Benefits Aggregation for Attractive Electricity Storage Value Propositions

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Introduction

This paper briefly describes just a few of the possibilities that do or that could exist for savvy aggregation of benefits into attractive value propositions. Benefits aggregation involves combining two or more compatible benefits to create value propositions whose total benefit exceeds cost.

Those value propositions are comprised of benefit "building blocks" that are characterized in a draft report entitled "Energy Storage for the Electricity Grid: Benefits and Market Potential" that was sponsored by the U.S. Department of Energy and managed by Sandia National Laboratories (SNL).[1]

Definition of Value Proposition

In simple terms a value proposition reflects value defined as benefit minus cost. The benefit could be revenue and/or avoided cost. "Attractive" value proposition is one for which the benefit exceeds the cost. Cost includes expenses plus the necessary return on capital. Other criteria that could be used to determine whether a value proposition is attractive include: a) up-front capital requirement, b) payback period and c) opportunity cost.

Core Benefits

Core benefits are those which can be internalized either as a cost reduction or as revenue. Five broad benefit categories and core benefit building blocks within each category are listed in Table 1.

Table 1. Benefits by Category

Category	Benefits
Electric Supply	1. Electric Energy Time-Shift 2. Electric Supply Capacity
Grid Operations (Ancillary Services)	3. Load Following 4. Area Regulation 5. Electric Supply Reserve Capacity 6. Voltage Support
Grid Infrastructure	7. Transmission Support 8. Transmission Congestion Relief 9. Transmission and Distribution Upgrade Deferral 10. Substation Onsite Power
End-User	11. Time-of-Use Energy Cost Management 12. Demand Charge Management 13. Electric Service Reliability 14. Electric Service Power Quality
Renewables Integration	15. Renewables Energy Time-Shift 16. Renewables Generation Capacity Firming 17. Wind Generation Grid Integration

Electric supply includes electric energy and electric capacity (power) needed to serve load. *Grid operations* benefits reflect avoided cost to provide various ancillary services needed for efficient, effective and reliable grid operation. *Grid infrastructure* involves: a) the electrical performance and b) load carrying capacity of the transmission and distribution (T&D) system. *End-User* benefits reflect electricity-related costs incurred by electricity users, including costs related to poor power quality and to power outages. Finally, *Renewables integration* benefits include avoided costs for integrating significant amounts of grid-connected renewable energy capacity into the grid.

Incidental Benefits

Incidental benefits may exist for any specific storage plant. They are distinguished from core benefits by their generally smaller magnitude. Incidental benefits also tend to be difficult for storage owners to internalize as there is usually no specific price signal reflecting the benefit. For example, by charging storage at night, total T&D I^2R energy losses could be reduced by several percentage points; though, the storage owner will not be able to internalize that benefit – the benefit accrues to society and utility ratepayers at large.

Incidental benefits include: 1) avoided T&D "I^2R" energy losses (on peak minus off peak), 2) avoided transmission access charges, 3) increased asset utilization (generation and transmission, possibly distribution), 4) power factor correction, 5) flexibility (e.g. for expansion planning), 6) reduced T&D investment risk (using modular capacity additions) and 7) generation fleet dynamic operating benefits. Fleet dynamic operating benefits identified by the Electric Power Research Institute (EPRI) include reduced: a) ramping, b) part load operation, c) wear and tear, d) fuel use (per kWh) and e) air emissions.

Locational Benefits
When identifying and evaluating benefits, it is important to note that some benefits can be internalized *only* if storage is deployed at the location where it is needed. Also, in general, more benefits could accrue if storage is deployed in distributed mode.

The most notable core *locational* benefits are: 1) voltage support, 2) transmission congestion relief and 3) T&D deferral. If distributed storage is used for ancillary services, it will probably have to be aggregated into large enough blocks. For example, some grid operators require 1 MW of capacity for ancillary services. This could be accomplished by collaborating with load and/or distributed generation aggregators.

Notably, several incidental benefits are somewhat or very location-specific: 1) avoided T&D I^2R energy losses, 2) avoided transmission access charges, 3) increased asset utilization and 4) power factor correction.

Attractive Conventional Electric Supply Value Propositions
Utility-Owned Storage
Perhaps the most common conventional electric energy storage value proposition is a utility-owned plant used to: a) store low value and/or surplus off-peak energy, b) discharge energy when it is valuable, c) discharge energy to reduce need for peaking and/or load following generation capacity and, to some extent, d) provide ancillary services. Almost all utility-owned electric energy storage is pumped hydroelectric.

Power Purchase Agreement
A common value proposition for electricity generation resources is the power purchase agreement (PPA). PPAs are negotiated between: a) a utility that is in need of on-peak electric resources and b) a generation owner, either a utility or a non-utility independent power producer (IPP). The PPA may also include ancillary services.

Depending on circumstances, the same storage used to satisfy the PPA could also be used to participate in the wholesale electricity marketplace – for energy, capacity and ancillary services – when not being used to meet PPA-related obligations.

Merchant Storage Plant
A merchant storage plant is used to derive profit by participating in the bulk/wholesale electricity marketplace. In most cases, the plant is charged with low priced electric energy, when demand is low. Stored energy is sold during on-peak times when energy is expensive (electric energy time-shift benefit). Where applicable that storage may also qualify for capacity payments (electric supply capacity benefit). The plant is also used to provide ancillary services. Almost all merchant storage is pumped hydroelectric.

This value proposition calls for a "real options" approach. Returns are optimized by savvy purchase of energy at the lowest possible price and use of that energy for the most valuable combination possible of energy sales, capacity payments and sale of ancillary services.

Attractive Conventional End-User Value Proposition
Bill Reduction
Though relatively uncommon; energy end-users may utilize energy storage to reduce their overall electricity bill. Perhaps the most common type of storage used to date for bill reduction is cold storage. The cold storage is used to offset real-time cold production user compressors during times when on-peak energy and demand charges apply.

If *electricity* storage is used for bill reduction, the same storage could be designed to provide backup power and/or high quality power, if doing so is valuable. In fact, there may be existing end-users for which that increased reliability and/or improved power quality is important but not significant enough to justify the cost of an uninterruptible power supply (UPS). In those cases, if the marginal cost for extra storage needed for bill reduction is less than the marginal benefit for bill reduction, then the storage is that much closer to being cost effective.

Depending on circumstances, the same storage used for bill reduction could also be used during non-peak times to provide ancillary services.

Attractive New Value Propositions
Distributed Storage for Utility T&D Deferral
Another value proposition entails reducing electric utility cost-of-service by deferring expensive transmission and distribution (T&D) upgrades. Anchoring a value proposition with the T&D deferral benefit is compelling for several reasons. First, the T&D deferral benefit for just one or two years of deferral can be significant. Second, in general, distributed storage can be used to derive more types of benefits than centrally/remotely located storage. Finally,

consider that, in most cases, output from storage used for T&D deferral tends to be quite valuable if it offsets the need for on-peak energy and/or peaking generation capacity (electric supply capacity).

For perhaps as much as 8,000 hours per year, the same storage could also be used for electric supply reserve capacity, voltage support and if located where needed, for transmission congestion relief.

To illustrate the significance of the T&D deferral benefit, consider the following generalized approach for estimating the single-year deferral value. First, note two important assumptions described below: fixed charge rate and upgrade factor.

A fixed charge rate is used to estimate *annual* carrying charges (a.k.a. annual revenue requirement for a utility) for equipment installed. As an example, if T&D equipment cost $1 Million to buy and install (*installed* cost), then a fixed charge rate of 0.13 means that the *annual* cost to own the equipment (utility revenue requirement) is 0.13 * $1 Million = $130,000. T&D

Upgrade Factor refers to the amount of load carrying capacity *added* when the T&D upgrade occurs. An example of the 0.33 value used – a typical value – is an upgrade of a 12 MW T&D node so it can serve 16 MW. The 4MW added / 12 MW existing = 0.33.

Values for the resulting T&D deferral benefit (reflecting a fixed charge rate of 0.13 and an upgrade factor of 0.33) are shown in Figure 1.

In that figure, there are plots for various “Storage Power” (levels) – expressed as a portion of peak load to be served by the storage. Plotted on the X Axis is the cost per kW of nameplate rating for T&D capacity. The resulting deferral benefit per kW of storage, for the respective storage power, is shown on the Y axis. [2]

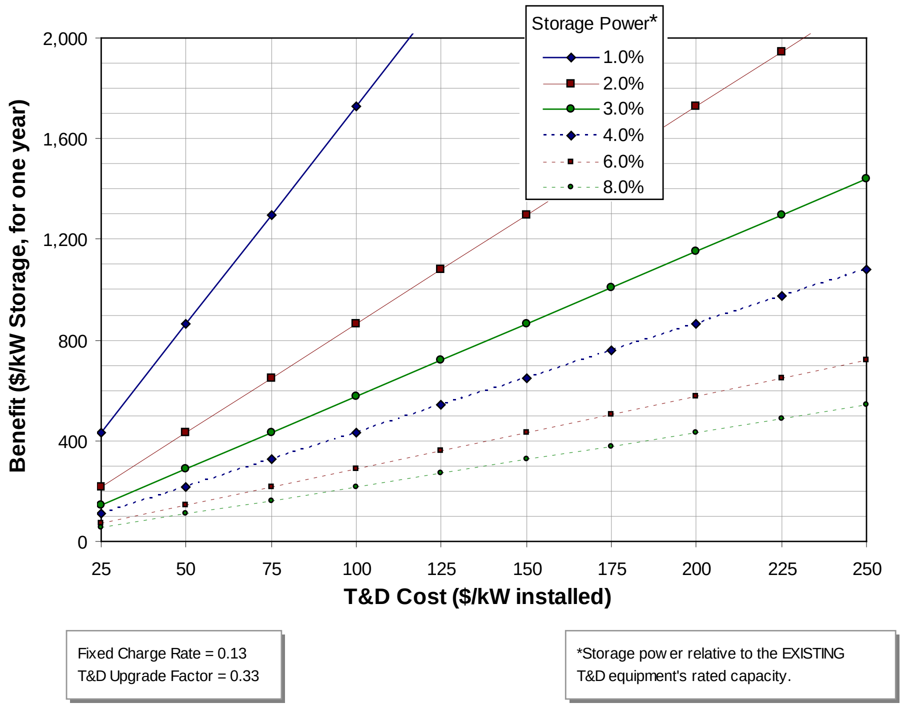

Figure 1. Benefit for T&D Upgrade Deferral of One Year

Consider an example of how the benefit is estimated using this approach.

T&D equipment costing $50/kW and storage power of 2%. In that example, the single year benefit is $450/kW of storage. For storage power of 4% and T&D cost of $75/kW the single year benefit is about $350/kW of storage. Though somewhat uncommon, T&D costs exceeding $75/kW installed do exist.

<u>Storage for Small-to-Medium Compressor-Based Air Conditioning</u>

For at least three reasons, small-to-medium air conditioning (A/C) units are especially challenging loads for utilities and grid operators. First, they contribute a significant portion of peak load during hot summer months. However, in many cases they are only operated for tens or hundreds of hours per year meaning that a large portion of the grid capacity is used for a small portion of the year – which is very poor asset utilization and expensive. Second, when that equipment is operating it uses very expensive energy. Finally, the compressor motors in smaller and medium sized A/C equipment can have a significant effect on voltage because they draw increasing amounts of current to maintain power as voltage drops, which may reduce the voltage further.

Given the stakes, there may be opportunities – involving savvy benefits aggregation – to use storage in conjunction with A/C. It could be on-site or nearby community storage. Depending on circumstances, several core benefits could be aggregated. Primary among them are: a) electric supply capacity and b) electric energy time-shift for wholesale market participants, or c) demand charge reduction and d) reduced time-of-use energy charges for retail end-users.

If located where needed, the same storage could be used for "targeted" voltage support, especially during grid voltage emergencies. Storage could provide voltage support several ways: 1) pick up the loads, 2) turn off the loads and inject power and/or reactive power and/or 3) power factor correction. That is compelling because: a) reactive power used to offset voltage problems does not travel far over the grid and conversely b) the voltage support is supplied at or near the location of especially loads with the most significant effect on grid-wide voltage drops.

Depending on the circumstances, the same storage could be used for electric supply reserve capacity and if located where needed, for transmission congestion relief.

<u>Renewables Plus Distributed Storage</u>

A potentially attractive value proposition is use of distributed storage in conjunction with renewables. Two examples are on-site or nearby storage coupled with: 1) co-located rooftop/distributed photovoltaics (PV) or 2) bulk wind farms whose output is transmitted to the storage (note that it is common for wind farms' output to occur mostly at night during peak demand months). In either case, low priced off-peak grid energy could also be used to charge the distributed storage if necessary.

For PV, the storage is used to firm output during peak demand hours. For bulk wind farms, the storage is discharged during peak demand hours. That is done primarily either: a) for electric supply energy and capacity payments or b) to reduce end-user time-or-use energy and demand charges. Depending on the circumstances, because it is distributed, that same storage could also provide several other core benefits including: a) transmission congestion relief, b) T&D deferral, c) ancillary services, d) improved electric service reliability and e) improved electric service power quality.

<u>Wind Generation Integration</u>

An important challenge for integration of wind generation resources into the grid is that wind is inherently variable, and sometimes unpredictable. Wind generation integration benefits reflect costs associated integrating significant amounts of grid-connected renewable energy capacity into the grid that could be avoided if storage is used.

Though there are no direct price signals, renewables integration related benefits will be reflected by increased demand for, and in some cases prices for, electric supply capacity and ancillary services. Depending on location, they may also be reflected in transmission congestion charges or for transmission upgrades and/or capacity expansion required to accommodate wind generation capacity.

Storage can be used to reduce short-duration (seconds) output "volatility" (e.g. due to wind gusts) by charging and discharging to smooth the wind generation output. That may reduce ramping of other generation on the grid and it may also improve the power quality of the wind generation output.

Storage can also be used to offset longer duration (minutes to hours) wind generation variability. Doing so can make the wind generation capacity somewhat-to-much more valuable as a grid resource. In some cases, storage could be used for transmission congestion relief by charging storage with wind generation output that exceeds available transmission capacity. Another longer duration use of storage for wind generation integration is to provide "backup" should there be an unexpected and significant wind (and wind generation) shortfall. Finally, storage used for longer duration benefits could be used to reduce minimum load violations (times when electric supply exceeds demand) by charging when there is more wind energy than is needed, usually during late night and early morning hours.

<u>Societal Value Proposition</u>

Though it may be challenging to quantify most societal benefits for storage, utility ratepayers at large and society as a whole also have an important stake in the success of electric energy storage. If nothing else, several of the societal benefits from storage would be reflected as a reduction of total revenues required by the utility to cover cost for generation and/or purchase of and delivery of a given amount of electric energy.

Some important facets of the societal value proposition for storage include, in no particular order: a) lower electricity prices, b) increased grid robustness which improves reliability, power quality and grid security, c) enables superior integration of intermittent renewables, d) more optimized electric supply fleet operation, (increased efficiency, reduced air emissions and reduced equipment wear and tear, aka dynamic operating benefits), e) reduced electric supply and T&D capacity needs and f) reduced T&D I^2R energy losses.

Conclusions
An important premise assumed for this paper is that, in most cases, two or more benefit types must be aggregated for the total benefit to exceed cost (i.e. for the value proposition to be attractive). Several possible examples are presented.

Though the current electricity marketplace is not especially accommodating of storage – particularly modular/ distributed storage – prospects do seem likely to improve. Specifically, as the electricity marketplace transitions to a more open and competitive arena, conventional value propositions may be more attractive, and new attractive value propositions will emerge. Important indicators of an electricity marketplace that can readily accommodate energy storage include: a) regulatory permission exists for utilities to own or to contract with storage owners (risk and reward sharing), especially for distributed storage located within the distribution system and b) efficient pricing of electric energy and capacity (generation and T&D), possibly including locational marginal pricing (LMP) or location-based marginal pricing (LBMP).

Other important drivers of the storage opportunity include, in no particular order: a) an increasing emphasis on intermittent renewable energy fueled generation, b) generation and transmission capacity constraints and transmission congestion, c) growing use of demand response, d) increasing emphasis on Smart Grid, e) increasing prevalence of load aggregation and to a lesser extent aggregation of distributed generation capacity, f) the important ongoing role of independent power providers and energy services providers, g) growing emphasis on modular distributed energy resources (DERs) including distributed generation, geographically targeted demand response and energy efficiency, and distributed energy storage and h) proliferation of new storage technologies and improved versions of existing storage technologies.

Sources
[1] Eyer, James M. Corey, Garth. *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide.* Draft report. October 2009.

[2] Eyer, James M. *Electric Utility Transmission and Distribution Upgrade Deferral Benefits from Modular Electricity Storage.* July 2009. Report # SAND2009-.