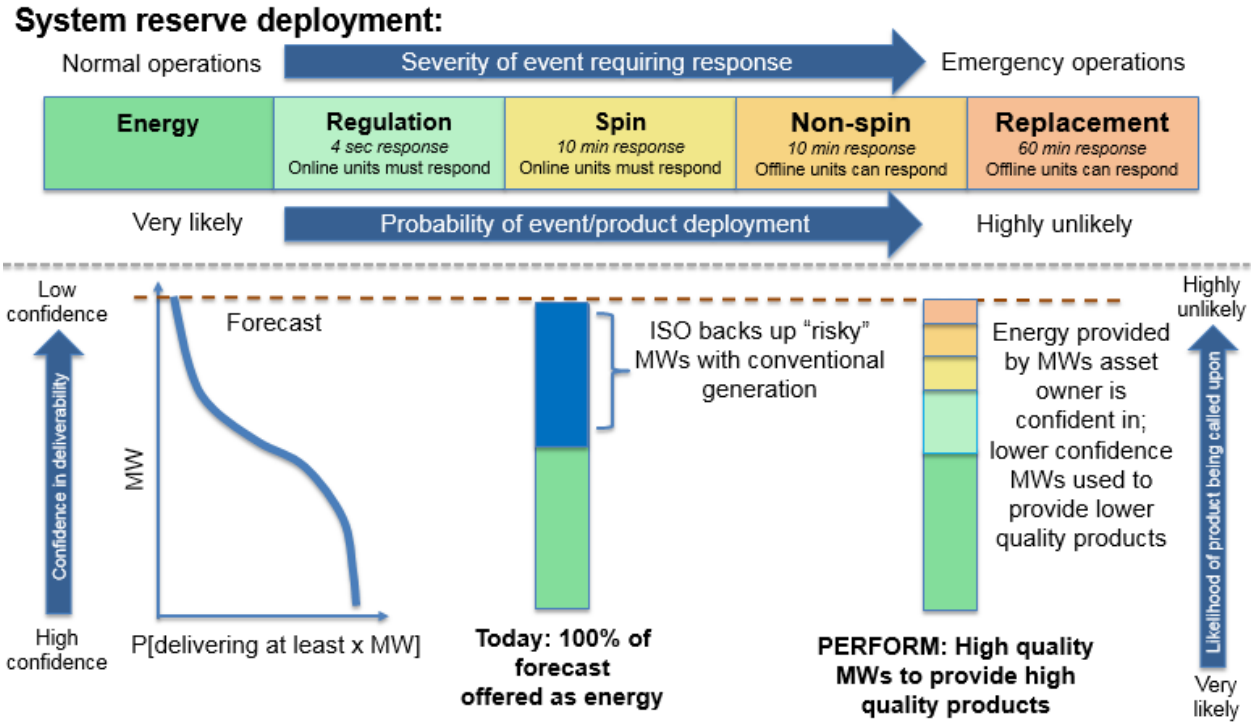

Figure 9. Asset Offers as a Function of Delivery Risk[79,80]

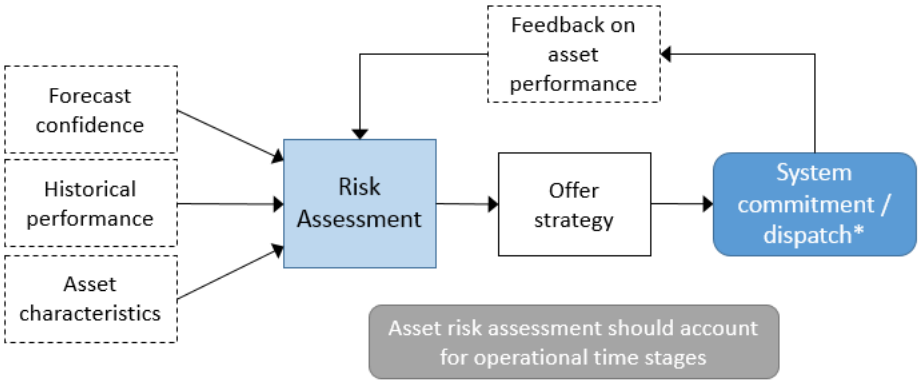

Figure 10. Example of Thrust 1 Framework and Interaction with the System Level
*Innovation in system-level management systems is covered under Thrust 2. However, Thrust 1 projects are expected to include some representation of asset integration at the system level.

Applicants may focus applications exclusively on innovation for Thrust 1. Applicants focused exclusively on Thrust 1 are required to provide some representation of asset integration at the system level. At a minimum, Applicants should consider information transfer and feedback loops between the asset level and the system level.

[79] Visit the ARPA-E PERFORM Workshop website, https://arpa-e.energy.gov/?q=workshop/performance-based-energy-resource-feedback-optimization-and-risk-management, and the presentation: PERFORM_Mod.ppt at the bottom of the website for additional slides on how the asset offer may vary based on the time stage.
[80] Note that there are more ancillary services than what is specified in this figure.

ARPA-E requires that Applicants validate their proposed approach. Validation efforts should include counterfactual analysis. Asset performance should be tracked for both existing practices and using the proposed risk assessment methodology and risk measure(s) (including out-of-sample testing on hypothetical operational states). The validation process should demonstrate: (i) the risk assessment appropriately reflects the asset's performance (coupled with offer strategy), (ii) that updates to the risk assessment are rational and properly correspond to performance enhancements or asset offer defaults, and (iii) the new risk assessment methodology leads to improvements in asset performance measures when compared against the performance achieved with existing operational practices.

For Thrust 1, counterfactual analysis involves using in-sample scenarios to determine strategic asset offers under both existing practices and the Applicant's new approach.[81] Figure 11 gives an example of a counterfactual analysis for existing practices and proposed approaches. The existing approach and the proposed approach may start with the same in-sample scenario data; however, the two approaches are likely to vary based on how that data is utilized. Applicants will be expected to generate or obtain additional scenarios that are not used for offer development. Solutions will be further evaluated and performance metrics[82] will be calculated using these additional scenarios (out-of-sample testing). ARPA-E expects that Applicants will demonstrate the benefit of their proposed methodologies over existing practices through counterfactual analysis. ARPA-E notes that there are various ways to structure validation efforts. Applicants must propose some form of counterfactual analysis, along with adequate justification, but it need not be structured as displayed by Figure 11.

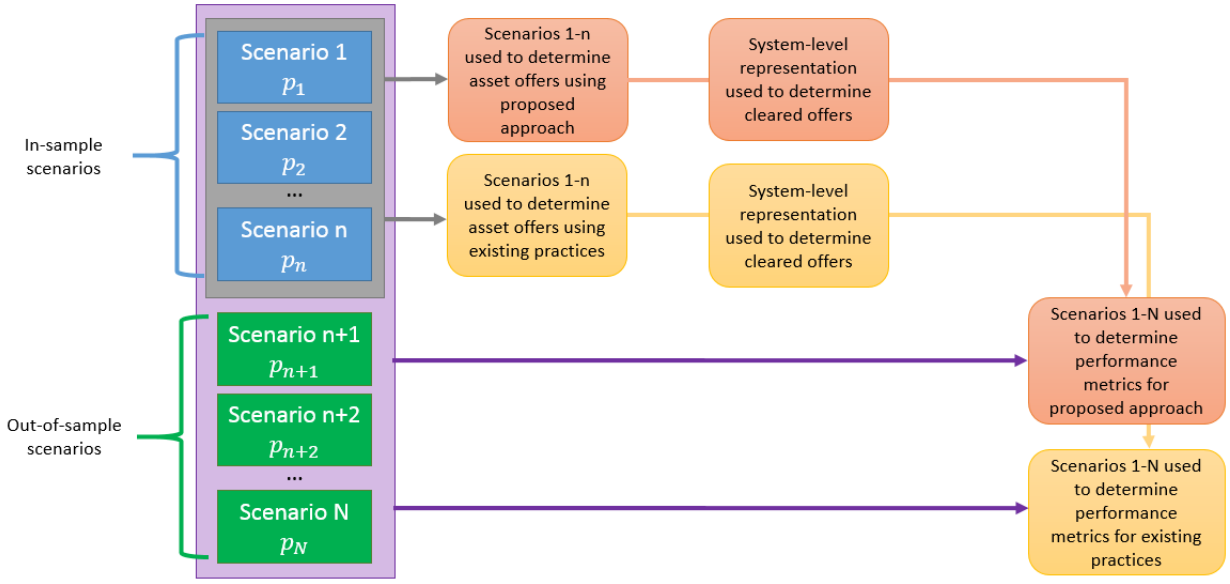

Figure 11. Expected Process for Counterfactual Analysis at the Asset Level

[81] Scenarios may include wind and solar forecasts and realizations, unit availability, etc.
[82] See Section I.E of the FOA.

Applicants will need to specify data requirements. Applicants will likely require data regarding forecasts, historical performance (e.g., given previous forecast data at different time stages, how often and by how much did the asset deviate from its offer), and asset characteristics (e.g., equipment type, location, equipment age). Applications should address data acquisition and data quality challenges, including cases where assets may not be able to monitor and confirm availability; Applicants should provide strategies for overcoming data shortfalls.[83,84]

3. THRUST 2: SYSTEM RISK ASSESSMENT AND MANAGEMENT

The goal of Thrust 2 is to develop methodologies to assess and manage risk at the system level. Thrust 2 projects will take assets' offers and corresponding assets' risk assessments as inputs, along with assets' correlations and forecasted system conditions (including load forecasts and system-level information and expectations) to determine an efficient and reliable schedule. For example, Thrust 2 Applicants may choose to develop a decision making under uncertainty engine that internalizes asset risk at the system level. Figure 12 gives an example of how an existing system scheduling tool could be expanded to include a new risk-driven paradigm.

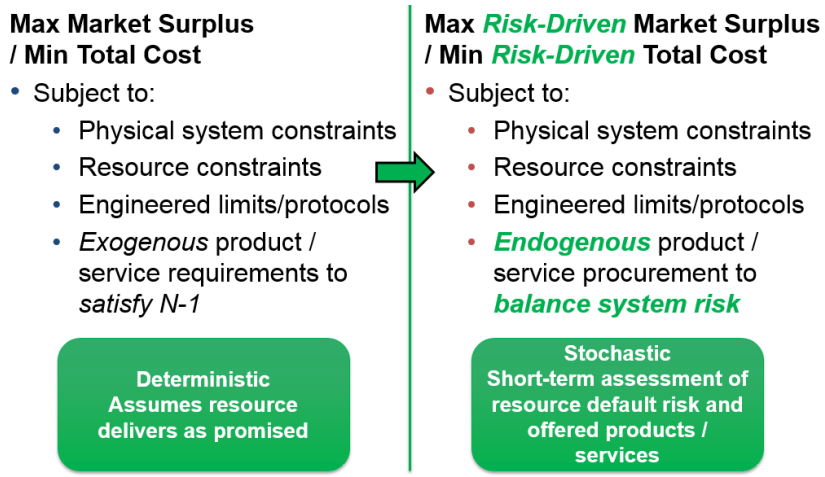

Figure 12. Thrust 2 Targets[85]

Projects under Thrust 2 should target solutions that optimally manage both cost and risk *while maintaining or improving grid reliability.*[86] Similarly, Applicants may also choose to redefine

[83] This is likely to be a challenge when considering DERs and DER aggregators.

[84] Applicants may choose to team up with a data provider (e.g., a utility, an IPP, an ISO, or some other industry entity), develop synthetic data, or plan to use ARPA-E data to which ARPA-E has provided access such as from a third party (see Section I.F of the FOA).

[85] Visit the ARPA-E PERFORM Workshop website, https://arpa-e.energy.gov/?q=workshop/performance-based-energy-resource-feedback-optimization-and-risk-management, and the presentation: PERFORM_Mod.ppt at the bottom of the website for additional information.

[86] N-1 reliability is a NERC requirement. N-1 reflects on both bulk generator assets and transmission assets. N-1, for generation assets, reduces in influence on system operations as the size of the largest generator diminishes. For systems with more distributed assets and fewer large assets, N-1 decreases in influence. Applicants should consider how reliability should be maintained, on top of existing NERC requirements, for future systems.

reserve products and reserve requirements to best serve the grid of the future.[87] Applicants choosing to redefine existing practices will need to provide justification. Long-term planning to near-term grid management fall under Thrust 2. However, ARPA-E expects that applications that target nearer-term grid management solutions (e.g., day-ahead to real-time operational decisions) will have a more immediate impact on system-level risk mitigation.

Thrust 2 applications will need to address the various time stages associated with operational decision making. Figure 13 shows an example of time stages that Applicants may consider. Applicants may choose which time stages to target or may choose to redefine decision-making stages within the context of their proposed methodology. As an example, Applicants may choose to create a baseline model of an existing ISO day-ahead forward market.[88] Then, Applicants could propose: (i) how the inputs would change to account for the asset-level risk assessment (e.g., risk/performance scores, distributional forecasts, stochastic models), (ii) whether market products should be modified or new products defined to accommodate the risk-driven paradigm, (iii) how the day-ahead forward market (the mathematical program itself) would change to accommodate the Applicant's proposed risk-driven advancements and additional risk-driven modules, (iv) how the outputs may change, and (v) how market settlements would evolve. Applicants may innovate in one or multiple critical decision-making time stages. Note that a similar approach can be proposed for a vertically integrated utility.

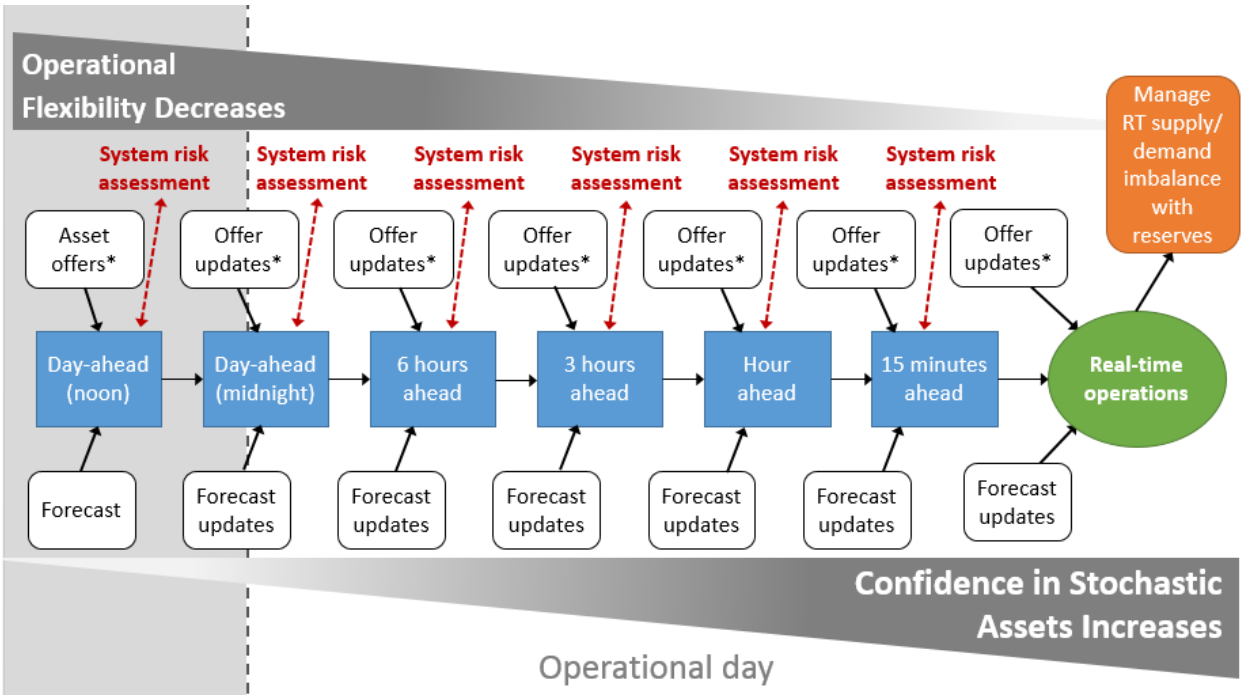

Figure 13. Operational Time Stages Examples
These may change depending on Applicant-defined use case.
*Risk-driven offers are a product of Thrust 1.

[87] Reserve requirements in a future grid should dynamically depend on the system risk position.
[88] A. Casto, "Overview of MISO Day-Ahead Markets," Midcontinent Independent System Operator. Online. Available: http://www.atcllc.com/oasis/Customer_Notices/NCM_MISO_DayAhead111507.pdf.

Applicants may consider grid planning under a risk-driven paradigm that mirrors financial portfolio management in which each individual asset's risk is considered as a part of the resource portfolio. Applicants will need to consider the correlation between assets in order to properly understand system risk and identify mitigation techniques to hedge against overall risk exposure at various operational and planning time stages. Applicants may develop new products (financial and physical) to: (i) facilitate the management of risk and (ii) achieve a true valuation of risk-mitigating technologies (e.g., storage). Applications that innovate in Thrust 2 should consider the tradeoff between asset-level risk and return in order to understand the most efficient means of improving system position in order to identify Pareto-dominant solutions over existing practices (i.e., achieve a Pareto improvement). Figure 14 illustrates that an innovative risk management strategy can shift the efficient frontier as new technologies and practices usher in Pareto-dominant solutions.

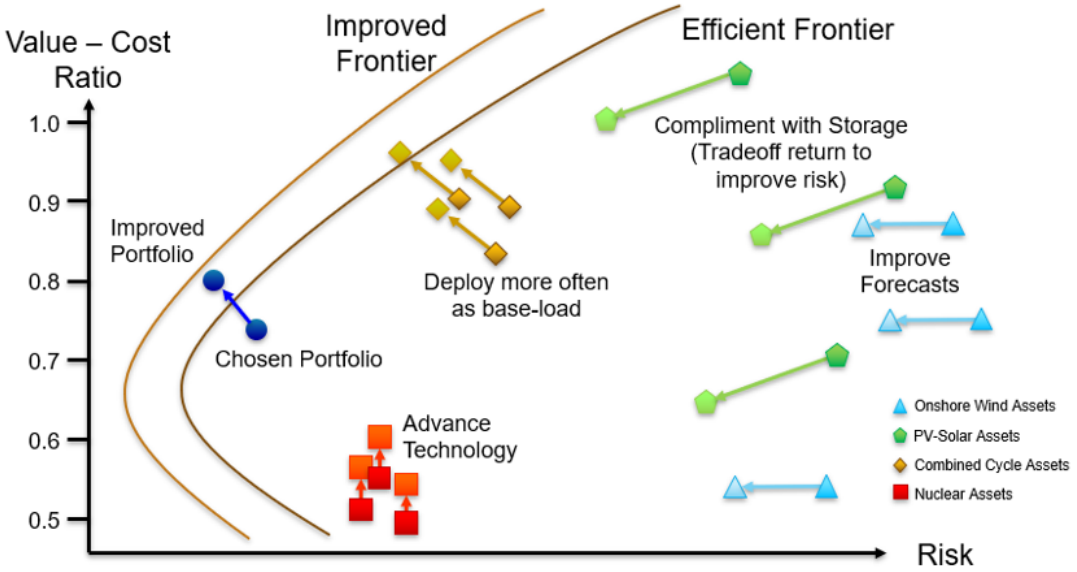

Figure 14. Incorporate a New Quantification of Asset Risk in Portfolio Management[89,90]

Applicants should describe the operational framework of their approach, the manner in which the asset level and the system level interact, and the validation process. A high-level example to describe the operational framework for a potential Thrust 2 approach is given by Figure 15, which depicts the information flow, core modules, and the potential solutions. Applicants are not required to follow the structure of Figure 15; it is meant only as an example.

[89] Value-Cost Ratio is used as a proxy for "return" and is defined by the U.S. Energy Information Administration (EIA) as the ratio of Levelized Avoided Cost of Electricity (LACE) to Levelized Cost of Electricity (LCOE). Sample values derived from: U.S. Energy Information Administration, "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2019," Online. Available: https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

[90] Visit the ARPA-E PERFORM Workshop website, https://arpa-e.energy.gov/?q=workshop/performance-based-energy-resource-feedback-optimization-and-risk-management, and the presentation: PERFORM_Mod.ppt at the bottom of the website for additional examples.

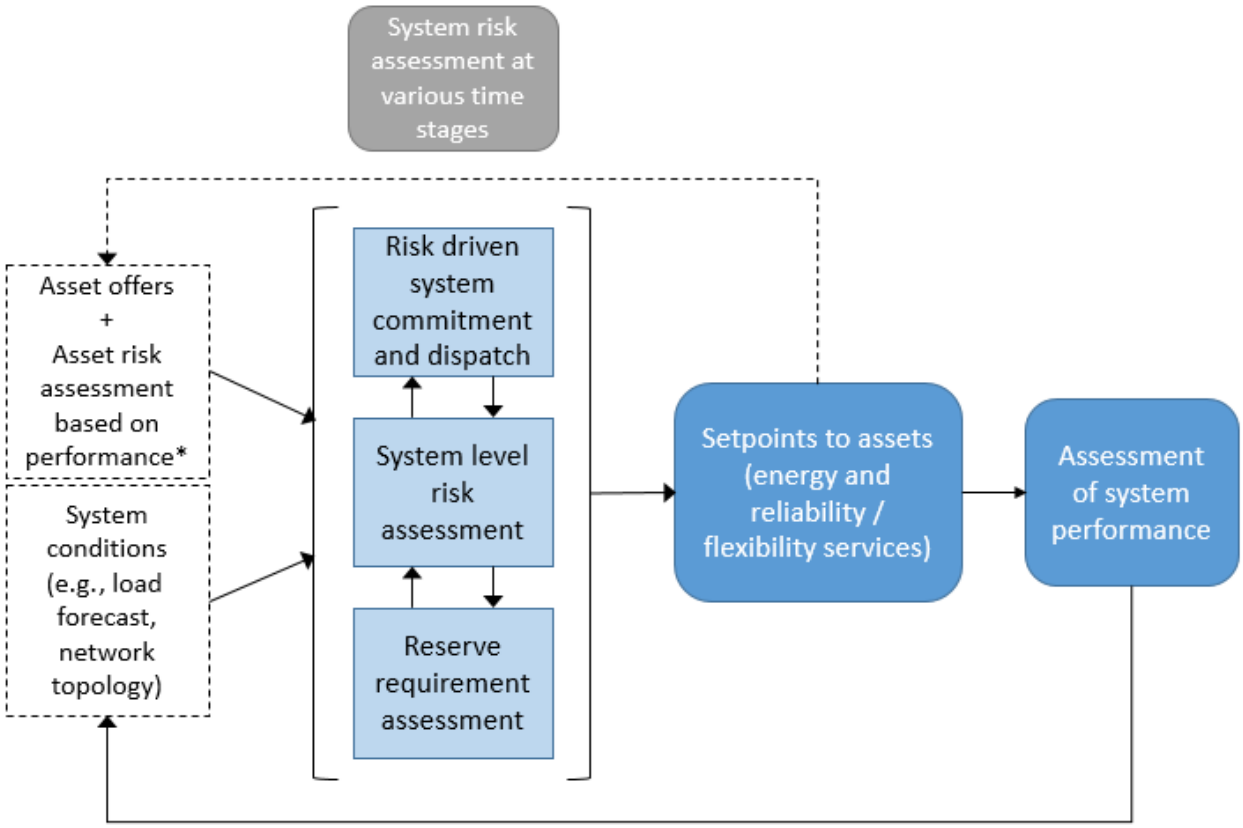

Figure 15. Example of Thrust 2 Framework and Interaction with the Asset Level
*Innovation in asset-level risk assessment is the focus of Thrust 1; however, Thrust 2 projects must include some representation of asset-level risk.

Applicants innovating in Thrust 2 will need to acknowledge and integrate system-level analysis with the risk assessment at the asset level (Thrust 1). Information regarding asset risk and asset offers must be built into the system level; the resulting asset performance (e.g., whether the asset delivered on its offer) will need to be communicated to the asset level as feedback. Applicants must show that the proposed management approach maintains an efficient and reliable operation while experiencing asset setpoint deviations and other forms of asset non-performance. Applicants focused exclusively on Thrust 2 innovation are required to provide justifiable representation of asset-level performance.

Applicants must propose a plan to validate their approach. Validation should include a counterfactual analysis in which system performance measures are tracked over a test period under both existing practices and using the proposed risk measures (including out-of-sample testing on hypothetical operational states). The validation process should demonstrate: (i) a Pareto-dominant improvement in system cost and system reliability and (ii) improvements in system performance measures when comparing existing practices to operations under the proposed risk assessment methodology. Applicants must address expected validation processes within the context of their proposed methodologies.

Applicants are expected to conduct counterfactual analysis. At the system level, counterfactual analysis may include a stochastic model (e.g., generating or obtaining operational scenarios, including associated probabilities of occurrence as shown in Figure 16).[91] The assumed stochastic model is used to determine asset setpoints under existing conditions and for the proposed approach. Applicants will also be expected to generate or obtain additional operational scenarios that are not used for setpoint determination; solutions will be further evaluated and performance metrics[92] will be calculated using these additional scenarios (out-of-sample testing). ARPA-E notes that there are various ways to structure validation efforts. Applicants must propose some form of counterfactual analysis, along with adequate justification, but it need not be structured as displayed by Figure 16.

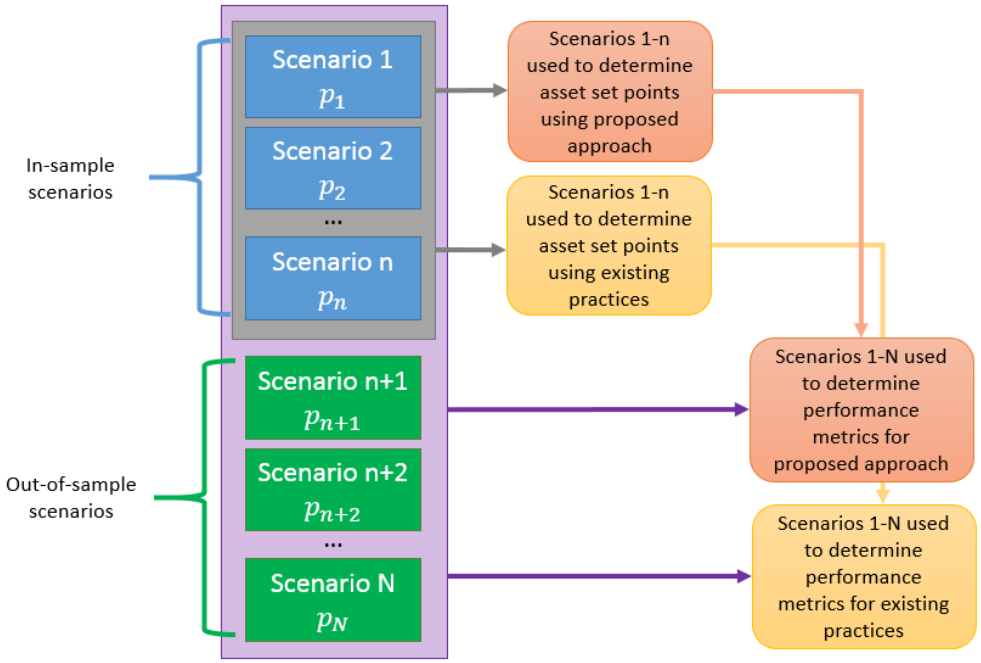

Figure 16. Example of Counterfactual Analysis Process at the System Level

Applicants will need to define the data necessary for developing system-level risk assessment. For example, Applicants will likely require information about system forecasts at different time stages, information about the physical system and assets, load, ancillary services requirements, and historical system performance relative to forecasts (e.g., given previous load and system conditions, what was the cost to serve load, was reliability maintained, what ancillary services were activated, etc.). Applicants should include a detailed discussion of how required data pertains to their approach (i.e., architectural design, solution methodology, and control methods) along with a plan that describes how to acquire the data.[93]

[91] Scenarios may include wind and solar forecasts and realizations, unit availability, load forecasts and realizations, etc.
[92] See Section I.E of the FOA.
[93] Applicants may choose to team up with a data provider (e.g., a utility, an IPP, an ISO, or some other industry entity), develop synthetic data, or plan to use ARPA-E provided data (see Section I.F of the FOA).

4. THRUST 1 + THRUST 2: HOLISTIC APPROACHES

Applicants may propose innovative approaches for Thrust 1 and Thrust 2. APRA-E anticipates that holistic approaches will have the highest industrial impact.

5. TECHNOLOGY-TO-MARKET RISKS

ARPA-E is mandated to fund technologies with the goal to bring transformative and disruptive change to industry. These technologies span the spectrum from evolutionary to revolutionary and the adoption risk correspondingly increases. Preference will be given to applications that include strong technology-to-market efforts that address industry acceptance and adoption risk. PERFORM aims to overcome the resistance to change in this mature, entrenched industry. Applicants should address industry adoption risk and propose mitigating strategies. Critical industry adoption risks may include the following.

- Resistance to market design changes from market operators and market participants
- Disruption to existing long-term power purchasing agreements (PPA)
- Financial impairment of assets or portfolios that are not optimized for a risk-based framework due to asset age, maintenance history, or location
- Resistance to providing relevant asset data
- Resistance to asset assessment and asset performance if it were necessary to publicly disclose asset performance information
- Complexity of a new risk-driven framework and increase in asset responsibilities
- Limited software vendors and the expense to replace legacy-based, proprietary management systems
- Complexity and challenge to modernize management systems, including the computational complexity and scalability challenges of risk-driven approaches

E. TECHNICAL PERFORMANCE TARGETS

Technical performance metrics[94] are provided in this section. Applicants are required to address the application requirements in Section I.E.1 of the FOA and should review the metrics listed in Section I.E.2 of the FOA for Thrust 1 and Section I.E.3 of the FOA for Thrust 2. Applicants should choose the metrics that align with their approach. Applicants are encouraged to extend or modify the metrics presented in this FOA and are also encouraged to propose their own quantifiable metrics. All chosen metrics should be explained and justified relative to the approach and aligned with the chosen use cases and look-ahead decision-making time stages (see category 1.1 in Table 1). The following section, along with Table 1, provides an outline for the details expected for the concept paper phase as well as the details expected in the full application phase.

[94] The FOA uses ***measures*** to describe a risk or performance tracking mechanism proposed by Applicants for industry adoption; this could be a risk score or a quality of service ***measure*** used in industry in a risk-driven paradigm. The FOA uses ***metrics*** to reference the quantifiable targets proposed by the awardee and agreed upon by ARPA-E for project evaluation during the three-year funded PERFORM program. Note that a ***measure***, which is proposed by an Applicant for industry implementation, may also be used as a ***metric*** during the project term for evaluation.

1. APPLICATION REQUIREMENTS

In Table 1, each category heading states whether the Applicant should address that category in the concept paper (categories 1, 6, and 7 only) or in the full application (all categories required).

Table 1. Overview of PERFORM Application Requirements

Category[95]		Asset Level (Thrust 1)	System Level (Thrust 2)
1	**Targeted Problem: Concept Paper + Full Application**		
1.1	Define use case(s) including at a minimum: decision-making time stage(s) (e.g., day-ahead), end users[96], and targeted program thrust(s) (note: preference will be given to applications with innovation across both thrusts)	Applications focused on Thrust 1 alone must still have some representation of asset interaction at the system level (i.e., representation may be a simple approximation where it is assumed all offers clear at the system level or a more complex representation of interacting with a utility, a distribution system operator (DSO), an ISO, or some other system-level entity).	Applications focused on Thrust 2 alone must still have some representation of risk assessment at the asset level (i.e., representation may be a simple, contrived risk measure, confidence intervals, distributional forecasts, scenarios, or some combination of asset model and stochastic representation of asset performance).
1.2	Define existing practices and associated performance metrics relative to chosen use case(s)	Applications should specify existing asset management strategies including asset risk assessment and asset offer strategy relative to chosen use case(s).	Applications should specify existing system-level management for optimal operations subject to reliability requirements (e.g., N-1) relative to the chosen use case(s).
1.3	Define proposed paradigm beyond existing practices relative to chosen use case(s)	Proposed methodologies should: (i) assess asset performance in a quantifiable manner (e.g., a risk score, a confidence interval, or other approaches), (ii) achieve a *quantifiable, transparent, agreeable, and verifiable* comparison of risk and performance across asset types by considering: a) historical performance (backward looking), b) look-ahead predictions (forward looking), and c) risk-driven offer strategies. ***Applications must explicitly address uncertainty.***	Proposed methodologies should: (i) design decision support systems reflective of chosen use case(s) and (ii) assess system risk position given a) performance assessment of individual system assets, b) correlation across assets, c) system-level constraints, and d) system-level reliability requirements. ***Applications must explicitly address uncertainty.***

[95] Applicants should use Table 1 to guide the scope of their application. Applicants are not required to follow the exact structure of the categories listed in Table 1.
[96] End users include, but are not limited to, ISOs, utilities, load serving entities, aggregators, market participants, and rating agencies.

Table 1. Overview of PERFORM Application Requirements (continued)

	Category	Asset Level (Thrust 1)	System Level (Thrust 2)
1	**Targeted Problem: Concept Paper + Full Application**		
1.4	Describe stochastic modeling approaches	In connection with the data requirements (see the data requirements category in this table, division 4), applications should describe the methods to capture and model the stochasticity of assets.	Applications should describe the methods to capture and model the impact of stochastic resources at the system level, including correlation across assets, and should describe modeling of potential unforeseen events at the system level (e.g., N-1).
2	**Validation Metrics: Full Application**		
2.1	Identify baseline metrics, e.g., cost, value, reliability, relative welfare ratio, quality of service, and performance metrics (see Section I.E.2 and Section I.E.3 of the FOA); define quantitative targeted improvements relative to baseline metrics	Applications should choose from the list of metrics in Section I.E.2 and Section I.E.3 of the FOA and add new metrics as needed for the particular approach. Preference will be given to applications that select metrics covering a wide range of issues (e.g., cost, reliability, performance, relative welfare ratio, or quality of service) and target aggressive improvement goals.	
3	**Counterfactual Validation Process: Full Application**		
3.1	Describe counterfactual validation process	Applications should compare "existing practices" in parallel with their proposed methodology while including out-of-sample testing (simulations of hypothetical operational states) to demonstrate improvements in chosen metrics. See Section I.D of the FOA for more information related to Thrust 1 and Thrust 2.	

Table 1. Overview of PERFORM Application Requirements (continued)

Category		Asset Level (Thrust 1)	System Level (Thrust 2)
4	**Data Requirements: Full Application**		
4.1	Describe qualitative data	For example, applications may describe: (i) forecast data at varying time stages coupled with realized data, (ii) generator/DER characteristics, (iii) network information (e.g., bulk vs. distributed), and (iv) additional requirements associated to the proposed methodology.	
4.2	Describe quantitative data	For example, applications may describe: (i) required quantity of data (e.g., prior 5 years), (ii) sample frequency (e.g., 5 min intervals), and (iii) additional requirements associated to the proposed methodology.	
4.3	Describe offline data used for model development, testing, and refinement	This may include, but is not limited to, past historical observed data and/or synthetic data.	
4.4	Describe data used for validation	This may include, but is not limited to, future observed data/realized data and/or synthetic data for out-of-sample testing.	
4.5	Describe data source	Applications should describe data partnerships, collaborations, access to public datasets, and/or reliance on access to data provided by ARPA-E (see Section I.F of the FOA).	
4.6	Describe data handling and processing	Applications should specify whether the proposed approach requires fundamental changes to data handling and processing in practice today. If the proposed approach requires added data handling and processing requirements for implementation, Applicants should assess any industry adoption risk that may be associated to that data management, storage, and exchange.	

Table 1. Overview of PERFORM Application Requirements (continued)

Category		Asset Level (Thrust 1)	System Level (Thrust 2)
5	**Computational Platform and Metrics: Full Application**		
5.1	Describe the computational platform	For methodologies proposing novel modules for future industry implementation (e.g., to replace or build upon existing modules), the computational platform should closely reflect industry standards (e.g., hardware) or realistic upgrades end users are willing to adopt (e.g., HPC). For offline analyses and validation efforts to demonstrate milestone achievement (e.g., R&D evaluation efforts not reflective of industry practices), computational requirements are flexible.	
5.2	Describe the computational metrics	For methodologies proposing novel modules for future industry implementation (e.g., to replace or build upon existing modules), the proposed targets for the computational performance metrics (e.g., model complexity, solution time, optimality gap, robustness of the approach) should closely reflect industry standards. For offline analyses and validation efforts to demonstrate milestone achievement (e.g., R&D evaluation efforts not reflective of industry practices), the targets for computational metrics are flexible.	
6	**Technology-to-Market: Concept Paper + Full Application**		
6.1	Describe industry adoption risk and risk mitigating strategies	Applications should describe industry acceptance risk, widespread adoption risk, complexity risk (scalability), deployment cost risk, and other critical risks. Applications should also describe the necessary risk mitigation strategies. See Section I.D.5 of the FOA.	
6.2	Describe future pilot projects pursuits	Describe any strengths or weaknesses that your approach and team may have associated with participating in pilot projects (joint efforts with potential end users) after the end of the PERFORM R&D program.[97]	
7	**Team: Concept Paper + Full Application**		
7.1	Describe any unique team requirements and capabilities for the proposed approach	Applications should describe the expertise required to execute proposed efforts and any critical partnerships. ARPA-E prefers diverse teams that can drive innovative solutions through to industry for disruptive change.	

[97] Please note that the follow-on pilot portion of PERFORM is tentative and funds have not been dedicated to these additional pursuits at this time. ARPA-E encourages industry entities interested in pilot projects to contact ARPA-E: ARPA-E-CO@hq.doe.gov.

2. POTENTIAL THRUST 1 ASSET-LEVEL METRICS FOR PROJECT EVALUATION

The following Thrust 1 metrics may be considered and built upon for project evaluation.

The **Availability** metric is already in use in industry today and is defined as the percent of time that the asset fulfills its obligation, within a specified tolerance. This is a summation of indicator functions, which produce a value of one when the asset is within the acceptable tolerance (e.g., 5%) and zero otherwise, divided by the total number of observations.

The following **Quality of Service** (QoS) metrics track whether the asset has the ability to provide its service(s) in real-time relative to its forward obligation(s). The following four mechanisms enable tracking of an asset's quality of service for both energy and ancillary services: (i) the amount *offered* by the asset, (ii) the amount *cleared* (obligated) from a forward look-ahead time stage, (iii) the *available* capacity, (iv) the amount of the product *delivered*, and (v) the amount *activated* (i.e., the amount called upon to be provided in real-time). For (firm) energy, it is assumed that the amount cleared is always the same as the amount activated, i.e., the central operator automatically activates all cleared (firm) energy products for delivery. For the ancillary services, the amount cleared (obligated) at a look-ahead time stage is a capacity the asset must withhold while the system may activate only a fraction of the withheld capacity.

With these five tracking mechanisms, there are four quality of service metrics, as shown by (1)-(4). The most useful metric is QoS_C^A, which tracks whether the asset has the available capacity to meet the obligated (cleared) product.

$$QoS_C^A = \frac{Available}{Cleared} \tag{1}$$

QoS_C^D can be identical to QoS_C^A except for situations where there is excess capacity available that is not activated by the system operator. QoS_C^D is intended for assets that may not be able to provide an accurate assessment of their overall availability.

$$QoS_C^D = \frac{Delivered}{Cleared} \tag{2}$$

QoS_{Act}^D tracks the fraction of the activated product that was delivered.

$$QoS_{Act}^D = \frac{Delivered}{Activated} \tag{3}$$

QoS_O^A is useful only for market settings and it reflects whether the asset made an aggressive or conservative offer relative to what is available in real-time. This metric could be used to analyze the asset's bidding strategy and risk preference.

$$QoS_O^A = \frac{Available}{Offered} \tag{4}$$

Table 2 provides examples of potential outcomes for the four QoS metrics. The asset in example 1 has perfect availability; note that QoS_C^D is an imperfect estimation of QoS_C^A based on its 0.8 score. In example 2, the asset is able to fulfill the activated product but it did not have enough available capacity if more were to be requested. In example 3, the asset is short on its obligation; in this setting, both QoS_C^A and QoS_{Act}^D can be useful to describe that an asset's available capacity failed to meet the cleared obligation substantially while the delivered product more closely met the required deliverability. In example 4, the operator does not call upon the asset for any of the cleared product and, thus, QoS_C^A and QoS_O^A are the only useful metric. In example 5, the asset's availability exceeds the cleared amount. In example 6, the asset is not cleared by the market whatsoever; only QoS_O^A communicates added information.

Table 2. Numerical Examples Associated to Asset Level Metrics

	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6
Cleared (MW):	10	10	10	10	8	0
Activated (MW):	8	8	4	0	4	0
Delivered (MW):	8	8	2	0	4	0
Available (MW):	10	8	2	10	10	10
Offered (MW):	12	12	12	10	10	4
$\boldsymbol{QoS_C^A}$	1	0.8	0.2	1	1.25	NA
$\boldsymbol{QoS_C^D}$	0.8	0.8	0.2	0	0.5	NA
$\boldsymbol{QoS_{Act}^D}$	1	1	0.5	NA	1.0	NA
$\boldsymbol{QoS_O^A}$	0.83	0.67	0.17	1	1	2.5

ARPA-E will not give preference to an approach that resembles these metrics; rather, the example metrics are meant for illustrative purposes only. Applicants are encouraged to propose their own way to track asset performance and capture asset delivery risk in general.[98] Applicants are also encouraged to consider how metrics are tied to the varying decision-making time stages. Accurate prediction of the asset's position grows in difficulty as the look-ahead time stage horizon lengthens.

3. POTENTIAL THRUST 2 SYSTEM-LEVEL METRICS FOR PROJECT EVALUATION

ARPA-E has provided potential longer-term system-level metrics and targets aligned with the PERFORM objectives, see Table 3. Applicants should propose metrics that are tied to a hypothetical study for a system with higher penetration levels of stochastic resources, similar to the targets in Table 3. Applicants are also encouraged to have numerical targets aligned for a particular existing system; such targets may differ from the targets in Table 3.

[98] While these ***metrics*** may be used for project evaluation purposes during the three year PERFORM R&D program, certain ***metrics,*** like the QoS ***metrics***, may also be useful as risk or performance ***measures*** within industry practice; Applicants should clearly identify ***measures*** for industry adoption and ***metrics*** for project evaluation.

Table 3. Thrust 2: Potential System-Level Metrics

System operational cost	>15% Average reduction
N-1 system reliability[99]	0 N-1 violations
Overall Reliability Index	<1 day in 10 years
Overall Reliability Index Comparison:	>20% Reduction in outage hours per year
Overall Reliability Index Comparison:	> 20% Reduction in outage cost
Percentage of energy met by bulk renewables and distributed energy resources	>75%
Percentage of energy met by clean resources (including nuclear power plants, bulk storage, bulk renewables, distributed energy resources, carbon capture and sequestration (CCS) based fossil fuel plants, and hydro power)	100%
Percentage of ancillary services met by bulk renewables, distributed energy resources, and flexible load	>75%
Percentage of ancillary services met by clean resources (including nuclear power plants, bulk storage, bulk renewables, distributed energy resources, flexible load, CCS-based fossil fuel plants, and hydro power)	100%
Operator discretionary changes, e.g., out-of-market/merit corrections (OMC) to commitments, setpoints, ancillary services, and other discretionary operator changes[100,101]	>75% Reduction (measured by commitment + MW)
Curtailment of bulk renewables and distributed energy resources	>20% Reduction
Relative welfare ratio	>20% improvement

ARPA-E seeks a system risk index against which new approaches can be compared.[102] Applicants are encouraged to consider how future grid operations will evolve and are required to propose a system risk index. Applicants are also required to propose metrics[103] to evaluate performance of the proposed risk-driven operational paradigm.

Inspired by the Sharpe Ratio[104] or the Information Ratio,[105,106] which is used to evaluate a portfolio's risk-adjusted return, ARPA-E has provided two examples of a performance metric, both of which are referred to as a type of ***risk-adjusted relative welfare ratio***. These example

[99] N-1 system reliability subject to a look-ahead single point forecast for net load.
[100] Y. Al-Abdullah, M. A. Khorsand, and K. W. Hedman, "The Role of Out-of-Market Corrections in Day-Ahead Scheduling," *IEEE Transactions on Power Systems*, vol. 30, no. 4, pp. 1937-1946, July 2015.
[101] Y. Al-Abdullah, M. A. Khorsand, and K. W. Hedman, "Analyzing the Impact of Out-of-Market Corrections," *IREP Symposium*, pp. 1-10, Rethymnon, Greece, August 2013.
[102] This is analogous to a portfolio being compared against an index, such as the S&P 500.
[103] The one day in ten years criterion is a system risk metric in use today but may not be sufficient to evaluate future grid operations as the grid moves towards higher penetrations of distributed and stochastic resources.
[104] William F. Sharpe, "The Sharpe Ratio," *The Journal of Portfolio Management,* Stanford University, Fall 1994, Online. Available: http://web.stanford.edu/~wfsharpe/art/sr/sr.htm
[105] T. H. Goodwin, "The Information Ratio," *Financial Analysts Journal*, vol. 54, no. 4, pp. 34-43, July-August 1998.
[106] Corporate Finance Institute, "What is the Information Ratio," Online. Available: https://corporatefinanceinstitute.com/resources/knowledge/finance/information-ratio/

metrics provide a comparison of the risk-adjusted social welfare[107] of competing approaches. Applicants may use these examples or propose their own performance metrics.

The first example is shown by (5a)-(5c). In (5a), $W_{a,t}$ is the social welfare of approach a, for some operational state t. $W_{e,t}$ is the social welfare of the existing status quo approach e for the same operational state. Equation (5a) calculates the expectation, over varying scenarios, of the ratio between $W_{a,t}$ and $W_{e,t}$ while (5b) determines the standard deviation of that ratio. Equation (5c) is a risk-adjusted relative welfare ratio, R_a, which weights new approaches relative to existing practices. To understand (5c), first inspect (5a). The value of (5a) is equal to one when no change is achieved; it is less than one when the new approach fails to provide an improvement, and it is greater than one when it increases social welfare. Equation (5b) captures the variation of that value and (5c) provides a risk-adjusted relative welfare ratio. Note that since the welfare of the proposed approach is normalized by the existing approach, the influences of varying load levels and, thus, varying welfare levels are ignored.

$$\mu_a = \frac{1}{|T|}\left(\sum_{\forall t} \frac{W_{a,t}}{W_{e,t}}\right) \tag{5a}$$

$$\sigma_a = \sqrt{\mathrm{var}\left(\frac{W_{a,t}}{W_{e,t}}\right)} \tag{5b}$$

$$R_a = \frac{\mu_a}{\sigma_a} \tag{5c}$$

The second example is shown by (6a)-(6c) and also includes $W_{a,t}$ and $W_{e,t}$. A new term is introduced, $W_{pf,t}$, which represents the social welfare given perfect foresight.[108] $W_{pf,t}$ is an upper bound[109] on any other approach since it is a best case outcome given the idealistic assumption that all stochastic outcomes are known with certainty. $W_{pf,t}$ is similar to what is known as *perfect dispatch* analysis conducted by certain ISOs. For the following equations, $W_{pf,t}$ is used as a benchmark to compare against, akin to how the Sharpe Ratio uses a risk-free return. Equations (6a) and (6b) both compare the risk-adjusted welfare of the approach, (6a), and the existing practice welfare, (6b), against this perfect foresight welfare, $W_{pf,t}$. Then, (6c) is a risk-adjusted relative welfare ratio for the perfect foresight case, R_a^{pf}, and is equal to one when the proposed approach makes no difference when compared to existing practices; it is less than one when the proposed approach is doing worse than existing practices and above one when it is doing better.

$$S_e = \frac{\frac{1}{|T|}\left(\sum_{\forall t} W_{pf,t} - W_{e,t}\right)}{\sqrt{\mathrm{var}[W_{pf,t} - W_{e,t}]}} \tag{6a}$$

[107] Short-term social welfare is defined as the total surplus (net economic welfare) for all of society or a particular group. The short-term social welfare for the grid would be the overall economic benefit for all participants in that system. In a market setting, this is often referred to as the market surplus.

[108] Perfect foresight assumes that all stochastic inputs are perfectly known so a true optimal solution can be determined.

[109] $W_{pf,t}$ is an upper bound on all approaches as long as the mathematical optimization problem is solved to optimality.

$$S_a = \frac{\frac{1}{|T|}\left(\sum_{\forall t} W_{pf,t} - W_{a,t}\right)}{\sqrt{\mathrm{var}[W_{pf,t} - W_{a,t}]}} \quad (6b)$$

$$R_a^{pf} = \frac{S_e}{S_a} \quad (6c)$$

Applicants should propose a performance metric and may choose to use (or build off) the risk-adjusted relative welfare ratio detailed in equations (5a)-(6c). Applicants should demonstrate that their new approach can beat a valid baseline system risk index based on existing practices. Applicants are encouraged to propose metrics that are aligned with their approach, including extensions, modifications, and/or additions to these metrics. Applicants may also consider how the proposed targets may vary based on the chosen portfolio of assets (e.g., the amount of renewable resources or storage in the test case).

Applicants should note that ARPA-E reserves the right to require particular metrics, which would be discussed during the negotiation phase for the selected Applicants.

F. TECHNICAL SUPPLEMENT: PERFORM DATA PLAN

Note that Section I.F., the PERFORM Data Plan, describes efforts by ARPA-E to support the PERFORM R&D Program. This section is included for informational purposes only.

ARPA-E anticipates supporting the PERFORM R&D Program by obtaining: (i) synthetic data that will be made publicly available and (ii) real data from industry entities. Applicants may propose to use this data to design, develop, and validate their approaches. ARPA-E makes no promises or guarantees concerning the agency's ability to obtain any data, availability of data for use by Applicants, or adequacy and compatibility of this data relative to Applicant needs. Applicants that propose to depend upon data ARPA-E plans to make available assume all risk of data sufficiency for use under any prospective agreement.

Applicants are encouraged to acquire their own data to ensure they have access to sufficient and appropriate data required by their unique approaches. Should any data not obtained, or obtained and provided by ARPA-E prove to be insufficient to achieve the objectives and milestones set forth in any agreement, ARPA-E may act under the agreement's substantial involvement clause (refer to ARPA-E Model Agreement Documents, Attachment 1, Clause 7, found at https://arpa-e.energy.gov/?q=site-page/funding-agreements) to revise the statement of project objectives or take other appropriate action(s) in accordance with the clause.

The availability of real data is subject to industry participation and may require nondisclosure or special handling agreements with a third party by those accessing the data. Synthetic data is anticipated to be built using publicly available data and tools, the specifics of which will be included with the datasets. Synthetic data would be made available without restriction on further use.

Datasets are likely to include grid information, including generator and network information (e.g., line characteristics and locations). The datasets will necessarily include coincident load and renewable (wind and solar) resource location, forecast, and actual availability at various look-ahead timeframes and at specified resolutions (at least hourly, likely at a 15 minute resolution, or potentially for every minute).

ARPA-E will provide updates about data anticipated to be obtained. Applicants may include requests for specific data in their applications; however, ARPA-E cannot promise the fulfillment of specific requests. ***Industry entities interested in the data pursuits of ARPA-E to support the PERFORM R&D Program or interested in the pilot projects are encouraged to contact ARPA-E directly: ARPA-E-RFI@hq.doe.gov.***

Applicants are encouraged to check back with the ARPA-E and eXCHANGE websites for updates regarding the data plans.

G. TECHNICAL SUPPLEMENT: PERFORM PILOT PROJECTS

Note that Section I.G., the PERFORM Pilot Projects, describes anticipated efforts by ARPA-E beyond this FOA and this section is included for informational purposes only.

ARPA-E anticipates future pilot projects through which PERFORM awardees will demonstrate their risk assessment approaches in a real-world setting. The pilot projects will allow the most successful PERFORM project teams to pair with industry entities. ARPA-E plans to pursue and develop potential pilot project opportunities during the three-year PERFORM R&D program, with the intention to start pilot projects as soon as possible.

ARPA-E envisions that the pilot projects will include industry participants of varying size and need (e.g., ISO/RTOs, distribution system operators (DSOs), and vertically integrated utilities), who are faced with the challenges of transitioning to a clean and sustainable grid heavy with emerging technologies. In particular, ARPA-E is pursuing the following opportunities for pilot projects: (i) an entity working to form a retail market, (ii) an ISO pursuing a market reform, (iii) a distribution system operator and/or DER aggregator(s), (iv) a vertically integrated utility that has high levels of stochastic resources and is moving to redefine the day-ahead operational planning to real-time scheduling, and/or (v) a relatively small and isolated utility[110] with high levels of stochastic resources. Through the pilot projects, top-performing PERFORM awardees will run their approaches alongside existing practices and management systems to show: (i) improvements in cost and reliability measures, (ii) better use of the full capability of new

[110] By isolated utility, ARPA-E is referring to a utility that is primarily self-reliant, i.e., the utility has limited ability to rely on a larger interconnected system that provides inertia, backup support, and ancillary services. This could also be a utility or microgrid that receives minimal or fixed imports while managing its own reliability and real and reactive power requirements. The purpose of this pursuit is to achieve a very clear, near-term demonstration of the concepts from PERFORM on a system with a heavy amount of stochastic resources, which are capable to provide essential energy and reliability services.

technologies, (iii) ability to rely on all grid assets for essential products and services instead of primarily relying only on conventional technologies, (iv) a clear understanding of asset delivery risk and system risk position, and (v) scalability and commercial relevance of their approach.[111] Applicants should note that the pilot projects are subject to successful performance in the PERFORM R&D program (see Figure 6). ARPA-E is actively engaging with industry to identify potential pilot projects that would, if approved, receive federal funds (with a required cost share). Applicants are encouraged to describe how their proposed approach, for the PERFORM R&D program, will impact industry practices and how their approach may fit within a pilot project to achieve near-term adoption and long-term transformational benefits.

[111] Commercial relevance might include: open source software and algorithms, commercial software, proprietary algorithms, software and/or design processes.

II. AWARD INFORMATION

A. AWARD OVERVIEW

ARPA-E expects to make approximately $30 million available for new awards under this FOA, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 8-12 awards under this FOA. ARPA-E may, at its discretion, issue one, multiple, or no awards.

Individual awards may vary between $250,000 and $10 million.

The period of performance for funding agreements may not exceed 36 months. ARPA-E expects the start date for funding agreements to be July 2020, or as negotiated.

ARPA-E encourages submissions stemming from ideas that still require proof-of-concept R&D efforts as well as those for which some proof-of-concept demonstration already exists.

Submissions requiring proof-of-concept R&D can propose a project with the goal of delivering on the program metric at the conclusion of the period of performance. These submissions must contain an appropriate cost and project duration plan that is described in sufficient technical detail to allow reviewers to meaningfully evaluate the proposed project. If awarded, such projects should expect a rigorous go/no-go milestone early in the project associated with the proof-of-concept demonstration. Alternatively, submissions requiring proof-of-concept R&D can propose a project with the project end deliverable being an extremely creative, but partial solution. However, the Applicants are required to provide a convincing vision how these partial solutions can enable the realization of the program metrics with further development.

Applicants proposing projects for which some initial proof-of-concept demonstration already exists should submit concrete data that supports the probability of success of the proposed project.

ARPA-E will provide support at the highest funding level only for submissions with significant technology risk, aggressive timetables, and careful management and mitigation of the associated risks.

ARPA-E will accept only new submissions under this FOA. Applicants may not seek renewal or supplementation of their existing awards through this FOA.

ARPA-E plans to fully fund your negotiated budget at the time of award.

B. RENEWAL AWARDS

At ARPA-E's sole discretion, awards resulting from this FOA may be renewed by adding one or more budget periods, extending the period of performance of the initial award, or issuing a new

award. Renewal funding is contingent on: (1) availability of funds appropriated by Congress for the purpose of this program; (2) substantial progress towards meeting the objectives of the approved application; (3) submittal of required reports; (4) compliance with the terms and conditions of the award; (5) ARPA-E approval of a renewal application; and (6) other factors identified by the Agency at the time it solicits a renewal application.

C. ARPA-E FUNDING AGREEMENTS

Through cooperative agreements, other transactions, and similar agreements, ARPA-E provides financial and other support to projects that have the potential to realize ARPA-E's statutory mission. ARPA-E does not use such agreements to acquire property or services for the direct benefit or use of the U.S. Government.

Congress directed ARPA-E to "establish and monitor project milestones, initiate research projects quickly, and just as quickly terminate or restructure projects if such milestones are not achieved."[112] Accordingly, ARPA-E has substantial involvement in the direction of every Cooperative Agreement, as described in Section II.D below.

1. COOPERATIVE AGREEMENTS

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients.[113]

Cooperative Agreements involve the provision of financial or other support to accomplish a public purpose of support or stimulation authorized by Federal statute. Under Cooperative Agreements, the Government and Prime Recipients share responsibility for the direction of projects.

ARPA-E encourages Prime Recipients to review the Model Cooperative Agreement, which is available at https://arpa-e.energy.gov/?q=site-page/funding-agreements.

2. FUNDING AGREEMENTS WITH FFRDCS/DOE LABS, GOGOS, AND FEDERAL INSTRUMENTALITIES

Any Federally Funded Research and Development Centers (FFRDC) involved as a member of a Project Team must provide the information requested in the "FFRDC Lab Authorization" and "Field Work Proposal" section of the Business Assurances & Disclosures Form, which is submitted with the Applicant's Full Application.

When a FFRDC/DOE Lab (including the National Energy Technology Laboratory or NETL) is the

[112] U.S. Congress, Conference Report to accompany the 21st Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).

[113] The Prime Recipient is the signatory to the funding agreement with ARPA-E.

lead organization for a Project Team, ARPA-E executes a funding agreement directly with the FFRDC/DOE Lab and a single, separate Cooperative Agreement with the rest of the Project Team. Notwithstanding the use of multiple agreements, the FFRDC/DOE Lab is the lead organization for the entire project, including all work performed by the FFRDC/DOE Lab and the rest of the Project Team.

When a FFRDC/DOE Lab is a *member* of a Project Team, ARPA-E executes a funding agreement directly with the FFRDC/DOE Lab and a single, separate Cooperative Agreement with the rest of the Project Team. Notwithstanding the use of multiple agreements, the Prime Recipient under the Cooperative Agreement is the lead organization for the entire project, including all work performed by the FFRDC/DOE Lab and the rest of the Project Team.

Funding agreements with DOE/NNSA FFRDCs take the form of Work Authorizations issued to DOE/NNSA FFRDCs through the DOE/NNSA Field Work Proposal system for work performed under Department of Energy Management & Operation Contracts. Funding agreements with non-DOE/NNSA FFRDCs, GOGOs (including NETL), and Federal instrumentalities (e.g., Tennessee Valley Authority) will be consistent with the sponsoring agreement between the U.S. Government and the Laboratory. Any funding agreement with a FFRDC or GOGO will have similar terms and conditions as ARPA-E's Model Cooperative Agreement (https://arpa-e.energy.gov/?q=site-page/funding-agreements).

Non-DOE GOGOs and Federal agencies may be proposed to provide support to the project team members on an applicant's project, through a Cooperative Research and Development Agreement (CRADA) or similar agreement.

3. OTHER TRANSACTIONS AUTHORITY

ARPA-E may use its "other transactions" authority under the America COMPETES Reauthorization Act of 2010 to enter into an other transaction agreement with Prime Recipients, on a case-by-case basis.

ARPA-E may negotiate an other transaction agreement when it determines that the use of a standard cooperative agreement, grant, or contract is not feasible or appropriate for a project.

In general, an other transaction agreement would require a cost share of 50%. See Section III.B.2 of the FOA.

D. STATEMENT OF SUBSTANTIAL INVOLVEMENT

ARPA-E is substantially involved in the direction of projects from inception to completion. For the purposes of an ARPA-E project, substantial involvement means:

- Project Teams must adhere to ARPA-E's agency-specific and programmatic

requirements.

- ARPA-E may intervene at any time in the conduct or performance of work under an award.
- ARPA-E does not limit its involvement to the administrative requirements of an award. Instead, ARPA-E has substantial involvement in the direction and redirection of the technical aspects of the project as a whole.
- ARPA-E may, at its sole discretion, modify or terminate projects that fail to achieve predetermined Go/No Go decision points or technical milestones and deliverables.
- During award negotiations, ARPA-E Program Directors and Prime Recipients mutually establish an aggressive schedule of quantitative milestones and deliverables that must be met every quarter. In addition, ARPA-E will negotiate and establish "Go/No-Go" milestones for each project. If the Prime Recipient fails to achieve any of the "Go/No-Go" milestones or technical milestones and deliverables as determined by the ARPA-E Contracting Officer, ARPA-E may – at its discretion - renegotiate the statement of project objectives or schedule of technical milestones and deliverables for the project. In the alternative, ARPA-E may suspend or terminate the award in accordance with 2 C.F.R. §§ 200.338 and 200.339.
- ARPA-E may provide guidance and/or assistance to the Prime Recipient to accelerate the commercial deployment of ARPA-E-funded technologies. Guidance and assistance provided by ARPA-E may include coordination with other Government agencies and nonprofits to provide mentoring and networking opportunities for Prime Recipients. ARPA-E may also organize and sponsor events to educate Prime Recipients about key barriers to the deployment of their ARPA-E-funded technologies. In addition, ARPA-E may establish collaborations with private and public entities to provide continued support for the development and deployment of ARPA-E-funded technologies.

III. ELIGIBILITY INFORMATION

A. ELIGIBLE APPLICANTS

This FOA is open to U.S. universities, national laboratories, industry and individuals.

1. INDIVIDUALS

U.S. citizens or permanent residents may apply for funding in their individual capacity as a Standalone Applicant,[114] as the lead for a Project Team,[115] or as a member of a Project Team. However, ARPA-E will only award funding to an entity formed by the Applicant.

2. DOMESTIC ENTITIES

For-profit entities, educational institutions, and nonprofits[116] that are incorporated in the United States, including U.S. territories, are eligible to apply for funding as a Standalone Applicant, as the lead organization for a Project Team, or as a member of a Project Team.

FFRDCs/DOE Labs are eligible to apply for funding as the lead organization for a Project Team or as a member of a Project Team that includes institutions of higher education, companies, research foundations, or trade and industry research collaborations, but not as a Standalone Applicant.

State, local, and tribal government entities are eligible to apply for funding as a member of a Project Team, but not as a Standalone Applicant or as the lead organization for a Project Team.

Federal agencies and instrumentalities (other than DOE) are eligible to apply for funding as a member of a Project Team, but not as a Standalone Applicant or as the lead organization for a Project Team.

3. FOREIGN ENTITIES

U.S. incorporated subsidiaries of foreign entities, whether for-profit or otherwise, are eligible to apply for funding under this FOA as a Standalone Applicant, as the lead organization for a Project Team, or as a member of a Project Team, subject to the requirements in 2 C.F.R. § 910.124, which includes requirements that the entity's participation in this FOA's Program be in

[114] A Standalone Applicant is an Applicant that applies for funding on its own, not as part of a Project Team.

[115] A Project Team consists of the Prime Recipient, Subrecipients, and others performing any of the research and development work under an ARPA-E funding agreement, whether or not costs of performing the research and development work are being reimbursed under any agreement.

[116] Nonprofit organizations described in section 501(c)(4) of the Internal Revenue Code of 1986 that engaged in lobbying activities after December 31, 1995 are not eligible to apply for funding as a Prime Recipient or Subrecipient.

the economic interest of the U.S. The Full Application must state the nature of the corporate relationship between the foreign entity and domestic subsidiary or affiliate.

Entities not incorporated in the U.S., whether for-profit or otherwise, are not eligible to apply for funding, but may be proposed by an Applicant as a member of a Project Team.

All work under an ARPA-E award must be performed in the U.S. The Applicants may request a waiver of this requirement in the Business Assurances & Disclosures Form, which is submitted with the Full Application and can be found at https://arpa-e-foa.energy.gov/. Please refer to the Business Assurances & Disclosures Form for guidance on the content and form of the request.

4. CONSORTIUM ENTITIES

Consortia, which may include domestic and foreign entities, must designate one member of the consortium as the consortium representative to the Project Team. The consortium representative must be incorporated in the United States. The eligibility of the consortium will be determined by reference to the eligibility of the consortium representative under Section III.A of the FOA. Each consortium must have an internal governance structure and a written set of internal rules. Upon request, the consortium entity must provide a written description of its internal governance structure and its internal rules to the Contracting Officer (ARPA-E-CO@hq.doe.gov).

Unincorporated consortia must provide the Contracting Officer with a collaboration agreement, commonly referred to as the articles of collaboration, which sets out the rights and responsibilities of each consortium member. This collaboration agreement binds the individual consortium members together and shall include the consortium's:

- Management structure;
- Method of making payments to consortium members;
- Means of ensuring and overseeing members' efforts on the project;
- Provisions for members' cost sharing contributions; and
- Provisions for ownership and rights in intellectual property developed previously or under the agreement.

B. COST SHARING[117]

Applicants are bound by the cost share proposed in their Full Applications.

[117] Please refer to Section VI.B.3-4 of the FOA for guidance on cost share payments and reporting.

1. BASE COST SHARE REQUIREMENT

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients (see Section II.C.1 of the FOA). Under a Cooperative Agreement or Grant, the Prime Recipient must provide at least 20% of the Total Project Cost[118] as cost share, except as provided in Sections III.B.2 or III.B.3 below.[119]

2. INCREASED COST SHARE REQUIREMENT

Large businesses are strongly encouraged to provide more than 20% of the Total Project Cost as cost share. ARPA-E may consider the amount of cost share proposed when selecting applications for award negotiations (see Section V.B.1 of the FOA).

Under an "other transaction" agreement, the Prime Recipient must provide at least 50% of the Total Project Cost as cost share. ARPA-E may reduce this cost share requirement, as appropriate.

3. REDUCED COST SHARE REQUIREMENT

ARPA-E has reduced the cost share requirement for the following types of projects:

- A domestic educational institution or domestic nonprofit applying as a Standalone Applicant is not required to provide cost share.
- Project Teams composed exclusively of domestic educational institutions, domestic nonprofits, and/or FFRDCs/DOE Labs/Federal agencies and instrumentalities (other than DOE) are not required to provide cost share.
- Small businesses – or consortia of small businesses – may provide 0% cost share from the outset of the project through the first 12 months of the project (hereinafter the "Cost Share Grace Period").[120] If the project is continued beyond the Cost Share Grace Period, then at least 10% of the Total Project Cost (including the costs incurred during the Cost Share Grace Period) will be required as cost share over the remaining period of performance.

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[118] The Total Project Cost is the sum of the Prime Recipient share and the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs and FFRDCs.

[119] Energy Policy Act of 2005, Pub.L. 109-58, sec. 988.

[120] Small businesses are generally defined as domestically incorporated entities that meet the criteria established by the U.S. Small Business Administration's (SBA) "Table of Small Business Size Standards Matched to North American Industry Classification System Codes" (NAICS) (http://www.sba.gov/content/small-business-size-standards). Applicants that are small businesses will be required to certify in the Business Assurances & Disclosures Form that their organization meets the SBA's definition of a small business under at least one NAICS code.

- Project Teams where a small business is the lead organization and small businesses perform greater than or equal to 80% of the total work under the funding agreement (as measured by the Total Project Cost) are entitled to the same cost share reduction and Cost Share Grace Period as provided above to Standalone small businesses or consortia of small businesses.[121]
- Project Teams where domestic educational institutions, domestic nonprofits, small businesses, and/or FFRDCs perform greater than or equal to 80% of the total work under the funding agreement (as measured by the Total Project Cost) are required to provide at least 10% of the Total Project Cost as cost share. However, any entity (such as a large business) receiving patent rights under a class waiver, or other patent waiver, that is part of a Project Team receiving this reduction must continue to meet the statutory minimum cost share requirement (20%) for its portion of the Total Project Cost.
- Projects that do not meet any of the above criteria are subject to the cost share requirements described in Sections III.B.1 and III.B.2 of the FOA.

4. LEGAL RESPONSIBILITY

Although the cost share requirement applies to the Project Team as a whole, the funding agreement makes the Prime Recipient legally responsible for paying, or ensuring payment of, the entire cost share. The Prime Recipient's cost share obligation is expressed in the funding agreement as a static amount in U.S. dollars (cost share amount) and as a percentage of the Total Project Cost (cost share percentage). If the funding agreement is terminated prior to the end of the period of performance, the Prime Recipient is required to contribute at least the cost share percentage of total expenditures incurred through the date of termination.

The Prime Recipient is solely responsible for managing cost share contributions by the Project Team and enforcing cost share obligations assumed by Project Team members in subawards or related agreements.

5. COST SHARE ALLOCATION

Each Project Team is free to determine how much each Project Team member will contribute towards the cost share requirement. The amount contributed by individual Project Team members may vary, as long as the cost share requirement for the project as a whole is met.

6. COST SHARE TYPES AND ALLOWABILITY

Every cost share contribution must be allowable under the applicable Federal cost principles, as described in Section IV.G of the FOA.

[121] See the information provided in previous footnote.

Project Teams may provide cost share in the form of cash or in-kind contributions. Cash contributions may be provided by the Prime Recipient or Subrecipients. Allowable in-kind contributions include but are not limited to personnel costs, indirect costs, facilities and administrative costs, rental value of buildings or equipment, and the value of a service, other resource, or third party in-kind contribution. Project Teams may use funding or property received from state or local governments to meet the cost share requirement, so long as the funding or property was not provided to the state or local government by the Federal Government.

The Prime Recipient may not use the following sources to meet its cost share obligations:

- Revenues or royalties from the prospective operation of an activity beyond the period of performance;
- Proceeds from the prospective sale of an asset of an activity;
- Federal funding or property (e.g., Federal grants, equipment owned by the Federal Government); or
- Expenditures that were reimbursed under a separate Federal program.

In addition, Project Teams may not use independent research and development (IR&D) funds[122] to meet their cost share obligations under Cooperative Agreements. However, Project Teams may use IR&D funds to meet their cost share obligations under "other transaction" agreements.

Project Teams may not use the same cash or in-kind contributions to meet cost share requirements for more than one project or program.

Cost share contributions must be specified in the project budget, verifiable from the Prime Recipient's records, and necessary and reasonable for proper and efficient accomplishment of the project. Every cost share contribution must be reviewed and approved in advance by the Contracting Officer and incorporated into the project budget before the expenditures are incurred.

Applicants may wish to refer to 2 C.F.R. Parts 200 and 910, and 10 C.F.R Part 603 for additional guidance on cost sharing, specifically 2 C.F.R. §§ 200.306 and 910.130, and 10 C.F.R. §§ 603.525-555.

7. COST SHARE CONTRIBUTIONS BY FFRDCS AND GOGOS

Because FFRDCs are funded by the Federal Government, costs incurred by FFRDCs generally may not be used to meet the cost share requirement. FFRDCs may contribute cost share only if the contributions are paid directly from the contractor's Management Fee or a non-Federal source.

[122] As defined in Federal Acquisition Regulation SubSection 31.205-18.

Because GOGOs/Federal Agencies are funded by the Federal Government, GOGOs/Federal Agencies may not provide cost share for the proposed project. However, the GOGO/Agency costs would be included in Total Project Costs for purposes of calculating the cost-sharing requirements of the applicant.

8. COST SHARE VERIFICATION

Upon selection for award negotiations, Applicants are required to provide information and documentation regarding their cost share contributions. Please refer to Section VI.B.3 of the FOA for guidance on the requisite cost share information and documentation.

C. OTHER

1. COMPLIANT CRITERIA

Concept Papers are deemed compliant if:

- The Applicant meets the eligibility requirements in Section III.A of the FOA;
- The Concept Paper complies with the content and form requirements in Section IV.C of the FOA; and
- The Applicant entered all required information, successfully uploaded all required documents, and clicked the "Submit" button in ARPA-E eXCHANGE by the deadline stated in the FOA.

Concept Papers found to be noncompliant may not be merit reviewed or considered for award. ARPA-E may not review or consider noncompliant Concept Papers, including Concept Papers submitted through other means, Concept Papers submitted after the applicable deadline, and incomplete Concept Papers. A Concept Paper is incomplete if it does not include required information. ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.

Full Applications are deemed compliant if:

- The Applicant submitted a compliant and responsive Concept Paper;
- The Applicant meets the eligibility requirements in Section III.A of the FOA;
- The Full Application complies with the content and form requirements in Section IV.D of the FOA; and
- The Applicant entered all required information, successfully uploaded all required documents, and clicked the "Submit" button in ARPA-E eXCHANGE by the deadline stated in the FOA.

Full Applications found to be noncompliant may not be merit reviewed or considered for award. ARPA-E may not review or consider noncompliant Full Applications, including Full

Applications submitted through other means, Full Applications submitted after the applicable deadline, and incomplete Full Applications. A Full Application is incomplete if it does not include required information and documents, such as Forms SF-424 and SF-424A. ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.

Replies to Reviewer Comments are deemed compliant if:

- The Applicant successfully uploads its response to ARPA-E eXCHANGE by the deadline stated in the FOA; and
- The Replies to Reviewer Comments comply with the content and form requirements of Section IV.E of the FOA.

ARPA-E will not review or consider noncompliant Replies to Reviewer Comments, including Replies submitted through other means and Replies submitted after the applicable deadline. ARPA-E will not extend the submission deadline for Applicants that fail to submit required information due to server/connection congestion. ARPA-E will review and consider each compliant and responsive Full Application, even if no Reply is submitted or if the Reply is found to be noncompliant.

2. RESPONSIVENESS CRITERIA

ARPA-E performs a preliminary technical review of Concept Papers and Full Applications. The following types of submissions may be deemed nonresponsive and may not be reviewed or considered:

- Submissions that fall outside the technical parameters specified in this FOA.
- Submissions that have been submitted in response to other currently issued ARPA-E FOAs.
- Submissions that are not scientifically distinct from applications submitted in response to other currently issued ARPA-E FOAs.
- Submissions for basic research aimed solely at discovery and/or fundamental knowledge generation.
- Submissions for large-scale demonstration projects of existing technologies.
- Submissions for proposed technologies that represent incremental improvements to existing technologies.
- Submissions for proposed technologies that are not based on sound scientific principles (e.g., violates a law of thermodynamics).
- Submissions for proposed technologies that are not transformational, as described in Section I.A of the FOA.
- Submissions for proposed technologies that do not have the potential to become disruptive in nature, as described in Section I.A of the FOA. Technologies must be scalable such that they could be disruptive with sufficient technical progress.

- Submissions that are not distinct in scientific approach or objective from activities currently supported by or actively under consideration for funding by any other office within Department of Energy.
- Submissions that are not distinct in scientific approach or objective from activities currently supported by or actively under consideration for funding by other government agencies or the private sector.
- Submissions that do not propose a R&D plan that allows ARPA-E to evaluate the submission under the applicable merit review criteria provided in Section V.A of the FOA.

3. SUBMISSIONS SPECIFICALLY NOT OF INTEREST

Submissions that propose the following will be deemed nonresponsive and will not be merit reviewed or considered:

- Applications that fall outside the technical targets specified in Section I.E of the FOA
- Applications that are not scientifically distinct from applications submitted in response to other currently issued ARPA-E FOAs
- Applications for large-scale demonstration projects of existing approaches
- Applications that represent incremental improvements to existing practices
- Applications that are not based on sound scientific or economic principles
- Applications that are not transformational, as described in this FOA
- Applications that do not have the potential to become disruptive in nature, as described in this FOA. Approaches must be scalable such that they could become disruptive with sufficient technical progress.
- Applications that are not scientifically distinct from existing funded activities supported elsewhere, including within the Department of Energy
- Applications that ignore the uncertainty and variability of stochastic resources
- Applications that are strictly academic in nature and do not explicitly address industry adoption risks or implementation challenges
- Applications that do not include a plan for data acquisition and management (see Section I.E.1 of the FOA for the data requirements and Section I.F of the FOA)
- Applications for proposed Thrust 1 approaches that do not include any representation of asset integration at the system level (see Section I.D.2 of the FOA for details)
- Applications for proposed Thrust 2 approaches that do not include any representation of asset risk assessment (see Section I.D.3 of the FOA for details)
- Applications that only target policy changes or regulatory structure
- Applications that ignore physical and engineering constraints for operating the electric power system (e.g., transmission or distribution limitations, asset characteristics and limitations, reliability requirements, etc.)
- Applications that propose financial credit scores for plants tied to financial default

4. LIMITATION ON NUMBER OF SUBMISSIONS

ARPA-E is not limiting the number of submissions from Applicants. Applicants may submit more than one application to this FOA, provided that each application is scientifically distinct.

IV. APPLICATION AND SUBMISSION INFORMATION

A. APPLICATION PROCESS OVERVIEW

1. REGISTRATION IN ARPA-E eXCHANGE

The first step in applying to this FOA is registration in ARPA-E eXCHANGE, ARPA-E's online application portal. For detailed guidance on using ARPA-E eXCHANGE, please refer to Section IV.H.1 of the FOA and the "ARPA-E eXCHANGE User Guide" (https://arpa-e-foa.energy.gov/Manuals.aspx).

2. CONCEPT PAPERS

Applicants must submit a Concept Paper by the deadline stated in the FOA. Section IV.C of the FOA provides instructions on submitting a Concept Paper.

ARPA-E performs a preliminary review of Concept Papers to determine whether they are compliant and responsive, as described in Section III.C of the FOA. Concept Papers found to be noncompliant or nonresponsive may not be merit reviewed or considered for award. ARPA-E makes an independent assessment of each compliant and responsive Concept Paper based on the criteria and program policy factors in Sections V.A.1 and V.B.1 of the FOA.

ARPA-E will encourage a subset of Applicants to submit Full Applications. Other Applicants will be discouraged from submitting a Full Application in order to save them the time and expense of preparing an application submission that is unlikely to be selected for award negotiations. By discouraging the submission of a Full Application, ARPA-E intends to convey its lack of programmatic interest in the proposed project. Such assessments do not necessarily reflect judgments on the merits of the proposed project. Unsuccessful Applicants should continue to submit innovative ideas and concepts to future FOAs.

3. FULL APPLICATIONS

Applicants must submit a Full Application by the deadline stated in the FOA. Applicants will have approximately 45 days from receipt of the Encourage/Discourage notification to prepare and submit a Full Application. Section IV.D of the FOA provides instructions on submitting a Full Application.

ARPA-E performs a preliminary review of Full Applications to determine whether they are compliant and responsive, as described in Section III.C of the FOA. Full Applications found to be noncompliant or nonresponsive may not be merit reviewed or considered for award. ARPA-E makes an independent assessment of each compliant and responsive Full Application based on the criteria and program policy factors in Sections V.A.2 and V.B.1 of the FOA.

4. REPLY TO REVIEWER COMMENTS

Once ARPA-E has completed its review of Full Applications, reviewer comments on compliant and responsive Full Applications are made available to Applicants via ARPA-E eXCHANGE. Applicants may submit an optional Reply to Reviewer Comments, which must be submitted by the deadline stated in the FOA. Section IV.E of the FOA provides instructions on submitting a Reply to Reviewer Comments.

ARPA-E performs a preliminary review of Replies to determine whether they are compliant, as described in Section III.C.1 of the FOA. ARPA-E will review and consider compliant Replies only. ARPA-E will review and consider each compliant and responsive Full Application, even if no Reply is submitted or if the Reply is found to be non-compliant.

5. PRE-SELECTION CLARIFICATIONS AND "DOWN-SELECT" PROCESS

Once ARPA-E completes its review of Full Applications and Replies to Reviewer Comments, it may, at the Contracting Officer's discretion, conduct a pre-selection clarification process and/or perform a "down-select" of Full Applications. Through the pre-selection clarification process or down-select process, ARPA-E may obtain additional information from select Applicants through pre-selection meetings, webinars, videoconferences, conference calls, written correspondence, or site visits that can be used to make a final selection determination. ARPA-E will not reimburse Applicants for travel and other expenses relating to pre-selection meetings or site visits, nor will these costs be eligible for reimbursement as pre-award costs.

ARPA-E may select applications for award negotiations and make awards without pre-selection meetings and site visits. Participation in a pre-selection meeting or site visit with ARPA-E does not signify that Applicants have been selected for award negotiations.

6. SELECTION FOR AWARD NEGOTIATIONS

ARPA-E carefully considers all of the information obtained through the application process and makes an independent assessment of each compliant and responsive Full Application based on the criteria and program policy factors in Sections V.A.2 and V.B.1 of the FOA. The Selection Official may select all or part of a Full Application for award negotiations. The Selection Official may also postpone a final selection determination on one or more Full Applications until a later date, subject to availability of funds and other factors. ARPA-E will enter into award negotiations only with selected Applicants.

Applicants are promptly notified of ARPA-E's selection determination. ARPA-E may stagger its selection determinations. As a result, some Applicants may receive their notification letter in advance of other Applicants. Please refer to Section VI.A of the FOA for guidance on award notifications.

B. APPLICATION FORMS

Required forms for Full Applications are available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov), including the SF-424 and Budget Justification Workbook/SF-424A. A sample Summary Slide is available on ARPA-E eXCHANGE. Applicants may use the templates available on ARPA-E eXCHANGE, including the template for the Concept Paper, the template for the Technical Volume of the Full Application, the template for the Summary Slide, the template for the Summary for Public Release, the template for the Reply to Reviewer Comments, and the template for the Business Assurances & Disclosures Form. A sample response to the Business Assurances & Disclosures Form is available on ARPA-E eXCHANGE.

C. CONTENT AND FORM OF CONCEPT PAPERS

The Concept Paper is mandatory (i.e. in order to submit a Full Application, a compliant and responsive Concept Paper must have been submitted) and must conform to the following formatting requirements:

- The Concept Paper must not exceed 4 pages in length including graphics, figures, and/or tables.
- The Concept Paper must be submitted in Adobe PDF format.
- The Concept Paper must be written in English.
- All pages must be formatted to fit on 8-1/2 by 11 inch paper with margins not less than one inch on every side. Single space all text and use Times New Roman typeface, a black font color, and a font size of 12 point or larger (except in figures and tables).
- The ARPA-E assigned Control Number, the Lead Organization Name, and the Principal Investigator's Last Name must be prominently displayed on the upper right corner of the header of every page. Page numbers must be included in the footer of every page.
- The first paragraph must include the Lead Organization's Name and Location, Principal Investigator's Name, Technical Category, Proposed Funding Requested (Federal and Cost Share), and Project Duration.

Concept Papers found to be noncompliant or nonresponsive may not be merit reviewed or considered for award (see Section III.C of the FOA).

Each Concept Paper must be limited to a single concept or technology. Unrelated concepts and technologies must not be consolidated into a single Concept Paper.

A fillable Concept Paper template is available on ARPA-E eXCHANGE at https://arpa-e-foa.energy.gov.

Concept Papers must conform to the content requirements described below. If Applicants exceed the maximum page length indicated above, ARPA-E will review only the authorized number of pages and disregard any additional pages.

1. CONCEPT PAPER

a. CONCEPT SUMMARY

- Describe the proposed concept with minimal jargon, and explain how it addresses the Program Objectives of the FOA.

b. INNOVATION AND IMPACT

- Clearly describe existing practices and identify the problem to be solved with the proposed technology concept.
- Describe how the proposed effort represents an innovative and potentially transformational solution to the technical challenges posed by the FOA.
- Explain the concept's potential to be disruptive compared to existing or emerging technologies.
- To the extent possible, provide quantitative metrics in a table that compares the proposed technology concept to current and emerging technologies and to the Technical Performance Targets in Section I.E of the FOA for the appropriate Technology Category in Section I.D of the FOA.
- Describe how the proposed effort will address industry acceptance and adoption risks.

c. PROPOSED WORK

- Describe whether the proposed effort is focused on Thrust 1, Thrust 2, or both.
- Describe the final deliverable(s) for the project and the overall technical approach used to achieve project objectives.
- Discuss alternative approaches considered, if any, and why the proposed approach is most appropriate for the project objectives.
- For Thrust 1 approaches, clearly articulate how the asset-level risk assessment will be represented at the system level. For Thrust 2, clearly articulate how the asset risk assessment will be included in the system level and clearly articulate the proposed system level risk index.
- Describe the background, theory, simulation, modeling, experimental data, or other sound engineering and scientific practices or principles that support the proposed approach. Provide specific examples of supporting data and/or appropriate citations to the scientific and technical literature.

- Describe why the proposed effort is a significant technical challenge and the key technical risks to the project. Does the approach require one or more entirely new technical developments to succeed? How will technical risk be mitigated?
- Identify techno-economic challenges to be overcome for the proposed technology to be commercially relevant.

d. TEAM ORGANIZATION AND CAPABILITIES

- Indicate the roles and responsibilities of the organizations and key personnel that comprise the Project Team.
- Provide the name, position, and institution of each key team member and describe in 1-2 sentences the skills and experience that he/she brings to the team.
- Identify key capabilities provided by the organizations comprising the Project Team and how those key capabilities will be used in the proposed effort.
- Identify (if applicable) previous collaborative efforts among team members relevant to the proposed effort.
- Briefly describe whether the team is reliant on ARPA-E providing access to data through its Data Plan (see Section I.F of the FOA for more information) and/or will address its own data needs.
- Briefly describe whether the proposed effort and team are well aligned for a pilot project (see Section I.G of the FOA).

D. CONTENT AND FORM OF FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN DECEMBER 2019]

E. CONTENT AND FORM OF REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN DECEMBER 2019]

F. INTERGOVERNMENTAL REVIEW

This program is not subject to Executive Order 12372 (Intergovernmental Review of Federal Programs).

G. FUNDING RESTRICTIONS

[TO BE INSERTED BY FOA MODIFICATION IN DECEMBER 2019]

H. OTHER SUBMISSION REQUIREMENTS

1. USE OF ARPA-E eXCHANGE

To apply to this FOA, Applicants must register with ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/Registration.aspx). Concept Papers, Full Applications, and Replies to Reviewer Comments must be submitted through ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/login.aspx). ARPA-E will not review or consider applications submitted through other means (e.g., fax, hand delivery, email, postal mail). For detailed guidance on using ARPA-E eXCHANGE, please refer to the "ARPA-E eXCHANGE Applicant Guide" (https://arpa-e-foa.energy.gov/Manuals.aspx).

Upon creating an application submission in ARPA-E eXCHANGE, Applicants will be assigned a Control Number. If the Applicant creates more than one application submission, a different Control Number will be assigned for each application.

Once logged in to ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/login.aspx), Applicants may access their submissions by clicking the "My Submissions" link in the navigation on the left side of the page. Every application that the Applicant has submitted to ARPA-E and the corresponding Control Number is displayed on that page. If the Applicant submits more than one application to a particular FOA, a different Control Number is shown for each application.

Applicants are responsible for meeting each submission deadline in ARPA-E eXCHANGE. **Applicants are strongly encouraged to submit their applications at least 48 hours in advance of the submission deadline.** Under normal conditions (i.e., at least 48 hours in advance of the submission deadline), Applicants should allow at least 1 hour to submit a Concept Paper, or Full Application. In addition, Applicants should allow at least 15 minutes to submit a Reply to Reviewer Comments. Once the application is submitted in ARPA-E eXCHANGE, Applicants may revise or update their application until the expiration of the applicable deadline.

Applicants should not wait until the last minute to begin the submission process. During the final hours before the submission deadline, Applicants may experience server/connection congestion that prevents them from completing the necessary steps in ARPA-E eXCHANGE to submit their applications. **ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.**

ARPA-E may not review or consider incomplete applications and applications received after the deadline stated in the FOA. Such applications may be deemed noncompliant (see Section III.C.1 of the FOA). The following errors could cause an application to be deemed "incomplete" and thus noncompliant:

- Failing to comply with the form and content requirements in Section IV of the FOA;
- Failing to enter required information in ARPA-E eXCHANGE;

- Failing to upload required document(s) to ARPA-E eXCHANGE;
- Failing to click the "Submit" button in ARPA-E eXCHANGE by the deadline stated in the FOA;
- Uploading the wrong document(s) or application(s) to ARPA-E eXCHANGE; and
- Uploading the same document twice, but labeling it as different documents. (In the latter scenario, the Applicant failed to submit a required document.)

ARPA-E urges Applicants to carefully review their applications and to allow sufficient time for the submission of required information and documents.

V. APPLICATION REVIEW INFORMATION

A. CRITERIA

ARPA-E performs a preliminary review of Full Applications to determine whether they are compliant and responsive (see Section III.C of the FOA). ARPA-E also performs a preliminary review of Replies to Reviewer Comments to determine whether they are compliant.

ARPA-E considers a mix of quantitative and qualitative criteria in determining whether to encourage the submission of a Full Application and whether to select a Full Application for award negotiations.

1. CRITERIA FOR CONCEPT PAPERS

(1) *Impact of the Proposed Technology Relative to FOA Targets* (50%) - This criterion involves consideration of the following:

- The potential for a transformational and disruptive (not incremental) advancement compared to existing or emerging technologies;
- Achievement of the technical performance targets defined in Section I.E of the FOA for the appropriate technology Category in Section I.D of the FOA;
- Identification of techno-economic challenges that must be overcome for the proposed technology to be commercially relevant; and
- Demonstration of awareness of competing commercial and emerging technologies and identifies how the proposed concept/technology provides significant improvement over existing solutions.

(2) *Overall Scientific and Technical Merit* (50%) - This criterion involves consideration of the following:

- The feasibility of the proposed work, as justified by appropriate background, theory, simulation, modeling, experimental data, or other sound scientific and engineering practices;
- Sufficiency of technical approach to accomplish the proposed R&D objectives, including why the proposed concept is more appropriate than alternative approaches and how technical risk will be mitigated;
- Clearly defined project outcomes and final deliverables; and
- The demonstrated capabilities of the individuals performing the project, the key capabilities of the organizations comprising the Project Team, the roles and responsibilities of each organization and (if applicable) previous collaborations among team members supporting the proposed project.

Submissions will not be evaluated against each other since they are not submitted in accordance with a common work statement. The above criteria will be weighted as follows:

Impact of the Proposed Technology Relative to FOA Targets	50%
Overall Scientific and Technical Merit	50%

2. CRITERIA FOR FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN DECEMBER 2019]

3. CRITERIA FOR REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN DECEMBER 2019]

B. REVIEW AND SELECTION PROCESS

1. PROGRAM POLICY FACTORS

In addition to the above criteria, ARPA-E may consider the following program policy factors in determining which Concept Papers to encourage to submit a Full Application and which Full Applications to select for award negotiations:

I. **ARPA-E Portfolio Balance**. Project balances ARPA-E portfolio in one or more of the following areas:
   a. Diversity of technical personnel in the proposed Project Team;
   b. Technological diversity;
   c. Organizational diversity;
   d. Geographic diversity;
   e. Technical or commercialization risk; or
   f. Stage of technology development.

II. **Relevance to ARPA-E Mission Advancement.** Project contributes to one or more of ARPA-E's key statutory goals:
   a. Reduction of U.S. dependence on foreign energy sources;
   b. Stimulation of domestic manufacturing/U.S. Manufacturing Plan;
   c. Reduction of energy-related emissions;
   d. Increase in U.S. energy efficiency;
   e. Enhancement of U.S. economic and energy security; or
   f. Promotion of U.S. advanced energy technologies competitiveness.

III. **Synergy of Public and Private Efforts**.
   a. Avoids duplication and overlap with other publicly or privately funded projects;

b. Promotes increased coordination with nongovernmental entities for demonstration of technologies and research applications to facilitate technology transfer; or
c. Increases unique research collaborations.

IV. **Low likelihood of other sources of funding.** High technical and/or financial uncertainty that results in the non-availability of other public, private or internal funding or resources to support the project.

V. **High-Leveraging of Federal Funds**. Project leverages Federal funds to optimize advancement of programmatic goals by proposing cost share above the required minimum or otherwise accessing scarce or unique resources.

VI. **High Project Impact Relative to Project Cost.**

2. ARPA-E REVIEWERS

By submitting an application to ARPA-E, Applicants consent to ARPA-E's use of Federal employees, contractors, and experts from educational institutions, nonprofits, industry, and governmental and intergovernmental entities as reviewers. ARPA-E selects reviewers based on their knowledge and understanding of the relevant field and application, their experience and skills, and their ability to provide constructive feedback on applications.

ARPA-E requires all reviewers to complete a Conflict-of-Interest Certification and Nondisclosure Agreement through which they disclose their knowledge of any actual or apparent conflicts and agree to safeguard confidential information contained in Concept Papers, Full Applications, and Replies to Reviewer Comments. In addition, ARPA-E trains its reviewers in proper evaluation techniques and procedures.

Applicants are not permitted to nominate reviewers for their applications. Applicants may contact the Contracting Officer by email (ARPA-E-CO@hq.doe.gov) if they have knowledge of a potential conflict of interest or a reasonable belief that a potential conflict exists.

3. ARPA-E SUPPORT CONTRACTOR

ARPA-E utilizes contractors to assist with the evaluation of applications and project management. To avoid actual and apparent conflicts of interest, ARPA-E prohibits its support contractors from submitting or participating in the preparation of applications to ARPA-E.

By submitting an application to ARPA-E, Applicants represent that they are not performing support contractor services for ARPA-E in any capacity and did not obtain the assistance of ARPA-E's support contractor to prepare the application. ARPA-E will not consider any applications that are submitted by or prepared with the assistance of its support contractors.

C. ANTICIPATED ANNOUNCEMENT AND AWARD DATES

[TO BE INSERTED BY FOA MODIFICATION IN DECEMBER 2019]

VI. AWARD ADMINISTRATION INFORMATION

A. AWARD NOTICES

1. REJECTED SUBMISSIONS

Noncompliant and nonresponsive Concept Papers and Full Applications are rejected by the Contracting Officer and are not merit reviewed or considered for award. The Contracting Officer sends a notification letter by email to the technical and administrative points of contact designated by the Applicant in ARPA-E eXCHANGE. The notification letter states the basis upon which the Concept Paper or Full Application was rejected.

2. CONCEPT PAPER NOTIFICATIONS

ARPA-E promptly notifies Applicants of its determination to encourage or discourage the submission of a Full Application. ARPA-E sends a notification letter by email to the technical and administrative points of contact designated by the Applicant in ARPA-E eXCHANGE. ARPA-E provides feedback in the notification letter in order to guide further development of the proposed technology.

Applicants may submit a Full Application even if they receive a notification discouraging them from doing so. By discouraging the submission of a Full Application, ARPA-E intends to convey its lack of programmatic interest in the proposed project. Such assessments do not necessarily reflect judgments on the merits of the proposed project. The purpose of the Concept Paper phase is to save Applicants the considerable time and expense of preparing a Full Application that is unlikely to be selected for award negotiations.

A notification letter encouraging the submission of a Full Application does not authorize the Applicant to commence performance of the project. Please refer to Section IV.G of the FOA for guidance on pre-award costs.

3. FULL APPLICATION NOTIFICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN DECEMBER 2019]

B. ADMINISTRATIVE AND NATIONAL POLICY REQUIREMENTS

[TO BE INSERTED BY FOA MODIFICATION IN DECEMBER 2019]

C. REPORTING

[TO BE INSERTED BY FOA MODIFICATION IN DECEMBER 2019]

VII. AGENCY CONTACTS

A. COMMUNICATIONS WITH ARPA-E

Upon the issuance of a FOA, only the Contracting Officer may communicate with Applicants. ARPA-E personnel and our support contractors are prohibited from communicating (in writing or otherwise) with Applicants regarding the FOA. This "quiet period" remains in effect until ARPA-E's public announcement of its project selections.

During the "quiet period," Applicants are required to submit all questions regarding this FOA to ARPA-E-CO@hq.doe.gov. Questions and Answers (Q&As) about ARPA-E and the FOA are available at http://arpa-e.energy.gov/faq. For questions that have not already been answered, please send an email with the FOA name and number in the subject line to ARPA-E-CO@hq.doe.gov. Due to the volume of questions received, ARPA-E will only answer pertinent questions that have not yet been answered and posted at the above link.

- ARPA-E will post responses on a weekly basis to any questions that are received that have not already been addressed at the link above. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.
- ARPA-E will cease to accept questions approximately 10 business days in advance of each submission deadline. Responses to questions received before the cutoff will be posted approximately one business day in advance of the submission deadline. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.
- Responses are published in a document specific to this FOA under "CURRENT FUNDING OPPORTUNITIES – FAQS" on ARPA-E's website (http://arpa-e.energy.gov/faq).

Applicants may submit questions regarding ARPA-E eXCHANGE, ARPA-E's online application portal, to ExchangeHelp@hq.doe.gov. ARPA-E will promptly respond to emails that raise legitimate, technical issues with ARPA-E eXCHANGE. ARPA-E will refer any questions regarding the FOA to ARPA-E-CO@hq.doe.gov.

ARPA-E will not accept or respond to communications received by other means (e.g., fax, telephone, mail, hand delivery). Emails sent to other email addresses will be disregarded.

During the "quiet period," only the Contracting Officer may authorize communications between ARPA-E personnel and Applicants. The Contracting Officer may communicate with Applicants as necessary and appropriate. As described in Section IV.A of the FOA, the Contracting Officer may arrange pre-selection meetings and/or site visits during the "quiet period."

B. DEBRIEFINGS

ARPA-E does not offer or provide debriefings. ARPA-E provides Applicants with a notification encouraging or discouraging the submission of a Full Application based on ARPA-E's assessment of the Concept Paper. In addition, ARPA-E provides Applicants with reviewer comments on Full Applications before the submission deadline for Replies to Reviewer Comments.

VIII. OTHER INFORMATION

A. TITLE TO SUBJECT INVENTIONS

Ownership of subject inventions is governed pursuant to the authorities listed below. Typically, either by operation of law or under the authority of a patent waiver, Prime Recipients and Subrecipients may elect to retain title to their subject inventions under ARPA-E funding agreements.

- Domestic Small Businesses, Educational Institutions, and Nonprofits: Under the Bayh-Dole Act (35 U.S.C. § 200 et seq.), domestic small businesses, educational institutions, and nonprofits may elect to retain title to their subject inventions. If Prime Recipients/Subrecipients elect to retain title, they must file a patent application in a timely fashion, generally one year from election of title, though: a) extensions can be granted, and b) earlier filing is required for certain situations ("statutory bars," governed by 35 U.S.C. § 102) involving publication, sale, or public use of the subject invention.
- All other parties: The Federal Non-Nuclear Energy Research and Development Act of 1974, 42. U.S.C. 5908, provides that the Government obtains title to new inventions unless a waiver is granted (*see below)*.
- Class Waiver: Under 42 U.S.C. § 5908, title to subject inventions vests in the U.S. Government and large businesses and foreign entities do not have the automatic right to elect to retain title to subject inventions. However, ARPA-E typically issues "class patent waivers" under which large businesses and foreign entities that meet certain stated requirements, such as cost sharing of at least 20%, may elect to retain title to their subject inventions. If a large business or foreign entity elects to retain title to its subject invention, it must file a patent application in a timely fashion. If the class waiver does not apply, a party may request a waiver in accordance with 10 C.F.R. §784.
- GOGOs are subject to the requirements of 37 C.F.R. Part 501.
- Determination of Exceptional Circumstances (DEC): DOE has determined that exceptional circumstances exist that warrant the modification of the standard patent rights clause for small businesses and non-profit awardees under Bayh-Dole to maximize the manufacture of technologies supported by ARPA-E awards in the United States. The DEC, including a right of appeal, is dated September 9, 2013 and is available at the following link: http://energy.gov/gc/downloads/determination-exceptional-circumstances-under-bayh-dole-act-energy-efficiency-renewable. Please see Sections IV.D and VI.B of the FOA for more information on U.S. Manufacturing Requirements.

B. GOVERNMENT RIGHTS IN SUBJECT INVENTIONS

Where Prime Recipients and Subrecipients retain title to subject inventions, the U.S. Government retains certain rights.

1. GOVERNMENT USE LICENSE

The U.S. Government retains a nonexclusive, nontransferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States any subject invention throughout the world. This license extends to contractors doing work on behalf of the Government.

2. MARCH-IN RIGHTS

The U.S. Government retains march-in rights with respect to all subject inventions. Through "march-in rights," the Government may require a Prime Recipient or Subrecipient who has elected to retain title to a subject invention (or their assignees or exclusive licensees), to grant a license for use of the invention. In addition, the Government may grant licenses for use of the subject invention when Prime Recipients, Subrecipients, or their assignees and exclusive licensees refuse to do so.

The U.S. Government may exercise its march-in rights if it determines that such action is necessary under any of the four following conditions:

- The owner or licensee has not taken or is not expected to take effective steps to achieve practical application of the invention within a reasonable time;
- The owner or licensee has not taken action to alleviate health or safety needs in a reasonably satisfactory manner;
- The owner has not met public use requirements specified by Federal statutes in a reasonably satisfactory manner; or
- The U.S. Manufacturing requirement has not been met.

C. RIGHTS IN TECHNICAL DATA

Data rights differ based on whether data is first produced under an award or instead was developed at private expense outside the award.

- Background or "Limited Rights Data": The U.S. Government will not normally require delivery of technical data developed solely at private expense prior to issuance of an award, except as necessary to monitor technical progress and evaluate the potential of proposed technologies to reach specific technical and cost metrics.
- Generated Data: The U.S. Government normally retains very broad rights in technical data produced under Government financial assistance awards, including the right to distribute to the public. However, pursuant to special statutory authority, certain categories of data generated under ARPA-E awards may be protected from public disclosure for up to five years in accordance with provisions that will be set forth in the award. In addition, invention disclosures may be protected from public disclosure for a reasonable time in order to allow for filing a patent application.

D. PROTECTED PERSONALLY IDENTIFIABLE INFORMATION

Applicants may not include any Protected Personally Identifiable Information (Protected PII) in their submissions to ARPA-E. Protected PII is defined as data that, if compromised, could cause harm to an individual such as identity theft. Listed below are examples of Protected PII that Applicants must not include in their submissions.

- Social Security Numbers in any form;
- Place of Birth associated with an individual;
- Date of Birth associated with an individual;
- Mother's maiden name associated with an individual;
- Biometric record associated with an individual;
- Fingerprint;
- Iris scan;
- DNA;
- Medical history information associated with an individual;
- Medical conditions, including history of disease;
- Metric information, e.g. weight, height, blood pressure;
- Criminal history associated with an individual;
- Ratings;
- Disciplinary actions;
- Performance elements and standards (or work expectations) are PII when they are so intertwined with performance appraisals that their disclosure would reveal an individual's performance appraisal;
- Financial information associated with an individual;
- Credit card numbers;
- Bank account numbers; and
- Security clearance history or related information (not including actual clearances held).

E. FOAS AND FOA MODIFICATIONS

FOAs are posted on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/), Grants.gov (http://www.grants.gov/), and FedConnect (https://www.fedconnect.net/FedConnect/). Any modifications to the FOA are also posted to these websites. You can receive an e-mail when a modification is posted by registering with FedConnect as an interested party for this FOA. It is recommended that you register as soon as possible after release of the FOA to ensure that you receive timely notice of any modifications or other announcements. More information is available at https://www.fedconnect.net.

F. OBLIGATION OF PUBLIC FUNDS

The Contracting Officer is the only individual who can make awards on behalf of ARPA-E or obligate ARPA-E to the expenditure of public funds. A commitment or obligation by any individual other than the Contracting Officer, either explicit or implied, is invalid.

ARPA-E awards may not be transferred, assigned, or assumed without the prior written consent of a Contracting Officer.

G. REQUIREMENT FOR FULL AND COMPLETE DISCLOSURE

Applicants are required to make a full and complete disclosure of the information requested in the Business Assurances & Disclosures Form. Disclosure of the requested information is mandatory. Any failure to make a full and complete disclosure of the requested information may result in:

- The rejection of a Concept Paper, Full Application, and/or Reply to Reviewer Comments;
- The termination of award negotiations;
- The modification, suspension, and/or termination of a funding agreement;
- The initiation of debarment proceedings, debarment, and/or a declaration of ineligibility for receipt of Federal contracts, subcontracts, and financial assistance and benefits; and
- Civil and/or criminal penalties.

H. RETENTION OF SUBMISSIONS

ARPA-E expects to retain copies of all Concept Papers, Full Applications, Replies to Reviewer Comments, and other submissions. No submissions will be returned. By applying to ARPA-E for funding, Applicants consent to ARPA-E's retention of their submissions.

I. MARKING OF CONFIDENTIAL INFORMATION

ARPA-E will use data and other information contained in Concept Papers, Full Applications, and Replies to Reviewer Comments strictly for evaluation purposes.

Concept Papers, Full Applications, Replies to Reviewer Comments, and other submissions containing confidential, proprietary, or privileged information must be marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Government is not liable for the disclosure or use of unmarked information, and may use or disclose such information for any purpose.

The cover sheet of the Concept Paper, Full Application, Reply to Reviewer Comments, or other submission must be marked as follows and identify the specific pages containing confidential, proprietary, or privileged information:

Notice of Restriction on Disclosure and Use of Data:

> Pages [___] of this document may contain confidential, proprietary, or privileged information that is exempt from public disclosure. Such information shall be used or disclosed only for evaluation purposes or in accordance with a financial assistance or loan agreement between the submitter and the Government. The Government may use or disclose any information that is not appropriately marked or otherwise restricted, regardless of source.

The header and footer of every page that contains confidential, proprietary, or privileged information must be marked as follows: "Contains Confidential, Proprietary, or Privileged Information Exempt from Public Disclosure." In addition, every line and paragraph containing proprietary, privileged, or trade secret information must be clearly marked with double brackets or highlighting.

J. COMPLIANCE AUDIT REQUIREMENT

A prime recipient organized as a for-profit entity expending $750,000 or more of DOE funds in the entity's fiscal year (including funds expended as a Subrecipient) must have an annual compliance audit performed at the completion of its fiscal year. For additional information, refer to Subpart F of: (i) 2 C.F.R. Part 200, and (ii) 2 C.F.R. Part 910.

If an educational institution, non-profit organization, or state/local government is either a Prime Recipient or a Subrecipient, and has expended $750,000 or more of Federal funds in the entity's fiscal year, the entity must have an annual compliance audit performed at the completion of its fiscal year. For additional information refer to Subpart F of 2 C.F.R. Part 200.

IX. GLOSSARY

Ancillary Services (AS): The services required to ensure synchronized and stable grid operations as well as reliable delivery of power from generators to end consumers. These may include products to support frequency control, voltage control, and contingency protection.

Applicant: The entity that submits the application to ARPA-E. In the case of a Project Team, the Applicant is the lead organization listed on the application.

Application: The entire submission received by ARPA-E, including the Concept Paper, Full Application, and Reply to Reviewer Comments.

ARPA-E: is the Advanced Research Projects Agency – Energy, an agency of the U.S. Department of Energy.

Asset Offer: Amount of energy or ancillary service products and associated price an asset owner submits as available to an ISO, RTO, or other power sector entity.

Bulk Renewables: Large-scale renewable energy facilities, owned and operated by a utility or independent power producer. Examples may include utility-scale solar farms, wind farms, hydro power, or other sources of renewable energy.

CEII Data: Critical Energy Infrastructure Information (CEII), as defined by the Federal Energy Regulatory Commission (FERC). Protected data of power plants and grid assets that could be misused to plan an attack on critical infrastructure or reveal strategic information of grid or plant operations.

Cleared Offer: Amount of offered energy or ancillary service products cleared by a market operator. This is based upon the energy or ancillary service offer the asset owner submits and is typically a product of grid management software (and operator input).

Conditional Value at Risk (CVaR): Expected shortfall given losses exceed a specified amount. Also known as tail risk.

Conventional Grid Resources: Traditional thermal and hydro generation technologies including, but not limited to: coal, gas, nuclear, and hydro. A common characteristic of most of these technologies is that they are mid to large in size and are controllable through a setpoint.

Cost Sharing: Means the portion of project costs not paid by Federal funds (unless otherwise authorized by Federal statue). Refer to 2 C.F.R. § 200.29.

Counterparty Risk: The likelihood and impact that one of the entities involved in a transaction may fail to fulfill their obligations. Counterparty risk is similar to delivery risk except that it includes the risk associated to *some other entity* in a multi-party contractual agreement defaulting on contractual obligations.

Curtailment: The amount of energy that was available but not utilized.

Deliverable: A deliverable is the quantifiable goods or services that will be provided upon the successful completion of a project task or sub-task.

Delivery Risk: The likelihood and impact as to whether an asset delivers on its operational obligations.

Direct Current Optimal Power Flow (DCOPF): A direct current optimal power flow (DCOPF) is an extension of economic dispatch by including transmission limitations based on a linear approximation of the non-convex power flow (network flow) equations.

Dispatchable Resource: Resources that have a firm capacity and (almost) full ability to control the production of their plant, given a controllable fuel source.

Distributed Energy Resources (DER): Distributed, grid-edge resources including, but not limited to, small-scale renewable energy facilities (e.g., rooftop solar), distributed storage, electric vehicles, demand response, flexible demand, deferrable demand, distributed direct load control, and smart home electric appliances/devices.

Distributed Energy Resource (DER) Aggregator: Entity that combines and manages local distributed energy resource capabilities into an offer that another entity (e.g., utility, ISO, or RTO) can manage.

Distribution System Operator (DSO): Managers of electric distribution systems (typically low and medium voltage).

DOE: U.S. Department of Energy.

DOE/NNSA: U.S. Department of Energy/National Nuclear Security Administration

Economic Dispatch: An operational plan or schedule to operate generation assets (while acknowledging their characteristics and limitations), based on defined dispatch setpoints, to economically satisfy demand.

Efficient Frontier: Boundary derived representing the Pareto efficient combinations of various assets based on expected return versus risk.

Energy Management System (EMS): Operators use these computer decision-making tools to monitor, control, and optimize power system operations.

FFRDCs: Federally Funded Research and Development Centers.

FOA: Funding Opportunity Announcement.

Firm Product: Energy or ancillary service products that are obligated to be delivered.

Flexible Loads: Energy demand that can be controlled by grid operators and therefore is consider a dispatchable grid asset.

GOCOs: U.S. Government Owned, Contractor Operated laboratories.

GOGOs: U.S. Government Owned, Government Operated laboratories.

HPC: High-Performance Computing.

Independent System Operators (ISO): Independent organizations created from FERC Orders 888 and 889, which oversee grid operations to maintain reliable and equitable access to transmission within their jurisdictions.

Information Ratio: A variant of the Sharpe Ratio indicating the relative return of a portfolio as compared to a benchmark or index, adjusting for portfolio risk.

Intermittent Resources: See stochastic resources.

Key Participant: Any individual who would contribute in a substantive, measurable way to the execution of the proposed project.

Load: Electricity demand.

Load serving entity (LSE): Utility, electric company, or aggregator that is responsible for providing electricity to customers.

Locational Marginal Price (LMP): The price of electric energy, $/MWh, which is based on the incremental cost to deliver a MWh to a particular location in the power grid. More precisely, an LMP is the dual variable corresponding to the node balance equation in the primal formulation of the market auction model; LMPs can also be determined based on three components: (i) the energy component, (ii) the marginal loss component, and (iii) the marginal congestion component.

Look-Ahead Decision Making Time-Stage: Points in time ahead of real-time operations at which procurement decisions must be made. Examples of conventional look-ahead decision-making time stages include: day-ahead, intra-day, hour-ahead, and 15-minutes ahead.

Loss of Load Expectation: The expected number of days per year during which the system demand will exceed the available generation capacity.

Loss of Load Probability: The probability that the system demand will exceed the available generation capacity during a given time period.

Market Management System (MMS): Suite of tools used to communicate between an ISO/RTO and market participants, determine commitment and dispatch of available resources at the ISO/RTO level, and develop market prices for energy and ancillary services.

Milestone: A milestone is the tangible, observable measurement that will be provided upon the successful completion of a project task or sub-task.

MWs: Megawatts. A common unit of measure for electric power.

N-1 Reliability: NERC requirement that no involuntary loss of load should occur given the loss of any single bulk grid asset (transmission or generation asset).

Net Load: Electricity demand minus renewable resource supply.

Non-Firm Product: Energy or ancillary service products whose availability is not guaranteed and whose delivery is governed by a set contractual agreement and established set of conditions.

North American Electric Reliability Corporation (NERC): Not-for-profit international regulatory authority whose mission is to assure the effective and efficient reduction of risks to the reliability and security of the electric grid.[123]

Obligation: Contractual obligation, related to a grid product or service, that a power sector entity must provide over a specified time period.

Offer stack: Price-quantity pairs of energy and ancillary services offered by an asset owner.

Pareto-Dominant Solution: A solution from which it is impossible to find an improved position for any individual entity while maintaining the same benefit (or better) for the remaining entities. The set of Pareto dominant solutions forms an efficient frontier which represents the best possible outcomes at different tradeoffs.

Prime Recipient: The signatory to the funding agreement with ARPA-E.

[123] NERC, "About NERC." Online. Available: https://www.nerc.com/AboutNERC/Pages/default.aspx

PI: Principal Investigator.

Project Team: A Project Team consists of the Prime Recipient, Subrecipients, and others performing any of the research and development work under an ARPA-E funding agreement, whether or not costs of performing the research and development work are being reimbursed under any agreement.

R&D: Research and development.

R&D&D: Research, development, and demonstration.

Regional Transmission Organizations (RTO): Organizations created from FERC Order 2000 to coordinate, control, and monitor multi-state regions of the North American grid.

Reliability: Reliability is used throughout this FOA in the manner in which it is used within the electric power sector and reflects upon the various reliability requirements of NERC.

Reserve Requirement: Excess capacity (online or offline) that is required to maintain reliable and stable operation of the electric grid. The reserve requirement is typically calculated based on forecasted peak demand and estimated available capacity.

Resource Variability: Foreseen variations in resource availability or resource production.

Resource Uncertainty: Unforeseen deviations from expected resource availability.

Robustness: The ability for an optimization algorithm to find a feasible solution for a variety of operational cases/scenarios.

Security-Constrained Economic Dispatch (SCED): A security-constrained economic dispatch (SCED) formulation is a particular type of DCOPF problem that contains security criteria. SCED formulations often include reserve requirements and network flow limitations (transmission limitations) for both pre-contingency and post-contingency (N-1 transmission contingencies) operational states. SCED formulations vary as to whether they include a single-period or a multi-period formulation; multi-period formulations then introduce inter-temporal constraints such as ramp rates. SCED formulations are often linear programs based on the DCOPF formulation, a piecewise linear objective function, and linear constraints governing generators, reserves, and the network flow formulation. SCED formulations are often used within real-time electric energy spot markets.

Security-Constrained Optimal Power Flow (SCOPF): Security-constrained optimal power flow (SCOPF) formulations are often similar to SCED formulations with the exception that they often contain a full ac optimal power flow (ACOPF) formulation rather than relying on the DCOPF linear approximation. SCOPF formulations are, thus, nonlinear and non-convex optimization

problems. SCOPF formulations also often include more advanced features regarding transmission asset modeling, e.g., the introduction of control variables for various transmission assets like transformers.

Security-Constrained Unit Commitment (SCUC): Security-constrained unit commitment (SCUC) is a particular type of unit commitment model with added constraints to capture security criteria. SCUC formulations are extensions of SCED formulations by introducing or extending the multi-period formulation, more advanced modeling of generators (commitment, no-load cost, startup costs, and inter-temporal constraints), and may also include more advanced modeling of reserve requirements, transmission contingencies, and generator contingencies. SCUC formulations are typically represented by a mixed-integer linear program formulation Day-ahead forward electric energy markets employ variations of SCUC formulations.

Sharpe Ratio: A metric developed by William Sharpe, which is used to evaluate a portfolio's risk adjusted return. It captures the expected return of a portfolio, relative to the risk free return, divided by the standard deviation of the excess return of the portfolio (portfolio's return minus the risk free return).

Standalone Applicant: An Applicant that applies for funding on its own, not as part of a Project Team.

Subject Invention: Any invention conceived or first actually reduced to practice under an ARPA-E funding agreement.

Setpoint: A desired or control level for power plant output set either locally or remotely.

Stochastic Resources: Grid assets whose normal operation contains some degree of random or probabilistic power production or availability (beyond a low chance of a critical shutdown or plant trip, i.e., a contingency); resources that are variable and uncertain in nature. Also referred to as Intermittent Resources, Variable Energy Resources (VERs), or Variable Generation (VG).

Storage: A device or facility with the ability to temporarily store and then release energy to/from the grid. Technologies may include electric batteries, flywheels, compressed air facilities, pumped hydro storage, and others.

Task: A task is an operation or segment of the work plan that requires both effort and resources. Each task (or sub-task) is connected to the overall objective of the project, via the achievement of a milestone or a deliverable.

Team Diversity: Diversity in regards to technical knowledge and experience, relevant to PERFORM.

Technology-to-Market (T2M): See Section I.D.5 of the FOA for more information.

Total Project Cost: The sum of the Prime Recipient share and the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs, FFRDCs, and GOCOs.

Transactive Energy System: "A system of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter."[124]

TT&O: Technology Transfer and Outreach. (See Section IV.G.8 of the FOA for more information).

Uncertainty: the state of being uncertain, not known or definite.

Unit Commitment (UC): The mathematical problem to determine the status (commitment: on/off) of generation assets (units); unit commitment often determines the optimal commitment and dispatch setpoints for a fleet of generators.

Value at Risk: A measure of how much a portfolio may lose over a specified period of time, given a specified probability of loss (i.e., 5% VaR).

Variable Energy Resources (VER): See stochastic resources.

Variable Generation (VG): See stochastic resources.

Vertically Integrated Utilities: Utilities that own all levels of the electricity supply chain: generation, transmission, distribution, and the right to serve customers. Vertically integrated utilities exist in states that still operate and administer regulated markets.

Virtual Bidders: An entity (i.e., a speculator) that holds no physical position to match its obligation within the electric energy markets. Speculation occurs in regards to the spread between forward and spot prices and in the financial transmission rights markets.

[124] National Institute of Standard and Technology, "Transactive Energy: An Overview," Online. Available: https://www.nist.gov/engineering-laboratory/smart-grid/transactive-energy-overview