FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

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

Generating Realistic Information for Development of Distribution and Transmission Algorithms (GRID DATA)

Announcement Type: ~~Initial Announcement~~ Modification 01
Funding Opportunity No. DE-FOA-0001357
CFDA Number 81.135

FOA Issue Date:	June 10, 2015
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, July 13, 2015
Submission Deadline for Concept Papers:	5 PM ET, July 20, 2015
Second Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, TBD
Submission Deadline for Full Applications:	5 PM 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 $7 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 $7 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.
- ARPA-E will not review or consider noncompliant or nonresponsive applications. For detailed guidance on compliance and responsiveness criteria, see Sections III.C.1 and III.C.2 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).

MODIFICATIONS

All modifications to the Funding Opportunity Announcement (FOA) are highlighted in yellow in the body of the FOA.

Mod. No.	Date	Description of Modifications
01	7/13/2015	• Deleted erroneous reference in Section I.C of the FOA. • Clarified Concept Paper Innovation and Impact section in Section IV.C.1.b of the FOA. • Clarified Concept Paper Review Criteria in Section V.A.1 of the FOA. • Updated Concept Paper template to reflect clarification made to Innovation and Impact Section of Concept Paper content requirements.

TABLE OF CONTENTS

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	5 PM ET, July 20, 2015
Full Application	[TO BE INSERTED BY FOA MODIFICATION IN SEPTEMBER 2015]	Mandatory	IV.D	5 PM ET, TBD
Reply to Reviewer Comments	[TO BE INSERTED BY FOA MODIFICATION IN SEPTEMBER 2015]	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 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 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 "systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met" and defines "development" as the "systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements."[1] Applicants interested in receiving financial assistance for basic research should contact the DOE's Office of Science (http://science.energy.gov/). Similarly, projects focused on the improvement of existing technology platforms along defined roadmaps may be appropriate for support through the DOE offices such as: 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://nuclear.energy.gov/), and the Office of Electricity Delivery and Energy Reliability (http://energy.gov/oe/office-electricity-delivery-and-energy-reliability).

B. PROGRAM OVERVIEW

This program seeks to fund the development of large-scale, realistic, validated, and open-access electric power system network models (transmission and distribution) that have the detail required for the successful development and testing of transformational power system optimization and control algorithms. In conjunction, the program will also fund the creation of an open-access, self-sustaining repository for the storage, annotation, and curation of these power systems models, as well as others generated by the community. These advancements would promise to substantially reduce the barriers to the testing and adoption of new strategies for grid optimization and control, including new Optimal Power Flow (OPF) algorithms. The public availability provided by open-access to these models and the repository is required for more accurate and comprehensive evaluation of emerging grid operation optimization algorithms, including optimization competitions, as have been successfully employed in many other optimization-dependent fields and industries.[2,3,4] These new optimization algorithms promise to enable increased grid flexibility, reliability and safety, while also significantly increasing economic and energy security, energy efficiency and substantially

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[1] OMB Circular A-11 (http://www.whitehouse.gov/sites/default/files/omb/assets/a11_current_year/a11_2014.pdf), Section 84, p. 8.

[2] McKinsey & Company, "And the Winner is…Capturing the Promise of Philanthropic Prizes," July 2009, http://mckinseyonsociety.com/capturing-the-promise-of-philanthropic-prizes/

[3] T. Hong, P. Pinson and S. Fan, "Global Energy Forecasting Competition 2012," *International Journal of Forecasting,* vol. 30, no. 2, pp. 357-363, April-June 2014, doi: 10.1016/j.ijforecast.2013.07.001

[4] A. Ostfeld, "The Battle of the Water Sensor Networks (BWSN): A Design Challenge for Engineers and Algorithms," *J. Water Resour. Plann. Manage.,* vol. 134, no. 6, pp. 556-568, November 2008, doi: 10.1061/(ASCE)0733-9496(2008)134:6(556)

reducing the costs of integrating variable renewable generation technologies into the electric power system in the United States.

C. BACKGROUND

Since the dawn of the age of electrification, electric power system designers and operators have been required to manage (due to the absence of large-scale cost effective electricity storage) the real-time matching of instantaneous electricity generation and demand. Achieving a continuous match between supply and demand requires utilities, grid operators, and other stakeholders to use a variety of sophisticated optimization algorithms operating across a wide range of timescales. These include tools for determining optimal transmission line and power plant siting and construction, maintenance scheduling, and long-term, day ahead, hour ahead, and five minute electricity dispatch rates.

A number of emerging trends, including the integration of high penetrations of renewable electricity generation, changing electricity demand patterns, and the improving cost effectiveness of distributed energy resources (including storage), will substantially alter the operation and control of electric grids over the next several decades. For example, more active optimization and control of electric distribution systems are likely to be required, including the near real-time estimation, optimization, and control of distribution network power flows. The expected growth in system complexity will require the development of substantially improved software optimization and control tools to assist grid operators, and deliver the societal benefits of improved grid performance. While many new grid optimization methods have been proposed in the research community in recent years, the research community and industry currently lack high-fidelity, public, large-scale power system models for early-stage evaluation and investigation of these new tools. New power system models that realistically describe potential future grid characteristics, including high penetrations of renewable and distributed generation, are also needed to allow for a full assessment of the potential benefits associated with new optimization approaches. The absence of these models is substantially slowing the development and adoption of these new optimization and control strategies by industry.

This section is organized as follows. Section I.C.1 introduces the Optimal Power Flow (OPF) problem, briefly describes the benefits that could be offered by improved OPF algorithms, and introduces some of the new methods that have been recently proposed. Section I.C.2 describes the characteristics and limitations of existing publically available power system R&D models. ~~Section I.C.3 briefly introduces some of the methods that could be used to create new power system models under this program.~~

1. OPPORTUNITIES IN GRID OPTIMIZATION

The OPF problem is the central optimization challenge underlying the entire suite of grid planning and operations tools. Simply stated, the OPF problem is that of finding the optimal dispatch settings for power generation, flexible customer demand, energy storage, and grid control equipment that maximize one or more grid objectives.[5,6,7] In order to be deployable, the recommended settings must satisfy all physical constraints of electric power infrastructure and applicable operating standards (including, for example, minimum/maximum voltages at each bus, minimum/maximum power generation from all generators, thermal transmission constraints, and constraints related to the security of the system when contingencies occur). For a more complete history and formal problem formulation, we refer the reader to a history authored by the Federal Energy Regulatory Commission (FERC).[8]

Improved OPF algorithms could yield significant benefits. Recent studies have suggested that enhanced OPF algorithms could offer as much as 5-10% reductions in total U.S. electricity cost due to the alleviation of grid congestion (corresponding to $6-$19B saved depending on energy prices).[9, 10] In addition to monetary savings, improved optimization algorithms are likely to help ensure reliable system operations as power flows become more dynamic in the future.[11] To fully realize the potential benefits of renewable generation as well as recently developed electric transmission power-flow controllers, distribution automation technologies, distributed generation, energy storage, and demand-side control will require more complex (and fundamentally non-linear) grid operation optimization and dispatch algorithms. Further, as the number of controllable resources connected to electric power systems (at both transmission and distribution voltages) grows substantially, distributed or decentralized versions of OPF algorithms could become increasingly important. The cost effective and reliable operation of future renewable-intensive electric power systems is likely to rely more on algorithm outputs and decision support tools and less on operator intuition.

The core OPF solution methods predominantly used in industry today were designed in an era when computers were far less capable and more costly than they are currently and formal

[5] J. Carpentier, "Contribution to the economic dispatch problem," Bulletin de la Société Française des Électriciens, ser. 8, vol. 3, pp. 431-447, 1962

[6] H.W. Dommel and W.F. Tinney, "Optimal power flow solutions," IEEE Transactions on Power Apparatus and Systems, vol. 87, no. 10, pp 1866-1876, October 1968

[7] There are a variety of specific applications for OPF. The specific objective function and most important constraints can vary widely. In many applications, where demand is considered fixed, the objective is considered to be minimization of total generation cost. In the context of electric distribution systems, this problem is often focused on minimization of system losses.

[8] M. B. Cain, R. P. O'Neill, and A. Castillo, "History of optimal power flow and formulations," Federal Energy Regulatory Commission, Washington, DC, August 2013, http://www.ferc.gov/industries/electric/indus-act/market-planning/opf-papers/acopf-1-history-formulation-testing.pdf

[9] M. Ilic, "Modeling of hardware and systems related transmission limits: the use of AC OPF for relaxing transmission limits to enhance reliability and efficiency," Presentation at FERC Staff Technical Conference on Increasing Real-Time and Day-Ahead Market Efficiency through Improved Software, Washington, DC, June 2013, http://www.ferc.gov/CalendarFiles/20140411131533-T2-B%20-%20Ilic.pdf

[10] M. B. Cain, R. P. O'Neill, and A. Castillo, "History of optimal power flow and formulations," Federal Energy Regulatory Commission, Washington, DC, August 2013, http://www.ferc.gov/industries/electric/indus-act/market-planning/opf-papers/acopf-1-history-formulation-testing.pdf

[11] GE Energy, "Western wind and solar integration study," National Renewable Energy Laboratory, Technical Report No. NREL/SR-550-47434, May 2010, http://www.nrel.gov/docs/fy10osti/47434.pdf

general purpose optimization solvers were in their infancy. Therefore grid operators and OPF vendors were required to make a range of simplifying assumptions, most commonly a set of linearizing assumptions which ignore voltage and reactive power optimization referred to as "DC-OPF."[12] Many proprietary variations on these algorithms have been developed over the past several decades by vendors. Despite improvements in DC-OPF formulations and solvers, there are no tools currently in widespread use in industry that use the full AC power flow equations (without linearizing assumptions) and simultaneously co-optimize both real and reactive power generation (known as "AC-OPF"). The OPF tools in use today often result in conservative solutions that additionally must be iteratively checked for physical feasibility of solutions before implementation. When non-physical solutions are found, the OPF algorithm must be run again with a modified set of constraints to generate a new solution.

Dramatic improvements in computational power and advancements in optimization solvers in recent years have prompted research on new approaches to grid operation and new approaches to solving OPF and other grid optimization problems.[13] Since the turn of the millennium, the performance of the most powerful supercomputers has increased by almost four orders of magnitude (while the cost per computational step has dropped by approximately the same factor).[14,15] Improvements in optimization and search methods have evolved similarly, especially those related to Mixed Integer Programming (MIP) and heuristic-based optimization methods. The relative speed of commercial general-purpose solvers such as CPLEX and GUROBI has also increased by over three orders of magnitude on fixed hardware.[16,17] "Cloud computing as a service," which can be used to leverage many of these gains, has also started to gain more widespread interest within the power system engineering community.[18]

In tandem, many new approaches to solving OPF problems have been proposed in the literature in recent years; it appears increasingly likely that scalable and more accurate approaches to solving the full AC-OPF may be within sight. For example, fast and accurate convex relaxations have been formulated where the global minimum can be found efficiently using semi-definite and second order cone programming (under certain system assumptions and conditions).[19,20,21,22] Often it can be shown that these relaxations give global solutions to

[12] A. J. Wood, B. F. Wollenberg, and G. Sheblé, *Power generation, operation, and control*, 3rd ed. Hoboken, NJ: John Wiley & Sons, 2013

[13] P. Panciatici et al. "Advanced optimization methods for power systems." *Proceedings of the 18th Power System Computation Conference*, Wroclaw, Poland, August 2014, pp. 1-18, doi: 10.1109/PSCC.2014.7038504

[14] http://www.top500.org/

[15] https://intelligence.org/2014/05/12/exponential-and-non-exponential/

[16] http://www.gurobi.com

[17] T. Koch et al., "MIPLIB 2010," *Mathematical Programming Computation*, vol. 3, no. 2, pp. 103-163, June 2011, doi: 10.1007/s12532-011-0025-9

[18] J. Goldis et al., "Use of Cloud Computing in Power Market Simulations" Presentation at FERC Staff Technical Conference on Increasing Real-Time and Day-Ahead Market Efficiency through Improved Software, Washington, DC, June 2014

[19] S. Low, "Convex relaxation of optimal power flow, Part I: Formulations and equivalence," *IEEE Transactions on Control of Network Systems*, vol. 1, no. 1, pp. 15-27, March 2014, doi: 10.1109/TCNS.2014.2309732

[20] S. Low, "Convex relaxation of optimal power flow, Part II: Exactness," *IEEE Transactions on Control of Network Systems*, vol. 1, no. 2, pp. 177-189, May 2014, doi: 10.1109/TCNS.2014.2323634

the original, non-convex problem.[23,24] Distributed and parallelizable OPF algorithms have also been proposed, for example, using the Alternating Direction Method of Multipliers (ADMM), suggesting that AC-OPF can leverage more advanced computational hardware.[25,26,27] These same algorithms could enable the real-time coordination and/or optimization of large numbers of distributed energy resources. Finally, many unique methodologies using techniques such as genetic algorithms, neural networks, fuzzy algorithms and holomorphic embedding have also emerged, claiming, in many cases, to revolutionize solution methods for OPF. [28,29]

The end-result has been numerous research projects and papers on improved grid optimization strategies and many new algorithms that may be able to significantly impact grid operation and control. However most of these advances have not yet moved past the early research stage. One critical roadblock to their adoption has been the lack of publicly available, large-scale, and high-fidelity power system network models on which to test new solution methods and/or perform valid comparisons. Most recent grid operation optimization advances remain non-validated on realistic, large-scale test models and their operational limits also remain largely unexplored.

2. EXISTING R&D POWER SYSTEM MODELS

The value of benchmark systems for the comparison of algorithms for optimizing grid operations has long been recognized.[30] There exist a number of standard power system network models that have been used extensively (mostly for early development of new transmission system optimization algorithms). The transmission power system models currently

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[21] R. Madani, S. Sojoudi, and J. Lavaei, "Convex relaxation for optimal power flow problem: Mesh networks," *IEEE Transactions on Power Systems*, vol. 30, no. 1, pp. 199-211, May 2014, doi: 10.1109/TPWRS.2014.2322051
[22] D. Molzahn et al., "Implementation of a large-scale optimal power flow solver based on semidefinite programming," *IEEE Transactions on Power Systems*, vol. 28, no. 4, pp. 3987-3998, April 2013, doi: 10.1109/TPWRS.2013.2258044
[23] J. Lavaei and S. Low, "Zero duality gap in optimal power flow problem," *IEEE Transactions on Power Systems*, vol. 27, no. 1, pp. 92-107, August 2011, doi: 10.1109/TPWRS.2011.2160974
[24] L. Gan et al., "Exact convex relaxation of optimal power flow in radial networks," *IEEE Transactions on Automatic Control*, vol. 60, no. 1, pp. 72-87, June 2014, doi: 10.1109/TAC.2014.2332712
[25] A. Sun, D.T. Phan, and S. Ghosh, "Fully decentralized AC optimal power flow algorithms," Presentation at IEEE Power and Energy Society General Meeting, Vancouver, BC, Canada, July 2013, doi: 10.1109/PESMG.2013.6672864
[26] S. Magnússon, P. Weeraddana, and C. Fischione, "A distributed approach for the optimal power flow problem based on ADMM and sequential convex approximations," *arXiv preprint* arXiv:1401.4621, January 2014
[27] B. H. Kim and R. Baldick, "A comparison of distributed optimal power flow algorithms." *IEEE Transactions on Power Systems*, vol. 15, no. 2, pp. 599-604, May 2000, doi: 10.1109/59.867147
[28] X. F. Wang, Y. Song, and M. Irving, *Modern power systems analysis*, New York, NY: Springer Science & Business Media, 2008
[29] A. Trias, "The holomorphic embedding load flow method," Presentation at IEEE Power and Energy Society General Meeting, San Diego, CA, July 2012, doi: 10.1109/PESGM.2012.6344759
[30] P. Wong et al., "The IEEE Reliability Test System-1996. A report prepared by the Reliability Test System Task Force of the Application of Probability Methods Subcommittee," *IEEE Transactions on Power Systems,* vol. 14, no. 3, pp. 1010-1020, August 1999, doi: 10.1109/59.780914

available comprise a total of 30-40 unique topologies. An illustration of one such topology, corresponding to the widely used IEEE 118 bus system, is illustrated in Figure 1. These are available from different sources, including a University of Washington test archive, the Edinburgh Test Case Archive, and as part of the popular MATPOWER toolkit.[31,32,33] Similarly, there are a relatively small number of existing distribution system models and several different distribution test case archives.[34,35,36] These benchmark systems were originally created with various goals in mind. For example, some of the systems were developed primarily for teaching purposes.[37] For some of the benchmark models, the data (many of which date back several decades) were designed with the goal of testing simple AC power flows, and were not originally intended for more complicated tasks such as the investigation and/or benchmarking of AC-OPF, unit commitment, optimal transmission line switching, stochastic network planning, load forecasting, distributed energy resource coordination, and other emerging problems of interest to the optimization, grid reliability, and regulatory communities.

[31] R. D. Christie (August 1999), *Power Systems Test Case Archive* [Online], Available: http://www.ee.washington.edu/research/pstca/
[32] W. A. Bukhsh and Ken McKinnon (April 2013) *Network data of real transmission networks* [Online], Available: http://www.maths.ed.ac.uk/optenergy/NetworkData/
[33] R.D. Zimmerman, C.E. Murillo- Sánchez, and R.J. Thomas, "MATPOWER: Steady-State Operations, Planning, and Analysis Tools for Power Systems Research and Education," *IEEE Transactions on Power Systems*, vol. 26, no. 1, pp. 12 -19, February 2011, doi: 10.1109/TPWRS.2010.2051168
[34] R. Kavasseri and C. Ababei, *REDS: REpository of Distribution Systems* [Online], Available: http://www.dejazzer.com/reds.html
[35] Distribution Test Feeder Working Group, IEEE Power and Energy Society Distribution System Analysis Subcommittee (August 2013), *Distribution Test Feeders* [Online], Available: http://www.ewh.ieee.org/soc/pes/dsacom/testfeeders/index.html
[36] K.P. Schneider et al., "Modern Grid Initiative: Distribution Taxonomy Final Report," Pacific Northwest National Laboratory, November 2008, http://www.gridlabd.org/models/feeders/taxonomy_of_prototypical_feeders.pdf
[37] R. N. Allan et al., "A reliability test system for educational purposes-basic distribution system data and results," *IEEE Transactions on Power Systems*, vol. 6, no. 2, pp. 813-820, May 1991, doi: 10.1109/59.76730

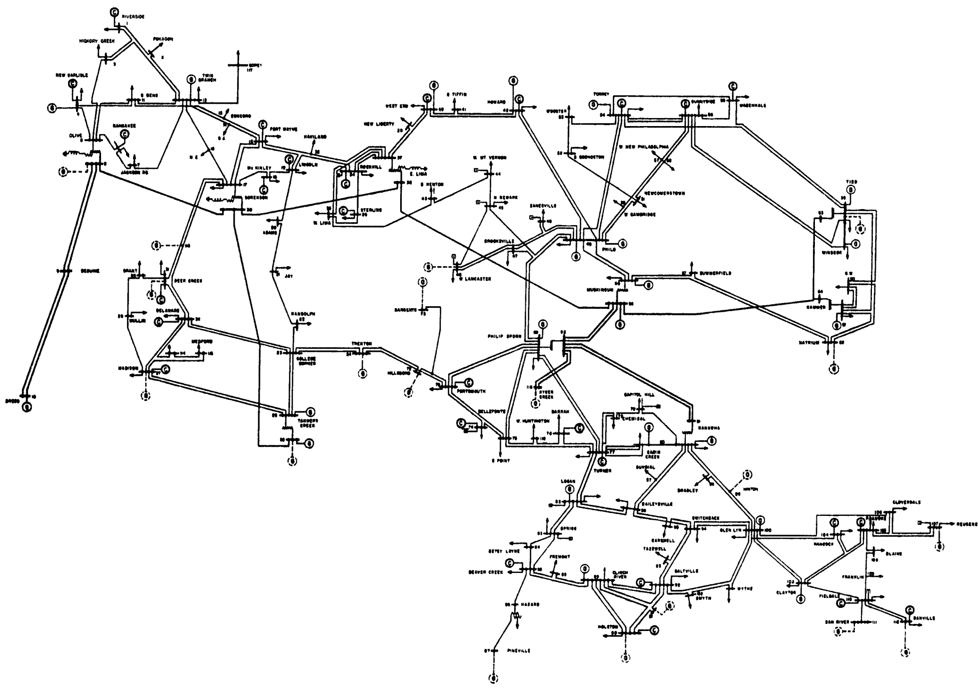

Figure 1: Illustration of the IEEE 118 Bus Test Case representing a portion of the American Electric Power System as of December 1962.

Though it is currently accepted practice, there are several problems with using these models to evaluate many of the emerging grid optimization algorithms. First, existing models are, in general, far smaller than the field operating systems that need to be optimized in many modern grid applications and do not generally allow for thorough testing of the scalability of grid optimization algorithms. Small-scale models also cannot generally be used to estimate the benefits offered by new grid optimization approaches as they neither reflect the scale of real networks, nor the physical coupling existing between different parts of the grid. Most existing transmission system models consist of fewer than 1,000 electrical buses and few generators; the IEEE 118 bus model, for example, only has 19 generators. Modern transmission system algorithms must optimize systems ranging from 5,000 to 50,000 buses, with hundreds to thousands of generators. In recent years, a few new models have gained traction in the research community, including several Polish power system cases that are included within the MATPOWER package and, more recently, a 9,421 bus case that was constructed as part of the Pan European Grid Advanced Simulation and State Estimation (PEGASE) project.[38,39] Distribution system models are also lacking; most commonly used test feeders have fewer than 1,000 nodes and have few defined, independent scenarios. While the recently developed IEEE

[38] http://www.fp7-pegase.com/

[39] S. Fliscounakis et al., "Contingency ranking with respect to overloads in very large power systems taking into account uncertainty, preventive, and corrective actions," *IEEE Transactions on Power Systems*, vol. 28, no. 4, pp. 4909-4917, November 2013, doi: 10.1109/TPWRS.2013.2251015

8,500 node case represents a challenging voltage control case, most existing distribution system network models were not designed to challenge distribution system OPF algorithms.[40]

Existing publically available power system models also generally have few different loading conditions (scenarios) explicitly defined. The changing relative magnitude of electricity demand and/or distributed generation at various system locations is not accurately captured in most models. The small number of scenarios available with most existing models does not adequately address the scale at which industry requires OPF to be solved. As an example, solving an OPF problem on a one hour-ahead timescale requires finding solutions for 8,760 different scenarios ***for a single electrical network every year***. It is also critically important to test the robustness of new OPF solutions and the ability to investigate "corner cases," such as degenerate operating conditions that result in a large family of equivalent optima. Unfortunately, publicly available power system models typically do not have a sufficient number of scenarios to fully test the robustness of new algorithms.

Existing R&D power systems models are also incomplete. OPF problems must include a minimum set of line thermal limits, generator cost functions, and generator capacity information to be reflective of real-world optimization challenges. As has been pointed out, many of the models in common use today are missing this critical data.[41] For research purposes, this data is often generated artificially and arbitrarily, in ways that poorly represent real, modern transmission systems.[42,43,44] For example, in some models, many line limits are set to large values which never bind and generator cost curves are often assigned identical quadratic functions (introducing an unrealistic amount of symmetry and degeneracy into the problem). It is clear, however, that the way in which these constraints are added can result in substantially different solutions; in particular adding constraints in an unprincipled way can easily lead to infeasibility and lack of convergence. [45]

Many of the available power system models have also been shown to poorly represent real system characteristics. It has been pointed out, for example, that many of the existing IEEE transmission test systems have low base voltages and an overabundance of voltage control

[40] R.F. Arritt and R.C. Dugan, "The IEEE 8500-node test feeder," *Proceedings of the 2010 IEEE PES Transmission and Distribution Exposition*, New Orleans, LA, USA, April 2010, pp. 1-6, doi: 10.1109/TDC.2010.5484381
[41] C. Coffrin, D. Gordon, and P. Scott., "Nesta, the NICTA energy system test case archive," *arXiv preprint arXiv:*1411.0359 (2014)
[42] W.A. Bukhsh et al., "Local solutions of the optimal power flow problem," *IEEE Transactions on Power Systems*, vol. 28, no. 4, pp. 4780-4788, August 2013, doi: 10.1109/TPWRS.2013.2274577
[43] S. Dutta and S. P. Singh, "Optimal rescheduling of generators for congestion management based on particle swarm optimization," *IEEE Transactions on Power Systems*, vol. 23, no. 4, pp. 1560-1569, November 2008, doi: 10.1109/TPWRS.2008.922647
[44] F. Gubina and B. Strmcnik, "Voltage collapse proximity index determination using voltage phasors approach," *IEEE Transactions on Power Systems*, vol. 10, no. 2, pp. 788-794, May 1995, doi: 10.1109/59.387918
[45] P. A. Lipka, R. P. O'Neill, and S. Oren, "Developing line current magnitude constraints for IEEE test problems," Staff Technical Paper, April 2013, http://www. ferc. gov/industries/electric/indus-act/market-planning/opf-papers/acopf-7-lineconstraints.pdf

capacity compared to modern transmission systems.[46] This can result in AC-OPF solutions that are physically not achievable or undesirable, such as unrealistically large voltage drops across some lines. Existing models also do not capture the full detail and control range of the grid today. Lists of contingencies, emergency (short term) equipment ratings, protection system details, generator ramp rates and real and reactive capability curves, transformer tap settings, capacitor bank locations and settings, phase shifting transformer characteristics, energy storage capacity, line switching capabilities, and flexible demand are more often than not omitted from publically available R&D power system models. Furthermore, most existing models use a bus-branch description that necessarily removes some system details, including, for example, substation circuit breaker topologies. The additional details included in node-breaker models are important for some emerging optimization algorithms such as those involving line switching or distribution system automatic reconfiguration. Security constraints and relative control priorities and costs are particularly poorly described in existing power system models.

As recently discussed,[47] many of the existing publically available power system models and recently proposed approaches to solving OPF problems also do not realistically reflect:

- the distinction between "soft" constraints (which can be violated at a difficult-to-quantify cost) and "hard" constraints, which must never be violated.
- priority levels for different types of control objectives (for example, prioritizing "cost free" controls not captured in the objective function); this is especially important when the full optimization problem is infeasible.
- other engineering-level objectives such as suppressing oscillations and penalizing too frequent control movements.

These control requirements or preferences are central to the design and testing of industrial tools and they often fundamentally impact the core formulation of OPF software. However, existing power system models simply do not provide sufficient information on these requirements. The important evolution of control variables and constraint functions during an OPF solution process (possibly in ways that cannot be formulated analytically) is, of course, very difficult to capture in a model.

Existing publically available power system models appear unrealistically easy to optimize. While the general ACOPF problem is mathematically NP hard,[48] finding near optimal solutions to many of the existing benchmark power system models has proven to be easier than experience with more realistic systems indicates. Fast AC heuristics have found OPF solutions

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[46] R. D. Christie (August 1999), *Power Systems Test Case Archive* [Online], Available: http://www.ee.washington.edu/research/pstca/

[47] B. Stott and O. Alsaç, "Optimal power flow–basic requirements for real-life problems and their solutions," *White Paper,* July 2012, http://www.ieee.hr/_download/repository/Stott-Alsac-OPF-White-Paper.pdf

[48] B. Alzalg et al., "A Computational Analysis of the Optimal Power Flow Problem," Institute for Mathematics and Its Applications, University of Minnesota, IMA Preprint Series #2396, May 2012, http://www.ima.umn.edu/preprints/pp2012/2396.pdf

that are <1% from the total cost global minimum for the vast majority of existing publically available power system models.[49] The lack of difficulty is likely to be due to the above factors, i.e. the lack of realism in the existing models. A recent effort to improve some of the most commonly used power system models by performing data mining on public datasets describing generation characteristics (to establish missing generator capacities) and by estimating the distributions of thermal line limits in real world power systems (to establish missing realistic line limits with the models). These modifications significantly increased the difficulty of solving OPF.[50]

Existing models also do not typically have sufficient detail related to emerging trends in power system infrastructure. For example, existing models typically have limited descriptions of solar and/or wind generation resources and do not adequately describe the correlation between generation located at various network locations. Most models also omit large penetrations of distributed generation such as rooftop photovoltaics, fuel cells, or small-scale engines. The development of GridLAB-D has recently provided the research community with new capabilities for the detailed analysis of electric distribution systems, including detailed descriptions of electrical loads in buildings.[51] However, most existing publically available distribution feeder models have limited details on flexible demand control and optimization characteristics. More detailed system models incorporating large penetrations of distributed generation are needed to comprehensively evaluate new, possibly more decentralized models for grid optimization and control.

Given the challenges described above, an obvious solution might be to perform research only on real information on power system networks provided by utility companies. Indeed, ARPA-E has had some recent success required this approach in other power systems optimization-related programs.[52] Demonstrating new algorithms on utility data is critical to gaining commercial traction, however, in these situations, research groups can only report results in aggregate form without detailed information about the power system or their optimization solutions. If new insights are discovered, they cannot be made public in any detailed way. Access to such models also requires non-trivial and lengthy Non-Disclosure Agreement and confidentiality approval processes to address proprietary, security, and privacy concerns. If these issues are surmounted, it is usually a challenge to clean and prepare the model information for simulations; research groups often spend more time cleaning and completing the model (which typically was never intended for early stage applied R&D) than developing and studying their new algorithms. Difficulty in obtaining realistic power system models for

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[49] C. Coffrin, D. Gordon, and P. Scott, "Nesta, the NICTA energy system test case archive," *arXiv preprint arXiv*:1411.0359 (2014)
[50] *Ibid.*
[51] http://www.gridlabd.org
[52] ARPA-E "Green Electricity Network Integration (GENI)" Funding Opportunity Announcement Number DE-FOA-0000473, April 2011, https://arpa-e-foa.energy.gov/Default.aspx?Archive=1#FoaId21311ad3-e25b-408d-8429-4c6efdd867a7

open research also substantially increases the barrier to entry for technical experts from other disciplines who have no previous power systems research experience.

The cumulative result of the lack of adequacy of existing publically available power system models is that recently proposed grid operation optimization approaches (including new OPF solution approaches) cannot be tested and verified openly and transparently; the early-stage applied research community has remained "siloed" with extremely limited standard benchmarking or comparison of results, and also largely disconnected from the industrial power systems engineering community. This is a particularly acute issue for researchers from other technical disciplines whose expertise may have value in application to power systems optimization. Given the dynamics, complexity, and uncertainty of emerging power systems, this broader research community could provide transformative opportunities for achieving timely and effective solutions.

D. TECHNICAL PROGRAM OBJECTIVES

ARPA-E seeks to fund innovative ideas for the creation of large-scale, realistic power system models (transmission, distribution, and hybrid models that include both transmission and distribution), validated by real data, and relevant for the testing and evaluation of emerging power system optimization algorithms. The models created under this program must be releasable to the public with no restrictions. Power system network models (section D.1) will be accompanied by a large number of detailed scenarios that represent specific operating points. These scenarios should correspond to the characteristics of the grid today as well as future (i.e. scenarios that reflect different load characteristics or with substantial renewable generation). ARPA-E also seeks to fund the creation of a public power system model repository (section D.2). It is intended that the repository will become a long-term community resource existing well past ARPA-E's initial investment. The models and repository created in this program may be used as the basis for an ARPA-E OPF algorithm competition.

The models to be developed in this program must be able to support the many aspects to efficiently and reliably solving OPF problems, including the design of solution algorithms and the design of the mathematical representation or modeling of the power system to be used by those algorithms. However, the development of new OPF solution methods and the development of solution enhancing modeling approaches are not included in the scope of this FOA. Instead, the goal of this FOA is to create power system models that, as accurately and comprehensively as possible, describe "the world" (both current and future) of one or more representative power systems. New OPF solution methods and/or innovative solution enabling modeling approaches for OPF may be pursued in the future in an ARPA-E OPF algorithm competition.

1. Power System Model Creation

ARPA-E seeks applications to create three different types of models and associated scenarios in this program: transmission system models, distribution system models, and hybrid power system models that include detailed representations of both transmission and distribution networks with associated generation and load details. Throughout this FOA we refer to the physical description of a power system and limits of control equipment available (including generators, loads, capacitor banks, LTC taps, etc.) as a "power system model." Variable input data defining each snapshot in time for that model (defining instantaneous power demand, renewable generation, generator and line availability, etc.) is referred to as a "scenario."

Power system models created within this program should include a clear, detailed description of the suitability of proposed models for addressing the grid objectives defined in Section I.C and evaluating algorithms seeking to solve one or more specified OPF problems. The objective and required information for the selected OPF problem(s) must be comprehensively described. Applicants must clearly describe the extent to which improved OPF algorithms for the selected OPF problem would address ARPA-E's mission areas.

Models should correspond to today's grid and provide for assessment of OPF algorithms with future possible infrastructures as anticipated by current projections. For example, models should include significant renewable penetration and/or increased demand-side flexibility and control, with the ability to modify the amount and configuration of those new resources in reasonable ways. The models should be designed in a way that allows users to introduce independent variables (e.g. #, type, location of electricity storage facilities) and determine the dependent changes in system efficiency, reliability, etc. However, the models should also explicitly define a baseline system configuration that can be used without further modification to evaluate new OPF algorithms.

Finally all models must include hypothetical GPS coordinates for major components of their systems. Applicants may also consider adding hypothetical:

- details on system geography (coasts, rivers, mountains, etc.)
- demographic information related to population and load centers (including divisions into commercial and residential electricity consumption)
- correlation of environmental variables with traditional and renewable generation resources.

In models that include hypothetical geographic information, the physical location of power system infrastructure (lines, generators, energy storage, etc.) should reasonably correspond with geographic features.

a. ELECTRIC TRANSMISSION SYSTEM MODELS

Transmission system models created within this program must include a clear, detailed description of all system attributes relevant to calculating system power flows and solving one or more specific bulk power system, security constrained OPF problems. Transmission system models must include, at minimum:

- transmission system network topology
- detailed generator characteristics and limits (including economic details such as heat rate and start-up/shut-down costs)
- thermal line ratings and lengths
- voltage limits on all equipment and at all buses
- detailed transformer specifications (including LTC positions)
- details on reactive power sources/sinks
- critical contingency lists (including multi-element contingencies)
- descriptions of local (automated) control schemes
- energy storage equipment details
- renewable generation capacity and characteristics.

In addition, Applicants may also consider including

- detailed generator and load dynamic characteristics in order to allow for comprehensive stability evaluations of OPF solutions (or to enable the evaluation of future OPF solution methodologies that explicitly include consideration of system stability)
- individual contingencies that explicitly test voltage and/or transient stability
- contingencies that can result in inter-area oscillations
- protection system details, including Remedial Action Schemes or Special Protection Systems
- environmental details such as generator emissions characteristics or water use
- forecasts for fuel costs, renewable generation, loads, and/or other uncertain phenomena.

b. ELECTRIC DISTRIBUTION SYSTEM MODELS

Electricity distribution system models created in this program will need to include many of the same details as required for transmission network models. However, in contrast to transmission networks, distribution systems are inherently unbalanced and therefore, require more detailed individual phase descriptions. The application of OPF in distribution systems also often has different objectives. As distributed energy resources (including photovoltaic generation) proliferate, dynamic phenomena such as rapidly varying voltage magnitudes are likely to play a role of growing importance in the operation of distribution systems. Therefore, all distribution models created in this program must include sufficient detail necessary to optimize distribution system operation subject to rapid resource changes (though, the primary focus may remain on steady state optimization and not dynamic control). Distribution models that include a very large number of customers (> 1 million customers) would also be particularly valuable to evaluate the full potential of meshed distribution systems or distribution systems that can be routinely reconfigured.

Distribution models created in this program must include, at minimum:

- detailed three phase topology for multiple distribution feeders originating from one or more substations
- feeder connected equipment descriptions (including transformer characteristics and any reactive power sources/sinks)
- detailed electricity load characteristics (including a variety of load in appropriate proportions)
- sufficient detail to optimize distribution system operations subject to rapidly changing distribution generation.

c. Hybrid Transmission/Distribution Models

Realizing the full range of benefits offered by growing penetrations of distribution generation may also require more complete studies of the interactions between transmission and distribution systems. Therefore, in addition to improved transmission and distribution models described above, there is a critical need for hybrid transmission/distribution models that contain all of the above details and also represent the coupling between systems in a realistic way. In order to be most useful, hybrid models must meet the requirements for both transmission and distribution systems.

The development of hierarchical power system models would be attractive. Hierarchical modeling has been used extensively in other disciplines such as electrical circuit simulation. Hierarchical models can function with a high level behavioral description of a part of the network when detailed information is not required for a particular type of analysis. Switching between high-level behavioral views and detailed representations can allow much faster simulation, while preserving the details in the part of the network, where detailed solutions are desired.

2. Power System Scenario Creation

Applicants must also plan to deliver a large number of scenarios or specific operating points for each infrastructure model. These must include:

- the magnitude of real and reactive power demand (or other parameters that define electricity demand characteristics) at each bus
- information on temporary equipment unavailability (generators, lines, transformers, etc.)
- details regarding instantaneous variable power generation capabilities (i.e. solar and wind generation potential)

and any other variables that change over time.

Scenario sets should be designed with temporal resolutions and time coupling suitable for solving one or more specific OPF problems (for example, solving one day-ahead unit commitment problems would require at least 1-hour resolution whereas 5-minute economic dispatch problems would require scenarios with at least 5-minute resolution). Models created for the analysis of electric distribution systems often feature time resolutions of at least 1-minute. Scenario sets with shorter time resolutions will be preferred (as long as there is no loss in scenario or model fidelity).

Scenarios may also include:

- fuel costs
- instantaneous demand response capacity available
- probabilistic information (such as provided probability distribution functions or lists of forecasted vs. actual values) for renewable generation and/or power consumption for future periods.

It is important for power systems network models to represent a range of difficulty to OPF optimization algorithms. Applicants must confirm that the majority of scenarios are AC-OPF feasible. However, an important feature of some OPF algorithms is the explicit identification of system infeasibility. Therefore, it will also be valuable to generate some scenarios that are confirmed to be infeasible. For example, there should be at least some scenarios where a major generator is unavailable and/or there is unusual congestion. The scenarios should also probe a range of operating conditions including realistic peak/minimum load conditions as well as peak/minimum renewable generation and combinations thereof. Applicants should describe their plan for generating and testing scenarios of varying difficulty.

3. POSSIBLE APPROACHES TO MODEL AND SCENARIO CREATION

There are two possible tracks for model and scenario creation (though a hybrid of these tracks is also possible). The first option is for Applicants to partner with an ISO or utility and use actual data to generate new models. Due to the obvious concerns regarding both the proprietary nature of some data and critical infrastructure security concerns, this approach to model creation would necessarily involve careful anonymization (for example topology perturbation, randomization/obfuscation of edge and generator details, etc.). Indeed, this method has been used successfully in the past for public distribution system model development.[53] Applicants wishing to pursue this track must clearly and comprehensively describe their technical approach to anonymization. Applicants must describe in detail the process for utility review and release and should include letters of support acknowledging the certain future public release of

[53] K.P. Schneider et al., "Modern Grid Initiative: Distribution Taxonomy Final Report," Pacific Northwest National Laboratory, November 2008, http://www.gridlabd.org/models/feeders/taxonomy_of_prototypical_feeders.pdf

the models created in the program. Risk mitigation plans for likely, possible, and unforeseen barriers in this process should also be described in detail. This aspect of the proposed work is critical.

A second possible method for high fidelity model creation is to construct purely synthetic power system models. There are a number of routes Applicants might pursue to keep models highly reflective of real power networks. One option would be to derive these from power system expert input, or other, auxiliary datasets known to correlate to power networks (such as roadway maps). Applicants might also construct a set of new random graph models, similar to those that have been developed for social and informatics networks, relevant to transmission and/or distribution systems.[54] These synthetic models might be developed by constructing new ensembles or using a set of ensembles already in the literature (for example, Exponential Random Graph Models), with sufficient statistics chosen specifically for transmission or distribution networks.[55] The parameters of this model might be set by mining existing public power system models, extracting parameters from related auxiliary datasets (for example EIA data for generator characteristics, real estate and census data for electricity load estimation, satellite photos for infrastructure information, etc.), or by using features from real data in collaboration with an ISO or utility company.

Methods for scenario creation are likely to share many similarities to those for model creation. Data defining specific scenarios can be created using engineering judgment or may be based on historical data. For example, information on equipment availability should correlate to established failure rates for each specific type of equipment (if known). Historical data, such as weather-related information can also be used to help define specific scenarios. Applicants may also propose to collect new measurements on system characteristics or performance.

Applicants are also encouraged to build or adapt model conversion tools to convert the new models developed in this program to and from commonly used formats for existing commercial and open source simulation tools. Tools to extract model details for specific types of analysis would also be valuable.

4. POWER SYSTEM MODEL VALIDATION

Ultimately, the value of the new models created under this program will be determined by the extent to which they are sufficiently representative of one or more real-world power systems. In particular, new power system network models should reflect the characteristics of one or more actual utility systems. Network models should reflect heterogeneity in network density corresponding to different population densities as well as the appropriate level of mismatch

[54] M. E. J. Newman, "The structure and function of complex networks," *Society for Industrial and Applied Mathematics (SIAM) Review*, vol. 45, no. 2, pp. 167-256, May 2003, doi: 10.1137/S003614450342480
[55] G. Robins et al., "An introduction to exponential random graph (p*) models for social networks," *Social Networks*, vol. 29, no. 2, pp. 173-191, March 2007, doi: 10.1016/j.socnet.2006.08.002

between the location of generation and major population centers (especially, for example, large-scale renewable generation). Applications may also include explicit recognition of the existence of multiple balancing authorities and/or the existence of loosely connected (asynchronous) interconnections. Finally, network models should have a realistic distribution of system voltages and an appropriate mix between ac and dc transmission lines.
Model validation will be an essential component of all projects in this program. Specific approaches to validation are expected to be unique to each model creation method; Applicants must describe their specific approach to carefully validating new power system models and must provide specific quantitative validation criteria and targets in their applications. This validation will be critically important to ensuring that the research community quickly and widely adopts the new models. Model validation approaches may include (but are not limited to) one or a combination of the following:

- Statistical comparison (for example degree distributions, clustering, etc.) and/or goodness of fit testing against real power systems and/or auxiliary datasets
- Detailed validation from industry stakeholders including utility and/or ISO staff
- An evaluation of the performance of OPF algorithms on the new model compared to the same on real-world systems (obtained under NDA)
- Validation of system frequency response after a simulated disturbance and/or characterization of system oscillatory modes (for those models that include detailed dynamic data).

Applications will be judged on level of detail to be included in the proposed network models, the strength of proposed validation approaches, and the ability of the models to test the limitations of existing and emerging OPF algorithms.

5. POWER SYSTEM MODEL REPOSITORY CREATION

The establishment of the large global open source software development community over the past 20 years have enabled, for the first time, highly productive, widely distributed, technical collaboration involving thousands or millions of individual users.[56] In addition to formal technical collaboration sites, crowd-sourced information and review websites allow users to provide detailed comments and reviews on everything from local businesses to the latest electronic gadgets. ARPA-E believes such resources could be leveraged to substantially strengthen the power system optimization research community given the development of a large-scale power system network model repository. This is likely to become even more important as the scale and level of detail contained in power system models increase.

ARPA-E seeks to fund the development of a public, interactive, high-fidelity, power system model repository that supports additional collaborative power system model creation in the

[56] https://github.com/about/press, Accessed May 2015.

future. As described above, public archiving of network models suitable for OPF optimization algorithm development and testing is currently limited almost entirely to the University of Washington's Power Systems Test Case Archive and the MATPOWER MATLAB package, which store versions of the commonly used IEEE test-sets and several other systems.[57,58] These archives are "what you see is what you get" in nature and do not include the ability for researchers to easily contribute and share new models. (Applicants who modify the archived power systems have few options for distributing their modified test systems to the broader community).

A repository designed specifically to allow the power system engineering technical community to collaboratively build, refine, and review various types of power system models could accelerate the pace of grid optimization algorithm development. An example is recent success with a model repository and simulation platform known as the "Open Model Framework"[59] developed by the National Rural Electric Cooperative Association (NRECA) for cooperative utilities. While there are many forms that the repository could take, it should serve initially as a central location where the research community can both contribute and download power system models for a wide range of analysis. Users should have the ability to provide detailed reviews on individual models. These reviews could assess different attributes of models (for example, completeness, relative difficulty, and/or realism). Version control is often a critical feature in online technical collaboration tools. In this context, individual users should have the ability to submit modified versions of existing models (with explicit recognition of the relationship between different models), allowing the models to evolve continuously as the most important power system challenges and opportunities evolve over time. To be most effective, the repository must be designed to allow specific model versions to be referenced in technical publications. The use of a unique identifier would also, of course, facilitate collaborations between research groups in different locations (who might not be able to easily exchange larger, more detailed models). The ability for the repository to hold multiple versions of models in different file formats would also be valuable, as would the ability for the repository to have the capability to convert models from one format to another or to/from a standard format that could be used to represent all models. The repository should be fully compatible with network models for a range of different types of analysis and control and optimization algorithm design. Further, in the future, it would be valuable for the repository to validate the interoperability of different models (for example detailed models for specific types of equipment). The capability for the repository to validate model formats would be particularly valuable if hierarchical modeling frameworks are used. The repository would likely be used to provide access to the power system models used in ARPA-E's envisioned OPF competition.

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[57] R. D. Christie (August 1999), *Power Systems Test Case Archive* [Online], Available: http://www.ee.washington.edu/research/pstca/

[58] R.D. Zimmerman, C.E. Murillo- Sánchez, and R.J. Thomas, "MATPOWER: Steady-State Operations, Planning, and Analysis Tools for Power Systems Research and Education," *IEEE Transactions on Power Systems*, vol. 26, no. 1, pp. 12 -19, February 2011, doi: 10.1109/TPWRS.2010.2051168

[59] http://www.nreca.coop/what-we-do/bts/smart-grid-demonstration-project/open-modeling-framework/

The most valuable repository would be one that is self-funded or maintained well after ARPA-E's development funding ends. Applications must describe a plan for self-funding maintenance and curation of the repository past the initial period of ARPA-E funding. This plan should detail annual cost and delineate specific and reliable funding sources and cash flows (with detailed letters of support from any relevant agencies, companies, or universities). Once again, this aspect of the application is critically important; without a detailed, specific and realistic plan for sustenance beyond ARPA-E's initial funding, applications will be judged as non-responsive.

E. Power System Model & Repository Technical Requirements

ARPA-E intends to fund projects in two separate categories, power systems models and power systems model repositories. Applicants may apply to one or both categories.

1. Category I: Power System Network Model and Scenario Creation

Applicants seeking to build new power system network models and sets of scenarios must address all technical specifications in Tables 1 and 2.

TABLE 1: POWER SYSTEM MODEL TECHNICAL SPECIFICATIONS

ID	TITLE	TECHNICAL SPECIFICATION
1.1	Problem Specification	System models created within this program must include a clear, detailed description of the suitability of proposed models for addressing the grid objectives defined in the introduction to Section I.C and evaluating algorithms seeking to solve one or more specified OPF problems. The objective and required information for the selected OPF problem(s) must be comprehensively described. Applicants must clearly describe the extent to which improved OPF algorithms for the selected OPF problem would address ARPA-E's mission areas.
1.2	Power System Model Creation Method	Any method(s) may be used to create test systems (using real-world data or purely synthetic approaches). Preference will be given to Applicants proposing to create test systems based on one or more real world transmission or distribution networks in collaboration with utilities, ISOs, or existing industry vendors.
1.3	Power System Model Scale	All Applicants must plan to create models at multiple scales, and may choose to address (i) a transmission/bulk power system, (ii) a distribution system, or (iii) a hybrid transmission and distribution system. The application should clearly indicate which type is of system is addressed. Applicants who choose to create electric transmission system network models must plan to create at least one small network

		model having between 50 and 250 electrical buses (for initial OPF algorithm development) and at least one large network model having > 5,000 buses. Larger test systems may not consist of repeated duplicates of smaller systems. Applicants are encouraged to include the design, validation, and release of smaller scale models early in the project to allow for immediate, early feedback from the broader research community. Applicants who choose to create electric distribution system models must create at least one model with at least 3 independent feeders originating at one or more substations, corresponding to a minimum of at least 5,000 individual customers.
1.4	Power System Model File Format	Applicants may select any existing file format for new power system network models. To the greatest extent possible, Applicants are encouraged to use existing commonly used power system model formats, such as those associated with common commercial power flow tools and/or the IEEE common data format.[60,61] Unfortunately, many of these existing formats have limited flexibility and/or are limited to static data (i.e. not time-based information). ARPA-E expects that new formats may need to be developed (or extended from emerging ones such as the utility Common Information Model or the recently proposed utility Open Data Model) to include the required system information such as generator dynamic characteristics, market data, descriptions of the limits of power flow controllers, and/or to define the characteristics of local control schemes. [62] Many of these specific details are rarely available in existing OPF-focused power system network models. Applicants may utilize either a bus-branch or a breaker-node system representation of power systems. Applicants are encouraged to develop equivalent versions for all test systems (with consistent naming conventions) in both formats. The availability of a more detailed breaker-node representation could be particularly useful for emerging grid optimization strategies such as those that employ line switching.

[60] http://w3.usa.siemens.com/smartgrid/us/en/transmission-grid/products/grid-analysis-tools/transmission-system-planning/pages/psserawdataformat.aspx
[61] IEEE Working Group. "Common data format for the exchange of solved load flow data." Trans. Power App. Syst 92.6 (1973): 1916-1925.
[62] http://community.interpss.org/Home/ieee-pes-oss

		Applicants who choose to develop a data standard for OPF-compatible power system models should describe in detail how they intend to design the new format. ARPA-E expects Applicants to have an explicit plan for soliciting detailed input on any new data formats from other projects in the GRID DATA program, the power engineering community at-large, and other related technical fields (such as mathematics, computer science, or operations research). Those Applicants who anticipate creating new model formats should also plan to create model conversion tools to convert models into more common formats (to the greatest extent possible). Tools to extract model details for specific types of analysis would also be valuable.
1.5	Power System Model Details	Transmission system models created within this program must include a detailed description of all system attributes relevant to calculating system power flows and solving one or more specific bulk power system, security constrained OPF problems. Transmission system models must include, at minimum: • transmission system network topology • detailed generator characteristics and limits (including economic details such as heat rate and start-up/shut-down costs) • thermal line ratings and lengths • voltage limits on all equipment and at all buses • detailed transformer specifications (including LTC positions) • details on reactive power sources/sinks • critical contingency lists (including multi-element contingencies) • descriptions of local (automated) control schemes • energy storage equipment details • renewable generation capacity and characteristics. In addition, Applicants may also consider including: • detailed generator and load dynamic characteristics in order to allow for comprehensive stability evaluations of OPF solutions (or to enable the evaluation of future OPF solution methodologies that explicitly include consideration of system stability) • individual contingencies that explicitly test voltage and/or

transient stability
- contingencies that can result in inter-area oscillations
- protection system details, including Remedial Action Schemes or Special Protection Systems
- environmental details such as generator emissions characteristics or water use
- environmental details such as generator emissions characteristics or water use
- forecasts for fuel costs, renewable generation, loads, and/or other uncertain phenomena.

Electricity distribution system models created in this program must include many of the same details as required for transmission network models. This must include, at a minimum:
- detailed three phase topology for multiple distribution feeders originating from one or more substations
- feeder connected equipment descriptions (including transformer characteristics and any reactive power sources/sinks)
- detailed electricity load characteristics (including a variety of load in appropriate proportions)
- sufficient detail to optimize distribution system operations subject to rapidly changing distribution generation.

Models should correspond to today's grid and allow introduction of variable future possible infrastructures as indicated by current projections. For example, models with significant renewable penetration or increased demand-side flexibility and control should be included, with opportunity to vary the amount and distribution of each.

Hybrid transmission/distribution models should contain all of the above details and also represent the coupling between systems in a realistic way.

Finally all models must include hypothetical GPS coordinates for major components of their systems. Applicants may also consider adding hypothetical:
- details on system geography (coasts, rivers, mountains, etc.)
- demographic information related to population and load centers (including divisions into commercial and residential electricity consumption)

		• correlation of environmental variables with traditional and renewable generation resources. In models that include hypothetical geographic information, the physical location of power system infrastructure (lines, generators, energy storage, etc.) should reasonably correspond with geographic features.
1.6	Power System Model Validation	Applicants must include a detailed plan for validation with technical success/fail criteria to ensure models are sufficiently representative of one or more real-world power systems.
1.7	Documentation and Public Access Requirement	Applicants are required to generate detailed, user-friendly documentation for all new power system models. This documentation must describe general power system characteristics while also providing details on the precise format and/or any naming conventions that are used. The documentation must specify units for all numerical quantities described in each model. Applications must include a Data Management Plan for making the models publicly available without restriction, which plan must include addressing intellectual property issues. The award for successful applications will include contract provisions implementing the proposed plan. For those Applicants proposing to use real-world data, all protected, proprietary, and/or security sensitive details must be removed prior to release. Final models must not contain any Critical Energy Infrastructure Information (CEII).[63] In cases where real world network model data is provided by a grid operator or utility, Applicants must have an established plan and timeline for the review and approval of models prior to public release. Risk mitigation plans for likely, possible, and unforeseen barriers in this process must also be described in detail.

[63] http://www.ferc.gov/legal/ceii-foia/ceii.asp

TABLE 2: SCENARIO TECHNICAL SPECIFICATIONS

ID	TITLE	TECHNICAL SPECIFICATION
2.1	Problem Specification and Minimum Number of Scenarios	Scenario sets must be designed with temporal resolutions and time-coupling suitable for solving one or more specific OPF problems. Applicants must clearly describe the problem(s) they anticipate addressing with their scenario sets and how improved OPF algorithms for the selected OPF problem would address ARPA-E's mission areas. This description must describe the OPF problem objective and the minimum information that must be included in the power system scenarios. Applicants must develop at minimum a full year of time-coupled physically feasible scenarios with at least hourly granularity. (i.e. Applicants must develop at least 8,760 individual scenarios with each snapshot corresponding to a single snapshot in time.). Applicants are strongly encouraged to propose using the shortest feasible time step between scenarios (5 minutes, 15 minutes, etc.). Scenario sets with shorter time resolutions will be preferred (as long as there is no loss in scenario or model fidelity). Applicants may also wish to design particularly difficult scenarios for single period OPF studies. Therefore, not all scenarios are required to be part of a time-coupled set. Applicants are also encouraged to design infeasible scenarios to test the ability for OPF algorithms to identify infeasibility quickly.
2.2	Scenario Creation Method	Any method(s) may be used to create power system scenarios (using real-world data or purely synthetic approaches). Data defining specific scenarios can be created using engineering judgment or may be based on historical data. Historical data, such as weather-related information can also be used to help define specific scenarios. Applicants may also propose to collect new measurements on system characteristics or performance.
2.3	Scenario Details	Scenarios must include all of the time-dependent operating characteristics required to fully evaluate new OPF algorithms. At minimum, scenarios must include: • the magnitude of real and reactive power demand (or other parameters that define electricity demand characteristics) at each bus • information on temporary equipment unavailability (generators, lines, transformers, etc.) • details regarding instantaneous variable power generation

		capabilities (i.e. solar and wind generation potential) and any other variables that change over time. These scenarios should be designed with temporal resolutions and time coupling suitable for solving one or more specific OPF problems (for example, solving one day-ahead unit commitment problems would require at least 1-hour resolution whereas 5-minute economic dispatch problems would require scenarios with at least 5-minute resolution). Models created for the analysis of electric distribution systems often feature time resolutions of at least 1-minute. Scenario sets with shorter time resolutions will be preferred (as long as there is no loss in scenario or model fidelity). Scenarios may also include: • fuel costs • instantaneous demand response capacity available • probabilistic information (such as probability distribution functions or lists of forecasted vs. actual quantities) for fuel costs, renewable generation, and electricity demand for future periods. It is important for power systems network models to represent a range of difficulty to OPF optimization algorithms. Applicants must confirm that the majority of scenarios are AC-OPF feasible. It will also be valuable to generate some scenarios that are confirmed to be infeasible. For example, there should be at least some scenarios where a major generator is unavailable and/or there is unusual congestion. The scenarios should also probe a range of operating conditions including realistic peak/minimum load conditions as well as peak/minimum renewable generation and combinations thereof. Applicants should describe their plan for generating and testing scenarios of varying difficulty.
2.4	Scenario Validation	Applicants must include a detailed plan for validation with technical success/fail criteria to ensure scenarios are sufficiently representative of a range of real-world power system operating conditions.

2. Category II: Repository Creation

Applicants seeking to establish a repository must address all technical specifications in Table 3.

TABLE 3: REPOSITORY TECHNICAL SPECIFICATIONS

ID	TITLE	TECHNICAL SPECIFICATION
3.1	Open access	The repository and portal must be completely open (including international access), giving researchers the ability to upload modified versions of existing models and designate relationships between different models (i.e. version control) as well as provide annotation and/or comments on specific models (similar to, for example, GitHub).
3.2	Flexibility	The repository should be able to accommodate different kinds of power system models (not just ones suitable for OPF control and optimization). For example, it should be flexible enough for planning cases and/or models specifically designed to study system dynamics and stability. The initial (beta form) for the repository must include a variety of existing power system models that are already in the public domain, including the standard IEEE power system models for OPF studies.
3.3	Scalability	The repository should have the ability to scale the repository to archive an arbitrary number of power system models within the proposed budget.
3.4	Self Sustainability	Applicants should propose a self-funding model that extends well beyond ARPA-E's development funding. The project should also include the establishment of a set of standards for models and a clear self-governance model for the portal. The Applicant should have a plan for increasing awareness and use of the repository throughout its operations.
3.5	Curation	The proposed work should include a plan for active curation of power system models, during and after ARPA-E's development funding. This should include standards for nomination of curators (either by the team in charge of the portal or the community at-large). Applicants should make clear the specific role of curators; these should include, at a minimum: the ability to annotate models, define new types of models, organize existing models, evolve existing standards for models and delete models which do not meet current standards. Applications must address intellectual property issues and acknowledge that if the repository is not maintained to the satisfaction of ARPA-E after a period of time the repository may be transferred to the Government or a party designated by the Government. The Government will also be afforded the right to create an additional repository with all publicly available models. For the repository, Applicants should include in their plan trademark protection of the identifier of the repository and possibly, the models and for managing the trademark(s) during the duration of the

		repository. The trademark(s) ownership would transfer with the management of the repository. The award for successful applications will include contract provisions requiring implementation of the proposed plan.

ARPA-E will not consider selecting projects for award that do not clearly demonstrate realistic, well-justified potential to meet or exceed the required technical targets.

II. AWARD INFORMATION

A. AWARD OVERVIEW

ARPA-E expects to make approximately $7 million available for new awards under this FOA, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 2-5 power system model creation awards for 1 to 2 years, and 1 data repository award under this FOA. While ARPA-E anticipates the initial repository creation to be a relatively short duration effort, ARPA-E intends to also fund operations, maintenance, and updates to the repository for up to a total duration of 4 years through this FOA. ARPA-E may, at its discretion, issue one, multiple, or no awards.

Individual awards may vary between $250,000 and $7 million.

The period of performance for model creation and validation awards may not exceed 24 months. The period of performance for model repository awards may not exceed 48 months. ARPA-E expects the start date for funding agreements to be March 2016, or as negotiated.

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

ARPA-E will accept only new applications 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. ARPA-E FUNDING AGREEMENTS

Through Cooperative Agreements, Technology Investment Agreements, 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."[64] Accordingly, ARPA-E has substantial involvement in the direction of every project, as described in Section II.C below.

1. COOPERATIVE AGREEMENTS

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients.[65]

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 http://arpa-e.energy.gov/arpa-e-site-page/award-guidance.

2. FUNDING AGREEMENTS WITH FFRDCS, GOGOS, AND FEDERAL INSTRUMENTALITIES[66]

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

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

When a FFRDC or non-DOE/NNSA GOGO is a *member* of a Project Team, ARPA-E executes a funding agreement directly with the FFRDC or non-DOE/NNSA GOGO 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 and the rest of the Project Team.

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[64] U.S. Congress, Conference Report to accompany the 21st Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).
[65] The Prime Recipient is the signatory to the funding agreement with ARPA-E.
[66] DOE/NNSA GOGOs are not eligible to apply for funding, as described in Section III.A of the FOA.

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, and Federal instrumentalities (e.g., Tennessee Valley Authority) generally take the form of Interagency Agreements. Any funding agreement with a FFRDC or non-DOE/NNSA GOGO will have similar terms and conditions as ARPA-E's Model Cooperative Agreement (http://arpa-e.energy.gov/arpa-e-site-page/award-guidance).

Non-DOE GOGOs and Federal agencies may be proposed as supporting project team members on an applicant's project.

3. Technology Investment Agreements

ARPA-E may use its "other transactions" authority under the America COMPETES Reauthorization Act of 2010 or DOE's "other transactions" authority under the Energy Policy Act of 2005 to enter into Technology Investment Agreements (TIAs) with Prime Recipients. ARPA-E may negotiate a TIA when it determines that the use of a standard cooperative agreement, grant, or contract is not feasible or appropriate for a project.

A TIA is more flexible than a traditional financial assistance agreement. In using a TIA, ARPA-E may modify standard Government terms and conditions. See 10 C.F.R. § 603.105 for a description of a TIA.

In general, TIAs require a cost share of 50%. See Section III.B.2 of the FOA.

C. 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.
- 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, 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.

- 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

1. INDIVIDUALS

U.S. citizens or permanent residents may apply for funding in their individual capacity as a Standalone Applicant,[67] as the lead for a Project Team,[68] 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[69] 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 are eligible to apply for funding as the lead organization for a Project Team or as a member of a Project Team, but not as a Standalone Applicant.

DOE/NNSA GOGOs are not eligible to apply for funding.

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

[68] The term “Project Team” is used to mean any entity with multiple players working collaboratively and could encompass anything from an existing organization to an ad hoc teaming arrangement. A Project Team consists of the Prime Recipient, Subrecipients, and others performing or otherwise supporting work under an ARPA-E funding agreement.

[69]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.

Non-DOE/NNSA GOGOs 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.

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

Foreign entities, whether for-profit or otherwise, are eligible to apply for funding as Standalone Applicants, as the lead organization for a Project Team, or as a member of a Project Team. All work by foreign entities must be performed by subsidiaries or affiliates incorporated in the United States (including U.S. territories). The Applicant may request a waiver of this requirement in the Business Assurances & Disclosures Form, which is submitted with the Full Application. 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 agreement binds the individual consortium members together and should discuss, among other things, 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[70]

The cost share requirement for research and development tasks (i.e. model/data set development and validation) under this FOA are as follows:

- Large businesses[71] are required to provide at least five percent of the Total Project Cost[72] as cost share when they are a Standalone applicant;
- Domestic educational institutions, domestic nonprofits, domestic small businesses and/or FFRDCs are not required to provide cost share where they are Standalone applicants, or where they have formed a Project Team composed exclusively of these types of entities; and
- Project Teams that include one or more large businesses are required to provide at least five percent of the Total Project Cost[73] as cost share.

If cost sharing is required, the funding agreement makes the Prime Recipient responsible for paying the entire cost share and enforcing cost share obligations assumed by Project Team members in subawards or related agreements.

1. 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 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 project period, the Prime Recipient is required to contribute at least the cost share percentage of total expenditures incurred through the date of termination.

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

[71] For the purposes of this FOA, a large business is defined as one that does not 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).

[72] To the extent that an award includes both R&D tasks (i.e. model/data set development), as well as information/outreach tasks (i.e. model repository), the five percent cost share requirement for large businesses will only apply to costs incurred for the R&D/model data set development tasks of that award rather than to Total Project Costs.

[73] See footnote 72 above.

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.

2. 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.

3. Cost Share Types and Allowability

Every cost share contribution must be allowable under the applicable Federal cost principles, as described in Section IV.G.1 of the FOA.

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 project period;
- 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[74] to meet their cost share obligations under cooperative agreements. However, Project Teams may use IR&D funds to meet their cost share obligations under Technology investment Agreements.

[74] As defined in Federal Acquisition Regulation Subsection 31.205-18.

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.

4. COST SHARE CONTRIBUTIONS BY FFRDCS AND GOGOS

Because FFRDCs and GOGOs are funded by the Federal Government, costs incurred by FFRDCs and GOGOs 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.

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.

5. 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.

ARPA-E will 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.

ARPA-E will 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 uploaded all required documents to ARPA-E eXCHANGE by the deadline stated in 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 will be deemed nonresponsive and will not be reviewed or considered (referred to herein as "Applications Specifically Not of Interest"):

- Applications that fall outside the technical parameters specified in Section I.E of the FOA
- Applications that have been submitted in response to other currently issued ARPA-E FOAs.
- Applications that are not scientifically distinct from applications submitted in response to other currently issued ARPA-E FOAs.
- Applications for basic research aimed solely at discovery and/or fundamental knowledge generation.
- Applications for large-scale demonstration projects of existing technologies.
- Applications for proposed technologies that represent incremental improvements to existing technologies.
- Applications for proposed technologies that are not based on sound scientific principles (e.g., violates a law of thermodynamics).
- Applications for models that will not enable the development of transformational grid optimization algorithms, as described in Section I.B of the FOA.
- Applications 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.
- Applications that are not scientifically distinct from existing funded activities supported elsewhere, including within the Department of Energy.
- Applications that propose the following:
  - Category 1 models without a detailed validation plan against real-world systems.
  - Category 1 models that are only slight modifications or additions to existing public test systems that do not satisfy the requirements specified in Section I.E.
  - Category 1 models without a detailed description of the process for utility review and release (including letters of support acknowledging the certain future public release of the models created in the program), and risk mitigation plans for likely, possible, and unforeseen barriers to the delivery of on-time, publically releasable models.
  - Category 2 repository designs without a detailed, specific and realistic plan for sustenance beyond ARPA-E's initial funding.
  - The development of new OPF algorithms or solution methods and OPF solution enhancing modeling methodologies.

3. Limitation on Number of Applications

ARPA-E is not limiting the number of applications that may be submitted by 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. ARPA-E makes an independent assessment of each compliant and responsive Concept Paper based on the criteria in Section V.A.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 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 30 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. ARPA-E reviews only compliant and responsive Full Applications.

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 and site visits, nor will these costs be eligible for reimbursement as pre-award costs.

ARPA-E may select applications for funding 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.

7. MANDATORY WEBINAR

All selected Applicants, including the Principal Investigator and the financial manager for the project, are required to participate in a webinar that is held within approximately one week of the selection notification. During the webinar, ARPA-E officials present important information on the award negotiation process, including deadlines for the completion of certain actions.

B. APPLICATION FORMS

Required forms for Full Applications are available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov), including the SF-424, Budget Justification Workbook/SF-424A, and Business Assurances & Disclosures Form. A sample response to the Business Assurances & Disclosures Form and a sample Summary Slide are also 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, and the template for the Reply to Reviewer Comments.

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.

ARPA-E will not review or consider noncompliant and/or nonresponsive Concept Papers (see Section III.C of the FOA).

Each Concept Paper should be limited to a single concept or technology. Unrelated concepts and technologies should 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 technical approach to the creation and validation of power system network models and/or the creation of a power system model repository with minimal jargon, and explain how it addresses the Program Objectives of the FOA.

b. Innovation and Impact

- Clearly 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 electric power system modeling challenges described in the FOA.

- Explain the concept's potential to be disruptive compared to existing or emerging publically available power system models and/or other means to enable the collaborative design and maintenance of power system network models.

- To the extent possible, provide quantitative metrics in a table that compares the proposed concept(s) to currently available and emerging power system models or power system model repositories and to the ~~technical performance targets~~ program objectives in Section I.~~E~~D of the FOA and the technical specifications for the appropriate Technology Category in Section I.~~D~~E of the FOA.

c. PROPOSED WORK

- Describe the final deliverable(s) for the project and the overall technical approach used to achieve project objectives. If applicable, describe all power system network details that will be included in the final project deliverables. Clearly describe how those details are to be created or collected. If applicable, describe all model repository capabilities to be demonstrated at the conclusion of the project.

- Discuss alternative approaches considered, if any, and why the proposed approach is most appropriate for the project objectives.

- 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 network models and/or repository to gain widespread adoption and use in the research community. Describe how the Project Team will work to overcome these challenges.

- If applicable, describe the Project Team's proposed approach to ensuring new power system network models can be publically released by the conclusion of the project.

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.

D. Content and Form of Full Applications

[TO BE INSERTED BY FOA MODIFICATION IN SEPTEMBER 2015]

E. Content and Form of Replies to Reviewer Comments

[TO BE INSERTED BY FOA MODIFICATION IN SEPTEMBER 2015]

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 SEPTEMBER 2015]

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 User 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 will not review or consider incomplete applications and applications received after the deadline stated in the FOA. Such applications will 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;
- 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 Concept Papers and 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 factors:

- The extent to which the proposed quantitative material and/or technology metrics demonstrate the potential for a transformational and disruptive (not incremental) advancement compared to existing or emerging technologies;

- The extent to which the proposed concept is innovative and will achieve the ~~technical specifications~~ program objectives defined in Section I.D of the FOA and the technical specifications for the appropriate technology Category in Section I.E of the FOA; and

- The extent to which the Applicant demonstrates 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 factors:

- The feasibility of the proposed work, as justified by appropriate background, theory, simulation, modeling, experimental data, or other sound scientific and engineering practices;

- The extent to which the Applicant proposes a sound 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;

- The extent to which project outcomes and final deliverables are clearly defined;

- The extent to which the Applicant identifies techno-economic challenges that must be overcome for the proposed technology to be commercially relevant; 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 SEPTEMBER 2015]

3. Criteria for Replies to Reviewer Comments

[TO BE INSERTED BY FOA MODIFICATION IN SEPTEMBER 2015

B. Review and Selection Process

1. Program Policy Factors

[TO BE INSERTED BY FOA MODIFICATION IN SEPTEMBER 2015]

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 SEPTEMBER 2015]

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 reviewed or considered. 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.2 of the FOA for guidance on pre-award costs.

3. Full Application Notifications

[TO BE INSERTED BY FOA MODIFICATION IN SEPTEMBER 2015]

B. Administrative and National Policy Requirements

[TO BE INSERTED BY FOA MODIFICATION IN SEPTEMBER 2015]

C. Reporting

[TO BE INSERTED BY FOA MODIFICATION IN SEPTEMBER 2015]

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. Answers to Frequently Asked Questions (FAQs) 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. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.

- ARPA-E will cease to accept questions approximately 5 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 posted to "Frequently Asked Questions" 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. 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.

B. 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.

C. 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.

D. 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.

E. 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.

F. 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 they elect to retain title, they must file a patent application in a timely fashion.

- All other parties: The Federal Non Nuclear Energy 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.

G. 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.

H. 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. Network models will not be accorded this special protected status. DOE may require delivery of the network models. In addition, invention disclosures may be protected from public disclosure for a reasonable time in order to allow for filing a patent application.

I. 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).

IX. GLOSSARY

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 within the U.S. Department of Energy.

Cost Sharing: is the portion of project costs from non-Federal sources that are borne by the Prime Recipient (or non-Federal third parties on behalf of the Prime Recipient), rather than by the Federal Government.

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

DOE: U.S. Department of Energy.

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

FFRDCs: Federally Funded Research and Development Centers.

FOA: Funding Opportunity Announcement.

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

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

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

PI: Principal Investigator.

Project Team: A Project Team consists of the Prime Recipient, Subrecipients, and others performing or otherwise supporting work under an ARPA-E funding agreement.

R&D: Research and development.

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.

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.

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.

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