Energy Storage Association

Including Advanced Energy Storage in Integrated Resource Planning: Cost Inputs and Modeling Approaches

November 2016

v1.1

Advanced energy storage costs are declining rapidly and large-scale storage deployments are increasing. However, utility integrated resource planning does not adequately consider advanced energy storage as an option for system capacity. With utilities planning to invest billions of dollars in new and replacement capacity over the next several years, the time is now to include storage in resource planning to ensure least-cost solutions for ratepayers and prudent long-term investments for reliability.

This primer provides an overview on how to appropriately include advanced storage in long-term utility resource planning processes and includes up-to-date cost inputs from public sources.

Jason Burwen

Policy Director

Energy Storage Association

j.burwen@energystorage.org

202-580-6285

Least-Cost Utility Planning Must Consider Advanced Energy Storage as a Capacity Resource

Utilities prepare integrated resource plans (IRPs) to determine the combination of resources that will enable them to meet forecasted annual peak and energy demand, plus some established reserve margin, over a specified future period, usually 10-20 years. Those IRPs then inform utilities' subsequent decisions on what kind of resources to build/own or to procure from other parties through long-term contracts.

While some utilities have demonstrated interest in understanding the costs and benefits of advanced energy storage in the context of IRPs, informational barriers remain: planning models are not granular enough to capture the operations of advanced storage, and models use inaccurate and out-of-date cost information. Utilities are thus missing the opportunity to analyze, evaluate, and procure advanced storage as a cost-effective capacity resource, putting ratepayers at risk of significant imprudent investments.

Utilities and utility commissions can address these barriers. Advanced energy storage is now commercially contracted—and procured competitively with traditional resources—at project scales up to 100 megawatts (MW), on par with natural gas-fired power plants. There are several validated commercial planning models available today that can capture intra-hourly operations of storage and other resource options. Also, storage cost estimates are available in public sources, many of which are updated annually or quarterly to support understanding of current trends. If utilities and utility commissioners update their approach to storage in IRPs, the choice of storage as a capacity resource can be made on a least-cost economic basis today, avoiding costs for ratepayers.

This document provides information on modeling and a framework for evaluation of benefits of storage resources in the context of IRP analysis. Additionally, this document offers a source for current and forecasted costs and benefits of advanced energy storage, using publicly available information from established sources with industry review from ESA members. In summary:

- Models that use sub-hourly intervals can quantify the value of both capacity and flexibility benefits provided by advanced energy storage;
- By subtracting those flexibility benefits from the cost of storage—thereby using a "net cost of capital" analysis of capacity investment options—planners can more accurately compare advanced energy storage with traditional capacity resources;
- Planners that use up-to-date cost estimates and forecasts in their models can more accurately identify near- and long-term prudency of advanced storage; and
- Utility commissions can ask their utilities to consider advanced storage in IRPs under their existing authority.

Utilities and Utility Commission Should Use More Granular Resource Modeling

Most utility IRPs use methods that do not adequately model advanced storage. Typical IRP models use three inputs—forecasted demand, the capital cost of available technologies, and those technologies' operating profiles—to calculate economic long-term options for system capacity. These models tend to be simple because they adequately capture the uncomplicated operations of traditional generation units providing capacity (see Box 1).

In contrast, current-day advanced energy storage provides high value flexibility services, like frequency regulation or ramping support, in addition to capacity. A large-scale energy storage resource dedicated to providing peak capacity when needed—typically a four-hour period in afternoon and early evening—can also provide grid services for the many hours when that peak capacity is not needed. Storage resources can do this because they are "always on" and available for service, in contrast to traditional generation units that need to be started up and shut down to provide services to provide peak capacity and other services. As a result, planners do not have the right tools to estimate the net cost of storage capacity.

For this reason, utilities and utility commissions should update methods in future IRPs to accurately model advanced storage. Utilities should employ models that use

Box 1: Time Intervals in IRP Modeling

Typical production cost models are relatively simple and calculate economic options by modeling generator operations to meet expected load for *each hour chronologically* over a period of many years. The main shortcoming of this type of model is that advanced storage can provide flexibility services on an *intra-hourly* basis, and there is no way to capture that service in an hourly model.

Some utilities employ even simpler models that extrapolate from a small *sample of hours* for each season to simulate load and generator dispatch patterns for all hours over a period of many years. The main shortcoming of this type of model is that advanced storage provides services, like system ramping for renewables, that is only captured by a full chronological series of hourly or sub-hourly intervals *over the course of a full day*. Thus, using a small number of sample hours will exclude significant storage services and result in erroneous extrapolation for long-term planning.

sub-hourly intervals that capture the flexibility of storage operations to provide both capacity and grid services. Several validated commercial models are available that can examine calculate economic resource options including intra-hourly dynamics, such as PLEXOS, PSO, and FESTIV. If sub-hourly modeling is not considered an option, then at minimum utilities should use an hourly chronological production cost model, rather than sampling from a small set of hours from each season.

Proper Advanced Storage Modeling Should Consider All Benefits to the System

The flexibility benefits of advanced storage operations are significant and represent a substantial addition to the capacity value of storage. The simplest method to incorporate such storage benefits into IRPs is to use a net-cost-of-capacity approach, as pioneered by Portland General Electric in their 2016 draft IRP[1] and the concept of which is illustrated in Figure 1:

Net cost of capacity = Total installed cost – Operational benefits (flexibility operations & avoided costs)

Some of the operational benefits of storage are flexibility services directly provided by the individual unit in question. Among these benefits are (1) regulation, (2) load following, and (3) contingency reserves. When the direct operational benefits of storage are modeled, they can represent as much or more than the capacity value of storage. For example, preliminary findings from Portland General Electric's 2016 draft IRP found that operational benefits of storage were expected to be approximately two times larger than the capacity value (~$90/kW-yr and ~$40/kW-yr, respectively).[2]

Other operational benefits of storage accrue to the entire system as avoided costs. Among these benefits are (1) reduced operating reserve requirements; (2) reduced start-up and shut-down costs of all generation facilities; (3) improved heat-rate of thermal plants and consequently reduced emissions; (4) reduced uneconomic dispatch decisions, in the form of uplift or revenue sufficiency guarantee payments; (5) reduced curtailment of renewable resources; (6) reduced risk of exposure to fuel price volatility; and (7) reduced local emissions for areas with emissions restrictions. As an example, a Massachusetts state-commissioned study of large-scale energy storage deployment found that the total value of these system benefits was greater than the value of the direct, compensated services of storage.[3] Indeed, because these benefits increase the efficiency of the overall grid, the must be ac-

Figure 1 Example Net Cost of Capacity Calculation

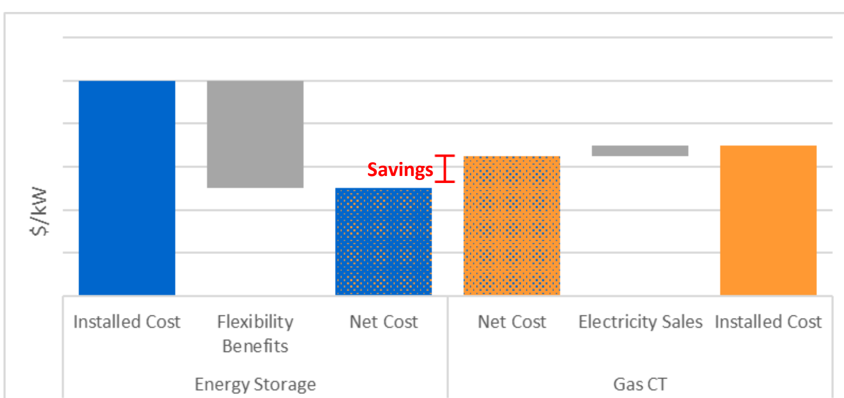


Table 1 Examples of Operational Benefits of Storage in Addition to Capacity Value

Benefit	Illustrative Value		Included in IRPs	Included in Sub-Hourly Models
Avoided capacity values				
Avoided generator start-up/shut-down	$20.10-$46.70/kW-yr[1] 10% system reduction[2]			X
Avoided generator fuel and O&M costs	$11.90-$61.00/kW-yr[1] 0.5% system reduction[2]		X	X
Reduced reserve requirements	30% regulating reserve reduction[3]			X
Sub-hourly operational values				
Regulation reserve	$35-41/kW-yr[1]	$75-90/kW-yr for ancillary services[4]		X
Load-following				X
Spinning reserve				X
Other system values				
Reduced wholesale prices	$0.19-0.29/MWh[5]			
Fuel hedging value	$21/kW-yr for doubling of gas prices[2]			
Environmental values				
Avoided NOx	60-70 g/MWh[6]			
Avoided CO2	600 MTCO2e/MW[5] 0.1-0.3 MTCO2e/MWh[6]			

[1] NREL (2015) *Operational Benefits of Meeting California's Energy Storage Targets*
[2] NREL (2013) *The Value of Energy Storage for Grid Applications*
[3] PJM (2013) *Performance Based Regulation: Year One Analysis*
[4] PGE (2016) *Portland General Electric 2016 Draft Integrated Resources Plan*
[5] MA DOER (2016) *State of Charge: Massachusetts Energy Storage Initiative Study*
[6] Energy Policy 96 (2016) *A framework for siting and dispatch of emerging energy resources to realize environmental and health benefits: Case study on peaker power plant displacement*

counted for at a system level, rather than at the level of an individual storage resource.

U.S. National Laboratories and others have sought to quantify the avoided costs of energy storage using commercially available production cost models.[4] For example, NREL's 2013 study of California market estimated storage will result in avoided costs from other generators as $35.70 – $58.50/kW-yr.[5] The conclusion of these studies is that the avoided cost and flexibility benefits of advanced storage are significant and need to be captured in a net cost of capacity approach.

Recognizing that utilities may have to use models available to them currently—and that those models may not be capable of capturing flexibility benefits and avoided costs of storage—utilities can estimate these values from other studies until such modeling is instituted. While it is beyond the scope of this document to quantify all the previously discussed operational benefits of storage or provide a methodology to do so, an illustrative table of benefits is provided below to guide utilities and utility commission that seek to account for these benefits when including storage in IRPs.

Current and Forecast Advanced Energy Storage Costs

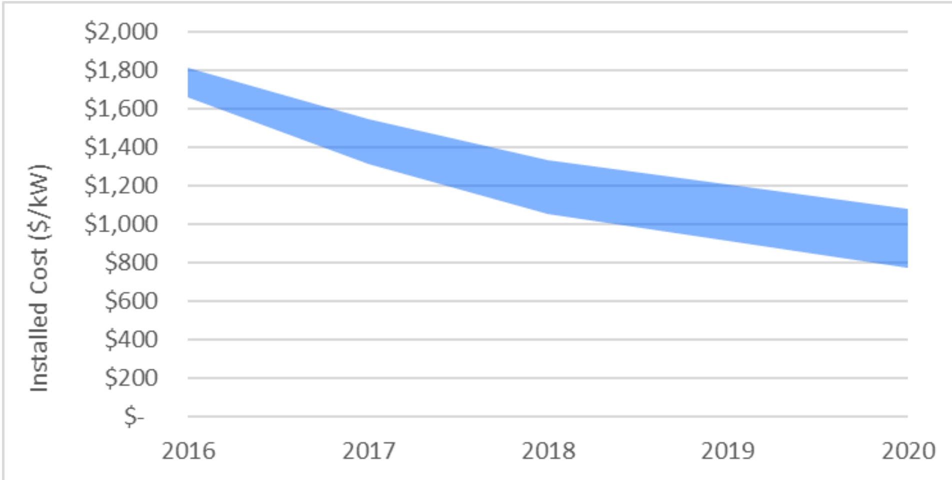
Numerous sources report that the installed cost of advanced energy storage has declined significantly in recent years, generally faster than market expectations.[6] Considering this rapid and recent technical progress, it is critical that planners use up-to-date advanced storage cost estimates and forecasts for IRP model inputs. This section offers an example of an estimate and forecast drawn from publicly available sources.

While advanced energy storage technologies are diverse, lithium-ion energy storage is the most common technology being deployed today. Figure 2 forecasts the cost of a 100 MW lithium-ion energy storage facility with 4-hour duration. Unit operating parameters are combined with recent cost data, forecasted installations, and technology learning curves. All data come from publicly available sources: cost data are sourced from IHS Research[7] and GTM Research[8]; learning curve estimates are sourced from BNEF[9]; and global installed capacity data are sourced from Navigant[10]. Note that total installed costs are described as a capacity value ($/kW) to make them readily comparable to traditional capacity options.[11] Total costs include batteries, balance of systems, financing costs, and O&M.

It is also important to note that many utilities' IRPs assume that the costs of conventional supply technologies increase over time, based on inflation. Advanced storage has demonstrated a declining cost curve, as the rapidly increasing scale of manufacturing capacity and deployment has resulted in significant unit cost reductions within the IRP planning window, and this trend is expected to continue for the foreseeable future.

As previously discussed, the most accurate way to model storage is as a net cost of capacity, which subtracts unmodeled operational benefits from total installed costs. Assuming just the illustrative values from the NREL 2015 study on avoided start-up/shut-down costs of ~$20/kW-yr and avoided fuel costs of ~$10/kW-yr and an 8% discount rate, Figure 3 presents forecast net cost of capacity from storage.

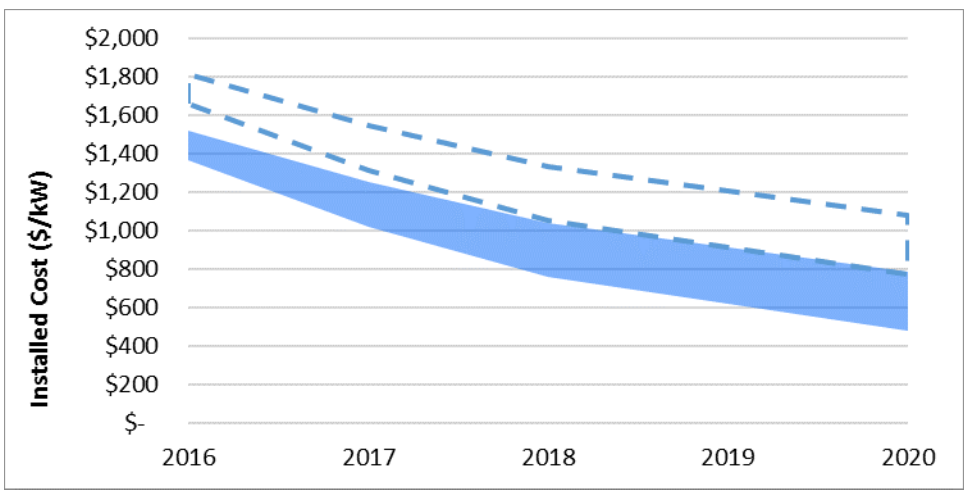
Figure 2 Forecast Installed Cost, 100 MW / 4-Hour Lithium-Ion Storage



	2016	2017	2018	2019	2020
Upper	$ 1,814	$ 1,549	$ 1,337	$ 1,209	$ 1,083
Lower	$ 1,660	$ 1,315	$ 1,056	$ 911	$ 774

Upper: GTM install costs, BNEF experience curve (low end, 14%), Navigant global installs
Lower: IHS install costs, BNEF experience curve (high end, 19%), Navigant global installs

Figure 3 Illustrative Net Cost of Capacity, 100 MW / 4-Hour Lithium-Ion Storage



	2016	2017	2018	2019	2020
Upper	$ 1,519	$ 1,255	$ 1,042	$ 915	$ 788
Lower	$ 1,365	$ 1,020	$ 762	$ 616	$ 479

Upper: GTM install costs, BNEF experience curve (low end, 14%), Navigant global installs
Lower: IHS install costs, BNEF experience curve (high end, 19%), Navigant global installs

The Time to Start Modeling Advanced Storage is Now

With billions of dollars of peak capacity additions planned in the next several years, and with storage costs continuing to decline rapidly and deployments increasing, the time is now to include storage in long-term planning to ensure utilities find least-cost solutions for their customers. In addition, as many systems are set to include higher levels of variable generation sources, flexibility of supply will be a critical must-have. Evaluating storage as a flexible resource choice for future capacity needs is thus an issue of prudency in utility decisions.

Utility commissions generally do not need new authorities to ask utilities to adequately consider energy storage as a capacity resource in their IRPs. ESA and its member companies welcome the opportunity to work with utility resource planners and utility commissions to include storage in IRPs and ensure they meet their duty to ratepayers.

ENDNOTES

1 See Chapter 8 in *Portland General Electric 2016 Draft Integrated Resources Plan*, issued 26 Sep 2016, available at https://www.portlandgeneral.com/-/media/public/our-company/energy-strategy/documents/2016-09-16-draft-irp.pdf
2 See Chapter 8 in *Portland General Electric 2016 Draft Integrated Resources Plan.*
3 See Massachusetts Department of Energy Resources, *State of Charge: Massachusetts Energy Storage Initiative Study*, Sep 2016, available at http://www.mass.gov/eea/docs/doer/state-of-charge-report.pdf
4 For example, see:

- National Renewable Energy Laboratory, *Operational Benefits of Meeting California's Energy Storage Targets*, Dec 2015, available at http://www.nrel.gov/docs/fy16osti/65061.pdf
- National Renewable Energy Laboratory, *The Value of Energy Storage for Grid Applications*, May 2013, available at http://www.nrel.gov/docs/fy13osti/58465.pdf
- Sandia National Laboratory, *NV Energy Electricity Storage Valuation*, June 2013, available at http://www.sandia.gov/ess/publications/SAND2013-4902.pdf
- Sandia National Laboratory, *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide*, Feb 2010, available at http://www.sandia.gov/ess/publications/SAND2010-0815.pdf

5 See National Renewable Energy Laboratory, *The Value of Energy Storage for Grid Applications*, May 2013, available at http://www.nrel.gov/docs/fy13osti/58465.pdf
6 See discussion of price declines exceeding forecasts at B. Nykvist & M. Nilsson, "Rapidly falling costs of battery packs for electric vehicles," *Nature Climate Change* 5, 329–332 (2015), doi:10.1038/nclimate2564, available at http://www.nature.com/nclimate/journal/v5/n4/full/nclimate2564.html. Additionally, several resources describe a 50% decline in energy storage costs in recent years; see IHS, *Future of Grid Connected Energy Storage*, Nov 2015, available at https://technology.ihs.com/512285/grid-connected-energy-storage-report-2015; see also
7 See IHS, *Future of Grid Connected Energy Storage*, Nov 2015, available at https://technology.ihs.com/512285/grid-connected-energy-storage-report-2015
8 See GTM Research, *Grid-Scale Energy Storage Balance of Systems 2015-2020*, Jan 2016, available at https://www.greentechmedia.com/research/report/grid-scale-energy-storage-balance-of-systems-2015-2020
9 See slide 70 in keynote presentation by Michael Liebrich from the BNEF New Energy Finance Summit, 5 Apr 2016, available at https://data.bloomberglp.com/bnef/sites/4/2016/04/BNEF-Summit-Keynote-2016.pdf#71
10 See Navigant Research, *Energy Storage for the Grid and Ancillary Services,* issued 2014, available at http://www.navigantresearch.com/research/energy-storage-for-the-grid-and-ancillary-services
11 Since storage provides flexibility services that are not valued by volume of output, a capacity cost metric ($/kW) is more appropriate than a levelized cost of energy metric ($/kWh), which best applies to resources that simply supply electricity.