An OASIS Energy Market Information Exchange Technical Committee White Paper

Transactional Energy Market Information Exchange (TeMIX)

An Information Model for Energy Transactions in the Smart Grid

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The OASIS eMIX Technical Committee works to define standards for exchanging energy characteristics, availability, and schedules to support the free and effective exchange of energy market information. Better communication of actionable energy prices will help enable and expand efficient markets that satisfy the growing demand for lower-carbon, lower-energy buildings, net zero-energy systems, and supply-demand integration that take advantage of dynamic pricing. Businesses, homes, electric vehicles and the power grid will benefit from automated and timely communication of energy price, characteristics, quantities, and related information.

This white paper was produced and approved by the OASIS Energy Market Information Exchange Technical Committee as a Committee White Paper. It has not been reviewed and/or approved by the OASIS membership at-large.

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1. Introduction

Transactional Energy requires clear signals that can be easily understood. Because most energy transactions are small, they must be carried out automatically to achieve full participation. Anything that makes the economic signals complex or unclear is a barrier to Transactional Energy.

The purpose of the OASIS Energy Market Information Exchange (eMIX) Technical Committee is to define standard information models for exchanging prices and product definitions in energy markets. The purpose of this White Paper is to use the eMIX information models to define information models to support Transactional Energy. These transactions are a subset of all possible energy transaction types that are selected to enable human and automated transactions of energy. This information model is called the Transactional Energy Market Information Exchange (TeMIX) model.

Transactional Energy is based on the clear and frequent communication of offers and transactions among buyers and sellers. Buyers and sellers may be generators, loads, or storage with metered delivery, or traders with no actual delivery and metering. A seller can be a load that is selling back from a contracted position. A buyer can be a generator that is buying back from a contracted position.

The core attribute of Transactional Energy is that a sequence of energy transactions for a delivery of a quantity of an energy product in a time period at a location results in a position. This position may then be modified by additional buy and sell transactions.

Transactional Energy also provides for capacity-like transactions that are modeled as energy options. These option transactions can be used for supply assurance, demand response, and ancillary services.

Transactional Energy needs no hierarchy. A party can transact with any other party, or with intermediaries as desired. Transactional Energy can simplify business for all parties including generators, Independent System Operators (ISOs) and Regional Transmission Operators (RTOs). Transactional Energy is the current model for most wholesale energy forward and futures transactions.

Transactional Energy offers an opportunity for the coordination of retail and wholesale energy consumers and producers including variable energy resources such as wind and solar. Coordination occurs through large numbers of frequent small transactions executed automatically by smart agents[1,2,3,4] responding to priced offers. The communications systems, interval metering and smart devices being installed for the Smart Grid will need Transactional Energy to implement high volume and high speed, unambiguous transactions.

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[1] For an overview of how Transactional Energy can support the big vision for the smart grid see the comments submitted by Edward Cazalet to the Federal Energy Regulatory Commission on Integration of Variable Energy Resource (VERS) http://www.cazalet.com/images/Comments_to_FERC_on_VERS_-_Cazalet.pdf

[2] The case for Transactional Energy is ably made by Lynne Kiesling, Smart Policies for a Smart Grid: Enabling a Consumer-Oriented Transactive Network. Presentation to the Harvard Electricity Policy Group, Fifty-Fourth Plenary Session. March 12, 2009.

[3] For an proposal on how ISOs and RTOs can work with Transactional Energy see http://www.cazalet.com/images/Enabling_24_7_Demand_Response-_ISO_RTO_Council.pdf

[4] A related paper focusing on the transactive control of devices is by Gale Horst of EPRI, "Concepts to Enable Advancement of Distributed Energy" Resources" http://www.smartgridnews.com/artman/uploads/1/EPRI_1020432ConceptsAdvancementDER.pdf

A. Transactional Energy Markets

Transactional Energy requires no information exchange other than that needed to offer and execute energy transactions. This information exchange is shown by the two-way arrows in Figure 1. The exchanges are priced offers and transactions. Such offers and transactions are for past, current, and forward intervals of time[5]. Describing the information models for these information exchanges is a principal focus of this White paper.

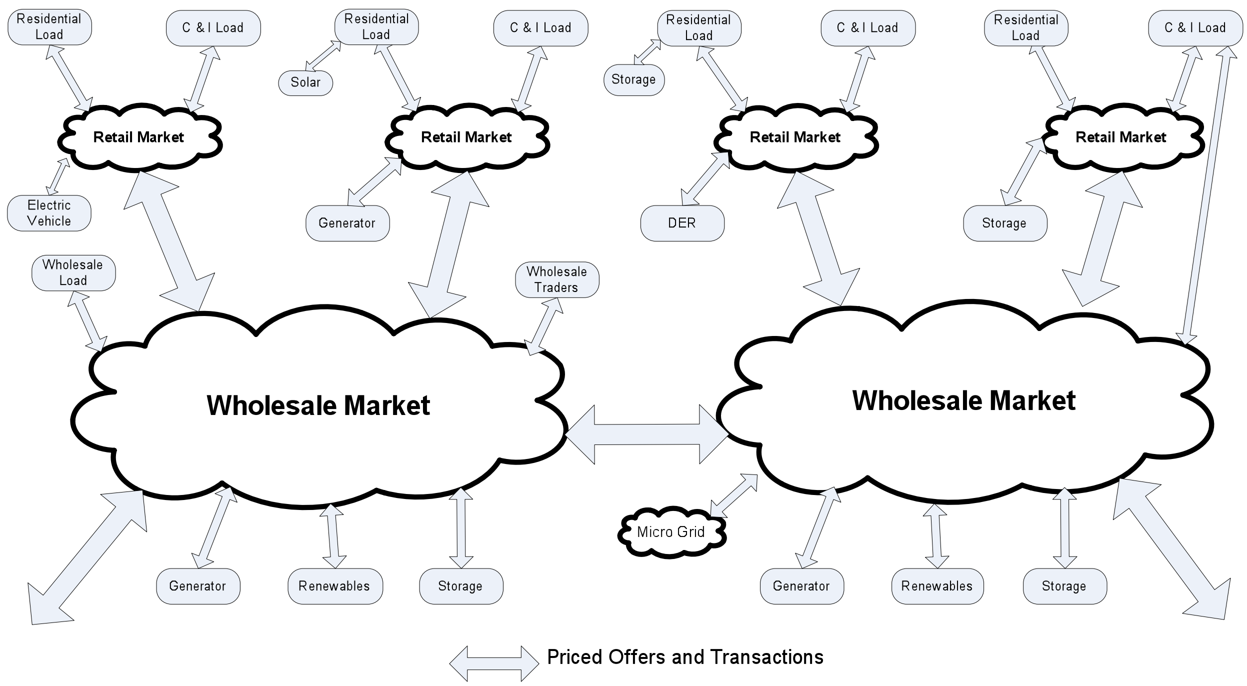

Figure 1 : Transactional Energy Markets

The information exchange in Figure 1 is the same for large generators, distributed energy resources (DER), variable energy resources such as wind or solar, commercial and industrial customers, homes, electric vehicles, microgrids[6], energy traders, brokers, exchanges, aggregators, or system operators. Transactions can occur between parties in retail and wholesale markets and between parties in different wholesale markets. Transactional Energy equalizes the opportunity for every technology and every participant on the grid including participants within a microgrid.

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[5] For example, a priced offer could be a vector of hourly price-quantity offers to sell for the next 24 hours. Transactions can be contracted forward of delivery or after delivery. Any party with adequate collateral can make offers or respond to offers.

[6] A microgrid is a small grid that may consist of a number of loads, generators and storage devices. If the microgrid is connected to a larger grid, then it may buy or sell to the larger grid. A microgrid may have the capability to operate independently of the larger grid under emergency conditions.

Naturally the transactions must account for the transmission and distribution costs, limits and losses. The transactions by parties with transmission and distribution providers are outside the scope of this White Paper. However, TeMIX, with minor modifications, applies to transmission and distribution transactions.

There are many market processes to exchange offers and reach agreements on transactions using the Transactional Energy model. Different parts of the energy market may employ different market processes. However, this White Paper focuses on the information models that support Transactional Energy no matter what market processes are employed, competitive or cost of service.

Transactional Energy is the current transaction model for forward wholesale energy transactions. TeMIX facilitates the extension of this wholesale transactional model to (1) retail markets and (2) transactions on smaller time intervals close to delivery. These close-to-delivery transactions are for spot market or balancing transactions. The transactional energy concepts are similar to concepts used in continuously traded bid/ask markets such as commodity and stock exchanges, and bilateral transactions.

B. The Core Transaction Types

The Transactional Energy Information Model (TeMIX) restricts the types of transactions in the model to only two core types:

1. **Obligation Energy Transaction** -
   An obligation transaction[7] in the TeMIX model is an obligation by the buyer to purchase and the seller to deliver energy over a given period of time (measured in hours or fractions of an hour) at a specific rate of delivery (kWh/hr or kW, for example). The rate of delivery of energy is also called power. The rate of delivery is constant over the entire period. The energy delivered under the transaction in kWh is the rate (kW) times the number of hours (hrs)[8].

2. **Obligation Energy Option Transaction** -
   A TeMIX obligation energy option transaction is a put (option to sell) or a call (option to buy) by one of the parties to the transaction. Once the option is exercised it becomes a TeMIX obligation energy transaction, as defined in (1).

All TeMIX offers and transactions are specified as to delivery location, time period, price and rate of delivery.

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[7] An obligation transaction is different from full-requirements transaction often used in retail service. A full-requirements transaction is a transaction that provides any amount of energy (up to the physical limits of the electrical service interface). With full-requirements transactions the rate-of-delivery in any interval is unknown so subsequent transactions do not have a defined baseline.

[8] Specifying a transaction as a rate of delivery is more useful and simpler than specifying the amount of energy delivery over a period because standard intervals such as a day, month and year have variable durations. For example, a 1 kW (kW/kWh) contract for a 24-hour day will provide 24 kWh. For a short, daylight savings day of 23 hours, 23 kWh would be delivered. For a long daylight day, 25 kWh would be delivered. If we had specified the energy to be delivered for a day as 24 kWh, then the rate of delivery would be 1.04347 kW for the 23-hour day, 1.0 kW for the 24-hour day, and 0.96 kW for the 25-hour day, which is confusing. Differences in days per month and days per leap year are other examples where specifying the rate of delivery (power level) is easier than specifying the total amount energy delivered.

With just these two transaction types and interval meters, we can support a wide range of retail and wholesale transactions where the contract positions and obligations of all participants are well defined and outcomes and payments are unambiguous.

An option transaction can provide "price insurance" or be used to transact capacity, ancillary services and demand response[9].

Transactional Energy will need to co-exist with other energy market models and processes. For example, spot markets operated by ISOs and RTOs do not fully comply with the Transactional Energy model[10]. However, intermediaries can offer retail and wholesale Transactional Energy services while also participating in an ISO/RTO dispatch market model that may have different information requirements and interactions.

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[9] Demand Response is conventionally an agreement by a customer to curtail load below a baseline amount that was predicted to be consumed[9]. In Transactional Energy with interval metering and forward contracting, the baseline is contracted and demand response is an option contract with a specified curtailment amount, option premium price and a strike price. For an excellent description of how demand response is better enabled with contracted baselines see "When It Comes to Demand Response, Is FERC Its Own Worst Enemy?" by James Bushnell, Benjamin F. Hobbs and Frank A. Wolak. http://www.ucei.berkeley.edu/PDF/csemwp191.pdf

[10] Independent System Operator (ISO) or Regional Transmission Operator (RTO) spot markets accept day-head forward and real-time priced offers and enter into transactions with participating parities. Each party's positions are unambiguous as in the Transactional Energy model. However, the information required of the participating parties such as generator and storage providers includes information on priced offers at all levels of operation (offer curve), start-up costs, no load costs, up and down ramp rate curves, no operation zones, stored energy levels, and storage efficiency in order to dispatch these devices. Such information is complex and device specific. The ISOs/RTOs use optimization (auction) software to dispatch the system while accounting for transmission constraints and losses.

Transactional Energy relies on self-dispatch of generation and storage using only priced offers to or from the parties. By using frequent small offers a Transactional Energy markets continuously work to improve the self dispatch of generation and price-responsive loads as variable energy resource generation and loads are continuously changing.

ISOs and RTOs can move closer to the Transactional Energy model, by promoting self-dispatch and providing more frequent auctions between day-ahead and real-time delivery, accepting only single-part priced offer of a limited size, and transacting capacity and ancillary services by using options for energy.

2. The Transactional Energy Market Information (TeMIX) Model

A. Actors in the TeMIX Information Model

The actors in this information model include any entity, metered device[11] or market that is a **Party** to a prospective or actual energy transaction. Each actor can take on either of the following two roles:

1. Buyer
2. Seller

Examples of Parties to energy transactions include: a metered retail customer, a retail aggregator of metered customers, a retail or wholesale customer owning a separately metered device (such as an electric vehicle or a generator), the owner of a metered grid connected generator or storage device, a retail or wholesale market operator (including the system operator markets), an exchange, a broker, or a power marketer. Any Party can be a Buyer or a Seller relative to their current contracted position for energy in a delivery period. Both human and automated agents can represent a Party in carrying out transactions.

B. Point-of-Delivery (Location)

The point-of-delivery for TeMIX transactions must be metered (typically a customer or a generator meter). Additionally, transactions may also have a point-of-delivery at intermediate electrical points or trading hubs with no metering. At such hubs, the total transactions during any interval of time must result in no net delivery of energy. The costs and losses for transmission and distribution must factor into the energy deliveries and prices of transactions at the retail and wholesale points-of-delivery.

C. Control Interface

For transactions terminating at a metered Point-of-Delivery, TeMIX assumes nothing about how devices on the other side of the meter are controlled. The control interface may be an Energy Services Interface or a Facility Interface[12] likely not embedded in the meter. Under TeMIX, the only information provided to and from the interface are priced offers to buy or sell energy and information on forward transactions and metered deliveries[13]. The intelligence to control devices in response to priced offers, to make offers, and to engage in transactions with other parties resides at the control interface.

D. Delivery Periods

Delivery periods are intervals of time with a start time and end time. For example a delivery period might be one or more consecutive calendar years, calendar months, days, hours, 5-minute intervals, or 4-

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[11] Devices behind an Energy Services Interface with a common meter are not considered to be a Party under this definition. A Party may control such devices and may or may not use priced offers as a basis for device control.

[12] Energy Services Interface / Facility Interface are described in a paper by David Holmberg, "Facility Interface to the Smart Grid "http://www.gridwiseac.org/pdfs/forum_papers09/holmberg.pdf .

[13] Priced Offers can be made by either party at the Interface.

second intervals. Some parties will transact for longer delivery periods than others depending on capabilities and needs.

E. Rate of Delivery

In TeMIX, the quantity of an energy transaction is specified by the rate of delivery (kW or MW, for example) over an interval of time, measured in hours. The amount of energy (kWh or MWh) delivered over the interval of time is the average rate of delivery over the interval times the duration of the interval measured in hours.

TeMIX requires that every transaction specify a constant rate of delivery over an interval[14,15]. A constant rate of delivery clearly defines the rate of delivery in subintervals of the interval, a necessary requirement to allow subsequent transactions of subintervals.

A contract to deliver at a rate of 1 kW (1 kWh/hr) over a 24-hour day is a contract for 1 kWh in each of the 24 hours (sub intervals) of the day (a total of 24 kWh) and 1/12 kWh in each 5-minute subinterval of the day. A short daylight savings day of 23 hours delivers 23 kWh. However, in every subinterval of the day the rate of delivery (power) is the same, until modified by a further possible transaction on a subinterval of a day.

By assembling a set of transactions, a party can shape the total energy delivery as desired. For each period, the sum of the rates of delivery for all transactions for a party (sell transactions netted against buy transactions) is the Party's *position* for the period. Note that a position for a Party could include transactions with several parties[16]. A position (rate of delivery) in a 5-minute interval can include positions in hourly or monthly intervals, for example.

It is essential to the TeMIX model that the rate-of-delivery at any instant be specified clearly as an obligation by both the selling Party and the buying Party. If the rate of delivery is not obligated, or not fixed, at any time then the basis for further transactions is ambiguous. For example, a full-requirements contract with flexible, variable rates of delivery does provide a basis for demand response or real-time pricing except by estimation of what might have been consumed (see Section F).

Transactions with fixed, shaped rates of delivery over a period are consistent with the TeMIX model. However, shaped delivery rates introduce an element of complexity that is unnecessary, as shaped rate transactions can be built up from a series of constant rate transactions over subintervals of longer intervals.

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[14] The requirement for constant rate of delivery excludes full requirements contracts used for utility retail sales. However, with the advent of interval metering and need for 24/7 price-responsive load and smart devices it is essential that the baseline for transactions be contracted and not estimated. In Section D we apply, with limitations, the TeMIX information model to full requirements contracts.

[15] An exception to the constant rate of delivery allows for variations in the rate of delivery within the metered delivery period. For example, if the metered delivery period is one hour, 5-minute meter readings would not be relevant. Likewise if the metered delivery period is 5-minutes then variations on 4 second intervals would not be measured.

[16] If a party has a position (rate of delivery) of 2 kW for a delivery hour, this implies a position (rate of delivery) of 2 kW in each 5-minute subintervals of the hour. If a transaction, in one 5-minute subinterval sells 1 kW then the position (rate of delivery) in that 5-minute interval will be 1 kW and remain at a 2 kW rate of delivery in the other 5-minute intervals of the hour.

F. Balancing Transactions

Some parties are able to transact within short intervals of time and therefore are able to participate in balancing supply and demand on short intervals. A party may choose to not accurately balance supply and demand and depend on another party (especially a balancing system operator) for balancing energy.

After a delivery period passes then the delivery obligation must be settled. If delivery occurs to a meter, then the imbalance energy for the period is the party's rate of delivery position multiplied by the length of the delivery period in hours less the meter reading for the period. The intervals will be at the resolution of the meter readings, such as an hour, 15-minutes, 5-minutes, or 4-seconds.[17]

A pure trading party will typically net out its position before delivery. If there remains an imbalance then the party must settle the imbalance as in the case of a metered delivery.

An imbalance implies that a party has a difference between its net contracted amount and its net delivered or consumed amount. There is no imbalance at the system level as the power consumed plus losses equals power generated. However, some parties will fully transact all deliveries in forward transactions and others may intentionally or unintentionally end with a positive or negative balance.

Intermediary parties such as system operators (but not limited to system operators) with access to grid level or microgrid metering and forecasting may engage in transactions to provide the net imbalance energy for the grid. After the delivery period passes, parties with a deficit or a surplus position must offset their imbalance with ex-post transactions.

G. Reliability

In today's electric energy markets, one party, the system operator, has the responsibility for service reliability. To that end, the system operator enters into various transactions and options with generators and loads to provide balancing services as described above in Section F.

In a smart grid with smart meters, micro grids and open markets, the choice of service reliability levels will be a customer choice and balancing services may be provided by multiple parties, but with a level of regulatory oversight. TeMIX supports both reliability models.

H. Collateral Requirements

All transactions in the TeMIX model are obligations to perform and pay. Most traded forward and futures contracts and clearing houses have standard contract terms. An obligation transaction obligates the buyer to take delivery of the energy and pay the contracted price. It also obligates the seller to deliver the energy at the contracted price. Imbalances typically are settled physically as described in Section F, above, with payments among the parties. Because of the risk of failure to pay by a party to a transaction, both parties to a transaction generally must post collateral. Collateral in support of transactions is a critical element of the TeMIX model and is managed by clearing houses, ISOs and others. Collateral management is a complex subject is beyond the scope of this White Paper.

[17] The imbalance energy (kWh) is calculated as the metered energy less the (kWh) position (rate of delivery) (kW) times the delivery period duration (hours). The imbalance rate of delivery (kW) is the imbalance energy (kWh) divided by the delivery period duration (hours). Typically the delivery period will be a fraction of an hour. The imbalance energy can be a buy or sell transaction.

Additionally, the exposure of one party to another depends on the total portfolio of all transactions between the parties and with third parties. Collateral management is likely to require regulatory oversight to prevent meltdowns of markets. Clearing houses can reduce the costs of collateral management by netting; requiring a collateral amount to be associated with every transaction is inefficient.

I. Ancillary Service Products

TeMIX, smart devices, interval metering and two-way communications can combine to facilitate the balancing of electricity supply and demand normally provided by standardized ancillary service products as described in Section F (see also Section 4.A.b). Other ancillary services such as voltage control are transacted as reactive energy.

Transactions for standardized ancillary services including reactive energy (VARs) are a product type in the eMIX information model and are beyond this scope of this White Paper.

J. Reliability Signals

TeMIX supports the eventual minimization of the use of arbitrary reserve targets and reliability criteria by a system operator as the exclusive method to address the contingency of large unexpected changes in generation or transmission status. TeMIX supports the eventual use of a market response by buyers and sellers to such contingencies; as an example, both buyers and sellers can post reserve bids in the transaction format, described above, for use by the system operator to address such contingencies.

A reliability signal is not a well-defined term. In the context of Transactional Energy, priced offers and options are the primary means to manage reliability which should reduce the frequency of emergencies. Under extreme emergency conditions, some devices, customers, circuits and areas may be disconnected from the grid to protect the grid. Additionally, public appeals to conserve in times of system stress and prohibitions on use of electricity for such purposes as decorative lighting may be employed.

Communication of reliability signals is outside the scope of TeMIX. However, the use of such reliability actions instead of priced offers and transactions may slow the response and reduce the incentives for parties to respond quickly and automatically to emergencies. Reliability signals may increase the social and economic costs of emergencies over the costs if priced offers are used to manage emergencies. This higher social cost occurs because some parties will bear extremely high costs of reliability signals that can be reduced if other parties are able to respond at a lower cost.

A high priced offer to every customer in an area to sell back to a generator that has failed or to a transmission operator that has lost a critical system element can be communicated and responded to automatically about as fast as customers and circuits can be disconnected. The inconvenience and cost to customers for an automated, short-term reduction in air conditioning, refrigeration, heating, pumping and light dimming resulting from priced offers should be much less than broad curtailments. And those customers who did not respond for whatever reason will continue to get service and share in paying those who did respond.

K. Environmental Commodities

The eMIX information model provides for transactions of environmental commodities (carbon credits and renewable energy certificates). Such transactions can be separated from the underlying energy transaction or an energy transaction could bundle environmental commodities with the energy.

The TeMIX model allows for bundled environmental commodity transactions. However, it is important to distinguish positions in bundled energy transactions with different ratios of environmental commodities. A customer can buy a green bundle and a brown bundle at different prices, but in managing his position in these two bundles he could not mix them. This adds a complexity to bundled transactions that we do not address in this White Paper.

The TeMIX model can be applied to separate transactions in environmental commodities, where a customer buys a standard electric energy product and then also buys one or more certificates for environmental commodities. However, modeling of environmental commodity offers and transactions is beyond the scope of this White Paper.

3. TeMIX Information Models

The information models described herein are based on the eMIX information model[18].

The Four information models defined for the Transactional Energy Model (TeMIX) are as follows:

1 **Energy Transaction:** A transaction between a buyer and a seller obligating both parties to deliver or consume energy at a constant rate over the delivery period.

2 **Energy Offer:** An offer of an Energy Transaction as in 1.

3 **Energy Option Transaction:** A put or a call option for an Energy Transaction as in 1.

4 **Energy Option Offer:** An offer for an Energy Option Transaction as in 3.

A. Process to Reach Agreements to Transactions

In this White Paper we abstract the energy business model to focus on the information model for the exchange of information required for energy transactions. Hence, it is beyond the scope of this document to address how buyers and sellers reach agreements on transactions or how a regulated utility or any other party would compute its offer prices.

The transaction process could be bilateral negotiation, quotes and acceptance, auctions, bid/ask continuous markets, or a retail regulated tariff or dynamic price offer. Typically, a sequence of one or more Energy Offers by either party leads to an Energy Transaction between the two parties. As noted above, Transactional Energy is based ideally on buyers and sellers offering and executing many frequent, small transactions.

To illustrate, a retail customer might make monthly transactions for his average peak and off-peak daily usage followed by hourly buy and sell transactions to shape the power to the customer's needs. Finally real-time transactions would account for the difference between the accumulated forward position and the ex-post meter reading in each metered period.

Generators will strive to maximize profits and manage risk of the transactions they agree to. Generators may offer long-term agreements of months or years and shorter term transactions based on hourly offers close to delivery to buy or sell. Shorter term transactions (less than an hour) typically will be automated.

A vector of priced offers on future delivery periods defines a forward price curve for buyers and sellers. As time passes, the future periods become present periods and then delivered periods. A forward price curve simplifies generator unit commitment and operation decisions as well as storage and customer management decisions such as air conditioner operation and electric vehicle charging.

[18] OASIS Energy Market Information Exchange Technical Committee Working Drafts are available at http://www.oasis-open.org/committees/emix at the Documents link.

In addition to Energy Transactions, parties may buy or sell “insurance” against very high or very low prices using Energy Option Transactions. An Energy Option Transaction, such as a call option, is an option that the buyer may exercise at a specified strike price up to a specified quantity (rate of delivery over an interval).

The buyer of a call option could be interested in protecting against extremely high prices in the event of a shortage. A seller of a call option could be interested in giving up a small chance of a very high price sale for two payments: (1) a guaranteed payment for the premium and (2) an energy payment at the strike price that that the call writer believes is unlikely to occur.

Energy Option Transactions are similar to capacity and ancillary services products. Also, an Energy Option can be a demand response contract with a contracted baseline. A demand response contract provides a party such as an ISO/RTO an option to buy energy during a specified period from a customer that has previously purchased energy for that same period. A contracted baseline means it is not necessary to estimate what the consumption would have been without the demand response transaction.

An Energy Option Offer by either party is an offer to initiate into an Energy Option Transaction. When the other party exercises that option, an Energy Transaction is created.

B. The Four Information Models

The information models described below in extended form. Nothing is assumed concerning the units, currency, location, or identity of the buyer and seller. A reduced, vector version of the information model is illustrated in Section C.

In the information models below, a Party can be a metered retail customer, a retail aggregator of metered customers, a retail or a wholesale customer owning a separately metered device (such as an electric vehicle or a generator), the owner of a metered grid connected generator or storage device, a retail or wholesale market operator (including the system operator markets), an exchange, a broker, or a power marketer. Any Party can be a Buyer or a Seller relative to their current contracted position for energy in a delivery period. A Party can be represented by a human or automated agent in carrying out transactions.

The four information models for TeMIX are described in Tables 1 to 4 as follows:

343 *Table 1: Energy Transaction Information Model*

	Energy Transaction Element	Specification[19]
1	**Extended Price**	The total cost of the transaction over the Delivery Period at the Rate of Delivery. The Extended Price is the Price times the Rate of Delivery times the duration of the Period.
2	**Rate of Delivery**	The constant rate of delivery over the Delivery Period. The seller is obligated to deliver at this rate and the buyer is obligated to take at this rate. The amount of energy to be delivered is the Rate of Delivery times the duration of the Period
3	**Delivery Period**	The interval of time during which the energy, was, is, or will be available for physical delivery. A Period is designated by a Start Time and an End Time. The duration of the Period is the End-Time - Start-Time.
4	**Buyer**	The Party buying the energy.
5	**Seller**	The Party selling the energy.
6	**Transaction Execution Time**	Date-Time the transaction was executed.
7	**Location**	The geospatial location for delivery of the energy (Point of Delivery).
8	**Meter ID**	If delivery[20] is at a meter, an identifier designating the meter.
9	**Currency**	Code for the currency used.
10	**Units**	The units of measure for the energy.

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[19] This specification relies on eMIX standards and other (OASIS) standards for security, authentication of offers and parties, time and intervals, locations, meter ID, currency and units. Product definition of environmental commodities is also part of eMIX.

[20] A meter could be at a customer site or at a generator site. The relevant meter is designated by the point of delivery of the transaction. Contracts for transmission and distribution between two points are outside the scope of this information model.

Table 2 : Energy Offer Information Model

	Energy Offer Element	Specification
1	**Price**	The offered price of a single unit of energy. If offered into a market this is a limit order price (the highest buy price or the lowest sell price offered).
2	**Rate of Delivery**	The constant rate of delivery over the Delivery Period. The seller is obligated to deliver at this rate and the buyer is obligated to take at this rate over the Delivery Period. The amount of energy to be delivered is the Rate of Delivery times the duration of the Period
3	**Delivery Period**	The interval of time during which the energy, was, is, or will be available for physical delivery. A Period is designated by a Start Time and an End Time. The duration of the Period is the End-Time - Start-Time.
4	**Buy/Sell Flag**	Boolean variable designating the offer as (1) an offer by the Offering Party to buy energy from the Counter Party, or (2) an offer by the Offering Party to sell energy to the Counter Party.
5	**Offering Party**	The Party offering the energy.
6	**Counter Party**	The Party(s) to whom the offer of energy is made.
7	**Offer Availability Interval**	The time period that the offer is available for a transaction designated by a Start Time and an End Time.
8	**Location**	The geospatial location for the delivery of the energy (Point of Delivery)
9	**Meter ID**	If delivery is at a meter, an identifier designating the meter.
10	**Currency**	Code for the currency used.
11	**Units**	The units of measure for the energy.

Table 3 : Energy Option Transaction Information Model

	Energy Option Element	Specification
1	**Extended Price**	The total cost of the energy option transaction (the option premium) paid to Seller.
2	**Strike Price**	The price to be paid to Seller for a single unit of energy upon exercising the option up to the Rate of Delivery.
3	**Rate of Delivery**	The constant rate of delivery over the Delivery Period.
4	**Delivery Period**	The interval of time during which the energy, was, is, or will be available for physical delivery. A Period is designated by a Start Time and an End Time. The duration of the Period is the End-Time - Start-Time.
5	**Buyer**	The Party with the right but not the obligation to exercise the option at the Strike Price.
6	**Seller**	The Party subject to the option.
7	**Put/Call Flag**	Boolean variable designating the option as a Put (an option to sell by the Buying Party) or a Call (an option to buy by the Buying Party).
8	**Transaction Execution Time**	Date-Time the option offer transaction was executed.
9	**Exercise Period**	The time interval the option is available to be exercised as designated by a Start-Time and an End-Time.
10	**Location**	The geospatial location for the energy delivery (Point of Delivery).
11	**Meter ID**	If delivery is at a meter, an identifier designating the meter.
12	**Currency**	Code for the currency used.
13	**Units**	The units of measure for the energy.

Table 4 : Energy Option Offer Information Model

	Energy Option Offer Element	Specification
1	**Option Price**	The offered price of an option on a single unit of energy (option premium per unit of Rate of Delivery).
2	**Strike Price**	The price to be paid for a single unit of energy for exercising the option.
3	**Rate of Delivery**	The constant rate of delivery over the Delivery Period.
4	**Delivery Period**	The interval of time during which the energy, was, is, or will be available for physical delivery. A Period is designated by a Start Time and an End Time. The duration of the Period is the End-Time - Start-Time.
5	**Offering Party**	The Party offering the energy option.
6	**Counter Party**	The Party(s) receiving the offer of the energy option.
7	**Exercise Party**	The Party that would hold the right as Buyer to exercise the option.
8	**Put/Call Flag**	Boolean variable designating the option as a put (sell option by the Exercise Party) or a call option (buy by the Exercise Party).
9	**Offer Availability Period**	The time period that the option offer is available for a transaction.
10	**Exercise Period**	The time period the option is available to be exercised designated by Start-Time and an End-Time.
11	**Location**	The geospatial location for the energy.
12	**Meter ID**	If delivery is at a meter, an identifier designating the meter (Point of Delivery).
13	**Currency**	Code for the currency used.
14	**Units**	The units of measure for the energy.

C. Vector Information Models

The four information models above are expressed in scalar, extensive form. Table 5 below illustrates the vector, compact form of the Energy Offer Information Model[21]. Additionally, given the context of an offer, the elements in grey may be inferred rather than transmitted in each message. The reduction in message size is evident.

Table 5 : Vector Energy Offer Information Model

	Energy Offer Element	Specification
1	**Price**	The offered price of a single unit of energy. If offered into a market this is a limit order price (the highest buy price or the lowest sell price offered).
2	**Rate of Delivery Vector**	The constant rate of delivery over each interval in the Delivery Period Vector. The seller is obligated to deliver at this rate and the buyer is obligated to take at this rate over each Delivery Period. The amount of energy to be delivered in each interval is the Rate of Delivery for each interval times the duration of each interval
3	**Delivery Period**	The interval of time during which the energy, was, is, or will be available for physical delivery. A Period is designated by a Start Time and an End Time. The duration of the Period is the End-Time - Start-Time.
4	**Buy/Sell Flag**	Boolean variable designating the offer as (1) an offer by the Offering Party to buy energy from the Counter Party, or (2) an offer by the Offering Party to sell energy to the Counter Party.
5	**Offering Party**	The Party offering the energy
6	**Counter Party**	The Party(s) receiving the offer of energy.
7	**Offer Availability Period**	The time interval that the offer is available for a transaction designated by a Start Time and an End Time.
8	**Location**	The geospatial location for the delivery of the energy.
9	**Meter ID**	If delivery is at a meter, an identifier designating the meter.
10	**Currency**	Code for the currency used.
11	**Units**	The units of measure for the energy.

The vector offer assumes that all of the offers in the vector have the same buy/sell flag, offering party, etc. Alternatively, a vector of both buy and sell offers for each period in the vector could be defined.

D. Swap and Multi-Leg Information Models

The basic information models in Table 1 to 4 can be combined to model swap and multi-leg offers and transactions.

A multi-leg offer is an offer consisting of several offers such that all offers must be transacted or none. A buyer may use a multi-leg offer want to purchase a power in a desired shape over the hours of a day,

[21] The OASIS Web Services Calendar Technical Committee is developing standards for communication of schedule and interval. The vector information model described here should adopt those standards when they become available. Useful vectors in TeMIX include all periods for the next hour, day, month or year, for example. Vectors could cover contiguous intervals or could be repeating sets of hours such as weekdays, weekends and holidays, or peak hours and off-peak hours of such days.

week or year. A generator may make an offer to sell enough power to start up his generator at a minimum load. Note that there could be multiple counterparties to a multi-leg offer by a single party.

A swap offer is typically an offer to buy and a transaction to sell for different delivery periods, which can be modeled as a multi-leg offer with two energy offers.

Table 6 : Multi-Leg Offer Information Model

	Energy Offer Element	Specification
1	**Price**	The offered price of a multi-leg transaction. If offered into a market this is a limit order price (the highest buy price or the lowest sell price offered).
2	**List of Offers**	List of two of more Offer ID for offers as defined in Table 2. All offers in the list must be transacted or none, and must have consistent elements such as Offering Party, Counter Party, Offer Availability Period, Currency and Units.

4. TeMIX Application Examples

This section illustrates the application of the TeMIX model to electricity transactions. The examples focus on the information exchange and not the processes for price calculation, negotiation, or market clearing[22]. The examples address only the direct costs associated with energy transactions.

First, we begin with examples of a mature application of TeMIX to energy and option transactions in open markets. Then we follow with a set of examples that apply TeMIX to regulated markets.

A. Mature Transactional Energy Markets

a) Mature Transactional Energy Example

This mature example applies to open competitive wholesale and retail markets with many participants[23]. The parties to the offers and transactions in this example are wholesale and retail parties. Transactions at retail will account for retail distribution and service costs in addition to wholesale costs. The example also applies to residential, commercial industrial and wholesale parties with loads, storage, electric vehicles, and generation.

A mature Transactional Energy market employs near continuous forward and real time energy transactions among all market participants as well as option transactions. A mature market has wide deployment of interval metering, two-way communication, and automated smart price-responsive devices. The process of negotiation and exchange is highly dynamic and automated. Table 7 summarizes the transaction process without being specific as to the means of negotiation. In Table 8, we add options to this example.

Table 7 : Dynamic Forward Energy Transactions with Ex-Post Balancing

1	**Forward Energy Planning:** Parties plan usage and supply, with automatic or manual response to forward **Energy Offers** and forecasts of power prices, needs, costs, weather, etc. Plans may change as the offers and forecasts change.
2	**Forward Energy Offers[24]:** Parties tender forward buy and sell **Energy Offer Vectors**, Table 5. The vectors of offers may be for each 5-minute interval[25] for the remainder of the hour and the next hour, hourly for the rest of the day and the next day, and daily, monthly or yearly. Each offer has an availability period that extends from the offer time for a short time or until it is withdrawn and replaced by refreshed offers, or the offer closes just before the start of delivery.

[22] The examples address only the direct costs associated with energy transactions. Additional costs that are independent of the amount of energy or the rate of delivery are not included here. It is important that all costs that do vary with energy or rate of delivery be reflected in the priced offers.

[23] Where markets are not fully competitive, parties with market power may be subject to price mitigation and must offer requirements. However, markets with substantial forward transactions are less vulnerable to market power.

[24] The order of offers then planning could be reversed. Effectively, the combined offer, planning and transaction process is an ongoing, back and forth process.

3	**Forward Energy Transactions:** Parties buy or sell a fraction of planned energy in each forward period. As plans and offers change, **Energy Transactions** add to or subtract from the customer's total rate of delivery (***position***) in each period. Parties make a number of small transactions across many forward intervals to build towards their planned positions. Each energy transaction is entered at its rate of delivery at the agreed price. The extended price (cost) for each transaction is the rate of delivery times the duration of the interval times the price. As plans and offers change, transactions may add to or subtract from the customer's total rate of delivery in each period.
4	**Energy Metering:** After delivery, the meter reports the energy delivered in each 5-minute interval. The balancing energy rate of delivery is equal to the meter reading (kWh) for the 5-minute interval times 12[26] , less the *position*, (net rate of delivery of all forward transactions[27]).
5	**Balancing Energy Transactions:** Parties including balancing market operators make and receive ex-post priced offers of balancing energy. Each party purchases or sells its balancing energy amount in one or more transactions. The extended price (cost) of each 5-minute balancing transaction is the 5-minute offer price times the 5-minute transaction rate of delivery divided by 12.
6	**Total Energy Costs and Revenues:** The total cost or revenue to each party is the sum of the extended prices (positive or negative) of all its **Energy Transactions.**

b) Mature Transactional Energy and Options Example

Reserve products (ancillary services), capacity products and demand response in the conventional sense may become obsolete with mature implementation of the smart grid vision and Transactional Energy. Parties will self select the amount of reliability and risk mitigation using call or put options for energy in addition to energy transactions as in Section a) above. Such options can be provided by both generators and by loads.

In continuous, energy-only markets, higher prices quickly signal shortages and lower prices quickly signal surpluses to all parties and devices on the grid. This provides all loads, generators and storage an opportunity and incentive to respond. Price caps and price floors[28] in these markets need to be very wide to provide the necessary incentives for reliability and efficiency. Near continuous energy markets and energy options will allow all to self-manage their risks.

Fast and reliable response as a function of price will be provided by loads, storage, and distributed generation resources. Today's generators on automated generation control (AGC) receive signals about

[25] As described in Section b), regulation services are transacted on 4-second intervals. This example could be carried out at the 4-second interval for parties where technology is available and economics allow.

[26] There are 12 5-minute intervals in an hour.

[27] If parties are transacting forward on 5-minute intervals, the ex-post balancing transactions are likely negligible, but perhaps necessary to assure that the forward transactions are balanced.

[28] Price caps and floors can be expected to continue in most mature energy markets to prevent extreme abuse in situations that may arise. However, price caps that are too low and price floors that are too high can mute the incentives of parties to self-manage risks though forward energy and option transactions. When the price cap is reached there may be a need for mandatory curtailment of service. In emergency situations prices above the normal price cap might be used for short intervals.

every 4 seconds. As we discuss in the next example, energy transactions based on 4-second priced offers are practical for some devices and can enhance reliability. To see that this is practical, we only need only to observe current financial markets where similar transactions in the billions are completed every day with round trip transactions times in milliseconds, or faster. Each financial market transaction has a buyer, seller, price and a quantity, just like energy. Obviously, for the smaller parties, short interval pricing, transactions, control, and billing will not be economic.

Loads desiring protection from higher prices can purchase forward energy contracts as in Section a), or call options from generators, other loads, or storage. The options can have a range of exercise prices, and notification lead times such that buyers can decide on the level of protection they want to buy. System operators or Retail Service Providers may offer demand response options to customers that are an option to buy back energy from customers at a defined strike price and while making a payment (option premium) to the customers for the option.

Examples of call options are options at strike prices less than or equal to the price cap with exercise periods ending 1-year, 1-month, 24-hours, 30-minutes, 10-minutes and 4 seconds before the delivery time. Such options mimic current capacity products and ancillary service products for regulation, spinning and non-spinning reserves.[29]

Table 8 : Dynamic Forward Option and Energy Transactions with Ex-Post Balancing

1	**Forward Energy Planning:** Parties plan usage and supply, with automatic or manual response to forward **Energy Offers** and forecasts of power prices, needs, costs, weather, etc. Plans may change as the offers and forecasts change.. **Forward Option Planning:** Parties plan how much to buy or sell how much to buy or sell as call *Energy Option* contracts[30].

[29] Spinning and non-spinning reserves typically are deployed only in the event of grid contingencies such as a sudden loss of generation or transmission. Thereafter, additional generation and load reduction usually are deployed to return the deployed reserves to reserve status. A call option with a strike price at or near the price cap would assure option buyers of delivery and price protection until higher prices adjust the balance of supply and demand to lower prices.

[30] Large generators may want to buy put options to cover some of the start-up costs of generators. Wind generators may want to buy put options to project against low prices in high wind situations.

2	**Forward Energy Offers:** Parties tender forward buy and sell **Energy Offer Vectors**, Table 5. The vectors of offers may be for each 5-minute interval[31] for the remainder of the hour and the next hour, hourly for the rest of the day and the next day, and daily, monthly or yearly. Each offer has an availability period that extends from the offer time for a short time or until it is withdrawn and replaced by refreshed offers, or the offer closes just before the start of delivery. **Forward Option Offers:** Parties also make and counter parties receive vectors of forward **Energy Option Offers** as in Table 4. The call options may be for exercise periods with a notice of 1-year, 1-month, 24-hours, 30-minutes, 10-minutes and 4-seconds before exercise. The vectors of option offers may be, hourly for the rest of the day and the next day, and then daily, monthly or yearly. Each option offer has an availability period that extends for a short time or until it is withdrawn and replaced by refreshed offers, or the offer closes just before the start of the exercise period. The strike price of the call options is a strike price that is less than the price cap. The option premium price is based on offer and acceptance.
3	**Forward Energy Transactions** Parties buy or sell a fraction of planned energy in each forward period. As plans and offers change, **Energy Transactions** add to or subtract from the customer's total rate of delivery (***position***) in each period. Parties make a number of small transactions across many forward intervals to build towards their planned positions. Each energy transaction is entered at its rate of delivery at the agreed price. The extended price (cost) for each transaction is the rate of delivery times the duration of the interval times the price. As plans and offers change, transactions may add to or subtract from the customer's total rate of delivery in each period.. **Forward Option Transactions** Parties buy or sell all or some fraction of planned energy schedule over their planning horizon using a set of call **Energy Option** transactions. Transactions are the result of accepting option offers received or making offers that are accepted by other Parties. For example, a load party might buy 50% of planned energy on one year notice, 10% on 24 hour notice, 4% on 30 minute notice, 3% on 10 minute notice and 1% on 4 second notice[32]. Generators or other loads would take the other side of these options. Parties make a number of small transactions across many forward intervals to build towards their planned energy and option positions. Each option transaction is entered at a rate of delivery at the option premium price. The extended price (cost) for each option transaction is the rate of delivery times the duration of the interval times the option premium price. As plans and offers change, transactions may add to or subtract from the customer's total call option rate of delivery in each period.
4	**Option Exercise:** In situations where the prices of energy offers exceed the option strike price, the exercise party of a call option will exercise the option up to its rate of delivery to assure delivery of energy at the strike price. The cost of exercise is the strike price times the exercised rate of delivery times the duration of the delivery period.
5	**Energy Metering:** After delivery, the meter reports energy delivered in each 4-second interval. The balancing energy rate of delivery is equal to the meter reading (kWh) for the 4 second interval times 900[33], less the net rate of delivery of all forward transactions including exercised option transactions.

[31] As described in Section b), regulation services are transacted on 4-second intervals. This example could be carried out at the 4-second interval for parties where technology is available and economics allow.

[32] A "demand response option" might be offered by a load to sell energy that the load has already purchased but at a strike price below or at the price cap. A "capacity option" would be an option to buy energy at a strike price below or at the price cap.

[33] There are 900 4-second intervals in one hour.

6	**Balancing Energy Transactions:** Parties including balancing market operators make and receive ex-post priced offers of balancing energy. Each party purchases or sells its balancing energy amount in one or more transactions. The extended price (cost) of each 4-second transaction is the offer price times the transaction rate of delivery divided by 900.
7	**Total Energy and Option Costs and Revenues:** The total cost or revenue to each party is the sum of the extended prices (positive or negative) of all transactions by the party.

B. Retail Real-Time Cost-of-Service Markets

The following retail real-time market examples are specific applications of TeMIX to regulated markets where a single Retail Service Provider (RSP) provides a real-time dynamic pricing tariff. The tariff offers are priced offers with no counter offers by the Customer as in mature Transactional Energy Markets. These examples are only more specific examples of the mature example provided in Table 7.

There are many ways to implement hourly, 15-minute or 5-minute real-time pricing. The following examples are a Retail Service Provider (RSP) offering hourly real-time dynamically priced service.

The first retail real-time pricing (RTP) example described in Table 9 is a simple Ex-Ante hourly sale offer. Ex-Ante means that the offer is made before the delivery period. In this first case, the offer remains available until after the interval passes.

Table 9 : Hourly Ex-Ante Hourly RTP

1	**Day-Ahead Hourly Offers:** At 12 noon, the RSP tenders to the retail customers a vector of **Energy Offers** to sell for the 24 hours of the next day. *Rate of delivery* limited only by the service connection.
2	**Real-Time Usage:** Customer self-manages electric usage with automatic and/or manual response to the hourly prices of the **Energy Offers**.
3	**Metering and Costs:** Meter reports energy delivered in each hour. An **Energy Transaction**, Table 1, is entered with the rate of delivery equal to the meter reading (kWh) for the hour. The extended price (cost) in each hour equals the hourly price of the **Energy Offer** times the meter reading for the hour.

The RSP can set the price in Table 9 equal to the hourly clearing price in a wholesale day-ahead market plus a retail adder. The RSP is carrying two risks: (1) the amount that will be transacted is unknown and (2) the RSP's cost of wholesale supply is unknown until delivery. The RSP can buy at the wholesale price by estimating the amount needed and bidding that amount into the Day Ahead hourly market. The retail customer knows the price in each hour of the next day, so the customer can easily manage his loads to minimize his costs with no price risk.

The second retail RTP example, Table 10, settles actual deliveries based on ex-post hourly priced offers. Customers rely on forecasts of the ex-post hourly prices. The risks are assumed by the retail customer and no price or quantity risks are borne by the RSP in procuring in the wholesale real-time markets.

Table 10 : Hourly Ex-Post RTP

1	**Day-Ahead Customer Forecasts:** Customer makes or receives frequently updated forecasts of 24 or more future hourly prices at various times before the interval. (Note that forecasted prices are not priced offers.)
2	**Real-Time Customer Usage:** Customer self-manages electric usage, with automatic and/or manual response based on the forecast hourly priced offers.
3	**Real-Time Ex-Post Offers:** After each hourly delivery period passes, an hourly ex-post sell **Energy Offer** is tendered by the RSP. (Note that ex-post offer prices will vary from forecasted hourly prices).
4	**Metering and Costs:** Meter reports energy delivered in each hour. An **Energy Transaction**, Table 1, is entered with a rate of delivery equal to the meter reading (kWh) for the hour. Extended price (cost) in each hour equals the ex-post hourly price times the meter reading for the hour.

The third retail RTP example provides clear price information to the buyer without imposing major risks on either party. In this example, both ex-ante hourly and 5-minute offers are provided. The hourly transaction is a forward transaction to the 5-minute delivery period transactions.

Table 11 : Hourly Ex-Ante Forward Sell Offers with Ex-Ante 5-Minute Buy/Sell Offers

1	**Day-Ahead Customer Planning:** Customer plans electric usage, with automatic and/or manual response to ex-ante hourly pricesd offers. Planned electric usage is developed for the 24 hours of the next day.
2	**Day-Ahead Hourly Ex-Ante Offers:** At 12 noon the day-head, a vector of ex-ante sell offers, Table 5, for each of the 24 hours of the next day are tendered by the Retail Service Provider (RSP). The offer availability period is from 12 noon the day before until 1 pm the day before.
3	**Day-Ahead Energy Transactions:** Customer purchases all or some fraction of planned energy for each of the 24 hours. An energy transaction, Table 1, is entered for each hour at the planned rate of delivery and at the ex-ante hourly offer price. The extended price (cost) is the rate of delivery times the ex-ante offer price.
4	**Real-Time Customer Usage:** Customer self-manages electric usage, with automatic and/or manual response to forecasted 5-minute prices.
5	**Real-Time Ex-Post Offers:** After each 5-minute delivery period passes, 5-minute interval ex-post buy and sell offers are tendered by the RSP. (Note that ex-post offer prices will vary from forecasted 5-minute prices).
6	**Metering and Costs:** Meter reports energy delivered in each 5-minute interval. A 5-minute energy transaction, Table 1, is entered equal to the meter reading for the 5-minute interval less the rate of delivery from the forward hourly transaction. The Extended price (cost) in each hour equals the ex-ante 5-minute offer price times the 5-minute transaction rate of delivery divided by 12.
7	**Total Customer Costs:** The total cost for each hour is the hourly transaction extended price plus the sum of the 5-minute interval transaction extended prices.

C. Retail Forward Baseline Transactions with RTP

Retail forward baselines provide a forward rate-of-delivery to retail customers in each delivery period. Actual deliveries may be more or less than the forward baseline and deficit and surplus amounts are transacted using real-time buy and sell offers. Forward baselines allow the customer and the RSP to fix the cost of a baseline amount of energy, while retaining the opportunity for the customer to manage consumption based on real-time priced offers and respond to grid conditions as reflected in priced offers.

The first baseline example in Table 12 illustrates a cost-of-service baseline together with RTP provided by an RSP. The second example in Table 13 The next example describes how a customer can hedge real-time prices to manage risk or reduce costs to the extent that he forecast forward prices are lower than real-time prices.

Table 13 also illustrates a retail customer making forward transactions to build his own baseline for RTP.

Combining both examples will allow a retail customer to take a cost-of-service baseline and reshape it in a series of forward transactions the better to match his needs. Each of the examples pair forward baseline transactions with different real-time transactions. The real-time transactions can take several different forms as illustrated in Section B.

Table 12 : Fixed Baseline with Hourly Ex-Ante Offers

1	**Cost of Service Baseline Allocation:** Customer accepts a cost-of-service fixed baseline **Energy Transaction** as in Table 1. The baseline amount will typically vary by time-of-day, day-of-week and season. The cost of the baseline transaction is a fixed amount per month. The monthly baseline cost can be a lower amount for low income groups.
2	**Day-Ahead Hourly Ex-Ante Offers:** At 12 noon the day-head, a **Energy Offer Vector**, Table 5, for each of the 24 hours of the next day are tendered by the Retail Service Provider (RSP). The offer availability period is from 12 noon the day before until the close of each delivery hour.
3	**Real-Time Customer Usage:** Customer self-manages electric usage, with automatic and/or manual response to ex-ante hourly priced offers.
4	**Metering:** Meter reports energy delivered in each hour. An **Energy Transaction**, Table 1, is entered with a rate of delivery equal to the meter reading (kWh) for the hour less the rate of deliver of the fixed baseline transaction. Extended price (cost) in each hour equals the ex-ante hourly offer price times the meter reading for the hour.
5	**Total Costs:** The total cost per month is the monthly base line **Energy Offe**r extended price plus the hourly transaction extended price (positive or negative) over all hours in the month.

The next example describes how a customer can hedge real-time prices to manage risk or reduce costs to the extent that he forecast forward prices are lower than real-time prices.

Table 13 : Build-Your-Own Base Line with Forward Ex-Ante Offers and 5 Minute Ex-Post Offers

1	**Customer Forward Planning**: Customer plans usage and supply, with automatic or manual response to forward **Energy Offers** by a RSP and forecasts of power prices, needs, costs, weather, etc. Plans may change as the offers and forecasts change.
2	**Customer Receives Forward Offers:** Customer receives vectors of forward buy and sell **Energy Offers** as in Table 5. Vectors of offers may be for each 5-minute period for the remainder of the hour and the next hour, hourly for the rest of the day and the next day, and then daily, monthly or yearly. Each offer has an availability period and all offers close before the start of delivery.
3	**Customer Forward Transactions (build-your-own baseline):** Customer purchases all or some fraction of planned energy over his planning horizon using a set of **Energy Transactions**. Each energy transaction is entered at its rate of delivery and at the ex-ante offer price. The extended price (cost) for each transaction is the rate of delivery times the ex-ante offer price. As the offers change, transactions may add to or subtract from the customer's total rate of delivery or position in each period.
4	**Real-Time Ex-Post Offers**: After each 5-minute delivery period, 5-minute interval ex-post buy and sell **Energy Offers** are tendered to the customer.
5	**Metering and Costs:** Meter reports energy delivered in each 5-minute interval. A 5-minute **Energy Transaction**, Table 1, is entered with a rate of delivery equal to the meter reading (kWh) for the 5-minute interval times 12), less the total rate of delivery from the all forward transactions. The Extended price (cost) of the 5-minute ex-ante transaction is the 5-minute offer price times the 5-minute transaction rate of delivery divided by 12. This extended 5-minute price may be negative or positive.
6	**Total Customer Costs:** The total cost of energy to the customer is the sum of the extended prices (positive or negative) of all transactions.

D. Full Requirements Tariffs and Contracts

Electricity is often sold under full-requirements tariffs and contracts to retail customers. A full-requirements retail contract is an offer to a customer by a retail service provider (RSP) to deliver any amount of power (at a rate-of-delivery up to the capacity of the customer's service connection) at an offer price over a specified period[34]. A full-requirements contract does not comply with the constant rate-of-delivery condition for a TeMIX compliant transaction. However, TeMIX can use the Energy Option Transaction Model to model a full requirements contract or tariff subject to the condition that no further transactions other than the full-requirements contract occur.

We offer below two examples with monthly and hourly rates and metering.

[34] A full requirements tariff is an option with significant flexibility for the buyer. As such, the option premium that may be built into a full requirements tariff price may be substantial.

Table 14 : Monthly Full-Requirements Rate with Monthly Metering

1	**RSP Offers Full Requirements Monthly Contract**: RSP offers retail customer a monthly call option to purchase any amount of energy up to a rate-of-delivery limited only by the customer service connection capacity as modeled by Table 3 at a specified strike price (rate). The exercise period expires after the close of the monthly delivery period.
2	**Monthly Metering and Costs:** Meter reports energy delivered in each monthly period. A monthly energy transaction, Table 1, is entered with a rate of delivery equal to the meter reading (kWh) for the month divided by the number of hours in the month. The Extended price (cost) of the month ex-ante transaction is the call option strike price (rate) times the monthly metered energy.

The hourly example below is a full-requirement tariff that can implement a Time-of-Use tariff.

Table 15 : Hourly Full Requirements Rate with Hourly Metering

1	**RSP Offers Full Requirements Hourly Contract:** RSP offers retail customer an hourly call option to purchase any amount of energy up to a rate-of-delivery limited only by the customer service connection capacity as modeled by Table 3 at a specified strike price (rate). The hourly strike price could be the same in all hours of a month, as in Table 14, or could vary by off-peak and on-peak hours (time of use rate). The exercise period expires after the close of the hourly delivery period.
2	**Hourly Metering and Costs:** Meter reports energy delivered in each hourly interval. An hourly energy transaction, Table 1, is entered with a rate of delivery equal to the meter reading (kWh) for the hour. The Extended price (cost) of the hourly ex-ante transaction is the call option strike price (rate) times the hourly metered energy.

E. Full-Requirements Block Tariffs and Contracts

Block tariffs provide a means to charge a higher price of energy to larger consumers either to subsidize smaller customers or encourage conservation from larger users. A block tariff with increasing prices on each block can be represented in TeMIX as a set of call options similar to single block full-requirements tariff modeled in the previous Section E.

Table 16 : Monthly Full-Requirements Block Rate with Monthly Metering[35]

1	**RSP Offers Full-Requirements Monthly Contract with Three Increasing Block Rates:** RSP offers retail customer three monthly call options to purchase any amount of energy up to a rate-of-delivery. The three blocks are each modeled by Table 3 at a specified strike prices (rates). The first block is a call option to purchase up to 300 kWh over the month at a strike price (rate) of $0.10 per kWh. The second block is for an additional 700 kWh at a strike price (rate) of $0.15 per kWh. The third block is for any amount over 1000 kWh at a strike price (rate) of $0.20 per kWh limited only by the customer service connection capacity. The exercise period for all blocks expire after the close of the monthly delivery period.

[35] This structure also applies to contracts with decreasing block rates.

2	**Monthly Metering and Costs:** Meter reports energy delivered in each monthly period. The monthly metered energy is first allocated to the first block, and then the remainder to the second and then the third block. Up to three monthly energy transactions, Table 1, (one for each block used are entered with a rate of delivery equal to the energy allocated to each block. divided by the number of hours in the month). The Extended price (cost) of each block is the month ex-ante transaction is the call option strike price (rate) times the monthly metered energy.

F. Estimated Baselines for Full Requirements Contracts

Real-time pricing, peak load pricing and event-based demand response require a baseline from which to measure and pay for customer response. A monthly full-requirements contract has no defined rate of delivery in each hour, for example. If a customer is offered a demand response transaction to reduce the rate of delivery in a given hour, then there is no contracted baseline rate of delivery to measure the demand reduction amount. Such contracts require estimation[36] of a baseline rate of delivery even if interval metering is available. Given such estimation, then further (demand response) transactions against this baseline may be possible. However, baseline estimation is subject to uncertainty and manipulation. Furthermore, 24/7 baseline estimation to add real-time pricing to a full-requirements contract is futile.

G. Event-Based Demand Response

Event-based demand response is a program where customers are paid to respond to requests for load curtailment. Event-based demand response can be modeled as an Energy Option Transaction as in Table 3, where customers are paid both an option premium to participate, and a strike price for energy curtailments when asked. There also may be a limit on the number of curtailment events or hours of curtailment over the operation period of the program and, in some cases, the customer may be allowed to opt out of a curtailment. Event-based demand response may be paired with full-requirements contracts as in Section D using estimated baselines as in Section G. Event-based demand response can also be paired with contracted, obligation baselines with retail customers as in Sections A and C with no need for baseline estimation.

Table 17 : Event-Based Demand Response with Estimated or Contracted Baseline

1	**RSP Event-Based Demand Response Call Option** RSP offers to a retail customer a call **Option Offer** (demand response program) as defined by Table 4. The **Option Offer** has an option premium price of $20 per kW-month and a **strike price** of $1 per kWh[37] for actual energy curtailments. The call option is for any weekday peak hour (12 noon to 8 pm) in the months of June through September. The option is constrained to be exercised up to 20 hours per month.

[36] "Estimating Demand Response Load Impacts: Evaluation of Baseline Load Models for Non-Residential Buildings in California" by Katie Coughlin, Mary Ann Piette, Charles Goldman and Sila Kiliccote, Lawrence Berkeley National Laboratory, January 2008, http://www.naesco.org/resources/industry/documents/2008-01.pdf

[37] If the baseline is a TeMIX obligation contract with real-time pricing then a demand response call option will only be useful once the real-time price reaches the market price cap. A call option bought by the RSP, ISO or RTO at a strike price equal to the price cap will have value to the system operator as an option to reduce load when higher prices are not allowed.

2	**Customer Accepts Event-Based Demand Response Offer:** Customer agrees to provide 2 kW of curtailment for a monthly payment of 2 kW times $20 per kW-month or $40 per month for the 4 months of June through September totaling $160.
3	**RSP Exercises Option based on ISO/RTO Demand Response Event:** At 1:30 pm, on July 16^{th}, the ISO or RTO calls a demand response event (Command) for two hours from 2 pm to 6 pm (4 hours) on July 16th. Per an ISO contract with the RSP, the RSP exercises the call option for four hours. RSP then **Commands** the customer to curtail 2 kW from 2 pm to 6 pm. (Note the ***chain-of-command***).
4	**Customer Curtails Usage:** Customer reduces his rate-of-delivery by 2 kW (**Energy Transaction**) from his contracted baseline *position* or, in the case of a full-requirements contract, an *estimated baseline*.
5	**Hourly Metering and Costs:** Meter readings verify the reduction vs. the baseline. If the reduction is not made penalties per the contract may apply. Customer is paid 2 kW times 4 hours times $1 per kWh or $8 for the actual curtailment. A similar calculation is applied to other events in each month. The customer is paid for all events during the month plus the monthly premium less any penalties for non-performance.