

Transactive Energy Market Information Exchange (TeMIX) using EMIX 1.0

Committee Note Draft 01 /
Public Review Draft 01

13 October 2011

Specification URIs

This version:

N/A

Previous version:

N/A

Latest version:

N/A

Technical Committee:

[OASIS Energy Market Information Exchange \(eMIX\) TC](#)

Chairs:

William Cox ([wtcox@coxsoftwarearchitects.com](mailto:wtcx@coxsoftwarearchitects.com)), Individual
Edward Cazalet (ed@cazalet.com), Individual

Editors:

Edward Cazalet (ed@cazalet.com), Individual

Related work:

This Work Product is related to:

- 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 document was last revised or approved by the OASIS Energy Market Information Exchange (eMIX) TC on the above date. The level of approval is also listed above.

Technical Committee members should send comments on this document to the Technical Committee's email list. Others should send comments to the Technical

This is a Non-Standards

Track Work Product.

The patent provisions of
the OASIS IPR Policy do
not apply.

Committee by using the "[Send A Comment](#)" button on the Technical Committee's web page at <http://www.oasis-open.org/committees/emix/>.

Citation format:

When referencing this document the following citation format should be used:

[EMIX-temix-v1.0]

Transactive Energy Market Information Exchange (TeMIX) using EMIX 1.0.
13 October 2011. OASIS Committee Note Draft 01 / Public Review Draft 01.

Copyright © OASIS Open 2011. All Rights Reserved.

All capitalized terms in the following text have the meanings assigned to them in the OASIS Intellectual Property Rights Policy (the "OASIS IPR Policy"). The full [Policy](#) may be found at the OASIS website.

This document and translations of it may be copied and furnished to others, and derivative works that comment on or otherwise explain it or assist in its implementation may be prepared, copied, published, and distributed, in whole or in part, without restriction of any kind, provided that the above copyright notice and this section are included on all such copies and derivative works. However, this document itself may not be modified in any way, including by removing the copyright notice or references to OASIS, except as needed for the purpose of developing any document or deliverable produced by an OASIS Technical Committee (in which case the rules applicable to copyrights, as set forth in the OASIS IPR Policy, must be followed) or as required to translate it into languages other than English.

The limited permissions granted above are perpetual and will not be revoked by OASIS or its successors or assigns.

This document and the information contained herein is provided on an "AS IS" basis and OASIS DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY WARRANTY THAT THE USE OF THE INFORMATION HEREIN WILL NOT INFRINGE ANY OWNERSHIP RIGHTS OR ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

This document is intended to become a Non-Standards Track Work Product. The patent provisions of the OASIS IPR Policy do not apply.

Table of Contents

1	Introduction	1
1.1	References	2
1.2	TeMIX Market Structure	2
2	The TeMIX Model	3
2.1	TeMIX Parties and Roles	3
2.2	TeMIX Products	5
2.3	Rate of Delivery	5
2.4	TeMIX Network	6
2.5	TeMIX Service Interface	6
2.6	TeMIX Market Processes	8
2.7	TeMIX Forward Transactions and Positions	9
3	The TeMIX Information Model and Services	9
3.1	TeMIX Products	9
3.2	The TeMIX Services	11
Appendix A.	Revision History	12

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 (1) owners of energy consuming devices, generators or storage with metered delivery, or (2) financial parties with no intention of actual delivery, (3) suppliers and consumers of physical energy transport services, or (4) suppliers and consumers of financial energy transport services. A seller can be a consumer that is selling back by reducing a purchased position. A buyer can be a supplier that is buying back from a sold position.

TeMIX needs no hierarchy. Where regulations permit, TeMIX provides that any party can transact with any other party, or with intermediaries as desired. For example a Retail Energy Provider (REP) might buy from and sell to 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 through 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 and OASIS Energy Interop. 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. One or more such transactions result 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 prices to coordinate retail and wholesale energy consumer and producer decisions. Coordination occurs through large numbers of frequent small priced tenders and transactions executed automatically by smart devices. 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. Where an element of control is necessary, TeMIX options provide that a party can agree to an option that a counterparty can exercise as desired.

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, Grid Interop 2010, 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.

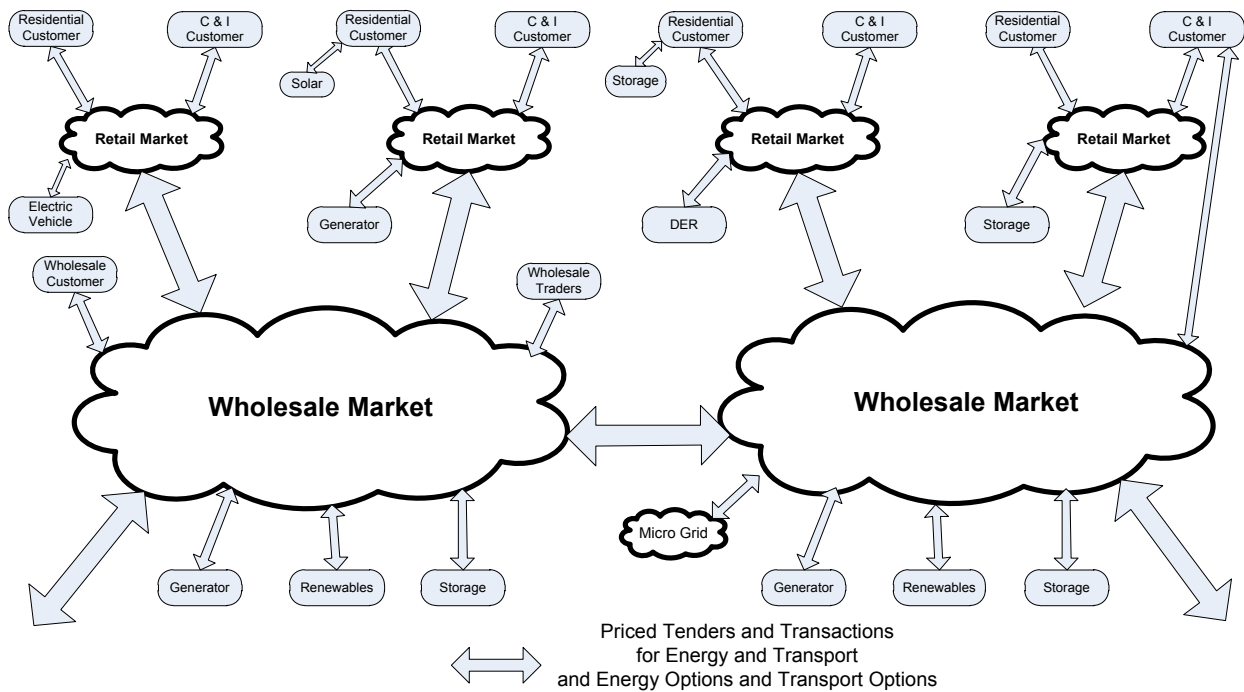


FIGURE 1 : TeMIX MARKET STRUCTURE

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

Instances 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.

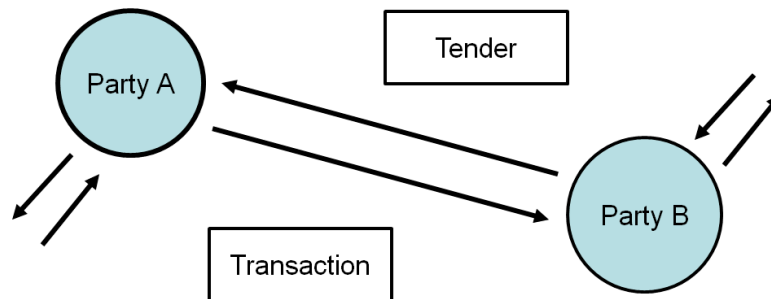


FIGURE 2: PARTIES INTERACTING WITH TENDERS AND TRANSACTIONS AS EITHER BUYERS OR SELLERS

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 caps and floors 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.

The 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 Start Date Time and Duration. TeMIX Products for each TeMIX Delivery Interval are tendered and transacted independently of the others. Delivery intervals are nested so that shorter duration intervals fit within longer duration intervals. A typical set of nested durations might be a calendar year, calendar month, day, hour, 5-minute, or 4-second interval.

2.3 Rate of Delivery

The quantity of a 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 interval¹. A constant rate of delivery clearly defines the rate of delivery in each nested subinterval of the interval, a necessary requirement to allow subsequent transactions on the 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 for an hour of the 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.

¹ 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.

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

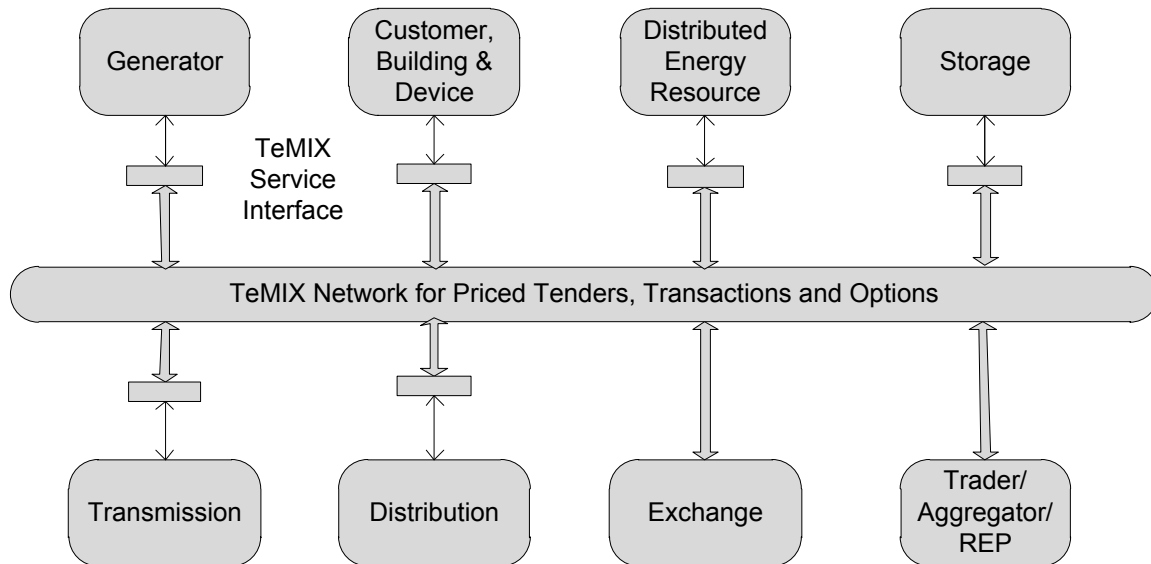


FIGURE 3: ILLUSTRATIVE TeMIX NETWORK

2.5 TeMIX Service Interface

The TeMIX Service Interface as shown in Figure 4 is an implementation of an EMIX Energy Services Interface. TeMIX Service Interfaces are associated with devices. In the case of intermediaries such as aggregators, traders, retail energy providers and exchanges, no devices are present.

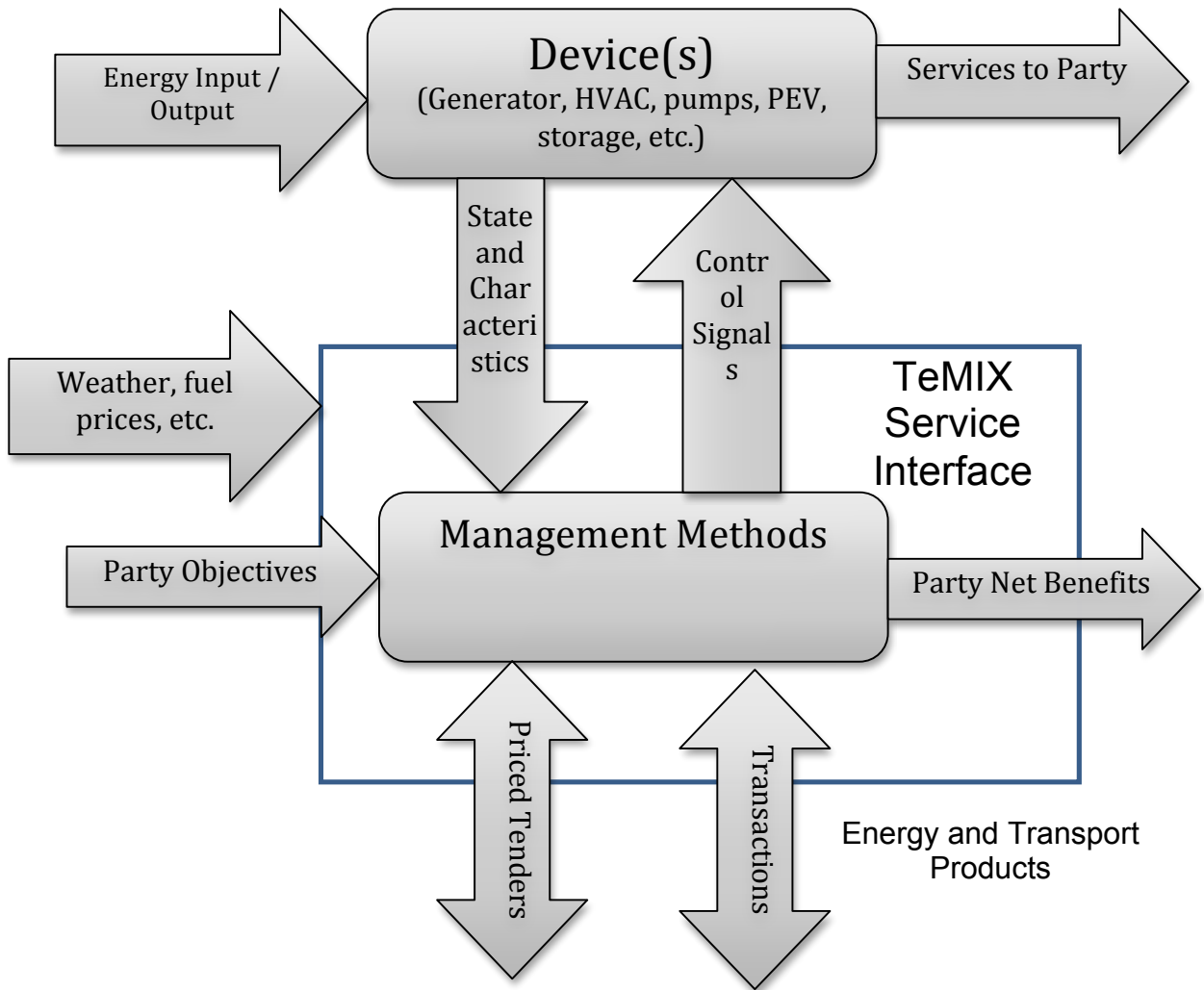


FIGURE 4: END DEVICE AND TeMIX SERVICE INTERFACE

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

An end device produces or consumes and may store electric energy. Large generators, distributed generation, variable wind and solar renewables, and storage are end devices. Residential, commercial and industrial customer air conditioning, heating, pump, lighting, and electronic equipment are also end devices.

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

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

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

generators, generators and storage typically do not 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.

Where optimization is used the objective is to maximize Party Net Benefits based on party objectives, current state and characteristics of the device, and external variables such as weather and fuel prices. Management optimization and control may be hosted in embedded processors in the device or within energy management systems controlling several devices at a site. Control may also be hosted by a 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 date 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 by a party may be with several different counterparties.

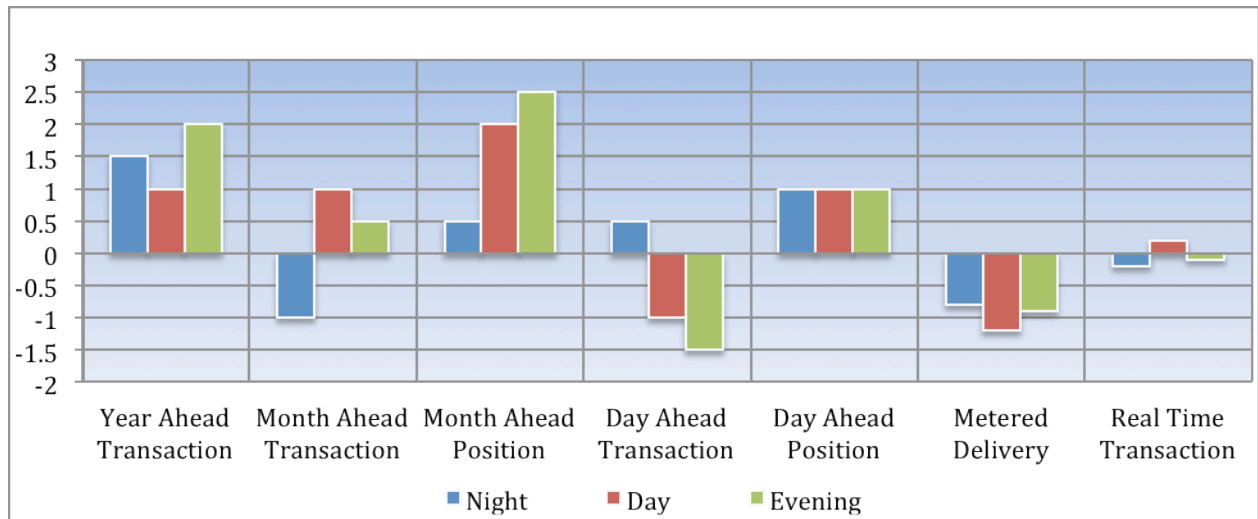


FIGURE 6: ILLUSTRATIVE SEQUENCE OF FORWARD AND REAL TIME TRANSACTIONS

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.

TeMIX Element	Description
Price	The Unit Energy Price for the Interval. TeMIX does not allow Relative Prices or Price Multipliers.
Energy Item	Total Real Energy (Power * Time) delivered over the Interval
Power Quantity	Rate of Delivery of Energy over the Interval.
Transactive State	Indication of Interest, Tender, Transaction, Delivery or Publish.
Side	Indicates side the information originator is on. Buy or Sell.
Expires Date	Date Time Tender expires. Only present if Transactive State is Tender.
Power Item	Units for the Rate of Delivery of Energy for the Interval.
Currency	Currency for the exchange.

224

225 For TeMIX Options the additional elements in Table 2 apply:

226 *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.

227

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

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

234 A TeMIX Option Product provides the Option Holder the right to instruct the Option Writer to
235 deliver (call) or take (put) a TeMIX Power or Transport Product up to the transacted quantity
236 (rate of delivery) of the Option at a Strike Price. A TeMIX Option can be exercised during the

237 Delivery Interval of the Option for any sub-Interval not smaller than the Option Interval
238 Granularity.

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

242 3.2 The TeMIX Services

243 TeMIX Services are defined in Energy Interop. At this time, the services for TeMIX and
244 Transactive Energy are in final development.

245 A TeMIX Service conveys a TeMIX Payload from a Party to a CounterParty

246 A TeMIX Payload conveys a TeMIX Product Description for a single interval.

247 Typically the Payload will consist of a Universal Identifier (UID), Start Date and Time, Price,
248 Power Quantity and Expires Date (for Tender only).

249 The UID references the remaining elements of the TeMIX Product Description described in Table
250 1 and 2. The UID may reference an EMIX Market Context directly or a WS-Calendar Gluon which
251 also references an EMIX Market Context where the remaining elements are placed. This
252 provides for a compact payload for each Tender or Transaction.

253 For Tenders the TeMIX Services are EiCreateTender, eiDistributeTender, EiCancelTender and
254 EiRequestTender.

255 EiCreateTender communicates a Tender from a Party to a list of one or more identified
256 CounterParties. EiDistributeTender communicates a Tender from a Party to a set of potential
257 CounterParties identified by a geo-location, group or other attributes.

258 For Transactions the TeMIX Services are EiCreateTransaction and EiRequestTransaction. A
259 Transaction is created between two parties when a CounterParty accepts a Tender using
260 EiCreateTransaction.

261 Similar services and payloads are provided for the other Transactive States (Indication of
262 Interest, Delivery and Publication).

263 Appendix 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.
Wd06	11 Oct 2011	Ed Cazalet	Editorial changes and initial summary of TeMIX Services

264

265