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Transactive Energy Market Information Exchange (TeMIX) using EMIX 1.0

Working Draft 05

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Technical Committee:
OASIS Energy Market Information Exchange (eMIX) TC

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- Energy Market Information Exchange (EMIX) 1.0 Committee Specification Draft 04 (http://docs.oasis-open.org/emix/emix/v1.0/csd04/emix-v1.0-csd04.html)

Abstract:
This note describes an Information Model for Energy Transactions in the Smart Grid

Status:
This Working Draft (WD) has been produced by one or more TC Members; it has not yet been voted on by the TC or approved as a Committee Draft (Committee Specification Draft or a Committee Note Draft). The OASIS document Approval Process begins officially with a TC vote to approve a WD as a Committee Draft. A TC may approve a Working Draft, revise it, and re-approve it any number of times as a Committee Draft.

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1 Introduction

Transactive Energy Market Information Exchange (TeMIX) is an information model and a communication model to enable energy transactions and decentralized management of energy use and supply at the edges of a smart electric grid. Using TeMIX, customer devices such as air conditioners, plug-in electric vehicles, distributed generation and storage can automatically interact with distribution grid devices such as transformers, high voltage transmission networks, and central generation and storage. TeMIX enables a smart grid to more efficiently balance supply and demand, reduce cost and serve customers while quickly adapting to high levels of variable renewables, plug-in vehicles, and storage.

TeMIX is based on the clear and frequent communication of tenders (priced offers) and transactions for energy and the means of energy transport among buyers and sellers. Buyers and sellers may be owners of generators, loads, or storage with metered delivery, or financial traders with no intention of actual delivery or suppliers of energy transport services. A seller can be a consumer that is selling back by reducing a purchased position. A buyer can be a generator that is buying back from a sold position.

TeMIX needs no hierarchy. Where regulations permit, any party can transact with any other party, or with intermediaries as desired. For example a Retail Energy Provider (REP) might buy and sell from retail customers but neither party would exert control over or require information from the other party except for information voluntarily offered by one party to the other or any obligations entered into though mutually agreed transactions.

TeMIX is a subset or profile of the OASIS eMIX information model and the OASIS Energy Interop services for *Transactive Energy*. The TeMIX profile is described by conformance rules defined in EMIX 12.3 and OASIS Energy Interop XX.X. OASIS eMIX provides an information model for price and product communication for energy related transactions. OASIS Energy Interop provides a set of transactive services to communicate eMIX price and product information for energy transactions among parties.

Transactive Energy is a business process for energy transactions. A *Transaction* is defined as an exchange among entities of a product for a price. Transactive Energy is most useful in decentralized markets, but it has applications in centralized cost-of-service, regulated markets. Generator and load response characteristics are not information elements of Transactive Energy; rather, the current responsiveness of supply and usage to price is discovered through frequent priced tenders and transactions among parties.

While many aspects of Transactive Energy can also be implemented without the conformance rules of TeMIX, this paper focuses only on TeMIX. The core attribute of TeMIX is a sequence of simple energy tenders and then energy transactions for a quantity of energy in a time interval at a location results in an energy position in that time interval. This position may then be modified by additional buy and sell transactions. Automation is easily applied to the processes that support TeMIX because of the standardization of TeMIX transactions.

A fundamental principal of TeMIX is that needs for complex transactions can be satisfied by building complex transactions from simple TeMIX transactions with savings in software and device management complexity. This principle promotes standardization, interoperability and liquid and efficient markets.

TeMIX uses price (priced tenders) to coordinate retail and wholesale energy consumer and producer decisions. Coordination occurs through large numbers of frequent small transactions executed automatically by smart devices responding to priced tenders. Balancing the grid on the basis of real-time prices without forward transactions and commitments can be unstable. TeMIX forward and real-time tenders and transactions support grid and market stability.

1.1 References

TeMIX White Paper, Edward G. Cazalet, An official white paper of the OASIS EMIX Technical Committee
http://www.oasis-open.org/committees/download.php/37954/TeMIX-20100523.pdf

TeMIX: A Foundation for Transactive Energy in a Smart Grid World, Edward G Cazalet,
http://www.cazalet.com/images/GI10-Paper_-Cazalet.pdf

1.2 TeMIX Market Structure

TeMIX requires no information exchange other than that needed to make and accept tenders for energy and transport transactions. This information exchange is illustrated by the two-way arrows in Figure 1. The exchanges are for tenders and transactions. Such tenders and transactions are for past, current, and forward intervals of time. For example, a priced tender could be a sequence of hourly priced tenders to sell in each of the next 24 hours. Tenders can be accepted forward of delivery or after delivery for settling delivery balances. Subject to regulatory constraints, any party with adequate collateral can make or accept TeMIX tenders.

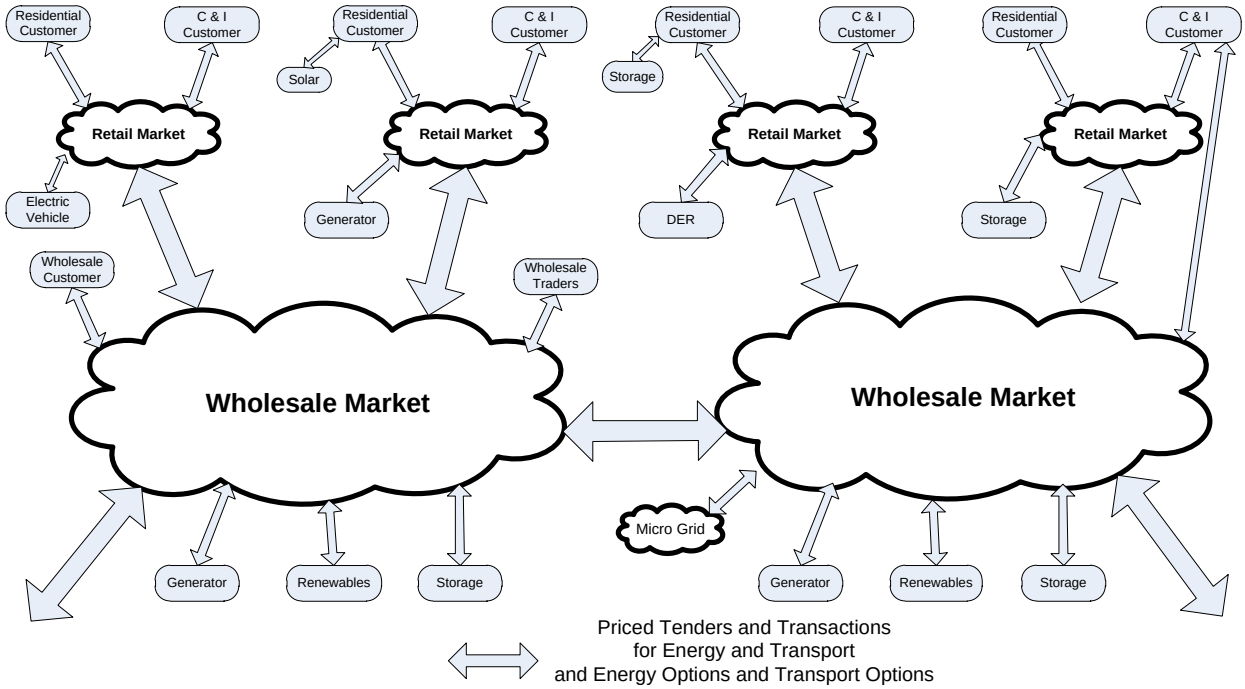


FIGURE 1 : TEMIX MARKET STRUCTURE

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

Many current wholesale system operator markets use a more centralized dispatch of bulk generation and transmission. TeMIX can coexist with such markets.

Energy transactions must account for the transmission and distribution costs, line limits and losses. Transport transactions transport energy in one location to another for a price. TeMIX Transport and Energy products work together to balance supply and demand across the grid while accounting for losses, constraints and cost. Generally, a party can purchase energy from another party at a given delivery location at a price that includes transport, or the party can purchase energy at another location and also purchase transport from that location to the delivery location. The price of TeMIX Transport is defined as a price that covers marginal losses, congestion costs and other fixed and variable costs between two grid locations.

2 The TeMIX Model

2.1 TeMIX Parties and Roles

Examples of a TeMIX Party 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, a power marketer, a distribution system operator, or a transmission system operator. Any Party can be a Buyer or a Seller relative to their current transacted position for energy or transport in a delivery period. Both human and automated agents can represent a Party in carrying out transactions.

A Party can take on two sides in TeMIX interactions:

- Buyer and
- Seller

TeMIX Parties interact both through tenders for transactions as illustrated in Figure 2.

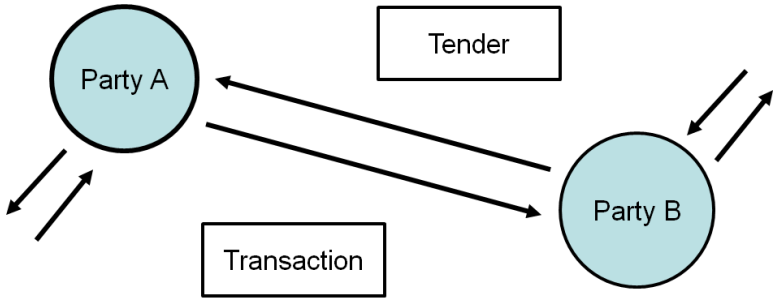


FIGURE 2: PARTIES INTERACTING WITH TENDERS AND TRANSACTIONS AS EITHER BUYERS OR SELLERS

A Party may simultaneously interact with several parties taking on different roles in each interaction. All TeMIX Interactions are pairwise: if a buy Tender by Party B to Party A is accepted by A, A becomes the Seller and B the Buyer with respect to the new Transaction.

At any moment, each Party has a position in the market for a given delivery interval. A Party selling energy relative to its current position takes the role of a Seller. A Party buying energy relative to its current position takes the role of a Buyer. A generator typically takes the role of a Seller, but can also take on the role of a Buyer but may take the role of a Buyer in order to reduce generation. An end-use customer typically takes the role of a Buyer, but if tendered an attractive price may curtail usage and thereby take the role of a Seller.

A distributed generator can take on the roles of both buyer and seller. For example, if a distributed generator sells 2 MW forward of a given interval, it may later decide to buy back all or a portion of the 2 MW if the price is low enough. A distributed storage device takes on the roles of buyer and seller at different times.

Two parties can also engage in an Option Transaction. An option is a promise granted by one Party (Option Writer) to a second Party (Option Holder) usually for a premium payment. The Option Holder is granted a right to invoke specific transactions for energy that the Option Writer promises to deliver. Demand response, ancillary services, and price cap transactions are forms of options. Any Party may take the role of a Buyer or Seller of a tender for an option transaction.

2.2 TeMIX Products

TeMIX is a subset or profile of the EMIX Power Products. The TeMIX Products are based on blocks of Power and Transport with a constant rate of delivery over a single Interval. Each transaction imposes

an obligation on the buyer to purchase and the seller to deliver a TeMIX Power Product. This simplicity reduces the number of products and interactions.

There four TeMIX Products are:

1. TeMIX Power Product
2. TeMIX Transport Product
3. TeMIX Option Power Product
4. TeMIX Option Transport Product

A TeMIX Delivery Interval is specified by Duration and a Start Time. Each TeMIX Delivery Interval is transacted independently of the others. For example a delivery period might be a calendar year, calendar month, day, hour, 5-minute interval, or a 4-second interval.

2.3 Rate of Delivery

The quantity of TeMIX energy or transport product is specified by the rate of delivery (kW or MW, for example) over an interval. The amount of energy (kWh or MWh) delivered over the interval 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[2]. 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 transaction to deliver at a rate of 1 kW (1 kWh/hour) over a 24-hour day is a transaction for 1 kWh in each of the 24 hours 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 hour of the day the rate of delivery (power) is the same, until modified by a further possible transaction on a hour 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. A position (rate of delivery) in a 5-minute interval can include positions in hourly or monthly intervals, for example.

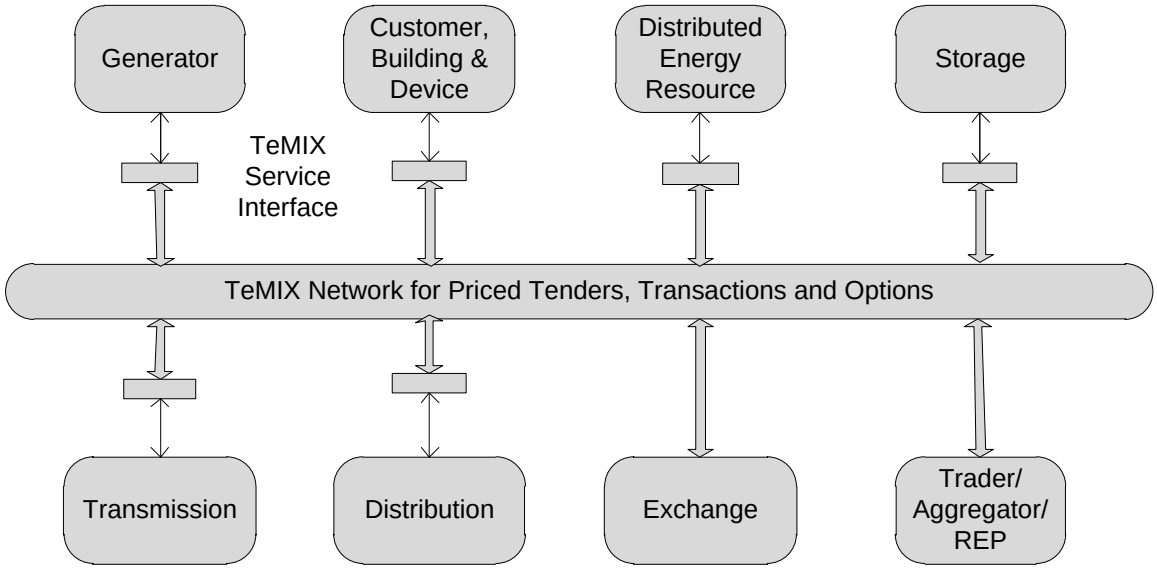
2.4 TeMIX Network

The TeMIX architecture facilitates the process of negotiation, contracting and delivery of electric energy between parties. A generator takes the role of a seller or a buyer relative to previous net sales. A customer takes the role of a buyer or a seller relative to previous net purchases.

Figure 3 illustrates a network of parties that may transact with each other using TeMIX. The parties illustrated include generators and customers, intermediate parties such as exchanges, traders,

[2] 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.

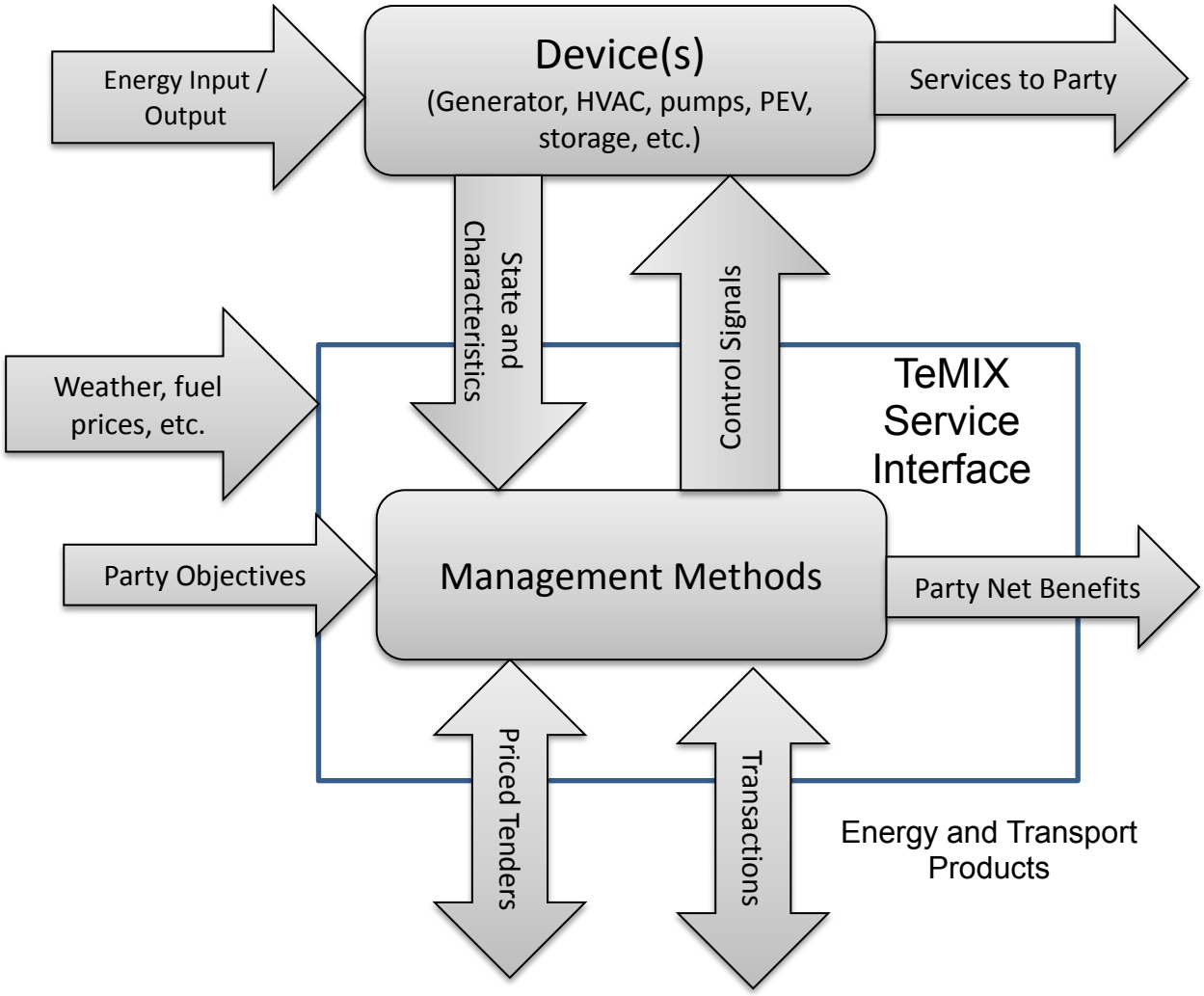
168 brokers, aggregators, retail energy providers (REP) and transmission and distribution operators. This
169 list is not intended to be exhaustive.



170
171 **FIGURE 3: ILLUSTRATIVE TEMIX NETWORK**

172 2.5 TeMIX Service Interface

173 The TeMIX Service Interface as shown in Figure 4 is an implementation of an Energy Services
174 Interface. TeMIX Service Interfaces are associated with devices. In the case of intermediaries such as
175 aggregators, traders, retail energy providers and exchanges, no TeMIX Service Interface is necessary
176 as there is no device to control.



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178 **FIGURE 4: END DEVICE AND TEMIX SERVICE INTERFACE**

179 A TeMIX Service Interface may reside at a device, at a facility, or in a network or cloud application. In
180 this section we describe a generalized TeMIX Service Interface for End Devices.

181 An end device produces or consumes and may store electric energy. Large grid-scale generators,
182 variable wind and solar renewables, and grid scale storage are end devices. Distributed generation
183 and storage are end devices. Residential, commercial and industrial customer air conditioning,
184 heating, pump, lighting, and electronic equipment are end devices.

185 End devices may be active (on / off, or variable control) or passive. Some devices respond rapidly
186 while others require lead time and longer ramps.

187 Figure 4 illustrates the TeMIX operation of end devices. At the top of the figure the device is
188 illustrated. At the bottom of the figure the TeMIX Service Interface is illustrated.

189 Power input and output and services to the device are determined by control signals and the physics
190 of the device. A generator outputs energy; a consuming device inputs energy and produces services
191 to the Party such as heating and cooling, and storage would both input and output energy.

Generators and Storage would not typically provide services to the Party other than the value of energy output.

The TeMIX Service Interface shown in Figure 3 has three functions: (1) determine the device's optimal operating levels, (2) receive and make forward tenders and (3) execute transactions with other parties based on their tenders. TeMIX Service Interfaces may also employ transport products to transact at other locations.

The Management Methods for a Device can be as simple as turn the device on when the price tendered is lower than a threshold and turn it on when the price is higher than the threshold. Or the Management may be based on optimal control, forward tenders and automated forecasting and machine learning.

The optimization maximizes the Party Net Benefits based on party objectives, current state and characteristics of the device, and external variables such as weather and fuel prices. Management may be hosted in embedded processors in the device or at energy management systems controlling several devices at a site. Control may also be hosted by a utility or third party at remote sites. Many devices will use simple rules for operation to mimic optimization.

2.6 TeMIX Market Processes

TeMIX supports decentralized decisions and coordination using near continuous, simultaneous communication of TeMIX priced tenders among Parties. Decision making is similar for all parties and devices but will be implemented at a level of detail that is practical in relation to the value of smart controls for each device.

There are many market processes to exchange tenders and reach agreements on transactions using the TeMIX model. Different parts of the energy market may employ different market processes.

Generally the TeMIX market processes can be characterized by the TeMIX Transactive States. TeMIX uses Transactive State to qualify the information model for TeMIX products and prices as illustrated in Figure 5 below.

Figure 5: TeMIX Transactive States

Five transactive states are used by TeMIX. An Indication of Interest is non-binding and may be (1) a request for a Tender, (2) a forecast of usage by a buyer, or (3) a forecast of price by a seller. A Tender is a bid or offer for a Transaction with an expiration time. A Transaction is formed by accepting a Tender. Delivery is the metered quantity delivered. Publication communicates transacted prices, quantities, costs, or revenues.

2.7 TeMIX Forward Transactions and Positions

TeMIX uses forward energy transactions to accumulate forward positions. If the transactions and positions are financial then the final position must be financially balanced to zero. If the forward

transactions are for delivery, differences between the forward positions and metered delivery are settled by real-time transactions. Figure 6 illustrates such a sequence of forward transactions and positions for delivery. In some markets, the forward transactions may be with several different counterparties.

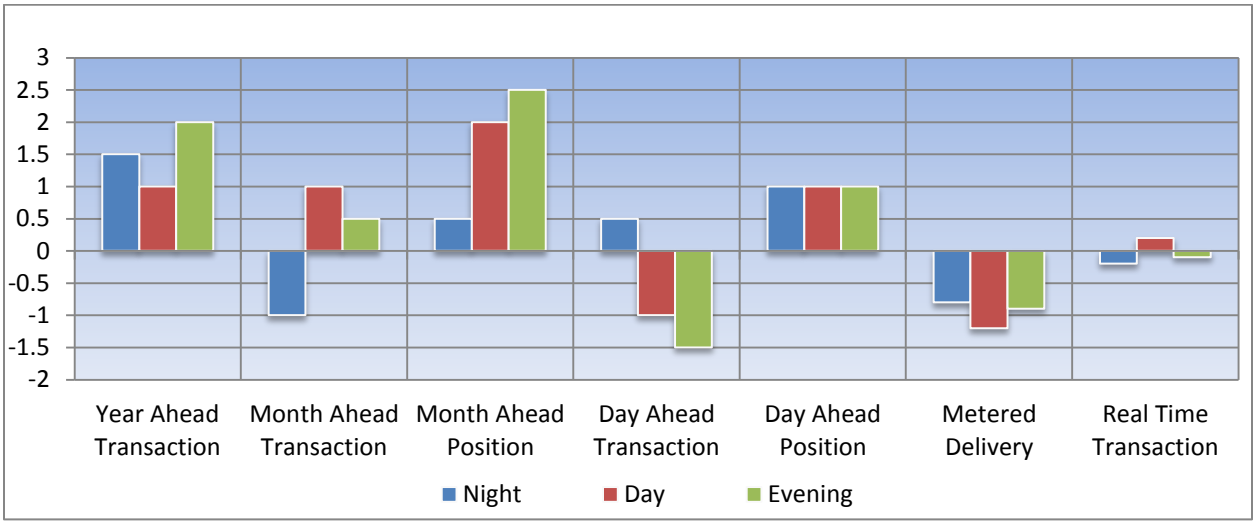

FIGURE 6: ILLUSTRATIVE SEQUENCE OF FORWARD AND REAL TIME TRANSACTIONS

The TeMIX concepts are similar to concepts used in continuously traded bid/ask markets such as commodity and stock exchanges, and energy bilateral transactions.

3 The TeMIX Information Model and Services

3.1 TeMIX Products

The elements of all four TeMIX Products are shown in Table 1.

Table 1: TeMIX Product Description

TeMIX Element	Description
Power Product Type	Enumerated type of TeMIX Power Product : Power, Transport, Power Options and Transport Option
EMIX Interface	The Interface where the transaction occurs. Generally, the Interface for a Power Product has one node and the Interface for a Transport Product has two nodes.
Start Date and Time	When the Interval begins.
Duration	The extent of time of the Interval.
Price	The Unit Energy Price for the Interval. TeMIX does not allow Relative Prices or Price Multipliers.
Energy Item	Total Energy (Power * Time), Real Energy delivered of the Interval
Power Quantity	Rate of Delivery of Energy for the Interval.
Transactive State	Indication of Interest, Tender, Transaction, Delivery or Publish.

TeMIX Element	Description
Side	Indicates which side of the agreement the information originator is on. Buy or Sell.
Expires Date	Date and Time Tender expires. Not present if the Transactive State is anything other than Tender.
Power Item	Units for the Rate of Delivery of Energy for the Delivery Interval.
Currency	Currency for the exchange.

For TeMIX Options the additional elements in Table 2 apply:

Table 2: TeMIX Power Option Product Description

TeMIX Element	Description
Option Holder Side	The side (buy or sell side of the option) which enjoys the benefit of choosing whether or not to exercise the option. The other side is the option writer.
Option Strike Price	The price at which the Option Holder can require option writer to deliver.
Exercise Lead Time	The Minimum Notification Duration expressed as an EMIX Term.
Option Exercise Schedule	The Availability Schedule expressed as an EMIX Term.
Temporal Granularity	If present, expresses the temporal granularity of requests as a Duration. For example, if the Duration is 15 Minutes, the option can be called at 10:00, 10:15, 10:30, or 10:45. Granularity is a Property of the Option Schedule.

The rate of delivery of a TeMIX Power Product is constant over all measured (metered) Intervals within a TeMIX Delivery Interval. For example the transaction could be for 1 hour, but the meter reads every 5 minutes.

The Price of a TeMIX Product is expressed in energy units. For the example above, when the price is $80 per MWh of energy, the extended price (cost) of 1 MW of Power for two hours between 3 and 5 PM is $160; the extended price for 1 MW of Power in each 15-minute Interval of the two hours is $20.

A TeMIX Transport Product is for transmission or distribution services to transport a TeMIX Power Product from one EMIX Interface to another.

A TeMIX Option Product provides the Option Holder the right to instruct the option writer to deliver (call) or take (put) a TeMIX Power or Transport Product up to the transacted quantity (rate of delivery) of the Option at a Strike Price.

TeMIX Options are either Call or Put Options on TeMIX Power and Transport Products. A TeMIX Option can be exercised during the Delivery Interval of the Option for any sub-Interval not smaller than the Option Interval Granularity.

For example, a TeMIX Option for 10 MW for a Day and an Option Interval Granularly of 1-hour and an Option Lead Time of 30 minutes would allow the Holder to exercise the option for any or all hours of the Day at the Strike Price by giving notice 30 minutes before each hour.

3.2 The TeMIX Services

To be completed based on EiIIndication, EiTender, EiTransaction, EiDelivery and EiPublication Services from Energy Interop.

A. Revision History

Revision	Date	Editor	Changes Made
[Rev number]	[Rev Date]	[Modified By]	[Summary of Changes]
Wd03	8 Aug 2011	Toby Considine	Brought forward from old White Paper to approved format
Wd04	06 Oct 2011	Ed Cazalet	Global changes of Transactional to Transactive, Offer to Tender, updating of entire paper to reflect work done in EMIX since the May 23 2010 White Paper. Updating to more fully explain TeMIX and its applications.
Wd05	06 Oct 2011	Ed Cazalet	Editorial changes to Wd04 for clarity.