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# Demand-side Integration in a Restructured Electric Power Industry

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## SUMMARY

Modern electric power systems are becoming over-stressed due to shrinking reserve margins, elevating electricity cost, permitting difficulties, and financial risks of bulk expansion. Demand-side integration (DSI) addresses these problems through programs that encourage the efficient and effective use of electricity in support of power systems and customer needs. A growing international community including CIGRE Working Group C6.9 has adopted DSI to refer to the underlying technical area encompassing all aspects of Demand Side Management (DSM) in today's restructured electric power industry [1] [2]. Common drivers, challenges, and forms of demand-side integration are shared internationally [1]. However, lack of consistent use of demand-side terminology creates the need for a framework that defines the relationships between traditional and newly developed methods of demand-side integration.

The paper identifies concepts and implementation methods of DSM that remain relevant in restructured environments. The authors analyze a broad range of demand-side implementations to develop a conceptual framework encompassing both vertically-integrated and restructured industry environments, including market environments where demand response programs coordinate customer usage with electricity market conditions. A comparison between load shape impact objectives of programs reveals noticeable terminology differences in regions where electricity markets exist. In these regions, the terms Demand Response and Energy Efficiency have increasingly replaced DSM. Terminology shifts and other industry trends validate the need to extend traditional DSM concepts and methods to formulate a generalized framework. The proposed DSI framework relates traditional and new forms of demand-side integration. The framework distinguishes implementation horizons, incentive methods, actuation methods, and objectives for integration.

System planners and regulators worldwide are utilizing regional codes and standards to increase energy efficiency and renewable resource adoption. Renewable portfolio standards and regional energy efficiency requirements speed adoption rates. The demand-side integration framework also encompasses such forms of implementation.

## KEYWORDS

Energy Efficiency, Demand Response, Demand Side Management, Demand-side Integration, Industry Restructuring, Electricity Markets, Resource Planning, Distributed Resources, Renewable Energy.

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# 1 Introduction

Section 2 identifies fundamental DSM concepts, trends associated with electric power industry restructuring, and terminology shifts resulting from restructuring. Section 3 proposes a framework for relating demand-side implementation methods of various types. The framework encompasses traditional, market operator administered, and emerging forms of demand-side integration. Based on extensive review of DSM program surveys and recent publications on DSI, the authors propose a conceptual framework in Section 4 for characterizing demand-side implementations. Section 5 applies the framework to characterize demand-side programs designed to support system planning and system operations, respectively. By identifying a few key program attributes, as described in the framework, close relationships between seemingly disparate programs are revealed. The proposed framework facilitates improved communication and understanding of concepts and methods for demand-side integration, despite regional differences in terminology and naming conventions in use.

# 2 From Demand-side Management to Demand-side Integration

Publications on DSM extend back to the 1970's. A compilation of early technical articles are organized in [3] and textbooks on DSM concepts and methods have been published in [4] and [5]. DSM surveys detail program objectives, incentives, and implementation methods applied by utilities [6], [7]. Many of the previously published concepts are applicable in restructured environments. In particular, modern implementation methods can be related with traditional ones through comparison of program objectives for impacting load shape.

## 2.1 Load Shape Impact

DSM programs are designed to attain desired load shape impacts, as represented by the load shape objectives shown in Figure 1. The first four, peak clipping (PC), valley filling (VF), load shifting (LS), and flexible load shape (FLS), represent objectives to alter electricity consumption at targeted times of days or seasons. Each of these four objectives can be affected in operational timeframes through utility load management. The latter two load shapes, strategic conservation (SC) and strategic load growth (SLG), represent objectives to decrease or increase load at levels remaining effective in the long-run. Each of these load shape objectives are further described in [5].

## 2.2 Terminology Shift

As discussed in [1] the applicability of DSM terminology has been in question with the advent of competitive electricity markets. Many end-use customers are no longer under an environment of centralized management driven by utilities. The concept of customer-driven response or demand response is more compatible with competitive market principles than centralized utility-driven load management. In restructured regions, the demand-side is generally comprised of energy retailers (i.e., utilities, energy service providers, and other load serving entities) participating in wholesale electricity markets on behalf of end-use customers. Together energy retailers and end-use customers may provide valuable demand-side services by utilizing demand-side resources to support grid or market needs. Indeed regional operators of competitive markets have established market-based demand response programs to impact system load shape. Applicable terminology therefore depends on status of industry restructuring in respective geographic regions.

Based on observations from interactions with diverse organizations regionally and internationally, the authors note several terminology shifts that have occurred. Among them, Load Management is increasingly being replaced by the term Demand Response. Energy Efficiency is commonly being used to refer to Strategic Conservation. Also Flexible Load Shape is being replaced by the concept of Dynamic Energy Management, which is enabled through dynamic systems [8].

Despite these terminology shifts, load shaping concepts originally devised in vertically integrated utility environments are still applicable in restructured environments. Figure 2 associates load shape objectives in traditional industries with those in restructured industries. Each objective is grouped into one of the following three categories:

1) **Demand Response** with the objective of

- reducing demand peaks, particularly when usage approaches supply limits,
- filling valleys of off-peak demand to improve load factor,
- shifting load between times of day or seasons, or
- inducing demand variations or desired load shapes determined in operational timeframes.

2) **Energy Efficiency** with the objective of reducing load levels in the long-run while maintaining user comfort or level of service

3) **Strategic Load Growth** with the objective of increasing load level through electrification.

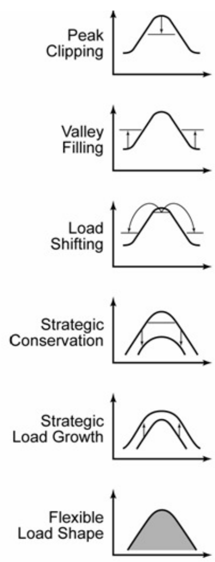


**Figure 1 : Load Shape Objectives**

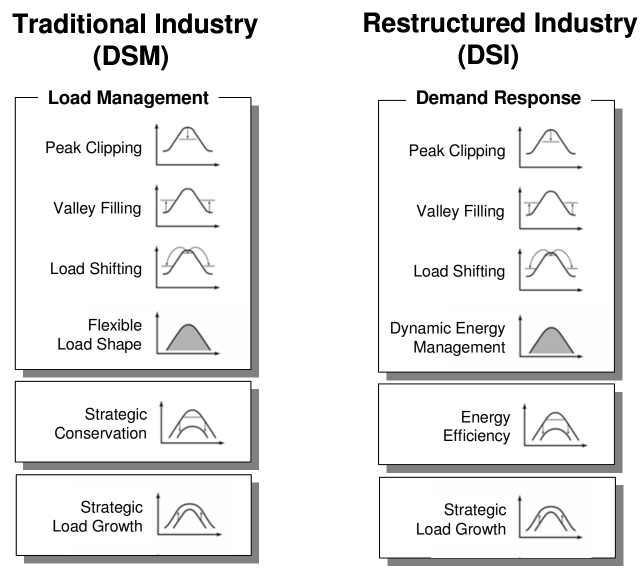


**Figure 2 : Terminology Shifts due to Industry Restructuring**

Modern emphasis in demand-side integration focuses on improving the efficient and effective use of electricity, particularly in resource-constrained regions. Consequently, implementations that have emerged after industry restructuring tend to target Demand Response and Energy Efficiency objectives rather than Strategic Load Growth.

## 3 Implementation Framework

### 3.1 Implementation Horizons and Types

Demand-side implementation methods each have a time horizon for addressing system imbalance risk. A method's associated time horizon indicates how far in advance the method must be applied to impact imbalance risk. Generally, methods designed for Energy Efficiency are applied in resource planning timeframes (i.e., at least a year ahead), whereas methods designed to incentivize Demand Response are used in system operations (i.e., minutes to days ahead). Methods that apply to operational planning, which occurs in month-ahead to seasonal timeframes, either advance Demand Response or Energy Efficiency objectives. Resource planning activities like alternative rate structures and direct incentives for equipment adoption can also advance Demand Response and Strategic Load Growth objectives.

Table I identifies demand-side implementation methods applicable by system planners and operators in traditional and restructured environments. Traditional (prior to industry restructuring) implementations [5] are listed in grey boxes, while other implementations including recently developed ones [9] are listed in white boxes. The table identifies implementation methods with solid bullets and examples with sub-bullets below each implementation method. Implementations are classified by applicable time horizon (i.e., resource planning, operational planning, day-ahead operations, and day-of operations) and by the following implementation types shown as column headings in Table I:

1. **Alternative Pricing**
   - utilizes pricing and rate structures, dynamic pricing, or rate discounts to directly affect customer behaviour in the operation of end-use devices and appliances
   - induces customer behaviour or response by impacting what customers pay for electric service
2. **Direct Incentives**
   - offers financial incentives to induce participation
   - pays participants for customer adoption or demand response performance
3. **Outreach and Cooperation**
   - requires no direct utility financial incentives to end-use customers
   - relies on outreach and information exchange to influence customer behaviour and response
   - participation is voluntary in nature
4. **Regional Codes and Standards**
   - in lieu of utility financial incentives, relies on regional codes or standards dictating minimum requirements or operating procedures
   - features a desired attribute such as energy efficiency, electric service level differentiation, or renewable energy
   - may require mandatory compliance to achieve desired load shape impact

These implementation types together with the time horizons described above comprise a framework for relating different demand-side implementation methods. The framework is useful for discerning relationships between seemingly disparate program implementations (see Section 3.2.2), and can be applied to reveal trends in program design after industry restructuring (see Section 3.2.1).

**Table I : Categorization of Demand-side Implementation Methods (bullets) and Examples (sub-bullets)**

| Implementation Type / Time Horizon | Alternative Pricing | Direct Incentives | Outreach and Cooperation | Regional Codes and Standards |
|---|---|---|---|---|
| **Resource Planning (years)** | • **Pricing and Rate Structures**<br>○ Demand charge<br>○ Time-based rate<br>○ Off-peak rate<br>○ Inverted rate<br>○ Seasonal rate<br>○ Variable levels of service<br>○ Promotional rate<br>○ Conservation rate<br>○ Net metering | • **Paid for Adoption**<br>○ Cash grant<br>○ Rebate<br>○ Buyback program<br>○ Low/no interest loan<br>○ Subsidized installation or modification<br>○ Employee rewards for successful program marketing<br>○ Billing credit<br>○ Resource Adequacy | • **Trade Ally Cooperation**<br>○ Training<br>○ Certification<br>○ Cooperative ads and marketing<br>○ Selected product sales/service<br>• **Direct Customer Contact**<br>○ Energy audit<br>○ Direct installation<br>○ Exhibits/displays/clinics<br>• **Ads and Promotion**<br>○ Mass media<br>○ Point of purchase advertising<br>○ Customer education | • **Energy Efficiency Standards**<br>○ Building codes<br>○ Appliance efficiency standards (e.g., Energy Star)<br>○ Industry efficiency requirements<br>• **Renewable Energy Standards**<br>○ Renewable portfolio standards |
| **Operational Planning (months)** | ○ Time of use | • **Paid for Performance**<br>○ Seasonal Conservation Credit<br>○ Installed Capacity | ○ Public conservation appeal (e.g., radio, TV, Internet, newspaper appeal) | • **Variable Service Subscription**<br>○ Demand subscription service |
| **Day-ahead Operations (days)** | • **Dynamic Pricing**<br>○ Critical peak pricing<br>○ Real-time pricing | ○ Regional operator economic demand response (DR)<br>○ Demand bidding of forward energy | • **Public Appeal**<br>○ Voluntary day-ahead DR (e.g., day-ahead appeal for DR) | ○ Demand limiting (e.g., day-ahead demand subscription)<br>○ Premium power (e.g., dispatachable |
| **Day-of Operations (minutes to hours)** | • **Discounted Rate**<br>○ Curtailable load<br>○ Interruptible load<br>○ Dispatchable standby generation<br>○ Direct load control | ○ Regional operator emergency DR<br>○ Demand bidding of ancillary services<br>○ Curtailable load<br>○ Interruptible load<br>○ Dispatchable standby generation<br>○ Direct load control | ○ Voluntary emergency DR<br>○ Voluntary emergency standby generation<br>○ Voluntary emergency load reduction (e.g., pre-planned voluntary interruptible/curtailable load) | standby generation)<br>○ Optional binding mandatory curtailment<br>○ Priority service<br>• **Emergency Operating Procedures**<br>○ Rolling blackout |

## 3.2 Implementation Methods

### 3.2.1 Post Industry Restructuring

The proposed implementation framework distinguishes day-ahead from day-of operations, respectively, to reflect distinct timeframes for coordination of demand response. Generally, programs supporting coordination through day-ahead operations enable demand response based on economics, whereas programs supporting coordination in day-of operations are used to resolve system emergencies.

As indicated by the grey boxes in Table I, many traditional demand-side implementations apply to system planning and day-of system operations, respectively. The concentration of white boxes in the last two rows of the table reflects a proliferation of program implementations designed to support both day-ahead and day-of system operations. These programs filled a void in demand-side activities in restructured regions. In North America, utilities in restructured regions questioned their role in planning and discontinued many DSM programs. They along with regional system operators of electricity markets created new programs to better coordinate demand-side response with regional market and system conditions. So the pattern of grey and white boxes in the table is attributable to industry restructuring and increased reliance on demand-side options to support system operations.

The implementation framework also encompasses renewable energy programs, as illustrated in the first row of Table I which shows Net Metering and Renewable Portfolio Standards (RPS). Net Metering is an example of a resource planning option utilizing Alternative Pricing, while RPS is an example utilizing Regional Codes and Standards. Since renewable energy sources are capable of impacting demand for grid-supplied electric service, their inclusion in the framework is useful for broader demand-side program analysis.

The last two columns in Table I identify implementation methods that do not require direct financial incentives from utilities to customers. Examples of non-traditional methods include public appeal for voluntary demand response, regional standards mandating minimum renewable energy procurement, and variable service subscription programs. Although versions have been piloted in the past, restructuring has led to new examples of variable service subscription, which offers individual customers a choice in level of electric service. Enhanced customer choice is a natural outcome of competition, which tends to foster innovation and increased product/service differentiation. Likewise, variable service subscription enables electric service differentiation.

### 3.2.2 Descriptive Summary

This section summarizes the implementation methods (bulleted items) in Table I and provides examples with an emphasis on non-traditional methods. References are also provided.

**Pricing and Rate Structures**
Utility planners influence customer behaviour by structuring retail prices and rates for electric service. Alternative pricing strategies are applied when customers are familiar with the equipment or technology involved and participation is neither excessively complicated nor inconvenient for the customer. Alternative pricing and rate structures are discussed in DSM literature [5]. Many examples are summarized in utility survey summaries [6],[7].

**Dynamic Pricing**
In Dynamic Pricing customers are provided with opportunities for bill savings by avoiding peak prices. Examples of Dynamic Pricing include Real-time Pricing (RTP) and Critical Peak Pricing (CPP) schemes. Typically these implementation forms mitigate operator exposure to price risk by financially exposing end-use customers to retail prices that can change over time. Although actuation of a response is not guaranteed, customer exposure to high prices financially incentivizes demand response during peak price events, and thereby helps mitigate commercial risk to energy retailers stemming from wholesale markets. [9]

**Discounted Rates for Demand Response**
Discounted Rate methods offer price breaks or discounts on retail rates in return for customer participation in demand response programs. In lieu of payments for performance, customers are provided with opportunities for bill savings by paying a lower rate for energy, demand, or both. Examples include Interruptible Load and versions of Direct Load Control that incentivize participation through rate discounts. Since customers “pay for energy used” rather than are “paid for energy not

used”, this approach is more compatible with utility billing systems. DSM survey summaries capture many utility load management programs that offer discounted rates in return for customer participation in curtailable/interruptible load, direct load control, and standby generation programs [7].

**Paid-for-Adoption**

Utility planners also influence customer behaviour through financial incentives for a desired action or response, such as customer adoption of energy efficient appliances or direct load control equipment. Examples of Paid-for-Adoption type programs include grants or rebates for equipment adoption, low interest rate loans to finance adoption, and bill credits for program adoption. Also program employees may receive financial rewards for successful program marketing leading to customer adoption. Generally, utilities use direct incentives to increase short-term market penetration of demand-side options by reducing the net cash outlay or payback period required. In this way, the upfront investment becomes more attractive. Furthermore, these financial incentives help reduce customer resistance to demand-side options, and are particularly important in the absence of proven performance history [5].

**Paid-for-Performance**

Paid-for-Performance schemes compensate customers for measured reductions in electric energy usage. A net reduction in load on the electric grid may be enabled through direct load control, interruptible/curtailable load, or standby generation. For payment purposes, the reduction is a calculated value based on the customer’s actual and historic usage. Paid-for-Performance incentives are commonly used in restructured regions of North America and Europe to compensate demand response participants. Examples include Regional Operator Emergency and Economic Demand Response programs, respectively, including Demand Bidding. Under Paid-for-Performance, participants receive payments commensurate with their delivered response, which is computed or verified after triggered events. The operator calculates the amount of actuated response by comparing metered usage against an established customer baseline. Although Paid-for-Performance incentives are prevalent in restructured regions, the baseline and payment requirements increase administrative overhead, as discussed in [9].

**Outreach and Cooperation Methods**

Outreach and Cooperation methods influence customer behaviour and adoption by increasing customer awareness, knowledge, and receipt of customized services. Through targeted communications and other methods of outreach, system planners can engage customers without direct financial incentives. Examples include printed or broadcasted ads and promotions that increase customer awareness of program options, and direct customer contact to administer customized information or professional services. Direct contact enables greater levels of customer interaction through face-to-face interaction with utility representatives or trade allies via energy audits, direct installation, or other means of customized service delivery. Furthermore, direct contact through workshops, store fronts, and exhibits provides venues for obtaining customer feedback [5]. Alternatively, system operators may resort to Public Appeal to engage customer cooperation in voluntary demand response. Customers who respond voluntarily to such appeals generally are motivated by the desire to avoid system outages [9].

**Regional Codes and Standards**

Regional Codes and Standards encourage customer adoption through regional requirements or procedures. Implementation methods of this type are listed in the last column of Table I. Each involves application at a regional level. Examples include Energy Efficiency and Renewable Energy Standards established by regional governments, Emergency Operating Procedures enforced by regional system operators, and Variable Service Subscription programs operated within utility service territories. References [9] and [10] compel the need for variable service levels through customer subscription. Through Regional Codes and Standards, public interests in other desired attributes like energy efficiency or green power can be advanced. Compliance may be mandatory as in the case of national appliance efficiency standards, local building codes, and Renewable Portfolio Standards.

## 4 Characterization Framework

Based on extensive analysis of demand-side implementations worldwide [2, 6, 7, 9], the authors propose an over-arching framework to characterize demand-side programs in both vertically-integrated and restructured industry environments. Through a few program attributes, system planners and operators may readily associate their demand-side programs despite regional differences in terminology and naming convention. This is a useful initial step for facilitating regional collaboration towards overcoming industry challenges in achieving widespread demand-side integration.

The characterization framework is an extension of a framework developed in [9] for characterizing demand response programs. The proposed framework encompasses additional types of programs including those targeting energy efficiency and strategic load growth objectives. The resulting generalized framework characterizes programs by objective, incentive method, and in the case of demand response programs, actuation method. These program attributes are shown in the heading of Figure 4 and described below.

### 4.1 Program Objective

Each demand-side program is designed to achieve a primary *program objective*. The objective of Alternative Pricing and Rate Structures is to impact load shape in one of the ways depicted in Figure 1. Customer adoption is a common objective of Regional Codes and Standards as well as Paid-for-Adoption programs. In contrast, Outreach and Cooperation type programs target a diverse set of objectives, such as customer awareness, knowledge, feedback, and adoption as well as trade ally support. Finally, programs supporting system operations are designed with the objective of mitigating an operational risk (i.e., price risk and/or quantity risk). Each of these is a possible entry under the Program Objective column of Figures 4 and 5. These objectives are described in traditional DSM literature, expect for operational risk mitigation which is explained in [9].

### 4.2 Incentive Method

Every program aims to achieve an objective using a specific *incentive method* to encourage participation. The incentive method defines an *incentee* to be engaged, *incentive structure* (or rationale for engagement), and an *administrator* (i.e., the entity that administers services to achieve the identified program objective). Figures 3 and 4 concisely summarize the participation rationale, incentee, and administrator for each program type identified. Programs designed to support system operations commonly engage the customer as incentee and involve the system operator as administrator. Programs designed to support operational planning are administered by planners and engage the customer as incentee. Program options supporting resource planning typically are administered by system planners or regulators and engage one of many possible incentees such as customers, trade allies, independent contractors, vendors, and builders.

### 4.3 Actuation Method

Programs designed to support system operations are also characterized by *actuation method*. The actuation method specifies the *actuator* and type of information *trigger* used to coordinate demand response with actual system or market conditions. Coordination is required to address daily operational risk. Actuation of demand response is managed by the actuator, the entity responsible for actuating a response based on a pre-designated trigger. The trigger is the information signal used to coordinate demand response with system or market conditions. Examples of triggers include notification, price, and control signals as well as local measurements of demand or frequency deviations. Triggers are associated with demand response programs and procedures in Figure 4.

## 5 Application of Framework

### 5.1 Programs Supporting System Planning

Demand-side programs applicable in system planning (Figure 3) are typically implemented anywhere from months to years in advance of real-time system balancing. The first three columns of Figure 3 indicate the implementation horizon, type, and method associated with each program identified in the fourth column. These first four columns are useful for relating programs by implementation characteristics. The remaining columns in Figure 3 characterize programs by program objectives (fifth column) and incentive methods (last three columns). Such a structure enables comparison of programs by primary characteristics, and reveals program relationships based on implementation characteristics.

As indicated in Figure 3, programs applicable to resource planning address diverse objectives. System planners structure Alternative Pricing and Rate schemes to incentivize customers to alter usage patterns. Through Advertisement and Promotion, planners enhance customer awareness of demand-side equipment and program options. Customer awareness and public perception is influenced through mass media communications, point of purchase advertising, customer education (e.g., bill inserts, brochures, information packets, displays, clearinghouses, direct mailings), and joint marketing with trade allies. Planners offer Paid-for-Adoption incentives to reduce the net cash outlay or payback period for customer adoption of promoted equipment and programs. They also utilize Direct Customer Contact to influence customer adoption and Trade Ally Cooperation to achieve the indicated program objectives in Figure 3. In Direct Customer Contact, a trade specialist administers customized service (e.g., evaluation, installation, information services) to enhance customer adoption rates.

| Time Horizon | Implementation Type | Implementation Method | Program Name | Program Objective | Incentive Structure | Incentee | Admin-istrator |
|---|---|---|---|---|---|---|---|
| Op Plan | Alternative Pricing | Variable Service Subscrip | Demand Subscription Service | Peak Clipping | Pay and served per seasonal demand subscription | Customer | Planner |
| Op Plan | Alternative Pricing | Pricing & Rate Structures | Time of Use | Load Shifting | Save by avoiding peak times | Customer | Planner |
| Op Plan | Direct Incentives | Paid for Performance | Seasonal Conservation Credit | Strategic Conservation | Billing credit for seasonal performance | Customer | Planner |
| Op Plan | Outreach & Coop | Ads and Promotion | Public Conservation Appeal | Strategic Conservation | Reduce likelihood of system shortages | Customer | Planner |
| Res Plan | Outreach/Cooperation | Ads and Promotion | Mass Media (radio, TV, Internet, news) | Customer Awareness | Public awareness through mass media | Customer | Planner |
| Res Plan | Outreach/Cooperation | Ads and Promotion | Point-of-Purchase Advertising | Customer Awareness | Public awareness through point-of-purchase ads | Customer | Planner |
| Res Plan | Outreach/Cooperation | Ads and Promotion | Customer Education | Customer Awareness | Customer awareness through directed media | Customer | Planner |
| Res Plan | Outreach/Cooperation | Direct Customer Contact | Energy Audits | Customer Adoption | Customized evaluation services | Customer | Planner |
| Res Plan | Outreach/Cooperation | Direct Customer Contact | Direct Installation | Customer Adoption | Customized installation services | Customer | Planner |
| Res Plan | Outreach/Cooperation | Direct Customer Contact | Store Fronts/Exhibits/Displays | Customer Adoption | Customized information | Customer | Planner |
| Res Plan | Outreach/Cooperation | Direct Customer Contact | Workshops/Energy Clinics | Customer Adoption | Customized information | Customer | Planner |
| Res Plan | Outreach/Cooperation | Trade Ally Cooperation | Cooperative Advertising and Marketing | Customer Awareness and Adoption | Subsidized advertising | Trade Ally | Planner |
| Res Plan | Outreach/Cooperation | Trade Ally Cooperation | Training | Trade Ally Support and Advice | Subsidized training | Trade Ally | Planner |
| Res Plan | Outreach/Cooperation | Trade Ally Cooperation | Certification | Product/Service Validation | Stamp of approval or distinction | Trade Ally | Planner |
| Res Plan | Outreach/Cooperation | Trade Ally Cooperation | Selected Product Sales/Service | Customer Adoption | Various (rebates, free advertising, etc) | Trade Ally | Planner |
| Res Plan | Alternative Pricing | Pricing & Rate Structures | Time-Based Rates (TOU) | Load Shifting | Save by avoiding peak times | Customer | Planner |
| Res Plan | Alternative Pricing | Pricing & Rate Structures | Demand Rates | Peak Clipping | Save by reducing peak demand | Customer | Planner |
| Res Plan | Alternative Pricing | Pricing & Rate Structures | Off-Peak Rates | Valley Filling | Pay lower rate for off-peak end uses | Customer | Planner |
| Res Plan | Alternative Pricing | Pricing & Rate Structures | Seasonal Rates | Load Shifting | Save by seasonal shifting of usage | Customer | Planner |
| Res Plan | Alternative Pricing | Pricing & Rate Structures | Inverted Block Rates | Strategic Conservation | Save by reducing block usage | Customer | Planner |
| Res Plan | Alternative Pricing | Pricing & Rate Structures | Variable Levels of Service | Dynamic Energy Mgmt | Pay for subscribed level of service reliability/PQ | Customer | Planner |
| Res Plan | Alternative Pricing | Pricing & Rate Structures | Promotional Rates | Strategic Load Growth | Save on total energy cost through electrification | Customer | Planner |
| Res Plan | Alternative Pricing | Pricing & Rate Structures | Conservation Rates | Strategic Conservation | Pay lower rate if meet minimum efficiency targets | Customer | Planner |
| Res Plan | Direct Incentives | Paid for Adoption | Low/No-Interest Loan | Customer Adoption | Finance adoption at below-market interest rate | Customer | Planner |
| Res Plan | Direct Incentives | Paid for Adoption | Cash Grant | Customer Adoption | Subsidized adoption | Customer | Planner |
| Res Plan | Direct Incentives | Paid for Adoption | Subsized Installation/Modification | Customer Adoption | Subsidized installation | Customer | Planner |
| Res Plan | Direct Incentives | Paid for Adoption | Rebate | Customer Adoption | Rebate for equipment adoption | Customer | Planner |
| Res Plan | Direct Incentives | Paid for Adoption | Billing Credit | Customer Adoption | Billing credit for equipment adoption | Customer | Planner |
| Res Plan | Direct Incentives | Paid for Adoption | Buyback Program | Customer Adoption | Subsidized installation | Installer | Planner |
| Res Plan | Direct Incentives | Paid for Adoption | Employee Rewards for Successful Program Marketing | Customer Adoption | Rewards for successful adoption outcomes | Program Employee | Planner |
| Res Plan | Direct Incentives | Paid for Adoption | Resource Adequacy | Customer Adoption | Subsidized resource expansion | Developer | Planner |
| Res Plan | Regional Codes/Stds | Energy Efficiency Stds | Appliance Energy Efficiency Standards | Customer Adoption | Meet minimum appliance efficiency standard | Vendor | Regulator |
| Res Plan | Regional Codes/Stds | Energy Efficiency Stds | Industry Energy Efficiency Requirements | Customer Adoption | Meet industry energy efficiency requirements | Industry | Regulator |
| Res Plan | Regional Codes/Stds | Energy Efficiency Stds | Building Codes | Customer Adoption | Meet mandatory building efficiency requirements | Builder | Regulator |
| Res Plan | Regional Codes/Stds | Energy Efficiency Stds | Energy Star | Customer Adoption | Meet voluntary product certification requirements | Vendor | Regulator |
| Res Plan | Regional Standard | Renewable Energy Stds | Renewable Portfolio Standard | Customer Adoption | Meet minimum regional renewable requirements | Utility | Regulator |
| Res Plan | Alternative Pricing | Pricing & Rate Structures | Net Metering | Strategic Conservation | Pay net of usage and electricity production | Customer | Planner |

Figure 3: Programs designed to support system planning are characterized by objective and incentive method. A few support operational planning (Op Plan), while the rest support resource planning (Res Plan). Each is a demand-side planning option, except the last two which are planning options for renewable energy integration.

The first four programs listed in Figure 3 support operational planning by engaging end-use customers in energy efficiency or demand response programs that are applied seasonally. For example, planners may utilize Seasonal Conversation Credit and Public Conservation Appeal to encourage energy efficiency during high energy usage seasons. They may encourage demand response be applying Time of Use for load shifting and Demand Subscription Service for peak clipping.

The incentive structure of each program listed is concisely summarized in the figure. Although the majority of programs involve system planners engaging customers, some are administered by non-planners to engage other entities. For example, regulators use energy efficiency and renewable energy standards to mandate compliance of utilities, builders, and businesses with regional codes and standards. Besides customers, incentees of resource planning programs could be manufacturers, product vendors, installation contractors or trade allies.

## 5.2 Programs Used in System Operations

Demand-side programs are designed and *installed* in resource planning timeframes. However, programs implemented to support coordination of demand response are *used* in operational timeframes. Figure 4 identifies a wide range of programs used to support system operations. The last two columns of the figure specify the *actuation method* (i.e., actuator and trigger) that enables coordination of demand response with actual system or market conditions.

Demand response is provided through demand-side resources like standby generation, interruptible/curtailable load, storage, and other sources capable of impacting demand for grid-supplied electric service. An operator applies these resources to mitigate operational risk (i.e., price and quantity risks) inherent in day-to-day system operations. Programs designed to mitigate price risk typically pass all or a portion of the commercial risk stemming from fluctuating wholesale market prices to end-use customers. In contrast, programs designed to mitigate quantity risk have provisions that enable operators to rely on a designated quantity of demand response from customer resources. Reference [9] describes risk mitigation objectives of system operators, incentive structures, and actuation methods for most of the programs characterized in Figure 4. The term Variable Service Subscription, however, is newly introduced in this paper to encompass all demand response programs that provide customers a choice in level of electric service. Variable Service Subscription is typically tied to alternative pricing or rate structures that introduce variability in level of service per customer preferences (i.e., Variable Levels of Service, a resource planning option in Figure 3). Variable service is enabled by onsite resources like dispatchable standby generation and technologies like advanced meters and demand-limiting fuses. Variable service is compared to Rolling Blackout below.

| Implementation Type | Implementation Method | Program Name | Program Objective | Incentive Structure | Incentee | Admin-istrator | Actuator | Trigger |
|---|---|---|---|---|---|---|---|---|
| Direct Incentives | Paid for Performance | Direct Load Control | Mitigate Quantity Risk | Paid for performance | Customer | Operator | Operator | Control |
| Direct Incentives | Paid for Performance | Dispatchable Standby Generation | Mitigate Quantity Risk | Paid for performance | Customer | Operator | ~Customer | Notification |
| Direct Incentives | Paid for Performance | Regional Operator Emergency DR | Mitigate Quantity Risk | Paid for performance | Customer | Operator | ~Customer | Notification |
| Direct Incentives | Paid for Performance | Demand Bidding - Ancillary Service | Mitigate Quantity Risk | Paid for performance | Customer | Operator | ~Customer | Notification |
| Direct Incentives | Paid for Performance | Regional Operator Economic DR | Mitigate Price Risk | Paid for performance | Customer | Operator | Customer | Notification |
| Direct Incentives | Paid for Performance | Demand Bidding - Forward Energy | Mitigate Price Risk | Paid for performance | Customer | Operator | Customer | Notification |
| Alternative Pricing | Discounted Rate | Direct Load Control | Mitigate Quantity Risk | Pay lower rate | Customer | Operator | Operator | Control |
| Alternative Pricing | Discounted Rate | Dispatchable Standby Generation | Mitigate Quantity Risk | Pay lower rate | Customer | Operator | ~Customer | Notification |
| Alternative Pricing | Discounted Rate | Interruptible/Curtailable Load | Mitigate Quantity Risk | Pay lower rate | Customer | Operator | Customer | Notification |
| Alternative Pricing | Dynamic Pricing | Critical Peak Pricing (CPP) | Mitigate Price Risk | Save by avoiding peak times & prices | Customer | Operator | Customer | Price |
| Alternative Pricing | Dynamic Pricing | Real-time Pricing (RTP) | Mitigate Price Risk | Save by avoiding peak prices | Customer | Operator | Customer | Price |
| Outreach/Cooperation | Public Appeal | Voluntary Demand Response | Mitigate Quantity Risk | Reduce likelihood of system outages | Customer | Operator | Customer | Notification |
| Outreach/Cooperation | Public Appeal | Voluntary Emergency Standby Generation | Mitigate Quantity Risk | Reduce likelihood of system outages | Customer | Operator | Customer | Notification |
| Regional Codes/Stds | Emergency Operating Procedure | Rolling Blackout | Mitigate Quantity Risk | Equally pay and equally served | Customer | Operator | Operator | Control |
| Regional Codes/Stds | Variable Service Subscription | Premium Power | Mitigate Quantity or Price Risk | Better served with dispatchable standby generation | Customer | Operator | Operator | Control |
| Regional Codes/Stds | Variable Service Subscription | Optional Binding Mandatory Curtailment | Mitigate Quantity Risk | Better served for performance | Customer | Operator | Customer | Notification |
| Regional Codes/Stds | Variable Service Subscription | Demand Limiting | Mitigate Quantity Risk | Pay and served per subscribed demand limit | Customer | Operator | Operator | Demand |
| Regional Codes/Stds | Variable Service Subscription | Priority Service | Mitigate Quantity and Price Risk | Pay and served per subscribed priority of service | Customer | Operator | Operator | Various |

Figure 4 : Programs designed to support system operations are characterized by program objective, incentive method, and actuation method. Implementation characteristics associate programs of common implementation method and type. (The symbol ~ is used in the table as an abbreviation of the word "typically").

**Rolling Blackout**

Upon threat of severe system-wide supply shortages, regional operators may initiate Rolling Blackouts, in which outages of circuits on the distribution system are coordinated in rotating sequence until system balance is restored. In the absence of electric service reliability differentiation distinguished in retail tariffs, most customers pay equally for service reliability and consequently are equally served in the event of rotating outages.

**Variable Service Subscription**

Although Rolling Blackout and Variable Service Subscription programs differ by incentive structure and actuation methods, each is applicable as a procedure of last resort during system emergencies. Variable Service Subscription enables customers to select service level preferences that remain in effect during system emergencies. For example, Premium Power [11] dispatches customer-sited standby generation to deliver more reliable power to participants despite service disruptions that may occur on the utility grid. Also in Optional Binding Mandatory Curtailment (OBMC) [12], participating customers are exempt from rotating outages in return for reducing load on their distribution feeders during extreme supply shortages. This is unlike traditional practice of only exempting loads that supply essential public services, such as hospitals and airports, from rotating outages.

Other examples of Variable Service Subscription include Priority Service [10] and Demand Limiting [9], which enable customers to pay rather than perform for subscribed levels of service. Demand Limiting however does not require the breadth of regional coordination that Priority Service does to enforce customer preferences. Regional coordination through system operations enables delivery of greater levels of service reliability to higher priority end uses and lower costs to lower priority uses. In resource constrained regions where system reliability is at risk, such options that differentiate customer demand for service reliability [13] are compelling. Dispatchable standby generation, demand limiting meters and fuses, and control technologies at the customer's site can be used to actuate demand response and manage delivery of premium service. Furthermore, modern advanced metering capabilities enable management of Priority Service subscriptions in day-of system operations. This improves upon implementations of Demand Limiting and Demand Subscription Service that require longer lead times (e.g., truck rolls) to adjust service subscriptions.

## 6 Conclusion

The paper identifies DSM concepts and implementation methods that remain relevant in restructured environments, as well as terminology shifts resulting from industry structuring. A framework [9] for characterizing demand response programs is extended in this paper to characterize additional types of demand-side programs, including those targeting energy efficiency and strategic load growth objectives. The framework defines distinct attributes of programs applicable to system planning as well as programs used in system operations. Through extensive review of traditional as well as newer forms of demand-side integration, the authors also propose a framework for relating implementation methods by type and applicable time horizon. An over-arching framework enables a common reference point for analysis and discussion of demand-side integration concepts and methods. Centering future discussion using the DSI framework developed here should provide the electric power industry with a solid foundation for improved collaboration towards resolving industry challenges in demand-side integration.

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