SMART GRID INTEROPERABILITY PANEL

Customer Energy Storage in the Smart Grid:

An Analysis and Framework for Commercial and Industrial Facilities and Electric Utilities

A white paper developed by the Smart Grid Interoperability Panel –August 20, 2014

Disclaimers

About the Smart Grid Interoperability Panel

The Smart Grid Interoperability Panel (SGIP) orchestrates the work behind power grid modernization. SGIP was established to identify technical and interoperability standards harmonization that accelerates modernization of the grid. As a member-funded, non-profit organization, SGIP helps utilities, manufacturers and regulators address standards globally: utilities gain improved regulatory treatment for investment recovery and manufacturers obtain enhanced commercial opportunities worldwide. SGIP members stay competitive, informed and well-connected. To learn more about SGIP, visit http://sgip.org/.

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1 Summary

This paper examines commercial and industrial facility energy storage and presents several facility internal and external use cases for energy storage that must be considered when examining energy storage in facilities. Despite the focus on commercial and industrial facility energy storage, the principles may be applicable to residential energy storage as well.

This paper examines various types of energy storage in the facility domain and discusses how each type of energy storage can support grid reliability. For the energy storage systems, the parameters that might be relevant for evaluating energy storage applicability to use case requirements are defined. In addition, values of key parameters are presented, allowing comparison between various systems. Additionally, this paper reviews related work that classifies energy storage.

The paper then presents a framework for grid interactions with the facility domain and proposes actions that can be appropriately developed by the Smart Grid Interoperability Panel (SGIP) to enable greater use of facility energy storage to meet customer cost/benefit responsibilities while contributing to grid reliability needs.

2 Introduction

Many commercial and industrial (C&I) facility owners already have various forms of energy storage, including the following examples:

- hot water tanks,
- natural gas supply and fuel oil tanks to fuel generators or heaters,
- ice thermal storage for building cooling,
- raw materials and intermediate products as input to industrial processes, and
- batteries in fork lift trucks and fleet vehicles.

What kinds of interaction between utilities and C&I customers will enable many of the energy storage resources in the customer space to serve the needs of the grid? How can these different forms of energy storage be compared in their ability to support grid needs?

The benefits of customer-based energy storage in facilities are significant. Clearly, energy storage is needed to support increased non-dispatchable renewable energy generation, and distributed energy storage reduces transmission and distribution grid losses. But beyond this, engaging the many forms of customer-owned energy storage to serve grid-side use cases is akin to exposing and connecting to a large untapped resource.

This resource is manifested in two ways. First, there are many already-installed energy storage resources in the customer space that might be used to serve grid needs.

Second, there are energy storage resources that are charged by non-electrical fuel sources but which can offset or shift the time of electricity requirements.
The goal of this white paper is to provide information that will support implementation efforts for facility-side energy storage and to present a customer energy storage integration framework. This paper looks at facility use cases for energy storage, and it looks at types of energy storage in the facility domain. It then examines how each of these types of energy storage can support grid reliability.

Additionally, this paper reviews related work that classifies energy storage and then presents a framework for grid interactions with the facility domain. Finally, the paper proposes actions that can be appropriately developed by SGIP to enable greater use of facility energy storage to contribute to grid reliability needs while meeting customer facility use requirements.

When examining energy storage, there are a number of factors to consider, such as the utility-customer relationship, the customer's economic justification of energy storage, and the use of distributed renewables. A key principle for engaging the full array of customer energy storage for grid reliability is that the customer must control the facility resources. The customer knows the resources, availability, and complexities. Therefore, the communications to and from grid-side service providers (e.g., demand response events or energy buy/sell transactions) must be at a higher level—a level that communicates to the customer what the needs are on the grid side and the value to the customer in meeting those needs. Ultimately, the customer must justify all energy storage resources based on economics and the ultimate impact on the Return on Investment.

In the current utility-customer interaction paradigm, there are several ways that utilities interact with customers. One arrangement is through a contract to manage generation at the customer site, including examples such as the following:

- combined heat and power (CHP),
- backup generation,
- photovoltaic (PV) generation, or
- electrical storage.

Another arrangement is via demand response (DR) programs, where the customer may commit to reducing load, and the DR program may be tied to specific systems in the building (such as heating, ventilation, and air conditioning, or HVAC, loads). The large majority of customer energy storage assets will not be available to utilities via direct control unless the facility has backup resources (such as thermal storage) that can maintain building services even as load is reduced.

One energy storage-related issue that is growing in importance for utilities involves the rise of distributed renewables as an energy source. With photovoltaic generation, for example, there can be a late-afternoon steep load curve rise.[1] With wind generation, on the other hand, there can be negative pricing created by surplus night wind.[2] Energy storage is needed to apply surplus peak solar to later peak loads, and to store peak wind to meet peak loads when the wind is not blowing.

All these considerations must be taken into account when examining how each of these types of energy storage can support grid reliability.

3 Facility Energy Storage: Use Cases and Resources

Facility resources are used to meet facility business needs at appropriate economic and social costs. There are significant distributed energy resources (DER), including energy storage, operated in facilities for facility purposes, and many of them are fueled by the utility distribution grids. This section will describe these energy storage resources and how they may support grid reliability. This section includes use cases which have been identified by the SGIP Building to Grid (B2G)/Industry to Grid (I2G) Joint Domain Expert Working Group (DEWG), based on efforts in several other industry groups. These efforts include the work of the Energy Information Standards Alliance as input to the ASHRAE 201P Facility Smart Grid Information Model standards effort, the work represented in the International Electrotechnical Commission (IEC) PC118 Technical Report “Smart Grid User Interface,” and the work emerging from SGIP over the past five years.

4 Internal and external use cases

There are several internal and external use cases that must be considered when examining energy storage in commercial and industrial facilities.

Table 1, “Internal facility energy services use cases,” lists six use cases specific to internal facility energy services. For internal use cases, the customer is using storage resources for the benefit of facility internal needs. These use cases may include making decisions based on external information.

[1] As seen in the “Duck Chart” created by the California Independent System Operator (CAISO). http://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

[2] http://www.bloomberg.com/news/2013-03-11/nuclear-industry-withers-in-u-s-as-wind-pummels-prices-energy.html

Table 3 Internal facility energy services use cases

Use Case	Title
Int.1	Energy source switching based on real-time (RT) cost—switching energy source for cooling equipment (for charging thermal storage), heating (boiler, charging thermal storage, process heat) or other. [EIS Alliance UC4[3]]
Int.2	Arbitrage in RT markets—using energy storage to buy when electricity price is low and sell when high. [EIS Alliance UC6[4]]
Int.3	Microgrid management—using storage to help in operating the facility as an independent (off-grid) microgrid. [DRGS A.1-7[5]] [EPRI NEDO BEMS[6]]
Int.4	Back-up power source--using energy storage as back-up power source for emergencies. [DRGS A.1-7[7]]
Int.5	Demand limiting—maintaining energy consumption below contractual limit by management of storage, loads, and generation. [EIS Alliance UC1[8]] [DRGS A.1-3, A.1-6[9]]
Int.6	Power quality management for facility systems—using storage systems to improve power quality via inverter frequency pattern. [DRGS A.1-4, A.2-1, A.3-1[10]]

[3] Energy Information Standards (EIS) Alliance Customer Domain Use Cases, v2, www.eisalliance.org, UC4 "Balance Power Purchases between Utility and On-site Generation"

[4] EIS Alliance Customer Domain Use Cases, v2, www.eisalliance.org, UC6 "Buy or Sell Electric Power"

[5] SGIP Distributable Renewables, Generation & Storage (DRGS) Domain Expert Working Group, Subgroup B, Use Cases, Information Exchange, and Object Models White Paper (draft), UC A.1-7, "Provide backup power including balancing the generation with the load" available at SGIP.org DRGS documents

[6] EPRI Use Case repository, http://smartgrid.epri.com/Repository/Repository.aspx, "NEDO - BEMS Control of DERs and HVAC Equipment in a Commercial Building Which Enables Islanding Operation and Demand Response"

[7] Ibid Int.3 above

[8] EIS Alliance Customer Domain Use Cases, v2, www.eisalliance.org, UC1 "Manage Power Demand to Minimize Cost"

[9] SGIP DRGS Subgroup B, Use Cases, Information Exchange, and Object Models White Paper (draft), UC A.1-3, "Generate specified energy output at specific times to offset peak load" and A.1-6 "Offset local loads through DER generation," available at SGIP.org DRGS documents

[10] SGIP DRGS Subgroup B, Use Cases, Information Exchange, and Object Models White Paper (draft), UC A.1-4, "Modify energy output in response to local voltage variations in order to damp voltage deviations" and A.2-1 "Provide reactive power by a fixed power factor", and A.3-1 "Support frequency regulation through autonomous modifications of real power output to counter frequency deviations," available at SGIP.org DRGS documents

Table 2, "External facility energy services use cases," lists five use cases specific to grid interactions. For external use cases, the customer is using facility storage resources to directly support grid needs.

Table 4 External facility energy services use cases

Use Case	Title
E.1	Peak reduction and valley filling (DR application)—customer reduces consumption in response to DR event or price signal. [EPRI B2G-1,2,3, NEDO BEMS, IC-1[11]]
E.2	Voltage/frequency regulation (4 sec response)—customer provides voltage/frequency regulation service to grid [DRGS A.4-6[12]]
E.3	Synchronized/spinning reserve (10 min response)—customer provides synchronized/spinning reserve service to grid [DRGS A.4-6[13]]
E.4	Reactive power control—customer provides reactive power control service to grid [DRGS A.2-1, A.2-2[14]]
E.5	Other: system inertia and black start—customer provides other ancillary service to grid [DRGS A.4-8[15]]

It is important to note that an energy storage resource may serve multiple use cases, both internal and external. Justifying energy storage for a facility depends on the financial costs and benefits of serving multiple use cases. There may also be other non-financial drivers for justifying energy storage, such as reducing Green House Gas (GHG) emissions and promoting corporate social responsibility.

[11] EPRI Use Case repository, http://smartgrid.epri.com/Repository/Repository.aspx, B2G-1 "B2G - DR Load Profile Management Via Pricing Mechanisms," B2G-2 "B2G - DR Load Profile Management Via Reliability Based Signals," B2G-3 "B2G - Load Management with Dynamic Tariffs, DR and DER," NEDO BEMS "NEDO - BEMS Control of DERs and HVAC Equipment in a Commercial Building Which Enables Islanding Operation and Demand Response," IC-1 "Demand Response Providers Adjust Consumer's Energy Consumption in Response to ISO Dispatch Instructions"
[12] SGIP DRGS Subgroup B, Use Cases, Information Exchange, and Object Models White Paper (draft), A.4-6 "Provide 'spinning' or operational reserve so that real power is available at short notice (seconds or minutes)," available at SGIP.org DRGS documents
[13] Ibid E.2 above
[14] SGIP DRGS Subgroup B, Use Cases, Information Exchange, and Object Models White Paper (draft), A.2-1 "Provide reactive power by a fixed power factor," and A.2-2 "Volt-var management by providing dynamic reactive power injection through autonomous responses to local voltage measurements," available at SGIP.org DRGS documents
[15] SGIP DRGS Subgroup B, Use Cases, Information Exchange, and Object Models White Paper (draft), A.4-8 "Provide black start capabilities," available at SGIP.org DRGS documents

5 Energy storage resources

Many different forms of energy storage exist which can serve the use cases listed above.

The types of energy storage covered in this paper are listed in Table 3, "Facility energy storage resource types."

Table 5 Facility energy storage resource types

Type of Energy storage	What is stored
Ice Storage	Cold
Hot Water Storage	Heat
Building thermal mass storage	Heat or cold
Shiftable electric loads	Heat, cold, electricity, or fuel switching
Sheddable electric loads	Virtual stored energy*
Natural Gas/diesel/H_2/other fueled generation	Fuel storage for fuel switching to supply heat or power
Cogeneration plant	Fuel storage (natural gas or otherwise)
Industrial process	Raw materials or intermediate products
Batteries/ electrical storage**	Electricity in/out
Solar renewable generation (PV, wind)	Virtual stored energy*

* Included here because sheddable loads and solar PV generation both can deliver power (actual or "nega-watts") similar to what electrical storage can deliver.
** May include electric vehicle batteries. EV batteries are dual-purpose, like other energy storage in the customer space. It serves the needs of the vehicle owner first for transportation, then for additional services.

In the table above, sheddable electrical loads (e.g., lights, elevators, pumps, etc.) are not recharged later. The same may apply to air cooling loads; for example, if the indoor air temperature set point is raised (shedding the chiller), this action allows the building indoor air temperature to rise slowly with a rate of temperature increase tied to the amount of building thermal mass storage. At the same time, raising the temperature set point reduces thermal losses to the outside such that total energy use is decreased. The indoor temperature may be reduced at night using natural cooling (no chiller), or at least the chiller power required will be less (due to more efficient operation in the cooler night air) and cost of that electricity reduced due to lower nighttime energy prices.

6 A brief review of thermal storage

Thermal storage can be charged at any time, but only discharged when the cold or hot resource is needed (although this might not strictly be true, such as for frequency regulation application). A hot resource might typically be needed on winter morning heating peaks and a cold resource during afternoon summer air conditioning (AC) peaks, but the thermal energy storage can only meet the energy needs of the HVAC/hot-water system to which it is tied/integrated. Such an arrangement might cover 90% of peaks, which makes thermal storage a good choice for addressing peaks.

Shifting thermal loads can result in energy, cost and carbon savings. Thermal storage may be charged with night wind or noon solar or minimum price electricity for cost and carbon savings. As an example of energy savings, HVAC cooling recharge is more efficient at a cooler time of day—that is, it requires less energy for the chiller to make ice at night with cooler night air than to get the same amount of cooling in the hot afternoon air. Many publications provide data about thermal storage and its application [1, 2, 3, 4]

7 Energy Storage Parameters

The B2G/I2G Joint DEWG has identified the energy storage parameters that might be relevant for evaluating energy storage applicability to use case requirements. The most relevant parameters are given in Table 4, “Energy storage parameters for facility energy storage systems.”

Table 6 Energy storage parameters for facility energy storage systems

Energy storage parameters
Use cases served by this energy storage resource
Ramp Rate (in/out) (time to ramp up fully)
Capacity (min/max) (kWh)
Power (min/max) (W)
Electricity Flow – into storage, out of storage, or both
Round Trip Energy Efficiency (RTEE)
Customer Class using this energy storage (residential, commercial, industrial)
GHG emissions impact of using this energy storage resource

In addition to these eight parameters, other parameters were examined. One subset of parameters is associated with the connection to the energy storage system. Some are metered, some are not. There may be no electrical connection to the energy storage system, such as to an ice storage unit, a fuel tank, or a production line storage bin. The question also arises as to who (or which system) typically manages or controls the energy storage asset. It may be a facility system controller or higher-level energy management system. A specific device controller might also be operated remotely by a service provider.

This paper briefly considers the information requirements needed to enable use of these resources for external use cases. This is covered in greater detail elsewhere [5, 6, 7].

8 Energy storage application matrix

While electrical storage can broadly serve almost any storage use case (although practical application may be limited by economics), most other forms of energy storage have additional limits to application. Other (non-electrical) forms of energy storage may be tied to a single facility sub-system or tied to season of the year or time of day. The energy storage application matrix (Table 5) shows estimated values of the identified energy storage parameters (from Table 4) for each of the various energy storage systems (from Table 3) in addition to showing which of the different identified use cases (from Tables 1 and 2) are served by each energy storage technology.

This energy storage application matrix shows the potential for various types of facility energy storage to meet grid needs. In general, non-electrical storage has relatively slow response times compared to batteries, although electric heat and lighting and some other loads can be turned on/off, lights dimmed, variable speed drives reduced, with response times of less than a second. Most building energy storage can only respond in one direction: thermal storage only consumes electricity (returning storage indirectly via reduced load when thermal resource is requested), while generators consume stored fuel to produce electricity. Combining generation with thermal storage load reduction might provide virtual storage. Power and capacity levels vary significantly between and within storage types.

Table 7 Facility energy storage application matrix

Facility-sited DER system	Use Cases served	Ramp Rate (in/out)	Capacity (min/max)	Power (min/max)	Electric Flow	Round Trip Energy Eff (RTEE)	Customer Class	GHG emissions
Ice storage	Int.2,Int.5, E.1,E.3,	<3 min	20 - 2000 kWh	10 - 300 kW	None	Very high (90-100%)	C&I, Res	Stores energy. Small GHG change.**
Hot water storage	Int.1, Int.2,Int.3, Int.5,E.1,E.2,E.3	<1 sec	1-50 kWh	5 - 50 kW	1-way in	Very high (90-100%)	R&C	Same**
Building thermal mass storage	Int.2,Int.3,Int.5, E.1	<1 min	10 - 1000 kWh	10 - 300 kW	None	High--energy from air, returned to air (80-90%)	R&C	Same**
Shiftable electric loads	Int.2,Int.3,Int.5, E.1, (maybe E.2,E.3),	1 s - 1 min	Various. Cap equivalent to (load**x**dur) of shed. Recharged later.	Various. Equals load (may operate at dif power levels).	1-way in	>100% for thermal,* 100% for product line.	All	Less GHG than without
Sheddable electric loads	Int.2,Int.3,Int.5, E.1 peak red	s - min	Various (as above)	Various, as above	1-way in	n/a	All	Less GHG because using less energy
Natural gas/H_2/ diesel/ other fueled generation	Int.1,Int.2,Int.3, Int.4,Int.5, Int.6, E.1 peak red, E.3	Ramp 10 s. Output 3 min.	n/a (may be emissions limits)	kW - MW	1-way out	n/a	C&I (maybe Res)	Bad for diesel gen. Good for fuel cell.
Cogeneration power plant	Int.1-6 (all Int) E.1 peak red, E.3	Ramp 3 min. Output (dep. on size).	n/a	kW - MW	1-way out	n/a	All	NG GHG
Industrial process (products)	Int.2,Int.5, E.1	10 s	Energy value of stored product kWh-MWh	Power of production line	1-way in	Very high (maybe 100%)	I	Storage at high RTEE = low GHG emissions
Batteries/ electricity storage	All	< 1 s	Various	Various	2-way	80-90%	All	Some increase due to losses (RTEE) (none if charge with PV or wind)
Solar renewable generation (PV, wind)	Int.3, E.2,E.4	No control	n/a	kW - MW	1-way out	n/a	All	No GHG

*As indicated in the note about sheddable load in the text below Table 3, it is possible that energy stored at night (when the chiller operates more efficiently, and when transmission and distribution (T&D) losses are less), combined with a high thermal storage system efficiency, can result in an overall greater than 100 % RTEE when combining all these factors. (Note: the difference in T&D also increases the RTEE of batteries charged at night and discharged in the day.)
** For the same reasons as given in the note above (*), GHG emissions may be reduced.

9 Grid Interaction Framework for Greater Integration of Customer Energy Storage

This section of the white paper will provide an overview of existing work by other organizations on the topic of energy storage and introduce a customer energy storage integration framework that will guide the implementation efforts for facility-side energy storage.

10 Review of other work

Electric Power Research Institute (EPRI) and California Public Utilities Commission (CPUC) developed an Energy Storage Framework [8] that groups energy storage systems (ESS) according to utility end uses or services or value streams. While the report has a very broad definition of ESS, the report does not include any analysis or valuation of thermal storage. The Energy Storage Framework is based on services, not "type of energy storage." It identifies different services, and it groups these relative to location. The framework does not cover real system parameters (including costs) that would allow a user to evaluate the applicability of a specific energy storage system to a specific application. Other reports also provide valuable analyses for the use of electrical storage to meet the varied grid application requirements, including financial information that helps judge economic viability for a specific application [9,10,11,12,13].

The *Pacific Northwest National Laboratory* (PNNL) ESS protocol [14], now under development, analyzes energy storage technologies (eventually to include thermal energy storage) to develop testing protocols that will allow standard comparison of performance across different types of systems to meet a small set of use cases (currently, only the two use cases of peak shedding and frequency regulation). This protocol will be very helpful for the comparison of battery and thermal storage technologies.

The reports cited above are largely looking at electrical storage from the perspective of a grid-side service provider (e.g., utility) and the benefit of that energy storage resource to the grid alone. While thermal storage is acknowledged, other forms of energy storage (e.g., thermal building mass, shiftable loads, fossil fuel storage, and industrial process raw materials and intermediate products) are not mentioned. To effectively integrate these additional facility-side resources, it will be important to look beyond a dispatch approach. The resources must remain under the control of the customer, thereby serving to maximize the customer benefit via economic reward for providing services to the grid.

11 An abstract framework for energy storage integration

How can a more effective path be enabled that integrates customer energy storage (and other customer DER) into the grid (e.g., to support grid reliability, adequacy, and environmental concerns)? This paper presents here a framework which relies on an abstract interface and decoupling of customer internal systems' controls from interactions with external service providers. While outside direct control of internal systems may be acceptable for providing dispatchable resources to support grid health, a more abstract interface will support a greater response from customer systems for applications such as peak shaving and frequency regulation. If the customer is given the flexibility, and has the automation capabilities, then the customer can take advantage of multiple energy storage, load, and generation resources to meet the needs of the facility while also supporting grid reliability.

Figure 1, "Abstract framework for engaging customer responsive load/DER," summarizes the energy services interface (ESI) concept as developed previously by the SGIP B2G/I2G Joint DEWG. At the highest level of abstraction seen here, an outside service provider interacts with a building-level interface, likely some energy management system (ESI-EM in Figure 1). While the meter may also host the ESI, the idea shown in Figure 1 is that the meter is logically separate from the ESI. The meter here is a metrology device, reporting energy use back to the energy service provider.

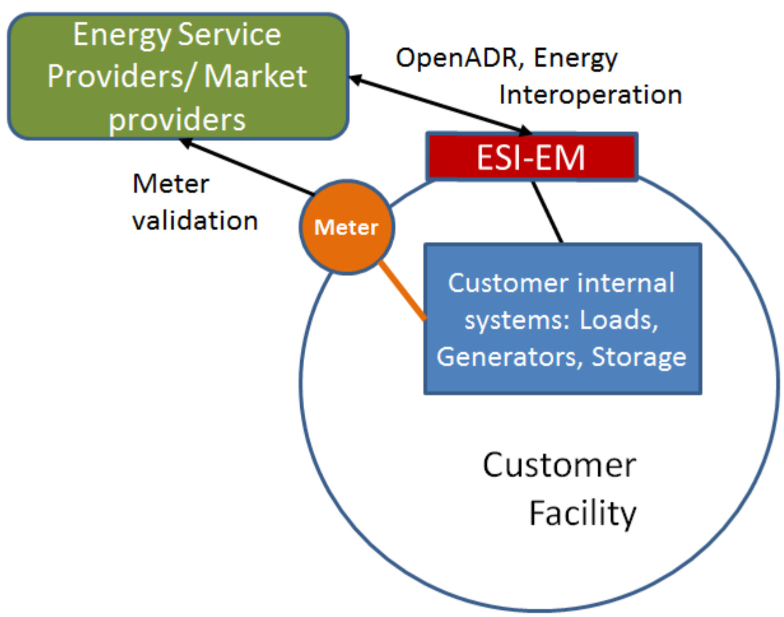

Figure 1 Abstract framework for engaging customer responsive load/DER

Figure 1 shows the abstraction of hiding internal customer system details. The ESI-EM (itself an abstraction of perhaps more than one energy management system) manages loads, generation, and storage to meet facility needs as well as to provide services to the grid. The customer is able to engage many resources to meet service requirements, and the customer understands all of the complexities of the various systems [6]. OpenADR and OASIS Energy Interoperation (EI) serve as the protocols of the ESI-EM. OpenADR is a profile of EI. EI also includes services for market transactions that are not currently part of OpenADR. It is the tender and transaction interaction process with both price and quantity (i.e., transactive energy) that puts both the customer and the energy service providers on an equal basis without having to turn customers into "virtual power plants" to service the grid.

The ASHRAE Facility Smart Grid Information Model standard uses the information model components from Energy Interoperation (in addition to Green Button for energy usage; Weather Information Exchange Model, WXXM, for weather data; and IEC 61850, Communication Networks and Systems in Substations, for direct control of DER). Energy Interoperation (including OpenADR) serves as the bridge for a decoupled interaction with customer systems that will enable the greatly increased utilization of customer resources to meet grid needs.

OASIS Energy Interoperation uses within it the information model from the OASIS Energy Market Information Exchange (EMIX) standard. EMIX provides a standard information model for energy storage parameters, and thus an abstract model of energy storage. EMIX includes the four parameters identified in the PNNL ESS protocol (Capacity, Round-trip Energy Efficiency, Ramp Rate, Response Time). The EMIX information model allows communicating availability and other status information that can be used to plan forward use of the energy storage for load management or other purposes. On the other hand, EMIX also enables market interactions, communicating power purchase bids and transactions. These transactions enable taking advantage of the energy storage capabilities for arbitrage, demand limiting, and power quality control, abstracting the four parameters just mentioned such that they do not need to be communicated.

Implementing the ESI will have profound benefits for the energy storage equation—releasing more customer energy storage resources to support the grid. Because the customer understands customer systems and limitations, the customer can utilize all available resources within the customer facility to act together to provide peak shaving, valley filling, frequency regulation, or any other valuable service, according to available systems.

12 Recommendations for SGIP Action

What are the next steps for SGIP and the integration of customer-side energy storage resources? This paper presents SGIP-identified standards from Priority Action Plan (PAP)-03 “Common Price Communications Model;” PAP-04, “Common Schedule Communication Mechanism;” and PAP-09, “Standard DR and DER Signals” that are relevant to integration of customer load, generation, and energy storage resources. Because this is a relatively new area of consideration, there are potential issues on the regulatory and policy side to consider when advancing use of these standards. The SGIP Distributed Renewables, Generation & Storage (DRGS) DEWG is preparing a white paper on “Potential Regulatory Barriers and Challenges to Deployment of Distributed Generation and Storage,” which will provide a starting point for examining some of the regulatory issues.

Incentivizing commercial and industrial customers to install energy storage and make it available for service to the grid depends on the ability to monetize the investment, which in turn depends on tariffs. SGIP might consider addressing requirements for an interoperable tariff standard to promote customer energy storage in smart grid.

SGIP might also build on this white paper to produce a guide for facility managers and utilities that shows which customer energy storage types are best for which use cases and how those resources can serve the grid. This might be similar to the Sandia report (“DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA”) cited earlier [13]. SGIP could focus on the ability of customer facility-sited energy storage to serve grid-side use cases, following the EPRI white paper (“Cost-Effectiveness of Energy Storage in California”) cost-effectiveness analysis approach [11], using an additive approach to benefits and seeing what profit is potentially realizable.

13 Endnote References

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