Transactive Energy Workshop Proceedings

Prepared by

The GridWise Architecture Council

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About this Document

The GridWise Architecture Council was formed by the U.S. Department of Energy to promote and enable ***interoperability*** among the many entities that interact with the electric power system. This balanced team of industry representatives proposes principles for the development of interoperability concepts and standards. The Council provides industry guidance and tools that make it an available resource for smart grid implementations. In the spirit of advancing interoperability of an ecosystem of smart grid devices and systems, this document presents a model for evaluating the maturity of the artifacts and processes that specify the agreement of parties to collaborate across an information exchange interface. You are expected to have a solid understanding of large, complex system integration concepts and experience in dealing with software component interoperation. Those without this technical background should read the *Executive Summary* for a description of the purpose and contents of the document. Other documents, such as checklists, guides, and whitepapers, exist for targeted purposes and audiences. Please see the www.gridwiseac.org website for more products of the Council that may be of interest to you.

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INTRODUCTION

The goal of this workshop was to address different approaches to the use of variable pricing models throughout the power system - from generation through transmission and distribution to consumption. Techniques based on such approaches are called "transactive energy."

Transactive Energy Workshop Participants
May 18, 2011

From the left, back row: Christopher Irwin, Ron Ambrosio, Robert Burke, Todd Halter, Farrokh Rahimi, Terry Oliver, Anna Scaglione, Mahnoosh Alizadeh Front row: Ron Melton, Rob Pratt, Ed Cazalet and Ali Ipakchi

PARTICIPANTS

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GridWise Architecture Council Administrator
Pacific Northwest National Laboratory

Edward G. Cazalet
CEO and President
TeMix Incorporated

Lynn Kiesling
Senior Lecturer
Northwestern University

Anna Scaglione
Professor
UC Davis

Mahnoosh Alizadeh
Student
UC Davis

Overview and Opening Remarks

Workshop Leader: Ron Melton, Pacific Northwest National Laboratory

This new term, transactive energy, is beginning to be used by different groups within the electric power industry. Under the sponsorship of the GridWise Architecture Council (GWAC) this workshop brought together a small group of experts working in the domain. The workshop was intended to start discussions on defining what is meant by transitive energy, discussing the benefits of extending the market based economic model throughout an electric power system, discussing different dimensions such as regulatory and technical aspects, summarizing examples of current transitive energy approaches and their relationship to current systems and practices, identifying open issues, and finally proposing a path forward for work in this area.

For this workshop, transactive Energy is defined as: processes, systems and policies to support transactions of energy between willing buyers and sellers.

Items to be addressed

- Payment for energy used
- Payment for optionality (reliability, capacity and hedging)
- Transactions are voluntary
- Transactions are temporal
- Transactions are between willing buyers and willing sellers
- Transactive approach is innovative in its own right and enables innovation across the industry and stakeholders.

PRESENTATIONS

For this workshop, each participant was required to give a presentation on their current work dealing with transactive energy. They were also asked to submit a white paper on their presentation. The following are the abstracts on the presentations, and links to the slides and white papers.

TRANSACTIVE CONTROL WITH REAL-TIME PRICES AND A RETAIL DOUBLE-AUCTION

SPEAKER: ROB PRATT, PACIFIC NORTHWEST NATIONAL LABORATORY

This presentation and summary paper will describe a transactive control design for deployment in a smart grid demonstration project being conducted by a large mid-west utility. The design combines

- a 5-minute retail real-time price (RTP) reflecting wholesale locational marginal price (LMP) and capacity values
- an RTP tariff designed to be revenue neutral for the average customer prior to any load shifting induced by the rate, and to robustly protect the consumer and the utility from long-term fluctuations in market prices
- a retail double-auction market design that directly manages congestion at the distribution feeder level
- a retail market scheme capable of managing a share of congestion occurring at levels in the grid above a distribution feeder, allocated to responsive load served by that feeder
- an economically-rational heating/cooling thermostat design able to balances a customer's desire to save on their electric bill in exchange for their willingness to be flexible and bid on the price and quantity at which the load it controls will operate (or not)
- A price-normalization scheme that eliminates the need for a customer to understand or specify price levels as (for example) high, medium, and low, and that adapts to both short-term (days) and long-term (years) changes in price.

The summary describes the operational objectives driving the project and the design incorporating the elements listed above. It also discusses key issues associated with such approaches, including equity between customer and utility benefits, the transition of customers from fixed to RTP rates, equity across customers served by different feeders, privacy issues, the provision of ancillary services, and implications of the system architecture.

Transactive Control with Real-Time Prices and Double-Auction Market for Distribution Feeder Capacity Presentation.

TRANSACTIVE CONTROL: AN APPROACH FOR WIDESPREAD COORDINATION OF RESPONSIVE SMART GRID ASSETS

SPEAKER: RON MELTON, PACIFIC NORTHWEST NATIONAL LABORATORY

This paper summarizes a technique referred to as transactive control that has been developed as a means of coordinating the response of smart grid assets at all levels of the power system. In simple terms, transactive control may be thought of as extending the notion of locational marginal pricing throughout the power system from generation to end-use. The transactional nature of the technique, however, introduces a new element by using a pair of signals to implement an equivalent to market clearing distributed in space and time.

The first of these signals, referred to as the transactive incentive signal (TIS), represents the cost of electrical energy delivered to any specific point in the power system. This signal includes both the current cost and a forward projection of estimated future cost. Following the flow of power through the system, the value of the TIS is updated at each point in the system where a constraint may exist or a decision about the flow of power through that point can be made.

The second of these signals, referred to as the transactive feedback signal (TFS), represents the estimated behavior of loads or other responsive elements in the power system. This signal is aggregated upwards in the system at nodes serving the loads. As with the TIS, the TFS includes both the current load and a forward estimate of the load.

At certain points, or nodes, in the power system where the flow of power may be affected, control elements, referred to as transactive control nodes, are created. The transactive control nodes have several functions: blending incoming TIS values to create a composite representing the inputs (assuming more than one source of power into the node); aggregation of TFS values to create an aggregated result representing the estimated future behavior of assets served through the node; analyzing the TIS, TFS and local conditions to make decisions affecting the behavior of responsive assets attached to the node; and adjusting the future estimates of TIS and TFS based on consideration of each with respect to the other taking into account local information. This latter function causes the overall transactive control system to be a closed loop system with the closure distributed in both space (because it is happening at each of the topologically distributed nodes) and time (because it is based on consideration of the future values of each of the two signals with respect to each other.)

This paper will summarize the basic principles of the technique and then discuss some of the challenges in applying the technique in the Pacific Northwest Regional Smart Grid Demonstration Project. This project is applying the technique in a five state region (Washington, Oregon, Idaho, Montana and Wyoming) through the participation of eleven utilities.

Transactive Control: An Approach for Widespread Coordination of Responsive Smart Grid Assets Presentation.

IMPLEMENTING TRANSACTIVE CONTROL: LOOSELY-COUPLED INTEGRATION AND INTEROPERABILITY

PRESENTER: RON AMBROSIO, IBM, GRIDWISE ARCHITECTURE COUNCIL

Transactive Control is a loosely-coupled approach for managing responsive energy assets in an electricity grid. Its intended application will span large geographic regions of the grid. There are a number of challenges to designing and implementing such a system on a large, distributed scale. This paper discusses both the challenges and the objectives that have been defined in the Pacific Northwest Smart Grid Demonstration project.

Designing an implementation architecture and software runtime environment for the project requires a flexible interoperability framework that supports transactive nodes operating from bulk generation domain through transmission and distribution domains, and out to customer domain. This is an extremely diverse set of execution environments, but they must support a relatively homogeneous transactive control solution that overlays the whole space.

In addition, because of the potentially long, multi-node communication paths involved along any particular transactive signal route, the design must eliminate synchronous dependencies wherever possible, to minimize the latency of transactive incentive signals and transactive feedback signals flowing through the system. This requires the interoperability framework and corresponding implementation architecture and software runtime environment to provide a fully asynchronous, event-driven programming abstraction.

After laying out the challenges and objectives, and the high-level architectural issues above, the paper presents some of the details in the system architecture and interoperability framework being used on the Pacific Northwest Smart Grid Demonstration, which is based on Final Draft International Standard ISO/IEC 18012-2. This includes a description of how the transactive control node functionality is encapsulated in ISO/IEC 18012-2 control elements, and how the overlay network of transactive control nodes is composed into a loosely-coupled asynchronous application that spans a wide geographic area and a highly heterogeneous set of computing and network communication resources.

Implementing Transactive Control: Loosely-Coupled Integration and Interoperability Presentation.

TRANSACTIVE ENERGY – LESSONS LEARNED FROM BULK POWER OPERATIONS

PRESENTER: ALI IPAKCHI AND FARROKH RAHIMI, OATI

Many transactive tools and techniques have been developed over the last two decades for management of bulk power operations and wholesale energy markets. These include scheduling, pricing, transmission capacity reservation and auctions, congestion management, and many others both in bilateral and centralized market environments. Lessons learned from bulk power operations and wholesale energy markets can be applied to distributed resources, demand response, retail markets, and distribution system operations. This presentation will review the existing North American bulk power transactive practices, and will address similarities and differences when dealing with retail markets and distributed resources. More specifically, the following topics will be addressed:

- Scheduling and dispatch of demand side resources with economic and reliability based objectives.
- Distribution congestion management and capacity reservations.
- Distribution capacity auction to hedge against limited distribution capacity.
- Variable generation balancing using demand-side resources, including scheduling and operational considerations.

Transactive Energy – Lessons Learned from Bulk Power Operations Presentation.

Economic and Regulatory Aspects of Transactive Energy

Presenter: Lynne Kiesling, Northwestern University

Transactive energy is inherently economic in its foundations: instead of using centralized mechanisms, it employs digital technology to enable diverse, heterogeneous individual agents to engage in decentralized retail market transactions to coordinate consumption and production. In this discussion I will point out the fundamental economic concepts that, when coupled with digital technology, can enable transactive energy systems. Carrying this discussion into the reality of implementing mutually beneficial transactive energy systems also requires analyzing the effects of existing utility regulation. Therefore we will explore the "ideal set" characteristics of regulatory institutions that would best enable and facilitate transactive energy systems that create widespread benefits for agents in the system.

Economic and Regulatory Aspects of Transactive Energy Presentation.

Wholesale Energy Markets – An Overview of Day-Ahead and Real-Time Energy Markets in New England

Presenter: Robert Burke, ISO New England

There are 10 Independent System Operators ("ISOs") and Regional Transmission Organizations ("RTOs") in North America. These ISOs and RTOs serve two-thirds of electricity consumers in the United States and more than 50 percent of Canada's population. Some of the ISOs and RTOs only operate real-time energy markets while other ISOs and RTOs, such as ISO New England Inc. ("ISO NE", the RTO for the New England control area), operate both day-ahead and real-time energy markets. This paper will provide information on the day-ahead and real-time energy markets' operations, and pay particular attention to how entities must participate in these wholesale markets.

A reliable electric system must balance every electric cycle throughout the entire day. This requires reliable load forecasts and sufficient reserve generating capacity (both online and quick start) to respond to disruptions, weather or imperfections in the load forecast. The ISOs and RTOs play an important part in ensuring reliable energy for the regions that they serve. The paper will try also to present the necessity for the ISOs and RTOs to balance both energy and reserves.

Wholesale Energy Markets – An Overview of Day-Ahead and Real-Time Markets in New England Presentation, Whitepaper.

TeMix: A Standard Protocol for Transactive Energy in a Smart Grid World

Presenter: Ed Cazalet, TeMix Incorporated

Transactive Energy Market Information Exchange (TeMIX) is a standards-based architecture and protocol for real-time, physical forwards and financial futures transactions for all electricity products including energy, capacity, transmission, distribution, and ancillary services. With interval metering, improved communications, smart devices, smart controls, sensors and TeMIX protocols, most electricity transactions can be executed automatically in high volumes and at high speed, resulting in benefits for customers without burdening customers or suppliers with complexity. TeMIX by design enables decentralized decisions and control at the edges of the network to supplement and support the necessary reliability functions of system operators. TeMIX extends and integrates naturally with existing wholesale forward markets.

Using TeMIX, customer devices such as air conditioners, plug-in electric vehicles, customer generation and storage automatically interact with distribution grid devices such as transformers, high voltage transmission networks, central station generation and storage. TeMIX thus enables a smart grid that can quickly adapt to high levels of distributed and bulk renewables, plug-in vehicles, and storage while integrating with bulk generation and ISO/RTO systems. TeMIX also makes full use of investments in interval metering, smart appliances, sensors and storage while reducing the need for more investment in fossil generation, transmission and distribution facilities.

TeMIX is furthermore a standard for forward retail and wholesale transactions and dynamic retail tariffs. TeMIX combines subscriptions for power with dynamic real-time prices. TeMIX provides customers with personalized rate plans that they, rather than the utility, choose while at the same time profitably engaging the customer in balancing the grid with high levels of variable renewables and providing revenue certainty and risk mitigation for utilities.

This paper provides a high level description of TeMIX real-time and forward transaction services for use by smart devices, customers, suppliers, distribution and transmission operators and intermediaries.

TeMix: A Standard Protocol for Transactive Energy in a Smart Grid World
[Presentation](#)

A CELLULAR MODEL FOR ENERGY MANAGEMENT SERVICES WITH DIGITAL DIRECT LOAD SCHEDULING

PRESENTER: ANN SCAGLIONE, UC DAVIS

Currently, there are two main approaches for Demand Side Management and Demand Response System: 1) Price-based load control strategies and 2) Load control through curtailment and scheduling.

Both approaches are exploiting the elasticity of the customer demand to close the loop on the load offered to the grid. One is tied to the intention of realizing an efficient market, where the customer needs are met at the correct time and price. The second one is simply exploiting the elasticity of the customer without using market information directly to do so, so it may not realize an efficient market model but is not subject to possible unforeseen dynamics of the customers that can be a threat to the grid stability.

The model we propose strikes what we believe is the right balance between these two DSM and DRS models and offers also a concrete roadmap to develop the cyber-physical control architecture that is amenable to incorporate increasing sophistication in the load behavior.

Our model is a control architecture enabling the optimal dispatch of Microgrid Renewable Energy Sources (RES) power and power from the transmission network, through a capillary control of the activation time of smart loads at the edge of the transmission network. The architecture is structured with a cellular access model, where each cell is matched roughly to a substation. The cell controller is called Community Energy Management System (CEMS), and its role is to perform a Digital Direct Load Scheduling (DDLS), modulating the activation of high Wattage smart loads requesting service from CEMS subscribers in the cell so as to optimize the economic dispatch of power. The essence of the DDLS control is the modular classification of smart loads based on their signature temporal profile of active and reactive power, and their association to service queues to dispatch green and traditional power optimally, by switching on via feedback the loads with an optimal delay. Specifically, the digitized load profile acquired by Home EMS (HEMS) subscribers is used to communicate the request to the CEMS controller, which subdivides them in service queues. During the day, the traffic in the queues is scheduled optimally over finite horizon windows, with the objective of having the aggregate load profile match opportunistically peaks of available renewable generation, minimizing the inconvenience cost of delaying the customers loads and, last but not least, presenting a residual load to the substation that adheres as closely as possible to the day-ahead bid.

A Cellular Model for Energy Management Services with Digital Direct Load Scheduling
[Presentation.](#)

Opportunities for Collaboration

- Smart Grid interoperability Panel Priority Action Plan (PAP) 3, 4, and 9 activities need to be injected into real projects
  - OATI is working on 3 investment grant projects in the area
- Outreach to other organizations to include
  - IRC
  - NRECA
  - WECC
- Vermont Electric would like to have a prices-to-devices demo project
- Interoperability is key to transactive approaches, and should be addressed by
  - GWAC
  - SGIP
- It will be important to involve NARUC

Key Research Questions

1. Does "prices to devices" make sense?
2. What are the relationships relative to other cross-cutting elements of GWAC stack?
3. What is the stability and predictability of transactive techniques?
4. Are transactive energy approaches optimal?
5. What is the basic logic for bidding by individual loads?
6. What are the latencies, processor speeds, bandwidth, etc. needed to implement on a scaled up magnitude?
7. What are other disciplines that can contribute to understanding and resolving related problems?
8. How do we achieve decentralized solutions?
9. How do we integrate transactive approaches with reliability requirements?
10. What is the business case for transactive approaches?
11. What are the future needs of the electric power system that are met through transactive approaches?
12. How do we extend the current transactive approaches used in the bulk power system?
13. What are the policy / regulatory issues?

Future Transactive Energy Workshops

The second workshop will be held on March 28th and 29th, 2012 at T.J. Watson Research Center, Yorktown Heights, NY.

TRANSACTIVE ENERGY WORKSHOP SUMMARY

Ron Melton
GWAC Administrator, PNNL

The summary of the workshop is addressed in the workshop's whitepaper.
http://www.gridwiseac.org/historical/tew2011/tew2011.aspx

To learn more, please visit
https://gridwiseacdev.pnl.gov/historical/tew2011/tew2011.aspx

Closing Comments & Special Thanks

We would like to thank all the participants, OATI, and the Department of Energy for a very successful workshop. The workshop resulted in a focused discussion on transactive energy that will be fully described in a white paper to be released in the first quarter of 2012.

Reference Material

Important Links

Transactive Energy Workshop
http://www.gridwiseac.org/historical/tew2011/tew2011.aspx

GridWise Architecture Council
http://www.gridwiseac.org/

National Institute of Standards and Technology
http://www.nist.gov/smartgrid/

Pacific Northwest National Laboratory/Energy and Environment Directorate:
http://energyenvironment.pnl.gov/

APPENDIX A - AGENDA

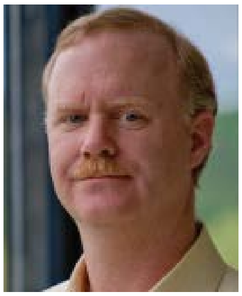
Wednesday, May 18, 2011

8:30 – 9:00 am	**Introduction and Opening Remarks** *Ron Melton & Chris Irwin*
9:00 – 9:45 am	**Transactive Control with Real-Time Prices and a Retail Double-Auction** *Rob Pratt*
9:45 – 10:30 am	**Transactive Control: An Approach for Widespread Coordination of Responsive Smart Grid Actions** *Ron Melton*
10:30 – 11:15 am	**Implementing Transactive Control: Loosely-Coupled Integration and Interoperability** *Ron Ambrosio*
11:15 am – 12:00 pm	**Transactive Energy – Lessons Learned from Bulk Power Operations** *Ali Ipakchi*
12:00 – 1:00 pm	**Lunch**
1:00 – 1:45 pm	**General Comments about Bonneville Power Administration's Needs** *Terry Oliver*
1:45 – 2:30 pm	**Economic and Regulatory Aspects of Transactive Energy** *Lynne Kiesling*
2:30 – 3:15 pm	**Wholesale Energy Markets- An Overview of Day-Ahead and Real-Time Energy Markets in New England** *Robert Burke*
3:15 – 4:00 pm	**TeMIX: A Standard Protocol for Transactive Energy in a Smart Grid World** *Ed Cazalet*
4:00 – 4:45 pm	**A Cellular Model for Energy Management Services with Digital Direct Load Scheduling** *Anna Scaglione*
4:45 pm	**Adjourn**

Thursday, May 19, 2011

8:30-9:30am	**What are the Opportunities for Collaboration?** *Ron Melton*
9:30-10:00am	**What are the Key Research Questions?** *Ron Melton*
10:00-11:30am	**What Additional Research is Needed?** *Ron Melton*
11:30am-12:00pm	**Working Lunch**
12:00-1:00pm	**Does it Make Sense to Have a Larger Meeting?** *Ron Melton*
1:00pm	**Adjourn**

APPENDIX B – SPEAKERS' PROFILES



Ron Ambrosio

Chairman, GridWise Architecture Council / IBM T.J. Watson Research Center

Ron Ambrosio oversees IBM's Energy & Utilities Industry activities in its eight world-wide Research Laboratories. Ron joined IBM in 1981 at the T.J. Watson Research Center, working in a variety of areas including embedded operating systems, distributed application frameworks, and pervasive computing environments, ultimately focusing on networked embedded computing with particular emphasis on what he coined "Internet-scale Control Systems" – the interoperability of sensor networks and control systems with enterprise systems and business processes. He helped establish IBM's activities in both Intelligent Utility Networks and Sensors & Actuators.

Robert Burke

Markets Development Principal Analyst, ISO New England

Mr. Burke is a Principal Analyst in Market Development with ISO New England (the Regional Transmission Organization "RTO" for the New England control area). He has thirty-five years of experience in the energy industry. Since joining ISO-NE, he has held various positions and been involved with the development and subsequent on-going improvement of the wholesale energy markets, and worked with market participants regarding demand resource integration issues. In his present position, he works on development of market rule changes for all areas of the New England wholesale markets and their FERC fillings. Mr. Burke has a B.E. in heat and power from Stevens Institute of Technology, and an MBA and MS in Computer Science from Rensselaer Polytechnic Institute. He has furthermore completed all examination requirements in Connecticut for a CPA.

He is a member of IEEE, and since 2009 working on smart grip interoperability as a member of the GridWise Architecture Council. He has made presentations at over three-dozen panel discussions and technical seminars, and authored or coauthored more than a dozen technical papers.

Ed Cazalet

CEO, The Cazalet Group

An internationally recognized electric industry expert, Dr. Cazalet is a leader in the analysis and design of markets for electricity and the analysis of transmission, generation and load management investments. For his industry contributions, Public Utilities Fortnightly magazine in 2000 named Dr. Cazalet "Innovator of the Year". Ed is also VP and Co-founder of MegaWatt Storage Farms, Inc., a storage advisory and project development firm. He formerly was a Governor of the California Independent System Operator, and founder and CEO of both Automated Power Exchange, Inc. (APX) and Decision Focus, Inc. (DFI). He has a PhD from Stanford in Engineering-Economic Systems. Dr. Cazalet is co-chair of the OASIS Energy Market Information Exchange (eMIX) Technical Committee, and a member of the OASIS EnergyInterOp and WS-Calendar Technical Committees.

Todd Halter

Scientist, Pacific Northwest National Laboratory

Todd Halter has over 20 years experience in the Computer Science, Physics, Mathematics, and Chemistry. Since 1998, Halter has been working on the Department of Energy's Atmospheric Radiation

Measurement (ARM) Program as a value added products and data system developer and project manager collaborating closely with atmospheric scientists to obtain a thorough understanding of the data management requirements within atmospheric sciences. Mr. Halter has served as a group manager, project manager, system architect, and developer with experience in all aspects of project management (budget, schedule, resource, and risk analysis), architecture and system design, coding, testing, installation, and maintenance.

Ali Ipakchi

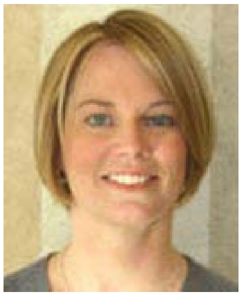
Vice President of Smart Grid and Green Power, OATI

Dr. Ipakchi has over 30 years of experience in the application of information technology to power systems and electric utility operations. As the VP of Smart Grid and Green Power at OATI, he is responsible for growth of the business in these emerging areas. Prior to OATI, he was Vice President of Integration Services at KEMA, assisting utility clients with roadmaps, specifications, business and implementation strategies for automation and technology projects. Prior to KEMA, Dr. Ipakchi held various senior management positions at leading vendors supporting power application development and system solutions delivery to the power industry. He has led new business-line and organizational development initiatives, and has managed product development and delivery teams. His areas of experience include Smart Grid, utility automation, power systems operations, enterprise and operational IT systems, systems for ISOs/energy markets, utility control centers, trading floors, power generation, distribution operations, and advanced metering. He holds a PhD from University of California at Berkeley, and is co-holder of three US patents on power systems applications and instrument diagnostics.

Irwin, Christopher

Smart Grid Standards and Interoperability Coordinator, U.S. Department of Energy

Christopher Irwin has spent over 17 years in a diverse spectrum of high technology fields from HVAC to III-V semiconductor manufacturing, and most recently in communication networks for advanced metering (AMI) and Smart Grid infrastructure. He is a member of the Department of Energy team administering the Smart Grid Investment Grants, and is responsible for standards and interoperability activities, including participation in the NIST-led Smart Grid Interoperability Framework. Prior to joining the Department of Energy, he served as Director of Products at an AMI communications vendor, also participating in Technology Discovery and Business Development. In that role, he gained a full market perspective on the electric energy sector, as well as natural gas and water infrastructure. This experience, combined with his semiconductor and satellite communications background, contributes to a unique perspective on the US energy business under transformation. Chris holds a B.S. in Mechanical Engineering from the University of Maryland, College Park, and an M.B.A. from the W.P. Carey School of Business at Arizona State University.



Lynne Kiesling

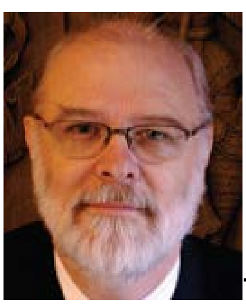
Senior Lecturer, Northwestern University

Lynne Kiesling is a Senior Lecturer in the Department of Economics at Northwestern University, and in the Social Enterprise at Kellogg (SEEK) program in the Kellogg Graduate School of Management at Northwestern University. At Northwestern she is also a Faculty Member in the Northwestern Institute on Complex Systems (NICO) and a Faculty Affiliate in the Center for the Study of Industrial Organization CSIO). Lynne is the author or coauthor of many academic journal articles, book chapters, policy studies, and public interest comments, most of which analyze electricity policy and market design issues. Her specialization is experimental economics and organizational economics. She also teaches undergraduate courses in energy economics, environmental economics, and history of economic thought, and writes about economics as the editor/owner at the website www.knowledgeproblem.com. Lynne has a Ph.D. in Economics from Northwestern University and a B.S. in Economics from Miami University, Oxford, Ohio. Her previous appointments include Assistant Professor, College of William and Mary, Manager, PricewaterhouseCoopers LLP, Director of Economic Policy, Reason Foundation, and Research Scholar, Interdisciplinary Center for Economic Science at George Mason University.

Ronald Melton

Administrator, GridWise Architecture Council, Pacific Northwest National Laboratory

Ron Melton is the administrator of the GridWise Architecture Council (GWAC) and a senior power systems engineer at Pacific Northwest National Laboratory. He is also Project Director for the Pacific Northwest Smart Grid Demonstration Project, managed by the Pacific Northwest Division of Battelle. Dr. Melton has over 25 years of experience in systems engineering applied to interdisciplinary problems. He received his BSEE from University of Washington and his MS and PhD in Engineering Science from the California Institute of Technology.



Terry Oliver

Chief Technology Innovation Officer, Bonneville Power Administration

Terry Oliver has worked globally to advance energy conservation and renewable energy. He has worked for BPA since 1981.

In the Pacific Northwest he managed one of the world's largest residential energy conservation programs, the PNW Residential Weatherization Program, lead ground-breaking research on community-based energy conservation applications in the Hood River Conservation Project, and established two enduring icons of energy efficiency innovation, the Lighting Design Lab and the Energy Ideas Clearinghouse. In 1992 he moved to Bangkok, Thailand, to lead the Asia Regional Office of the International Institute for Energy Conservation (IIEC).

In 2000, Terry returned to BPA where he worked on BPA's EnergyWeb concept and its application to the PNW. As part of this effort he helped create BPA's Non-Wires Solutions initiative, participated in EPRI's Intelligrid grid architecture initiative, and lead the GridWise Alliance Demonstrations Working Group.

In June 2005 Terry was appointed Bonneville Power Administration's first Chief Technology Innovation Officer, responsible for re-energizing, focusing, and managing BPA's research and development activities.

Rob Pratt

Pacific Northwest National Laboratory

Rob Pratt manages PNNL's Smart Grid R&D program activities for the U.S. Department of Energy. He leads the GridWise™ initiative, which spawned a new DOE program and an industry alliance that both share a vision of an information-rich future for the power grid. He heads a team with a focus on communications architecture, advanced control technology, and simulation and analysis of the combined engineering and economic aspects of the future grid. Mr. Pratt also leads a PNNL initiative that recently commissioned the new Electricity Infrastructure Operations Center, a fully-equipped grid control center capable of serving as a back-up center, with live phasor data resources from around the U.S. and state-of-the-art analysis tools. It serves as a unique technology development, valuation, training, and technology transfer platform. The initiative is currently developing advanced grid control and situational awareness technologies and watershed/hydro system management capabilities. Mr. Pratt received his B.S. in Ocean Engineering from Florida Atlantic University and an M.S. in Mechanical Engineering from Colorado State University.

Farrokh Rahimi

Vice President of Market Design and Consulting, Open Access Technology International, Inc. (OATI)

Farrokh Rahimi is Vice President of Market Design and Consulting at Open Access Technology International, Inc. (OATI), where he is currently involved in analysis and design of power and energy markets and Smart Grid solutions. He has a Ph.D. in Electrical Engineering from MIT, along with over 40 years of experience in electric power systems analysis, planning, operations, and control, with the most recent 5 years in the Smart Grid area. Before joining OATI in 2006, he collaborated with California ISO, Folsom, CA for eight years, where he was engaged in market monitoring and design. His prior experience included eight years with Macro Corporation (subsequently KEMA Consulting), five years with Systems-Europe, Brussels, Belgium; one year with Brown Boveri (now ABB), Baden, Switzerland; ten years, as a university professor, researcher, and consultant in power and industrial control systems, and two years with Systems Control, Inc. (now ABB Systems Control, Santa Clara, CA), where he started his professional career. Dr. Rahimi is a Senior Member of IEEE, and a number of Smart Grid task forces and committees, including NERC Smart Grid Task Force, NAESB Smart Grid Task Force, WECC Variable Generation Subcommittee, and Open Smart Grid Users Group

Anna Scaglione

Professor, University of California Davis

Anna Scaglione is a Professor in Electrical and Computer Engineering at the University of California at Davis, where she joined in 2008. Previously, she was an Associate Professor at Cornell University, in Ithaca, NY,. and an Assistant Professor at the University of New Mexico since 2011, Ms. Scaglione is a Fellow of the IEEE. She served as Associate Editor for the IEEE Transactions on Wireless Communications from 2002 to 2005, and from 2008 to 2011 in the Editorial Board of the IEEE Transactions on Signal Processing. As first author, Dr. Scaglione received the 2000 IEEE Signal Processing Transactions Best Paper Award, received the NSF Career Award in 2002 and was a co-recipient of the Ellersick Best Paper Award (MILCOM 2005). Ms. Scaglione received the Laurea (M.Sc. degree) in 1995 and the Ph.D. degree in 1999 from the University of Rome, "La Sapienza."

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