The Department of Energy
Office of Energy Efficiency and Renewable Energy
BUILDING TECHNOLOGIES OFFICE

Technical Meeting on the *Reference Guide for a Transaction-Based Building Controls Framework: Unlocking energy efficiency and grid service values for building energy consumers*

Meeting Purpose: The purpose of this meeting is to review with industry stakeholders a recently published report articulating the U.S. Department of Energy's Building Technologies Office (DOE-BTO) vision for a transaction-rich buildings energy ecosystem that will unlock the energy efficiency and grid services values and deliver them to consumers. Developed for DOE-BTO by Pacific Northwest National Laboratory, the *Reference Guide for a Transaction- Based Building Controls Framework* articulates prototypical use cases for transactions that reveal value opportunities for consumers in terms of energy and efficiency services for the buildings they own and occupy, from their response to energy markets and the provision of services to the grid, and for meeting needs of society as a whole. It illustrates the range of such transactions for homes and buildings, and describes typical networks and the basic properties of a generic building "node" that supports such exchanges within them.

DOE-BTO's goal is to incubate these concepts in a systematic way so those parties interested in deploying transactive energy systems, or similar solutions, are in agreement as to the basic attributes and architecture of the solution. We invite interested parties such as building operators, HVAC control vendors, utilities and others that have shown a willingness to explore or experiment with transactive energy concepts and installations to comment on DOE-BTP's vision for this new energy ecosystem and suggest critical aspects or dimensions that the Reference Guide should address or improve.

Summary: Technological advances in monitoring, control and sensor equipment are opening up new possibilities across the energy sector. Real-time information is improving the efficiency of the grid, making the energy use in homes and buildings (hereafter buildings) transparent and supporting more than just energy and energy cost savings for building owners and building operators. Added to these developments is the proliferation of photovoltaic systems, appliances and equipment with embedded intelligence and communications capability, small-scale natural gas generators as well as other distributed generation sources; in combination, these technologies afford building owners additional opportunities to reduce their energy costs and increase the reliability of their supply. Yet an even larger opportunity is emerging with the potential to coordinate smart assets and new generation within buildings, across different buildings, between buildings and the grid, between buildings and third-party providers and even beyond. This opportunity will incorporate previously untapped assets, such as electric vehicles.

Using a transactional framework to coordinate a wide range of different entities has the potential to provide substantial energy savings and new cash flow opportunities to participants, effectively turning currently distributed, separate and passive assets into coordinated engines of efficiency and productivity. This report lays out the concept of the transactional framework that will enable the integration of distributed assets and loads into the energy system of the future. It contains examples of the transactions that would

occur in such an environment, and describes potential benefits to the customer, whether it be a building owner, operator, tenant, or the driver of an electric vehicle.

In this technical meeting, participants will discuss the proposed transactive energy framework described in the Reference Guide, as well as discuss and identify potential use cases – especially for building owners and operators – that could be supported by adopting such a framework. The desired outcome from the meeting is to identify a framework that is open and scalable at the national level.

Logistics Information

The meeting will be held in the Maxwell Conference Room of the Energy Systems Integration Facility (ESIF) at the National Renewable Energy Laboratory, in Golden Colorado (as indicated on the map at the end of the book). However, guests must first go to the Visitors Center to check in. Guests should park at the Visitor Center Lot.

If you have a multi-day visitor badge, you need to show your visitor badge at the Site Entrance Building, and then you can go directly to the ESIF.

If it is your first day at NREL, you will need to go to the Site Entrance Building to verify that you are on the expected visitor list, then proceed to the Research Support Facility and get your visitor badge. You will then be directed to the ESIF. Someone will be at the ESIF lobby door to let meeting participants in and take them to the conference room.

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Additional Information

*Coffee, tea and a working lunch will be provided during the meeting

For more information about the Energy Systems Integration Facility please visit:
http://www.nrel.gov/esi/esif.html

AGENDA

7:00 AM Registration, continental breakfast, coffee

7:30 AM Introductions and purpose (Joe Hagerman, DOE)

8:00 AM Vision and precedent

- Transactive Energy Markets and Grid Services: Field Demonstrations and the GridWise Architecture Council's Roadmap (Steve Widergren, PNNL)
- Rooftop A/C Unit Transactional Network, a DOE/BTO research project (George Hernandez, PNNL)
- Specification of Transactive Control for a Microgrid (Erich Gunther, Enernex)

9:00 AM Break

9:15 AM Overview of the Reference Guide (Rob Pratt, PNNL)

- Categories of services
- Transactive networks, nodes, and information model
- Overview of use cases

9:45 AM Illustrative Buildings/Consumer Use Cases (Ebony Mayhorn, PNNL)

10:30AM DOE/EERE's Multi-Year Plan for the Grid Integration Initiative (Kevin Lynn, DOE)

11:00 AM Facilitated discussion/Working Lunch

1:00 PM Adjourn formal meeting

1:15PM Continue informal discussions (Optional) Facilitator

3:00 PM Conclude Meeting

Reference Guide for a Transaction-Based Building Controls Framework
Draft Report prepared for the Building Technologies Office,
U.S. Department of Energy

S Somasundaram, RG Pratt, ET Mayhorn, et al. Pacific Northwest National Laboratory

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Executive Summary

Buildings consume over 40% of the total energy in the U.S. and over 70% of the nation's total electricity today. Since the mid-1970s, more concerted efforts to increase energy efficiency in commercial and residential buildings have led to substantial reductions in energy use per square foot. Yet while new buildings offer opportunities to builders and operators to take advantage of state-of-the-art energy efficient technologies and know-how, the existing building stock would require comprehensive, "deep" retrofits to achieve similar savings.

A new building diagnostic and controls revolution is underway within the buildings sector, primarily in the commercial buildings sector. In it, application-based systems are presenting an opportunity to implement strategies in which highly "optimized" control capable of constantly increasing efficiency levels while improving resource allocation (both local and global) is an inherent attribute of the strategy rather than an explicitly programmed feature. These building controls and algorithms can also be part of deep retrofits in existing buildings that result in energy savings not just today, but also ensure persistent energy savings over the life of the buildings through improved operation and maintenance. At the same time, the introduction of sensors and controls, as well as information technology and communication protocols between the buildings and the electric grid, has led to digitized sensing, metering, communication and controls. This "smart grid" revolution is adding intelligence to the energy ecosystem, allowing power generators and grid operators to see the system at unprecedented levels of granularity. Added to these developments is the proliferation of photovoltaic cells, small-scale natural gas generators, as well as other distributed generation sources; giving building owners additional opportunities to reduce their energy costs and increase the reliability of their supply.

Using these technological advances and careful coordination, buildings could provide valuable comfort and productivity services to building owners and occupants, such as automatically and continuously improving building operations and maintenance, while at the same time reducing energy costs. Ultimately, buildings could even act as dispatchable assets, providing services to the power system, such as absorbing the fluctuations of intermittent renewable energy.

This document proposes a framework concept to achieve the objectives of raising buildings' efficiency and energy savings potential benefitting building owners and operators. We call it a transaction-based framework, wherein mutually-beneficial and cost-effective market-based transactions can be enabled between multiple players across different domains. Transaction-based building controls are one part of the transactional energy framework. While these controls realize benefits by enabling automatic, market-based intra-building efficiency optimizations, the transactional energy framework provides similar benefits using the same market-based structure, yet on a larger scale and beyond just buildings, to the society at large.

The premise of transaction-based control is that interactions between various components in a complex energy system can be controlled by negotiating immediate and contingent contracts on a regular basis in lieu of or in addition to the conventional command and control pattern. In the buildings arena, transaction-based controls would bring an array of changes. Existing buildings would be retrofit with transaction-based automatic fault detection and diagnostics and controls technologies on various types of commercial equipment. They would provide insights into current and projected energy use, comfort preferences of tenants or owners, and generation capacity from distributed resources. The added technology base would fulfill two main purposes. Owners and tenants could benefit from the diagnostics, commissioning and retuning capabilities in several ways. The sensing and metering technology could, for example, provide building-specific advice to owners, outlining return on investments and timescales for efficiency upgrades, such as new equipment or motors, or calculate and point to the amount of energy wasted per year. Transaction-based controls could also provide specific advice for occupants willing to trade their comfort and convenience levels against a monetary gain by, for example, adjusting their smart thermostat settings to let the temperature fluctuate within a pre-determined band and getting compensated for the potential change to their comfort level. Unlocking the vast resource of trading comfort levels at a certain cost is one of the key value propositions the transaction-based energy system engenders.

In general, using a transactional framework to coordinate currently disparate entities has the potential to provide substantial energy savings and new cash flow opportunities to buildings, effectively turning currently disparate and passive assets into coordinated engines of efficiency and productivity. The framework offers the opportunity to extract services out of loads and assets that previously did not exist; delivering building owners targeted benefits while enabling ancillary benefits, such as reduced energy costs, reduced energy use and reduced emissions to society as a whole.

This document discusses a non-exhaustive, but representative set of exchangeable products, services, and rights in the context of four major types of transactional interactions: 1) end-user services, 2) energy market services, 3) grid services, and 4) societal services. End-user services include building diagnostics and valuations, which support the operations and maintenance of end-use assets and enhance overall customer comfort and convenience. Energy market services support the efficient utilization of resources and assets by helping customers modify their energy consumption behavior through mechanisms such as time-of-use and real-time pricing. Grid services could include ancillary or regulatory services that buildings could provide using transactive mechanisms. Lastly, societal services could include participation in energy efficiency or emissions cap-and-trade markets using transactive mechanisms.

The document then describes the services nodal network that will help researchers and private vendors develop solutions that can be deployed at a large scale across the various participating domains, and ensure that such solutions are compatible and interoperable. A general framework and set of communication protocols that support interoperability are outlined. Listing real-world examples, this reference guide describes the network topology of participating logical and physical nodes and the communication interfaces between them.

The document is complemented by four chapters corresponding to each of the four service categories described above. Each of the four chapters contain separate groups of comprehensive use cases of transactive energy, including the timescales of transactions, the needed equipment and technology, the benefits for buildings, the grid, efficiency gains and renewable energy integration, and outlines contracts and regulations and current examples of these transactions.

Vision and Precedent

Transactive Energy Markets and Grid Services: Field Demonstrations and the GridWise Architecture Council's Roadmap – Steve Widergren

How can low cost computation platforms and ubiquitous communications change the way we manage and operate the electric system? To address this question, consider expanding the investments in intelligence at the high energy portions of the system into the devices and systems in the distribution level. The integration of technology and the number of interactions leaps by orders of magnitude. Next consider the growing capabilities of building automation and smart end-use systems. The vast numbers of devices and systems at the fringe of the grid pose an enormous challenge for operations using classical modeling and optimization techniques. Beyond that, end users are electricity players that are in charge of their own complex domains and not slaves of electric grid masters. As automation acts on behalf of their owners, these intelligent agents need to act more socially and coordinate their actions in a participatory framework. These notions lead one to consider decentralized decision-making approaches. One such approach uses software agents to broker fee-for-service agreements. A collective version of this involves the running of an energy market.

Developing ideas along these lines, PNNL lead architecture, simulation, and demonstration projects that support the idea of engaging end-use resources based on the contributions of their local decisions. The first project was the Olympic Peninsula demonstration. Here roughly 100 homes and a few distributed generators participated in a 5 minute retail energy market. Subsequently the American Recovery and Reinvestment Act of 2009 funded a similar project with AEP Ohio's gridSMART® Real-time Pricing demonstration to engage nearly 200 homes in a larger and refined version of this market, while the Pacific Northwest Smart Grid Demonstration project developed a transactive approach for engaging distributed energy resources at the lower levels of the system and integrating their response into the transmission level, helping to resolve challenges of flow constraints and variable renewable resource integration.

In parallel with these efforts, the GridWise Architecture Council (GWAC), a group of smart grid experts representing the major electric system stakeholders, initiated activities to enable the high degree of connectivity envisaged in a smart electric system. This work has resulted in emphasizing the importance of interoperability to address system integration issues. Embedded in the interoperability philosophy is the simplicity of integration and robustness to system evolution that can come from decentralized control approaches, such as transactive control. The GWAC has spent the last couple of years developing a framework for transactive energy, and more recently has embarked on a roadmap for promulgating transactive approaches into electric system operations.

This talk introduces the transactive mechanisms used in the demonstration projects and lessons learned, and reviews the progress made by GWAC and its affiliates on a transactive energy framework and roadmap.

Steve Widergren contributes to new solutions for reliable operation of electric power systems. Common throughout his career is the application of information technology to power engineering problems including, simulation, control, and system integration. He is a principal engineer at Pacific Northwest National Laboratory where he directs electric power projects and supports the U.S. Department of Energy. He is a member of the board and past Plenary Chair for the Smart Grid Interoperability Panel and was also the founding administrator for the GridWise Architecture Council – both groups formed with the mission to enable interoperability of automated systems related to the electric system. Prior to joining the Laboratory, Mr. Widergren worked in industry for an electricity control center supplier, and electric utility service providers. In these positions, he engineered and managed energy management systems products for electric power operations and supported power system computer applications, including information modeling, SCADA systems, and power system reliability assessment tools. He received his BS and MS degrees in electrical engineering from the University of California, Berkeley, and is an active member of IEEE.

Rooftop A/C Unit Transactional Network, a DOE/BTO research project – George Hernandez

Today's buildings do not participate significantly in the energy market or provide services to power system operators. However, new smart grid technologies are creating a significant potential for buildings to participate in energy markets by providing ancillary services to power system operators. Communication networks and advanced control systems are a necessary enabler of this new potential, and the proposed research provides building owners with information needed to invest in the improvement of their communication and control capabilities. First-year proof-of-concept with existing tools and building systems is needed to establish a baseline of potential savings in out-year deployment.

To do that, DOE's Building Technologies Office is funding a project that will deliver a 'Transactional Network that supports energy, operational and financial transactions initially between roof top units (RTUs), between RTUs and the electric power grid using applications, or 'agents' that reside either on the equipment, on local building controllers or in the Cloud.

The purpose of this project is to demonstrate and propagate an open source, open architecture platform that enables a variety of site/equipment specific applications to be applied in a cost effective and scalable way. This will lower the cost of entry for both existing and new service providers as the data transport or information exchange typically required for operational and energy related products and services will be ubiquitous and interoperable.

The initial target market is all existing packaged air conditioners and heat pumps that are installed on commercial buildings. These units contribute to 60% of air-conditioning consumption, which is roughly 571 trillion Btus of site electricity and 1.8 quads of source energy annually.

The Transactional Network project scope is currently being expanded to include supermarket refrigeration, but it is expected that as the platform matures, its applicability will be for the residential and light industrial markets as well.

George Hernandez joined PNNL in 2009 and works in the Building Energy Controls group. Mr. Hernandez is a Staff Scientist and senior demand side management professional with innovative and detail-oriented knowledge to develop and produce successful programs that deliver products and services to the commercial and industrial energy marketplace. Mr. Hernandez is distinguished by exceptional execution skills that enable efficient concept to product delivery. Currently, Mr. Hernandez is on detail at the Department of Energy as a Technical Advisor specifically in the area of Sensor and Controls. While at DOE, he has co-authored the High Performance RTU Challenge, the Buildings Performance Database, the

Low Cost Wireless Metering Challenge, Energy Information Handbook, the Portable Sensor Suitcase, Open Source Small Building Control System, and the Transactional Network project. Mr. Hernandez has extensive knowledge, skills, and capabilities derived from a substantial career in demand side utility management across a wide variety of commercial and industrial sectors and utilities as both a corporate employee and an independent consultant. Mr. Hernandez received his BS in Mechanical Engineering from California State University and his Masters in Mechanical Engineering from The University of California at Berkeley. He is a Licensed Professional Engineer (PE) by the State of California.

Specification of Transactive Control for a Microgrid – Erich Gunther

Transactive Energy does not necessarily have to involve significant regulatory change, the development of new markets, or even interaction with existing markets. In its simplest form, transactive energy can be implemented in a large building or campus environment to manage energy sources, simple and complex electrical loads, manage reliability, quality, and building occupant comfort and productivity. This basic implementation of transactive energy – probably more correctly called transactive control – can serve as a model for how a wide area implementation of transactive energy that does involve a market might evolve. In this presentation, a case study for the design of a large green field corporate campus will be described that utilizes the concepts of transactive energy. The core business drivers for the design are described and an example scenario of how such a system might behave to optimize itself to address changing renewable energy supply characteristics.

Erich W. Gunther, IEEE Fellow, Chairman, CTO and Co-founder of EnerNex

Erich has more than 30 years of experience in the design and development of innovative solutions to a wide array of power system problems, most notably in ways to take advantage of communications networks and technology to improve the efficiency, operating practices, and security of the electric power system. Erich received his BSEE from Gannon University in 1980 and his Master of Engineering degree in Electric Power Engineering from Rensselaer Polytechnic Institute in 1984.

In 2011 Erich was recognized for his career long work in the field of electric power quality by being named an IEEE Fellow. In 2004, Erich was appointed to the U.S. Department of Energy (DOE) GridWise Architecture Council, served as its Chairman from 2010-2012 and continues to actively participate as member and chairman emeritus. The council is a team of experts assembled to articulate the guiding principles that constitute the architecture of a future, highly interoperable, intelligent, energy system. Erich also serves as the chairman of the board for the Utility Communication Architecture International Users Group (UCAIug), is a member of the IEEE Power and Energy Society governing board, a member of the Smart Grid Interoperability Panel board of directors, and the UTC Smart Networks Council board of directors.

Erich is a licensed private helicopter and instrument rated fixed wing airplane pilot and aircraft owner (N1334X), commercial radiotelephone and ship radar operator, an amateur radio operator (WG3Q), and an accomplished home brewer.

Overview of the Reference Guide: Categories of services, transactive networks, nodes, and information model, overview of use cases – Rob Pratt

This presentation will provide an introduction and overview to the *Reference Guide to a Transaction-Based Building Controls Framework*. It describes a vision for a transaction-rich buildings energy ecosystem that will:

- Improve the energy and service performance of buildings through diagnostics, advice, better controls, making cost/comfort tradeoffs explicit and user-defined, and the integration of services from third-party providers.
- Provide the communication, intelligence, and controls platforms needed for building to provide a wide variety of services to the electric power grid that improve its reliability, cost efficiency, and help integrate renewable generation (and to earn credits or incentives in the process).

The general notion behind the framework is to extend the revolution in information technology to the buildings environment, with the organizing principle of using financial transactions as the fundamental basis for control within buildings, and exchanges of service between buildings and between buildings and the electric power grid and third parties. This will enable a rich environment for providing innovative services of all types.

The presentation will define what we mean by a transaction, and describe four broad categories of transaction-based services. It then lists a number of example use cases for each category. These are not intended to be definitive; rather they are designed to tangibly illustrate the range of potential services that would be enabled. To further illustrate transactive energy concepts, several types of transaction networks are be mapped to their associated physical systems and/or the energy exchanges involved. The proposed role and basic functionality of a generic node in such networks is then described. Finally, the broad outline of an information model for a transaction is described as the proposed high-level interoperability framework for transactive networks.

Rob Pratt, Senior Staff Scientist at Pacific Northwest National Laboratory, is one of the early thought leaders behind the smart grid, focused on an information-rich future for the power grid. He currently manages Pacific Northwest National Laboratory's (PNNL's) Distribution and Demand Response Business Line for PNNL. He leads a team studying communications and operational architectures, advanced control technology, and simulation of the combined engineering and economic aspects of the future grid. Rob also led the PNNL initiative that commissioned the Electricity Infrastructure Operations Center – a fully-equipped grid control center with live data resources from around the U.S. It is a unique technology development, valuation, training, and technology transfer platform used for advanced grid applications and situational awareness.

Prior to his involvement in smart grid in 1999, Rob's primary research activities focused was the development of automated diagnostics and commissioning for commercial buildings, and on analysis of metered building end-use data for utility planning and evaluation applications. Prior to coming to PNNL, Rob had his own mechanical engineering consulting company specializing in passive solar buildings and mechanical system design. Rob has a M.S. in Mechanical Engineering from Colorado State and has been a scientist at PNNL since 1985.

Illustrative Buildings/Consumer Use Cases – Ebony Mayhorn

A new revolution is underway to transition to a new energy ecosystem characterized by a more distributed power system, blurring currently clear lines between producers and users of power. The Buildings-Grid Integration Reference document introduces a transaction-based framework that would seamlessly integrate distributed generation ant other smart assets (e.g. responsive loads, EVs, etc.). The idea is to be able to control and connect assets and loads, within buildings, between buildings, as well as, between buildings, the grid and third-party providers. In addition, the framework will enable participants to transact in ways that support various micro and macro energy objectives, while adding value to building owners/customers and other third parties in the new energy ecosystem. On the micro scale, these objectives include more efficient buildings and energy savings. On the macro level, more efficient buildings will lead to reduced greenhouse gas emissions, increased grid reliability, an increased share of clean energy sources, the creation of clean energy jobs, etc.

This talk will focus on a set of illustrative examples of potential implementations within the framework. These use cases are envisioned to outline the benefits of transactional energy to stakeholders in the energy ecosystem, define essential components that would enable transactions in the energy and energy-related domains, and give practical examples to the broader community of electric power and buildings technology organizations, researchers, manufacturers, standards- and codes-developing organizations, and system and technology vendors to spur innovation.

Ebony Mayhorn obtained a BS in Mechanical Engineering from Prairie View A&M University in 2005, and then earned a M.E. in the same major in 2007 from Texas A&M University. She is now Research Engineer at PNNL, as well as, an Electrical Engineering Ph.D. candidate with focus in the area of Power Systems at Texas A&M University. Since joining PNNL, she has contributed to research related to microgrid resource coordination, demand response characteristics of home appliances, and Building-to-Grid Integration.

DOE/EERE's Multi-year Plan for Grid Integration Initiative – Kevin Lynn

The Grid Integration Initiative is one of several DOE/EERE high-impact internal crosscutting initiatives in the FY 2015 Budget Request to Congress that are closely coordinated across EERE's efficiency and renewable programs. The goal of these initiatives is to break down silos and maximize the coordination and impact of taxpayer investment. The Grid Integration Initiative focuses on EERE-specific activities that enable seamless integration of EERE technologies – including smart and efficient buildings and equipment into the electrical grid at scale. In coordination with DOE's cross-cutting grid modernization efforts, EERE's activities target the development of next-generation technologies and solutions that will enable smarter, interactive systems for intermittent and distributed EERE technologies that better enable integration into the grid in a safe, reliable, and cost-effective manner. EERE has developed a draft multi-year strategic plan to guide and prioritize the Initiative's activities, and in February of this year, EERE hosted a workshop to review the draft plan with industry, universities, utilities, and other stakeholders to help identify challenges, opportunities and activities at the building, campus, distribution, and regional scales. The manager of the Initiative, Kevin Lynn, will provide an overview of the Initiative and multi-year plan during this session.

Kevin Lynn works for the Department of Energy as the Director of Energy Systems Integration within the Energy Efficiency and Renewable Energy office. In that position, he coordinates all cross-organizational activities focused on resolving the technical, market, and regulatory challenges that limit the integration of renewable electricity generation technologies, electric vehicles, demand response, and other technologies into the grid in a safe, reliable, and cost effective manner.

Previously he worked for the Department of Energy as part of the SunShot Initiative, a national initiative to enable the widespread adoption of solar energy. There he was the Program Manager of the Systems Integration team supporting research in grid integration, PV system performance and reliability, and balance of system hardware. During that time he developed funding opportunities in grid integration, balance of system hardware, plug and play technologies, and solar forecasting.

Kevin also worked as a Senior Research Engineer at the Florida Solar Energy Center (FSEC). There he was the principal investigator on several projects including the Southeast Regional Experiment Station, a project with the Department of Energy focused on photovoltaic system research.

Facilitated Discussion Questions

Q1: Thinking in terms of the earlier presentation, are you aware of other examples/demonstrations that would be considered transactional?

Q2: What types of services are to be transacted?

Q3: What other types of services are to be transacted?

Q4: Would you be able to use or provide this concept? If yes, how do you envision using it? If not, what does it not provide?

Q5: What should be the role and policy of government and national labs?