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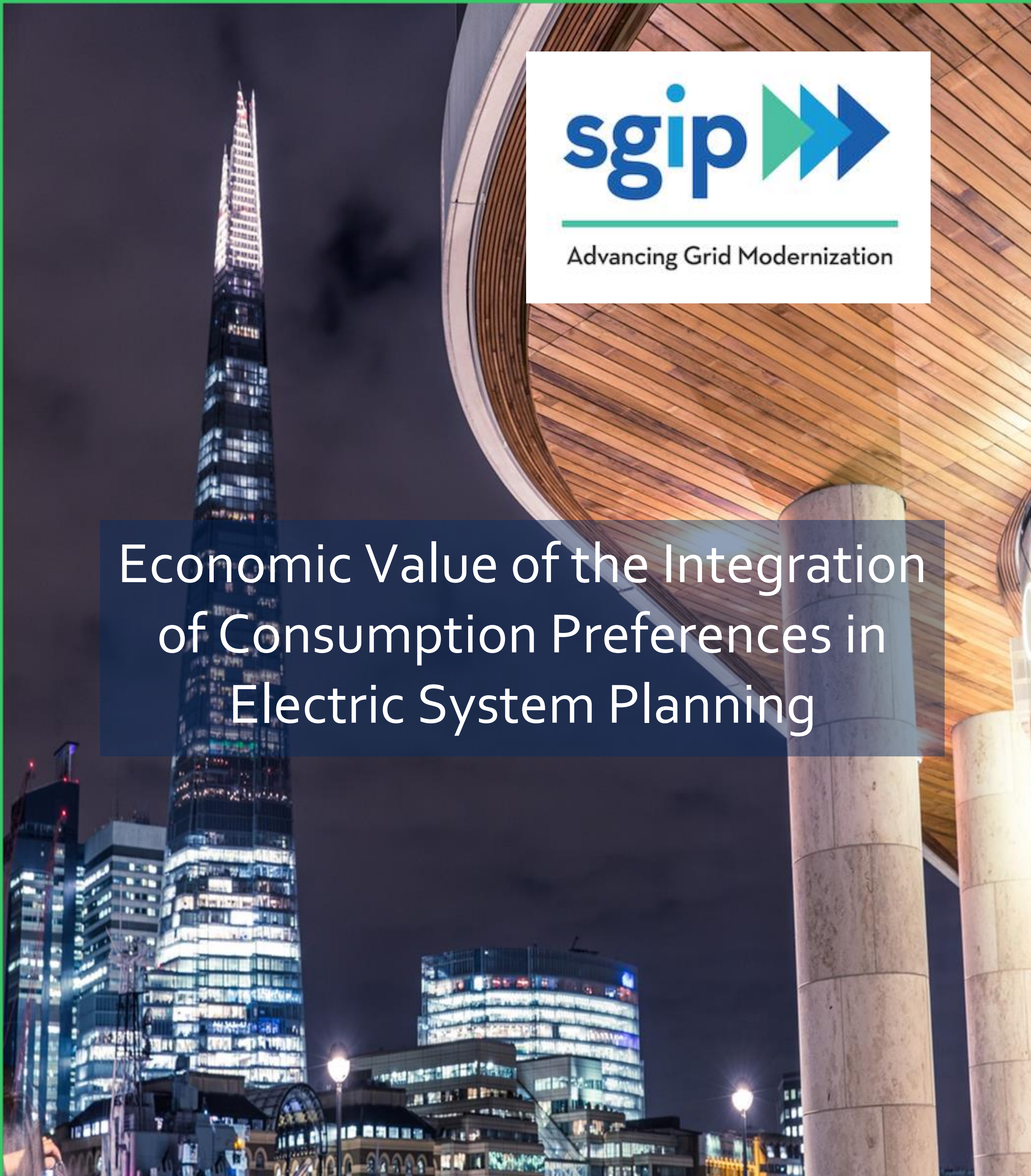

Economic Value of the Integration of Consumption Preferences in Electric System Planning

- Distributed Energy Resources
- Interoperability
- Grid Architecture
- Cybersecurity

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WHITE PAPER

An SGIP White Paper

A white paper developed by the Home/Building/Industry-to-Grid Domain Expert Working Group (H/B/I2G DEWG)

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About SGIP

SGIP is an industry consortium representing a cross section of the energy ecosystem focusing on accelerating grid modernization and the energy Internet of Things through policy, education, and promotion of interoperability and standards to empower customers and enable a sustainable energy future. Our members are utilities, vendors, investment institutions, industry associations, regulators, government entities, national labs, services providers and universities. A nonprofit organization, we drive change through a consensus process. Visit www.sgip.org.

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DESCRIPTION OF TERMS

(As referenced in this paper)

Ancillary services	Services that support and complement the physical delivery of electric energy, including transportation (transmission and distribution), reliability, electric energy quality, power factor minimization, AC frequency regulation, and loss-mitigation from reactive energy.
Capacity factor	The percentage of time the resource is utilized. Defined as ((average energy produced)/(energy capacity)).
Economic dispatch	The increasing cost order in which resources are dispatched (brought on or off line) to serve loads in order to achieve the most economically-efficient solution.
Electric energy (KWh)	Electric energy is the end product of the electric industry that provides the ability to fulfill applications such as operating electronics, electric vehicles, machinery, and heating devices.
Incremental Dispatch Cost	Cost, inclusive of the variable costs of operation that constitutes a minimum market-clearing price to dispatch resources for operation.
KW Capacity	The maximum power output capability of a resource at any point in time. Capacity depends on equipment design and prevailing conditions including fuel, wind, solar, and hydro conditions.

DESCRIPTION OF TERMS (*continued*)

Market-clearing Price	The prices at which supply and demand coincide in an open-access, competitive market with transparent prices. In the electric energy market, the point of equilibrium and corresponding prices are established when resources are economically dispatched to price-sensitive demand.
Price Variability	Anticipated fluctuations in price resulting from changes in electric energy supply and changes in demand.
Price Volatility	Price fluctuations resulting from unanticipated changes in supply due to rapidly-changing conditions.
Revenue Requirements	The accumulation of both fixed and variable costs underlying the cost of service to customers by utilities, subject to regulatory approval. Variable costs include fuel and plant operating costs. Fixed costs include fixed operation and maintenance, as well as fixed investment costs (capital recovery, return requirements, taxes, and regulatory fees).
Value Proposition	The election of customers to consume when the incremental cost of supply is below the price level customers elect to not consume.
Vertically Integrated Services	The combined services provided by existing utilities to include the generation and transmission of electric energy, the distribution of energy, regulation and administrative costs, and utility program costs. Costs are generally aggregated into the utility revenue requirement costs for recovery and administered through cost of service allocation in the determination of customer tariffs.

Preface

This paper identifies the underlying economic basis for industry decision-makers to select among electric-energy alternatives. The metric to be used is analogous to the equilibrium price that balances supply and demand in open-access, competitive markets. In the electric energy market, it is the price (sometimes called the marginal price) for a unit of energy that is delivered at a specific time and place. This metric is necessary to achieve supply/demand equilibrium in markets with transparent prices providing economic signals to all constituents. The application of this metric provides a basis for determining economic value for both supply and demand alternatives.

Economic value identifies the most economically-efficient alternatives providing greatest customer value and investment opportunity. The market-clearing price is established when supply and demand equilibrium is achieved and customer actions reflect market conditions. In the absence of a transparent market where customer price signals correspond to market-clearing prices, decisions made on behalf of customers (such as by utilities and regulators) should replicate the actions of an open-access market to achieve economic parity. The market-clearing prices or opportunity costs are, to a limited extent, applied in several aspects of economic decision making in the existing electric energy industry in the selection of both near- and long-term alternatives.

Currently, pricing signals in the electric energy industry fail to provide the correct economic behavior incentives. Pricing signals to customers through utility tariff prices have little relation to the cost consequence of changes in consumption. As a result, decisions for consumption by customers do not align with customer value. To a lesser degree, industry planners often fail to identify sufficient detail necessary to measure the correct alternative costs. Examples of such details include the dynamics influenced by renewable generation, energy required for system stability, and resource operating constraints. The appropriate inclusion of all detailed inputs manifests in highly-volatile clearing prices to achieve supply/demand equilibrium.

In the near-term, the economic dispatch of supply is achieved in the wholesale market by identifying resources having the least energy cost to fulfill the customer energy demands.

Wholesale energy prices are currently posted in many regions such as PJM and The Electric Reliability Council of Texas (ERCOT), as well as in international markets, which constitutes a significant portion of the market-clearing prices described in this paper.

Long-term decisions address the need for the development of additional energy resources and include the economic comparison among competing alternatives to provide a least cost solution. Historically, utility planners have assumed that demand was non-variant to changes in price, thereby overly generalizing avoidable cost opportunities. They failed to incorporate customer consumption preferences and changes in demand as a function of cost. Although not universally applied, economic determination based upon least customer cost has historically been the underlying basis for supply decisions in the industry. Prospectively, the determination of value using the market-clearing price metric is relevant for measuring the economic effectiveness of all considerations for changes in demand behavior.

Currently, the industry does not capture the full economic benefit of a more robust, dynamic competitive market having consumption reactions to volatile prices. Use of the appropriate underlying metric to include this dynamic allows for the economic determination of achievable benefits for industry stakeholders, including actions taken by utilities, end use customers, participants in electric-energy transactions, and electric-energy service providers.

The utilization of this economic value metric is useful for considering current alternatives and for measuring economic value based on the evolution of the electric energy market. Today's decisions must provide a measure of the achievable economic value inclusive of practical demand response actions, providing a relative scale for their overall effectiveness. The comparison of the economic merit among alternatives should be made independent of how costs and benefits accrue to participants (such as customers and utilities). The objective is to enhance customer value.

The selection among alternatives in open-access, competitive markets is fundamentally based upon price signals. This paper highlights the relevance of using the metric of market-clearing prices, which are common in open-access, competitive markets. Market-clearing prices are proposed for determining the economic benefits of integrating supply and demand decisions in the volatile and dynamic electric energy industry. A fundamental understanding of the comparative economic benefits will help decision-makers weigh in on how best to achieve those benefits by comparing all feasible alternatives.

Market-clearing prices are dynamically established inclusive of all changes in either supply or demand. Hence the market-clearing prices, inclusive of altered energy demand, are used by energy suppliers to determine value. The determination of clearing prices is more problematic in immature markets that have not achieved a stable equilibrium level and have the potential of allowing some overreaction by either supply or demand.

Furthermore, the electric energy industry has extreme volatility with rapidly-changing conditions that affect the level and incremental cost of supply. As a result, the price signals corresponding to market-clearing prices must be anticipated using detailed simulations of supply and demand actions and accurate computer models.

Market-clearing prices are dynamically established in both the near- and long-term markets. Long-term changes in the level of supply or demand response capabilities alter anticipated market-clearing prices. Long-term changes in either supply or demand capabilities are based upon economic considerations where alternatives having the greatest economic value are adopted ahead of other alternatives. As anticipated prices dynamically shift, decreasing economic value of continued developments result in market saturation.

Historically, the inclusion of economic considerations of demand response in the electric energy industry attempted to adhere to economic principals, but it lacked the inclusion of necessary detail corresponding to the volatility of prices in an open-access, competitive market to capture the individual preference of customers.

Previously, fewer resource technologies existed in the mix of supply resources, making it easier to identify the avoidable energy resource that might correspond to a change in energy demand. The avoided resource was used to determine the avoided energy cost, which included both the variable and fixed investment costs. The avoided costs methodology provided the equivalence to market price concepts, matching incremental benefits that corresponded to the incremental cost of additional energy supply.

Supply decisions have historically received a more thorough economic scrutiny than demand-side considerations when evaluating the life cycle revenue requirement costs relative to the costs of other supply-side options. Similarly, utility resource planners evaluated supply alternatives specific to their utilization in a volatile and changing electric energy market.

In the evolving electric energy industry, many conditions have improved the ability of utilities to align with customer preferences more accurately. This improvement resulted from changes in technology, information flow, and increased opportunity to integrate renewable resources. The industry, however, has been slow to accept the concept of using prices corresponding to those established in open-access, competitive markets for demand response applications. The factors contributing to the reluctance of providing incentives based upon market prices include:

- Essential services are at risk.
- Customers are not sensitive to prices for most services.
- Customers cannot be provided appropriate price incentives to alter behavior.
- Current consumer devices do not have readily-accessible, real-time pricing information, or automated devices to take advantage of such pricing information. However, consumers are receptive to these ideas if the solutions are easy to enable, privacy is not compromised, and economic benefits can be realized. (ref : SGIP white paper: *Barriers to Appliances at Scale*)
- Consumer applications cannot easily react to changing price conditions.
- The supply options require a large infrastructure with limited options.

Decisions regarding the use of electric energy are currently far from optimal for fulfilling customer needs, both in quantity and price. Achieving consensus among industry experts about the benefits of smart grid technologies and the appropriate market design is made difficult because of diverse views, regulatory policies, industry affiliations, and differing visions of a feasible objective. The process of establishing a road map among the various industry trade groups lacks a common direction resulting in fragmented dialogue, which often conflicts with overlapping objectives. This paper addresses the need for establishing alignment of smart grid developments toward a clear and common objective to advance the industry.

The need for the adoption of the correct price signals based upon market-clearing prices has increasing urgency. As a result of an expanding and diverse set of supply options resulting in greater market price variability, the current regulatory paradigm has less similarity to the economic efficiency achieved in a competitive free market. Utilities and regulators increasingly recognize that current prices in the industry do not accurately reflect associated changes in costs that occur due to changes in demand.

The measure of economic benefits using equilibrium price is not dependent on the creation of an open-access, competitive market place. However, the greatest effectiveness is most readily achieved when price signals are transparent to industry stakeholders. A transparent market achieves the highest level of benefits. Energy-supplier actions can approach that level if they balance market solutions with customer preferences.

In summary, this paper emphasizes the relevance of using a metric based on market price signals reflected in a transparent volatile/dynamic market to determine the economic benefits of integrating supply and demand decisions, and the importance for decision makers to maintain a focus on achievable objectives.

The utilization of the metric corresponding to the market-clearing prices is not dependent on the transition of the industry to smart grids, but is applicable in both current and future considerations of supply and demand alternatives. An identification of achievable economic benefits will help decision-makers weigh in on how to best establish an action plan and template for the industry.

Executive Summary

Fundamentals of Open-access, Competitive Markets Versus Traditional Utility Pricing

Conceptually, economic efficiency is achieved in free markets with a balance between consumer demand and market supply through market pricing. Customers elect to make consumption purchases corresponding to the incremental cost of supply, providing a continuum of customer value. Suppliers elect to make consumer offerings with appropriate compensation. Suppliers have no obligation to provide additional supply that is not supported by consumer demand corresponding to prevailing market prices.

In open-access, competitive markets, economic efficiency is achieved by balancing supply and demand via pricing. Less supply with more demand yields higher prices and vice versa. Simply stated, an equilibrium price is established continuously based upon the intersection of supply and demand. The clearing price (as indicted in the hourly day-ahead prices in Figure 1) is the marginal cost of providing supply or reducing demand corresponding to that price. In most competitive markets, this amount is nearly equal to the highest variable cost of the supplier to fulfill consumer demand.

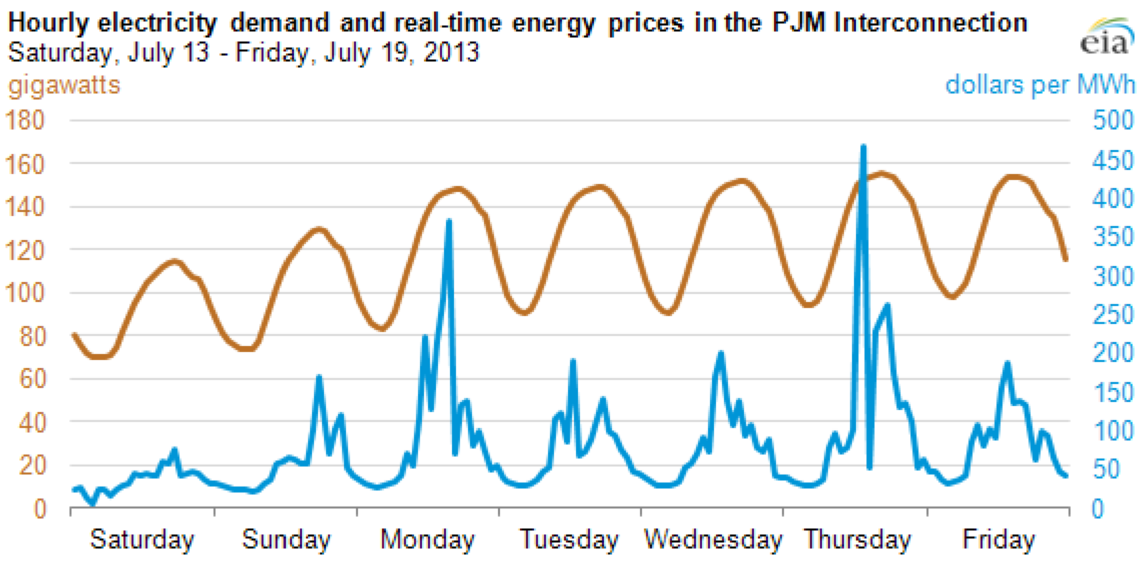


Figure 1 – Example of Fluctuating Hourly Electricity Prices from the U.S. Energy Information Administration

In the electric energy market, prices are extremely volatile as conditions of both supply and demand are continuously changing. This poses many logistic and conceptually difficult problems. However, with advancing technologies, these concerns become less problematic. Furthermore, industry participants and stakeholders provide diverse and complex solutions to align with achievable objectives described by an equilibrium price.

Electric energy and energy prices can be treated as a commodity. However, electric energy can be differentiated based on the lead-time and requirement to provide system stabilization. Examples include day-ahead, hour-ahead, 15-minute-ahead and balancing electric energy. Analogous to bidding, various uses of supply and demand can be employed to fulfill alternative functions based upon respective costs and value.

Historically, electric energy has been largely viewed as a monopoly, requiring regulatory oversight and offering customers little price incentive that would influence consumption behavior. The paradigm under regulation was determined to be necessary in the absence of a competitive market to encourage capital investments by providing recovery for investments in generating resources and transmission. Prices were not reflective of the dynamics as established in open-access, competitive markets, but were administered through tariffs that provided revenues corresponding to the investment and operating costs of the utilities. The tariff rates were generally not reflective of real time conditions, providing little incentive or value proposition for customers.

The emergence of smart grid technologies, improved methods for communicating prices, and greater variability of outputs from electric energy sources such as DER (Distributed Energy Resources), including renewable energy sources, has challenged the regulatory structure. The traditional utility structure needs to incorporate or replicate market-driven price incentives to avoid diminishing the potential benefits of emerging technologies.

Metric Applied in Emerging Electric Energy Market

To achieve the full economic benefit of implementing demand response alternatives, it is essential to identify the underlying metric from which a multitude of regulations and decisions among competing alternatives can be effectively measured. As in competitive markets, the determination of cost effectiveness and creating customer value is based upon **equilibrium price**, the measure from which all alternatives may be comparatively evaluated.

The application of the proposed metric to provide incentives for consumption behavior is aligned with customer needs and corresponding value. As in all markets, the *customer* is the fundamental benefactor and the reason for the existence of the industry. The current regulatory paradigm and determination of customer price signals fail to reflect the dynamics of the market. Often decisions are made on behalf of customers by both regulators and utilities, but they often fall short of achieving the potential gain in customer value.

Since individual customers value energy uniquely, it is not economic to take focus solely on the perspective of cost minimization, but to include that in a more comprehensive view toward maximizing customer value. Customer value of energy is unique to timing and application, and cannot be addressed as simply establishing a minimum cost of delivery assuming an indifference to timing.

Since each customer is unique and has diverse uses and applications of energy, a single approach lacks precise actions to achieve potential benefits. The metric of **equilibrium price** is essential to evaluate the effectiveness of competing solutions, ranking them in their effectiveness to achieve the greatest benefits for customers.

The metric can be universally applied in the consideration of market solutions such as Transactive Energy (TE), real-time pricing (RTP), utility incentive programs, distributed generation, micro grids, and regulatory changes. There are many competing paths that can, either individually or in combination, achieve the economic benefits of aligning the customer's timing and use of energy to achieve increased customer value.

The determination of economic value using the metric of equilibrium price is consistent with supply-side options (both central station and distributed generation), providing solutions that align with customers' preferences, both timing and price, consistent with competitive market economic concepts. Market-clearing prices provide both near- and long-term price signals that are at play in a competitive market.

In the near-term, all supply-side options are dispatched when market prices exceed the marginal cost of operation and hence provide a contribution toward the recovery of fixed costs. In the long term, only that amount of electricity is produced that can be utilized and recover fixed investment costs above their variable costs of operation. Insufficient margins that do not provide either investment incentives or changes in demand response result in reduced supply and correspondingly increasing prices (supply/demand). Higher prices provide the market dynamics to incentivize investment until an equilibrium level is reached.

Customer Values Aligned with Market Price Decision-making (Price and Quantity)

The metric provides alignment of competing solutions to achieve greatest customer value (both price and desired service quality). It should be carefully noted that this does not imply minimum cost, a stated objective in the regulatory paradigm, but a measure of satisfying customer needs based upon their value proposition.

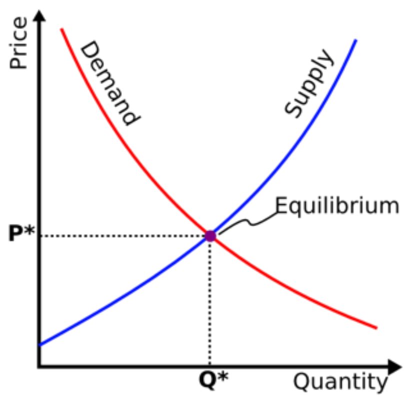
When provided the opportunity, customers will elect to make energy decisions based upon individual preferences and desire for consumption behavior. The application of the metric described in this paper will be explained and compared to industry alternatives. We will show that this metric achieves benefits of an open, transparent market where customers elect to consume or avoid the purchase based upon individual preferences, creating greater economic efficiency.

Competitive Market Economics

Market Pricing

In open-access, competitive markets, decisions made by consumers related to both quantity and timing of purchase are based upon the market price. As in nearly any competitive market, the determination of price is based upon the marginal cost of supply necessary to satisfy price-sensitive consumer demand. At any instance, the equilibrium price will be established by the supplier having the highest marginal cost willing to enter the market at the equilibrium price, while a higher price corresponds to a reduction in the quantity desired.

In open markets, market-clearing prices provide an incentive for both suppliers and consumers to make corresponding decisions based upon value. This perspective is most easily understood when considering that all value-based decisions stem from the perspective that the industry exists to provide value to the customer. Value to suppliers exists only when demands, based upon customer preferences, provide incentives that support cost recovery corresponding with supply options, including investment incentives. This important and fundamental notion is essential to appreciate the perspectives of this paper.



A price that is based upon satisfying both supply and demand at any instance is the market-clearing price. In most dynamic markets, there are no separable charges for capital investments. They are recovered from prices established by market transactions. Traditional utility pricing struggles with this concept, since revenue requirement determination of prices are inclusive of separable costs corresponding to investments and not based upon market pricing. For example, a supplier of produce to a grocery store does not change his price to include a separate charge for his equipment but makes corresponding decision about his investments based upon anticipated revenues corresponding to competing market conditions.

Suppliers offer a product when prices exceed their variable costs based upon near-term capability, providing a contribution to investment cost recovery and other fixed costs. This scenario provides the market-clearing price where supplies compete with one another up to the margin where equilibrium is established. The supply capability is a result of suppliers building infrastructure, including investment decisions based upon anticipated cash flows of future market conditions, promoting investment incentives.

Long-term Adequacy of Supply

Market economics are applicable to both immediate and long-term solutions for providing adequate supply to accommodate consumer demand. Since suppliers have both variable and fixed costs, revenues must be sufficient to maintain adequate recovery of these costs, including required levels of profitability. If revenues are insufficient to stimulate additional investment, supplies are reduced, resulting in an increase in market price until investment incentives become sufficient to fulfill customer demands corresponding to the price.

Competing suppliers, having different levels of variable cost, recover some portion of fixed costs resulting from these differences in variable cost and market prices. Similarly, the marginal supplier has opportunities to recover fixed costs at different times when prices exceed the variable costs incurred. For any single resource, it is the accumulation of these value contributions over time that provides the investment recovery.

The U.S. Department of Energy's Clean Energy Investment Center

Investment decisions must provide anticipated value from future operations providing adequate assurance of recovery and a return on the investment commensurate with the risk. In an open, transparent market where customers have full freedom of selecting among suppliers, the cost of capital reflects the true economic cost where the risks of positions taken are borne by the investor. In conditions where risk is shared between customers and investors, as in the utility industry, the true, economic cost differs from financing costs as a result of a sharing of risk between customers and investors.

Electric-energy investments include central station generation, distributed generation (customer or electric energy provider) and conservation investments. Each of these investment considerations will have different levels of risk specific to the investment, including market competition, displacement, and time before the investment is recovered.

Resource value created in dispatching resources (central-station generation, distributed generation, and demand control devices) is reflective of operations corresponding to volatile market prices. Resources have unique operating parameters affecting how each unit can be operated to maximize value. For example, large thermal units must maintain operation for a minimum number of hours when they dispatch, hence their operation may include periods with negative value (variable costs exceeding market prices) to capture the overall benefit during the minimum period of operation. Similarly, hydro-units must maintain minimum flows, resulting in reduced benefits compared to dispatching based upon market prices.

Similarly, demand response actions may have operating constraints including limitations that can result in intervals containing periods of negative value. The economic viability, like supply decisions, occur when there is adequate overall value that exceeds the value of other competing alternatives.

Total investor cash flow is inclusive of the accumulated contribution of values, resulting from resource operations. The accumulation of anticipated value is necessary to provide the incentive of investor compensation over the lifetime of the investment.

Market Penetration

Market prices adapt to changes in supply and demand dynamically. Market pricing enables economic solutions for electric energy investments. As a result, the incentive for additional development diminishes as market prices are reduced, resulting from increased supply or lower demand. Thus, upon adoption of all supply and demand side options, market incentives for further investment decrease. Assuming all considerations are made in a competitive manner, the options that provide the greatest economic value are selected ahead of other options, hence capturing the low hanging fruit prior to reaching market equilibrium.

Investment decisions are made in anticipation of future market prices and expectation of profit providing the incentive. As a result of future actions taken (both supply and demand), the expectation of market prices is altered based upon the equilibrium price inclusive of anticipated supply-and-demand actions. The anticipated prices are based upon a forecast of future actions and lack accuracy resulting in both over- and under-built conditions.

As markets mature, prices become more predictable, thus providing increased identification of viable options for development. In the long term, only those investments having the greatest economic potential get developed, reducing anticipated market prices to a level where any incentive for additional investment is eliminated.

Application in the Electric Industry

Economic Price Signals in the Electric Energy Industry

On the surface, the electric energy industry would appear to be far afield from an open-access, competitive market having transparent market-clearing prices. The construct of customer pricing under regulation shifts the timing of recovery of utility costs; however, the incremental cost consequence as included in utility decision-making is closely aligned with competitive market economics. In the utility industry, the selection among competing supply alternatives is fundamentally based upon the opportunity or avoided cost of the next closest competing alternative.

Markets can be viewed within the electric energy industry based upon competing energy alternatives, provided they are interconnected. In a broad sense, these markets are illustrated in the following image where several of these markets have physical interconnections. Energy transfers within a market region incur costs for transmission and any losses. On the wholesale energy level, costs can be specified using locational marginal pricing (LMP), which includes costs between specific locations.

U.S. Energy Information Administration – Electricity Market Regions

The determination of the clearing price, however, does not end at the wholesale level, but also includes distribution costs down to the customer level. This can be most easily understood when observing costs for other competitive markets. For example, the cost of an item of produce may be uniform to a point of delivery for a town. However, the price at a specific location includes costs for local delivery.

Near-term decisions regarding the economic dispatch of available resources attempt to minimize the cost of energy in selecting among these resources (dispatch supply stack) to satisfy demand at the lowest cost. These costs are generally known and shared among resource dispatchers and are currently posted in day-ahead and hour-ahead forecasted prices in some wholesale energy markets such as PJM and ERCOT. The market transparency of posting such prices allows supply and demand constituents to participate, improving the economic efficiency and fulfilling customer objectives.

Upon additional transformation of the industry, the current price signals are anticipated to be refined to include a broad range of differentiated products that provide adequate fulfillment of customer demands. Differentiated products will be specific to assuring the reliability of energy delivery at specific locations. The list is anticipated to be extensive and is not comprehensively specified in this paper.

As a result of the extreme volatility in the electric energy market, conditions and resulting market-clearing prices change rapidly, resulting in an extreme challenge when compared to the markets of most other commodities. Under the conditions of most other commodities, the conditions of supply or demand are less volatile and predictable, corresponding to prices in the recent past. This is not the case with electricity, which travels from the source to the end user at the speed of light with the energy supply and demand changing continuously affecting the marginal or opportunity cost.

As a result, prices must be anticipated to be utilized by stakeholders as are prices posted in wholesale energy markets. Anticipated prices are based upon forecasted conditions and require sophisticated tools such as market simulation tools that can be used to forecast prices based upon supply/demand equilibrium. The industry is considering possible methods and data sources for forecasting-anticipated prices to provide appropriate pricing signals.

History of Utility Planning

The investor-owned, electric energy market has developed as a regulated industry, having the legal obligation to serve at the least possible cost. As a result of increased environmental concerns, utilities have been required by public policy to adopt technologies that would otherwise not be deemed economic, such as the case with renewable technologies like solar and wind. The adoption of these technologies is not usually based upon the fundamental economic criteria addressed in this paper. However the resulting electricity generated from these technologies affects the market-clearing price that satisfies the equilibrium of supply and demand.

Historically, customer loads were forecast largely independent of price using anticipated patterns. Resources were developed with enough operating flexibility to meet the anticipated range of customer loads, including resources that were run as base loaded and peaking units.

Resource planning and decisions were made from the perspective of least cost revenue requirements. Customer loads were considered non-elastic to changes in price, hence were not included as alternatives in the consideration of least cost options. Utilities have an obligation to serve customers resulting in assuring adequate supply to meet peak load conditions while allowing only a very low probability of an inadequate supply. Regulators were satisfied with this paradigm, since customers were being served in a least cost manner, which was an approximation to the economic development of supply that would have existed in a market with inelastic consumption.

The mix of resources available to fulfill load requirements has become increasingly diverse, with the rapid expansion of renewable resources, primarily wind and solar. Because these resources have much less predictable outputs, the underlying supply has much greater variability, resulting in a greater incremental range of cost for units operating on the margin and correspondingly volatile market-clearing prices.

Several fundamental differences make this regulated market less efficient than market decisions, assuming current and evolving conditions as reflected in competitive, open markets. Fundamental changes include;

- Increased awareness that customer loads are elastic to price.
- Increase in resources having intermittent operations resulted in greater volatility of electric energy prices.
- Changes in technologies that allowed for greater ease of customer load control.
- Information about real-time electric energy conditions and corresponding prices.

Parallel to Intent of Regulated Industry

Utility Supply-side Economics

Utilities generally include a more refined measure of the value of generation corresponding to their utilization under volatile conditions and corresponding changes in marginal value. Prior to having better computer models that incorporate this volatility, other measures, such as load duration curves, were used for approximating the value of competing resource technologies.

Computer models that simulate the economic dispatch of both supply and demand allow for a more refined measure of value under varying conditions.

The economic viability of anticipated supply-side resources occur when the accumulated values of resources economically dispatched exceed the fixed costs incurred, including both investment costs and ongoing fixed costs. Analysis includes the dynamics of interconnected competing alternatives, inclusive of supply and demand.

Demand-side Economics

Currently, the recognition of demand response alternatives is much less comprehensive and not inclusive of the breadth of demand response alternatives that may be forthcoming. As a result, customers do not have incentives for economic behavior, because the infrastructure of end-use controls is not available yet. Since customers are not appropriately motivated by utility tariff rates, utilities incentivize targeted customers based upon specific actions and corresponding savings to alter their behavior. These incentives have been labeled as avoided electric-energy cost, whereby utilities provide an incentive adder to the rates charged in tariffs to correspond to the avoided cost. Avoided costs correspond to the period over which costs are incurred and are conceptually equivalent market prices.

The rate-making process established under regulation separately identifies fixed and variable costs associated with the recovery of costs of generating resources. The variable portion of costs is typically included in the power costs of the utility, whereas the investment costs (for fixed investment costs) are included in several line items of a typical utility income statement. These costs include the recovery of the capital investment (equity return, interest expense, and book depreciation) and associated income and property taxes.

For most products, prices are established to achieve equilibrium between supply and demand. Electricity has traditionally been priced by accounting for both variable and fixed costs corresponding to incremental investments required to serve loads. Demand elasticity has generally not been considered.

Utility economists often contend that prices corresponding to highest marginal cost of supply do not provide sufficient incentive to create supply side options. The underlying misconception of this perspective is a result of utilities historically having few supply-side options and not providing customers with price incentives that allow for changes in load behavior corresponding to prevailing conditions. This generally is not the case in robust, competitive markets. In robust, competitive markets, prices are reflective of a myriad of supply options or changes in behavior corresponding to price.

Current utility pricing and more limited supply options may, in some cases, require extra compensation beyond market-clearing prices to provide an adequate level of capacity to meet load requirements during conditions where supply is scarce and necessary loads must be served. In some jurisdictions, capacity charges have been applied to provide additional investment incentives. However this is debated among industry experts. Capacity charges are anticipated to have a diminishing role as customers exercise greater response to prevailing prices.

Volatility of Market-clearing Prices in the Electric Energy Market

Market prices in the current electric energy market are highly volatile because of fluctuations in electric energy supply and consumer demand being unaffected by appropriate market price signals, resulting in supply and demand for energy that fluctuate independently. This produces a unique and complex problem in the electric energy industry, since changes occur rapidly within very short time intervals.

This paper addresses those items that can be managed with information flows resulting in demand behavior that has a stabilizing effect on market-clearing prices. We will not attempt, however, to address all issues that may be required for system operators to provide system stability and reliability.

In electricity production, the cost is significantly different among suppliers based on the resources and fuels used to produce the electricity. This range differs considerably from other products like food or automobiles where the cost of production is similar to meet a standard specification. Electric energy prices are based on the rapid transport and delivery of electric energy with fluctuating generation and demand. As a result, the market-clearing prices to satisfy supply and demand equilibrium become volatile. This provides a unique set of problems and, until recently, was felt to be unmanageable except through regulatory measures.

Effect of Increased RPS Resources Having Varied Output Generation

Wind- and solar-powered energy is available when conditions allow production with nearly zero variable cost. These resources, by their nature, have highly-variable operations, often with very low predictability. As a result of regulatory and legislative mandates, an increasing amount of generation must come from these resources, requiring an increasing number of thermal and hydro resources, which have a high degree of dispatchability to accommodate customer electric energy demands and provide system stability.

The resulting market-clearing price fluctuates wildly as resources on the margin must enter and exit the dispatch stack of supply-side resources. The prices spike upwards based upon peaking units with low efficiencies and expensive fuel cost to near zero prices within just a few hours.

Effect on Customer Demand With Incentives Based Upon Market-clearing Prices

Customers loads can, with appropriate pricing signals, incorporate automatic-load control devices that capture the benefit of using electric energy when prices are low and curtail the use of electric energy when prices are high. Although much of this automation does not currently exist, the recognition and measurement using the appropriate metrics will provide the respective value to other supply/demand alternatives for economic comparison.

Upon implementation, electric energy market prices will stabilize as a result of customer loads responding to prices that reflect the marginal cost of supply. This is a fundamental concept of the equilibrium price established by the supply and demand in a competitive market.

Markets Applied to Energy Products

The Customer Considerations

Electric energy is the end product that provides utility or benefit for customers. All other services (transportation, reliability, and ancillary services) are related to electric-energy delivery and reliability. Energy provides the basic function of heat, light, mechanical action (including air conditioning and motors), and enables the operation of electronic devices. For each customer application, the following considerations are made to fulfill customer value and objectives.

(a) Value determination of consumption corresponding to prevailing prices
   (i) Election to take or not take service at current prices – or
   (ii) The timing of purchases: the election to take energy at periods with more favorable prices
(b) Consideration of other energy supply options including determination of self-generating (distributed or back-up)

Customer value decisions are based upon the preference unique to each customer for diverse energy applications. Considering electric energy (KWh) as a single product fails to recognize diverse uses, each having a unique value assessment by the customer. In economic measures, it is more appropriate to consider energy as a multitude of electric energy services to the customer, with each specified by how it is utilized and not solely as the value of a single commodity.

The Supply Market Considerations

Prospectively, the application of market principles in the electric energy market may be better described if we examine electric energy delivered as a specific amount of energy during a specific time interval in the future. The supplier may require different resources to deliver the supply depending on the amount of energy and the time of delivery. Each of these "energy products" will have corresponding market prices based upon the supply/demand functions described in this paper. For example, we may break down electric energy into day-ahead, four-hour-ahead, hour-ahead, 15-minute demand meter intervals, while offering energy as discrete products—each having a difference in the magnitude of electric energy required and corresponding price.

The amount of electric energy required is in part based upon the predictability of system demands, with each having a corresponding price relative to the required marginal cost of supply. Each of these products and services can be examined based upon market principles of supply and demand resulting in a corresponding price to satisfy conditions. In general, it is anticipated that the shorter the time prior to delivery, the higher the cost of supply or greater the value of a demand corresponding to the market equilibrium price. Supply options that can be utilized for multiple services maximize their respective value given the competing dynamics of the market.

Other factors that are ancillary to the primary delivery of electric energy include the reliability of delivery, quality of electric energy delivered, the transportation of electric energy, and the ability to accommodate reactive loads while minimizing power losses. Without energy and the delivered electricity product, none of these ancillary services are relevant. Each of these ancillary services requires investment and operating costs to provide the respective functions, which may be viewed from a competitive position, or from a cost of service when markets cannot be established. These services are described in more detail in Appendix B.

Transactions in Advance of Delivery

Markets are inclusive of positions taken in advance of real-time energy delivery and corresponding prices. These positions are established by electric-energy suppliers and end-use customers. Also, a host of other intermediary interests take financial positions, including energy aggregation and energy trading. Each of these positions, whether between a supplier and customer, or within a string of transactions, are ultimately based on anticipated market prices. Each of these types of energy transactions will be described briefly.

In general terms, all investment decisions, whether supply or demand, represent positions taken in anticipation of future market prices. A utility develops a resource, now corresponding to a specific load, and enters into a power sales agreement, whereby the electric energy is pre-sold at a specified price or may be indexed to a variable price such as a fuel cost. This provides financial assurance and a predictable stream of revenues that allow for greater financial leverage.

Assuming the electric energy were to be sold in a volatile energy market, investors would have appreciable risk and a corresponding requirement for a high-equity percentage. Customers additionally take electric energy management positions corresponding to anticipated market energy prices. These may include distributed generation, solar generation, appliance efficiency and control, and conservation measures. Each of these has a corresponding cost and anticipated savings according to the action taken.

Similarly, customers without contract purchases are at risk with the variation in the market. As a result, customer actions will correspond to their appetite for risk versus price. Suppliers, whether they are electric energy aggregators, individual generations, or utilities, are subject to the variations and uncertainty of market prices.

Energy aggregators or energy traders lie in between the electric-energy supplier and end use customer. On the surface, it can appear that those positions have little or no bearing on market prices. However, each of those positions is dependent on other positions taken, with each having relevance to the market energy price corresponding to the time of delivery.

The above transactions provide entitlement to electric energy at a given price, which can result in the actual delivery of energy or may precipitate secondary transactions that capture additional economic benefits as real-time market prices have greater certainty. For example, conditions that result in a lower-than-anticipated market price may result in a reduction of the output of a generating resource when previously-assumed operation is uneconomic. Hence opportunity exists to alter contracts for greater economic gain. This applies when actual prices differ from those previously forecast that underlie the initial transactions.

Summary of a Market in Transition

The economic drivers of both changes in supply and demand are correspondingly incentivized by appropriate prices corresponding to an open market. Prices in nearly all markets frequently change as conditions of supply, cost of supply, and customer propensity for consumption change. The emerging technologies in the electric energy market are providing opportunities to capture the benefits of a market that allows for increased customer choice for consumption, which was previously unattainable.

Market Dynamic Applied

Prospective supply-side resources must forecast market prices, anticipate operation, and dispatch power generators to produce sufficient revenues that, over time, recover both fixed and variable costs. To maximize customer value, demand response to volatile electric energy prices must similarly coincide with dispatch supply-side decisions, altering the equilibrium point at which supply meets demand.

> To maximize customer value, demand response to volatile electric-energy prices must similarly coincide with dispatch supply-side decisions, altering the equilibrium point at which ***supply*** meets ***demand***.

Emphasis on the dynamics of market prices based upon clearing prices invokes economically-efficient actions of both supply and demand decisions. Market prices are essential elements for creating stability and for incentivizing actions (supply and demand) that improve economic conditions. Prices can create stability if they correspond to prevailing real-time conditions by providing incentives to reduce (or increase) demand corresponding to resource insufficiency (or surplus).

The dynamics are applicable for determining instantaneous prices, as well as the level of supply or demand development that may occur. To that end, the amount, or penetration, of supply- and demand-side options will be established by anticipated forward prices that are inclusive of other actions taken over the investment recovery period. With greater penetration of economically-driven alternatives, prices are moderated, thereby reducing the incentives for additional development of supply or demand options.

The perspectives of market pricing apply to electric energy markets where broad participation may occur by consumers and suppliers, as well as in smaller, more specialized markets that include balancing, system reliability, and other ancillary services. Specific market applications will require some creative solutions and may lack the elegance of ideal market solutions, but are necessary for system integrity.

Other large, capital-intensive industries that had little price competition, like the telephone and airline industries, have transformed to more market-based pricing, but not without significant financial reformation. Asset values among investors were out of step with investments that would occur in a competitive market. In these industries, as in the electric energy industry, there are customer substitutions and alternatives with varying price and performance, such as using land lines, pay phones, cell phones at different times, and driving rather than flying to a destination. Substitutions for electric energy can be anticipated in many forms, including options as to when to consume electric energy, implying energy storage options, election on consuming energy at prevailing prices, and distributed energy generation, just to name a few.

Emergence of Technology Enabling Transformation

The following changes promote the transitions in the industry to align customer load behavior and increase customer value. The rate at which these items will influence the industry is debatable but generally viewed as being the direction the industry is headed.

Market Pricings and Incentives – Technologies and many programs are underway that provide greater transparency of electric-energy prices. These range from utility programs with incentive rates to real-time pricing.

Device Controls – Technologies are rapidly emerging that allow for both manual and automated optimization controls of electric energy uses affecting both the timing and amount of electric energy consumed.

Market Awareness – Customers are becoming increasingly aware of market electric-energy prices and the acceptability that prices are volatile. This knowledge has increased the awareness that gains can be made from the smarter use of energy.

Supply Alternatives and Competition – Competition is one of the key drivers affecting the rate at which customer pricing will change. Competition forces competing suppliers to provide customer prices that correspond to their respective cost of service, hence customers that elect to take electric energy when prices are suppressed from increased supply have price set correspondingly, otherwise competitors will be more attractive. The converse is also true.

Comparison of Market-based Prices to Utility Prices

Market Price Signals and Utility Pricing

This paper does not advocate that the electric utility industry adopt market-clearing prices as the basis for revenues and recovery of costs, only that the market-clearing price is used as the basis or metric in the evaluation of economic alternatives (both supply and demand) to achieve the greatest economic value reflecting customer choice. The determination and resolution around the recovery of investment costs and other associated costs incurred are complex issues that deserve a lot of detail and attention and are well beyond the scope of this paper.

Specific issues include the recovery of sunk investment costs incurred that may be greater or less than incremental costs reflected by market-clearing prices and other associated costs incurred by the industry corresponding to other vertically-integrated services not addressed in this paper. Other vertically-integrated services include energy distribution costs, administrative services, and utility programs to mention a few. Some of these costs may overlap with market prices and others recovered independently.

Construction of Utility Pricing

There are two basic reasons why utility pricing is distinctly different from pricing in a competitive market: (1) revenue requirement costs are allocated to utility customers via regulation and (2) the cost- and risk-sharing relationship between customers and investors differs from the regulated industry and free market economics. Although both provide the full recovery of fixed and variable costs incurred, the determination of prices differs at any point in time based upon the relationship differences between customers and investors, as well as the market dynamics versus regulation.

Although it is not significant that we address utility pricing, we need to recognize that differences exist, making it necessary to provide the appropriate incremental change in incentives to reflect market-clearing prices. Appendix D provides a discussion and background descriptions of differences that occur between market-clearing prices and utility pricing.

Illustrative Examples

The following examples provide a fundamental explanation of the market mechanics affecting price and drivers to alter supply/demand development decisions. This simplified example lacks the robust nature of market with a multitude of both supply and demand actions. However, the principals remain the same.

Simplified Examples

These examples are simplified to illustrate the applicability of market-clearing prices for resource dispatch decisions. The Phase II examples include resource value assessment. The simplified example includes a small isolated grid with a defined number of supply and demand side actions. In this example, we consider a simple electric-energy supply including both low- and high-cost incremental resources. Customer loads are identified as a portion being essential, an amount of load being discretionary depending on electric-energy price, and in the last example, transferable to alternate periods of consumption.

The following examples are included:

Phase I – Existing set of resources with no added investment considerations

1) Utility dispatch of resources with no demand response actions
2) Customer with demand response based upon price signal

Phase II – Assumed load expansion and resource expansion

Case 1 – Utility dispatch and resource expansion with demand response

Case 2 – Resource expansion with the customer having demand response to price

Case 3 – Same as Case 2 with additional ability to shift load between periods

The first set of examples (Phase I) includes comparisons of load/resource decisions in the economic dispatch of an existing supply, both with and without customers being incented to change price-induced load behavior. The price incentive corresponds to the market-clearing price to achieve supply/demand equilibrium based upon the prevailing conditions at the time of consumption. The second phase (Phase II) illustrates the economic principles at play in the formation and selection of supply and demand alternatives corresponding to market-clearing price signals.

Each example includes two distinct time periods with the only difference being a supply-side resource (wind in this example) generating electric energy during one period. As a result of a change in the resource availability, one must go to a more expensive resource on the economic stack to obtain the necessary electric-energy supply, or in the case of the implementation of demand response, load may be reduced if market-clearing prices provide sufficient incentives.

Fundamental economic rules and criteria are implemented in each phase of the examples. The **first economic rule** applied is the least cost; economic dispatch of all available options, including both supply and demand alternatives, provide the greatest utilization of resources at the lowest cost. This is a fundamental economic principle that is at play in nearly all open competitive markets where the greatest margin of profit exists by the lowest cost producers based upon variable costs, providing the greatest contribution towards the recovery of fixed costs.

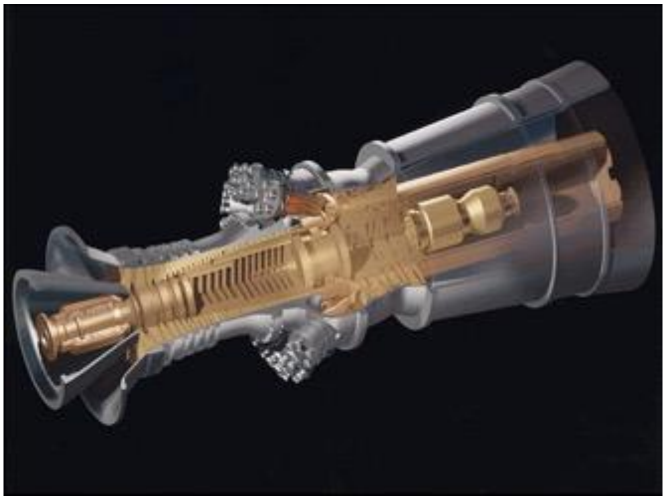
In the electric industry, options are selected based upon least-available costs. Hence, energy suppliers dispatch supply options starting with those at the lowest cost and move up the dispatch stack in order to attain an equilibrium price that aligns with consumer preferences.

The **second economic rule** is applied to the second phase of examples when resource expansion occurs among competing resource alternatives. The economic rule applied is that resources that have positive economic value are assumed to be placed in service. Investment value occurs when the resource (supply or demand) recovers both fixed and variable costs over the period the resource is anticipated to operate.

The fixed cost is inclusive of the investment costs, including a return of and on the investment to provide sufficient investment incentive. The measure of economic performance and operation in based upon market-clearing prices, which are dynamically established based upon a forecast of supply development. As a result, those resources, having achieved the greatest value, get placement ahead of less-desirable resources. Prices dynamically get reduced with added supply until the investment incentive margin dissolves.

The following assumptions and parameters as illustrated in Table 1 are used in the example. Please note that the figures were not intended to reflect actual costs, rather serve to illustrate the concepts of market-based economics. The example includes four supply resources connected to the supply grid, including wind, which has only 50 percent production availability (on or off), a combined cycle (CC) gas-fired turbine, a simple, cycle-gas turbine, and an internal-combustion generator. The summation of the capacity of available generation assures electric energy availability under all conditions in the example.

These resources are dispatched (brought into service) in order corresponding to their variable cost of production to provide economic efficiency assuming no demand response. The fixed costs correspond to those costs that are not variable with generation and will occur irrespective of generation. The fixed costs indicated in the example are inclusive of the total fixed costs for the two periods, both with and without wind in the example.



Gas Turbine for electrical power generation by United States Department of Energy

Note that the resources costs are minimized when not considering demand response options. Hence the gas turbine has greater economic efficiency when being operated for both periods in the example. The internal combustion turbine has greater efficiency when only being required for half the period in the example (10+1 variable + fixed vs., 5+4 variable + fixed for gas turbine; in cents/kWh). In simplistic terms, this corresponds to the least cost methodology used by utility planners. Wind and solar energy, in this example, are excluded from least cost consideration, since they are presumed to be mandated.

The customer load to be serviced in this example is 100 kWh in each period, inclusive of a portion that is demanded regardless of cost and a portion at three different levels that would not be consumed if the incremental cost to serve exceeded the maximum price for consumption.

Table 1: Phase I – Supply and Demand Example Assumptions

Grid Supply- 4 Resouces				
	Resouce Cost		Energy Potential	
	Variable Cents / kwh	Fixed Cents/ MW	KW Capacity	Percent Availability
Wind	1	8	20	50%
CC Gas Turbine	4	5.5	50	100%
Simple Cycle Turbine	5	4	20	100%
Internal Combustion	10	1	20	100%
			110	
Customer Supply				
Solar	0	8	10	100%
			10	
			120	
Demand				
	KW	Hurdle Rate cents/ kwh		
Essential	70			
Discretionary Load 1	9	12.0		
Discretionary Load 2	12	9.5	4.5	
Discretionary Load 3	9	6.5		
	100			

The Table 2 illustrates the change in the level of electric-energy demanded as a result of including the customer's preference for consumption based upon market-clearing prices, both with and without demand response for each of the conditions with and without wind generation. The initial case illustrated in Table 2 without demand response (Utility w/o Demand Response) indicates the same level of demand regardless of supply conditions and corresponding changes in marginal prices. As illustrated in the case with demand response (Demand Response Included w/o Customer Supply Options), customer demand level diminishes as marginal price of supply exceeds the customers' hurdle price, or level the customers would elect to take additional energy.

Table 2: Phase I – Resulting Energy Demanded

	Utility w/o Demand Response Included		Demand Response Included w/o Customer Supply Options	
	Condition w/ Solar	Condition w/o Solar	Condition w/ Solar	Condition w/o Solar
Customer Load (kw)				
Essential	70	70	70	70
Discetionary Load 1	9	9	9	9
Discetionary Load 2	12	12	12	1
Discetionary Load 3	9	9	9	0
	100	100	100	80

Table 3 includes the variable and fixed costs incurred to serve the customer load in each of the two periods, one with wind power available and the second period with no wind generation available. Both periods serve the same 100-kW load with the period having no wind generation requiring the dispatch of the internal combustion generator when the wind generation is unavailable. As illustrated, the highest cost resource dispatched during periods with wind generation available is 5 cents/kWh and 10 cents/kWh when wind is unavailable.

Table 3: Phase I – Resulting Energy Supply

	Utility w/o Demand Response Included				**Demand Response Included w/o Customer Supply Options**			
	Supply Energy (KWh)		Energy Cost ($)		Supply Energy (KWh)		Energy Cost ($)	
	Condition w/ Wind	Condition w/o Wind	Condition w/ Wind	Condition w/o Wind	Condition w/ Wind	Condition w/o Wind	Condition w/ Wind	Condition w/o Wind
Variable Power Costs								
Wind	20	0	20	0	20	0	20	0
CC Gas Turbine	50	50	200	200	50	50	200	200
Simple Cycle Turbine	20	20	100	100	20	20	100	100
Internal Combustion	0	20	0	200	0	0	0	0
Solar	10	10	0	0	10	10	0	0
Total Varialbe Cost	100	100	320	500	100	80	320	300
Fixed Investment Cost								
Wind			80	80			80	80
CC Gas Turbine			137.5	137.5			137.5	137.5
Simple Cycle Turbine			40	40			40	40
Internal Combustion			10	10			10	10
Solar			40	40			40	40
Total Fixed Cost			308	308			308	308
Total Cost			628	808			628	608
				1,435				1,235
Market Clearing Price			**5.0**	**10.0**			**5.0**	**9.5**

Allowing customer preference for consumption corresponding to price increases customer value. In the case without demand response, the customer is served electric energy above the hurdle or indifference point, resulting in an excessive charge of 0.5 cents/kWh (10 cents over a 9.5-cent hurdle rate) for the less-attainable level of discretionary energy of 12 kWh, and 3.5 cent/kWh (10 cents over a 6.5-cent hurdle) for the more attainable discretionary portion of the load of 9 kWh.

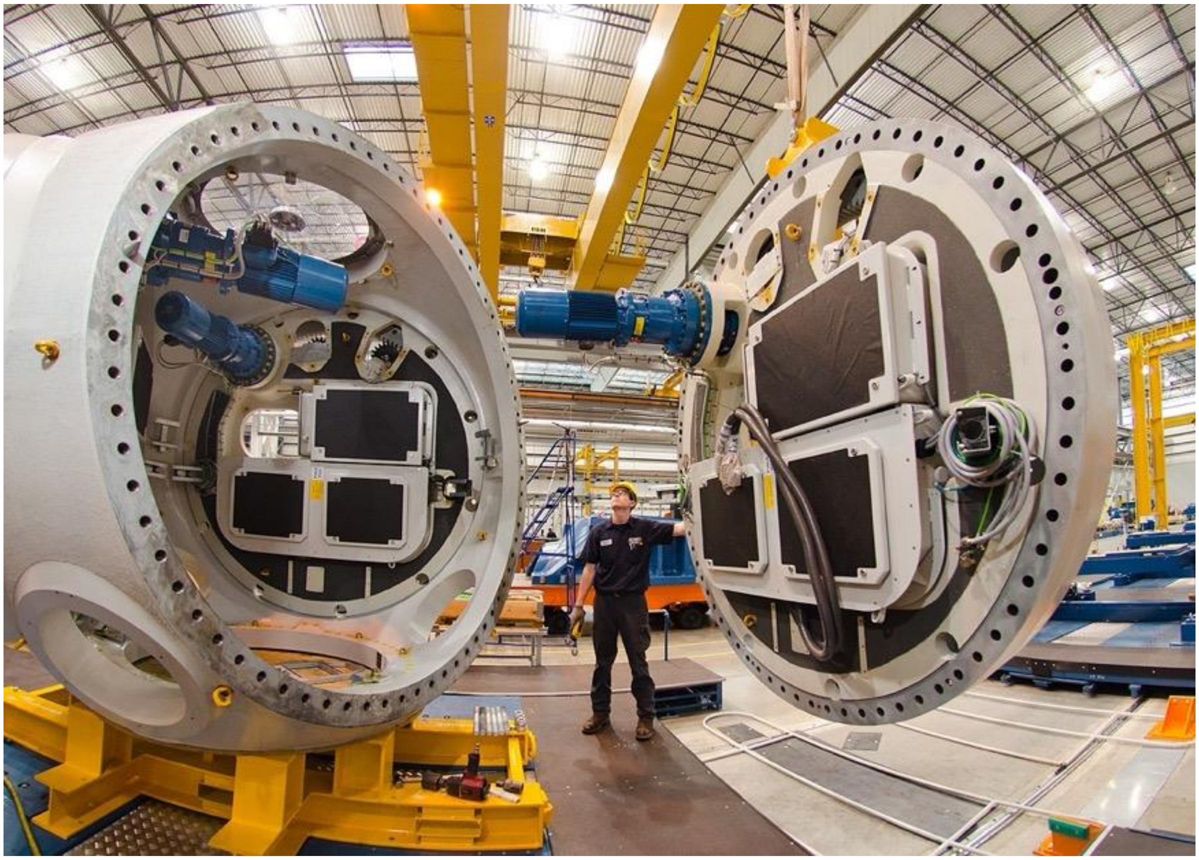
Traditional utility least cost resource planning does not include customer preference while attempting only to reduce energy supply, ignoring periods where prices exceed individual customer preference to take electric energy for diverse applications.

Phase II – Relevance of Market-clearing Prices in Supply/Demand Continuum

The next adaptation examined in the example discusses the relevance of the recognition and application of market-clearing prices relative to decision making among increasing supply and demand options. In this phase, three cases are illustrated including no demand response (Case 1) as well as two differing demand-response options (Cases 2 and 3).

The example assumes (see assumptions in Table 4) that we start with the same supply and loads as in the previous example. It adds an equal additional amount of load and offers us freedom to make future resource decisions assuming the resource costs and options are available as in the initial example without resource expansion.

As in the first example, the resources are listed in order of their incremental dispatch cost from lowest to highest. The fixed costs are costs recoverable in both utility rates as well as investor considerations in open markets; however they do not effect resource operations and the order of dispatch. They only have bearing on the revenue requirement costs of a utility as included in rates or to investors where fixed costs are anticipated to be recovered based upon the accumulative value of operations based upon market-clearing prices that are in excess of variable operating costs.



Nordex USA American Wind Manufacturing Facility, Jonesboro, Arkansas

Also, corresponding to the initial example, wind is assumed to be available 50 percent of the period, and all other resource options are 100 percent available as needed. Solar energy was assumed to double in capacity, corresponding the doubling of load and, as in the initial example, has 100-percent availability in both periods. The last item in the assumptions table is the fixed and variable cost to transfer the demand for electric energy from one period to the other, which is an option incorporated in Case 3 only.

It will be significant to note that the simplified example lacks the elegance of a robust market with numerous supply options having differing costs and a nearly unexhausted list of customers with differing preferences for their many electric-energy applications, creating a nearly continuous supply and demand curve. Additionally, the market-clearing prices as described are based upon the dynamics of supply demand solutions; hence a change in either the level of supply or demand will affect the market-clearing price.

The following examples lack the elegance required to provide a narrowly-established market price. Due to the limitation of resources and demand options in these examples, prices can move by large amounts as we move up the supply chain.

Table 4: Phase II – Expansion in both Supply and Demand

Existing Resources and New Resource Options

	Resouce Cost		Energy Potential			
	Variable Cents / kwh	Fixed Cents/ internval	Existing Capacity	Future Potential	Total Potenti al	Percent Available
Wind	1	8	20	20	40	50%
CC Gas Turbine	4	5.5	50	50	100	100%
Simple Cycle Turbine	5	4	20	20	40	100%
Internal Combustion	10	1	20	20	40	100%
			110	110	220	
Customer Supply						
Solar	0	10	10	10	20	
Transfer/Storage	0.5	1		10	10	
			10	20	30	

Table 5 illustrates the resource expansion and dispatch of resources to fulfill load requirements under traditional utility planning and operations. The loads and resulting resources with capacity expansion were merely twice the values from the initial example without additional load. This would be expected if the initial set of resources corresponded to utility least cost planning criteria and the parameters were identical. The selection of additional resources would replicate the initial selection.

The least cost method selects among resource alternatives to serve load in a least cost fashion. In our example, the internal-combustion generation is lower cost (fixed and variable) than the simple-cycle turbine when operated with a 50 percent capacity factor (only one of the two periods considered). The cost of the internal combustion resource to be operated in one of the two periods is 10 + 1 = 8.4 variable and fixed compared to a simple cycle turbine of 5 + 4 = 9.0 variable and fixed cost.

Table 5: Phase II (Case 1) – Resulting Supply and Demand, No Demand Response with Expansion

Anticipated Economic Development of Resources

Case 1

Utility w/o Demand Response Included

	Variable Cents / kwh	Fixed Cents/ internval	KW Capacity
Wind	1	8	40
CC Gas Turbine	4	5.5	100
Simple Cycle Turbine	5	4	40
Internal Combustion	10	1	40
Solar	0	10	20
			240

Customer Load Level

	Condition w/ Wind	Condition w/o Wind
	KW	KW
Essential	140	140
Discretionary Load 1	18	18
Discretionary Load 2	24	24
Discretionary Load 3	18	18
Transfer/Storage	0	0
	200	200

Utility w/o Demand Response Included

	Supply Energy (KWh)		Energy Cost ($)	
	Condition w/ Wind	Condition w/o Wind	Condition w/ Wind	Condition w/o Wind
Variable Power Costs				
Wind	40	0	40	0
CC Gas Turbine	100	100	400	400
Simple Cycle Turbine	40	40	200	200
Internal Combustion	0	40	0	160
Solar	20	20	0	0
Total Varialbe Cost	200	200	440	560
Fixed Investment Cost				
Wind			160	160
CC Gas Turbine			275	275
Simple Cycle Turbine			80	80
Internal Combustion			20	20
Solar			100	100
Transfer/Storage			-	-
Total Fixed Cost			455	455
Total Cost each Period			895	1,015
Total Cost all Periods				1,910
Market Clearing Price			5	**10.0**

The Case 2 example as shown in Table 6 includes the same option for demand response as in the initial example. Given the ability now to select among resource alternatives, the ability to satisfy customer price-sensitive demand at a lower cost can be achieved without dispatching the internal combustion generator. As a result, an additional internal combustion generator is not required. In fact, the previously existing internal combustion generator is also no longer utilized under any condition (in this example). That being the case, the plant could be retired and any future fixed cost incurred would be avoided.

The two levels of demand response provide the 40 kW lost from the wind generation at cost below the cost of the turbine: 18 kW at 6.5 cents/kWh and 22 kW at 9.5 cents/kWh. Although this is not truly a cost but a point of consumption indifference, it provides a basis for the market-clearing price, which equates supply to demand.

The market-clearing prices for the two periods provide investment incentives up to the simple cycle turbine but not sufficient for the internal combustion generation (at the investment threshold and not required to serve load with lower variable cost resources). The simple-cycle turbine is dispatched in both periods in the example.

During the first period, wind is available, resulting in a market-clearing price of 6.5 cents/kWh, 1.5 cents/kWh above the variable cost of the simple cycle turbine. The second period, however, has operations when market-clearing prices are up to 9.5 cents/kWh, 4.5 cents above the variable operating costs equal or six cents/kWh, exceeding the four cents/kwh fixed cost of the turbine.

The internal-combustion generation is not operated in the conditions when demand response is applied, and as a result, there is no value to be applied against the fixed cost of this resource. If the generator were to retire, since it has zero value in our example, the range of the market-clearing price extends up the highest-cost level for demand response of 10 cents.

Table 6: Phase II (Case 2) – Resulting Supply and Demand

Anticipated Economic Development of Resources

Case 2

Demand Response Included w/o Energ;y Transfer Options

	Variable Cents / kwh	Fixed Cents/ internval	w/ Demand Response
Wind	1	8	40
CC Gas Turbine	4	5.5	100
Simple Cycle Turbine	5	4	40
Internal Combustion	10	1	20
Solar	0	10	20
			220

Customer Load Level

	Condition w/ Wind	Condition w/o Wind
	KW	KW
Essential	140	140
Discretionary Load 1	18	18
Discretionary Load 2	24	2
Discretionary Load 3	18	0
Transfer/Storage	0	0
	200	160

Demand Response Included w/o Customer Supply Options

	Supply Energy (KWh)		Energy Cost ($)	
	Condition w/ Wind	Condition w/o Wind	Condition w/ Wind	Condition w/o Wind
Variable Power Costs				
Wind	40	0	40	0
CC Gas Turbine	100	100	400	400
Simple Cycle Turbine	40	40	200	200
Internal Combustion	0	0	0	0
Solar	20	20	0	0
Total Varialbe Cost	200	160	640	600
Fixed Investment Cost				
Wind			160	160
CC Gas Turbine			275	275
Simple Cycle Turbine			80	80
Internal Combustion			10	10
Solar			100	100
Transfer/Storage			-	-
Total Fixed Cost			445	445
Total Cost each Period			1,085	1,045
Total Cost all Periods				2,130
Market Clearing Price			5	9.5

The last example (Case 3, Table 7) includes the ability to shift customer loads from one period to another based upon a market price differential between the two operating periods. The assumptions used in this example allow for a transfer of up to 10 kWh based upon a price differential of not less than 0.5 cent per kWh. The corresponding customer investment of one cent is allocated for both periods in this example.

As a result of a much greater market-price differential between the periods with and without wind, the customer would exercise the option providing savings that recover both fixed and variable costs specific to the transfer capability. The shift of electric energy out of the period when wind was unavailable and having correspondingly higher market-clearing prices decreased the electric-energy supply requirement. The period without wind generation now has a reduction in the electric energy demanded and is confronted with either reducing the amount of generation or re-opting to take load that was otherwise not elected prior the shift in load.

The customer value for the highest-value of electric energy not taken was 9.5 cents, whereas the variable cost of electric-energy saved (based upon highest variable cost of generation) is five cents. Given that the value of the electric energy is greater than the incremental cost, the economic choice would be to reduce amount of energy that was not previously taken, increasing energy demand back to the previous level.

The period when wind was available could normally expect to increase the load requirements by that amount. However, as a result of providing additional generation at a cost higher than the customer indifference rate, the demand for discretionary electric energy was reduced, resulting in zero net increase. Given the resource development assumed in Case 2, the market-clearing price would be based upon the highest-cost action taken in the supply chain, which would be demand response at 6.5 cents/kWh.

The optimizations of supply decisions are reflective of the comparative value of every supply and demand consideration and the dynamics of their effect of market prices. The selection among alternatives is based upon their comparative value, which is fundamentally based upon the greatest difference between market prices and corresponding cost of that option. With the inclusion of additional resources placed in service, market prices corresponding are reduced, providing less incremental value for continued development.

Table 7: Phase II (Case 3) Resulting Supply and Demand

Anticipated Economic Development of Resources

Case 3

Demand Response Included w/ Energy Transfer Option

	Variable Cents / kwh	Fixed Cents/ internval	w/ Demand Response
Wind	1	8	40
CC Gas Turbine	4	5.5	100
Simple Cycle Turbine	5	4	40
Internal Combustion	10	1	20
Solar	0	10	20
			220

Customer Load Level

	Condition w/ Wind	Condition w/o Wind
	KW	KW
Essential	140	140
Discretionary Load 1	18	18
Discretionary Load 2	24	12
Discretionary Load 3	8	
Transfer/Storage	10	(10)
	200	160

Demand Response Included w/ Customer Transfer/Storage Options

	Supply Energy (KWh)		Energy Cost ($)	
	Condition w/ Wind	Condition w/o Wind	Condition w/ Wind	Condition w/o Wind
Variable Power Costs				
Wind	40	0	40	0
CC Gas Turbine	100	100	400	550
Simple Cycle Turbine	40	40	200	200
Internal Combustion	0	0	0	0
Solar	20	20	0	0
Total Varialbe Cost	200	160	640	750
Fixed Investment Cost				
Wind			160	160
CC Gas Turbine			275	275
Simple Cycle Turbine				
Internal Combustion			10	10
Solar			100	100
Transfer/Storage				
Total Fixed Cost			445	445
Total Cost each Period			1,085	1,195
Total Cost all Periods				2,280
Market Clearing Price			6.5	9.5

Conclusions from a Simplified Example

The concept of market economics, where decisions are incented based upon prevailing price signals, promotes economic efficiency aligned with customer values. With the inclusion of customer actions based upon preferences for consumption corresponding to price signals, conditions exist where negative customer value are avoided (customer cost exceeds level of indifference to consumption).

The use of market-clearing prices is applicable among diverse applications of supply and demand. The market-clearing price metric is specific to the instance of time to anticipate the operation of each alternative and any contribution in value towards fixed-cost recovery.

The simplified example does not provide a full, conceptual understanding of the dynamics and breadth of actions taken to provide a comprehensive understanding. Our example only considers a small number of supply and demand solutions with limited coverage to a fully engaged market.

In a fully-engaged market having many potential options at the onset, those options that have the greatest comparative value are anticipated to be adopted ahead of other alternatives. Since the incentives based upon market-clearing prices are dynamically established corresponding to supply and demand actions, a saturation level is reached such that no additional actions are incented.

The dynamic process of establishing the appropriate price incentive includes options that can bear few similarities. The forecast of anticipated actions leading to equilibrium prices requires the rigor and application of complex computer models and linear program solutions.

Upon consideration of the expansion of supply and demand alternatives, available supply- or demand-side options are measured based upon anticipated operations and margin of value based upon market-clearing prices. All options that meet or exceed fixed costs are determined to be viable and placed into service.

The dynamics of investment position decisions alter anticipated future market-clearing prices, thereby altering the economic opportunity of other investments. Decisions requiring fixed cost investments are made in anticipation of future market prices that can achieve the recovery of invested capital. As in all markets, since perfect foresight is never fully attainable, there will always be conditions of over/under building and investing.

Examples Using Computer Simulation

Solutions require a rigorous determination and cost-effective reaction to immediate price signals and long-term investment behavior in anticipation of future prices. The historical approach has been to assimilate an order-of-selection of resource and demand-side alternatives based upon dispatch frequency and corresponding economic cost. This approach fails to examine the interplay of both responses in demand and operational dispatch of supply-side resources in markets where energy prices are highly volatile and dependent on market dynamics. Hence, an effective economic market model that includes the corresponding simulation is essential.

Conclusions

a) ***Greatest** customer value* is achieved when consumption coupled with supply-side options are incentivized based upon ***market-clearing prices***. Market-clearing prices are established by satisfying the supply/demand equilibrium. These prices represent the marginal value for both supply and demand side considerations.

b) Although achieving the full benefit is somewhat theoretical, the identification and utilization of this metric allows for the comparative measure among industry solutions to achieve targeted objectives better than with price regulation. This metric is applicable throughout the industry, electric-energy suppliers, utilities, regulators, aggregators, and end-use customers.

c) Movement toward this goal is realized as markets solutions evolve. The effectiveness of changing load behavior will increase customer value as market price signals become more transparent.

d) Key to achieving the full benefits discussed in this paper is the wide-spread availability of automated consumer devices with customer preference settings, and a communications infrastructure to enable interactions with energy service providers that support market-based solutions.

Appendices

Appendix A – System Stability

The studies reviewed (as endemic with any study) were based upon a certain set of assumptions that drove the result. Not to say they were biased, but a different set of assumptions would have produced differing results. Many of the studies were made from the perspective of a single or small number of control operators that were attempting to assure system stability and not based upon a diverse market reaction to prices.

From our perspective, the concerns over stability were largely based upon a lag between the price incentives and the appropriate economic signals specific to the load/balance condition. Hence the pricing signal may be compelling the customer to perform the opposite action exacerbating the load imbalance. We believe the opposite to be true, that the application of appropriate price signals will increase stability.

The reasons for our contrarian view are based upon the following:

- Customers have always elected to take electric energy based upon the prices offered to them, which has resulted in greater instability of higher demand during periods when supply is less available (during super-peak periods).
- Providing customers appropriate price signals (via Transactive Energy, regulation, utility programs, or real time pricing) will allow for a matching of resource availability and customer demand resulting in the levelization of prices.
- Customer pricing incentives will include both anticipated price signals (day ahead, hour ahead, 10-minute, 5-minute ahead, etc.) that allow for both bulk electric-energy use, as well as balancing, to occur. There is no one price; each fulfills a different market need and supply source.
- Customer actions are highly diverse without major load shifts occurring in unison as a result of each customer acting independently for diverse reasons. Nevertheless, there is still need for a system balancing authority to assure stability on the grid. We certainly cannot rely on a market solution for stability.

Appendix B – Product Differentiation

i) Ancillary services to electric energy

(1) Reliability

(a) System Integrity

The value of electric energy is dependent on the assurance of delivery, either from the source or to the transportation network. The value (cost) of loss of load is measured by the energy that would have been consumed electively at the prevailing market price. Hence during conditions of supply deficiency, market prices are correspondingly high and the resulting cost of unserved energy corresponds to essential loads demanded at that price.

(b) Assurance of adequate electric-energy supply – power

Power (kW) is a measure of the ability to provide electric energy – kWh; hence, power provides no benefit unless it can be utilized over time. Resources not being currently utilized are measured by their <u>potential</u> to deliver energy in kW.

(c) Electric-energy delivery (price and quantity)

During periods conducive to high prices, customers may elect to defer consumption with the expectation that prices will diminish, but as a result of uncertain future conditions, there is no guarantee prices will fall. Customers elect to purchase optionality (insurance) to be assured to both quantity and price caps.

ii) Transportation services — Cost adders include the delivery of electric energy from the source of generation including fixed investment costs and resulting losses in transportation. Electron flow is similar to the perspective of filling a bucket of water: there may be many different suppliers; consumers consuming water are relevant to the equilibrium price corresponding to the total amount taken. Fixed investment costs may be recovered by a reservation fee or recovered specific to energy transmitted. The fixed costs are not affected by the cost of generation as are losses which require additional energy to be produced.

(1) Distribution

Services are specific to identified end-use customers and identifiable as to the cost of service provided (both import and transport). Problematic pricing is inclusive of the use of equipment for transport, which varies based upon continually-changing conditions.

(2) Transmission

Charges are associated with bulk electric-energy flows. Fixed investment charges are more straightforward than consideration of energy losses. If the point of delivery from the transmission system is on the load end, the cost of loses becomes an additional adder to the delivery cost since more electric energy must be provided on the supply end. If the transmission is not inclusive of loses, the energy consumer must assure more energy is delivered at the cost to the consumer.

(3) Reactive Power Support (VAR)

System modifications (capacitors, inductors) required to reduce system losses and stability result from end-use customers having reactive element of load. Modifications are specific to the accumulated effect of customer reactive loads and are specific to a location. Reactive loads have net-zero electric energy (stores and releases energy within a cycle); however, reactive power increases the current flowing across resistive loads in wires transporting electric energy resulting in voltage drops, heating of the wires, and wasted energy.

Appendix C – Fundamentals – Comparison of Market-to-utility Pricing

First, the cost of service included in utility rates differentiates variable costs and fixed costs, including costs associated with required investments. Variable costs are included in utility prices near the time incurred, often with some lag and corresponding “true ups.” Fixed investment costs are allocated based upon the recovery of costs over their anticipated useful life. Cost recovery includes interest and return on equity, and associated income and property taxes.

Utility prices correspond to established positions taken as a result of the allocation of costs, as well as the relationship established via regulation between utilities and customers. The long-standing relationship between regulated-utility customers and investors was established back at the inception of the regulated market, often referenced as “the regulatory compact,” providing for the investment recovery of prudent investments via regulatory approval. Under the regulatory paradigm, utilities include the return on and of investments as a cost of service as included in rates.

In purely competitive markets, investors are compensated as a result of realized investment cash flows. The required rate of return corresponds to associated-investment risk providing appropriate compensation to incent investment. The regulatory pact between utilities as approved by regulators provides a rate of return that is included as a cost of service, providing a reduced required return to commensurate investors. As a result, the level of reduced risk via regulation is a result of increased risk to consumers that provide added assurance for investment recovery; hence there is a risk shift that must be addressed in an “apples to apples” comparison.

Positions taken by utilities can be higher or lower over time than prices realized in a competitive market, since incurred costs do not align with current technologies on the margin. Competitive market prices correspond to the incremental cost to serve, hence reflect the cost of current technologies available to serve load. Therefore, utility electric-energy costs are a culmination of market prices adjusted for positions taken for resources, contracts, etc., which may result in prices higher or lower than market. Utility investors do not generally have returns reflecting those positions, but receive a regulated rate of return on approved investments.

Secondly, in competitive markets, customers are subjected to prices necessary to provide sufficient recovery of costs to fulfill demand. This results in price signals corresponding to the incremental cost to fulfill demand. Prices are volatile and customers have incentives to make decisions corresponding to the incremental cost of service. Conversely, utilities charge for the cost of supply, assuming generally that customers' demand is inelastic, not corresponding to the equilibrium price established in a truly competitive market.

(1) Utility Revenue Requirement costs are inclusive of vertically-integrated costs of (1) power costs, (2) transmission, and (3) distribution costs. Each includes capital investment carrying costs, fixed, and variable operating costs.

(2) Power costs include an aggregation of positions taken (assets, contracts and market purchases) with corresponding revenue requirement costs associated with each. The positions taken are relative to market prices and have value (or costs) relative to the market. Example: an owned asset may have a production cost (both fixed and variable) of $4/MWh and be generating energy when market electric-energy prices are $5/MWh. As a result, customers benefit from having entitlement to the resource output and have lower-than-market energy prices. Equivalently, customers could be assumed to be served energy out of the market at $5/MWh, and the electric energy from the asset could be sold in the market for a net gain of $1/MWh, for which customers receive a credit; netting the same total cost. The equivalence is helpful in understanding the difference between utility power costs.

(3) Utility prices differ from generally-established open market prices in that utilities maintain entitlement to positions taken (either having positive or negative costs relative to market prices). In markets that transition from regulated to open markets, such as occurred with the airline industry, the assets (either having positive value or negative such as stranded assets) are integrated into the adjusted investment value, whereas consumer costs and subsequent revenues are based upon market-derived prices.

(4) Financial costs under varying conditions can be significantly different as a result of a shift in the level of risk, which is equivalent to an open market perspective. Examples include (1) Power sales agreements, (2) IOUs versus public ownership versus open market sales, and (3) buy/lease back arrangements. In each of these cases, there is a significant transfer of risk that has a profound effect of the resulting cost of capital to the owner of the asset.

(5) In recognition of this difference, utilities provide customer incentives based upon avoided costs, which are a measure of the market prices. Hence, as in the example above, customers would provide an additional incentive above their $4/MWh cost of $1/MWh or $5/MWh total to be equivalent to the incremental benefit measured by market prices.

Appendix D – Application and Use of Market Price Decisions

The following is a sample and description of the applications and significance of using market-clearing prices in decisions of both supply and demand in the electric energy industry. As described in this paper, market energy prices are specific to time and location and are further differentiated by the lead and commitment time to fulfill electric-energy requirements and assure grid stability.

Examples include energy requirements and options to provide hour-ahead energy and additional requirements to provide energy within a minute to ensure system stability through a balance of supply and demand. Each of the following entities plays a role in these markets with capabilities dispersed to maximize potential benefits (similar to competitive bidding). Further, market-clearing prices are dynamically established as a result of the aggregation of all decisions in both supply and demand.

- Electric-Energy Consumption – Decisions correspond to the value of end-use customers providing economic direction that optimizes their respective needs. Customer energy needs and applications are highly diverse and have individual value assessment, empowering each customer. Aggregation can occur with reduced price transparency having the consequence of reduced optimality.
- Timing of Electric-Energy Consumption - Corresponding to consumption decisions, customers are empowered to buy energy at times of lower prices for some applications such as appliance operation. Value decisions are inclusive of the cost of controls to adjust appliance operation and the anticipated benefits of energy consumption during periods of lower prices.
- Energy Storage – Similar to “timing of energy consumption,” storage options enable customers and energy suppliers to take or obfuscate energy over different time periods. The economic value is dependent on the cost of storage devices, efficiencies and the anticipated price differentials between periods when energy is either taken or obfuscated.
- Distributed Electric Energy – Decisions for electric-energy generation at or near customer loads are appropriately valued based on market-clearing prices specific to the customer loads. Distributed electric energy includes backup generation, solar energy,

and storage, which can be either integrated in the utility supply or operated independently. Value decisions include the cost and operation of distributed generation relative to market-clearing prices, which may be avoided or, if integrated, may provide a credit to the customer. Benefits involved in valuation include the electric-energy supply in periods where utility service is unavailable.

- Renewable Energy – Renewable energy on the grid is correctly valued based upon market-clearing prices corresponding to the time of delivery. During periods where renewable energy is robust, prices are suppressed resulting from abundant supply, which if correctly conveyed to end use customers, will increase consumption during the same time interval, resulting in a partial rebound in prices.
- Conventional Electric-Energy Supply – The value of conventional, electric-energy supply, currently reflected in utility least cost planning, corresponds to market-clearing prices, and it is equivalent to instantaneous opportunity cost. Resources having differing operating characteristics are optimally included to provide an optimal plan. Since this, as well as other decisions, are dynamically determined, the overall effectiveness of decisions must be made in consideration of all attainable options and expected implementation.
- Resource Operating Decisions – Decisions for optimal resource utilization require value assessment based upon market-clearing prices. As described, market prices correspond to the lead time for electric-energy delivery and result in decisions to optimize resource utilization to include using resources ranging from base load operating to those services provided by balancing authority. The value of each resource is uniquely dependent on the range of attainable operations.
- Independent and Isolated Grid Operations and Decisions – Fundamentals of market-clearing prices correspond to the incremental benefits of interconnected loads and supply. The market-clearing price is established based upon interconnected supply and demand. Therefore, if there is no interconnection, the prices from outside are not relevant, only in the displacement of products and services that the use of electric energy provides. Applications include consideration of nano or micro grids that are at times independent of the utility grid.