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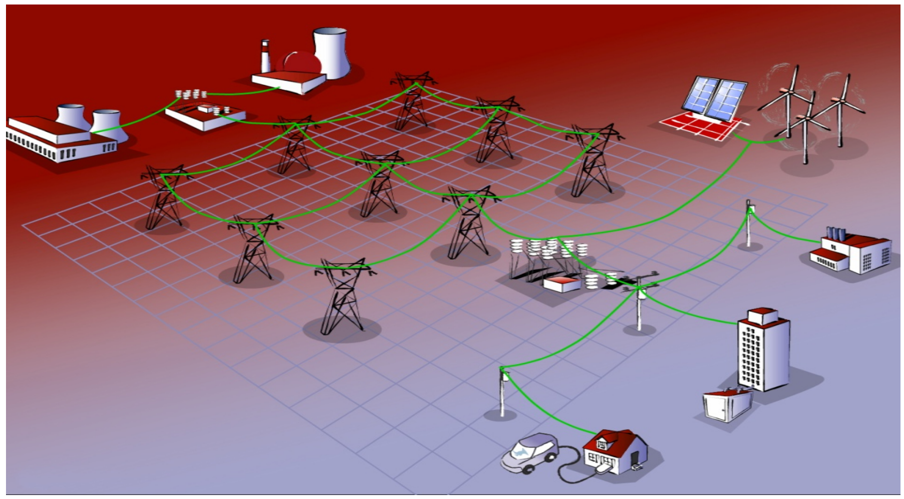

Smart Grid Principal Characteristic
Enables New Products, Services, and Markets

February 4, 2010

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U.S. DEPARTMENT OF ENERGY

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Office of Systems, Analyses and Planning

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Executive Summary

The systems view of the smart grid features seven principal characteristics, one of which is the characteristic of fully enabling new products, services, and markets (See Figure 1).

Principal Characteristics

- *Enable* active participation by consumers
- *Accommodate* all generation and storage options
- *Enable* new products, services, and markets
- *Provide* power quality for the digital economy
- *Optimize* asset utilization and operate efficiently
- *Anticipate & respond* to system disturbances (self-heal)
- *Operate* resiliently against attack and natural disaster

Figure 1: The Smart Grid Systems View provides a holistic perspective that considers all aspects and all stakeholders.

It is envisioned the Smart Grid will enable new products, services and markets. The Smart Grid will enable three evolutionary changes to the current electricity market. First, the future state will link the buyers and sellers of electricity, e.g., RTO to consumer. New opportunities will arise from distributed energy resources such as PHEVs and other energy storage assets along with distributed generation allowing brokers, integrators, aggregators and enabled consumers to interact in real time with the electricity market. Second, new electricity markets will be established through the introduction of new commercial goods and services. And lastly, restructured markets will provide for consistent market operation across the various regions.

Correctly designed and operated markets efficiently reveal cost-benefit tradeoffs to stakeholders by creating an opportunity for

competing services to participate. In general, the fully functioning smart grid will address all of the fundamental dynamics of the value-cost relationship. Some of the independent grid variables that must be explicitly managed are energy, capacity, location, quality, time, form (e.g., high voltage versus low voltage; AC versus DC), rate of change of capacity (e.g., ramp rates), emissions, and resiliency (e.g., ability to accommodate disturbances or frequency variations). Retail and wholesale markets can play a major role in the management of these variables.

The challenge for the smart grid is to facilitate, as much as possible, the ability of regulators, owners and operators, and consumers to modify their behaviors to suit operating and market conditions. Markets can enable efficient operation under both low-stress and high-stress conditions. Retail and wholesale markets can enable automatic reconfiguration of facilities and equipment as needed to operate reliably, economically, and efficiently. There are differing time frames, mechanisms, and infrastructure required for market operations (see Figure 2).

> "... better and cheaper technologies will be invented once retail energy is subject to free entry and exit. No one knows what combination of technology, cost, and consumer preferences will be selected. And that is why the process must be exposed to the trial-and-error experiment called free entry, exit and pricing. As in other industries, investors will risk their own capital – not your tax dollars or a charge on your utility bill – for investments that fail. Also, as in other industries with dynamically changing product demand, competition will force prices to be slashed off-peak, and increased on-peak to better utilize capacity." (Vernon Smith – 2002 Nobel laureate in economics, *Wall Street Journal*, 2003)

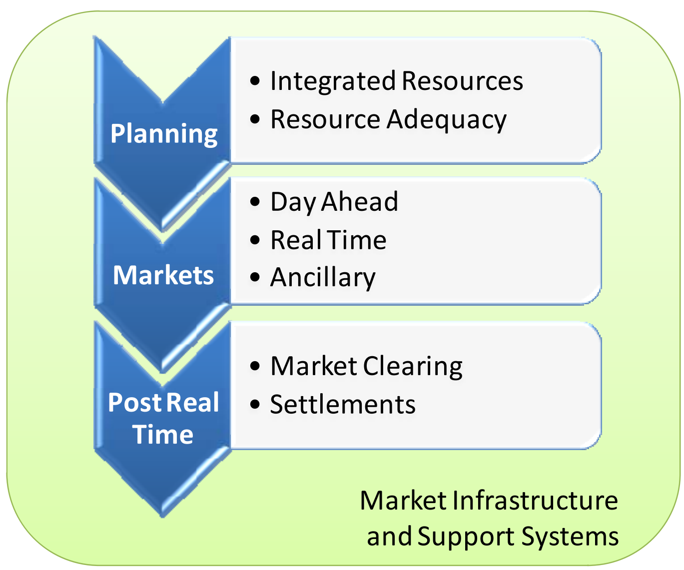


Figure 2: Time frames for market operations and their supporting infrastructure define the concept of enabling markets.

- **Planning —** addresses the long- and intermediate-term regional infrastructure (generation, transmission, and demand). These are the planning activities that forecast load and congestion, develop capacity and adequacy, and schedule outages.

- **Day ahead —** addresses the short-term planned capacity requirements, megawatt injections, megawatt withdrawals, financial transmission rights (FTR), and ancillary services.

- **Real time —** addresses the real-time generation dispatch, management of injections and withdrawals, congestion management, ancillary services, and real-time reliability management.

- **Post-real time —** addresses the settlement of the energy dispatch and financial transactions as well as analysis and auditing of the day ahead and real-time market operations.

Market processes that touch the consumer, "retail choice" or "retail markets," will drive important local goals for the electric system. Retail choice will help consumers more closely feel the dynamic nature of costs and benefits of electric service and enable decisions that will change behaviors and processes to minimize cost and maximize benefits. At the same time, these local drivers will facilitate decisions that add distributed renewables to the network for energy independence, environmental, and economic reasons.

Market infrastructure and support systems are critical factors to enable successful electricity markets in the smart grid. The advanced components, widespread communication, and measurement systems of the smart grid will support market operations in every time frame and provide full visibility of data to the market participants.

Although each can be read on its own, this paper supports and supplements "A Systems View of the Smart Grid."

CURRENT AND FUTURE STATES

Before we detail the requirements to realize the smart grid's "enable markets" characteristic, we need to understand the difference between the current state of electrical markets and their potential future state.

CURRENT STATE

The majority of the nation's electrical power system operates in accordance with rate structures established by state utility regulators. Rates are based on operational and maintenance expenses plus a reasonable return on investment. Some expenses are passed directly to the consumer. However, most consumers do not recognize the individual items that comprise their bill since the electricity is billed as a complete unit.

Retail Markets

Retail choice (retail electricity markets) represents less than 5 percent of the electric load in the nation. Retail markets operate in a few regions of the nation, governed by state requirements. Retail markets typically separate generation costs (the cost of generating electricity) and delivery costs (the transmission plus distribution expenses). With retail choice, consumers would see individual line items of charges on their bills.

However, since the consumer is served by the same electrical infrastructure (wires) used before the retail choice was enacted, the cost structure of the wires is the same and is billed as a fixed price-per-unit of energy delivered. There are no new savings to the consumer from retail choice related to delivery costs.

Today, in areas with retail markets, the consumer may choose from a list of providers of electricity. But the production of the energy is billed as a fixed price-per-unit of energy delivered. Since the competing providers of electricity buy power from the same wholesale competitive market, their price variations are minor. This is true whether there is a competitive wholesale market or not.

Wholesale markets select producers of electricity on an economic merit order, so the least expensive units are selected before more costly units. Customers are billed at the same cost per unit produced and delivered regardless of when it is produced or delivered, resulting in a consistent, fixed delivery charge, plus a production charge that only varies slightly in the total consumer energy bill from retail provider to retail provider.

The resulting minimal cost savings to consumers is the reason for low participation rates in the retail choice programs. Additionally, there are currently only two rate options in time-of-day (TOD) programs, on-peak rates and off-peak rates. Hours of use for on-peak and off-peak time periods are recorded with electric meters, and a consumer bill is normally produced monthly. The ratio of on-peak to off-peak rates only ranges from about 2:1 to 3:1. There is a much higher degree of variability in the wholesale market's hourly prices where a daily high-to-low hourly price ratio of 10:1 is a common occurrence.

There is a win-win scenario where the consumer takes a more active role, joins with other consumers into a large coalition (representing a large load or distributed generation supply) and sells those services in the marketplace at a fair price. The power of the consumer has reduced prices in other markets and, if organized, can do the same for electricity. The operators of the market also win in that they get a product that was previously not available, that will reduce the cost of delivered energy or increase reliability at a minimum cost.

Even though retail choice and wholesale markets have been around for more than a decade, they have not become the normal way we conduct energy business. Participation in retail markets and restructuring is low and has decreased since 2004, as shown in Figure 3.

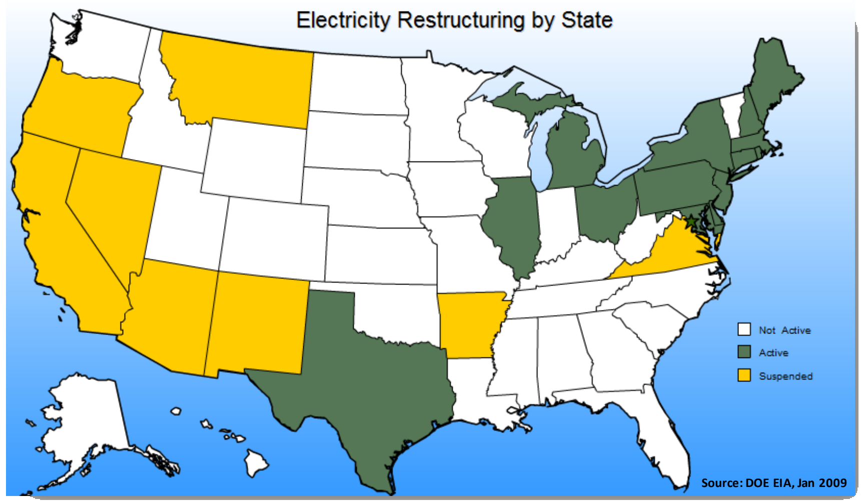
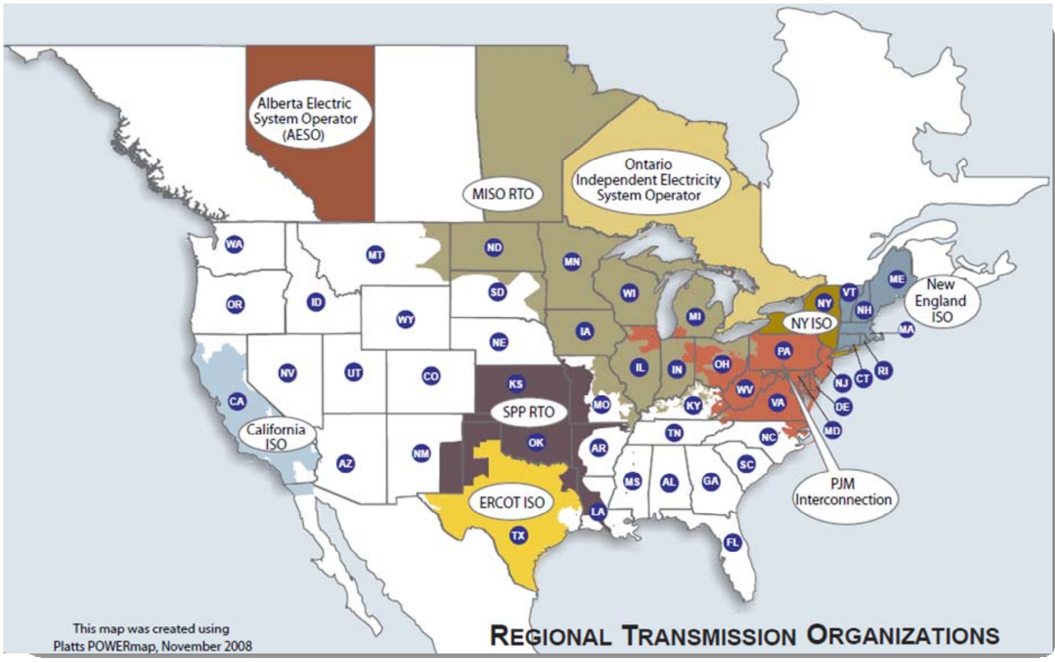


Figure 3: States Participating in Retail Choice or Electric Industry Restructuring Activity. (DOE EIA 2009)

<u>Wholesale Markets</u>

Wholesale market operations are also operating in several regions of the nation, governed by the Federal Energy Regulatory Commission (FERC) in coordination with state utility regulators. The process has four steps:

1. Generators initiate offers to sell their energy to the market, and load-serving entities submit bids to purchase it.
2. When a balance is reached between sellers and purchasers, then all loads are served and the market is declared to be "cleared."
3. Market participants are advised of the cleared results, to include supplied megawatts, megawatts of load, times of operation, and prices for each hour—thereby initiating their market responsibilities.
4. Settlements occur based upon the bids, offers, and actual injections and withdrawals of energy per hour.



Regions participating in wholesale markets are shown in Figure 4.

Figure 4: Regions participating in wholesale market competition. (FERC 2009)

In the United States, the extent of the nation's electricity market today can be described as follows:

> **"U.S. residential electric customers paid about $34 billion less for the electricity they consumed over the past seven years than they would have paid if traditional regulation had continued." (*Beyond the Crossroads – The Future Direction of Power Industry Restructuring*, CERA, Oct. 2005)**

- The majority of wholesale transactions are bilateral and long term.
- A small portion is using real-time wholesale energy markets.
- A smaller portion is using day-ahead wholesale energy markets.
- A small portion is using wholesale ancillary services markets.
- A portion is using zonal pricing models in wholesale markets.
- A small portion is using nodal (locational) pricing models in wholesale markets.

Several studies from 2005 to 2007 show that the benefits of the wholesale electricity markets are $5–$15 billion annually. An analysis of independent grid operators by the Independent System Operator (ISO) in New England showed that the value delivered by operators was a benefit to a cost ratio of 7:1.

Plus, several smart grid studies show that the benefit to cost ratio of implementing a smart grid is about 5:1. These studies include the Rand Corporation study on the benefits of a smart grid, the San Diego Smart Grid Study, and the West Virginia Smart Grid Implementation Plan, all showing the importance of elements of retail markets.

FUTURE STATE

> "A variety of analyses have concluded that the implementation of competitive power markets based on centrally-coordinated economic dispatch has reduced the cost of electric power within the regions served, relative to the level of costs that would otherwise have been incurred. The consumer benefits of centrally-coordinated wholesale markets are reflected in declines in fuel adjusted wholesale electric prices in ISO/RTO regions"." (*2009 State of the Markets Report*, ISO/RTO Council, September 2009)

In the future, the scheduling and use of electricity will be fully commoditized by creating open-access markets across the country based on wholesale and retail models. These economically designed market operations will enhance reliability in the grid and open utilities and consumers to new service models that better fit the needs of all grid participants. Electricity markets in the future will integrate many diverse technologies and allow control functions to include the following:

- All generating unit sizes (from 10 kilowatt to 1,300 megawatt) will be seamlessly integrated across the various markets.
- The vast majority of all types of consumers (industrial, commercial, and residential) will participate in the market seamlessly through the various forms of decision-assistant software available.
- All loads will have some measure of intelligent control, enabling new demand-response (DR) markets.

As mentioned above, the solutions set forth in the smart grid studies to date include retail market-base time-of-use (TOU) dynamic rates, demand response programs, and other distributed peak load reduction measures. More specific consumer elements and technologies of the retail market can be found in the paper, "Enable Active Participation by Consumers." Today, these innovations are found only in pilot projects and isolated applications. As such innovations in technologies and markets prove themselves across the industry, wider use will result, as well as expansion of these markets and their ability to engage distributed generation and energy storage to serve the retail and wholesale (as aggregated distributed resources) markets.

Regional differences in the network topology primarily affect the enabling of wholesale markets. In the Northeast, load is concentrated, so the network is compact. It may take only 100 miles of transmission line to "touch" one million consumers. In the West, except for major metropolitan areas, load is spread over an expansive geography, so it may take over 1,000 miles of transmission line to touch one million customers.

This would suggest that the cost of physically enabling a wholesale market in the West is greater than in the Northeast. However, if underground installation is required, the cost of transmission construction in the Northeast would be significantly more costly per mile. While challenges differ in the West and Northeast, it is equally true for both regions that curbing peak loads and making loads more predictable are common elements of wholesale markets, and all regions will improve in grid reliability through advanced control and protection.

The competitive wholesale market has steadily expanded services to participants, including day-ahead markets, reserve sharing, and ancillary services. This is beginning to touch the consumer. For example, several regional operators are aggressively pursuing demand-response service markets that aggregate consumer load for peak shaving and regulation services. This demonstrates the high value of interfacing the wholesale and retail markets in the future.

If present trends hold, generation resources of the future will be dispersed throughout the load areas, and they will be much smaller in electrical size. This change in generator size-mix over time requires new thought on how to control this vastly distributed resource as well as its impacts in the marketplace. Studies show that the nation can expect to add an additional 120,000 distributed generating units of less than 50 megawatts over the next 20 years. This will drive virtual power plants (VPP) that aggregate many consumer-owned smaller units operating at the distribution level to serve wholesale or retail ancillary markets with a portion of their duty cycle. This will also be true for distributed residential renewables and energy storage. Growing the power of the retail market in an innovative and flexible way can engage a myriad of these distributed resources as a new value to the grid.

The future will reveal the need for new market elements. The experiences of the various Regional Transmission Organizations (RTO) and ISOs show that participants in the market are active in requesting new services and market forums:

- Expansion of the ancillary services market offerings.
- Introduction of renewables, carbon trading, and other specialty markets.
- Inclusion of distributed energy resource (DER) market operations and other consumer-rich markets at the wholesale and retail market levels.
- Inclusion of neighborhoods or communities organizing VPP around its photovoltaic (PV) and distributed energy storage, to which members of the neighborhood subscribe.
- Spawning new products and applications for consumers that help empower them in the energy industry in many ways—consistent with the characteristic, "Enables Active Participation by Consumers."

REQUIREMENTS

Having examined the current state of electrical markets and their desired future state, what requirements must the smart grid meet to fully enable markets?

The basic requirements of electricity markets are the existence of a robust physical and informational infrastructure, sound market rules, vigilant oversight, and fair and equitable access.

- **Adequate infrastructure —** Markets can affect load and load can affect network reliability; therefore, a properly designed market supports a more reliable grid. Enhanced reliability also affects the market operations positively. This includes an information-and-control architecture adequate to provide needed information to appropriate decision makers.
- **Sound market rules —** Markets are based on proven first principles of physics and economics.
- **Vigilant oversight —** In each phase of the electricity market, there is independent monitoring and review of operations and participants to assure fairness in the market and grid reliability.
- **Fair and equitable access —** The foundation of the market is the idea that "it is the same electricity market for all who qualify." Those who "qualify" are those who have learned how to function in the market both financially and operationally.

DESIGN CONCEPT

Establishing new markets and market services usually requires new tariffs, systems, information flows, and training for market participants. Therefore, new markets and services must roll out in logical pieces. For example, a market may open with a day-ahead market only, and as the market gains experience, an ancillary services market may follow, as observed at both the Midwest Independent System Operator (MISO) and PJM RTO.

The seamless architecture of the smart grid can and must extend the electricity market into the electric distribution level. The distribution consumer may participate in DR or DER programs that, when aggregated, become a market commodity in the wholesale market. In order to serve consumers taking advantage of markets, to reap the environmental benefits of deep penetration of renewables, and to support regional markets, the distribution grid must enable a two-way power flow. Aside from the technical challenges, nearly all distribution systems are operated as state-chartered monopolies. Developing such markets in state-chartered monopolies is complex, but this is the area where the largest customer benefits reside, making it worth the challenge.

"The available resources include a record amount of emergency load management, 5,925 megawatts. Consumers in load management programs typically receive either a special rate or payments for stopping or reducing their use of electricity under emergency conditions. The amount of emergency load management has grown about one-third since last year. It has grown five-fold since 2003." ("REGION READY FOR HOT WEATHER POWER DEMAND – Voluntary Customer Usage Reductions Aid Reliability," PJM, May 2009)

In order to apply DR and DER as market commodities, the smart grid needs to expand current electricity market-thinking to include designs for open-access market participation. This expansion of the market may take place in the wholesale market, the retail market, a new intermediate market, or some combination thereof.

For the smart grid to provide seamlessly integrated markets, it must include interstate wholesale markets, intrastate retail markets, and methods to join them. Summarized, the design concept must include—

- Fully effective wholesale markets
- Selective expansion into retail markets
- New, presently unidentified markets that may not fit the traditional wholesale and retail models

Design Features and Functions

The design of the smart grid must be consistent enough to enable the electricity market to operate coast to coast and deliver economic benefits. In addition, the smart grid requires more sophisticated models to analyze options, refine market performance, and design new market components. The basic design can be described in the context of the market's time horizons and infrastructure (shown previously in Figure 2).

The general features and market functions can be seen in Figure 5

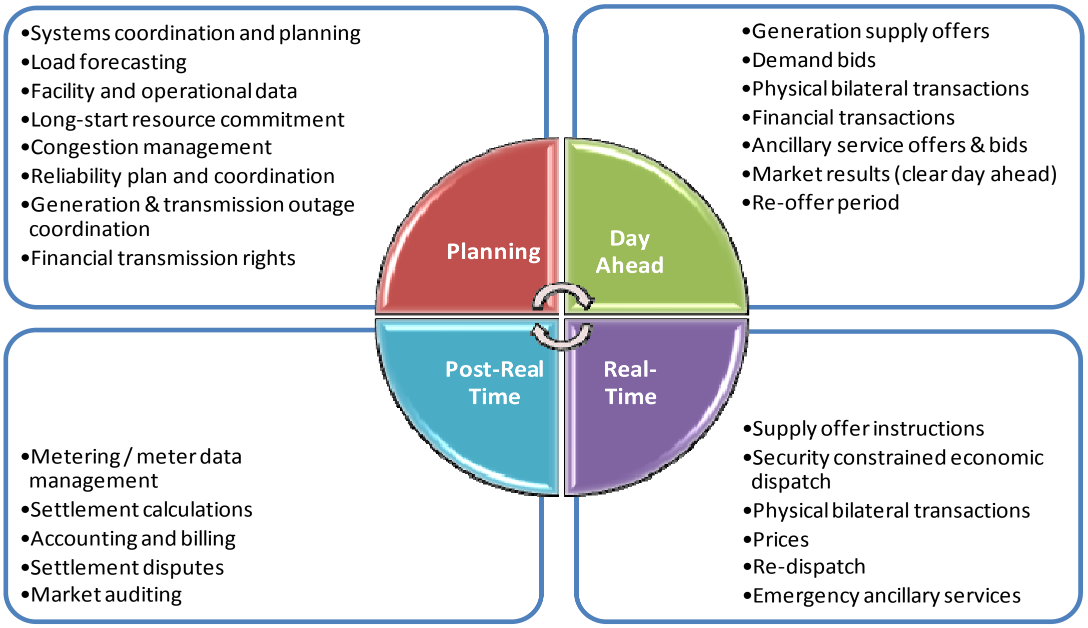


Figure 5: General wholesale market features and functions

Over time, the retail markets will develop in breadth and depth as observed over the last several years in the wholesale markets. The similarities will be more than the differences. For example, in the Day Ahead market (Figure 5), there are central-station generation supply offers that would be comparable to local retail markets in that the supply would be geared to distributed generation versus large central-station generation. The differences between the wholesale and retail markets will be seen in the details of the similar functions.

Taking this market development concept (Figure 5) to the retail market for specific resources and options available at the retail level, the following general retail market features and functions (Figure 6) will develop over the next 20 years. Today, at the retail market level, few of these functions are currently deployed. However, over time and with more experience, utilities, communities, aggregators, and consumers will push for more complete offerings in the retail market.

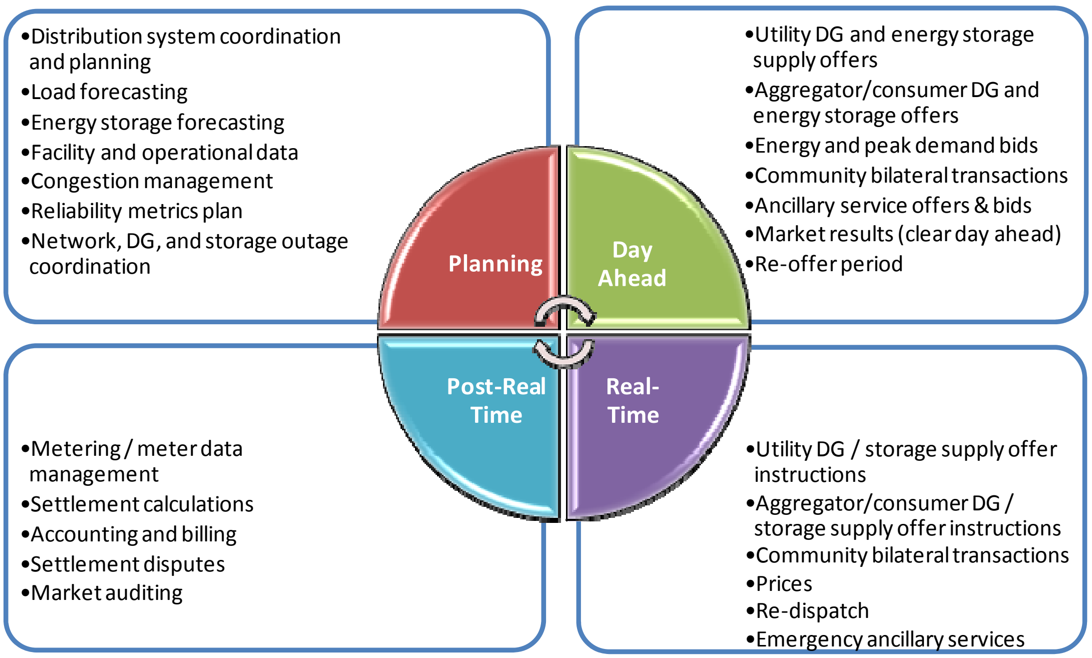


Figure 6: General retail market features and functions

Retail and new markets will include concepts that recognize local economics in such areas as TOU rates, critical peak pricing, and other dynamic conditions. From this transformation, stakeholders will clearly see the value that local, distributed, utility- and consumer-owned resources provide by lowering peak demand and accelerating the penetration of renewables into the market.

Market Infrastructure and Support Systems

Market infrastructure and support systems for the smart grid must be complete, robust, and of high quality. The following functions and processes are required for a wholesale and/or retail market infrastructure.

- **Systems functions —** Tagging and scheduling, Open Access Same-time Information System (OASIS), day-ahead and real-time market systems, power system simulation of the network and the real-time market, accounting system, configuration control, reserve-sharing applications, settlements application, algorithms for clearing market prices, etc.

- **Business processes —** Structured methods for converting tariffs to wholesale and retail market processes, jurisdictional market rules, back-up supply plans, published control area, aggregator, and resource-owner functions, emergency operations and when to engage, etc.

- **Market participant readiness functions —** Open wholesale or retail participant portal, market participant training and certification, aggregator-consumer relationship management, credit management system, etc.

- **Independent market monitor (IMM) functions —** IMM interface and connectivity, real-time market data access, etc.

- **Locational Marginal price (LMP) and state estimation (SE) functions —** Fundamental nodal model of the grid, high-speed network model, real-time telemetry, state estimator applications, reliability assessment and commitment (RAC) application, LMP model, prices to devices model, adequate resolution and precision in each system, etc.

- **Contingency functions and processes —** Back-up market and control operations systems and facilities for wholesale and retail, a process to accommodate RAC failure, systems for LMP and/or settlement with SE failure, etc.

- **Control area functions and processes —** Routine and emergency operations training, market participant (wholesale, aggregator, consumer) interface (message and response) via communication and telemetry, systems for network visibility, etc.

- **Joint operating agreement functions and processes —** Wholesale seams agreements, retail energy provider territory and market agreements, data communication with neighboring markets, handling of marginal losses and congestion across seams, etc.

OTHER REQUIREMENTS

Common Information Model

The Common Information Model (CIM) architecture is a critical element for standardizing data shared by the various elements of a smart grid.

"…the CIM facilitates the integration of Energy Management System (EMS) applications developed independently by different vendors, between entire EMS systems developed independently, or between an EMS system and other systems concerned with different aspects of power system operations, such as generation or distribution management." (IEC 61970-301)

CIM is a necessary foundational element of successful market development because the real-time information important to proper operation comes from hundreds of sources and dozens of entities (transmission owners, generators, market participants, etc.). For example, at MISO, state estimation, location marginal pricing, and network topology depend on commonly used information across more than 30 energy management systems (EMS), supervisory control and data acquisition systems (SCADA), and/or geospatial information systems (GIS) located at utilities.

Communications

For electricity markets to function properly, near real-time information communication must flow seamlessly between market systems and monitoring and control systems throughout the region. This will require a much dispersed, highly reliable, multi-variant communications infrastructure.

Policy and Regulation

For decades, the U.S. legislators enacted new energy policy about every 14 years. However, since 2005 the legislators have enacted the Energy Policy Act of 2005 (EPAct05), Energy Independence and Security Act of 2007 (EISA), American Recovery and Reinvestment Act (ARRA) of 2009 (with significant energy provisions), and they are contemplating significant energy regulation for 2010 regarding renewables and carbon emissions. With such significant policy change, the regulatory framework appears to be moving from an energy-infrastructure-build mindset to an energy-and-network efficiency-and-performance mindset.

Recently, Chairman Wellinghoff of FERC shared with state regulators, stating, "Where state regulators allow retail prices to vary with system conditions, the smart grid can enable customers to lower their electric bills by setting appliances to run when prices are lower or allow smart appliances to automatically sense prices and decide when it is cheapest to operate." This is one of many such statements from FERC commissioners explaining the value of engaging consumers in the ancillary markets through such programs as DR. Such encouragement from the federal regulators to the state regulators signifies the value of markets operating at all levels.

In the Spring of 2009, Commissioner Moeller of FERC congratulated the California ISO (CAISO) and its market participants for a successful transition to a new and improved market design, saying that "this new design brings great benefits to the region, including a more efficient and reliable use of the transmission grid, better signals for when and where to expand infrastructure, and a more intelligent grid."

Texas has been a very active state in the retail market. The Texas Electric Choice Education Program is aggressively reaching out to consumers to discuss the advantages of participating in the marketplace. The program asks, "Did you know that most Texans have the option to choose their Retail Electric Provider? Just like you shop around for car insurance, you can shop around to find the company and product that best fits your electricity needs." It also encourages consumers to compare choices: "Electric choice gives you options. You can choose an offer based on price, contract term and other requirements, green/renewable options or other factors important to you." The program provides tools for decision making and explains benefits of choice.

It is worthy to note that the industry is seeing unprecedented collaboration between federal and state regulators. There are collaborations ongoing in the areas of smart grid, competitive power procurement, demand response, and advanced metering.

Codes and Standards

Voluntary standards must be adopted by federal and state authorities as new law regulates performance of the grid and markets. For example, under the Energy Independence and Security Act of 2007, the National Institute of Standards and Technology (NIST) was directed "to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems . . . ."

Quality

Like the real-time operating systems that manage the smart grid, market infrastructure support systems must utilize standards, such as International Standards Organization-certified or Capability Maturity Model Integration (CMMI)-based software, to improve the openness, scalability, and maintainability of electricity market solutions.

User Interface

Traditionally, the electric grid has been managed by a select few individuals, with little interface between systems and consumers. Energy management systems use interfaces based on the specialized knowledge of grid operators.

With the introduction of expanded electricity markets, new users will bring a wide variety of needs, skills, and levels of knowledge. The user interface will require an easier, more socialized interface to accommodate this constituency. The available tools for consumer portals, home energy displays (HED), and home area networks (HAN) are expanding rapidly, driven by the consumer electronics and software industries.

This trend will gradually expand as the electricity marketplace is demystified and user interfaces become easy to use in an open-access environment. In time, accessing the smart grid electricity market will be as easy as logging on to eBay or Amazon.com. More information on the growing area of user interface can be found in the Smart Grid Characteristic paper, “Enable Active Participation by Consumers.”

BARRIERS

Meeting some of the basic requirements of enabling markets in the smart grid means overcoming some significant barriers.

Parochial regulations, limited skills of market participants, complex information infrastructure, and burdensome capital investments comprise some of the more common barriers.

- **Regulations —** Both federal and state regulations are required to support full-scale integrated markets to fulfill the needs of all consumers. The regulators of low-energy cost states are naturally reluctant to have their low-cost energy sent out of state to the detriment of their consumers. The regulators of high-energy cost states are pressed to find ways to lower costs. Both are pressed by consumers and environmental organizations to move to lower emissions. Competitive (wholesale and retail) markets with the right signals for prices and emissions are new territory for regulation and hold some risk. No one willingly takes on these risks; therefore, in the change to fully enabled markets, there will be winners and losers.

- **Market Participant, Aggregator, and Consumer Skills —** An educated participant, aggregator, and/or consumer are required to effectively operate in a market. That is true of all markets and should be expected in a new energy market. Different market participants, aggregators, and consumers have different goals in a marketplace. Some have a profit motive, others have a cost hedge or reduction motive, and yet others have an environmental stewardship motive. The best way for participants to meet various goals is to understand the detailed mechanisms of the market tariffs and procedures. This is no small effort, and every mistake will likely result in missing goals.

- **Information Infrastructure —** A vast amount of data is required to operate and run a market. In the startup of the MISO market, over one hundred thousand telemetry data points of system components were required to assure accurate pricing and operating signals. The collection and transmission of this data requires an extensive communications network. If multiple control areas are involved in operating a market, then common information protocols, security provisions, and timing add to the complexity.

- **Capital Investment —** It takes a large capital investment to set up, operate, and monitor a market. The market participants are the only source of funds. Generators of power must be convinced that they will be able to sell at higher prices, and load-serving entities representing the consumers must be convinced that they will be able to purchase power at cheaper prices. It takes a great deal of optimism to open a market with such risks.

New Market System Costs	Project Budget
CAISO MRTU	$199M
MISO Day 2	$247M
ERCOT Nodal	$660M

BENEFITS

As barriers are overcome, the infrastructure to enable markets will gradually be implemented, and important benefits will accelerate the evolution of the smart grid.

As consumers respond to market price increases, demand will be mitigated. Plus, consumers will become more engaged in determining alternate lower-cost solutions, which spurs new technology and process development. The load profile and generation profile will shift as alternate load management and distributed generation schemes become more prevalent in the industrial, commercial, and residential sectors. These drivers and changes will result in fewer and briefer interruptions.

From a marketplace looking for alternate and lower costs solutions, the smart grid will be able to offer a wide array of load-management strategies. Distributed generation, energy storage, demand-response strategies, and new ways to effectively manage voltage will emerge to cope with a more volatile operating environment. A smarter grid that enables power to flow two ways is essential to this new operating environment. In addition, such marketplaces spawn new ways to improve performance. The addition of a residential fleet of DER would also provide service for the self-healing feature of the smart grid. This is a vastly more complex operation than the grid can manage today. A smarter grid is required.

Fully enabled electricity markets will also drive smarter decisions about where to locate grid resources. Examples include the LMP as an added input to the siting of independent power producer (IPP) generation in Wisconsin and the added input to siting distributed generation found in Connecticut. From a systems view of the smart grid, it is important for generation siting to have all the related information available to make the best decisions possible.

Smart Grid-enabled markets will drive smarter decisions about the environment. Markets operating with a higher level of intelligence in the grid will facilitate a deeper penetration of renewables; provide incentive for demand response, conservation, and energy efficiency; and reward environmental stewardship. All of these actions reduce the emissions footprint for the electric system and consumers.

The smart grid's fully enabled market would open the electricity infrastructure to all consumers, not just transmission owners (TO) and IPPs. Extending electricity market participation to a wider stakeholder group (e.g., distribution companies, distributed generation owners, and consumers) can greatly increase the performance and reliability benefits of a market, whether wholesale or retail. For example, the open access of the cable television industry has greatly expanded services, which now provide telephone and Internet service along with programming selections. The open access to the electricity market will likely result in a similar expansion of services and options.

RECOMMENDATIONS

Four broad actions taken in parallel would ensure that the smart grid's design and implementation will fully enable markets for electrical power.

1. Modify existing and create new policies and regulations that remove the economic and political barriers to integrated markets. It will take a systems view and, most likely, federal directives to align policies toward integrated markets that benefit all consumers. For example, retail markets can perform well around TOU rates (real-time or not). The underlying requirements are that (1) market rate design needs to have rates that fairly represent costs at any TOU, and (2) consumers need access to the market. There are complex issues to be undertaken and, as in any political process, no one wants to end up with a disadvantage.

2. Provide widespread market education to all stakeholders in the smart grid, especially distribution-level consumers. Thousands of consumers may join a DR group that gives incentives participation, including selling the aggregated DR in the real-time market to offset energy costs. Knowing the potential gain and potential liability of such a venture is a must for consumers.

3. Standardize the communication of market information throughout the design of the smart grid with equipment, software processes, and protocols. Having a broker of market information is to the advantage of all market participants, like the reporting of stock values. Any consumer should have access through non-proprietary equipment.

4. Provide incentives for capital investment in new technology and the integration of existing advanced technologies. Regulators wish to have access to competitive markets to lower prices, yet are reluctant to (or prohibited to) authorize investments that spread benefits outside their regulatory jurisdiction or to utilize new technology. Options for resolution require some managed risk.

SUMMARY

"Enables Markets" is the name we give to one of the principal characteristics featured in the systems view of the smart grid. It is an important characteristic because well-designed and well-operated markets efficiently reveal cost-benefit tradeoffs by creating opportunities for competing services to participate.

Wholesale and retail markets will be attained by a market infrastructure that supports the four time frames of market operations:

1. **Planning —** For intermediate and long-term regional operations.
2. **Day ahead —** For short-term capacity requirements.
3. **Real time —** For managing generation dispatch, congestion relief, and reliability.
4. **Post-real time —** For settlements, analysis, and auditing.

Attaining fully enabled market infrastructure for the smart grid requires action in four broad areas:

1. **Regulations —** Federal and state regulation must be overhauled to remove barriers to a seamless integration of electrical markets.

2. **Market education —** To maximize their individual goals, all market participants must gain a detailed understanding of the operations and economics of electrical power services.

3. **Information infrastructure —** The collection and distribution of the vast amount of market data requires an extensive network, common information protocols, and trustworthy information.

4. **Capital investment —** Market participants must be reasonably certain their investments will be profitable, given the large commitment needed to set up, operate, and monitor the market.

Even partial successes in these four broad areas will provide benefits:

- As consumers respond to market data about increases in price, demand will be mitigated and consumers will seek alternate and lower-cost solutions in new technologies and products.

- Consumer demand for solutions will stimulate a market for distributed generation, energy storage, and other DERs that, in turn, will improve the reliability of the grid.

- Fully enabled markets will provide data for smarter decisions about where to locate grid resources.

- Access by all consumers, wholesale and retail, to the electrical market will expand commerce for future services and products that support their needs for lower cost energy.

For more information

This document is part of a collection of documents supporting a high-level overview of the smart grid. See "A Systems View of the Smart Grid." For additional background on the motivating factors for the smart grid, go to the website where seven papers can be found that support and supplement these overviews by detailing more specifics on each of the principal characteristics of the smart grid.

Documents are available for free download from the website below:

Website: www.netl.doe.gov/smartgrid

Email: smartgrid@netl.doe.gov

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