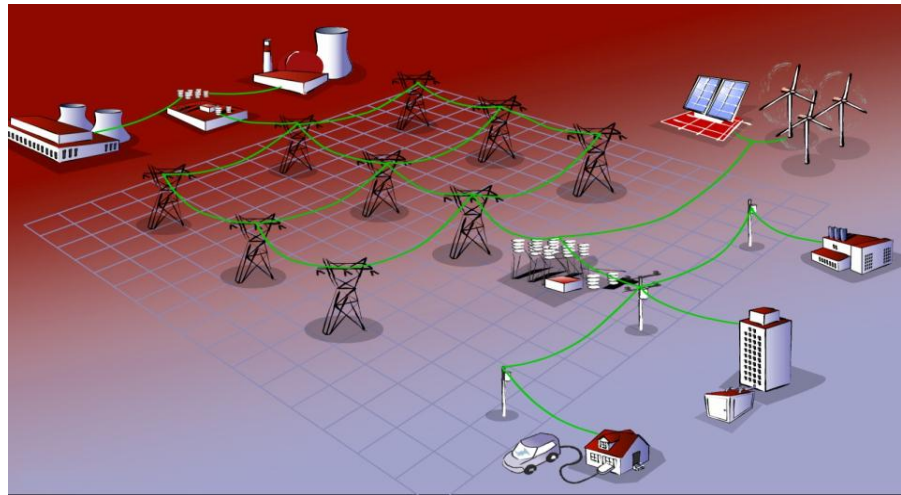




**U.S. Department of Energy**

**Office of Electricity Delivery and Energy Reliability**



## **Demand Dispatch—Intelligent Demand for a More Efficient Grid**

10 August 2011

DOE/NETL- DE-FE0004001



Prepared by:  
National Energy Technology Laboratory

## **Disclaimer**

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference therein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed therein do not necessarily state or reflect those of the United States Government or any agency thereof.

**Demand Dispatch:  
Intelligent Demand for a More Efficient Grid**

---

**DOE/NETL Contract: DE-FE0004001**

**10 August 2011**

**NETL Contact:**

**Keith Dodrill**

**(Senior Energy Infrastructure Analyst)  
Program Support and Analysis Team  
Project Management Center**

**National Energy Technology Laboratory  
[www.netl.doe.gov](http://www.netl.doe.gov)**

This page intentionally left blank

**TABLE OF CONTENTS**

**List of Acronyms and Abbreviations ..... vii**

**Executive Summary ..... 1**

**What is Demand Dispatch? ..... 4**

**Evolution of Demand Response ..... 4**

**The Synergy of Smart Grid with DR..... 5**

**Supply Dispatch (Generation) vs. Demand Dispatch (Load)..... 6**

**A Vision for Demand Dispatch ..... 8**

**Characteristics of Demand Dispatch..... 9**

**Key Processes and Technology Areas ..... 10**

**Convergence of Smart Grid, Demand Response, and Grid Efficiency..... 10**

**Current State of Demand Dispatch..... 11**

**What types of resources will support the Demand Dispatch concept? ..... 17**

**Architecture..... 20**

**What is the value proposition for Demand Dispatch?..... 21**

**Benefits..... 22**

**Benefit Analysis Summary..... 24**

**What are the barriers to implementation? ..... 25**

**Technical Challenges ..... 25**

**Regulatory / Market Challenges..... 26**

**Economic Challenges ..... 28**

**Addressing the Challenges ..... 29**

**Conclusions ..... 30**

**Recommendations ..... 32**

**References ..... 34**

**Appendices ..... 36**

**Original Abstract..... 36**

**Additional Resources of Interest..... 37**

**LIST OF FIGURES**

Figure 1: The Dispatch Spectrum ..... 2  
Figure 2: Demand Response Spectrum..... 4  
Figure 3: Supply and Demand Dispatch ..... 8  
Figure 4: Load Control to Balance Variable Generation ..... 12  
Figure 5: Broad Smart Grid Framework Incorporating Elements of Demand Dispatch ..... 15  
Figure 6: Demand and Demand-like Resources..... 17  
Figure 7: Demand Dispatch Resources ..... 18  
Figure 8: Dispatch Spectrum (with new means from demand resources and the Smart Grid) ... 19  
Figure 9: Dispatch Landscape ..... 20  
Figure 10: The Complete Electric Dispatch Model ..... 22

**LIST OF TABLES**

Table 1: SG and DR Synergies ..... 6

**Prepared by:**

**Booz Allen Hamilton, Inc. (BAH)**

**Jesse Goellner**

**Marija Prica**

**Horizon Energy Group**

**Joe Miller**

**Steve Pullins**

**John Westerman**

**Jess Harmon**

**Tom Grabowski**

**Heber Weller**

**Renz Consulting**

**Bruce Renz**

**Sextant Technical Services**

**Steve Knudsen**

**Deborah Coen**

**DOE/NETL Contract: DE-FE0004001**

# Acknowledgements

This report was prepared by Booz Allen Hamilton, Inc. (BAH) for the United States Department of Energy's National Energy Technology Laboratory. This work was completed under DOE NETL Contract Number DE-FE0004001, and performed under BAH Task 430.04.

The authors wish to acknowledge the excellent guidance, contributions, and cooperation of the NETL staff, particularly:

Keith Dodrill, Senior Energy Infrastructure Analyst



## LIST OF ACRONYMS AND ABBREVIATIONS

AC	Alternating current
ACE	Area Control Error
AGC	Automatic Generation Control
AMI	Advanced Metering Infrastructure
ARRA	American Recovery & Reinvestment Act of 2009
BAU	Business-As-Usual
BUGS	Back Up Generation Systems
CA	Control Areas
CO <sub>2</sub>	Carbon Dioxide
CHP	Combined Heat and Power
CPP	Critical Peak Pricing
DG	Distributed Generation
DOE	Department of Energy
DR	Demand Response
DRCC	Demand Response Coordinating Council
EE	Energy Efficiency
EIA	Energy Information Administration
EMS	Energy Management Systems
ERCOT	Electric Reliability Council of Texas
EV	Electric Vehicle
FERC	Federal Energy Regulatory Commission
G2V	Grid to vehicle
GW	Giga-watts
HAN	Home Area Networks
HVAC	Heating, Ventilation, and Air Conditioning

ICCP	Inter Control Center Protocol
ICT	Information and communications technology
IEEE	Institute of Electrical & Electronics Engineers
IOU	Investor owned utility
IPP	Independent power producer
ISO	Independent System Operators
LMP	Locational Marginal Price
MW	Mega-watt
MWh	Mega- watt hour
NAP Coalition	National Action Plan Coalition
NARUC	National Association of Regulatory Utility Commissioners
NETL	National Energy Technology Laboratory
NERC	North American Electric Reliability Corp.
NRT	Near-real-time
OASIS	Open Access Same-time Info System
PQ	Power Quality
PHEV	Plug-in Hybrid Electric Vehicles
RTO	Regional Transmission Operator
RTP	Real Time Pricing
SG	Smart Grid
U.S.	United States
V2G	Vehicle to Grid
VPP	Virtual Power Plant

## EXECUTIVE SUMMARY

The advent of the alternating current (AC) power system enabled electricity to be transmitted over long distances. This drove the construction of large centralized power stations that took advantage of economies of scale, leading to the centralized operating model we have today. Traditionally, load and generation have been continuously balanced in this centralized model by allowing load to take on the level of consumer demand and by economically dispatching the power produced at these central generating stations to satisfy that demand. Supply dispatch remains the predominant method for balancing load and generation in the United States (U.S.) today.

System load has grown over the years and infrequently supply has been limited, resulting in the need to reduce load using such methods as rotating blackouts and under-frequency load shedding to keep generation and load in constant balance. Direct load control and demand response programs have also been used for many years to accommodate these infrequent generation / load mismatches. Much is being done in the Demand Response (DR) community today to leverage the use of demand resources that are located behind-the-meter. Customer-owned generation and storage and controllable loads that can be curtailed or increased upon request can change the load as seen by the utility. And, with the expected capability of new Smart Grid processes and technologies, the ability to create even more sophisticated DR programs should be possible.

*Supply Dispatch relies on  
“generation following the load”  
while Demand Dispatch allows  
“load to follow generation”  
enabling full optimization of  
both supply and demand.*

This paper introduces the concept of Demand Dispatch—the complement to Supply Dispatch. Demand Dispatch represents a possible end state that can optimize grid operations beyond what can be achieved with Supply Dispatch alone. Supply Dispatch relies on “generation following the load” while Demand Dispatch allows “load to follow the generation” enabling full optimization of both supply and demand. The advent of renewable generation, which has a significant degree of variability, gives rise to this new concept.

Sandwiched between Supply and Demand endpoints on the operating spectrum are various incremental steps developed by the DR community (Figure 1) as described by the Demand Response Coordinating Council (DRCC) in 2008 [1]. Demand Dispatch, as described in this paper, differs from the incremental DR steps shown in Figure 1. Demand Dispatch considers load adjustments prior to committing generation, if those load adjustments – up or down – improve grid optimization and if such adjustments can be reliably dispatched as needed. Further, Demand Dispatch does not imply a reduced service level. Rather, if effectively

implemented, Demand Dispatch can help optimize reliability, peak load management, and energy efficiency throughout the value chain resulting in the most economical price for electricity. Having adequate quantities and capacities of demand resources is a critical enabler for Demand Dispatch.

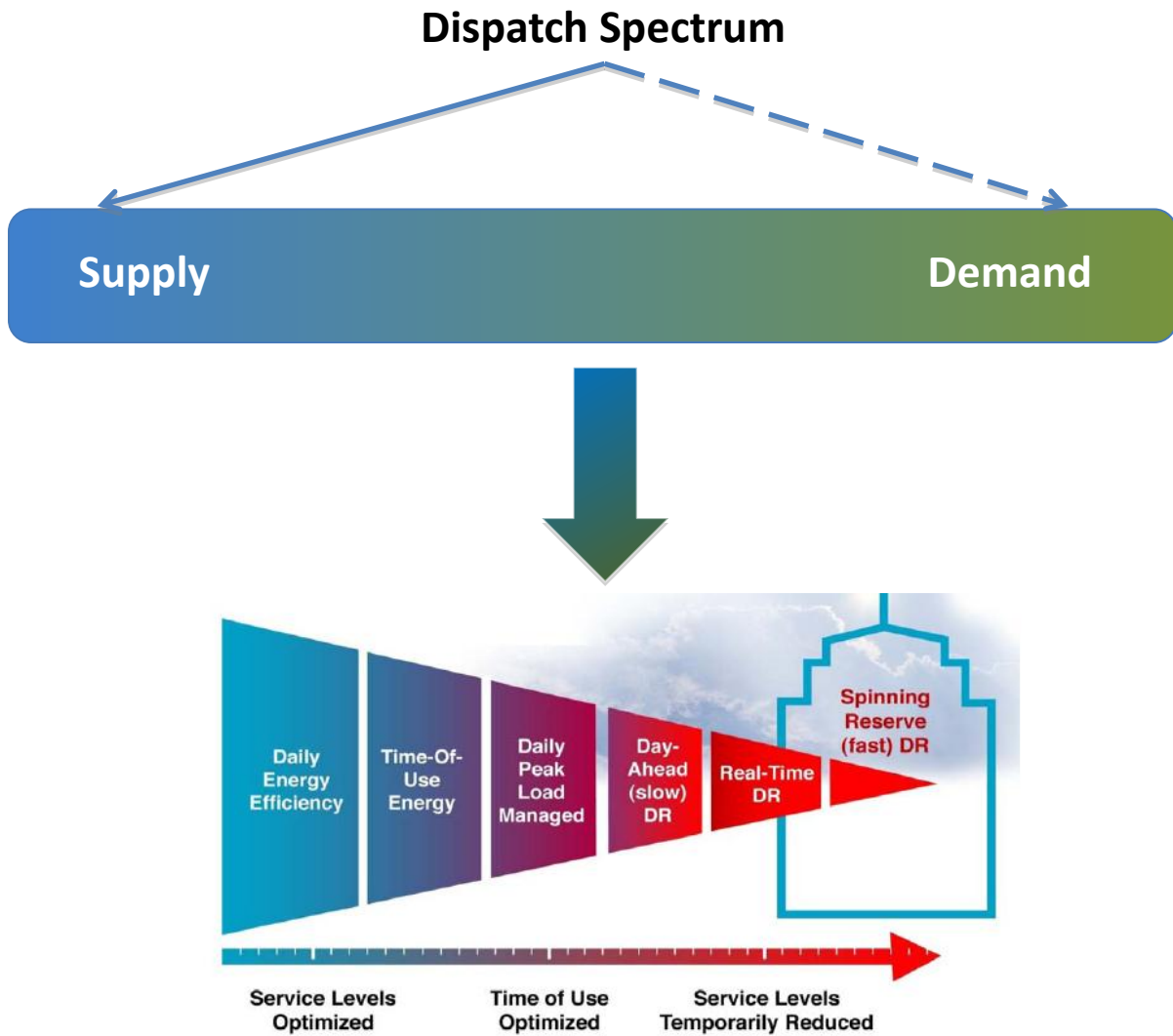


Figure 1: The Dispatch Spectrum

In addition to introducing the concept of Demand Dispatch, this paper evaluates its feasibility and value. The results suggest that:

- Demand Dispatch is a technically feasible operating model that can complement today's supply dispatch model
- Adequate numbers of Demand Resources exist to make Demand Dispatch useful

- The potential value provided by Demand Dispatch in the optimization of the grid in the areas of reliability, economics, and environmental may range in billions of dollars annually depending on the amount of demand resources participating (10% to 100%) in the market

Barriers and challenges must be overcome to make the Demand Dispatch concept possible.

The most significant challenges include:

- A compelling value proposition must be developed for consumers to motivate them to participate
- An attractive rate of return must be available for Demand Dispatch investments at the consumer / aggregator level
- Communications and control systems must be developed that provide the responsiveness required to compensate for renewable generation's variability and other market needs
- Consumer groups must support Demand Dispatch concepts so that adequate load is offered up for Demand Dispatch
- Policy and regulatory bodies must come together in a coordinated manner to facilitate Demand Dispatch deployment
- Markets for Demand Dispatch services must be in place.

*Demand Dispatch can help optimize reliability, peak load management, and energy efficiency throughout the value chain resulting in the most economical price for electricity.*

The key recommendations are:

- Hold additional discussion and deep debate on Demand Dispatch led by the National Action Plan (NAP) Coalition
- Construct a more equitable benefits-sharing model in tariffs
- Model and test Demand Dispatch strategies
- Develop new policy and regulation to value the price difference between the “point of production” and “point of delivery”
- Analyze and study the value of the Demand Dispatch operating model

Demand Dispatch is a promising new operating model that can be achieved in the future as Demand Response evolves within the Smart Grid (SG). This document is intended to raise the level of debate on this important topic and stimulate action towards further optimizing grid operations.

## WHAT IS DEMAND DISPATCH?

### EVOLUTION OF DEMAND RESPONSE

The spectrum of Demand Response (DR) is wide and varied. DR began decades ago as the interruption of specific loads at commercial and industrial customers' facilities in exchange for a reduced electricity rate. DR was then expanded to residential programs, directly controlling (on / off) hot water heaters, air conditioning, pool pumps, etc. Today, DR is becoming a more real-time application using time-based pricing incentives to encourage consumers of all types to respond to the needs of the grid on a more granular level (Figure 2) [2].

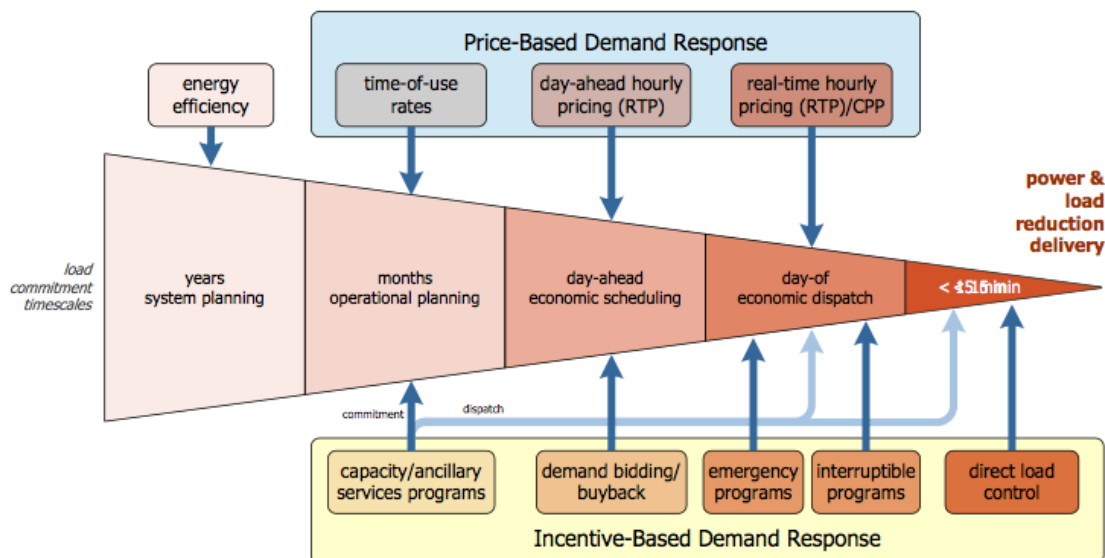


Figure 2: Demand Response Spectrum

Still, the majority of DR applications today are used to help mitigate system stress during periods of excessive loading conditions. Operationally, DR modifies specific loads over a period of minutes, or more, in response to either emerging overload conditions or projected spikes in wholesale prices.

The *Federal Energy Regulatory Commission (FERC) Order 719* [3] defined demand response in October 2008 as:

“A reduction in the consumption of electric energy by customers from their expected consumption in response to an increase in the price of electric energy or to incentive payments designed to induce lower consumption of electric energy.”

### Demand Dispatch— Intelligent Demand for a More Efficient Grid

This definition clearly defines DR as a *reduction* (only) in consumption, implies it is voluntary (*by customers*), and is accomplished in response to a pricing signal.

In addition, FERC issued the *National Action Plan on Demand Response* on June 2010 [4] which broadened the definition of DR:

“Consumer actions that can change any part of the load profile of a utility or region, not just the period of peak usage.”

This definition removes the restriction that DR is only a reduction and allows that it may occur at any time during the day. Under this definition, however, control of the consumers’ loads remains with the consumer (*consumer actions*). This definition does not explicitly include the option of Demand Dispatch, where grid operators are granted the capability to adjust the load in near real-time when system conditions require it.

More recently (February 2011), FERC included a definition of demand response in its *FERC Assessment of Demand Response and Advanced Metering* [5] that reads:

“Changes in electric use by demand-side resources from their normal consumption patterns in response to changes in the price of electricity, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.”

The difference here seems to be a new emphasis on reliability and a broadening of the base to include a range of “demand-side resources”. This opens DR opportunities to entities other than end-use customers; presumably such entities as third-party aggregators. This change in the DR base also aligns with the North American Electric Reliability Corporation (NERC) Demand Response Availability Data System being developed by NERC’s Demand Response Task Force.

While the definition of DR is evolving, it is clear that the scope is broadening to include most any influential action associated with electric usage.

## **THE SYNERGY OF SMART GRID WITH DR**

The Smart Grid (SG) transition is expected to create an infrastructure that will enable the efficient integration of distributed generation and storage, including intermittent and variable resources such as wind, solar, and electric vehicles as well as dispatchable loads and microgrids. Many of these resources will be “behind-the-meter” (i.e., demand resources) and will have the capability to participate in electricity markets.

The characteristics of the Smart Grid (SG) are well defined [6]. Table 1 highlights how the achievement of each of the SG Characteristics has synergy with the concepts of DR.

**Table 1: SG and DR Synergies**

Smart Grid Characteristics	Synergy with Demand Response
<b>Enable active participation by consumers</b>	Demand is created by consumers. Enabling their participation is fundamental to DR.
<b>Accommodate all generation and storage options</b>	Large deployments of “behind the meter” resources are enabled by the SG.
<b>Enable new products, services, and markets</b>	Linkage of electricity markets to consumers provides the incentive and mechanisms to participate in DR programs (often via aggregators).
<b>Provide power quality (PQ) for the digital economy</b>	The SG’s emphasis on PQ will create opportunities for consumers and utilities to use DR as one possible way to address PQ.
<b>Optimize asset utilization and operate efficiently</b>	SG can be used as a foundation to increase the granularity and reduce the response time of DR programs to further improve grid optimization around may important metrics (reliability, economics, environmental, etc.)
<b>Anticipate &amp; respond to system disturbances (self-heal)</b>	DR control of behind the meter resources enhances the self-healing nature of the SG.
<b>Operate resiliently against attack and natural disaster</b>	SG focus on grid security provides a more secure infrastructure for DR programs.

The synergy of SG and DR processes and technologies creates the potential for a new approach for system operation—the ability to dispatch both supply (generation) and demand (load). This capability would provide incremental value by further optimizing grid operations beyond what SG or DR can provide alone. It becomes essential for demand to “get smart” to fully realize the value of a more efficient grid. This additional method of dispatch is known as Demand Dispatch.

**SUPPLY DISPATCH (GENERATION) VS. DEMAND DISPATCH (LOAD)**

Today, grid operators are responsible for ensuring that electric supply and demand are always in balance. To meet this responsibility, the interconnected grid is divided into a number of control areas (CA). Operators monitor any mismatch between generation and load within their



responsible control area(s) and continuously adjust supply (generation) to minimize the instantaneous mismatch and to ensure that over time it is near zero.

Control areas are clearly defined regions of network topology within which the balancing of generation and load is controlled to ensure system frequency remains within limits.

Historically, control areas generally included the assets of individual vertically integrated utilities, but today groups of utility control areas have been integrated into larger footprints and operated at a higher level by Regional Transmission Operators (RTOs).

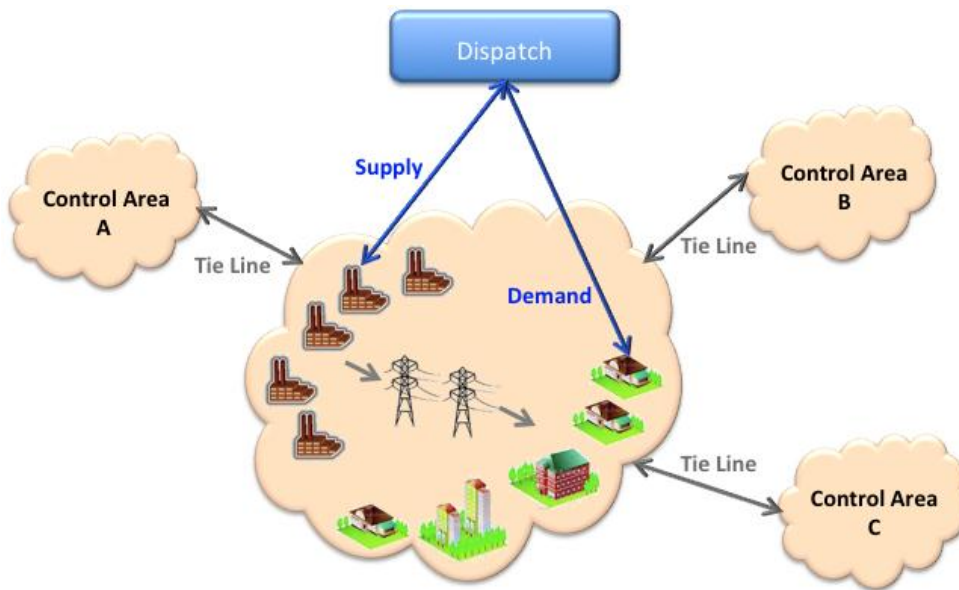
Control area operators utilize Automatic Generation Control (AGC) Systems, also known as Energy Management Systems (EMS), to monitor net flows into (or out of) the control area. These flows are measured at the interchange points among the various control areas (also known as tie-lines). Any deviation in the actual flows from what is planned / scheduled represents a mismatch in load and generation within the control area. AGC acts upon this deviation, known as Area Control Error (ACE), and sends control signals to the **generating** units

in the control area to raise or lower their outputs to reduce ACE to zero.

*... Demand Dispatch gives control area operators the capability to “increase and decrease” load in addition to the traditional method of using “raise and lower” generation signals ...*

Demand Dispatch could provide an additional mode of control to support grid operations, creating an opportunity to significantly improve the optimization of grid assets. In the Demand Dispatch operating mode, “behind-the-meter”

resources are dispatched as a complement to supply dispatch. These selected loads would be dispatched, just as generating plants are currently, to maintain ACE within limits. In this mode of operation, Demand Dispatch gives control area operators the capability to “increase and decrease” load in addition to the traditional method of using “raise and lower” generation signals alone (see Figure 3).



**Figure 3: Supply and Demand Dispatch**

Commands generated in the Demand Dispatch operating mode to increase or decrease load can be satisfied by the “load resources” in four ways: by reducing load, increasing load, increasing “behind-the-meter” generation, or decreasing “behind-the-meter” generation. At the control area level, these responses produce the same results as changing the output of generating plants the traditional way, i.e., interchange tie-line flows adjust to reduce ACE. At the local level, Demand Dispatch can mitigate local voltage and overload conditions as an alternative to transmission upgrades.

Demand Dispatch is the complement of Generation Dispatch behaving as a “virtual power plant” when viewed at the tie-line level. The addition of this new method for balancing load and generation at the control area level would create new options and substantial opportunity for further optimizing grid operations as well as assist in addressing local reliability issues.

### **A VISION FOR DEMAND DISPATCH**

Demand Dispatch is a new operating concept that represents a different approach to balancing generation and load. Unlike traditional DR, Demand Dispatch is continuously active, not just during peak times, providing continuous rapid control of loads in both directions (net decrease and net increase). Customer-owned loads, generation, and storage resources operate collectively as a complement to traditional power plants and create a new operating paradigm—rather than supply (generation) following demand; demand is adjusted to accommodate the optimal needs of supply (generation) in near real time. For example, area control error (ACE) could be significantly impacted by a demand issue on a fraction of the

distribution grid. A local demand-side control action, Demand Dispatch, could alleviate the issue to the benefit of the entire grid.

***Demand Dispatch is defined as:***

“An operating model used by grid operators to dispatch “behind-the-meter” resources in both directions—increasing and decreasing load as viewed at the system level—as a complement to supply (generation) dispatch to more effectively optimize grid operations.”

Implementation of the Demand Dispatch concept requires the participation of consumers and their resources in the electricity markets and physical / contractual mechanisms to ensure these resources are in fact available to grid operations when needed. This raises questions about how consumers will be compensated for this participation.

***Key Value Areas for Demand Dispatch***

The convergence of DR and SG processes and technologies will undoubtedly provide substantial opportunity for grid optimization. However, Demand Dispatch as a complementary operating option to Supply Dispatch is expected to provide additional opportunities for grid optimization by taking advantage of the synergies of this convergence. This incremental optimization translates into improvements in a number of areas:

- Reliability (fewer and shorter outages, reduced customer impact when outages do occur)
- Efficiency (improved energy efficiency across the value chain including reduced line and generation losses, more effective use of generation, etc.)
- Economics (reduced wholesale prices for electricity when compared to business-as-usual and the creation of a revenue stream for consumers who participate in Demand Dispatch)
- Environmental (reduction in carbon dioxide (CO<sub>2</sub>) over Business-As-Usual (BAU) as greater amounts of renewables can be integrated, thermal plants can operate more efficiently, expanded use of electric vehicles (EVs), etc.)
- Security (customer-owned resources can support recovery from major outages)

These value areas and the corresponding Demand Dispatch value proposition are discussed later.

**CHARACTERISTICS OF DEMAND DISPATCH**

The concept of Demand Dispatch has a number of characteristics that are enabled by the convergence of DR and SG capabilities:

- Shifts the dispatch paradigm—complements supply dispatch to improve optimization of overall grid operations. Rather than accepting the day-ahead load forecast, Demand Dispatch drives the modification of the forecast to better schedule unit commitments, thereby optimizing system reliability, operational risks, costs, prices, energy efficiency, and environmental impacts
- Utilizes physical and contractual mechanisms to ensure committed behind-the-meter resources do in fact participate as expected
- Provides bi-directional (raise and lower load) dispatch capabilities when viewed from the system (tie line) level
- Provides capability for near real-time response to dispatch commands
- Provides incentives for consumer participation.

### **KEY PROCESSES AND TECHNOLOGY AREAS**

As advanced DR and SG process and technology deployments increase, the opportunity to put Demand Dispatch in place as an operating mode will also increase, provided those implementing DR and SG retain Demand Dispatch as a possible end state opportunity. Some of the key areas needed for Demand Dispatch include:

- High speed, two-way communications with adequate bandwidth, latency, security, and reliability
- Behind-the-meter and centralized control systems that enable loads, distributed generation (DG), and storage resources to respond to rapidly changing Demand Dispatch requirements
- Advanced Metering Infrastructure (AMI) to a large number of residential consumers
- Programs that enable consumer participation in electricity markets (capacity, energy, regulation, reserves, etc.)
- Regulatory policies that remove barriers of entry for consumers to conduct business with electricity markets.

### **CONVERGENCE OF SMART GRID, DEMAND RESPONSE, AND GRID EFFICIENCY**

Significant progress has been made in the evolution of DR. Given its early start and the fact the SG implementation is at its beginning, DR has not had the opportunity to take full advantage of the benefits of emerging and evolving SG technologies. Exactly how it might be expanded in the future to take full advantage of new and emerging smart grid technologies remains unclear. Now is the time for the SG, DR, and Energy Efficiency (EE) communities to unite to ensure that

*Demand Dispatch may be the “killer application” that integrates many of the Smart Grid, DR, and Energy Efficiency capabilities.*

opportunities such as Demand Dispatch are considered. Successful Demand Dispatch depends on the future capabilities of the SG and the vast experience of the DR and EE communities.

For example, EVs could vary their charging rates or act in “vehicle to grid” mode to follow the variations in renewable resources (e.g., wind, solar). Large numbers of EVs operating in this mode could be a valuable asset for optimizing the integration of renewables. Other consumer loads and distributed energy resources could also be used to support Demand Dispatch. And, the future deployments of microgrids could provide an effective platform for supporting Demand Dispatch.

Further, Demand Dispatch provides an opportunity to reduce the substantial electrical losses associated with transporting electric energy from remote generation sources. A fully implemented Demand Dispatch method of control would complement today’s supply dispatch method, change the paradigm in grid operations and perhaps be the “killer application” that integrates many of the SG and DR capabilities.

This paper examines the transition of DR and its synergy with SG to ultimately achieve Demand Dispatch as a new mode of dispatch operations where specific load, distributed generation, and storage resources operate as “virtual power plants” in real-time. It examines the current state of advanced DR and the value proposition in moving to the end state of Demand Dispatch. Conclusions are then reached on its feasibility.

## **CURRENT STATE OF DEMAND DISPATCH**

Grid operations cannot be fully optimized without Demand Dispatch. Consumers pay for idle central-station generation capacity built to address peak demand whenever it occurs. The average central-station generation capacity factor has dropped from 54.9% in 1999 to 44.9% in 2009 (Department of Energy (DOE) Energy Information Administration (EIA) Electric Power Annual 2009, Table 5.2) [7]. This means for the U.S. fleet of 1,064 GW of central-station capacity, less than half (44.9%) is producing on an annual basis. For nearly two decades, the power industry has built much peaking generation that is under-utilized (actual production / annual production capacity). The cost of building generation is borne by consumers in their electricity rates and demand charges. Thus, in a national sense, if generation were better utilized, consumers would be paying less for their electric service. Demand Response and Demand Dispatch provide ways to increase that utilization.

This issue is commonly misunderstood by consumers and policy makers, and it is unlikely to change given the current incentive structure for investor-owned utilities. When an investor-owned utility builds a central-station power plant, invested stockholder money pays for it, and investors are awarded a regulated return on top of that investment. The cost of the power plant and the stockholder return on the investment are factored into the consumer rates. As

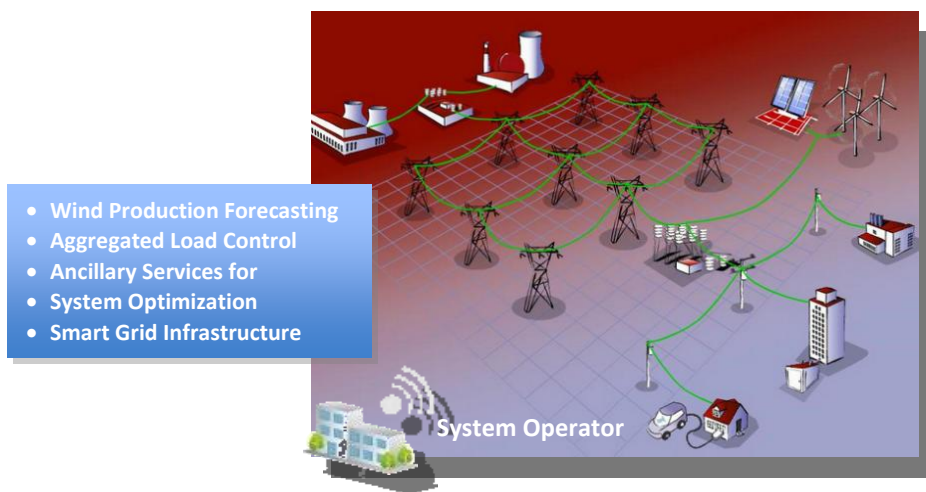
power plant assets depreciate, investor-owned utilities are inclined to build new power plants to maintain the rate of return. The same is true for transmission and distribution assets.

The BAU case is premised on the “obligation to serve” the consumer. Historically, this has been interpreted as the need to build total central-station generation capacity to meet the peak demand at any given moment. Thus, more power plants are added annually to the fleet and the average capacity factor continues to drop which increases the average price of electricity in the nation.

*If the consumer were offered the choice to reduce their demand by 5% for 50 hours per year, or build 53,000 MW of central-station generation, what would they say?*

If the consumer were offered the choice to reduce their demand by 5% for 50 hours per year, or build 53,000 MW of central-station generation, what would they say? Today, the dispatching of demand in the U.S. is limited to several direct load control and consumer-owned generation dispatch programs, therefore most consumers do not have the choice. But with the emergence of the Smart Grid, new opportunities to take a different approach present themselves; and some companies are beginning to exploit those opportunities.

One of the best examples of this is the project underway in New Brunswick, Canada. The four-year demonstration project reported by Power Shift Atlantic [8] - which will monitor more than 1,000 homes and businesses across the Maritime Provinces - aims to balance customer load and variable energy supply from wind turbines (Figure 4). The project involves controlling the usage of electricity by water heaters, air conditioning, ventilation, and refrigeration systems as a way to continuously balance the variation in wind power. This approach could replace the need for costly generation systems to supplement the wind.



**Figure 4: Load Control to Balance Variable Generation**

This is the first project in the world to use aggregated load for the integration of wind power into the system. And, the technology could also be applied to other renewables such as solar power. New Brunswick has been a good place for such innovations, due to the province's 100% broadband connectivity, small business investor tax credit - which provides a 30% personal income tax credit up to \$75,000 - and easy access to information and communications technology (ICT) talent. Creating an environment that encourages such Demand Dispatch programs is one key to the expansion of this technology.

Matching load to wind provides an added important, but not widely recognized, benefit. It eliminates the need for fossil fuel plants to fill in the generation gaps created by wind's variability. As fossil fuel plants are not well suited to cyclical operation, operating costs and performance suffers significantly when forced to supplement wind or solar generation. Shifting to a Demand Dispatch approach offers the following benefits as viewed from a thermal plant perspective:

- Improved thermal plant efficiency
- Reduced CO<sub>2</sub> emissions from thermal plants
- Improve thermal plant reliability
- Reduced congestion and line losses
- Elimination of rapid ramp rate requirements.

Here, then, is an excellent example of the convergence of Demand Dispatch with energy efficiency programs.

In addition to New Brunswick, other projects attempt to mitigate the variability of renewable resources. Denmark has been moving away from centralized generation for a number of years, placing a heavy emphasis on distributed wind power. The Danes are now developing a power cell controller that will integrate wind generation, thermal generation, and load management to maintain a continuous balance of generation and load. This project will apply such control to a large dedicated area of the grid that will attempt to operate as an island. Generation within this 61 MW load area is comprised of 37 MW of combined heat and power (CHP) and 39 MW of wind. If successful, benefits will include:

- Increased security of supply
- Improved operator knowledge of actual system conditions both locally and centrally
- Efficient system control, particularly during emergencies
- Active usage of distributed generators
- Black starting capabilities using distributed generators
- Organization of distributed generators into controllable Virtual Power Plants.

This type of overall control is what will be needed to support an integrated Demand Dispatch program.

**Demand Dispatch— Intelligent Demand for a More Efficient Grid**

The U.S. is also employing demand side resources. There is a large commitment to this approach by the Independent System Operator (ISOs) [9]. For example, PJM Interconnection recently sought generation capacity for 2014 and beyond. As a result, some old coal fired generation exited the market, and some bid much higher prices to recover their costs of environmental compliance. New resources that replaced these more expensive thermal plants included wind, solar, and most significantly, DR, which contributed an additional 4,800 MW compared to the prior auction year. According to PJM, demand response mitigated unconstrained region-clearing price increases by 10 to 20%, and contributed 30% to the price reductions in the constrained region [9].

FERC reports that there is currently available about 37,000 MW of demand response capacity in the U.S. and that this capacity could grow to between 80,000 MW and 108,000 MW by 2030. A sizable portion of this potential can likely support Demand Dispatch [9].

PJM is not alone in their use of DR. For example, the Electric Reliability Council of Texas (ERCOT) also makes extensive use of load response. Over 1,100 MW of load response was delivered during an April 2006 frequency excursion [9].

Another U.S. program that addresses Demand Dispatch technology within a broad SG framework (Figure 5) is one sponsored by Con Edison under an American Recovery & Reinvestment Act of 2009 (ARRA) award [10]. The role of Demand Dispatch is an integral part of this comprehensive vision that links multiple sources and loads within an integrated control strategy. This project aims to demonstrate the load and source control necessary to optimize a multiplicity of parameters. Within the SG, advanced dynamic control will be required for simultaneous management of real time pricing, interruptible loads, electric vehicle recharging, solar, wind, and other distributed generation sources, many forms of energy storage, and microgrid management.



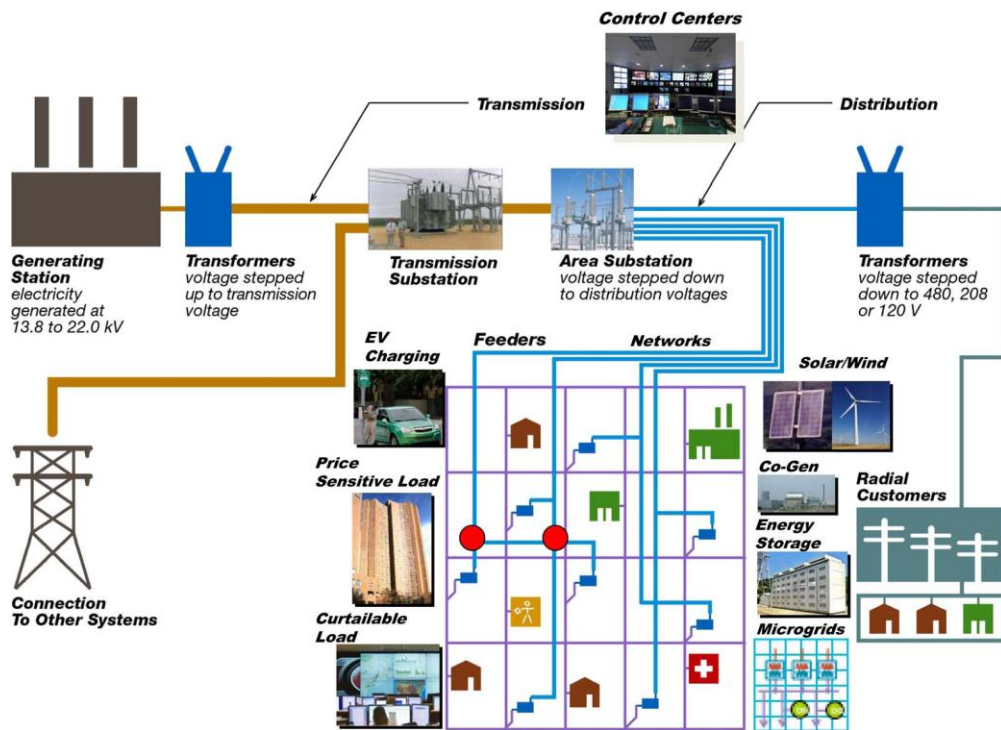


Figure 5: Broad Smart Grid Framework Incorporating Elements of Demand Dispatch

There is a growing awareness of the potential of Demand Dispatch, with current literature showing an increasing emphasis on this topic.

As an example of the latest thinking regarding the evolution of DR, the May-June 2010 issue of Institute of Electrical & Electronics Engineers (IEEE) Power and Energy magazine, offers an article titled, “*Demand Dispatch*”, [11] which lays out a vision for the broad application of Demand Dispatch. Describing how the Internet might be used for communication and control, it shows how loads that meet the communication and control requirements can be aggregated and dispatched-turned on or off-to help manage the grid. The article also describes some benefits of load-based ancillary services, such as the potential for very fast response, and explains how some characteristics of load-based services differ from power plants.

A January 2011 IEEE paper titled, “*Smart Operation: Risk-Limiting Dispatch*”, [12] describes the type of application supported by Demand Dispatch. Risk-limiting dispatch is a proposed new operating paradigm that uses the SG’s real-time information about supply and demand to address the stochastic nature of renewable sources and DR. Increased penetration of renewables, storage, microgrids, consumer choice, EVs, and smart appliances can increase uncertainty in both supply and demand of electric power. Traditional worst case dispatch counters this increased uncertainty by providing larger reserve capacity, with its associated carbon emissions. Alternatively, SG sensors, DR, and advanced communications provide more

#### Demand Dispatch— Intelligent Demand for a More Efficient Grid

accurate information about the power system and more refined means of control, which can be used to transition from worst case dispatch to risk limiting dispatch. According to the author of the January 2011 IEEE paper [12]:

“This shift can make renewables more profitable, reduce the subsidy they now receive, and encourage conservation through appropriate incentives.”

Still another IEEE paper, *“Towards Cooperative Grids: Sensor / Actuator Networks for Renewables Integration”*, [13] published in 2010 states:

“Faced with an uncertain path forward to renewables portfolio standard (RPS) goals and the high cost of energy storage, we believe that deep demand side management must be a central strategy to achieve widespread penetration of renewable energy sources.”

Deep demand side management, as proposed by the authors, employs a combination of energy information and physical control systems to dynamically match supply and demand. This is, in other words, Demand Dispatch. Predicting the output of renewables is a key to properly controlling consumption down to the appliance level. In the process, the quality-of-service requirements of the load must not be compromised while adapting to supply variations.

As the above suggests, a fundamental aspect of Demand Dispatch is the nature of the loads that are to be controlled. To successfully participate in Demand Dispatch events, loads must have the right energy consumption characteristics so that they deliver the intended load reduction without causing customer inconvenience. These characteristics include:

- Diversification (some kind of natural duty cycle)
- Not have real time response requirements (such as a TV)
- Well defined and understood energy consumption characteristics.

Potential Demand Dispatch contributors that appear to meet the above characteristics are:

- Water Heaters
- Heating, Ventilation, and Air Conditioning (HVAC)
- Plug-in Hybrid Electric Vehicle (PHEV) (chargers and battery components)
- Distributed Generation and Storage
- Solar Batteries
- Dryers
- Pool pumps
- Lighting.

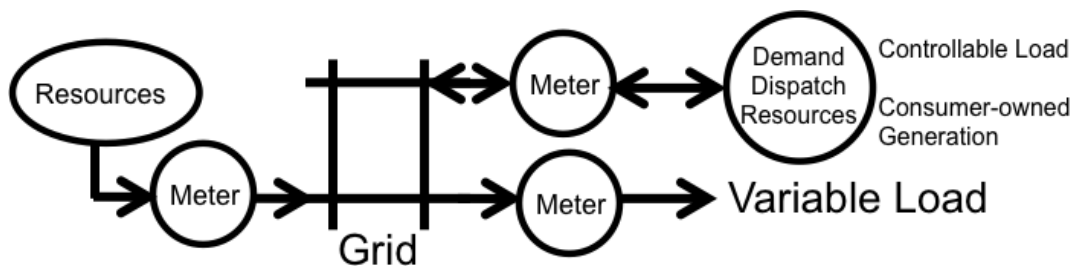
Another key Demand Dispatch consideration is who will lead its development. The first step is for RTOs to embrace the concept of Demand Dispatch and create an expanded market that can deliver the resources to support it. Once the expanded markets are created, it is likely that

aggregators and equipment vendors, both hardware and software, will become most active in delivering Demand Dispatch because of the increased market opportunities. These entities may be best suited to play the primary role of delivering Demand Dispatch, given the complicated customer interactions that will be required to manage potentially millions of loads and systems – all behind the meter. While the current business model does not support many of the Demand Dispatch functionalities, it is not a technology limitation, but rather often due to contractual limitations. By establishing a new relationship with clients, existing aggregator systems could be modified to support Demand Dispatch.

Why would utilities not be primary Demand Dispatch developers? Utilities are certainly capable of delivering Demand Dispatch, so it ultimately depends on whether they chose to have, or are directed to have, Demand Dispatch as part of the business function. Utilities have had success in the development of large dispatchable programs but most have not been, and often don't want to be, heavily involved in behind-the-meter activities. It is this cultural reality that may limit consumer participation in Demand Dispatch.

**WHAT TYPES OF RESOURCES WILL SUPPORT THE DEMAND DISPATCH CONCEPT?**

From the grid operator's perspective, nearly all loads (behind-the-meter) are variable and not controlled (Figure 6). Operators must respond to the variability of the load by balancing it with sufficient generation. Load, representing an amalgam of many electric devices within a residence or business, is ultimately variable in nature as not all appliances and individual loads run at the same time. Some of the load, in fact, is controllable through direct load control programs that have been in place at many utilities for years. Behind-the-meter, there also exists consumer-owned generation (exclusively commercial and industrial customers) that some utilities have harnessed to address peak demand periods with generation dispatch programs.

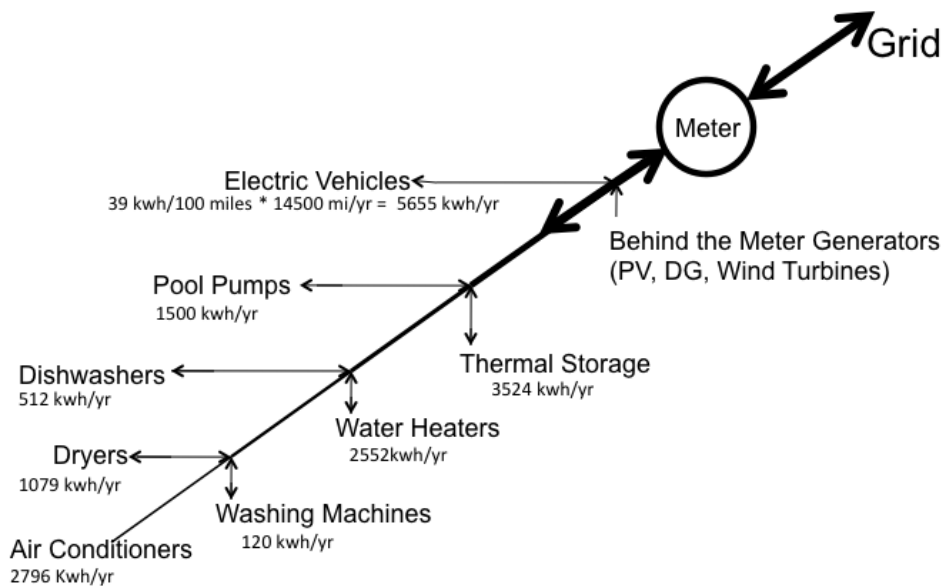


**Figure 6: Demand and Demand-like Resources**

Another key aspect of Demand Dispatch is the technology needed to support it. Communications systems must possess operational characteristics that support all Demand

Dispatch functionality. This will require performance characteristics in such areas as availability (e.g., greater than 99%), latency, and throughput capacity. Utilities that are deploying AMI systems today, for instance, should ask whether their current DR programs can support Demand Dispatch. The sophistication and complexity required to manage millions of end devices may require a reexamination of the type of architecture currently being deployed by many AMI / Home Area Networks (HAN) systems.

Demand resources can make the grid more efficient and reliable and will allow for successful islanding and sub-islanding, with microgrid and related deployment strategies, becoming a common component of the new SG. DR is already playing a significant power system role. Meanwhile, a solid foundation is currently forming for Demand Dispatch to play an equally important role in the power system of the future.

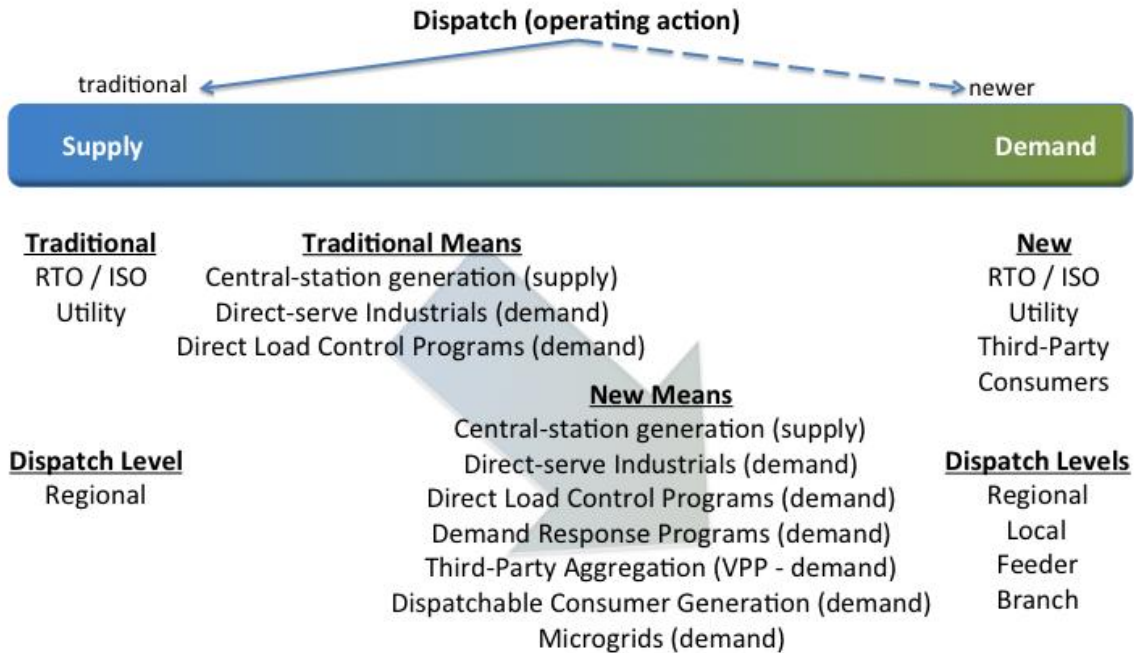


**Figure 7: Demand Dispatch Resources**

The controllable load, consumer-owned generation, and variable load represent a significant level of demand resources as observed by the grid operator (Figure 7).

Figure 7 shows typical U.S. residential loads for various appliances behind-the-meter. Some of these appliances (dryers, dishwashers, washing machines) operate intermittently, thus knowledge of their status is key to understanding if the appliance can be used for Demand Dispatch. Other appliances (pool pumps, air conditioners, water heaters, heat pumps) operate on continuous duty cycles, thus changes to duty cycles can be an effective means for Demand Dispatch.

The key to understanding Demand Dispatch is to recognize that it is an active operating model, not a consumer program or technology (Figure 8). Consumer programs and technology represent a means to actively operate grid “components”.



**Figure 8: Dispatch Spectrum (with new means from demand resources and the Smart Grid)**

The dispatch of demand resources can be under the control of RTOs, ISOs, utilities, third-party aggregators or service providers, or consumers as long as the required change in electric demand seen by the grid is dispatched by the grid operator and is deterministic. In other words, a dispatching operation requires a determined one-for one response, not an assumed probability that the load or resource will respond as dispatched.

Controllable loads and consumer-owned generation fit the deterministic dispatch model. However, variable load does not because its response to a grid operator dispatch signal has a possibility of being overridden or ignored by the consumer. Thus, inclusion of variable load in the Demand Dispatch operating model introduces uncertainty for magnitude and timing of the variable load response to a dispatch action. This is not the end of the world for dispatching variable load; it simply requires accurate, repeatable knowledge of what portion of the variable load will certainly respond to the grid operator’s dispatch command.

## ARCHITECTURE

The structural aspects of Demand Dispatch as an operating model must fit the overall dispatch concepts (Figure 9) and provide broad opportunity for participation in an open, transparent, repeatable, and scalable fashion. A robust architecture must be built to achieve the goals of Demand Dispatch.

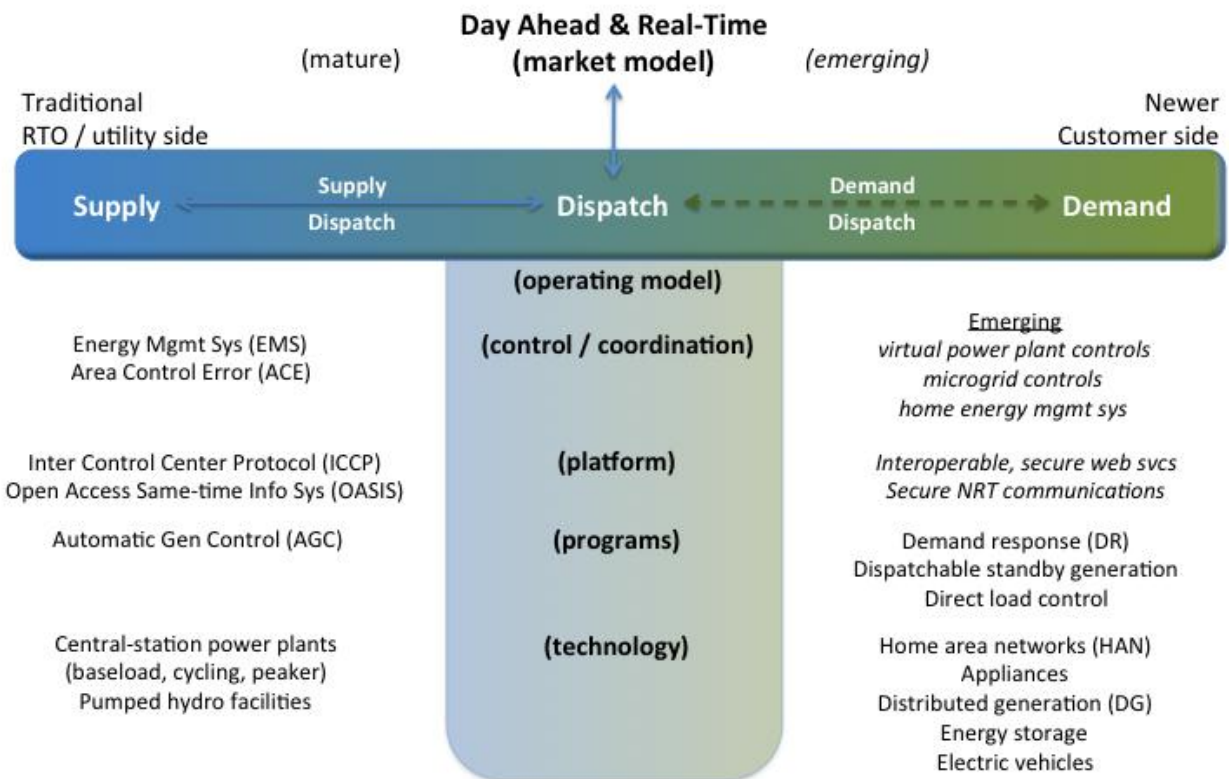


Figure 9: Dispatch Landscape

One key to the success of Demand Dispatch landscape is the integrated communications system(s) that support the monitoring, control, and recording of dispatch actions of consumer load and consumer-owned generation. Such communications must be secure and near-real-time (NRT) in nature. In addition, new control algorithms will be needed that make full use of both supply and demand resources, including an expanded version of economic dispatch.

## WHAT IS THE VALUE PROPOSITION FOR DEMAND DISPATCH?

Demand Dispatch can be a valuable tool for grid operators who traditionally address peak demand with costly peaking resources (natural gas peakers). Enabling the use of demand resources, including load, generation, and storage, with programs and technologies for grid operator dispatch offers an improved way to optimize the electricity value chain. However, since the consumer owns the demand resources, there must be a sharing of the value with them.

The Demand Dispatch value proposition for the consumer is essential for success. From the consumer's perspective the costs and value must be delivered in real terms:

- My electric vehicle is charged in the night and ready for my morning commute
- My thermal storage charges during the night and is ready for the morning discharge
- My pool pump now cycles on and off like my refrigerator
- My hot water heater cycles on and off more than it used to, but I still have the hot water I need
- My dishwasher may not run when I push the start button, but it will sometime today
- My air conditioning temperature varies more than it used to, but I am still comfortable
- My washing machine may not run when I push the start button, but it will sometime today
- My clothes dryer may not run when I push the start button, but it will sometime today
- My generator may come on and off at any time, but it is available to me during outages
- I receive monthly bills for my emergency generator fuel and electricity consumption, but I also receive monthly checks for my participation in Demand Dispatch
- My appliances may take longer to do the job, but the job gets done without a major delay.

With the inclusion of demand resources in the dispatch model, a more complete electric system dispatch model can be achieved (Figure 10). The traditional approach (left side of Figure 10) is dispatching central-station generation to provide energy to the consumers for their electric loads as well as dispatching portions of the fleet to provide ancillary services such as frequency regulation, voltage regulation, and spinning reserve.

However, as described previously, the generation fleet has a low average capacity factor (44.9%), and the electric delivery system that connects the supply to the load has a similar low capacity factor. Adding the capability to dispatch demand enables the operator to improve the efficient use of supply resources (more time at optimal performance levels) and the electric delivery system (less congestion and higher capacity factors).

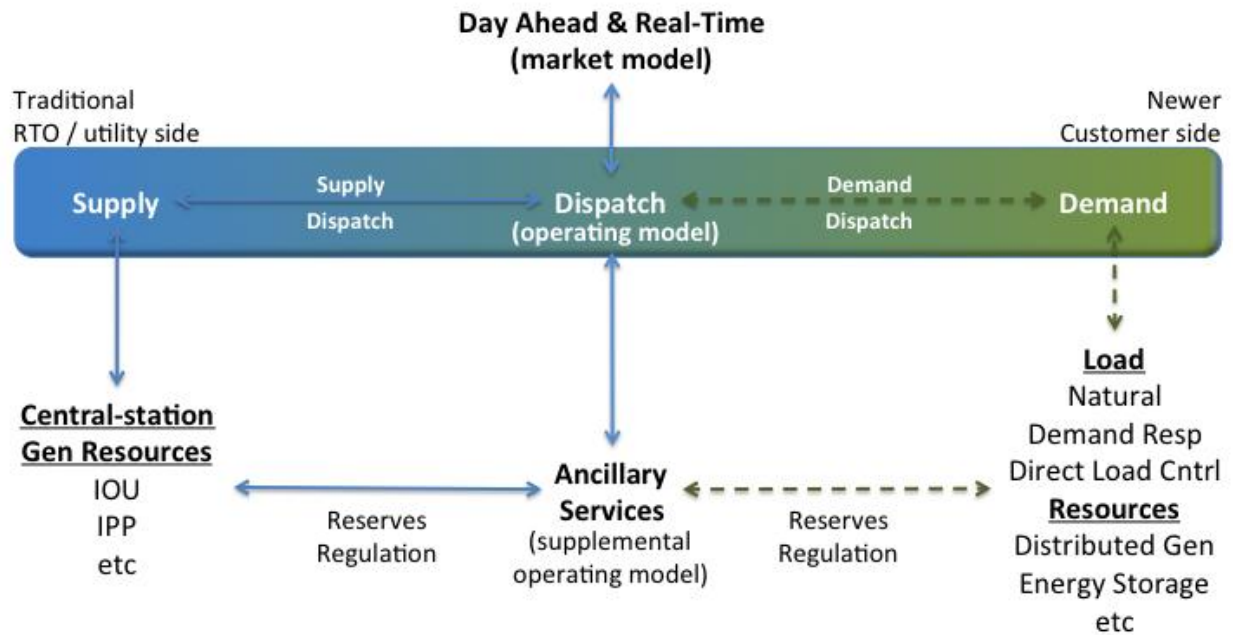


Figure 10: The Complete Electric Dispatch Model

## BENEFITS

With the inclusion of the demand side (right side of Figure 10) for dispatch, the **grid operator benefits** through the opportunity to further optimize the electric system by having additional resources under control to balance load and generation using both supply and demand

*As more appliances, homes, and distributed generation become more intelligent, and as smart grid communications coverage expands, the cost of enabling their dispatch decreases.*

resources. These additional resources create complexity, but also more options including the ability to target “pockets” of peak demand and local reliability issues with resources and controllable loads within those pockets.

The dispatch complexity associated with thousands, or perhaps millions, of demand resources in the dispatch model creates a viable business proposition for third-parties. Third-party aggregators have been providing distributed generation and load aggregation services to some utilities for years, but the cost of enabling the consumer-owned resources and loads has been a deterrent to broad use. As more appliances, homes, and distributed generation become more intelligent, and as smart grid communications coverage expands, the cost of enabling their dispatch will decrease. This improves the third-party aggregator business model for engaging demand resources in support of Demand Dispatch and provides a simplified Demand Dispatch service for the grid operator.



From the third-party aggregator perspective, air conditioners, water heaters, electric vehicles (G2V), pool pumps, thermal storage devices, dryers, washing machines, and dishwashers are new controllable loads to be offered into the marketplace as a portfolio of one or more profitable products for specific timeframes.

Likewise, consumer-owned generators and electric vehicles in vehicle to grid (V2G) mode would add their respective generating capacity to be offered by aggregators into the marketplace as one or more profitable portfolio products for specific times. The aggregator could also develop marketplace products representing a combined (bundled) portfolio, including the increase of load at times of low load when that is more optimal for the grid. For example, when the power system is challenged by minimum generation requirements, adding aggregated load in the form of charging electric vehicles could provide economic and reliability benefits.

With this business model, the aggregator offers his portfolio of products representing controllable loads and generating capacity into the marketplace. Awarded products are dispatched by the grid operator, and dispatched awards are paid to the aggregator who shares the revenue with the participating consumers. The **aggregator benefits** through profitable products related to his value added to the process:

- Assuming the risk of guaranteed delivery of reduced or increased demand to the grid operator in the timeframe required (contractual)
- Simplifying the complexity of managing broad and / or targeted dispatchable demand products that are of value and easy to use by the grid operator
- Organizing and encouraging the participation of a large number of consumers fitting into a portfolio of relevant products
- Investing in the Demand Dispatch infrastructure (i.e. no consumer investment required)

**Consumers benefit** from participation in Demand Dispatch in a number of ways:

- Financial savings on the retail “power bill” received from the “utility” from reduced energy consumption and reduced demand (for customers who have a demand charge.) Anytime the consumer uses less kWh their energy bill will be lower. Anytime the consumer keeps his demand below the “penalty level” it will avoid the demand charge. ***This is a savings from the retail slide.***
- Revenue earned from market participation in the wholesale market through interface with an aggregator, who provides the market interface between the consumer and the wholesale RTO. This revenue can come from the energy, capacity, and ancillary services markets. ***This is revenue earned by the consumer from the wholesale market via the aggregator.***

- Identification of new and permanent energy efficiency solutions that become obvious as variable loads are replaced with more efficient solutions (e.g., rather than modulate the ballasts of lighting from 100 watts to 80 watts as part of Demand Dispatch, just replace the lighting with more efficient, lower wattage lighting.)

**Society benefits** from the actions of individuals:

- By optimizing the use of the generation fleet and reducing the peak generation requirements, large capital investments in additional supply resources can be eliminated or deferred. This deferral or elimination reduces the future retail prices to consumers over what they would have been if these investments would have been made. ***(Incremental downward pressure on future prices over BAU)***
- By reducing the peak in the real time market, a less costly unit will clear the market, meaning the present price of wholesale electricity will be less than if a more costly unit was committed to meet the peak and that price cleared the market. ***This is a reduction in real time wholesale prices that all consumers benefit from*** even though only a small percentage of them participate in the Demand Dispatch transactions that actually cause the wholesale clearing price to be less.
- Demand Dispatch will enable an incremental increase on the amount of variable (renewables) supply resources that can be accommodated into grid operations. ***This incremental amount of renewables has a corresponding future value in reduced emissions of all types.***
- Demand Dispatch will enable a higher level of optimization of supply resources to occur in the real time “environmental market” (future carbon or emissions markets). This optimization can be done around minimizing emissions. ***This is a real time benefit in reducing emissions of all types.***

The consumer’s value of participation must be compelling, clearly conveyed, easy to do, and delivered in the end. The question still remains as to who will make the investment in the enabling technology.

## **BENEFIT ANALYSIS SUMMARY**

An analysis was performed to gain a sense of the value that might be created from Demand Dispatch for grid operators and consumers. From the analysis, several key insights emerge regarding the value of Demand Dispatch.

**The potential nationwide value of Demand Dispatch can be several billion dollars per year in reduced energy costs with 10% consumer participation.**

**Demand response capacity** is directly proportional to consumer participation reaching a total U.S. potential (100% consumer participation) of half the total US peak load.

**Annual savings** occur for all consumers when they offset their own usage by either self determining their load reductions or using onsite generation, or back up generation systems (BUGS) to offset their own consumption.

**Regulation and reserves have a benefit and a restriction.** Likewise for utilities and consumers, Demand Dispatch restricts the consumer's ability to do anything else associated with that load or consumer-owned generator. However, this may not be a burden for the consumer while participating in regulation and reserves.

To fully understand the benefits of Demand Dispatch and how they accrue to consumers, system operations, and society, a **more detailed quantitative analysis** needs to be developed.

## **WHAT ARE THE BARRIERS TO IMPLEMENTATION?**

Demand Dispatch has the potential to create significant value to all stakeholders as its application enables grid operation to be optimized far beyond its current capability, while also increasing the nation's use of renewable resources. But achievement of Demand Dispatch as a complement to Supply Dispatch faces a number of technical, regulatory / market, and economic challenges. Some of these issues are described below:

### **TECHNICAL CHALLENGES**

**Communication System Requirements**—Demand Dispatch requires high speed, two-way communications capability to support the rapidly changing control signals and other interactions required between the grid operators and the engaged demand resources. The requirements of the communications systems will vary depending on the function performed, e.g., seconds to support ancillary services, minutes to support variable renewable integration, and hours to support real time arbitrage. The bandwidth, latency, security, and reliability of the communication systems must be carefully specified and the loads, distributed generation, and storage resources that interact with Demand Dispatch must be capable of responding to such rapidly changing control signals as well. Will the communications infrastructure being deployed as part of today's SG deployments of AMI and distribution system technologies be adequate to support Demand Dispatch?

**Technology Development and Deployment**—Deployment of Smart Grid technologies is needed to support the vision of Demand Dispatch. ARRA funding has stimulated a number of pilot projects that are intended to provide the foundation for achieving the Smart Grid vision. Will the current level of progress in the deployment of Smart Grid technologies be sustained to the point that it enables the emergence of Demand Dispatch? What about the control systems

required at each level of a Demand Dispatch architecture? For example, at the residential level, how will each controllable device (e.g., a clothes dryer or pool pump) be integrated with the Demand Dispatch network and how will its availability and participation be monitored? And at the system level, will the rate of change of wind and solar generation be captured in real time so that compensating Demand Dispatch signals can be derived and sent to participating loads? How will this Demand Dispatch control be coordinated with today's automatic generation control? How about the distribution system level? Will Demand Dispatch be employed to improve reliability, power quality, and / or efficiency of each distribution feeder, lateral or individual line transformers (particularly as EVs and community energy storage systems grow in popularity)? If so, a new control and monitoring approach will be needed at this level as well. An overall Demand Dispatch control architecture will be needed to address these questions and take full advantage of the range of potential benefits.

***Measurement, Verification, and Settlement***—Demand Dispatch will require the participation of a large number of new participants, demand resources, and metering points. Many commercial and industrial consumers already participate in direct load control and other DR programs and have experience with interval metering and measurement, verification, and settlement. Demand Dispatch will include large numbers of residential consumers as well. Will AMI technologies be used to support Demand Dispatch at the residential level and how will these vastly larger numbers of metering points be settled to ensure the committed actions actually occurred? Will this increased volume of data and transactions cause the measurement and verification system to “collapse under its own weight?” More specifically, can today's AMI systems even provide the granular measurements required?

***Standards***—What additional standards are needed to support Demand Dispatch transactions? Do any of the current reliability standards prevent the emergence of Demand Dispatch? Failure of demand resources to deliver on ancillary service commitments, such as providing spinning reserve equivalents, could negatively impact grid reliability. How will the baselines of demand resources be determined to ensure requested reductions in net load actually do take place when called upon?

***Impact of Demand Dispatch on Life Cycle of Consumer's Equipment***—Demand resources will be modulated extensively in a Demand Dispatch environment. To what extent will these additional cycles impact the reliability and expected life of these demand resources? Will a new generation of more robust end use equipment be needed?

## **REGULATORY / MARKET CHALLENGES**

***Wholesale / Retail Regulations***—Demand Dispatch will engage demand resources which are located behind-the-meter at customer premises. How will the boundaries and jurisdictions of the various regulatory bodies be aligned to enable Demand Dispatch to be effectively

integrated into grid operations? How will the relationships and needs of RTO's, retail service providers, FERC, state public utility commissions and consumers interact to create the pathway for achieving the Demand Dispatch vision enabled by the Smart Grid? What new processes will be needed at the RTO and Distribution Operations level to accommodate Demand Dispatch?

**Rates and Compensation**—Demand Dispatch will not work without new rate structures, including some form of time-of-use rates, net metering rates, rates that support direct load control, program participation payment, rebate program, etc. Even the issue of rate decoupling, where rates are independent of consumer consumption, needs to be part of the Demand Dispatch discussion. Consumers will have little incentive to participate in Demand Dispatch unless their compensation for their delivered capacity, energy, and ancillary services is linked to the actual cost or inconvenience of providing these commodities / services. The reluctance to move forward with time-of-use and other innovative rates must be overcome or the value of SG technologies needed to support Demand Dispatch will be extremely limited.

**Market Monitoring**—An independent Market Monitor has been shown to be a needed component of the wholesale electricity market to ensure the market is functioning correctly. Is it also needed for Demand Dispatch and if so how will it be accomplished? Significant Demand Dispatch aggregation can add a new dimension to the market by creating the option to NOT buy energy. Can demand resources act together to create market power?

**Environmental Regulations**—Large numbers and capacities of BUGs, many diesel fueled, exist and could bring substantial capacity to support the Demand Dispatch vision. What environmental regulations (e.g., run times, etc.) impact the ability of BUG's to participate in Demand Dispatch and could these regulations be modified to be more supportive? Conversely, could these BUGs be modified to operate more cleanly in response to a growing Demand Dispatch opportunity?

**Consumer Participation Levels**—Demand Dispatch depends on the availability of enough demand resources to “make a difference” in grid operations. Consumer participation levels, therefore, must be high to attract adequate levels of capacity and energy to make Demand Dispatch work. Consumer knowledge, education, and acceptance are needed as initial first steps to encourage participation. How will this understanding and alignment be accomplished? Will regulations be simple, easy to understand and encouraging to customers, assuming the “price is right?” The good news is that there are examples across the U.S. where utility sponsored programs have achieved very high participation (%) levels with their legacy DR programs. Also, will consumer and environmental advocates be supportive or stand in the way?

## **ECONOMIC CHALLENGES**

**Pricing and Value to the Consumer**—Will the financial compensation paid to consumers for capacity, energy, and ancillary services provided by demand resources in a Demand Dispatch regime be “a compelling deal” for consumers? Will other additional incentives be needed to get to a tipping point? The investment in “behind the meter” technology, by the consumer, the utility, and / or others, will have to offer attractive returns if Demand Dispatch is to gain momentum. Plus, some consumers are also motivated by conservation and green objectives, which can be served by programs and products that reduce electricity consumption.

Based on the analysis using existing PJM rules as an example, insufficient incentives exist today for consumers to broadly engage in Demand Dispatch. Improved incentives for participation will be a necessary component of future Demand Dispatch programs.

The success of Demand Dispatch cannot be based on altruistic national interest alone, but must contain a value proposition for the consumer as well. Some structures of Demand Dispatch “programs” for consumers are compelling while others are not. For example, the greater sacrifice of appliance run time yields more savings for the residential consumer. This may be acceptable if the consumer perceives that his / her appliances included in the program can be turned off or set back with acceptable impact to him / her. The reward for this sacrifice becomes the compelling part of the program.

Achieving consumer participation in Demand Dispatch is only half the challenge. Will those who participate offer adequate levels of capacity, energy, and ancillary services to “make a difference” in the operation of the grid? Are there adequate numbers and types of demand resources that can be operated by grid operators without inconveniencing consumers to the point that they are unwilling to offer them to the market? Without adequate levels of demand resources, the economics of Demand Dispatch may not be compelling.

**Utility Disincentive**—Today’s rate structures reward investor-owned utilities for investing in capital projects to meet increasing demand. Promoting the Demand Dispatch concept and the increased reliance on demand resources it creates would reduce its need to invest in new generation, transmission, and perhaps distribution assets. A major question is whether or not utility commissions will allow the utility to make a return on Demand Dispatch investments – just like they do for traditional capacity investments. Most utilities are only allowed to recover DR cost without a return on investment – not a great incentive. How might this disincentive be overcome? Public power and cooperatives may not face this same disincentive--how might they be leveraged to advance the Demand Dispatch concept?

**Opposition from Generation Market**—Demand Dispatch would modify the generation requirements and ultimately impact the wholesale market-clearing price under some

conditions. As a result, the price and volume of energy sold by generators could be negatively impacted. How might the opposition from generators be mitigated?

***Value of Delivered Energy*** – The whole value chain from generation to end-use will need to resolve the economic value differences between “point of production” options and “point of delivery” options. Today’s policies reflect using “point of production” criteria for valuing “point of delivery” options which leads to mis-incentives for “point of delivery” options. The resulting consumer and utility / ISO value proposition is weak

### **ADDRESSING THE CHALLENGES**

Clearly, the challenges are significant. Raising the level of debate regarding the feasibility and value of the Demand Dispatch concept will help flesh out these and other issues. Resolution will require the collaborative effort of regulators, consumers, RTO’s, utilities and other impacted stakeholders. Understanding the Demand Dispatch concept and its potential value to consumers and society will be the key driver for addressing these challenges.

## CONCLUSIONS

- ***Demand Dispatch is highly synergistic with the Smart Grid’s Principal characteristics***, as illustrated in Table 2 below.

SG Characteristic	Demand Dispatch Synergy
<b>Enable active participation by consumers</b>	Demand Dispatch will provide incremental motivation for consumer participation by creating opportunities to reduce costs, generate revenues, and reduce environmental impacts
<b>Accommodate all generation and storage options</b>	Demand Dispatch employs and encourages the investment of demand resources and provides a mechanism for increased penetration of renewable resources on the grid
<b>Enable new products, services, and markets</b>	New Demand Dispatch markets attract consumers and innovations
<b>Provide power quality for the digital economy</b>	Demand Dispatch applications can include control of PQ and voltage regulation at the feeder level
<b>Optimize asset utilization and operate efficiently</b>	Demand Dispatch enables complete system optimization by allowing grid operators to dispatch both supply and demand to meet reliability, efficiency, economic, and environmental goals.
<b>Anticipate &amp; respond to system disturbances (self-heal)</b>	Demand Dispatch monitoring and control of demand resources enhances the self-healing nature of the SG.
<b>Operate resiliently against attack and natural disaster</b>	Demand Dispatch monitoring and control of demand resources allows faster restoration from outages. Increased penetration of distributed resources reduces grid vulnerability

**Table 2: Smart Grid and Demand Dispatch Synergies**

- ***Demand Dispatch can help optimize reliability, peak load management, and energy efficiency*** throughout the value chain resulting in the most economical wholesale price for electricity.
- ***Demand Dispatch also generates a number of societal benefits:***
  - ✓ By optimizing the use of the generation fleet and reducing the peak generation requirements, large capital investments in additional supply resources can be eliminated or deferred. This deferral or elimination ***reduces the future retail prices to consumers*** over what they would have been had these traditional investments been made



- ✓ By reducing the peak in the real time market, a less costly unit will clear the market, **reducing the real time price of wholesale electricity** compared to what that price would have been without Demand Dispatch. All consumers benefit even though only a small percentage participate in the Demand Dispatch transactions that actually cause the wholesale clearing price to be less.
- ✓ Demand Dispatch will enable an incremental increase in the amount of variable (renewables) supply resources that can be accommodated into grid operations. This incremental amount of renewables has a corresponding **future value in reduced emissions of all types**.
- ✓ Demand Dispatch will enable a higher level of optimization of supply resources aimed at minimizing emissions. This is a **real time benefit in reducing emissions of all types**.
- Valued and applied correctly, Demand Dispatch has the potential for very high long-term value to consumers and utility / ISOs. More than one-fourth of the 713 GW of the nation's demand is dispatchable under structures described here. This could offset new generation and transmission build for years, while facilitating increased renewable penetration. However, current policy and cost recovery mechanisms run counter to this potential.
- The potential nationwide value of Demand Dispatch is several billion dollars per year in reduced energy costs with 10% consumer participation.
- Despite these many synergies and benefits, positive examples of Demand Dispatch in operation today are few. According to DOE, demand-side load management programs today reduce the peak about 12 GW (EIA Electric Power Annual 2009, Table 9.1) [7], or about 1.7% (Net Internal Demand 713 GW, EIA EPA 2009, Table 4.2) [7]. The small percentage suggests there is much room for growth of Demand Dispatch utilization.
- For broad consumer participation to be achieved, the value proposition for the consumer must become more compelling.
- The regulatory and market challenges present significant policy needs to properly engage and incentivize the consumer to actively participate in Demand Dispatch. For example, the size of consumer participation incentives are not well understood, and market mechanisms to encourage increasing load at times of minimum generation issues have not been developed.
- Analysis suggests aggregator annual revenues could be about one billion dollars with 14 million end users participating. To enable this participation, aggregators would also need to provide and maintain all the new behind-the-meter Demand Dispatch equipment and controls. The cost of this investment will determine aggregator margins and whether or not they would be sufficiently compelling.

While technology gaps hinder widespread use of Demand Dispatch today, the technology barriers are solvable in the short term. In particular, rapid advances in SG communications

platforms, which can support a wide range of modern applications, can be expected to also accommodate Demand Dispatch.

An issue identified during the analysis is the phenomena observed in the RTO / ISO market with increasing regularity where significant renewables are being used. At times (usually night hours), the market hourly price goes to zero or negative values. This is related to increasing “must-take” renewable generation where thermal generation is backed off to accommodate it. At night with lighter loads on the bulk power network, the minimum generation requirements are challenged and it becomes more cost effective to increase load vice shutting down a thermal unit. The analysis showed that the incentive does not accrue to consumers, therefore increasing the consumers’ load to alleviate the minimum generation (i.e., negative prices) does not have a direct value to the consumers. For this valuable option for grid operators to be effective, it seems that the market rules will need to be modified. At the very least, this phenomenon needs further study.

## RECOMMENDATIONS

A number of specific recommendations are offered:

1. ***Additional discussion and deep debate on Demand Dispatch is needed*** to validate it as a potential end state application for integrating Smart Grid, Demand Response, and Energy Efficiency. This debate should be led by the National Action Plan (NAP) Coalition, FERC, and DOE to explore potential Demand Dispatch strategies that employ realistic value propositions for consumers, third-party aggregators, utilities, and ISOs.
2. A ***more equitable benefits-sharing model*** needs to be constructed in tariffs. This is a dilemma for bulk power markets (federal jurisdiction), retail markets (state jurisdiction), and retail tariffs (state jurisdiction). The operating model under Demand Dispatch creates benefits at the bulk power level as well as the distribution level and consumer level. Thus, organizations such as the FERC – National Association of Regulatory Utility Commissioners (NARUC) Smart Grid Collaborative need to address the benefits of Demand Dispatch that span federal and state jurisdictions.
3. Formulate, model, and ***test Demand Dispatch strategies*** and value propositions. As can be observed with the several references cited in this work, many organizations are exploring various elements of Demand Dispatch, but a more holistic systems view of Demand Dispatch programs and values would better serve the nation in formulating a beneficial Demand Dispatch strategy.
4. Recognize the ***difference in policy and regulation for the price at the “point of production” and “point of delivery”***, not just for the utility / ISO but also for the consumer.

5. There are several areas that require ***further analysis and study to clarify the value of the Demand Dispatch operating model:***

- Modeling the financial and environmental benefits of Demand Dispatch
- Developing an improved understanding of the commercial and industrial Demand Dispatch opportunity, since 84% of this analysis' value came from commercial and industrial consumers. (For example, is 15 minute / hour cycling realistic from a business perspective?)
- Exploring incentive structures for consumer participation in Demand Dispatch
- Developing a full understanding of the value of integrating electric delivery system efficiency into the Demand Dispatch operating model
- Exploring various market models that provide appropriate Demand Dispatch incentives based on the overall value it creates
- Exploring the aggregator business case

## REFERENCES

1. DOE, Coordination of Energy Efficiency and Demand Response – A Resource of the National Action Plan for Energy Efficiency, (Figure 2-2 source: DRCC, 2008), January 2010.
2. DOE, Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them – a Report to the United States Congress Pursuant to Section 1252 of the Energy Policy Act of 2005, Figure 2-3, pg 15, February 2006.
3. FERC Order 719, October 2008, <http://www.ferc.gov/whats-new/comm-meet/2008/101608/E-1.pdf>
4. National Action Plan on Demand Response, FERC, June 2010, <http://www.ferc.gov/legal/staff-reports/06-17-10-demand-response.pdf>
5. FERC, Assessment of Demand Response and Advanced Metering, Feb. 2011, <http://www.ferc.gov/legal/staff-reports/2010-dr-report.pdf>
6. A Vision for the Smart Grid, National Energy Technology Laboratory, June 2009, [http://www.netl.doe.gov/smartgrid/referenceshelf/whitepapers/Whitepaper\\_The%20Modern%20Grid%20Vision\\_APPROVED\\_2009\\_06\\_18.pdf](http://www.netl.doe.gov/smartgrid/referenceshelf/whitepapers/Whitepaper_The%20Modern%20Grid%20Vision_APPROVED_2009_06_18.pdf)
7. Department of Energy (DOE) EIA (Energy Information Administration (EIA), Electric Power Annual 2009, April 2011.
8. Power Shift Atlantic presentation: <http://www.questcanada.org/documents/ICESuccessStory-MichaelLosier-PowerShiftAtlantic.pdf>
9. Up in Smoke By Ade Dosunmu, Comverge, June 2011
10. Adaptive Stochastic Control for the Smart Grid, Proceedings of the IEEE, June 2011
11. Demand Dispatch: Using Real-Time Control of Demand to Help Balance Generation and Load; Brooks, A.; Lu, E.; Reicher, D.; Spirakis, C.; Weihl, B.; , "Demand Dispatch," Power and Energy Magazine, IEEE , vol.8, no.3, pp.20-29, May-June 2010

12. Varaiya, P.P.; Wu, F.F.; Bialek, J.W.; "Smart Operation of Smart Grid: Risk-Limiting Dispatch," *Proceedings of the IEEE* , vol.99, no.1, pp.40-57, Jan. 2011
13. Taneja, J.; Culler, D.; Dutta, P., "Towards Cooperative Grids: Sensor/Actuator Networks for Renewables Integration," Smart Grid Communications (SmartGridComm), 2010 First IEEE International Conference

## APPENDICES

### ORIGINAL ABSTRACT

Demand Dispatch is a new operating concept that represents a different approach to balancing generation and load. Unlike traditional Demand Response (DR), Demand Dispatch is continuously active, not just during peak times. Demand Dispatch aggregates and controls (adjusts) selected loads to match generation in real-time, as opposed to the historic approach of adjusting selected generation to match load. Aggregated loads (including dispatchable loads), distributed generation and storage operate as control areas under this concept.

Traditional DR is designed to modify specific loads over a period of minutes or more in response to either emerging overload conditions or projected spikes in wholesale prices. By contrast, Demand Dispatch is intended to operate in a very different time window; providing continuous rapid control of loads in both directions (net decrease and net increase) within fractions of a second. To achieve this speed of response, communications systems must be designed with adequate bandwidth, latency, security and reliability; and the loads, distributed generation, and storage resources that interact with Demand Dispatch must be capable of responding to such rapidly changing control signals.

Resources like Electric Vehicles and Plug-in Hybrids could vary their charging rates or act in “vehicle to grid” mode to follow the variations in intermittent resources (e.g., wind, solar). Large numbers of EVs operating in this mode could be a valuable asset for optimizing the integration of renewables. Other consumer loads and distributed energy resources could also be used to support Demand Dispatch. And the future deployments of microgrids could provide an effective platform for supporting Demand Dispatch.

Load management has been in place for many years, but how it might be expanded in the future to take full advantage of new and emerging smart grid technologies remains unclear. Renewable generation such as wind and solar is more variable and has lower inertia than previous forms of electrical supply, hence new approaches such as Demand Dispatch that will allow greater renewable penetration deserve serious consideration.

This paper examines the transition of DR to its ultimate potential of operating in a Demand Dispatch mode where specific load, distributed generation, and storage resources operate as control areas in real-time. Demand Dispatch’s objective is to support (follow) the needs of generation in order to optimize reliability, economics, and environmental parameters.

## ADDITIONAL RESOURCES OF INTEREST

1. <http://www.nrel.gov/docs/fy10osti/46698.pdf>
2. <http://www.smartcloudsw.com/DispatchableAssetRelatedDemand/tabid/85/Default.aspx>
3. [http://www.powermag.com/POWERnews/3529.html?hq\\_e=el&hq\\_m=2162991&hq\\_l=6&hq\\_v=fb1f0a10c3](http://www.powermag.com/POWERnews/3529.html?hq_e=el&hq_m=2162991&hq_l=6&hq_v=fb1f0a10c3)
4. Estimating the Costs and Benefits of the Smart Grid – A Preliminary Estimate of the Investment Requirements for a Fully Functioning Smart Grid” (Report # 1022519)  
[http://my.epri.com/portal/server.pt?Abstract\\_id=000000000001022519](http://my.epri.com/portal/server.pt?Abstract_id=000000000001022519)
5. Arktos project –Demand Dispatch optimization [Arktos Project: Demand Dispatch Optimization](#)
6. BPL Global - SG Demand Dispatch <http://www.bplglobal.net/eng/videos/power-sg-idd-video/index.aspx>
7. PJM Price Responsive Demand  
<http://www.pjm.com/documents/~media/documents/reports/pjm-whitepaper-on-price-responsive-demand.ashx>
8. Steffens electric thermal energy storage technologies (Dale Bradshaw input)
9. FERC 2010 Survey on Demand Response and Advanced Metering  
<http://www.ferc.gov/industries/electric/indus-act/demand-response/2010/survey.asp#skipnav>