Energy, Micromarkets, and Microgrids

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Abstract

Markets are the proven best means to balance supply and demand. Central allocation techniques such as Demand Response are less efficient; the need for baselines for curtailment introduce complexity and significant incentives for gaming; attempting to compose markets for curtailment with broader markets for energy and power introduces mismatches in information.

We define markets that are simple and scalable (micromarkets) and compare and contrast them with today's wholesale energy markets (macromarkets), detail their similarities and differences, and show how binding micromarkets to microgrids enhances balance of supply and demand. Micromarkets share many characteristics of macromarkets but are more local and use simpler market rules and interactions, reducing the cost of entry and transaction costs.

Using formal product definitions for micromarkets enables consistent sale and purchase of better-behaved energy and power products, and encourages transactions needed to balance a micromarket in a broader context.

In a previous presentation [StructuredEnergy] we showed how to compose microgrids using markets. Taking this concept further, we describe binding of simple markets to sets of microgrids to improve balance and quality of products transacted.

1. INTRODUCTION

We examine the similarities and differences between two broad classes of markets, consider the complexity of interactions, mechanisms, costs and barriers, and suggest novel ways to address those complexities.

As we described in [BusinessCase], the balance of supply and demand within a micromarket allows the offering and buying of better behaved products, which gives the ability to offer greater value and transact with more stable partners.

In many wholesale markets, the economic value of curtailment is not the same as that for generation [FERC, other refs]. The requirement to work within two markets (curtailment and energy/capacity), and the second-order effects of buying and selling (e.g.) curtailment to balance supply and demand on the margin appears less efficient than direct use of markets. We explore these and related notions in this paper, and provide definitions and mechanisms to implement such direct micromarkets.

Clearing transactions in a market requires delivery of products sold. Since delivery of energy requires switchgear and related technologies to implement microgrids, we propose directly binding micromarkets to microgrids.

Barriers to market entry include costs—of transactions, of participation—so we examine those costs and ways to limit their effect on market entry, clearing the way to market interactions for many small devices as opposed to fewer large participants.

2. DEFINITIONS

2.1. Micromarket

We apply the term *micromarket* to markets that are relatively simple and scalable. Micromarkets have requirements consistent with all markets, including

- Market clearing
- Converging algorithms
- Mechanisms for non-repudiation
- Clear rules

2.2. Macromarket

We use *macromarket* as a loose antonym of micromarket—loose because the characteristics on which they differ do not have clear dividing lines. Macromarkets, such as today's North American wholesale energy markets, tend to have relatively few participants (though a microgrid and micromarket may have fewer), more complex rules, and generally larger trading quantities. As a consequence, macromarkets may have complex (and non-automated) rules and procedures for market entry, and significant business risk and benefit associated with them.

Macromarkets have additional deployment requirements, which lead to greater overall complexity. These include

- Higher reliability
- Specialized security
- More specialized markets with regulation-based rules and algorithms

2.3. Balance

Markets provide a way to balance supply and demand without complete knowledge (the *Knowledge Problem* defined by [Hayek], Bastiat, and others).

3. MARKET SCALE

The scale of a market has at least five dimensions:

- The geographic dispersion of participants who may deliver or take delivery
- The density of participants within the geographic territory for the market
- The number of participants in the market
- The transaction size(s)
- Diversity of participants

Consider a market where needs for lighting affect market offers of devices on the level of light bulbs. The geographic dispersion is small (within a single facility, perhaps), the density is high, and the number of participants is also high. The transaction sizes would be on the order of Watts to kilowatts.

Contrast this to a wholesale market example, where geographic dispersion is regional or national, the density is low, the number of participants is low, and quantities are large (on the order of megawatts).

To take full advantage of market automation the scale is important—dividing the fixed costs of technology by millions versus hundreds of participants gives a very different value proposition. Leveraging the economics of software and chip-level hardware adds significant value. We therefore focus on reducing costs by simplification, consistent size, and increasing scale (and density) within a relatively small area.

The complexity of software systems can be high, showing barriers to participation and innovation. For example, if to provide a service one needs to understand thousands of pages of specification, the providers of that service will be limited.

On the other hand, low complexity of specification accompanied by high re-use of hardware and software can give significant economies of scale, evolution, and maintenance. Simple systems composed to carry out complex tasks without global knowledge is the essence of economic systems and markets.

This is not to argue that complexity is never needed; complex problems may be amenable to a variety of solutions: we suggest that the simpler solutions provide significant benefits in innovation, entrepreneurship (and its rewards), and adaptability.

4. WHY MICROMARKETS?

4.1. Local Decision and Action

One death is a tragedy; the death of thousands is a statistic[1].

The systems of dissimilar scale may display far greater diversity of characteristics than implied by the simple number representing that scale. While the technical aspects of micromarkets in energy naturally draw the practitioner's attention, it is the scale and the intimacy of these markets may have the most profound effect on technology and adoption.

Today's energy markets are national and regional, and are characterized by rigid requirements. Risk avoidance drives decisions: decisions about technology, about market participation, and about security. The resulting model hinders innovation, reduces engagement, and increases complexity. Each of these is a barrier to achieving the goals of smart energy.

Traditionally, no market was considered more local than real estate. An old saw has it that the three most important aspects of real estate are Location, Location, and Location. Real estate value was acquired through understanding the local purposes, and the local trade-offs. Real estate has never been a commodity.

Even in real estate, centralization of markets reduces small risks while increasing large ones. Recently, we have tried to treat real property and real property owners as commodities. Local knowledge was deprecated as assets were combined, and variability (risk) was tranched. Technocrats far away from the property, people, and their purposes discounted all asset value, financial wherewithal, and risk. Markets assumed that risk in aggregate, particularly local risk, could be eliminated almost completely. This encouraged greater leveraging of each market position. Like many an over-

[1] Attributed to Joseph Stalin

spanned, over-engineered approach, it worked until it didn't, and when it didn't work it caused a lot of collateral damage.

Beginning as early as 1967, North American power markets have tended in the same direction. Reliability was sought in binding together dissimilar assets; separate generation and distribution grids were bound ever closer to manage risk. Pervasive over-capacity allowed most problems to be solved, although occasional instabilities careened out of control.

Today's Demand Response programs can be considered an analogue of the tranches taken in today's finance to manage risks in real estate. Supply risk is sliced from the deal, ranked, and re-sold. Little concern is placed on the initial value of the load that is shed, or the purpose of the consumers. At least one current marketer bases its energy use more on the values of the hedges it can sell (ancillary services) than on the value received through energy use. The analogue of over-leveraging in finance is reduction of operating margins in power markets.

This works as long as the market remains simple. In power, as in real estate, systematic misuse of control to overcome ignorance of local value propositions can result in misallocation of power, and markets that are susceptible to gaming.

To counter this knowledge problem through central management, more sensing, more information, and more details are required. This hurts smart energy in three ways.

1) It reduces consumer buy-in to and acceptance of smart energy.
2) It slows the ability of the system to consume new technologies and new interactions, and is thereby a barrier to the rapid pace of innovation that smart energy will require.
3) It eliminates the cycle of early adoption defined by Rogers at al., reducing the willingness of new participants to enter the market.

Distributed energy introduces additional complexity that can break this model. Distributed energy creates local supply variations that may themselves never appear in the macromarket. These local supply variations, when paired with local demand variations, define the problem that can be that can most effectively solved locally: a local market to solved the local knowledge problem.

Micromarkets may have lesser requirements for security and for privacy than macromarkets. With these reduced requirements, there is less required complexity in each interaction. Because of the simpler interactions, a constrained system or device may be able to spend more resources on richness of services offered. As scale rewards population size above all, chipsets that offer a larger but configurable set of interactions may be more affordable than smaller, less functional chipsets aimed at the less granular and thereby more expensive systems that today participate in macromarkets.

4.2. Complexity and Functionality in Micromarkets

As distributed energy resources contribute a greater proportion of all power, the majority of markets (which may be different from the majority of power marketed) become local and most power transactions become are small. These small deals can coordinate large numbers of devices and systems. More and more transactions will be for the purchase or sale of power generated or controlled locally. Relatively few agents can still purchase power sources transmitted from far away; it will then be re-sold, in small transactions, in the local micromarket.

With a market based on such small transactions, it becomes essential to minimize transaction costs. Costs of even pennies a transaction are too large. The OASIS open standards for energy are freely available, free both as in free beer (at no cost to the implementer) and free as in free speech (with no restriction as to how used). These freedoms are both essential to the development of micromarkets.

Scale is another enabler of transaction costs small enough to potentiate micromarkets. The model of scale, as the term is used in technology, is that the silicon costs next to nothing, and the design and software costs are fixed. Units of systems sold or installed matter far more than the complexity of each system. A commercial building might represent a single market participant in the external market, and hundreds, if not tens of thousands of participants in its internal micromarket. The logic of scale may support more functionality within the micromarket than in the macro market, as the sum of micromarkets may have several orders of magnitude more participants.

4.3. Cost of entry and participation

Micromarkets may be more intimate than macromarkets. As at a local farmers' market, participants may know their suppliers, suppliers may know the needs of their customers. The security needs inside a micromarket may be much less than in the macromarket, not only less because the size of each transaction is less, but less because each transaction is inside the garden wall. With less effort on security for each exchange of information, the resources even of constrained agents are freed up to support richer interactions.

4.4. Emergent Order and Networks of Networks

Micromarkets and markets in general provide support for emerging order. See for example [KieslingGiberson] and Hayek [Hayek] [HayekNobel]. Our approach supports the understanding of markets as networks and networks of networks in which spontaneous order may develop within a simple framework. By attaching a micromarket to a microgrid, the market balances supply and demand at the local microgrid level; in turn the micromarket or its participants allow participation in further markets, where the locality of decision and balance takes place in a broader context.

[Galvin] defines microgrids as *"modern, small-scale versions of the centralized electricity system. They achieve specific local goals, such as reliability, carbon emission reduction, diversification of energy sources, and cost reduction, established by the community being served."* Under the Galvin "Perfect Power" model, the stability of larger grids is derived from the stability of the component microgrids.

Micromarkets are a means to balance energy supply and demand within a microgrid. Micromarkets hide the details of the technology in each participant/component under the common abstraction of the transaction. The microgrid as a whole can interact with other grids and microgrids using precisely the same abstractions and interactions. There is no inherent barrier to scale, as any collection or community can be sub-divided to fit the capabilities and requirements of the micromarket.

There is minimal impedance to the introduction of new participants, or new technologies. Systems are merely market participants. Microgrids are merely market participants in larger markets. Sub-dividing a microgrid merely results in multiple market participants. This approach is bottom-up; markets balance themselves, with needed inputs or outputs offered, bought, and sold in a broader (and likely less local) market, which in turn uses interactions in still broader markets to provide balance. Micromarkets align well with the [Galvin] model for improved grid stability.

In Figure 1 we see the self-organization without central control, built from local needs, shortages, and surpluses.

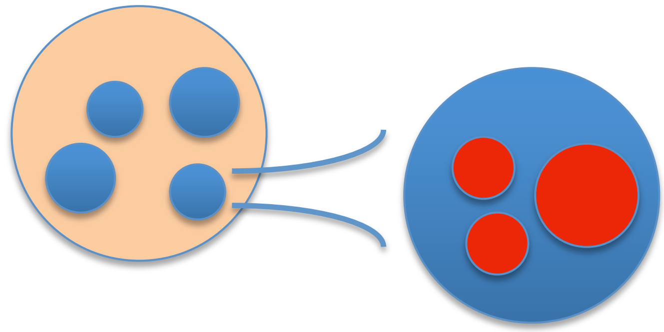

Figure 1 Micromarkets may be in turn composed of other micromarkets

Discoverable markets allow for dynamic evolution, which is critical for adaptation to changing circumstances.

4.5. Technology for Micromarkets

To maintain relatively low cost of development, deployment, and operation, we should assemble micromarkets from existing technologies where possible. The careful adherence to this philosophy will allow for simplicity scalability, and evolution of technologies to meet evolving needs.

5. FUNCTIONAL REQUIREMENTS

In this section we detail some technologies and interactions required for markets.

5.1. Discovery

Finding what products are traded, where to trade, and how to trade are all-important for automated configuration. A device that can participate in markets should be able to determine some aspects of the available markets without manual programming, thus assuring adaptability to multiple markets.

A device needs to make its own assessment of the relevance of local market products to itself. Some systems may come programmed with an invariant assessment of their own needs. Others may track [discover] their own market transactions [energy use] over time and in different scenarios. Time dependencies are as critical an element of this discovery as is energy use.

The third prong of discovery is the value of the services provided by a device when it provides them. Some, such as a life/safety system, may come pre-configured with an fixed or even mandated value for their services. Others may discover the value of the services they provide, including how it changes over time, through user interfaces or some coordinating application.

Each system or device, then, must discover the critical information it needs to act as an agent in the micromarket. It discovers market rules, market products, and something of the other market participants. If it is not pre-set and fixed, it must discover its own pattern of consumption or generation of market-relevant products. If it is not pre-set and fixed, it must discover the values of the services that it provides.

5.2. Simple Market Interactions

The required interactions are

- quote (give a price, one at which tenders may be made or not),
- tender (offer, bid)
- transaction (accept offer), and
- delivery (validate delivery as agreed)

The interactions may be with a single counterparty, or with one or more markets. Participation in more than one market allows the possibility of arbitrage.

5.3. Clearing Algorithms and Methods

We do not discuss algorithms and methods here except to say that simple algorithms and interactions are likely better for participants by reducing market operating costs and market entry costs.

Simpler algorithms will also improve scalability and evolvability. The OASIS specifications [EMIX] and [Energy Interoperation] do not presume any specific market algorithms or methods.

The discovery model described above, market, self, and service, presumes autonomy among agents of greater or lesser capability. The competence of a given agent acting as a participant in each market may be a distinguishing factor between different products offering the similar services.

Simple, non-deterministic market rules are likely to support rapid evolution of and competition between clearing algorithms and methods. Market clearing would then be best viewed as an emergent order, as it is in traditional markets.

5.4. Separation of Delivery and Market Transactions

On buying a product for delivery in a certain quantity, at a certain place, and at a certain time, the final step is to validate delivery. For a simple view of delivery see [EnergyInteroperation] section 7.5. Temporal separation between purchase of forward contracts or options requires separation of the post-transaction delivery validation.

6. DEPLOYMENT REQUIREMENTS

In this section, we detail some requirements on deployment of market technologies, focusing on micromarkets.

6.1. Scalability

The scale of the market is critical. Commercial software, particularly for web and eCommerce use, typically takes a multi-tiered approach [MultiTier] to deal with high transaction rates and scalability. [2]

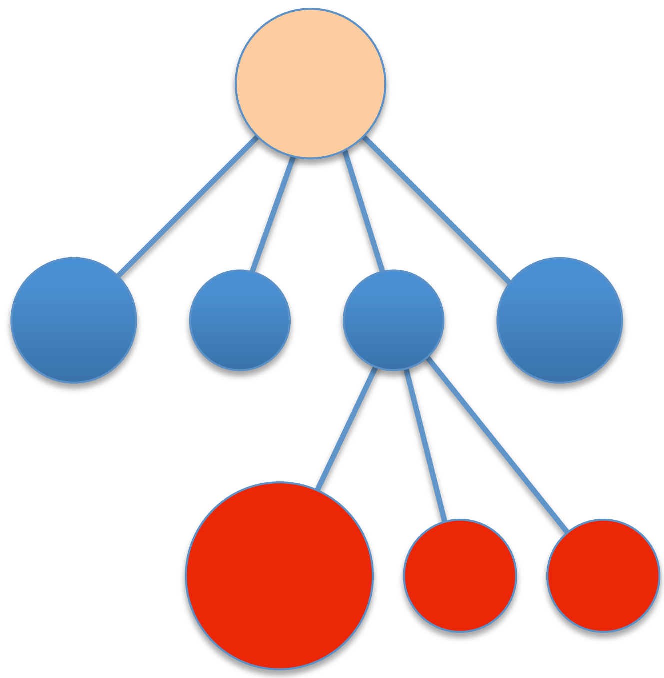

FIGURE 2 MULTITIER ARRANGEMENT OF MICROMARKETS

We suggest something very similar by defining and binding markets that have those characteristics, with an analogy to higher level markets in higher tiers. Note that this is Figure 1 redrawn to emphasize the multi-tier aspect.

6.2. Reliability

In typical eCommerce deployments, the reliability needed is composed into the interactions. One example would be composing a reliable messaging infrastructure (e.g. [WS-Reliability], [WS-ReliableMessaging]) or common combinations with (say) security. Reliability may be accomplished at the application or transport layers.

[2] Most examples, however, deal with presentation and web layers.

Interactions with a micromarket would tend to be similar across all participants, potentially simplifying the reliability choices.

6.3. Security

In a manner similar to reliability, after an analysis of security requirements, a deployment would compose the necessary security into the transport or application level for interactions.

6.4. Clearing Algorithms and Methods

It suffices for these simple markets to choose within their scope appropriate market design, rules, and methods. A micromarket determines clearing prices; the specific design is irrelevant. Market rules must align only with the volatility of energy supply and demand in the microgrid they support; momentary changes in energy use cannot be balanced with market rules that only clear daily.

The product definitions supported by a market arguably are more uniform, but even there the adaptation of markets to reasonable timeframes and common scale of purchases has evolved slowly.

7. SIMPLIFICATION IN MICROMARKETS

Work by Edward Cazalet [TEMIX] holds much promise for micromarket application. The simplifications proposed, e.g., to single blocks in a transaction, combined with Block Power products, drives simplification of interactions, with other mechanisms for combining the simple purchases and sales.

For example, in a TEMIX transactive interaction, if an energy profile needs to be purchased (say for an industrial process), the composition may be with Transaction Processing approaches (generally requiring the generality and loosely coupled nature of [WS-BusinessActivity]). In the alternative, composition of blocks can be expressed in [EMIX] allowing a single transaction to address a changing load. In that way the composition can be either inside or outside the product model

8. TOOLS TO BUILD MARKETS INTERACTIONS

There are some standard information models and interoperation patterns needed to assemble markets and implement market operations. We draw from interoperation specifications meant to communicate with and interoperate with any market.

OASIS Energy Market Information Exchange [EMIX] defines price and product definition in an information model rich enough to address all known Smart Grid markets and price communications, as well as an extensibility and evolution mechanism. EMIX artifacts can describe simple or complex schedules with product descriptions applied to them, and a simple profile of EMIX, Transactive EMIX, or TEMIX [TEMIX notes].

OASIS Energy Interoperation [EI] defines messages and payloads for transactive interactions and for generation and curtailment (DER and DR) events, building on the EMIX information model. The specification (in Public Review 3 as this conference opens) also defines three profiles for OpenADR2 (Open Automated Demand Response 2), for price distribution and for transactive operations.

The use of Transactive EMIX and the TEMIX profile of Energy Interoperation have been described by [Cazalet] [TEMIX Notes]

The Energy Interoperation architecture describes a directed graph of actors taking roles, each actor associated with application code. Though the examples [EI] are for distribution of energy curtailment or generation, they also can be used to convey price quotes and to structure market scopes.

In deployments, each edge in the directed graph is composed with appropriate security, reliability, and performance (through direct composition or designed in the implementation). By binding a market to sets of nodes in the directed graph of actors, a market can be implemented for part of a building or factory, a facility, a neighborhood, or an office park

We use these tools, defined by the authors and others in the OASIS standards process, to interact within, without, to, and from micromarkets.

9. BINDING OF MICROMARKETS AND MICROGRIDS

Micromarkets require delivery of the product. Microgrids allow (and in fact are defined by) the ability to shift energy and power within. There is a useful symmetry of managing the balance of supply and demand in a microgrid by means of a co-extensive micromarket.

Participants in more than one microgrid [StructuredEnergy] must be able to delivery and receive the products bought and sold. North American markets typically distinguish between transmission (longer distances) and distribution (shorter distances, more end points) with different regulatory regimes. Microgrids (composed or standalone) can be structured to allow avoidance of complex regulations designed for much larger scale enterprises. This will be and has been a continuing effort to avoid inappropriate regulation and permit

10. PARTICIPATION IN MARKETS

Macro-energy requires fungibility of product and requires normalization of energy delivery.

Micro-energy supports diversity of use, which supports diversity of product. Heat need not be converted to power and back, if heat can be transferred, exchanged, or used locally. A similar argument applies to potential energy. Storage can include in-process storage.

This increases potential diversity of participation, and expands the range of market-based interactions. Existing well-proven models such as the cogeneration models promulgated by the IDEA, are built on this premise. The models have traditionally required long and careful integration, and have been difficult to evaluate the net economic effects of each decision

Micromarkets offer a model for district energy that supports agile integration of devices, systems, and technologies.

Micromarkets also support diversity of external supply. They support balancing of diversity of Power source, whether traditional or supplied by local wind, sun, or storage.

In a similar way, they support fungibility of energy purchased externally, including moment-by-moment comparison of, say, externally source Power and Natural Gas. By abstracting the value of thermal energy and power to economic signals, they establish a fungeability of energy. This creates a model of comparison between these dissimilar sources, and their relative value at this site, with the current equipment, and with the current services expected by from not just the microgrid, but from the building.

11. SUMMARY AND CONCLUSIONS

We have defined and described micromarkets, a means of structuring and simplifying markets, along with a rationale for binding micromarkets to microgrids with switching capabilities.

Micromarkets allow the network of networks, the system of systems that is the Smart Grid to self-structure more rapidly, using bottom-up information on local needs, shortages, and surpluses.

The implementation of micromarkets is straightforward using the OASIS Collaborative Energy Standards. This combination realizes the promise of the Smart Grid by connecting better behaved loads and sources to broader but simpler markets.

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Biography

William Cox

William Cox is a leader in commercial and open source software definition, specification, design, and development.

He is active in the NIST Smart Grid Interoperability Panel and related activities. He contributed to the NIST conceptual model, architectural guidelines, and the NIST Framework 1.0.

Bill is co-chair of the OASIS Energy Interoperation and Energy Market Information Exchange Technical Committees, past Chair of the Organization for the Advancement of Structured Information Standards (OASIS) Technical Advisory Board, member of the Smart Grid Architecture Committee, and the WS-Calendar Technical Committee.

Bill has developed enterprise product architectures for Bell Labs, Unix System Labs, Novell, and BEA, and has done related standards work in OASIS, ebXML, the Java Community Process, Object Management Group, and the IEEE, typically working the boundaries between technology and business requirements.

He earned a Ph.D. and M.S. in Computer Sciences from the University of Wisconsin-Madison, with a Ph.D. minor in Electrical and Computer Engineering.

Toby Considine

Toby Considine is a recognized thought leader in applying IT to energy, physical security, and emergency response. He is a frequent conference speaker and provides advice to companies and consortia on new business models and integration strategies.

Toby has been integrating building systems and business processes for longer than he cares to confess. He has supported and managed interfaces to and between buildings, cogeneration plants, substations, chilled water plants, and steam and electrical distribution. This work led to Toby's focus on standards-based enterprise interaction with the engineered systems in buildings, and to his work in the Organization for the Advancement of Structured Information Standards (OASIS).

Toby is chair of the OASIS oBIX Technical Committee, a web services standard for interface between building systems and e-business, and of the OASIS WS-Calendar Technical Committee. He is editor of the OASIS Energy Interoperation and Energy Market Information Exchange (EMIX) Technical Committees and a former co-Chair of the OASIS Technical Advisory Board.

Toby has been national smart grid activities since delivering the plenary report on business and policy at the DOE GridWise Constitutional Convention in 2005. He is a member of the SGIP Smart Grid Architecture Committee, and is active in several of the NIST Smart Grid Domain Expert Workgroups.

Before coming to UNC, Mr. Considine developed enterprise systems for technology companies, apparel companies, manufacturing plants, architectural firms, and media companies old and new. Before that, Toby worked in pharmaceutical research following undergraduate work in developmental neuropharmacology at UNC.