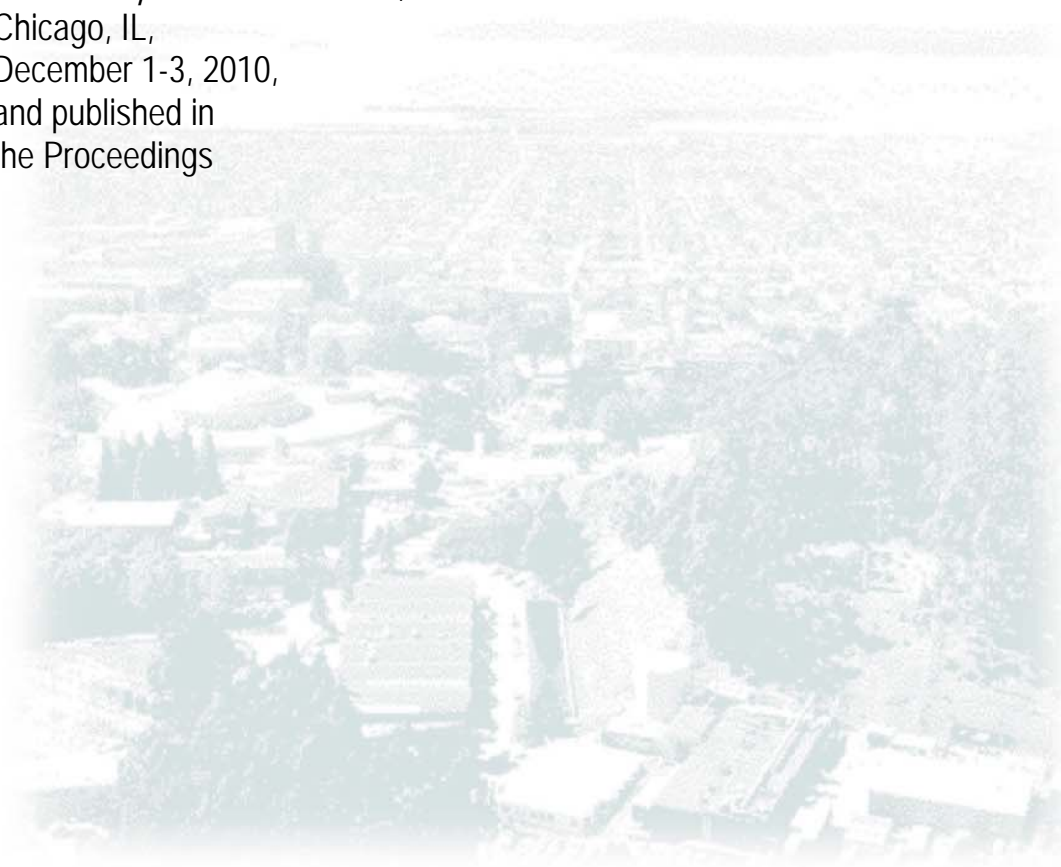# ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

Open Automated Demand Response Technologies for Dynamic Pricing and Smart Grid

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DISCLAIMER

Open Automated Demand Response Technologies for Dynamic Pricing and Smart Grid

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Abstract

We present an Open Automated Demand Response Communications Specifications (OpenADR) data model capable of communicating real-time prices to electricity customers. We also show how the same data model could be used to for other types of dynamic pricing tariffs (including peak pricing tariffs, which are common throughout the United States). Customers participating in automated demand response programs with building control systems can respond to dynamic prices by using the actual prices as inputs to their control systems. Alternatively, prices can be mapped into "building operation modes," which can act as inputs to control systems. We present several different strategies customers could use to map prices to operation modes. Our results show that OpenADR can be used to communicate dynamic pricing within the Smart Grid and that OpenADR allows for interoperability with existing and future systems, technologies, and electricity markets.

1. INTRODUCTION

Open Automated Demand Response Communications Specifications (OpenADR) were developed to allow standardized demand response (DR) communication from the utility or Independent System Operator (ISO) to commercial and industrial (C&I) customers [1]. The goal of standardization is to allow interoperability with existing and new systems and potentially lower the cost of deployment. OpenADR is a Web services-based open information model that has been used by California utilities' automated DR programs since 2007. It has also been used in several pilot programs in the Pacific Northwest [2], and is being considered internationally in Canada, Korea, India, and Australia [3]. OpenADR was developed by the California Energy Commission (CEC) Public Interest Energy Research (PIER) Program's Demand Response Research Center (DRRC) at the Lawrence Berkeley National Laboratory (LBNL).

OpenADR is part of the national Smart Grid interoperability standards framework and is being piloted in national and international programs. The open standard is intended to allow anyone to implement the signaling systems, providing either the automation server or clients. The standardized common information exchange model is designed to be compatible with existing open building automation and control networking protocols to facilitate communication between utility or ISO information systems and customer electrical loads.

This paper describes how OpenADR data models can be used to communicate dynamic electricity prices to facilities and how customers can use prices to automate DR strategies. It is a summary of a larger report [4].

We define dynamic pricing as electricity pricing available to the customer in regular intervals in which the consumer does not know the electricity prices more than a day in advance. Examples of dynamic pricing include:

a. Real-Time Pricing (RTP): Electricity prices vary continuously throughout the day as a function of environmental conditions (such as outdoor air temperature), or electricity supply and demand conditions. Real-time prices can be set with day-ahead or day-of schedules. Prices usually vary hourly.

b. Peak Pricing: In peak pricing, electricity prices on peak days are different than electricity prices on non-peak days. Prices are generally preset; however, the customer does not know if a certain day will be a peak day or a non-peak day until day-ahead or day-of. Peak days are called as a function of environmental conditions (such as weather forecasts) and/or electricity supply and demand conditions.

Here, Time-Of-Use (TOU) pricing is not considered a form of dynamic pricing because they follow a fixed schedule. We define TOU pricing as electricity pricing in which the consumer knows his or her electricity prices more than a day in advance, though the price varies throughout the day.

One key objective of this research was to develop a single OpenADR data model capable of communicating both dynamic electricity prices (real-time and peak prices and/or related signals) and TOU prices to C&I facilities and residential buildings using open communications and automation technologies.

We also investigated methods to simplify dynamic electricity prices so that they can be used directly by building and industrial production systems in C&I facilities. Specifically, common information exchange is made possible by mapping smart client information to simple client information, defined as follows [5]:

Simple Client Information: The simple client information mainly consists of event-pending signal (e.g., yes/no, or simple quantification of notification), building operation modes (e.g., normal, moderate), time, and operation mode schedules.

Smart Client Information: The smart client information consists of additional items such as event notification time, start time, end time, and other event related details (e.g., actual prices, information type) that a customer could use if needed. Smart client information was intended for facilities with sophisticated controls (e.g., Internet connectivity, logic processing) capable of using complete dynamic pricing data.

Mapping Structure: A mapping structure, customized by the individual facility, is an algorithm that resides within the facility, the third-party, or the utility (e.g., EMCS, OpenADR server) to map the smart client information into simple client information (e.g., mapping real-time prices to "normal, moderate, or high" operation modes).

Section 2 outlines key data elements of dynamic prices based on our analysis of several dynamic pricing tariffs offered in the U.S, with emphasis on California tariffs. Section 3 discusses the development of dynamic pricing data models using the current OpenADR specification [5]. Section 4 presents examples of ways to map dynamic prices into simpler information that facilities and/or end-use systems can more easily use. In Section 5, we discuss links to the GridWise® interoperability framework [6]. Such concepts are needed as the electric supply- and demand-side become more integrated. We conclude with key research needs and a summary of our findings. For more details on this research and our findings see Ghatikar et al. [4].

2. DATA ELEMENTS OF DYNAMIC PRICES

We evaluated several dynamic pricing tariffs offered in the United States in an effort to identify elements that should be represented within OpenADR data models. We also examined three wholesale electricity markets to understand how electricity prices and related information are published. This information was then used to determine which elements of dynamic pricing tariffs should be represented in OpenADR data models.

2.1. Dynamic Pricing Tariffs

There is a range of dynamic pricing tariffs offered by utilities in the United States, primarily for C&I facilities. The paper focuses on California because we were able to access tariff information and other technical information that might be necessary for OpenADR technology

integration. In addition, there are future plans to demonstrate California facilities' ability to respond to dynamic prices. We also examined a real-time pricing tariff in New York for applicability of the OpenADR dynamic pricing model outside California.

Peak pricing tariffs studied were Southern California Edison's (SCE) Critical Peak Pricing (CPP) Tariff, Pacific Gas & Electric Company's (PG&E) Peak Day Pricing (PDP) Tariff, and San Diego Gas and Electric's CPP Tariff. Real-time pricing tariffs studied were SCE's and New York Consolidated Edison's RTP Tariffs. All tariffs were offered to C&I customers. Details about each of the above tariffs can be found in Ghatikar et al. [4]. The OpenADR data model was developed to accommodate all of these dynamic pricing tariffs.

2.2. Wholesale Electricity Market Systems

We also examined the wholesale electricity markets operated by the California ISO (CAISO), ISO New England, and New York ISO to understand how wholesale electricity prices and related information are published: For each of these wholesale markets, wholesale prices for energy and ancillary services markets are published on ISO websites and available for download in a number of file formats. Some websites allow users to subscribe to real-time Internet feeds.

2.3. OpenADR Communication Architecture

The communication architecture was developed using OpenADR version 1.0 specifications [5]. The current system architecture uses three existing groups (Utility or ISO Operator, Participant Operator, and Client) that interface with the Demand Response Automation Server (DRAS). Figure 1 shows these three groups. The interfaces define exchange of DR information between utility information systems, the DRAS, and the participants using a secure Internet connection. Depending on the specific DR program, the DRAS OpenADR Application Program Interfaces (API) or data models can be fully integrated with the utility information systems [4].
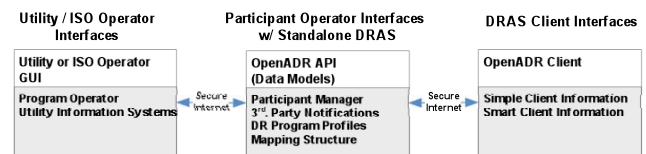

Figure 1. Current OpenADR Communication Architecture

Dynamic pricing tariffs were used to define elements that interface with existing OpenADR groups. The three interface groups were used in the communication architecture to communicate dynamic prices as follows:

a. Utility or ISO Operator OpenADR Interface: Publishes pricing schedules for dynamic and TOU tariffs.

b. Utility or ISO "Standalone OpenADR System": Used to create dynamic pricing profiles and mapping structures to send a common DR signal to the facilities. The "Participant (Facility) Operator Interface" will receive and track dynamic prices, configure the mapping structure and notifications (e.g., e-mail) and other customizations.

c. OpenADR Client Interface: Supports an OpenADR client that uses both the simple and smart client information for different end-uses.

These interfaces are building blocks that lead to definition of pricing schedules for dynamic and TOU prices.

2.4. Dynamic Pricing Schedules
We developed three electricity price schedules: an RTP rate, a peak pricing rate, and TOU rate. These schedules were used for the technology demonstration. The sources for each pricing schedule are listed in Table 1.

Table 1. Sources for Pricing Schedules

Pricing Structure	Sources of Prices
RTP	CAISO's Wholesale Energy Market Prices
Peak-pricing	PG&E's PDP Tariff
TOU Pricing	PG&E's TOU Tariff

While the source of the prices used for the peak and TOU pricing schedules were actual retail tariffs, the sources of the prices for the RTP schedule were not. The RTP pricing schedule was built with wholesale electricity prices published on CAISO's Open Access Same-time Information System (OASIS) [7]. We used the CAISO wholesale energy market prices for the RTP demonstration because OASIS is the only California system we have seen that uses automated real-time Internet feeds to publish easily accessible electricity prices. We anticipate that most retail dynamic pricing communication systems will use real-time Internet or similar feeds in the future. Therefore, using CAISO wholesale energy market prices allowed us to demonstrate a system in which OpenADR integrates with OASIS and extracts dynamic prices from real-time Internet feeds.

The OpenADR data model was developed to accommodate each pricing schedule, including prices that are published both day-ahead and day-of. Each pricing structure is discussed in the following subsections.

2.4.1. RTP Schedules
We examined several ways to structure an RTP schedule for day-ahead and day-of prices, as described in Table 2.

Table 2. RTP Price Structures

Day-ahead RTP (DA-RTP):	Day-of RTP (DO-RTP):
Prices set day-ahead, take effect next day.	Prices set each hour, take effect same day.

• Hourly (24 prices/day)	• Hourly (1 price/hour)
• 15-minute (96 prices/day)	• 15-minute interval (4 prices/hour)
	• x-minute interval (x/60 prices/hour)

The purpose of examining various RTP tariff structures was to understand how OpenADR data models could be used to communicate information for existing and potential RTP tariffs. We demonstrated two of these price structures with OpenADR: Hourly DA-RTP and 15-minute interval DO-RTP. These two RTP data models are representative of data models needed for similar RTP price structures. For example, using the same model developed for Hourly DA-RTP, 15-minute interval prices can be represented if the number of prices/day is increased from 24 to 96.

2.4.2. Peak-Pricing Schedules
In our study, we used PG&E's PDP tariff as our peak pricing schedule, though the OpenADR dynamic pricing data model also accommodates other types of peak pricing schedules such as variable peak pricing. PDP days are triggered by high temperatures, CAISO emergencies, or high market prices, and they are announced day-ahead. Nine to 15 peak days are called each year, and they can occur on any day of the week. On peak days, electricity costs increase during peak hours (2–6 pm or 12–6 pm, depending upon the rate schedule that the facility is on). Customers stay on their existing TOU tariff and a peak energy charge ($1.20/kWh) is added to existing energy costs during peak hours on peak days [8].

2.4.3 TOU Schedules
TOU prices can vary in different seasons (e.g., summer and winter) and may also vary daily (e.g., peak, part-peak, and off-peak). However, the prices are pre-set by the utility. Hence, customers know their electricity costs well into the future. TOU pricing structures are similar to peak pricing structures except that electricity prices are always known; unlike with peaking pricing tariffs there is no uncertainty about whether tomorrow will be a peak day or not. Therefore, TOU schedules could use the same data model as peak pricing schedules.

2.4.4. One Comprehensive Data Model
We have determined that one comprehensive data model will suffice for sending both dynamic and TOU prices. The RTP schedule potentially requires the largest number of elements. Therefore, the OpenADR data model developed for RTP can be used to represent both peak pricing and TOU schedules and related information.

2.5. Methods of Acquiring Price Schedules
We developed two ways of acquiring price schedules:

a. Manual Entry Interface: The utility or ISO operator, through a GUI, manually enters prices and publishes them day-ahead or day-of.

b. Real-Time Internet Feed: Prices are extracted from real-time Internet feeds. Specifically, the Web service from CAISO's OASIS for both day-ahead and day-of prices were used to create an OpenADR-compliant RTP data model (also in Web services).

Using real-time Internet feeds allows for automation with utility- or ISO-published prices and integration with its systems. The benefit of manual entry is that the utility operator has some flexibility to issue customer-directed dynamic pricing rates or DR events. An RTP schedule using a manual entry interface was also developed for an OpenADR demonstration project with residential pricing schedules, communication technologies, and related devices [9].

3. DYNAMIC PRICING DATA MODEL

This section describes the development of an OpenADR-compliant data model for communicating real-time electricity prices. We also developed a dynamic pricing communication architecture and system that use OpenADR specifications. In addition, we analyzed how peak pricing and TOU pricing schedules could be represented using the same data model.

3.1. Dynamic Pricing Communication Architecture

The data elements of dynamic prices were applied to the existing OpenADR communication architecture, discussed in Section 2.3. Figure 2 shows the communication architecture developed for dynamic pricing. The interfaces are as follows:

a. Utility or ISO Operator OpenADR Interface: Lists pricing schedules for both dynamic and TOU tariffs. This interface allows various functionalities (e.g., configure participant accounts, send OpenADR messages, manual and real-time Internet feeds for RTP) using a GUI, called the "Utility dashboard" or "ISO dashboard."

b. Utility or ISO "Standalone OpenADR System": Used to create dynamic pricing profiles and mapping structures to send common DR signals to facilities. The participant operator interfaces with the OpenADR system (using a GUI, called the "Participant Dashboard") to allow the following functionalities: monitoring OpenADR signals and prices, configuring mapping rules for simple client information, etc.

c. OpenADR Client Interface: Supports an OpenADR client that uses both the simple and smart client information for different end-use sectors for C&I and residential.
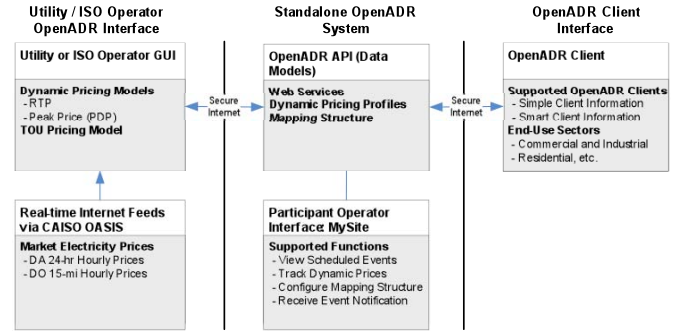

Figure 2. OpenADR Communication Architecture for Dynamic Pricing

3.2. Dynamic Pricing System

OpenADR for dynamic pricing uses the same standalone OpenADR system as California automated DR programs do. The OpenADR system GUIs for the utility or ISO, the participant operators, and the OpenADR client were enhanced for dynamic prices.

Figure 3 shows the structure of the OpenADR dynamic pricing system. It also shows client interfaces for C&I and residential customers. C&I facilities and residential customers could use smart and/or simple client information depending on the sophistication of their building control systems. Providing simple client information ensures backward compatibility to existing DR programs.

The residential demonstration project mentioned in Section 2.5 used "Bridge Clients" at a radio sub-station [9]. A Bridge Client translates Internet-based OpenADR RTP information into RTP profiles (price schedules and price intervals) and broadcasts these profiles using radio communications. Communicating devices within residences can use RTP profiles to both display price information and shed/shift loads. A Bridge Client is shown in Figure 3.

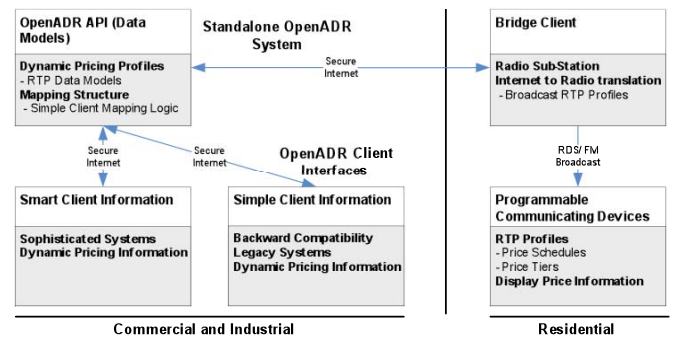**Figure 3. Structure of OpenADR Dynamic Pricing System: Architecture and Interfaces**

3.3. Dynamic Pricing Tariff Information

The following information must be determined in order to use OpenADR data models for a particular dynamic pricing tariff:

- Overall time period that the prices apply (e.g., entire day or some specific time period in the middle of the day). This is used to specify the start and end time for the DR event that is specified in the OpenADR signal.

- Whether the time period is broken up into a schedule of prices and, if so, the resolution of the time slots. OpenADR is flexible in allowing arbitrary schedules of time periods and can easily accommodate varied time periods (e.g., hourly, 15-minute).

- The type of price data to be sent, which is represented in OpenADR using three different types of price information, Absolute Prices (PRICE_ABSOLUTE), Relative Prices (PRICE_RELATIVE), and Price Multipliers (PRICE_MULTIPLIER). For example, PG&E's CPP tariff used price multiples while the PDP tariff uses relative prices.

3.4. RTP Data Model

An example of a representative OpenADR client interface data model for a day-ahead hourly RTP using eXtensible Markup Language (XML) is shown below.

```
<p:listOfEventState
xsi:schemaLocation="http://openadr.lbl.gov/src/1/EventSta
te.xsd" xmlns:p="http://www.openadr.org/DRAS/EventState"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
    <p:eventStates offLine="false" testEvent="false"
drasName="5.0" schemaVersion="1.0"
eventStateID="1960368957" drasClientID="LBNL.flr"
eventIdentifier="100208-151721" eventModNumber="0"
programName="RTP">
        <p:simpleDRModeData>
            <p:EventStatus>FAR</p:EventStatus>
<p:OperationModeValue>NORMAL</p:OperationModeValue>
            <p:currentTime>-22788.719</p:currentTime>
            <p:operationModeSchedule>
                <p:modeSlot>
<p:OperationModeValue>MODERATE</p:OperationModeValue>
                    <p:modeTimeSlot>0</p:modeTimeSlot>
                </p:modeSlot>
                <p:modeSlot>
<p:OperationModeValue>HIGH</p:OperationModeValue>

<p:modeTimeSlot>18000</p:modeTimeSlot>
                </p:modeSlot>
                <p:modeSlot>
<p:OperationModeValue>MODERATE</p:OperationModeValue>
<p:modeTimeSlot>82800</p:modeTimeSlot>
                </p:modeSlot>
            </p:operationModeSchedule>
        </p:simpleDRModeData>
        <p:drEventData>
         <p:notificationTime>2010-02-08T15:17:21.000-
08:00</p:notificationTime>
            <p:startTime>2010-02-09T00:00:00.000-
08:00</p:startTime>
            <p:endTime>2010-02-09T23:59:59.000-
08:00</p:endTime>
            <p:eventInfoInstances>

<p:eventInfoTypeID>PRICE_ABSOLUTE</p:eventInfoTypeID>
                <p:eventInfoName>price</p:eventInfoName>
                <p:eventInfoValues>[1]
```

1 Only one of the 24 *eventInfoValues* field is shown for an RTP event of 24-hour duration. This field could be extended to 96 prices/day (e.g., 15-minute prices), depending on specific RTP program requirements.

```
            <p:value>0.03638841</p:value>
            <p:timeOffset>0</p:timeOffset>
        </p:eventInfoValues>
            </p:eventInfoInstances>
        </p:drEventData>
    </p:eventStates>
</p:listOfEventState>
```

The OpenADR dynamic pricing data model contains the XML representation of metadata (bolded) such as location, version of data models (called schemas), DR program, client identifiers, and tariff name (e.g., RTP, PDP, CPP). Following the metadata, the OpenADR data model is split into two main sections for smart and simple client information. In the example above, price information is provided to the simple client as "normal", "moderate" and 'high' based on time and to the smart client as an absolute value of current price [4].

3.5. Using the RTP Data Model for Peak and TOU Prices

The OpenADR RTP data models can be used to communicate peak and TOU prices and related information. Information from PG&E's PDP rate E-20 (e.g., metadata, rate schedule, tariff, usage rates, intervals, date/time) was represented using the OpenADR RTP data models [4].

Additional peak pricing information not explicitly captured in the data model such as "Demand and Energy Rates" for seasons (such as summer, winter, summer and winter, etc.) and rate periods (e.g., On-peak, Part-peak, Off-peak), voltage, etc. are not necessary to communicate if the facility strategies are price-based and/or determined during the period of enrollment in dynamic pricing tariffs. Any other information is usually part of the utility contract with the facility or included in other OpenADR interfaces and can be excluded from the OpenADR client interface used to represent peak pricing.

TOU prices use the same structure as peak pricing except that the prices are static day-to-day. Therefore, the same data model used for peak pricing can also be used for TOU pricing.

4. DYNAMIC PRICING MAPPING METHODS

One way to simplify dynamic pricing signals and allow interoperability with existing OpenADR clients is to map smart client information to simple client information. Such a translation allows mapping actual dynamic prices to simple "operation modes" such as normal, moderate, and high. This section presents several ways to do this.

Simple client information is currently used by facilities in California automated DR programs such as PG&E's PDP Tariff and the Demand Bidding Program. This smart-to-simple mapping could be either external to the facility (e.g., utility or ISO OpenADR server) or internal to the facility (e.g., sophisticated control systems, gateway). Mapping prices to operation modes may facilitate wider customer

5

participation in dynamic pricing tariffs because it simplifies facility or EMCS processing of dynamic pricing signals and carrier communications, allows for backward compatibility with existing DR customers and their DR strategies, and allows interoperability with less-sophisticated or legacy controls.

Optimization against actual dynamic prices will yield higher energy savings. However, mapping allows facilities to reduce up-front programming and labor costs related to developing and maintaining optimal control strategies capable of using actual dynamic prices. Therefore, many existing or new facilities may opt to use operation modes instead of prices in order to simplify their control strategy design. A facility can always switch from using simple client information to using actual dynamic prices when desired.

Two strategies for mapping dynamic prices to operation modes (sent in one message) to the facility are: (1) absolute mapping of price ranges to operation modes and (2) relative mapping of prices to operations modes.

4.1. Absolute Price Mapping
Absolute mapping strategies allows the customer to set simple rules to map price ranges to operational modes (e.g., <12 cents/kWh is normal, 12-18 cents/kWh is moderate, and >18 cents/kWh is high). The CEC/Sacramento Municipal Utility District and the Electric Power Research Institute implemented absolute mapping strategies in two separate OpenADR technology demonstrations using different interoperable technologies [9, 10].

4.2. Relative Price Mapping
Using absolute mappings of price ranges to operation modes may be too simplistic for electricity markets where price variability (or volatility) needs to be addressed. Long-term (and, possibly, short-term) changes in electricity costs could have significant impact on facility operations and business. In such cases, relative mappings can be used to link prices to operation modes, participation time, etc. The goal of using relative mappings is to provide flexibility to the facilities in mapping prices to operational modes.

We propose several early concepts for relative price mapping methods that could deal with price volatility over time. These mappings can be based on customer choices (e.g., how long a customer is able to be in a certain operation mode), an "electricity price reference" (e.g., average or high price), or a price index (i.e., a non-dimensional number or percentage) that is customizable by individual facilities.

One simple concept to map prices to operational modes, as illustrated in Figure 4, would be to have the customer specify the number of hours they are willing to be in each operational modes each day and then, given DA-RTP rates, develop an operation schedule for the entire day. For

example, a customer chooses to be in high mode for "x hours" and in moderate mode for "y minus x hours" of the day. The transitional prices are determined by looking at the price duration curves, constructed much like load duration curves. In Year 1, the transition price between normal/moderate modes would be D and the transition price between moderate/high modes would be C. Similarly for Year 2, the normal/moderate transition would be B and the moderate/high transition would be A. This mapping method solves the problem of customers being in high and/or moderate mode more of the time due to increased energy costs over time. Customers could also specify different numbers of hours to be in different modes for different seasons, different days of the week, etc. For example, in California, it may make sense to be in high mode less in the winter than in the summer because retail prices are generally higher in the summer than in the winter.
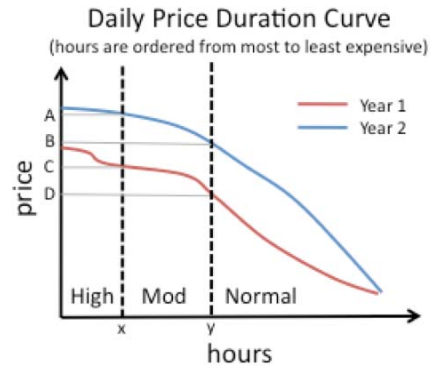

Figure 4. Relative Mapping by Choosing Number of Hours per Operation Mode

Other methods of relative price mapping could use an "electricity price reference" for next-day prices and map them to operational modes. Such methods could use average, low, and/or high electricity prices as a reference to calculate normal/moderate and moderate/high transition prices [4]. Another solution to consider would be to create some sort of "electricity price index" (i.e., a non-dimensional number or percentage) based on historical prices and customer choices resulting from those prices.

Whichever method is chosen, communicating both simple and smart client information is important when designing dynamic pricing models that are useful for both existing and future systems and technologies, and for interoperability. Simple client information generated with absolute or relative mapping methods supplements smart client information.

5. LINKS TO GRIDWISE INTEROPERABILITY FRAMEWORK AND SMART GRID
The GridWise® interoperability framework [6] was developed to facilitate systems integration and information exchange. The integration of OpenADR for dynamic pricing communication must meet the requirements for interoperability, backward compatibility (e.g. existing

commercial implementations), independent of technology (e.g., Web services, RDS/FM), and building communication protocols (e.g., BACnet®, Modbus®). These requirements vary based on the type and use of energy management and underlying protocols. For example, the BACnet® protocol [11, 12] can interoperate with OpenADR as both can communicate with Web services. The OpenADR communication infrastructure could be integrated with existing systems, as OpenADR is an application-layer information model that could be integrated into control systems protocols to meet the requirements of GridWise® context-setting framework.

Efforts to standardize OpenADR communication are already under way within national Smart Grid activities. The Organization for Advancement of Structured Information Standards (OASIS®) [13, 14], a standards body, and Utilities Communications Architecture (UCA®) [15], user groups, and other entities are working in close alignment to provide deliverables for the National Institute of Standards and Technology (NIST) Priority Action Plans (PAP), primarily PAP 09 for standard DR and Distributed Energy Resources signals [16].

6. RESEARCH NEEDS

While there has been significant progress in demonstrating the application of OpenADR to a variety of dynamic pricing structures, there are few remaining key challenges and research needs such as:

- The OpenADR data model has a placeholder for real-time energy use that allows real-time feedback control. This has only been used in a limited number of demonstrations [17, 18]. Real-time feedback control could allow facilities to achieve their load shaping goals, potentially minimizing energy costs.

- Research is needed on customer strategies to cope with the volatility of retail energy prices.

- Further research is needed into methods of mapping dynamic prices to operation modes. In addition, we need to explore where the mapping logic can/should exist: in the building control system or external to the building? The answer to this question is a function of the capabilities of the building control system.

7. SUMMARY OF FINDINGS

This research has explored how the OpenADR data model can support several dynamic pricing schedules such as RTP, peak pricing, and TOU pricing. Common data models facilitate transition of customers from one dynamic pricing tariff or DR program to another. OpenADR data models support most day-ahead and day-of dynamic pricing structures offered in California.

8. ACKNOWLEDGEMENTS

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