Interim Report: Transactive Valuation Methodology

Background

The U.S. Department of Energy (DOE) has tasked Pacific Northwest National Laboratory (PNNL) to develop a valuation methodology for transactive systems. Based on the DOE's Quadrennial Energy Review,[1] valuation within energy systems, in general, has become an important focus.

We started by gathering and reviewing existing materials concerning general and specific valuations that have been performed. On July 7-8, 2015, many of the experts and authors of such materials attended a meeting at PNNL convened by the GridWise® Architecture Council (GWAC). The organizations shown in Table 1 attended and shared their insights into this topic. The record of those discussions has been published by the GWAC.[2] On September 29-30, 2015, a draft of this interim report was shared with attendees at another GWAC meeting, which has not yet published its proceedings.

Table 1. Organizations that Participated in the July 7-8, 2015 Meetings at PNNL

Bridge Energy Group	Northwestern University
E3	OATI
Electric Power Research Institute (EPRI)	Pacific Northwest National Laboratory (PNNL)
ERCOT	QualityLogic, Inc.
Navigant Consulting	Rocky Mountain Institute (RMI)
National Institute of Science and Technology (NIST)	University of Washington
National Renewable Energy Laboratory (NREL)	U.S. Department of Energy (EPSA and OE)

This paper summarizes our initial insights and results in developing an organized valuation methodology. There is a core set of generally agreed upon grid benefits that are listed in most cost-benefit analyses (Table 2). However, each cost-benefit analysis or valuation study is conducted for different purposes and few practitioners currently select the same metrics, use the same methods, or come to the same conclusions. The valuation methods are unevenly documented and difficult to verify or compare. It is in this context that we introduce an organizational structure that many of you will (we hope) recognize as describing the purposes of your own valuation methods. We ask you to consider whether the organizational structure introduced here is suitable to be used to document and guide future valuations.

Why should the valuation of transactive systems differ from other valuations? A transactive system is not a typical asset to be purchased and used. A transactive system is itself a method for monetizing

[1] Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure, April 2015, U.S. Department of Energy.
[2] http://www.gridwiseac.org/pdfs/tes/pnnl_sa_112507_20150707_valuation_tes_proceedings.pdf

values and incentivizing assets to respond. There are different transactive approaches and alternative mechanisms that may be able to accomplish the same or similar objectives. A valuation methodology that helps compare methods against each other would be useful. The comparisons become not necessarily whether an asset is valuable or not, but whether one transactive system engages and coordinates the integration of assets better than another. A thesis of this paper will be that such subtle distinctions probably cannot be achieved by simply adding another module to existing valuation methods. Instead, the rich connections between stakeholders and assets must be carefully laid out and the interconnections must be functionally modeled.

Table 2. Benefits Commonly Cited in Grid-Related Valuations

Avoided energy cost - lost revenue	Reduced generation fuel
Capacity value (avoided/deferred infrastructure)	Reduced GHG emissions
Operations and maintenance expense	Reduced reserve requirements
Peak demand charge	Reduced T&D losses
Reduced electricity bill	

Transactive Systems

The GWAC has developed the "GridWise Transactive Energy Framework" which includes a formal definition of the term "transactive energy" as "A system of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter."[3] Here are some interesting characteristics of transactive systems:

- Monetize operational objectives through some sort of value-discovery mechanism, like a double auction market, for example
- Distribute control decisions and responsibilities
- Preferably automate assets' responses while accommodating the assets' states and owners' preferences
- Include a negotiation feedback mechanism that forces the price-signals and responses to converge.

Basic Methodology

The definitions in Table 3 are important to the discussion in this paper.

[3] http://www.gridwiseac.org/pdfs/te_framework_report_pnnl-22946.pdf, p. 11.

Table 3. Definitions that are Important to this Valuation Methodology

benefit	A quantifiable and observable outcome considered useful by one or more affected parties. Some *benefits* can be monetized. *Benefits* may be derived from other *benefits* or from *impacts*. *Critical benefits* are those that are required (based on a *hypothesis*) for a given valuation.
impact	A special class of *benefit* that can be directly quantified as an output of an *operational model*.
operational model	A model that that examines the operation of a generally fixed set of installed assets. This is in contrast to a planning model that projects operations and interactions over a multiyear planning horizon with a changing set of installed assets. New assets are not typically implemented while a *scenario* is being evaluated using an *operational model*. Operational strategies may be very complex, but they must not change while a *scenario* is being evaluated with an *operational model*.
planning model	A model that defines (1) growth (e.g., load growth, technology penetration rates, etc.) that occurs from one year to the next, and (2) the available assets (and their costs) that may be called upon if a *scenario* is found to violate an operational requirement during the year. For example, the assets available to a given utility might include up to four 1 MW units of water heater demand response, construction of a 100 MW gas generator, up to three blocks of 50 kW solar PV, etc. The output of a *planning model* is a set of alternative successive yearly viable operational *scenarios*. As in an IRP process, the "best" succession of yearly *scenarios* is the one found to have the least net present cost. The sensitivity of a *planning model* is often tested by subjecting it to high, medium, and low growth rates.
scenario	The collective set of systems, assets, operational preferences and requirements, functional interactions, predictions, programs, influences, etc. that specify the state of the system that is being evaluated. If evolution of the system is of interest to the evaluation, the initial *scenario* can also result in successions of yearly *scenarios*. We propose that the *scenarios* are, in fact, specified by the selected models and configurations of, or inputs to, those models. A *baseline scenario* and *test scenario* differ in defined ways that should cause the resulting *impacts* and costs to differ.
operational requirements	The part of a *scenario* that specifies the tests conditions under which a candidate *scenario* is deemed viable or not. An example might be a requirement for a minimum allowable capacity reserve margin. If the reserve margin falls below the minimum when a *scenario* is subjected to an appropriate *operational model*, the *scenario* must be modified and re-tested to include a new asset (or multiple assets) that does not violate the operational requirement.

<u>Basic structural relationships between benefits, impacts, and the models</u>. The basic structural relationships between the benefits, impacts, and models are shown in Figure 1. Interestingly, we

observe that the flow of valuation information typically flows downward in this diagram and the methodological planning for the valuation typically proceeds upward. During valuation planning (the "methodology"), (critical) benefits are selected to support hypotheses. (Critical) impacts are selected based on which ones are needed to derive (critical) benefits, and the (critical) impacts, in turn, create requirements for the selection and configuration of the models that will be needed.

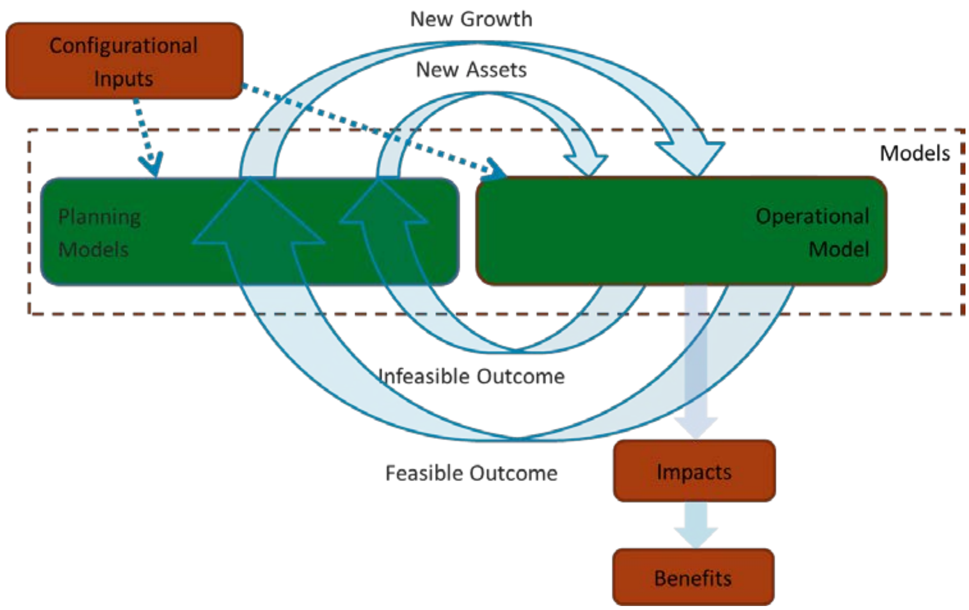


Figure 1. Structural Relationships between Benefits, Impacts, and Models

The classes of models shown in Figure 1 continue to increase as new scenarios and benefit types are encountered. For example, different models are needed to calculate employee retention, occupant comfort, and property value impacts associated with transactive energy systems in a building.

<u>Abstracted valuation method</u>. In the valuation methodology we are proposing, the structure and content of a valuation is determined by a set of hypotheses and the *benefits*, *impacts*, and models that would support each hypothesis. The basic abstracted method proceeds as follows:

1. Identify a treatment that is to be tested. Treatment could include a specific DER adoption/deployment and/or implementation of a transactive energy system. This treatment is the principal difference between the initial *baseline* and *test scenarios* or how the two scenarios will evolve over time.
2. Define assets and market conditions to be used in analyses of baseline and test scenarios. The analyst specifies the source of input data, whether it is through research, results of pilot of other projects, or assumptions.
3. Identify the *hypotheses* concerning how the *benefits* of the *baseline* and *test scenarios* and their evolutionary pathways will differ. The *hypotheses* specify stakeholder(s) who will be affected. Hypotheses should also be specified temporally and geographically to the extent possible.

4. List the metrics which will likely prove and quantify, or alternatively disprove, the listed hypotheses. These are *benefits*. *Benefits* should be monetized whenever possible and assigned to a certain stakeholder.
5. Map how these *benefits* will be derived from other *benefits*. This process stops with *benefits* that can be learned from *operational models*; such *benefits* are called *impacts*.
6. Specify the requirements for the *operational models* that will inform the *impacts*. A useful *operational model* will reveal the hypothesized differences between the *baseline* and *test scenarios* as they evolve over time and will achieve the geographical and temporal granularity desired.
7. Select the specific *operational models* that will satisfy the requirements from Item 6. Make clear where potential impacts are not included in the operational models and what assumptions if any are used instead.
8. Configure the operational models specific to the energy system under test and the treatment.
9. Configure the *planning model* specific to how a scenario will evolve/grow from one year to the next, including which new assets are available each year. The model might be different between the *baseline's* and *test scenario's* evolutionary pathways if that was the treatment (Item 1).

At this point, the valuation is entirely set up and ready to be executed by following these next steps:

10. Confirm that the initial *baseline* and *test scenarios* violate no operational requirements (e.g., line constraints, reserve margins, environmental impact limits) when they are tested by the *operational models* for Year 0.
11. Apply the growth predictions (i.e., load growth, annual equipment replacements, installed cost of DERs, inflation, etc.) within the *planning model* to both the *baseline* and *test scenario pathways.* Some growth predictions will cause assets to be implemented or replaced, which will introduce one-time costs for the new year.
12. Advance the year.
13. Test the new scenarios using the *operational models*.
14. Depending whether the new scenario violates one of the system's operational requirements,
    a. Violation case: Discard the scenario and formulate an alternative scenario by adding an available asset(s) from those in the *planning model* to the *scenario* from which the violation case evolved. Return to Item 13. This step may be repeated if there are multiple reasonable alternative asset candidates. New assets mean that one-time costs are introduced by the new scenario.
    b. No violation case: Continue.
15. Return to Item 11 until the desired time horizon has transpired, often 10-25 years.
16. Select baseline and test scenario pathways. These will often be the time series having minimum net present values.

The valuation's most important cumulative impact is generally the difference in net present values between the *baseline* and *test scenario* evolutionary pathways.

Sensitivity analysis may be conducted by modifying the growth assumptions within the *planning model* and re-evaluating. This could, for example, quantify the variability of the valuation under low, medium, and high load growth rates.

Addressing both detailed system integration and evolution of a system over time. There are two fundamental components in most existing valuation methods. First, an energy and related economics system and its dynamic elements are modeled in great detail. Specific events and their concurrences and correlations are of interest. The emphasis is on the adequacy of, and contingencies in, the energy and economics system. Some refer to this type of model as simply an "operational" model.

The other fundamental component of most valuations emphasizes the evolution of the energy and economics system over time. This approach is emphasized for planning cycles like integrated resource planning (IRP). Some refer to this component as a "planning" model.

The consistent treatment of operational and planning models seems to be a great source of perceived (if not true) complexity in existing valuation methodologies. We propose in this section that operational and planning models are complimentary. We shall try to explain how the two types of models should work together.

Figure 2 shows a test scenario and its baseline scenario being subjected to one or more operational models during a given year. The scenarios are a set of physical system states (e.g., assets and topology), functional behaviors (e.g., resource dispatch practices), and perhaps some operational requirements (e.g., reserve margin requirements). The scenarios are embodied by the operational models, by the inputs to these models, and by the way the models have been configured. A scenario does not change during a given time period. Assets, programs, preferences, performance, and topology remain the same during the year. Impacts and benefits are evaluated for the year by the operational models.

The scenarios may be accompanied by absolute and differential costs, as represented by the yellow shadows in Figure 2.

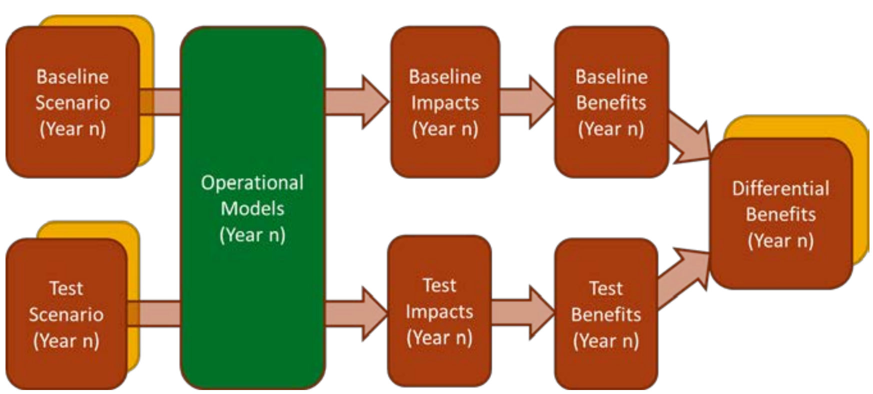
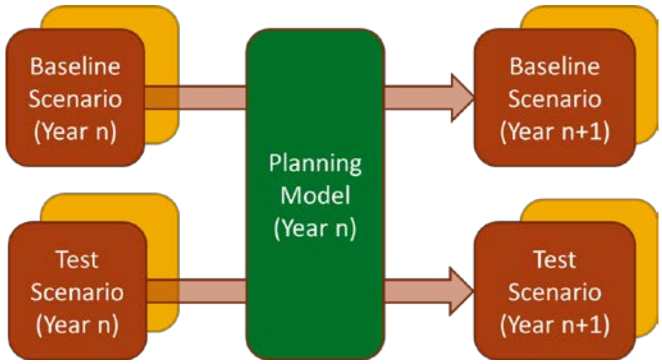


Figure 2. Operational Models Evaluate Impacts and Benefits in a Given Year.

For those valuations that include a future planning horizon—and most do—the scenarios from one year must be projected forward to the next year. This process is shown in Figure 3. The Planning Model includes forecast development. Note that in forecast development the characteristics of the basic configurational inputs are adapted from one year to the next. The “evolution” will often include the system’s projected electricity load growth, for example. The “evolution” could be as mundane as the expected changes in employees’ salaries, or the fact that 10% of a type of substation meter must be replaced each year, which would imply a cost for the resulting new scenario.



Forecasts and growth alone do not inform impacts or benefits

Figure 3. The Planning Model Predicts how a Baseline or Test Scenario will Change from One Year to the Next

The newly spawned scenarios must be again tested with operational models the next year, as shown in Figure 4. It is conceivable that a new scenario will be found to violate an operational requirement. The new scenario must then be discarded and modified with a new asset chosen from those that are allowed by the *planning model* that year. The newly spawned scenario must again be tested with the *operational models*.

The newly spawned scenarios may be accompanied by new asset costs, as suggested by the yellow shadow blocks.

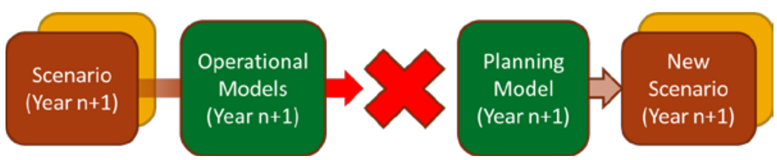


Figure 4. A new year’s baseline or test scenario may violate operational requirements when it is tested by the *operational models* for in the new year.

There may be multiple viable new scenarios if more than one of the available new assets is found to fix the violation of an operational requirement. This will happen often where there are questions of scale (e.g., should one, of two, of identical available generators be installed this year?). See Figure 5.

It is tempting to select only the cheapest alternative at this point, but doing so might not result in the best global solution at the end of the multi-year window. An investment in a costly asset must be allowed to accrue benefits over the remainder of the multi-year time window.

The new scenario is a branch of the previous year's scenario from which it evolved. One must keep track of the scenario from which each new scenario is spawned. This information is used when, at the end of the multi-year valuation window, one baseline pathway and one test pathway may be determined. The "best" pathway will usually be the one that is determined to have the greatest net present value.

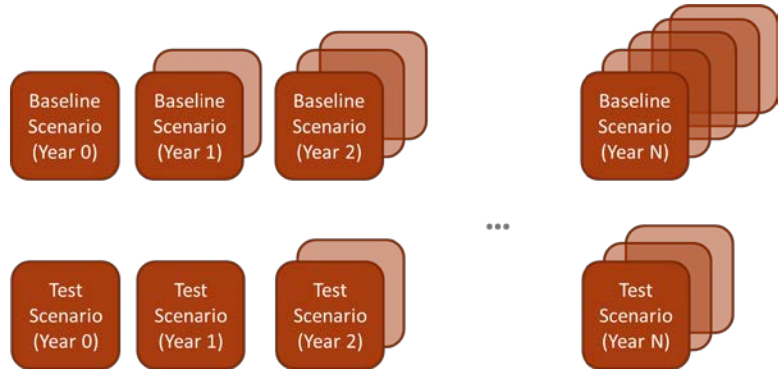


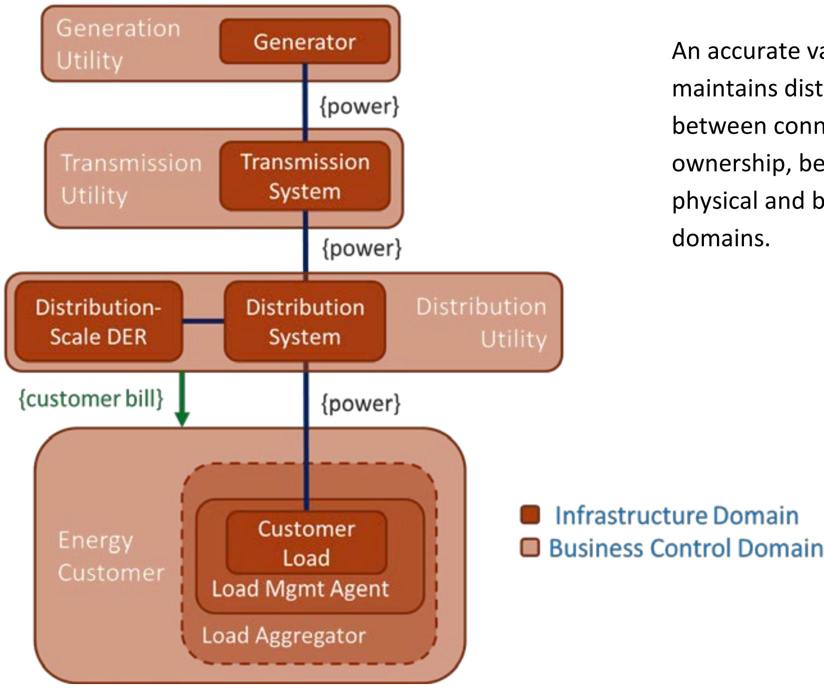
Figure 5. Multiple alternative technology pathways occur for the baseline and test scenarios. Each the baseline and test pathways may be trimmed to the pathways that have the least net present cost.

Maintaining stakeholder interests during valuations. Some valuations attempt to address not only costs and benefits to utilities and customers, but also the allocations of those benefits among classes of stakeholders. This section recommends structure and guidance for effectively tracking impacts at the stakeholder level.

Figure 6 shows a power-signal view that represents several stakeholder domains. Each box is a high-level container that could itself represent a deep hierarchy of nested subclasses.[4] For example, the container "Generator" could include a subclass for "Thermal Generator", which could include a subclass for "Coal Generator," and so on. The darker blocks make up the physical electric power system and are interconnected by "power" signals. We've chosen to use the word "signal" here because the interconnections represent influence between things that are electrically connected. The power connections have attributes that include energy, harmonics, power factor, voltage, etc.

The lighter blocks represent business-level entities. These entities "own" parts of the electric power system, but electricity does not flow through them. For example, an evaluation might involve multiple distribution utilities, each owning its part of the system being studied, and one of the distribution utilities might additionally own a battery storage system within its distribution system. Keeping the distinctions straight between connectivity and ownership is critical to accurate evaluations.

[4] These would likely be "domain packets" in UML terminology.



An accurate valuation maintains distinctions between connectivity and ownership, between physical and business domains.

Figure 6. Power-Signal View of Connectivity between Domains of Infrastructure and the Business Entities that Own the Infrastructure

The power-signal connectivity diagram is one of many dimensions of connectivity in a power system. Another relatively simple connectivity dimension was added to Figure 6 to make this point. A "customer bill" signal has been introduced. The customer bill is created by a distribution utility and is received by an energy customer. The "distribution utility billing" connectivity view probably deserves its own diagram. Still more new objects and business-level entities were introduced during that exercise. For example, a customer bill is related to customer electricity rates, and these rates are regulated by regulators.

This context has been established to provide the following recommended guidance:

- If a stakeholder benefit is of interest, the benefit should be stated in respect to that stakeholder. A weakly stated benefit invites questionable outcomes.
- The sets of hierarchical containers shown in connectivity diagrams should be used to also organize impacts and benefits. This rigor encourages precise definitions of stakeholders, benefits, and impacts. New impacts and benefits should be introduced only if they have not been captured higher up in the hierarchy.
- All the connections to a container box precisely represent the signals that influence the impacts and benefits that have been documented at that point in the connectivity diagrams.
- The interplay between the defined connections is the key to defining *operational models* and their requirements. For example, an electrical power-flow model enforces relationships between many or all of the power signals that are represented in the power-signal connectivity

diagram. Market-like mechanisms will be found to imply functional relationships between power signals and cost transactions.

Extensibility and standardization of the methodology. It is our intent to develop a high level methodology for approaching valuations of transactive energy systems and other technology types and penetrations. The recommendations in the previous section invite consideration of an organized repository for proven valuation methods. We may consider this as a recommendation to the U.S. DOE.

Standardization of a methodology. One goal of the present project is to lay groundwork that will make different valuations meaningfully comparable. One step toward accomplishing this goal would be to develop a template for documenting methods and assumptions so they can readily be reviewed and compared. We believe that such a template will provide support and structure to those embarking on or considering valuation projects. One outcome from this project should be a list of criteria with which completed valuations and valuation methods can be concisely compared and contrasted, as has been drafted in the appendix Table A1.

This discussion has intentionally avoided technical jargon. However, the content has been heavily influenced by object-oriented methods. Unified Modeling Language (UML)[5] was originally intended to standardize the design of software, but it has been used also to design non-software systems and even business practices. We believe it may be a key to the organization and documentation of valuations in the energy space. And this rigor and formality will be helpful as we attempt to value subtle, transactive mechanisms. UML is especially strong at documenting class hierarchies and associations (like the connectivity diagrams) and activities (as will be needed to more thoroughly document the formulations of the various market signals).

General Insights and Guidance

The following insights and guidance should be considered and adopted by valuation methodology:

- Harmonize terms
- Adopt a systems approach to value transactive systems
- Separate methods' growth and operations processes
- Create clear baseline comparisons
- Allow for extensibility for new cases and value streams
- Make assumptions visible
- Track valuations using defined signal pathways
- Handle both abstracted and specific valuations cases
- Separate stakeholders' business and hardware
- Map benefits to an extensible set of stakeholders

[5] See http://uml.org/.

- Adopt a standard way to represent valuations
- Establish an organized repository for best valuation practices and tools

Value of Transactional Building Energy Systems

Building energy systems, including space conditioning, ventilation, hot water, refrigeration, and lighting systems, link buildings, their owners, and occupants to the electricity, water and natural gas systems that serve them. Nationally, the electricity used by these systems dominates consumption and therefore represents the largest opportunity for transactive systems to provide grid services. Recognition of this fact has resulted in a "buildings-to-grid" perspective that has defined transactive system demonstrations to date. However, the potential value of transactive building energy systems extends beyond those services provided to the electricity grid. Transactional building energy systems have the potential to enable a wider variety of transactions, provide new services, expose additional value, and create business opportunities[6] independent of the electric grid.

Building Transactions

Transactions in and between buildings may take many forms, transact many different commodities, and occur at a variety of timescales. The *Transaction-based Building Controls Framework, Volume 1: Reference Guide* document provides a set of examples that illustrate a number of possible buildings-based transaction use-cases. The document classifies transactions according to transacting parties. For the purposes of this project, we adopt a subset of those established by that document which classifies the transactions as (1) Intra-building, (2) building-to-building, (3) building-to-other, (4) building-to-grid, (5) service-provider-to-service-provider, and (6) customer-to-customer. The classification adopted by this work is as follows:

<u>Building-to-grid</u> transactions occur between a building and utility entity (generation, transmission, distribution). These transactions are the type most commonly associated with building energy systems and include those that enable buildings to provide ancillary services.

<u>Building-to-other</u> transactions occur between a building and a third-party service provider, e.g. an ESCO, energy retailer or demand aggregator. These transactions may, for example, be motivated by shared energy savings realized through information exchange which improves building performance.

<u>Building-to-building</u> transactions occur between buildings and/or a larger community of buildings. Communities may be fixed, dynamic, formally defined, or ad-hoc. These transactions may be motivated by a shared need to limit aggregate demand, or balance local distributed energy resources.

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[6] Identifying opportunities that transactions expose creates a justification for transactive system investments and points to potential markets for commercialization.

Intra-building transactions occur between devices within a building. Motivation for transaction is purely building-centric. For example, equipment in buildings may compete for resources, leading to reduced energy consumption or improved occupant comfort.

Figure 7 depicts a transaction connectivity layer for entities in the buildings domain, where the arrows represent various transactions that might be designed within buildings, between buildings, with third-party service providers, and between buildings and grid entities.

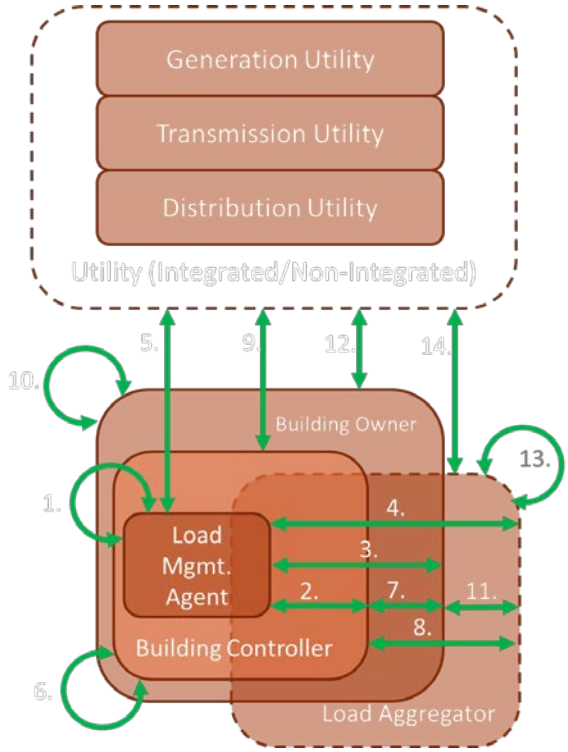

Figure 7. Transaction Signal Diagram Showing Transactions among the Building-Related Domains

Mapping Impacts

Identifying and mapping impacts to relevant stakeholders enables for the assignment of benefits. Impacts may be first order (primary), or second order and higher (secondary) impacts, and may affect stakeholders in different ways. For example, a primary impact of a transactive system may be a change in HVAC operation. This may result in reductions in electricity use and increased compressor cycling, both of which are secondary impacts of the transactive system. Furthermore, each of these impacts may in turn affect equipment lifetime or a customer bill; secondary impacts dependent on the preceding impacts in this chain.

Many of the impacts revealed through the mapping process may not be directly related to energy use or cost, whether or not the primary motivations for transactions are energy related (Figure 8). These impacts are extremely important to consider in a complete valuation, as non-energy costs dominate most business and personal expenses, and are often missing from grid-centric valuations. Non-energy impacts include water usage, equipment maintenance, worker retention, property value and insurance premiums. Works published by NAESCO[7], Rocky Mountain Institute[8], LBNL[9] and others have revealed many of these non-energy impacts and their associated value to buildings, owners, occupants and society more broadly. These works provide guidance to the mapping process and the quantification of impacts to multiple stakeholders.

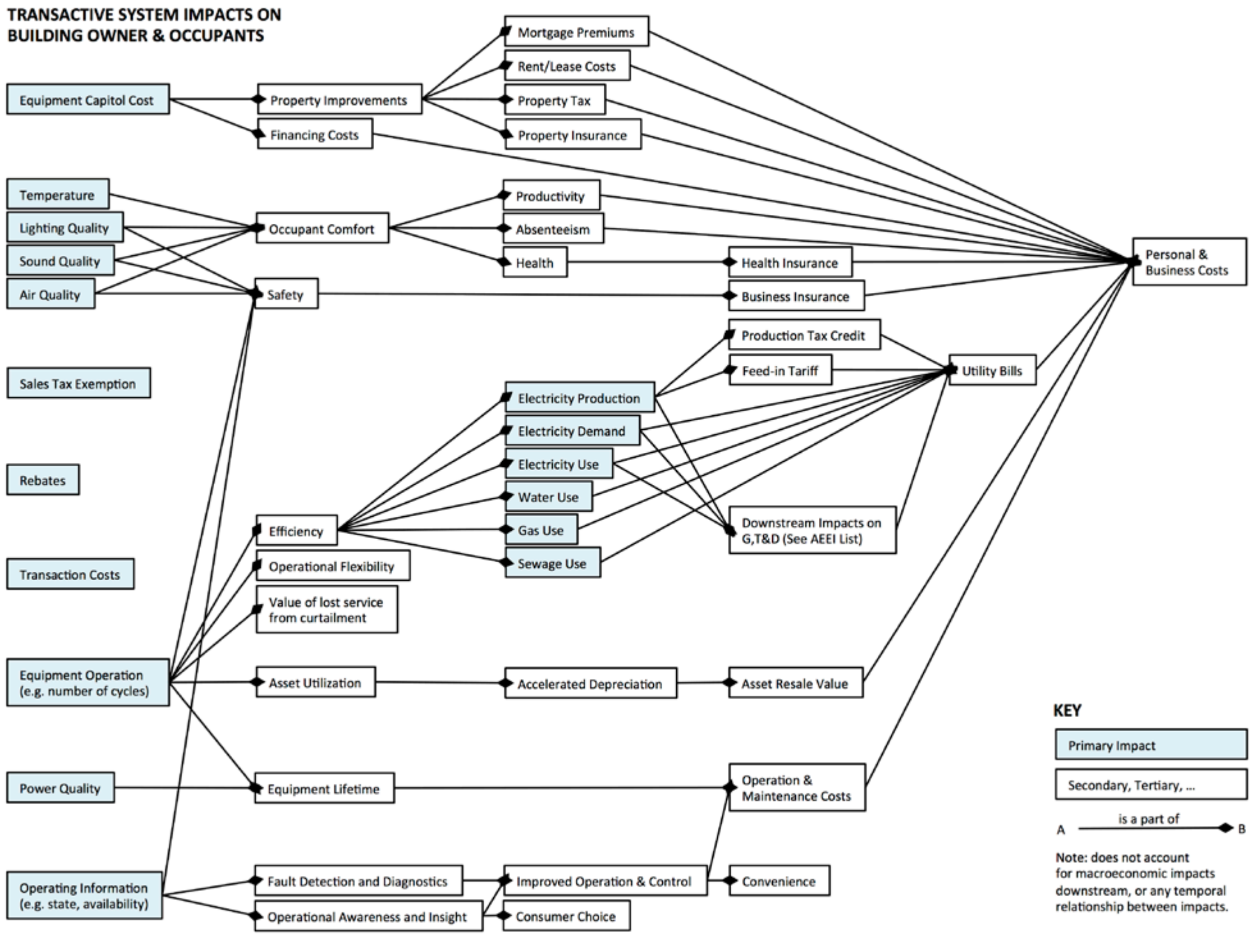

Figure 8. Relationships between Potential Impacts Realized in Transactional Building Energy Systems

It is important that those evaluating transactive systems have a strong understanding of the relationships between impacts. In some cases, impacts may be deeply nested, or feedback loops between impacts may exist. The evaluator must apply expert knowledge in order to determine how far down the chain of impacts one must travel when mapping these relationships.

[7] https://www.naesco.org/data/industryreports/NAESCO NEB Report 12-11-08.pdf
[8] http://www.rmi.org/retrofit_depot_deepretrofitvalue
[9] http://energy.lbl.gov/insurance/innovations.html

Mapping impact relationships helps the evaluator understand how the system benefits all of the various stakeholders. These relationships are critical to producing an accurate and meaningful valuation, and only through this process are the full implications of a transactive system understood.

Operational Modeling

Buildings are complex. Buildings are not as simple as other distributed energy resources like batteries; they have operational constraints that affect their availability and must be modeled accordingly. These operational constraints are critical to accurate valuation of these systems.

The mapping process described above assists the evaluator in identifying the information needed from operational models and informs the modeling approach. Depending on the impacts chosen by the evaluator, operational models may include whole-building energy simulation, occupant behavior simulation, or simulation of individual appliances and building devices.

Modeling many of these impacts is often difficult and may require very detailed simulations. For example, if a transactive system results in cooling set point changes leading to increased temperature in a home, the modeling method must have a way of estimating the comfort impacts. Modeling comfort impacts can be critical, as demonstrations have shown[10] that occupant discomfort can result in participant fatigue, thereby reducing or eliminating grid-related benefits.

Depending on the scale and expected impact of the transactive system, certain simplifying assumptions may be required, and reduced order modeling of impacts may be necessary. In the previous cooling set point example, information collected from a small pilot project may allow temperature impacts to be modeled as a simple linear system relating average indoor temperature increase to energy price. This approach might neglect the time or location dependence of the impact and may not be appropriate in all cases.

Model selection and simplification requires the evaluator to apply expert knowledge. In some cases, model selection may be accompanied by sensitivity studies. These studies assist the evaluator by identifying impacts that are most likely to be significant. The evaluator may then select models to capture the significant impacts, but not those less likely to occur in a given scenario or by a given transactive design.

Planning Models

Assessing value of transactional building systems over the long term requires additional assumptions and models that address how buildings evolve over time. Building characteristics are not static and change largely irrespective of the needs of the electric grid. This evolution may result from equipment degradation and replacement, occupancy and space usage changes, or may be driven by changes in regulations, building codes and policy. Some evolution may be driven by the deployment of transactive

[10] Widergren SE, K Subbarao, JC Fuller, DP Chassin, A Somani, MC Marinovici, and JL Hammerstrom. 2014. AEP Ohio gridSMART Demonstration Project Real-Time Pricing Demonstration Analysis. PNNL-23192, Pacific Northwest National Laboratory, Richland, WA.

systems and may represent an opportunity for co-investment. For example, the option to install a "grid-friendly" version of a system being replaced may enable grid-related transactions at a small incremental cost shared between building owner and utility. In practice, modeling the evolution of a building over the valuation periods is difficult and requires the evaluator to make a large number of assumptions about future regulatory conditions, building usage and equipment service life, among many others.

Quantification of Costs and Benefits

Benefits and costs derived from transactional building energy systems are most easily understood and compared in monetary terms. However, for many of the anticipated impacts these systems may have on buildings, owners, operators, and occupants, a method of monetization may not be practical or well established.

Consider a building-to-grid transactive system which affects lighting levels within the building. With an appropriately detailed model, it is easy to quantify the primary impact in terms of power measured at the utility interface, and the lighting intensity falling on work surfaces measured in lux. Secondary impacts from changes in lighting intensity extend to occupants in terms of visual comfort, and may ultimately result in decreased worker productivity. The value of worker productivity is itself a complex problem with a large body of literature devoted to the subject. A method of monetization may not be clear in this case. However, even if impacts cannot be easily monetized, the benefit (or likely cost in this example) must still be captured and quantified in order to provide a means of comparison. The identification and selection of models that monetize or otherwise quantify non-monetizable impacts is therefore a critically important aspect of a valuation effort.

Complications occur when transactive systems provide multiple services, such as peak load reduction and spinning reserve. In some cases, these services cannot be provided concurrently. Calculating costs and benefits without addressing concurrency can lead to overestimation.

Appendix: Draft Questions to Guide Comparisons of Different Valuations

Table A1. Draft Questions that May be Used to Compare and Contrast Different Valuations and Valuation Methods

OBJECTIVES AND KEY ASSUMPTIONS

Objective - Defining Valuation

1 What is/are the specific objective(s) of the valuation?
2 How will the results of the valuation be used?
3 Does valuation compare test case against a baseline?
4 Are critical operational requirements defined?
5 What is the locational and temporal granularity of the effort?

Key Assumptions

6 Is the basis of market assumptions made clear? What are they?
7 Are the bases of other assumptions stated?

OPERATIONAL MODELS

General

8 What level of granularity in space and time are used in operational models?

Generation and Transmision

9 Is a specific system being modeled or a prototype or generalized system?
10 What parameters and impacts are considered in G&T operational models?

Distribution

11 What parameters and impacts are considered in distribution system operational models?

Buildings/Assets

12 What parameters and impacts are considered in buildings/assets operational models?

Transactive Energy Systems

13 Are transactive systems and/or dynamic demand response capability included?
14 What transactive system design and performance details are included in operational models?

PLANNING MODELS

Forecasts

15 Are basis of growth rates and forecasts used in planning models made clear?

Resource Portfolio Planning

16 Does valuation consider future resource portfolio planning and dispatch?
17 What kinds of resources are considered in resource planning models?

18 Does model consider cumulative impacts?

Transmission Planning

19 Is transmission planning capability included?

20 Is transmission planning connected to generation and distribution planning?

Distribution Planning

21 Is distribution system planning included?

22 Which distribution system parameters and impacts are considered in planning models?

23 Does analysis include feedback between planning and operational models?

REGULATION AND RISK

Regulation/Rate Impacts

24 Are regulation / rate impacts considered?

25 What assumptions are made relative to regulation/rate impact?

26 Are alternative business models and system architectures considered?

Uncertainty and Risk

27 Is risk analysis performed?

28 Are risks associated with price volatility and environmental compliance considered?

IMPACTS TO STAKEHOLDERS

29 Which stakeholder perspectives are considered?

30 For which stakeholders are monetary costs and benefits assigned?

31 For which stakeholders are non-monetary impacts defined?

32 Are resilience impacts explicitly addressed?