# Deploying Systems Interoperability and Customer Choice within Smart Grid


**Girish Ghatikar**

**Lawrence Berkeley National Laboratory**
**1 Cyclotron Road, 90R3111, Berkeley, CA 94720**

GGhatikar@lbl.gov

**Ed Koch**

**Akuacom/Honeywell**
**781 Lincoln Ave., Suite 210, San Rafael, CA 94901**

ed@akuacom.com



**Keywords:** Open automation, systems interoperability, customer cooperation and choice, Smart Grid standards, OpenADR 2.0, OpenADR Alliance, market deployments



**Abstract**

In 2012, significant development of Smart Grid interoperability standards for customers and their systems readied those standards for deployments in commercial demand-response programs. These standards have led to the development of interoperable systems and products for communication between the grid-operating entities (e.g., independent systems operators, utilities) and customer energy management systems. This paper summarizes the efforts to standardize OpenADR in the United States, and traces its evolution from OpenADR 1.0 to an emerging success story, OpenADR 2.0. It also describes the development and deployment of OpenADR and how grid-operating entities and customers can use open and secure communication and technologies to provide interoperability and customer choice. It focuses on the development of OpenADR 2.0 specifications and the OpenADR Alliance (Alliance), a non-profit stakeholder and industry consortium with a mission to create "true" and "secure" interoperability and deployment for OpenADR 2.0, including providing the services of the testing and certification authority..

Finally, the paper provides insights into interoperability (with examples), the direction of the Alliance, and applicability of OpenADR experiences for the Smart Grid.


## 1. INTRODUCTION

Smart Grid interoperability standards for customers and their systems have undergone significant development over the past year and are ready for deployments in commercial demand-response (DR) programs. This has led to interoperable systems and products for communication between the grid-operating entities (e.g., independent systems operators, utilities), and customer's energy management systems. The paper reviews efforts in the United States to standardize DR and distributed energy resources (DER) communications (SGIP PAP 09, 2012). It also reviews how OpenADR 1.0 specification evolved to OpenADR 2.0 Profile Specification (Piette et al, 2009a), to provide Smart Grid interoperability and customer choice. It describes the development and deployment of OpenADR and how grid-operating entities and customers can use open and secure communication and technologies to provide interoperability and customer choice. It focuses on the development of OpenADR 2.0 Profile Specification and the OpenADR Alliance (Alliance), a non-profit stakeholder and industry consortium with a mission to create interoperability and security for OpenADR 2.0 and thus enable

- grid-operating entities to offer programs that interoperate with customer systems,
- product vendors and customers to market their offerings and identify new opportunities, and
- regulators to provide policy mechanisms for Smart Grid and customer interface DR- and price-responsive programs, and enable customer choice.

The paper provides insights into and examples of interoperability, discusses the direction of OpenADR, and identifies the direction for the Alliance and the Smart Grid from experiences thus far.

The paper is organized to provide: (a) a history of OpenADR development and market facilitation, (b) status of OpenADR 2.0 Profile Specification and links to the national efforts, (c) examples of key interface standards for customers and wholesale DR markets, and (d) interoperability framework to enable customer choice, with the following key objectives:

- Create a formal standard with industry and stakeholder consensus and compliance procedures.
- Pave the way for wide-scale adoption of OpenADR by addressing regulatory and market needs.
- Allow extensions to meet the requirements of wholesale and retail markets, as well as customers.

Finally, the paper provides lessons that may be learned from OpenADR development and deployment and insights into future directions of the Alliance.

## 2. OPENADR DEVELOPMENT AND MARKET FACILITATION

This section gives a brief history on the origin and development of OpenADR. Figure 1 below shows the OpenADR timeline, beginning with research and development through field tests, and ending with deployments. Key purposes are shown for each; these may be relevant to the broad context of standards and systems interoperability, as well as customer choice.

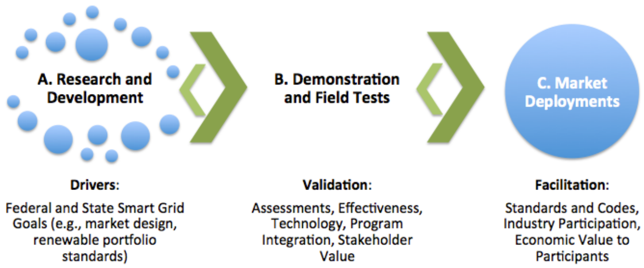


**Figure 1: Research, Demonstration, and Field Tests as Pathways to the Market Deployments**

**2002–2006:** The research and development (R&D) of OpenADR started at Lawrence Berkeley National Laboratory (LBNL) under primary funding by the California Energy Commission. The eXtensible Markup Language (XML) for both clients and servers was used as an interoperable language for facility control systems and commercial DR programs (Piette et al. 2009).

**2007–2008:** A broader understanding of Auto-DR and interoperable systems principles were defined with commercialization of OpenADR 1.0 by the California investor-owned utilities. *Automated DR* is defined as a signal initiated by the DR Service provider to enable a fully automated control systems to consume the signals and execute customer-determined strategies (Piette et al. 2009a).

**2008–2009:** OpenADR 1.0 specification was released for widespread use, to facilitate interoperable systems, and reduce costs (Piette et al, 2009b). OpenADR 1.0 is recognized as a U.S. Smart Grid standard for DR and Distributed Energy Resources (DER), which led to formal standards development by the Organization for Advancement of Structured Information Standards (OASIS) Energy Interoperation (EI) (OASIS, 2011a).

**2010 onward:** A member-based non-profit organization, the Alliance, was formed to foster OpenADR adoption and to create testing and certification framework using the EI 1.0 standards. An important goal of the Alliance is the development of compliant products, which will facilitate market acceptance, systems interoperability, and technology innovation (Ghatikar et al, 2011). The Alliance released the OpenADR 2.0 Profile Specifications (OpenADR 2.0) in August 2012 to advance OpenADR and deploy market-ready products (Alliance, 2012).

### 2.1. Differences Between OpenADR 1.0 and 2.0

OpenADR 1.0 contains a number of interface specifications, however only a subset of those is emphasized in OpenADR 2.0. Specifically, during the U.S. Smart Grid standards development, it was determined that the most important aspects of OpenADR 1.0 were the interactions between the DR Service provider, the customer, and their automation systems. These are inter-domain interactions, whereas the service-provider's intra-domain interfaces within the OpenADR 1.0 are of less importance from a standards perspective (Holmberg et al, 2012).

The main emphasis of the OpenADR 2.0 is on the inter-domain information exchanges between the DR Service Provider and the customer. With respect to these interactions, OpenADR 2.0 data models contain new attributes and features that allow it to address additional requirements not addressed in OpenADR 1.0. While the OpenADR 1.0 data models, which were used in the development of the EI 1.0 standards, are present in the 2.0 specifications, from a functional point of view the schemas used in OpenADR 2.0 are not compatible with the schemas used in 1.0. It is therefore fair to say that OpenADR 2.0 is semantically backwards compatible with OpenADR 1.0, but not syntactically compatible. There are ongoing efforts by LBNL to understand the co-existence of OpenADR 2.0 with legacy clients and OpenADR 1.0 transition. One such instance is the indication by the current vendors to support OpenADR 1.0 systems in order to support legacy devices deployed in commercial Auto-DR programs in California.

## 3. OPENADR 2.0 PROFILE SPECIFICATION

Similar to OpenADR 1.0, OpenADR 2.0 is an application layer data model for secure exchange of DR and price information between electricity service providers and aggregators and end users (customers). Figure 2 shows the architecture of Virtual Top Nodes (VTNs), which publish information to Virtual End Nodes (VENs), which subscribe to the information (Alliance, 2012). OpenADR 2.0 describes the data models for communication between the VTN and VEN (or VTN/VEN pairs) and includes specific DR power reduction, shifting strategies, and the customer actions.

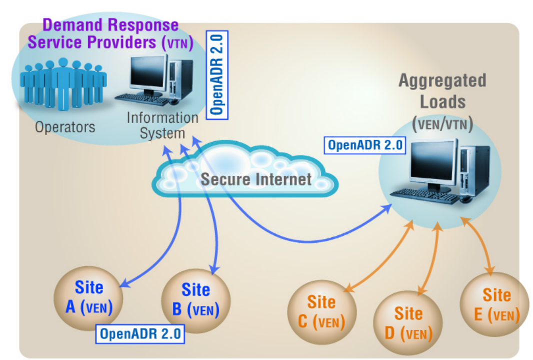


**Figure 2: OpenADR 2.0 Communication Architecture**

Getting to the present stage was a time-consuming task, mainly due to the scale of OpenADR applications, the time required for stakeholder consensus, and establishment of the

Alliance. Figure 3 below shows the many organizations that were consulted, and the relevant specifications that were reviewed to develop OpenADR 2.0. For a formal EI standard, OASIS formed three related technical committees—EI as described earlier, the Energy Market Information Exchange (EMIX) to represent price and product definitions (OASIS, 2011b), and the Web Services Calendar (WS-Calendar) to represent scheduling that is consistent with the Internet Engineering Task Force (IETF) standards that are in use for scheduling activities (OASIS, 2011c). Both EMIX and WS-Calendar are used in the EI and are part of OpenADR 2.0 specifications.

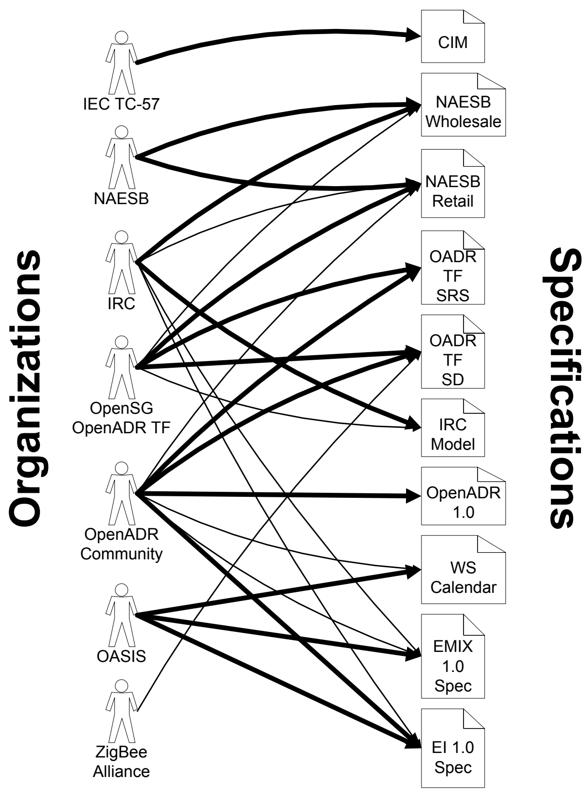


**Figure 3: Relevant Organizations and Specifications for OpenADR 2.0 Development (weight of arrows indicate degree of contribution by organization to specification)**

The scope of EI was broader than that of DR and price-responsive standards, therefore as part of the EI standards, OpenADR profiles were defined. Those profiles formed the basis of OpenADR 2.0 and its subsequent conformance and testing through the Alliance. The U.S. Smart Grid standards process to achieve interoperability has been a significant effort, and has also involved identification of interfaces with relevant emerging and existing standards (e.g., Smart Energy Profiles, BACnet).

### 3.1. The U.S. Smart Grid Standards and Process

In 2009, the National Institute of Standards and Technology (NIST) was identified as the organization responsible for coordinating Smart Grid interoperability standards efforts. As part of this coordination, NIST created two releases of the "NIST Framework and Roadmap for Smart Grid Interoperability Standards." These documents identified OpenADR as an important and relevant emerging standard for DR and DER communications between operations, service providers, and customer interactions to facilitate Auto-DR markets. The establishment of Interoperability Testing and Certification Authority (ITCA), or the Alliance, was included to advance adoption of these standards.

To accomplish this complex task, NIST initiated Smart Grid Interoperability Panel (SGIP) defined a number of Priority Action Plans (PAPs) each designed to address standards efforts within specific areas of the Smart Grid space (SGIP PAPs, 2012). Of note to OpenADR are the following PAPs:

- PAP03: Common Price Communication Model
- PAP04: Common Schedule Communication Mechanism
- PAP09: Standard DR and DER Signals
- PAP10: Standard Energy Usage Information
- PAP17: Facility Smart Grid Information Standard
- PAP19: Wholesale DR Communication Protocol

Of particular interest are PAP09 and PAP19, which are directly related to the DR signals defined by OpenADR (SGIP PAP09, 2012; SGIP PAP19, 2012). To a certain extent, PAP09 depends upon PAP03, PAP04, PAP10, and PAP17 (SGIP PAP03, 2012; SGIP PAP04, 2012; SGIP PAP10, 2012; SGIP PAP17, 2012). As part of the PAP09 efforts, the North American Energy Standards Board (NAESB) was identified as a significant party for creating requirements, and the OASIS EI was identified as a significant party to generate formal standards. The ISO/RTO Council (IRC) is responsible for PAP19.

The IRC collaborated closely with the OpenADR Task Force (OADR TF) to ensure consistency in data models and the documents produced by the NAESB. The NAESB documents were contributed to OASIS EI as requirements to their standards. As part of the PAP process, it was agreed that the Common Information Model (CIM - IEC 61970) would be used where appropriate to provide the data elements and semantics for each of the specifications. The organizations, NAESB, the OADR TF, and OASIS continue to follow this process.

### 3.2. OpenADR-Related Standards Efforts

As can be seen from the above discussion, a number of convoluted efforts have contributed to the creation of the OpenADR 2.0 specification. Figure 4 shows the relationship between each of the specifications being created and how they feed into the OpenADR 2.0 specification.

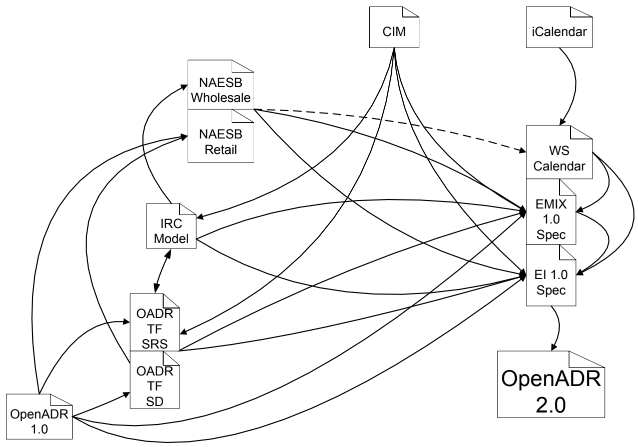


**Figure 4: Relationships of Organizations and Specifications for OpenADR 2.0 (arrows indicate contribution of specification to drafting of another)**

This paper provides examples of OpenADR interfaces with two key standards, Smart Energy Profile 2.0 (SEP 2.0) and Wholesale DR Markets. Both these are emerging standards where OpenADR can effectively interface with the demand- and supply-side systems and facilitate customer choice.[1]

### 3.2.1. Relationship Between OpenADR 2.0 and Smart Energy Profile (SEP) 2.0

Potential users often ask how OpenADR interfaces with the facility-centric standards. OpenADR 1.0 has demonstrated interoperability with commercial building protocols such as BACnet, Modbus, and others (Piette et al, 2009a). SEP 2.0, another key interface standard, has many DR aspects, so from a feature point of view, it overlaps with the functionality of OpenADR 2.0. The main differences are in their respective operations and roles. SEP 2.0 is primarily targeted for communications between devices within a Home Area Network (HAN), whereas OpenADR is targeted toward communications between the electricity service provider and customers. Furthermore, OpenADR 2.0 covers a broader range of DR and market rules, while SEP 2.0's features make it more amenable in residential direct load control applications. Table 1 summarizes key differences between OpenADR 2.0 and SEP 2.0 functionalities.

**Table 1:** Summary of Differences: OpenADR 2.0, SEP 2.0

| **Functionalities** | **OpenADR 2.0** | **SEP 2.0** |
|---|---|---|
| Direct Load Control | Limited[2] | Yes |
| Profile Structure | Tiered profile | Modular profile |
| Full Reporting Services | Yes | No |
| Supported Transports | Simple HTTP, XMPP | HTTP (REST-styled) |
| Non Repudiation | Optional | Not Specified |

[1] When this paper was published, these standards were under development.

[2] Signal types can be translated into DLC commands at the customer-side

There are ongoing efforts at national level to harmonize these different standardization efforts, in particular around price communications (NIST, 2010).

It is also worth noting that the OADR TF actively consulted the SEP 2.0 specification and incorporated features from it into their use cases, especially as they pertain to direct load control (DLC). Section 3.2.2 describes the existence and definition of DLC in the DR market and how this is part of customer choice in OpenADR.

### 3.2.2. OpenADR 2.0 and the Wholesale DR Markets

To facilitate both retail and wholesale DR requirements, NAESB prepared following high-level use cases: (1) Administrate DR Program; (2) Administrate Customer for DR; (3) Administrate DR Resource; (4) Execute DR Event, and (5) Post DR Event Management (NAESB 2010).

These use cases were organized as such to show different DR business processes. As stated in the NAESB document, almost all the detail surrounds use case 4, since that is the one that corresponds to the exchange of DR signals per the PAP09 charter. Although the uses cases are similar in scope, the organization is a little different than its representation in OpenADR 1.0. In the OpenADR 1.0 specification separate use cases were first developed corresponding to the existing DR programs, and then those were generalized into a single use case. Within that more general use case are embedded the various processes that are identified within the NAESB document. In general the use case diagrams in the OpenADR 1.0 specification are more actor-centric, whereas the use cases in the NAESB document are more process-centric. With PAP 19 Wholesale DR Communication Protocol (WDRCP) activities led by the IRC, the NAESB and PAP 19 framework was mapped to make sure that OpenADR 2.0 attributes meet the requirements of the wholesale DR markets. Table 2 shows key elements mapped between OpenADR 2.0 and WDRCP message structure (SGIP PAP19, 2012).

**Table 2:** OpenADR 2.0 and PAP 19 Message Mapping

| **OpenADR 2.0 (Profile B)** | **PAP 19 (WDRCP)** |
|---|---|
| *oadrDistributeEvent, oadrEvent, eiEvent, eventDescriptor, eiResponse* | Headers |
| *oadrDistributeEvent, oadrEvent, eiEvent, eventDescriptor, eiActivePeriod* | Demand Response Event |
| *oadrDistributeEvent, oadrEvent, eiEvent, eiActivePeriod, eiEventSignals, eiTarget, eiResponse* | Resource Deployment |

## 4. CUSTOMER CHOICE

Previous studies have defined how OpenADR fosters customer choice with Facility-centric Load Control (FLC), where the decisions on how loads are controlled are made entirely within the facility or enterprise control systems. The FLC is different from the traditional methods of Direct Load Control (DLC), where a third party decides how and when customer loads will be controlled, in most cases using proprietary device-centric signals (Koch et al, 2009). Table 3 provides a high-level summary of DLC and FLC.

**Table 3:** High-Level Summary of DLC and FLC Signals

| DLC Signals | DLC Customer Device Response | FLC Signals | FLC Customer Response |
|---|---|---|---|
| Temperature set points ($^oC$ or $^oF$) | Increase/Decrease set points | Load change or Price Signals (kW or $) | Program controls to Increase or Decrease set points |
| On or Off | Turn device On/Off | Load or Price levels | Program device to turn On/Off |
| Device Availability | N/A | The date/time for load change | Select the date/time when the loads are available for changes |
| Cancel participation | N/A | Opt-in/ Opt-out | Notify service providers to opt-in/opt-out of a specific event or series of events |

To facilitate technical and information interoperability to meet syntactic and semantic needs, OpenADR focuses on FLC concepts that have limited ability to provide DLC services. OpenADR provides services and attributes that can be used by the customers to pre-program their control systems in response to its organizational and business needs. Before discussing the pros and cons of DLC and FLC, it is important to understand the business contexts in which they evolved. The notion of DLC exists to make sure the service provider can get guaranteed load shed when needed to balance a complex electric grid and markets. However, if the same level of certainty can be provided by FLC, where customers determine the actions on when and how to respond to a specific DR or price signal, it will be a compelling case. Exposing the informational and technical aspects of data models in FLC allows other relevant standards to interoperate (e.g., interoperability with SEP 2.0, which is also an application-layer data model). The FLC model is also relevant for other similar standards that result from PAP 10 and PAP 17 efforts.

## 5. INTEROPERABILITY FRAMEWORK

The GridWise™ Architecture Council's (GWAC) interoperability context-setting framework facilitates interoperability at Organizational, Informational, and Technical levels (GWAC, 2008). OpenADR development closely aligns with this framework. OpenADR application-layer data models provide transport layer independence and integration with other building protocols, interoperability framework to devices (e.g., Thermostats or control systems), and other relevant standards (e.g., SEP 2.0, ASHRAE 201P). The different profiles by the OpenADR Alliance, which offer increasing levels of complexity, cater to different device types and market needs. Certified products for the "A" profile were available, and "B" and "C" profiles were in development, when this paper was published. Table 4 summarizes the services for these profiles.

**Table4:** Summary of Services of OpenADR 2.0 Profiles

| Smart Grid DR Services | Profile A | Profile B | Profile C |
|---|---|---|---|
| Simple DR Event, Price | X | X | X |
| Complex DR Event, Price | | X | X |
| Reporting/Feedback | | X | X |
| Opt-In/Opt-Out Schedules | | X | X |
| Registration | | X | X |
| Enrollment | | TBD | X |
| Transactional | | | X |

## 6. CONCLUSIONS AND FUTURE DIRECTIONS

With the resurgence of Smart Grid demonstrations and investments in recent years, the standards require an understanding and provision of the interoperability and market deployment paradigms described in this paper. The future focus of the OpenADR Alliance and OpenADR 2.0 efforts require an understanding of its use in DR programs, emerging markets, systems interoperability and customer choice, building codes and standards, and education. The immediate research needs are to link OpenADR 2.0 reporting services, which provide customer building- and end use-level historical and real-time energy-usage, and facility state information with: 1) PAP 10 customer energy usage information, or popularly known as, Green Button™ initiative; and 2) PAP 17 or ASHRAE 201P with facility information models for DER integration.

The work of the Alliance that is supported by the R&D, and demonstrations and field-tests will provide a better understanding of OpenADR applications in new markets (e.g., wholesale, renewable generation) and its value to different stakeholders will benefit its market deployments.

**Acknowledgements**

This work was sponsored by the Lawrence Berkeley National Laboratory's Demand Response Research Center (http://drrc.lbl.gov/), which is funded by the California Energy Commission's Public Interest Energy Research Program, under Work for Others Contract No. 500-03-026, Am #1 and by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231. The authors would like to thank the OpenADR Alliance and its members for their contributions.

**References**

Energy Interoperation Version 1.0. 18 February 2012. OASIS Committee Specification 02. http://docs.oasis-open.org/energyinterop/ei/v1.0/cs02/energyinterop-v1.0-cs02.html

Energy Market Information Exchange (EMIX) Version 1.0. 11 January 2012. OASIS Committee Specification 02. http://docs.oasis-open.org/emix/emix/v1.0/cs02/emix-v1.0-cs02.html.

Ghatikar G., R. Bienert. (2011). "Smart Grid Standards and Systems Interoperability: A Precedent with OpenADR." Presented at the proceedings of the Grid Interop Forum 2011.

The Gridwise Architecture Council (GWAC). (2008). "GridWise® Interoperability Context-Setting Framework."

Holmberg H., G. Ghatikar, E. Koch, and J. Boch. (2012). "OpenADR Advances." *ASHRAE Journal*, vol. 54, issue 11.

Koch E., M. A Piette. (2009). "Direct versus Facility Centric Load Control for Automated Demand Response." Presented at the proceedings of the Grid Interop Forum 2009.

National Energy Standards Board (NAESB). (2010). "Wholesale Electric Demand Response Phase Two Business Practices Standards" and "Retail Electric Demand Response Phase Two Business Practices Standards"

NIST PAP 3, 4, and 9 Tiger Team Meeting on Price Communications. (2010). http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/TTMeetingOnPriceCommunications

The OpenADR Alliance (Alliance). "OpenADR 2.0a Profile Specification: Revision Number 1.0." (2012). 20110712-1

The Organization for Advancement of Structured Information Standards (OASIS). (2011a). Energy Interoperation (Energy Interop) Version 1.0, available at: http://docs.oasis-open.org/energyinterop/ei/v1.0/energyinterop-v1.0.html.

The Organization for Advancement of Structured Information Standards (OASIS). (2011b). Energy Market Information Exchange (EMIX) Version 1.0, available at: http://docs.oasis-open.org/emix/emix/v1.0/emix-v1.0.html

The Organization for Advancement of Structured Information Standards (OASIS). (2011c). Web Services Calendar (WS-Calendar) Version 1.0. 30 July 2011. OASIS Committee Specification 01. http://docs.oasis-open.org/ws-calendar/ws-calendar-spec/v1.0/cs01/ws-calendar-spec-v1.0-cs01.html.

Piette M. A, G. Ghatikar, S. Kiliccote, E. Koch, D. Hennage, P. Palensky, and C. McParland. (2009a). "Open Automated Demand Response Communications Specification (Version 1.0)." California Energy Commission, PIER. CEC-500-2009-063.

Piette, M. A., G. Ghatikar, S. Kiliccote, D. Watson, E. Koch, and D. Hennage. (2009b). "Design and Operation of an Open, Interoperable Automated Demand Response Infrastructure for Commercial Buildings", *Journal of Computing Science and Information Engineering*, vol. 9, issue 2, no. 2.

SGIP PAPs. (2012). "Priority Action Plans." http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PriorityActionPlans

SGIP PAP03. (2012). "Develop Common Specification for Price and Product Definition." http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP03PriceProduct

SGIP PAP04. (2012). "Develop Common Schedule Mechanism for Energy Transactions." http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP04Schedules

SGIP PAP09. (2012). "Standard DR and DER Signals." https://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP09DRDER

SGIP PAP10. (2012). "Standard Energy Usage Information." http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP10EnergyUsagetoEMS

SGIP PAP17. (2012). "Facility Smart Grid Information Standard." http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP17FacilitySmartGridInformationStandard

SGIP PAP19. (2012). "Wholesale DR Communication Protocol (WDRCP) Retail Mapping" http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP19WholesaleDR

**Biography**

Girish Ghatikar is the Program Manager and Smart Grid Standards and Technologies lead at LBNL, and the Vice-Chairman for the OpenADR Alliance.

Ed Koch is a Senior Fellow at Honeywell and founder and CTO of Akuacom and specializes in enterprise systems for automated energy control and monitoring in commercial and residential buildings, especially as it applies to DR.