Review of [Energyinterop-CTS-v1.0]

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This white paper and comments are submitted to OASIS concerning a proposed draft of the Common Transactive Services profile [Energyinterop-CTS-v1.0] and may become publicly available by the review process.[1]

CTS, having been derived from wholesale electricity market practices, addresses the profile of an important but limited type of transaction between members of a transactive energy system. Namely, it represents a bid or offer of binary flexibility from an individual supply or demand object. CTS therefore may lack functionality needed for some emerging transactive energy systems. Specifically, the standard lacks abilities to represent

- Inflexible supply or demand
- Price-sensitive supply or demand
- Aggregation of supply offers and demand bids

There are potentially elegant ways to extend CTS to facilitate these capabilities that are currently missing from the draft standard.

Specific line-by-line comments and recommendations are offered toward the end of this white paper.

1. Binary Flexibility of Individual Objects

CTS is suited for representing the binary flexibility of individual supply or demand objects.

CTS is perfectly able to represent an offer from a conventional fueled generator, for example. The generator offers a quantity of supply at a strike price. The generator may become dispatched if the quantity is paired to willing demand via bilateral trading. Alternatively, the generator may become dispatched by a market if the market clears at a price greater than or equal to the strike price. It is irrelevant how the transactions proceed, but the CTS is suitable for either bilateral trades or real-time bilateral markets.

CTS can represent simple binary flexibility from an object. CTS could represent a bid from a residential water heater to consume a quantity of electricity, for example. The control action is binary. If the bid is accepted, the water heater heats water; if the bid is not accepted, it waits idle. CTS could have been used for PNNL's Olympic Peninsula field study, for example, which created a real-time double auction and managed devices as described in this paragraph.

However, the applicability of such binary flexibility works only for relatively short time intervals. Many end-use devices must eventually operate and provide a utility to their owners, which is why applicability of CTS may be limited to short-term, real-time market intervals. Over long time intervals such devices cannot remain off. An unstated requirement of CTS is apparently that it requires a pre-existing market position or baseline, and a CTS-based offer or bid represents a

[1] https://docs.oasis-open.org/energyinterop/ei-cts/v1.0/ei-cts-v1.0.pdf.

diversion from that baseline. It does not seem that CTS can represent the baseline itself, however, although its parent EMIX is said to have this capability.

It is argued that CTS can represent aggregated supplies and demands. For example, a bid or offer could be made via CTS for an entire building or for the entities within an energy microgrid. But this works only if the aggregate flexibility remains binary and can be represented at a single strike price. This limits the communication of priorities, as would be possible using supply and demand curves, where quantity may be a rich function of price alternatives.

CTS can apparently flag a bid or offer to indicate that its quantity may be partially accepted, but all subquantities then possess the same strike price. CTS also may communicate multiple "Tender" offers to buy or sell, but it does not address the association of such alternatives into a cohesive supply or demand curve and the resulting mutual exclusivity of such alternatives.

The commonality between all binary flexibility is that it can be represented by the pairing of a single quantity and single strike price. Figure 1 shows three alternative graphical representations of a CTS bid (or, more generally, of a single object's binary bid or offer). Panel (a) is a conventional way of showing supply and demand, as adopted from wholesale electricity practices. Both supply and demand are shown as positive quantities in the same quadrant. The top, right corner of the supply block is the offered quantity and strike price. Panel (a) shows a single offer. Demand is typically shown as a line. Here an inflection occurs at the demand quantity and strike price.

Panels (b) and (c) are alternative representations that use signed quantities and prices. The only differences between the two panels is that (b) shows price as a function of signed quantity, and (c) shows signed quantity as a function of price.[2] While these functional relationships could be mathematically represented in many ways, this white paper will use a piecewise linear approach, which provides a pathway for extension of CTS quite naturally to a broader set of TE applications. A CTS bid or offer requires a single pairing of price and quantity (i.e., a single "vertex"), but a second point is implied for the alternative binary action—the quantity zero at the strike price. This distinction is subtle, but it is important to the extensibility of CTS. Namely, CTS will be extensible if it explicitly includes what is now an implicit price/quantity pairing. Incidentally, all bid and offer prices should be understood to, in effect, extend to positive and negative infinity as shown in panels (b) and (c).

[2] Panel (c) is like the graphical representations used in Koen Kok's thesis. In this white paper, positive quantity is assigned to electric supply.

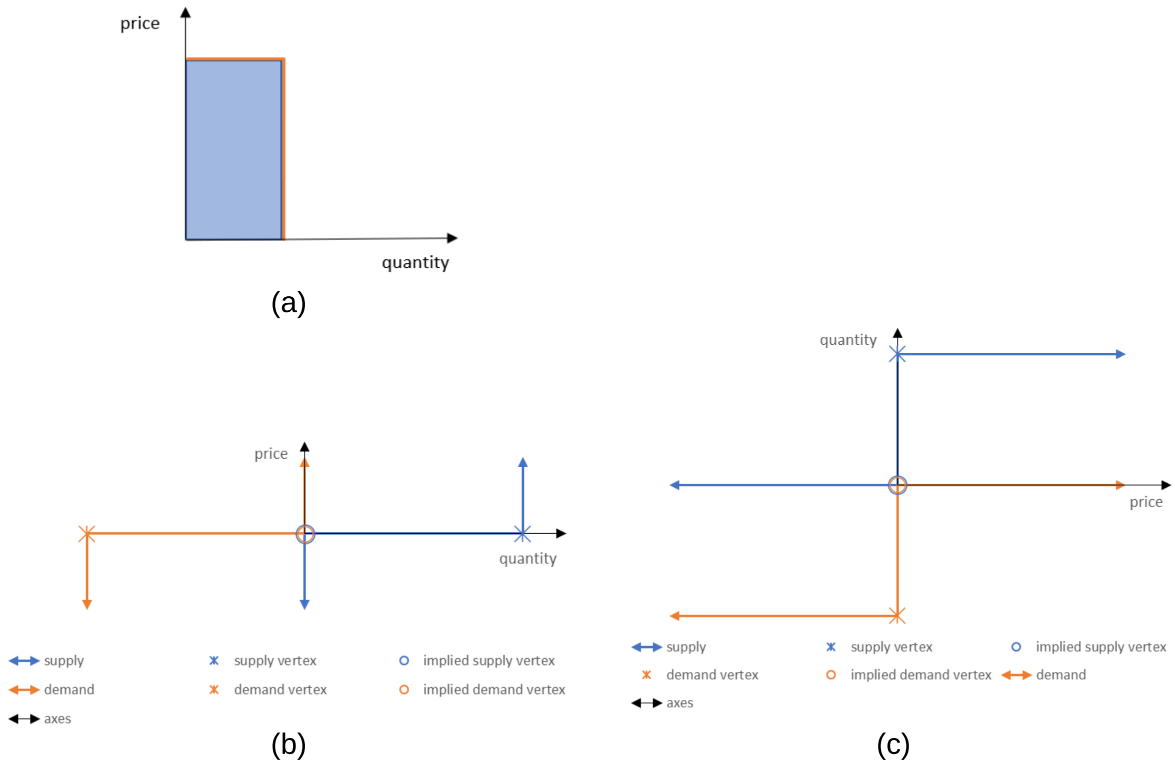

Figure 1. Alternative representations of binary flexibility for individual supply or demand objects. (a) Conventional unsigned supply block and demand line; (b) signed price as function of signed quantity; and (c) signed quantity as a function of signed price.

2. Representing Inflexibility

Transactive energy systems should be able to represent both their flexibility and inflexibility. Failure to do so will create exceptions and will rely on assumptions—like the existence of a predetermined market position or baseline. Consider, for example, a transactive system design that must communicate not only its available flexibility, but also its existing baseline apart from such flexibility. Regrettably, the number of objects having no flexibility is typically much greater than the number offering flexibility. Also consider the growth of renewable energy resources, which contribute virtually no flexibility to be controlled by prices but are becoming an important component of global electricity supply.

Figure 2 demonstrates alternative representations of inflexible supply and demand. Unlike the binary flexibility discussed in Section 1, inflexible supply or demand possess no meaningful strike price. Inflexibility implies that the quantity would be the same regardless of price. One way to extend CTS to represent inflexibility would be to populate the strike price with a value (e.g., ∞ or NULL) that would clearly indicate inflexibility. If this number or symbol is used consistently, it would be easy to identify and aggregate inflexible supply and demand.

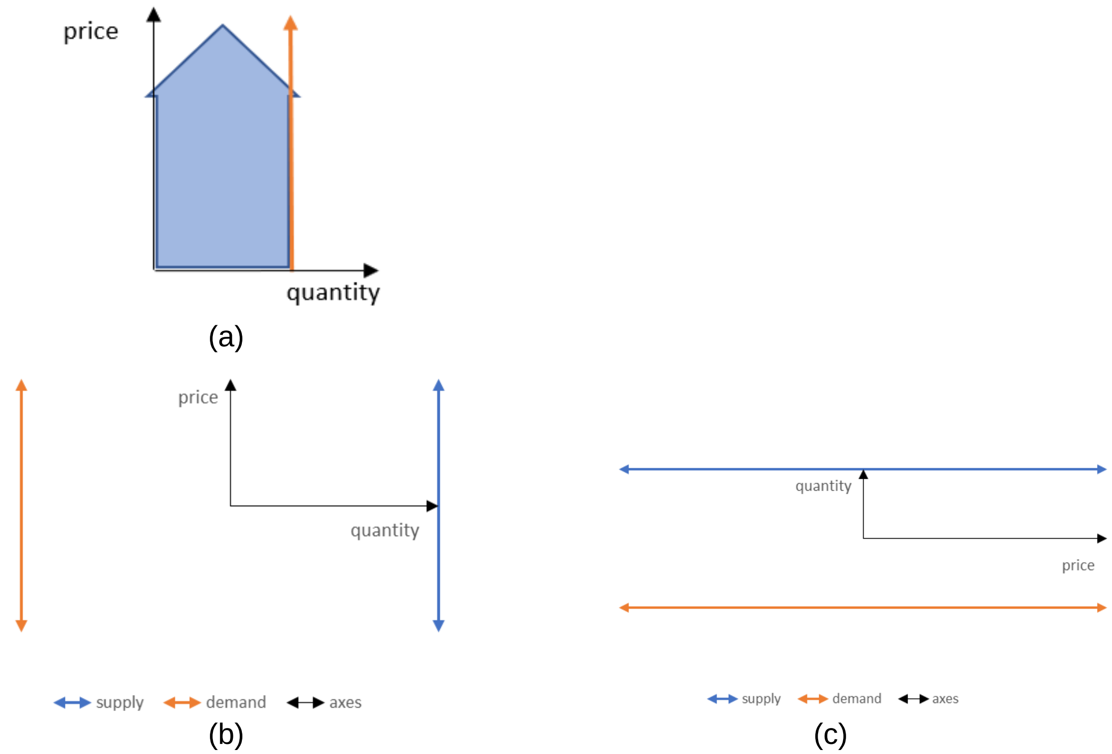

Figure 2. Alternative representations of inflexible supply or demand. (a) Conventional unsigned supply block and demand line; (b) signed price as function of signed quantity; and (c) signed quantity as a function of signed price.

3. (Linear) Price-Sensitive Flexibility

Transactive energy systems should also be able to represent non-binary opportunities like price-sensitive quantities. See Figure 3. The use of price sensitivity in bids and offers can improve the accuracy and effectiveness of energy balance achieved via auctions, especially as the system diverges from its normal, expected trajectory. Complete bid and supply curves can also reduce the numbers of iterations needed to discover prices using iterative consensus and game price-discovery mechanisms.

Price sensitivity appears quite naturally in conventional generator supply curves that are typically derived from their quadratic cost curves. If a cost curve is truly quadratic (not linear), offer prices are a linear function of generated quantity.

Price sensitivity also appears in transactive energy systems that discover price via centralized or distributed locational marginal pricing algorithms. Most notable is the effect of transport losses that make price become a function of system losses, which are in turn a function of transported quantity.

Price sensitivity comes into play for most controllable DER when time intervals become longer than what can be accommodated using binary on/off binary flexibility. Simple heuristic methods (e.g., thermostat bids based on zone temperatures) begin to fail when applied to relatively long future prediction horizons and long market intervals. Under these cases, bids and offers must more accurately predict the actual energy quantity and the impacts of any flexibility. One strategy is to optimize the likely outcome while monetizing the state of the utility (e.g., comfort or discomfort level) that is provided. The result of such an optimization is an indifference curve that expresses the willingness of a prosumer to exchange energy and money.

As suggested by Figure 3, CTS might be extended to support simple price sensitivity from an individual object if it were to support a second price/quantity pair. However, the next section will argue that CTS should preferably support communication of many price/quantity pairs if it is to represent effects of aggregation. Even individual objects might require multiple price/quantity pairs when their price sensitivity cannot be adequately represented by only two price/quantity pairs.

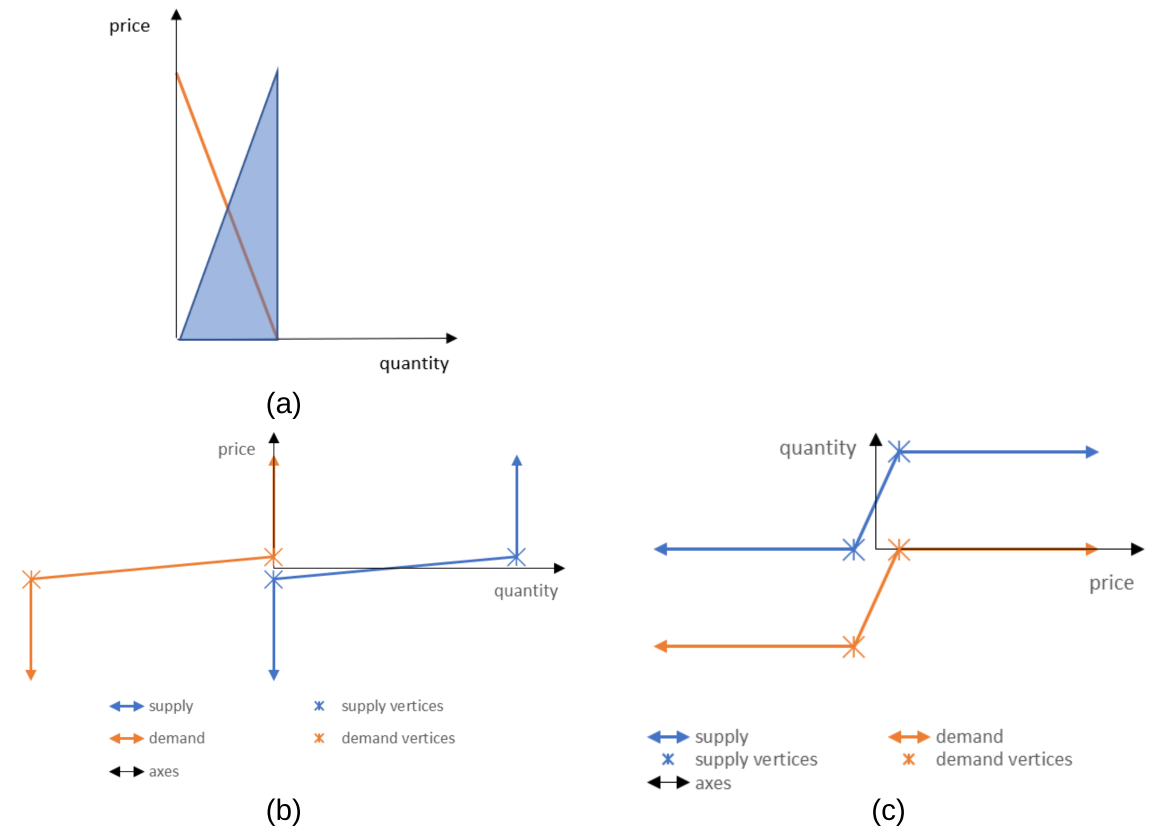

Figure 3. Alternative representations of individual price-sensitive supply or demand objects. (a) Conventional unsigned supply block and demand line; (b) signed price as function of signed quantity; and (c) signed quantity as a function of signed price.

4. Aggregated Flexibility and Inflexibility

Binary supply or demand flexibility might be acceptable for aggregation of household or building demand and supply. But it is unlikely that dissimilar objects' flexibility can be controlled in a binary fashion using the same strike price. Shouldn't DERs supplying utility of different value be prioritized by strike price?

In principle, a transactive energy system should be able to represent aggregations of bids and offers from sets of objects having binary flexibility, price-sensitive flexibility, and even inflexibility. The aggregation of an object without flexibility with another have binary flexibility is exemplified by Figure 4. In this example, there is no price at which the aggregate supply or demand quantity magnitude can be reduced to zero. A step appears at the strike price of the object offering binary flexibility.

If CTS were to support the supply and demand aggregations of example of Figure 4, it would need to communicate at least two price/quantity pairs. However, it would be better for CTS to support a greater or indefinite number of such pairs if rich aggregations of supply and demand are to be represented.

Incidentally, an aggregate curve could very well include both supply (positive quantity) and demand (negative quantity) price/quantity pairs, as would be needed for the indifference supply/bid curve from a battery system performing arbitrage. I recommend the consistent use of signed quantities, like those of panels (b) and (c), because the use of signed quantity avoids separation of an object's supply and demand components, as must be done when using unsigned quantities (i.e., panels (a)). Furthermore, the practice of using signed quantities greatly facilitates aggregation, requiring simply that objects' quantities be added at all defined strike prices, including inflexible quantities at strike price ∞.

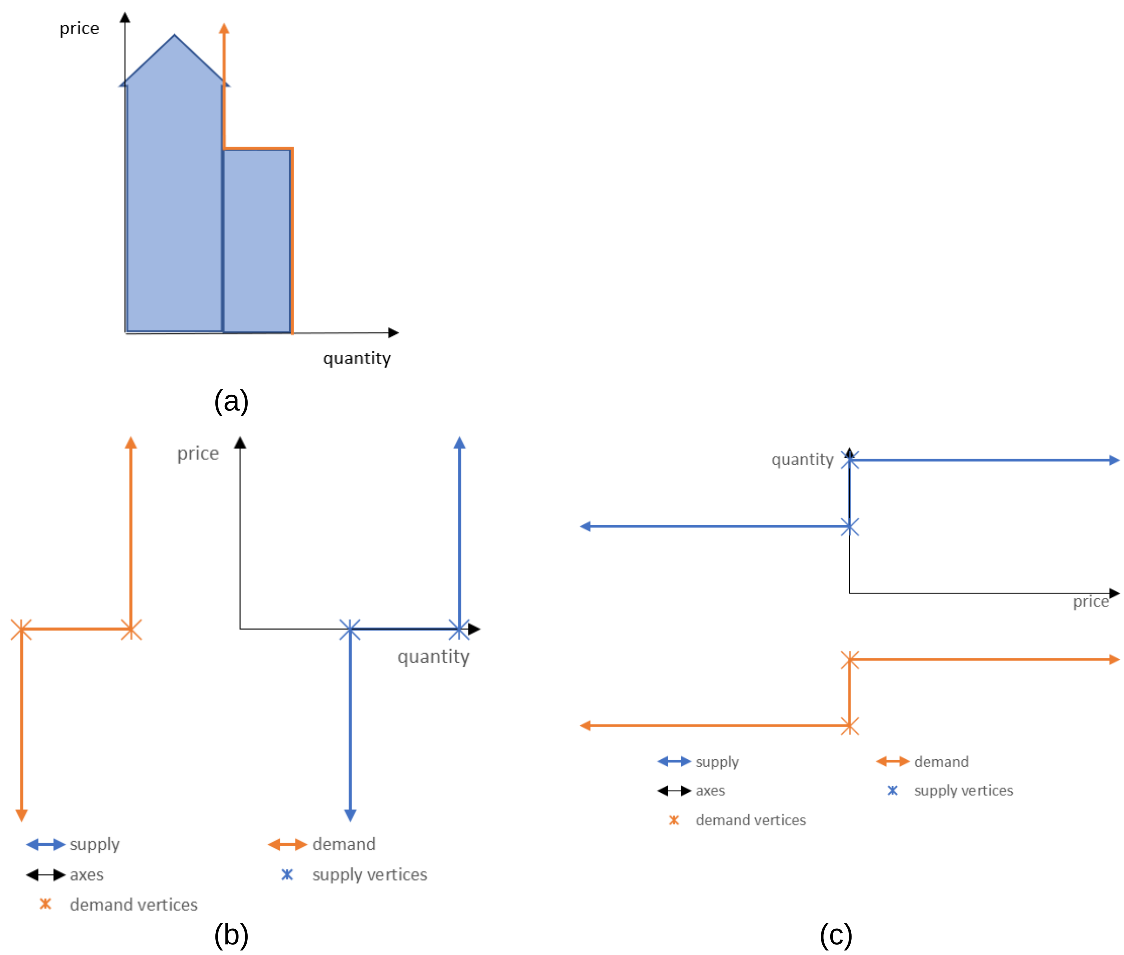

Figure 4. Alternative representations of aggregated supplies and demands including both inflexibility and binary flexibility. (a) Conventional unsigned supply block and demand line; (b) signed price as function of signed quantity; and (c) signed quantity as a function of signed price.

5. General Recommendations

Here is a summary of how CTS might be modified to extend its applicability to the future cases discussed in this white paper:

1. Select and use a sign convention that will allow electricity quantity to be consistently expressed as a signed quantity.
2. Consider the practice of supporting sets of price/quantity pairs (i.e., vertices) to approximate the functional relationships between price and quantity in a single time interval. This would be a natural extension to CTS, which currently supports a single price/quantity pair.
3. Specify a price (e.g. ∞) to indicate inflexibility. The pairing of this indication with a quantity would thereby represent a constant, inflexible supply or demand quantity. Upon completing this extension, the use of existing baseline quantities can become a design option rather than implied necessity. Regardless, documentation should not be silent concerning this current limitation of CTS to only flexible supply and demand components, which implies the need for a baseline apart from CTS.
4. CTS appears to be silent concerning the effects of location. While it is claimed that locational impacts are in scope, it is not clear that an Actor's circuit location must be communicated.

6. Specific Recommendations

Here are some specific editorial corrections and comments that refer to lines and sections of the draft CTS standard:

- Lines 19 – 22: It is problematic that the broader TE community does not universally accept this narrow definition of TE. CTS may work within this narrow definition of TE, but the application of market structs in electric distribution systems and end uses is an immature, evolving technology, and CTS is not yet adequate for communication in these newer visions.
- Lines 30 – 32: My content above explains why CTS may not be future proof for future TE systems and for mechanisms that already differ from that envisioned by the CTS authors.
- Line 49: Please see the content above concerning CTS limitations in respect to aggregations of collections of devices. The biggest limitation is that a CTS message possesses only one strike price, which is inadequate to represent aggregations of dissimilar, prioritized devices, that may have differing associated prices and quantities.
- Line 64: The "Side attribute" in an energy market is unneeded if signed quantities are used. How would a battery system offer to transition from being a buyer to being a seller at a given price, for example? It is potentially problematic that a baseline is being assumed but not defined for all TE implementations.
- Section 1.6: Do not jump between use of "EI," "Energy Interoperation," and "Energy Interoperation 1.0." I presume these are all covered by acronym and reference "[EI]".
- Section 1.6: I'm awaiting the novel value of this "minimal transactive profile." If valuable, why are the referenced standards not being extended instead of creating a separate CTS standard?
- Section 2.1.1: This claim of hierarchical or "fractal" application of CTS is questionable. It seems that CTS provides means of procuring needed and selling surplus energies in time, but it does not aggregate the opportunities that could be embedded in an aggregate supply or demand curve. It is unlikely that dissimilar aggregated devices or prioritizable actor preferences can be combined at the same identical strike price.
- Table 2-1: Row "Market Context": Acronym "URI" has not been previously defined and should be spelled out on its first use, please.
- Table 2-2: Facet "Marketplace" might be needed where multiple markets exist.
- Section 2.2.1: This treatment of "facets" seems to be a step backward and is not architecturally sound. The "facets" are first introduced as properties of interactions and

later as Actor roles. These are certainly not actor roles and do not inherently even belong to Actors. What an odd mix! (Maybe these are “interaction profiles”?)
  - The Market is an object from among Marketplaces and may have numerous attributes.
  - An Actor owns a Position via an accumulation of Instruments.
  - Tender, Transaction, Delivery, (Quote) address states of an interaction and were more clearly addressed by a TEMIX enumeration. This may be an unwise simplification, as it limits future extension of interaction attributes.
- Section 2.2.2: The attribute Side (i.e., Buy or Sell) is unneeded if signed quantities are employed.
- Table 3-2, Resource row: Consider offering an extensible enumeration for Resource. If this is not done, duplicate Designators and Names will evolve for the same Resource.
- Lines 355 – 6: Editing needed.
- Lines 349 – 362: Recommend deleting since content was addressed by EMIX and is permitted as stated in Line 363.
- Line 376: Editing needed.
- Line 378: “Products” ➔ “Instruments”?
- Throughout: Consistent capitalization of “Products”, “Instruments”, “Transactions”, etc. is needed.
- Section 4.1 and throughout: I’m finding usage of “facet” to be misleading and confusing. These must be properties of some object or class or references to objects’ behaviors. Part of the problem perhaps evolves from the double meaning of “transaction” that is being allowed. At times it refers generally to an interaction between Parties; at other times, it refers to a specific state of that interaction after a Tender has been accepted and contracted. If this confusion were resolved, you could make clearer reference to the various properties and states that surround interactions between parties.
- Throughout: Once defined, use “[EI]” consistently.
- Line 452 – 3: Since conformant CTS implementations need not be owned by the same implementer, it is unwise to permit omission of the UID property. This permission to omit also appears in Tables 5-1 & 5-2.
- Table 5-1, “Resource Designator” row: Shouldn’t this be a reference to a specific Product, not Resource?
- Section 6: This is finally made clear that the “Market Facet” refers to a defined query behavior or “interaction profile.” Why not use an informative, intuitive name like “Request Market Characteristics” instead of inventing all these “facets”?
- Section 7: As for the prior comment, use an informative name like “Party Registration” for this interaction. I would vote to entirely eliminate word “facet” from this document as it is not defined and useful within a standardization context.
- Section 7: The properties of a Party are not addressed, but the Party of an electricity market should specify location, I hope, if it is to support future location-specific transactions and outcomes.
- Section 8: This section points out the weakness of using transaction and Transaction differently. I liked the use of Transaction in TEMIX as a state of a transaction. All this subtle distinction is lost if capitalization is not used consistently, as is the case in this section.
- Lines 596 – 7: Editing needed.
- Table 9-2: I think the fact that an EiTransaction *always* has Transactive State=transaction is a vestige of an earlier, preferable approach. Wouldn’t it be much more elegant to define a single transaction behavior, in which the transaction migrates through its available states? Each of the Tender Facet, Transaction Facet (and possibly

Quote Facet) should be defined as state transition behaviors, but I question why the structure of the interaction payloads should differ at all.

- Line 669: Editing needed.
- Figure 11-2 (and elsewhere re payload intervals): I've observed that CTS streams reference integer interval series, whereas many interaction payloads reference Interval objects. It is unclear to me what, if anything, associates a Party's CTS streams to specific Instrument Interval objects.
- Section 12.1: Why must this [EI] content be duplicated and not included simply by reference?
- Section 12.2: Recommend deleting this section unless a useful distinction between "Tickers" and "Quotes" can be stated.