# DOE/OE Transmission Reliability Program

## June 2018 Peer Review Meeting Summary

*For projects funded under Reliability and Markets, and*
*National Energy Technology Laboratory (NETL) FOA 1493*

Modernizing America's electricity infrastructure is one of the top priorities of the U.S. Department of Energy (DOE, or The Department). The DOE Strategic Plan[1] states that today's electric grid needs to be more efficient, reliable, and secure. A modern, smarter electric grid may save consumers money, help our economy run more efficiently, allow rapid growth in renewable energy sources, and enhance energy reliability. The Department's research into a variety of tools that will improve advanced system monitoring, visualization, control, operations, and market structure will ultimately modernize the electricity transmission infrastructure to ease congestion, allow for increases in demand, and provide a greater degree of security.

DOE's Office of Electricity (OE) Transmission Reliability Program supports research focused on the modeling and computational methodologies and techniques needed to address the increasing risk and uncertainty facing electric power system planners and operators. This research is intended to integrate supply, delivery (transmission and distribution), and demand-side needs into an integrated stochastic planning and operational framework consistent with a vision of future engineering and market functions.

The Reliability and Markets activity focuses on five key areas: market design; long-term supply and transmission investment; renewable integration; demand response; and environmental impacts. Researchers use models and simulations to assess how new technologies, policies, environmental regulations, or market designs will impact electric grid reliability and electricity costs before actual implementation. The activity helps to ensure electric reliability, while also improving the efficiency and economics of market operations.

Within the Reliability and Markets activity, OE is currently focused on two main areas of research:

- ***Stochastic Planning and Operations.*** Development of techniques necessary for planning and operating a future grid system that will be required to accommodate many forms of uncertainty—especially that associated with variable renewable energy supply and new technologies such as electric vehicles and storage.
- ***Demand-Side, Environmental, and Reliability Issues.*** Development and applications of integrated market and engineering approaches which, when applied to carefully chosen case studies, provide useful information and analysis that informs policy making and investment decision making.

The Reliability and Markets activity is managed for DOE by the National Energy Technology Laboratory (NETL), and all of the projects within that activity are competitively solicited from university researchers. This work is reviewed annually by DOE/OE, and the review materials are made available on the DOE website.[2]

[1] See http://energy.gov/downloads/2011-strategic-plan
[2] See https://www.energy.gov/oe/services/technology-development/transmission-reliability

## 2018 Peer Review Meeting

The 2018 meeting was held on June 5, 2018 in Washington, DC. Attendees included research performers from participating national labs and research institutions. The meeting included 8 presentations, each with a research talk and a question-and-answer period. Presenters were asked to summarize progress to date, and to describe future activities for the coming fiscal year. This review included projects funded as part of the DOE/OE Reliability and Markets activity, which are managed by NETL, and projects awarded by NETL under FOA 1493[3].

### *Peer Reviewers*

Reviewers were chosen based on their research and industry knowledge. Reviewers with direct involvement with individual specific projects were recused from scoring those projects. The reviewers participating in the 2018 Program Review were:

- Paul Gribik, Pacific Gas & Electric (PG&E)
- Lorenzo Kristov, independent consultant (formerly, CAISO)
- Eugene Litvinov, ISO New England (ISO-NE)
- Richard O'Neill, Federal Energy Regulatory Commission (FERC)
- Paul Sotkiewicz, independent consultant (formerly, PJM)

### *Reviewer Scoring*

Reviewers were asked two questions:

1. How valuable is the research for DOE's R&D program?
2. What (if anything) should be done to improve this research activity?

In response to the first question, reviewers were asked to score each project on a scale of 1-5, with 1 being 'highest value' and 5 being 'low value.' The average score for each presentation is included in the summary section below. Following the meeting, each presenter was provided with their scores and the summary comments provided by the reviewers. A table of the final scoring (from highest to lowest) is included below, followed by summaries of each project reviewed with selected reviewer comments.

| Score | Project | Presenter/PI |
|---|---|---|
| **2.1** | *Models and Strategies for Optimal Demand-Side Management in the Chemical Industries* | Baldea, University of Texas |
| **2.4** | *Management of Risk and Uncertainty through Optimized Cooperation of Transmission System and Microgrids with Responsive Loads* | Anderson, Cornell |
| **2.5** | *Multistage Stochastic Transmission Expansion Algorithm for Wide-Area Planning* | Webster, Penn State |
| **2.9** | *Stochastic Continuous-Time Flexibility of Scheduling and Pricing in Wholesale Electricity Markets* | Parvania, University of Utah |
| **2.9** | *Economical and Engineering Aspects of Proactive Demand Participation* | Yu, UC Riverside |
| **2.9** | *Flexible Service Contracting for Risk Management within Integrated Transmission and Distribution Systems* | Wang, Iowa State |
| **3.1** | *Multi-stage and Multi-timescale Robust Co-optimization Planning for Reliable and Sustainable Power Systems* | Wu, Clarkson |
| **4.1** | *Probability-Based Model for Cost-Effective Integration of Renewables* | Adhikari, VA Tech |

[3] See https://www.netl.doe.gov/business/solicitations/details?title=6ba78cba-b8d5-4c4d-a83e-76fe99fffce7

## Projects Presented for Review in June 2018

### *NETL FOA 1493 Projects*

The following projects are solicited and managed by NETL under FOA 1493.

**Probability-Based Model for Cost-Effective Integration of Renewables**
*Rajendra Adhikari, Virginia Tech*
*Average Rating: 4.1*

| Highest Value (1) | Very Valuable (2) | Valuable (3) | Somewhat Valuable (4) | | Low Value (5) |
|---|---|---|---|---|---|
| | | x | xx | x | x |

The goal of this project is to address two issues for variable generation (1) Effective Load Carrying Capability (ELCC) numbers for resource adequacy (RA) calculations; and (2) production costing analysis based on uncertain renewable energy generation.

To address these issues, Virginia Tech is developing a production costing tool that use probabilistic data for renewable energy sources (both solar PV and wind farms), and treat these as generation candidates in a power system expansion plan. This is different from treating these as negative loads as is the current practice. This work will be carried out in three phases:

- Phase I will involve the development of the proposed expansion planning tool.
- Phase II will involve validation of the proposed tool with a well-known expansion planning tool, (such as WASP), as well as determining all possible alternatives.
- Phase III will involve running of a case study based on a real-world data to show applicability of the proposed tool.

The software tool and algorithm to be developed for this project will be presented in conference and journal publications during each year of the project. Additionally, Virginia Tech team is willing to work with ISOs/RTOs/utilities or wind farm operators to provide necessary training if there is an interest in adopting this software.

**Selected Reviewer Comments:**

- *ISOs do studies of expansion plans even though they are not formally responsible for expansion planning for generation. So it has use. The participants in the ISOs do plan for generation needs so they do expansion planning for cost min & meeting reliability requirements. They need such tools and use existing ones.*
- *Clearly define the advantages of the proposed approach. Compare to other wind models.*
- *Project might be more useful by (a) setting policy-mandated renewable energy targets, so that renewable generation quantity is exogenous and the system has to integrate renewables; (b) incorporating geographic and network aspects of generator locations (network constraints and diversity of solar and wind production); (c) including more diverse resource types with flexibility attributes, including flexible demand. Before the researchers invest greatly in these*

*enhancements, however, they should review existing tools to see what gaps exist to be sure they are addressing a real need.*

**Multistage Stochastic Transmission Expansion Algorithm for Wide-Area Planning**
*Mort Webster, Pennsylvania State University*
*Average Score: 2.5*

| Highest Value (1) | Very Valuable (2) | Valuable (3) | Somewhat Valuable (4) | Low Value (5) |
|---|---|---|---|---|
| x | xx | x | x | |

The overall objective of this project is to develop and demonstrate a computational method for solving the optimal transmission plan under uncertainty in future generation in multiple steps for a large network. The algorithm will be parallelizable to take advantage of high-performance computing networks, and will consist of a linear-programming-based approximate dynamic programming algorithm. This work will be completed in three phases:

- The objective of Phase I is to develop the algorithm and software tools to implement it, validate on a small test network where the optimal transmission plan is known, and to demonstrate on a moderate-sized network (e.g., ERCOT) as a test case.
- The objective of Phase II is to demonstrate the results of the method for a larger system (e.g., WECC), extend to solve for three or more decision stages, and to extend the algorithm to co-optimize generation and transmission.
- The objective of Phase III is to extend the algorithm to use AC optimal power flow to evaluate the proposed lines in each stage, and to conduct a detailed comparison of the results of the new solution algorithm to other methods in use, including robust optimization methods.

The primary expected result of the project is a dramatic reduction in the computation time required to determine the best high-voltage transmission lines to add to the existing grid in the near-term when we do not know where future generation, in particular renewable energy sources, will be located. Improved transmission planning would facilitate reduction in the cost of electricity and enable the integration of greater capacity of renewable generation.

The method to be developed, which would be placed in the public domain and shared freely, would enable ISO/RTOs and other regional organizations to more effectively plan for changes in the coming decades to the power system, and enable them to consider a broader range of alternative investments and possible future scenarios than current methods.

**Selected Reviewer Comments:**

- *Scenario reduction is key to developing efficient algorithms to address transmission expansion planning.*
- *With open retirements and renewables and shifting load setters this could be very impactful. Could work with other planning models. Very promising.*
- *Researchers should look at the CAISO transmission planning process and talk with planners there. The CAISO process is structured to consider alternative renewable generation scenarios based on the procurement plans of the entities procuring long-term renewable PPAs and their*

*regulators. It then identifies "least regrets" transmission projects that will be needed under a most likely "base" scenario and at least one other. It would be useful for the researchers to get input from the planners on whether/how their project could improve what the planners do today.*

**Stochastic Continuous-time Flexibility Scheduling and Pricing in Wholesale Electricity Markets**
*Masood Parvania, University of Utah*
*Average Score: 2.9*

| Highest Value (1) | Very Valuable (2) | | Valuable (3) | Somewhat Valuable (4) | Low Value (5) |
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| | x | x | xx | x | |

In this project, the University of Utah aims to develop a novel stochastic continuous-time unit commitment (UC) model that offers a different approach to sampling the information and decision variables in the wholesale market operation. The proposed UC formulation schedules the optimal continuous-time power trajectories of dispatchable generation resources and electric energy storage (EES) devices to balance the continuous-time variations of load and renewable energy sources (RES), respecting the transmission network constraints.

The proposed UC model reduces the approximation error in describing the continuous-time ramping phenomena in the day-ahead operation, capturing more accurately the essential information available about the load and RES evolution in time, while revealing the potential operational flexibility of resources that have significant impact on the day-ahead market solution, but is not captured by current UC formulation.

This project includes five main tasks:

1. Project Management and Planning.
2. Development of Continuous-time Energy Generation and Storage Scheduling Models.
3. Development of Continuous-time Locational Marginal Prices of Energy Generation and Storage.
4. Development of Stochastic Continuous-time UC Model for Wholesale Markets Operation.
5. Evaluation of Accuracy and Computational Complexity of Stochastic Continuous-time UC.

Deliverables include technical progress reports and one final report, as well as journal papers, conference presentations and papers, and a PhD dissertation. Project PIs will provide detailed briefings for presentation to DOE/NETL.

**Selected Reviewer Comments:**

- *Researchers should explain why scheduling the "optimal continuous-time power trajectories" is a good idea or needed improvement, what exactly would define "optimal" in this context, and how an ISO/RTO market operator would practically incorporate this into its market dispatch.*
- *As DA market is a financial market, it would be more appropriate to use the proposed method for real-time UC. How does the proposed approach compare to current practice of using fast start pricing units -> "wait and see". How is wind generation represented on sub-hourly basis? How does the quality of DA profile approximating quality affect the results?*

- *All the ISOs/RTOs have a day-ahead market structure featuring a day-ahead market that clears supply against bid-in demand, which is essentially a financial market and need not match the ISO's or anyone else's forecast of expected load and renewable energy production for the next day. This day-ahead market clearing is followed by a residual or reliability unit commitment ("RUC") that's intended to commit additional resources if needed to meet the ISO's forecast of net demand for the next day. One idea being explored in some ISOs/RTOs is to combine the day-ahead market clearing with the RUC into a single integrated process, rather than run two sequential processes as it done today. The researchers may want to consider (in consultation with ISO/RTO market designers) whether their methodology could be useful in formulating such an integrated process.*

## *Reliability & Markets Projects*

The following projects are funded under DOE/OE's Reliability and Markets activity, and are solicited and managed by NETL.

**Models and Strategies for Optimal Demand Side Management in the Chemical Industries**
*Michael Baldea, University of Texas at Austin*
*Average Score: 2.1*

| Highest Value (1) | | Very Valuable (2) | Valuable (3) | Somewhat Valuable (4) | Low Value (5) |
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University of Texas (UT) aims to exploit the Demand Response (DR) potential of industry, focusing on Dispatchable Demand Response (DDR) and Non-Dispatchable Demand Response (NDDR) of chemical, petrochemical, and refining processes—collectively referred to as "chemical processes." Chemical processes account for about 30% of industrial electricity consumption, and have significant DR capabilities. Yet, estimates put the actual exploited DR potential at about 20-50% of the available capacity, leaving an enormous portion untapped. UT's project will remedy this situation by addressing the following specific objectives:

1. Characterize the DR-relevant dynamics of chemical and petrochemical processes.
2. Develop models and DR scheduling optimization problem formulations that are amenable to real-time solution.
3. Create representations of the DR behavior of chemical process that can be embedded in power system models.

The research will to lead to generic tools and methodologies that are applicable to all manufacturing facilities in the chemical and petrochemical sector, and can be extended to other industries. UT will apply and validate its findings by collaborating with an industrial partner from the energy-intensive air separation sector. In addition to the benefits provided to the grid, UT's preliminary results suggest that engaging in DR programs can save up to 3% of operating cost in this sector, compared to operating at a constant production rate with fixed energy prices. Significant additional income can be generated from providing ancillary services, such as responsive reserve.

**Selected Reviewer Comments:**

- *Very important research. More funding needed. Can this process participate as price-responsive demand and participate as a reserve in the real-time market and day-ahead market?*
- *Improves ability of an ISO participant to optimize complex power utilization process based on price forecast and process constraints. ISO most likely could not control DR given the complexity and solution time. But there appears to be value based on participant controlling plant based on its forecasts.*
- *Expanding the dynamic capabilities of large-scale electricity users will be of increasing value as the generating capacity on the electric system shifts to more renewables.*

**Economical and Engineering Aspects of Proactive Demand Participation**
*Nanpeng Yu, University of California at Riverside*
*Average Score: 2.9*

| Highest Value (1) | Very Valuable (2) | Valuable (3) | Somewhat Valuable (4) | | Low Value (5) |
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The goal of this project is to perform critically needed research related to the retail market development and impact assessment of demand-side participation and its integration into the wholesale market. Specifically, the project objectives are as follows:

1. Develop and validate centralized and decentralized control algorithms at the distribution system level to coordinate the operations of heterogeneous flexible loads and Distributed Energy Resources (DERs);
2. Develop algorithms at the customer level which will enable proactive consumers to participate in the power system resource dispatch and price formation; and
3. Evaluate the impacts of demand-side participation on power system operations.

The proposed control frameworks and algorithms consider both engineering and economical aspects of proactive demand-side participation. Moreover, the proposed demand-side participation markets will be validated using small-scale campus demonstrations and large-scale computer simulations. Using rigorous mathematical analysis and real-world demonstrations, this proposal is aimed at providing a comprehensive framework for formulating, validating, and comparing demand-side participation markets.

By developing and evaluating demand-side participation for both centralized and decentralized control structures, while considering both engineering and economical aspects, this project addresses both theoretical and practical issues of demand-side participation. The project deliverables will enable high levels of penetration of flexible loads and DER economically through (1) transformation of grid operation from load-following to supply-following; (2) active participation of flexible loads and DERs; and (3) efficient distribution system management with centralized and decentralized coordination of largescale, heterogeneous and proactive customers.

The experience gained through control algorithm development, large-scale simulation, and small-scale demonstration will provide valuable guidance to ISO and electric utilities in policy making and in

designing distribution system operator managed markets. The technologies developed will remove the barriers to further penetration of demand-side participation and promote the integration of DERs such as PVs, PHEVs, and energy storage units. By jointly optimizing the centralized power plants and large-scale heterogeneous flexible loads and DERs, the proposed proactive demand-side participation scheme will be a critical tool for the mitigation of supply intermittency and for achieving a higher energy efficiency in the electricity markets.

**Selected Reviewer Comments:**

- *This research is asking important and timely questions that can help inform architecture of the more DER-based and decentralized power system that is evolving. In particular, there is a need for practical, realistic comparisons of two much-debated paradigms: the centralized approach in which a DSO aggregates DERs (in this case responsive buildings) to provide services to the ISO/RTO while ensuring feasibility on the distribution system, versus a decentralized approach whereby services are transacted among the responsive buildings in peer-to-peer fashion, with a central agent enforcing distribution feasibility.*
- *Optimizing operations on a DSO's system is an important problem that is still open. Running opt on single feeder seems overly restrictive.*
- *Should the objective be to minimize consumption, minimize costs or maximize value? How does this differ in performance and robustness from other approaches? For example, the penalties for reactive power. DSO suggests an alternative? How is this done?*

**Multi-Stage and Multi-Timescale Robust Co-Optimization Planning for Reliable and Sustainable Power Systems**
*Lei Wu, Clarkson University*
*Average Score: 3.1*

| Highest Value (1) | Very Valuable (2) | Valuable (3) | Somewhat Valuable (4) | Low Value (5) |
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The objective of this project is to develop a sophisticated decision tool called Multi-stage and Multi-timescale robust Co-Optimization Planning (MMCOP). This tool will help planner's facilitate generation and transmission co-optimization planning of emerging power systems. MMCOP will represent an efficient decision tool for augmenting the existing power utility capabilities to support collaborative planning, analysis, and implementation of emerging power systems and to effectively mitigate risks and uncertainties in both short-term operation dynamics and long-term policy/technology changes.

MMCOP will assist power market participants in vertically integrated utilities and regulatory agencies to analyze economics, reliability, and sustainability of various options for transmission upgrades along with planning new generation and transmission facilities. MMCOP can also be used by industry for teaching and training next-generation power system planners and operators for analyzing renewable energy integration uncertainties, identifying critical spots in power system operation, analyzing power system vulnerabilities, and providing credible decisions for examining operation and planning options. Upon the completion of the proposed study, a prototype version of MMCOP will be made available to DOE including a publicly available set of data, the proposed MMCOP features, and supporting documents.

The project will generate direct and profound impacts on the energy reliability and sustainability to the society through helping electricity grid planners and operators better plan additional resources, manage available resources, achieve higher reliability standards, and increase renewable energy penetration, which otherwise may not have been explored due to the lack of analytical tools for simultaneously addressing co-optimization of generation and transmission assets under uncertain environments. The project will increase public awareness and understanding of the complexity of power system planning, and appeal to researchers and educators with interests in power systems-based research and education.

**Selected Reviewer Comments:**

- *Longer term transmission models are going to become increasingly important.*
- *The problem is important but it is hard to tell what advance is being achieved. The formulation and solution approach seems similar to other approaches.*
- *The presentation of this project needs to start with an intuitive example that focuses on a more narrow objective, describes the current approach to that objective and why it's lacking, and then shows how this project will bring improvements that meet a practical need. Otherwise the level of abstraction and the scope of stated objectives are too great to allow a determination of whether and how the project will achieve its goals.*

**Management of Risk and Uncertainty through Optimized Cooperation of Transmission System and Microgrids with Responsive Loads**
*Lindsay Anderson, Cornell University*
*Average Score: 2.4*

| Highest Value (1) | Very Valuable (2) | Valuable (3) | Somewhat Valuable (4) | Low Value (5) |
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| x | xx | x | x | |

Cornell University's overarching objective of this project is the development of a scalable co-optimization solution for transmission and microgrids that includes demand response, storage, and renewable resources. This solution will incorporate realistic modeling and integration of responsive demand in the low-voltage system, to assist in management of uncertainty in the transmission system induced by renewable generation sources and contingencies. To achieve this objective, the project will proceed through four overlapping phases:

- Phase I will focus on new optimization and statistical approaches to properly characterize the uncertainty, spatial correlation, and serial correlation of renewables, including solar and wind.
- Phase II will be conducted in parallel with Phase I, which will identify and develop viable strategies and models for integrating demand response in the low-voltage grid and evaluating potential applications to mitigate risk and uncertainty in the grid.
- In Phase III of the project, the results of Phases I and II will be incorporated to examine the interaction between the high voltage and low voltage grid, with the objective of identifying synergistic strategies that will benefit the combined systems.
- The first three phases will then support Phase IV, which will develop the overall co-optimization framework that includes transmission and distribution systems with renewables, demand response, and storage capabilities. Solution methods will be implemented and used to conduct numerical case studies on various test systems.

Several outcomes are expected from the proposed research:

1. A performance comparison of renewable output forecasting/scenario generation methods.
2. A comprehensive framework for the interplay between the micro and macro grids.
3. An analysis of the impacts of different demand response strategies on power grid operation.
4. An analysis of the performance of combined stochastic decomposition methods to tackle the integration problem of responsive demand in the low voltage system.

**Selected Reviewer Comments:**

- *Coordinating microgrids with transmission system operations is a problem of great interest.*
- *Consider co-optimization vs coordination with different objective function on different levels.*
- *Nice work comparing Distribution and microgrid systems and showing deferred benefits and costs.*

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**Flexible Service Contracting for Risk Management within Integrated Transmission and Distribution Systems**

*Zhaoyu Wang, Iowa State University Science & Tech*
*Average Score: 2.9*

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| Highest Value (1) | Very Valuable (2) | Valuable (3) | Somewhat Valuable (4) | Low Value (5) |
|---|---|---|---|---|
| x | x | x x | | x |

Iowa State University's project aims to investigate the ability of "distribution resource aggregators" making use of innovative types of "swing contracts" to ensure the availability and real-time provision of flexible services from distribution resources (DRs) in order to facilitate the robust efficient management of risks and uncertainties for integrated transmission and distribution (T&D) systems. A Distribution Resource Aggregator (DRA) is any entity capable of providing dispatchable real-time services from DRs. A swing contract is a contract whose terms permit a diverse spectrum of services to be offered as ranges of values rather than as point values, thus permitting greater flexibility in their real-time implementation.

The specific objectives of this project are:

1. Market-based net service scheduling algorithms for various types of DRs.
2. A new methodology permitting DRAs to combine individual DR net service schedules into aggregate net service schedules permitting flexible services to be harnessed from DRs in valuable and usable forms.
3. A new market design based on swing contracting that permits DRAs to make use of aggregate net service schedules in order to offer both advance availability and real-time provision of flexible services in support of wholesale power market operations, with appropriate separate market-based compensation of availability and real-time performance.

The outcome of this project will be a new business model that will provide a new robust-control approach to the management of integrated T&D system risks/uncertainties that does not require detailed scenario and probability specifications or reliance on overly conservative worst-case designs.

Iowa State University is proposing to partner with nine sub-recipients. Of these, Iowa Energy Center, is providing cost share in the form of tuition, stipend, fringe and other associated costs dealing with student and faculty work on this project. The Energy Center is administered through the university. The sub-recipients' roles are technical advisors and providing data.

**Selected Reviewer Comments:**

- *The problem of acquiring flexibility of operating resources to manage risk is important.*
- *This project gets the prize for pushing the boundaries of the known power system paradigms, thinking ahead to a high-DER future and doing so in enough detail that it can be modeled and experimented with. The important context for this (in my own view, not completely explicit in the project presentation) is the need for new pricing, contracting and business models to replace ones that seem to be reaching their limits of usefulness. For example: increasing amounts of rooftop solar PV undermine the traditional use of volumetric (kWh) rates to recover T and D infrastructure costs; increasing amounts of utility-scale zero-marginal-cost renewable generation drive down wholesale spot market prices and revenues; increasing amounts of DERs drive needs for grid modernization and new UDC functional capabilities, but we haven't figured out methods to align charges for these services with cost causation; and at the retail level, fixed TOU period rates aren't granular enough to align the behavior of grid users with grid operational requirements. With the growth of renewable generation and DER, there is increasing need for grid services from non-conventional resource types, but the commercial framework for these is at an early state of development.*
- *This could be good but using pay-as-bid options contracts does not encourage truthful revelation. Mechanism is far more complex than needed using these contracts.*