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Energy Storage Financing: *Project and Portfolio Valuation*

Richard Baxter, Mustang Prairie Energy

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico
87185 and Livermore,
California 94550

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ABSTRACT

This study investigates the issues and challenges surrounding energy storage project and portfolio valuation and provide insights into improving visibility into the process for developers, capital providers, and customers so they can make more informed choices. Energy storage project valuation methodology is typical of power sector projects through evaluating various revenue and cost assumptions in a project economic model. The difference is that energy storage projects have many more design and operational variables to incorporate, and the governing market rules that control these variables are still evolving. This makes project valuation for energy storage more difficult. As the number of operating projects grow, portfolios of these projects are being developed, garnering the interest of larger investors. Valuation challenges of these portfolios can be even more challenging as market role and geographical diversity can actually exacerbate the variability, not mitigate it. By proposing additional visibility of key factors and drivers for industry participants, the US DOE can reduce investment risk, expanding both the number and types of investors, plus helping emerging energy storage technology into sustained commercialization.

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- Location San Francisco, CA
- DOE Speaker Imre Gyuk, U.S. Department of Energy
- Keynote Janea Scott, California Energy Commission
- Keynote Troy Miller, GE Power & Energy Storage Association
- Host Kirkland & Ellis, LLP, and Mustang Prairie Energy

January 14th, 2020

- Location New York, NY
- DOE Speaker Imre Gyuk, U.S. Department of Energy
- Keynote Chandrasekar Govindarajalu, The World Bank
- Keynote Alicia Barton, New York State Energy Research and Development Authority (NYSERDA)
- Host Kirkland & Ellis LLP and Mustang Prairie Energy

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EXECUTIVE SUMMARY

IMPORTANCE OF VALUATION

There are two key aspects of valuing an energy storage project; the methodology used, and the value arrived at. Both components are important, but the complexity of the methodology is many times overlooked (both unintentionally and intentionally). This is understandable as energy storage technologies possess a number of inter-related cost, performance, and operating characteristics that impart feed-back to impacts to the other project aspects. However, this complexity is the heart of the value potential for energy storage systems. For this reason, it is imperative to ensure that both components are designed to address the complexity and not allow implicit biases to be imparted as this can significantly impact the financing opportunity for the proposed project.

Different market segments utilize energy storage system in distinct ways, providing the opportunity to apply these different valuation methodologies to drive unique business strategies. An important aspect of this point is to understand that some applications have clear value that can be written as discrete revenue contracts, while other provide revenue streams that are not as easily monetized, and thus must be incorporated into larger structures to capture the value, such as a solar/storage project or rolled into the rate-base of a utility. These aspects will also affect the cost of capital for the project, also impacting its development path.

Non-lithium energy storage technologies many times are at a disadvantage to lithium systems as the core of the market has begun to evaluate not just the technologies, but the opportunities themselves through the lens of lithium-ion system costs and capabilities. In early market where one technology dominates, this is a typical occurrence. As the market continues to grow, it is a market of commercial maturity that customers begin to understand their needs sufficiently to highlight other opportunities that the early dominate technology is not designed for. Therefore, how the valuation methodology is developed is potentially more important than what the actual value metric is for the existing applications dominated by lithium systems.

PROJECT VALUATION

The approach to value a project is inherently based on how others view the asset. Since we are looking at potential projects, the approach used will utilize a standard project economic model to take into account all of the revenues and costs, with assumptions made to understand those parts of the model that are exogenous, allowing the developers to evaluate different design and operating strategies to support different applications.

It is important to recognize that all of the various actions of the project may not be valuable to all parties on the same basis. Some applications like asset deferral are quite valuable to a utility, but unless there is a contract for the full value of the performance of the duty to a 3rd party, a developer will not value it as the utility does. For this reason, when we discuss value streams for the applications for modeling purposes, we will be assuming they are revenue streams, unless identified later.

Finally, 3rd party valuation models have proliferated recently and have improved significantly to account for the myriad possible design and operating regimes of the system. These tools have been matched by improved risk management products by the insurance industry to improve the revenue assurance of the facility.

PORTFOLIO VALUATION

Developing a portfolio of assets can be seen as the inevitable evolution for energy storage project developers and private equity investors who are interested in leveraging their knowledge of the technology, expertise in project development, and access to capital. Having completed a few projects, it is natural to continue with the effort to leverage these more intangible capabilities into ownership and operation of valuable assets. This also dovetails nicely with the need of institutional investors to find investment opportunities for larger sums of capital, while lowering their investment risk. These portfolios—at least the successful ones—should not be seen as simply a larger collection of assets, but a planned portfolio to generate higher returns on the investment.

Portfolio theory follows a simple concept, a group of like assets can provide more stable, and thus a higher risk adjusted return than a single, large individual one. Portfolio theory comes from the investment industry, but is applicable to assets in the power sector, especially when some of the generating resources follow different patterns. This theory thus plays a component of least cost planning strategies for integrated resource planning.

Portfolio theory has proven to be very applicable to renewable assets as their resource base is typically highly variable from one location to the next. This also provides insights into how other factors impact the development of assets. Although New Mexico and Arizona have better solar resources than California, it was the regulatory support and higher power prices in the later promising greater returns which drove many developers to that State initially.

Developing portfolios of energy storage-based assets is an obviously emerging trend for the industry. To undertake this strategy successfully, developers need to leverage important lessons learned from the renewable sector which has developed advanced asset management and operational strategies for these renewable project. The development of energy management software is seen as a critical development due to the complexity of operating energy storage systems. Other strategies for risk management are also important to reduce potential areas of loss.

ROLE FOR THE U.S. DOE

The U.S. Department of Energy has an important role in establishing a foundation of resources, analytics, metrics, and commonality among definitions to supporting improved project and portfolio valuations. As the U.S. Department of Energy puts more resources toward improving the development of energy storage technologies, new and innovative programs are being developed, and existing programs are gaining additional support. Together, this will enable to U.S. Department of Energy to play a crucial role by providing a greater availability of data on the market, more powerful analytics, resulting in improved confidence for those looking to evaluate opportunities and invest in energy storage project assets.

ACRONYMS AND DEFINITIONS

Abbreviation	Definition
AC	Alternating Current
AHJ	Authority Having Jurisdiction
ANSI	American National Standards Institute
ARPA-E	Advanced Research Projects Agency-Energy
BESS	Battery Energy Storage System
BMS	Battery Management System
BTM	Behind-the-Meter
COD	Commercial Operation Date
CPUC	California Public Utility Commission
CRL	Commercial Readiness Level
CSR	Codes, Standards, and Regulations
DARPA	Defense Advanced Research Project Agency
DC	Direct Current
DCSSA	Demand Charge Shared Savings Agreement
DER	Distributed Energy Resources
DERMS	Distribute Energy Resources Management System
DOD	Depth of Discharge
DOE	Department of Energy
DRESA	Demand Response Energy Storage Agreement
ECI	Electrical Construction Industry
EOL	End of Life
EPC	Engineering, Procurement, and Construction
EPRI	Electric Power Research Institute
ERCOT	Electric Reliability Council of Texas
ESA	Energy Storage Association
ESCO	Energy Services Company
ESIC	Energy Storage Integration Council
ESPC	Energy Savings Performance Contract
ESS	Energy Storage Systems
FERC	Federal Energy Regulatory Commission
FTM	Front of the Meter
GADS	Generator Availability Data System
HVAC	Heating, Ventilation, and Air Conditioning

Abbreviation	Definition
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
INL	Idaho National Laboratory
IRP	Integrated Resource Plan
IRS	Internal Revenue Service
ISO	Independent System Operator
ISO	International Organization of Standardization
ISO-NE	Independent System Operator New England
ITC	Investment Tax Credit
kW	Kilowatt
kWh	Kilowatt hour
LBL	Lawrence Berkeley Laboratory
LCOS	Levelized Cost of Storage
LD	Liquidated Damage
LFP	Lithium Iron Phosphate
LMP	Locational Marginal Price
LPO	Loan Programs Office
MACRS	Modified Accelerated Cost Recovery System
MBTF	Mean Time Between Failure
MESA	Modular Energy Storage Architecture
MISO	Midcontinent Independent System Operator
MLP	Master Limited Partnership
MW	Megawatt
MWh	Megawatt hour
NAATBatt	National Alliance for Advanced Technology Batteries International
NEC	National Electrical Code
NECA	National Electrical Contractors Association
NEIS	National Electrical Installation Standards
NERC	North American Electric Reliability Corporation
NFPA	National Fire Protection Association
NCM	Lithium Nickel Cobalt Manganese Oxide
NRE	Non-Recurring Engineering
NRECA	National Rural Electric Cooperative Association
NREL	National Renewable Energy Laboratory
NTP	Notice to Proceed

Abbreviation	Definition
NY-BEST	New York Battery and Energy Storage Technology Consortium
NYISO	New York Independent System Operator
NYSERDA	New York State Energy Research and Development Authority
O&M	Operation & Maintenance
OEM	Original Equipment Manufacturer
ORNL	Oak Ridge National Laboratory
PCS	Power Conversion System
PJM	PJM Interconnection, Inc.
PLR	Private Letter Ruling
PNNL	Pacific Northwest National Laboratory
PPA	Power Purchase Agreement
PRBA	Portable Rechargeable Battery Association
PUC	Public Utilities Commission
PV	Photovoltaic
R&D	Research & Development
RA	Resource Adequacy
RFP	Request for Proposal
ROI	Return on Investment
RTE	Round Trip Efficiency
RTO	Regional Transmission Organization
SBIR	Small Business Innovation Research
SCADA	Supervisory Control and Data Acquisition
SDO	Standards Developing Organization
SGIP	Small Generator Incentive Program (CPUC)
SGIP	Small Generator Interconnection Procedures (FERC)
SNL	Sandia National Laboratories
SOC	State of Charge
SOR	Scope of Responsibility
SPE	Special Purpose Entity
SPP	Southwest Power Pool
T&D	Transmission and Distribution
TOU	Time-of-Use
TRL	Technology Readiness Level
UL	Underwriters Laboratories
UPS	Uninterruptable Power Supply

1. IMPORTANCE OF VALUATION

There are two key aspects of valuing an energy storage project; the methodology used, and the value arrived at. Both components are important, but the complexity of the methodology is many times overlooked (both unintentionally and intentionally). This is understandable as energy storage technologies possess a number of inter-related cost, performance, and operating characteristics that impart feed-back to impacts to the other project aspects. However, this complexity is the heart of the value potential for energy storage systems. For this reason, it is imperative to ensure that both components are designed to address the complexity and not allow implicit biases to be imparted as this can significantly impact the financing opportunity for the proposed project.

Different market segments utilize energy storage system in distinct ways, providing the opportunity to apply these different valuation methodologies to drive unique business strategies. An important aspect of this point is to understand that some applications have clear value that can be written as discrete revenue contracts, while other provide revenue streams that are not as easily monetized, and thus must be incorporated into larger structures to capture the value, such as a solar/storage project or rolled into the rate-base of a utility. These aspects will also affect the cost of capital for the project, also impacting its development path.

Non-lithium energy storage technologies many times are at a disadvantage to lithium systems as the core of the market has begun to evaluate not just the technologies, but the opportunities themselves through the lens of lithium-ion system costs and capabilities. In early market where one technology dominates, this is a typical occurrence. As the market continues to grow, it is a market of commercial maturity that customers begin to understand their needs sufficiently to highlight other opportunities that the early dominate technology is not designed for. Therefore, how the valuation methodology is developed is potentially more important than what the actual value metric is for the existing applications dominated by lithium systems.

1.1. Markets

Project valuation will vary significantly according to the market segment in questions. The two sides of the valuation equation—cost and revenue—will be impacted by the scale, participants, and drivers respective to each market segment. For this report, we will divide the market into three segments: front of the meter, commercial and industrial, and residential.

Costs for the different energy storage technologies will typically vary by scale, both power and energy. This scaling of costs mirrors the deployment opportunities, ranging from the typically smallest deployment in the residential market, scaling somewhat to the commercial and industrial market, and then on to the front of the meter market which incorporates the utility and independent project owner. This scaling in costs showcase the cost to the OEM in both supplying the equipment but also the cost spent to market it.

Revenues will also vary, in large part following the level of regulatory reform aimed at providing price visibility and revenue certainty into the different products and services provided by the different actors in the market.

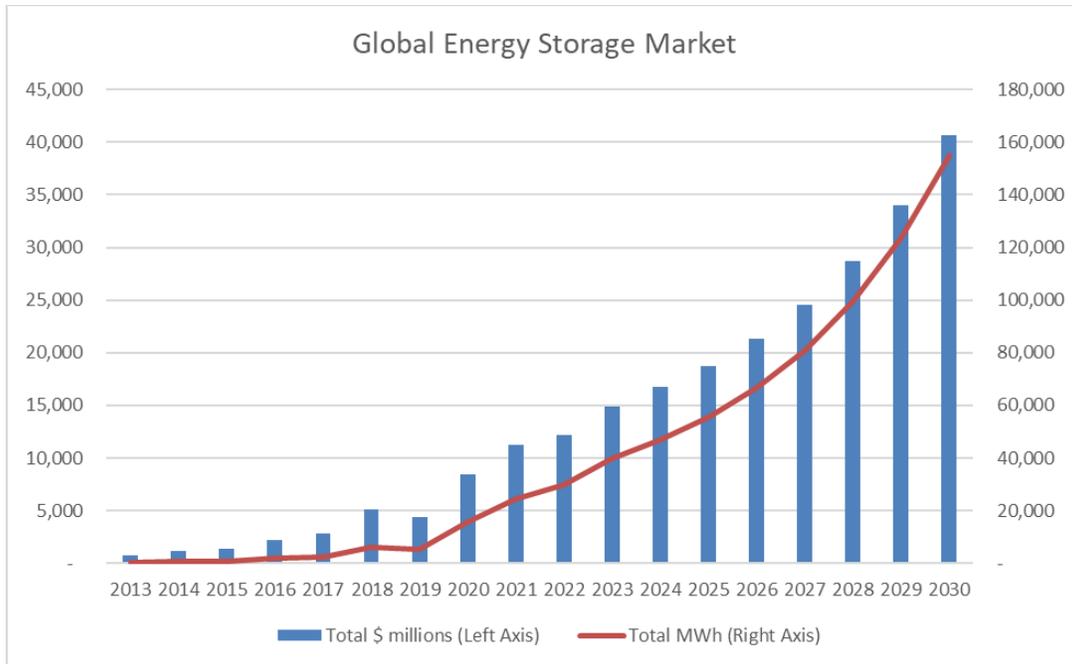


Figure 1-1. Global Energy Storage Market

Source: Wood Makenzie & Mustang Prairie Energy

1.1.1. **Front of the Meter**

Front of the meter customers include utilities and independent power facility owners, either active in the wholesale electricity market, or coupled with large renewable energy facilities. These groups look to energy storage systems for a variety of uses, highlighting the value these flexible assets can bring to the power sector. These uses typically revolve around leveraging existing assets to provide additional capability, or stand-alone storage performing specific applications with clearly defined revenue streams.

1.1.1.1. **Participants**

Ensuring a profitable—and hence, valuable—project is the core effort of project developers. As they are able to find and develop potentially profitable sites, their effort to convince capital providers becomes easier with a well devised project that is based on a rigorous evaluation of the economics of the project. This effort requires the coordination of not just those groups internal to the project—legal, engineering, equipment, etc. but also customers.

The coordination with those looking to contract with the developer for a proposed project is sometimes made easier by that groups production of an RFP, but there is always negotiation with them, so a developers ability to provide clear understanding of the project up front, but also support a supportive dialogue as the project is negotiated and developed, is a necessary step for the developer to move towards the development of portfolios of projects at multiple customer sites.

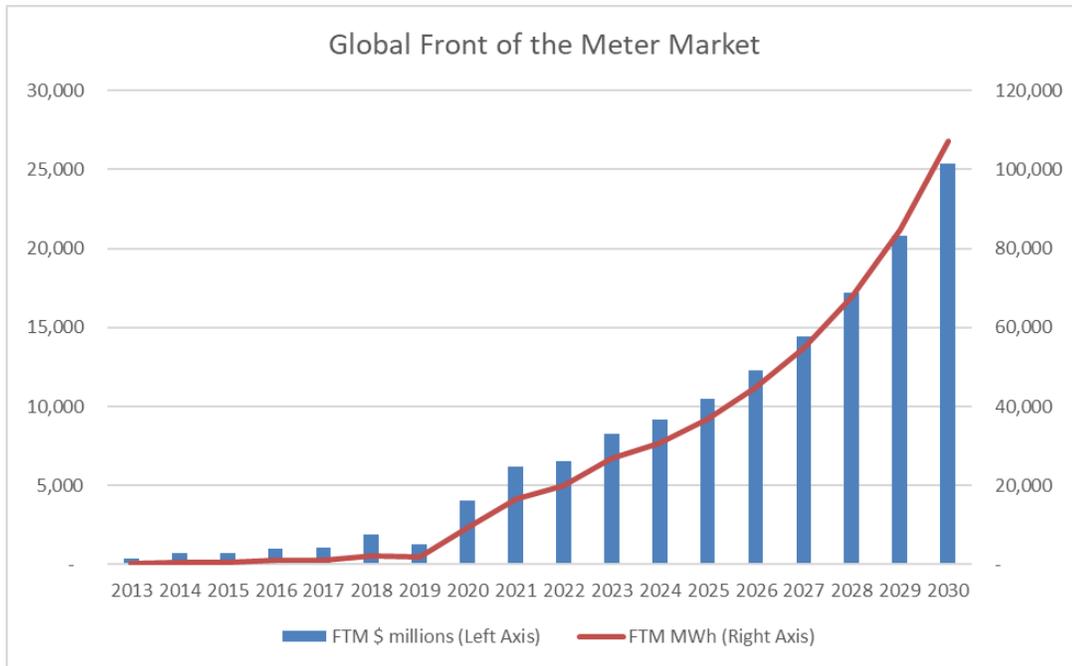


Figure 1-2. Global Front of the Meter Market

Source: Wood Makenzie, Mustang Prairie Energy

1.1.1.2. Value in Market

Energy storage system can address a number of opportunities in the front of the meter market today. The strategy as to how to leverage the capability is key to how the project value will be evident—either externally as with a stand-alone storage project with a PPA, or internally, as a component of a solar storage project. The level of expected return is commensurate with the level of understood risk.

What typically upends the value of the project in the market is this understood risk. If the developer has taken into account all of the technical, economic, and regulatory risks into the model—and even put in place strategies to mitigate those risks, then the value of the project will have a stronger footing for creating the expected return. In the energy storage market, however, there are always additional risks that you don’t even know you’re exposed to, so have a flexible means to mitigate those expected risks as the market changes, is the key to delivering reliable value in the form of a successful project.

1.1.1.3. Drivers

There are a number of factors supporting the introduction of energy storage system in the front of the meter market. In recent years public policy has swung to support the development of market reforms that aid in the development of clearly defined applications that energy storage systems can provide, and a clear means to provide price visibility into the value of those applications. System costs have continued to decline and improve in capability, providing a stronger supporting structure for project value.

What may be the most valuable to overall success is the clearly stronger interest by renewable groups and utilities based on internal valuation of the capabilities of energy storage systems to their own

needs. These other groups have evaluated the capability of energy storage systems and determined a value to their own needs that incorporate the capability of the storage asset in these other uses. The strength of these arguments is based on the ability of modeling software to not just model storage systems by themselves but incorporated into an overall hybrid asset use.

1.1.2. Commercial & Industrial

Commercial and industrial customers have experienced the largest change in their cost of service primarily through time-of-use rate impacts. The goals of these customers vary, with some groups looking to actively reduce their overall cost of service, while others simply want a predictable rate as electricity is not a significant portion of their operating costs, but the variability causes problems.

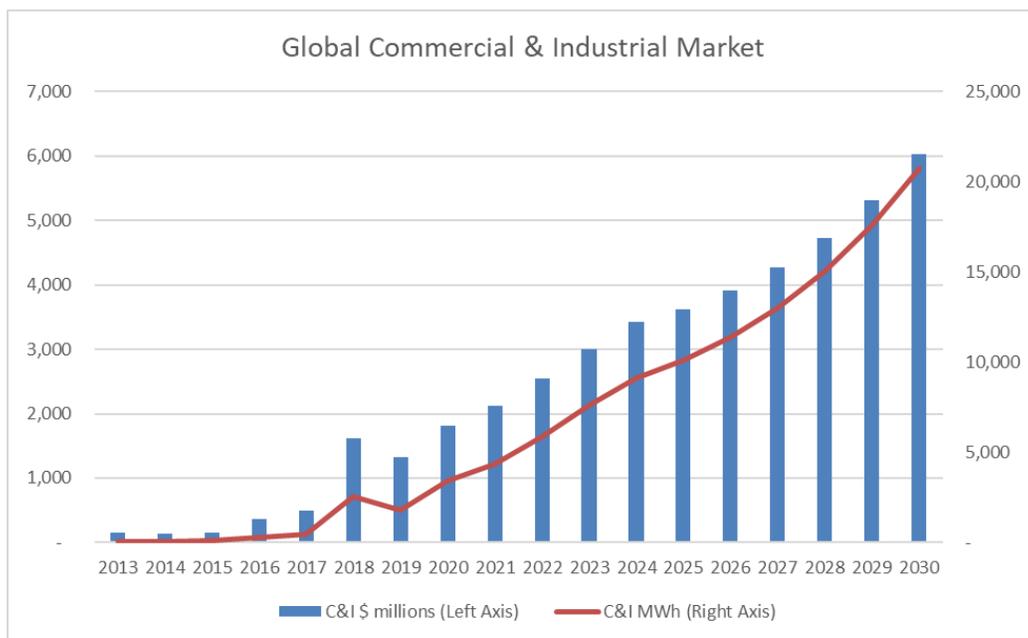


Figure 1-3. Global Commercial and Industrial Market

Source: Wood Makenzie, Mustang Prairie Energy

1.1.2.1. Participants

The key for driving development in the commercial and industrial market is to position the value of the energy storage system in a way that will resonate with the customer. In most markets, this is relatively straightforward, as people have an understanding of their need, evaluate all of the different products and services that can help them fill that need, and then chose the one with the least cost.

This process is unfortunately far more complicated for energy storage development. Many times, the customer’s needs are understood—lower costs, better service—but the metrics and comparative choices are not. Customer’s cost of service is based on tiered rates based on their historical usage, but also highly impacted by the cost of delivering that service by the utility—high cost areas have higher utility rates. The results are that customers cannot easily view energy storage as a product that can serve their needs—they know they want to pay less, but they have no way of knowing how—except to engage in energy efficiency strategies, which help, but do not address the peak demand uses directly.

1.1.2.2. Value in Market

Project developers have utilized the complexity of changing the customer’s tariff by utilizing energy storage to not just sell a product, but many time sell the service guaranteeing a reduction in their electricity costs. Depending on the level of involvement by the customer, this has either come as shared savings or a contract for service. These developers typically now already have an arrangement with lenders to provide financing as part of the offering.

1.1.2.3. Drivers

The primary driver for deployment in this market is cost of service reduction for customers. The result of a lot of the regulatory reform in the electric power market has been to change tariff structures to expose customers to more pronounced time of use rates and higher demand charges. This regulatory effort is expected to continue, both exposing more customers to this pricing regime, and also make the pricing variability greater. These changes are providing a very objective value opportunity for customers to utilize on-site energy storage.

Quickly growing in support of this driver is the use of the storage asset to support multiple functions, such as EV charging, utility program involvement, etc. in addition to enhancing onsite solar. As the needs of customers to be more flexible in their electric uses, this will rise in importance, highlighting those technologies that are able to provide greater throughput over their lifespan.

1.1.3. Residential

The residential energy storage market has become a surprisingly substantial component of the energy storage market and is expected to remain a significant portion of the market going forward as it gains support from related industries such as residential solar.

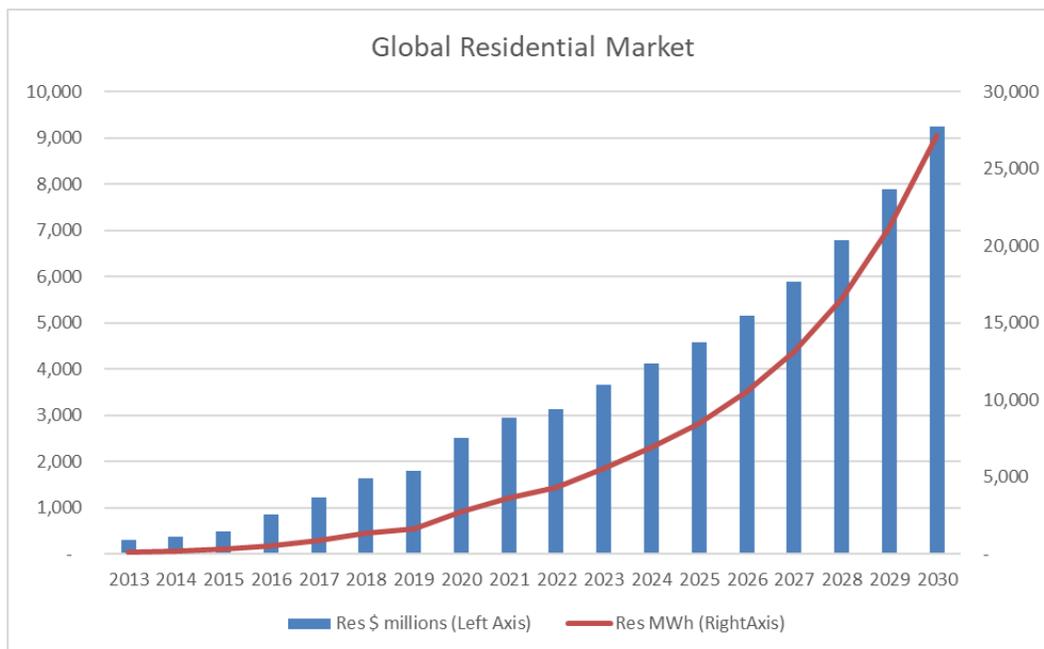


Figure 1-4. Global Residential Market

Source: Wood Makenzie & Mustang Prairie Energy

1.1.3.1. Participants

Many of the energy storage systems being deployed in the residential market are done so in conjunction with other power system—primarily solar, but also with home EV charging. Since economic use of energy storage products are not expected to be sufficient to drive sales for the foreseeable future, solar developers are expected to remain the primary sales channel for energy storage systems.

This bodes well for the continued growth of residential energy storage. The residential solar market is expected to continue expanding strongly, and as solar companies are promoting the co-location of storage with new PV system, the penetration of storage into the growing solar market will drive growth without significant effort by the storage developers. Financing for storage is simply an extension to the well-developed financing for residential PV systems, removing one potential barrier for growth.

Design and performance of the systems are focused on supporting the PV system, limiting the variability and multi-performance regimes usually responsible for increased costs. This effort is expected to continue driving the cost of these system down, but this focus will also limit potential value generation of the units to a narrow range that will persist until additional capabilities—hardware or software—are added to allow multiple avenues for value generation.

1.1.3.2. Value in Market

The value of energy storage in the residential market is driven largely by the ability to time shift daily onsite power generation (typically solar) to either reduce utility purchases or provide enhanced reliability. As the reliability of utility power has become suspect, as has been the case in CA during rolling blackouts, the value of storage has grown in customer's mind as the only way to effect reliable electricity service.

This provision of service is a good example of how services for customers many times can outweigh the metric available. For instance, the only price metric we have for this service would be the customer's monthly electric bill. However, it is apparent that these customers value the ability to have electrical service during frequent and expected blackouts during summer months. For this reason, rolling the capital costs of the battery system into the PV system cost is many time far outweighed by the perceived gain in value by the customer in having their own capacity to provide electrical service during emergencies.

1.1.3.3. Drivers

Residential customers are typically driven by up front capital costs of the system. For this reason, OEMS have been driven to develop standardized systems easily incorporated into the surrounding PV system.

The value of the energy storage system to residential customers is driven by both their physical and economic situation within the grid. Physically, if the customer is located remotely, or self generates an appreciable amount of their own power through on-site renewable technologies, then the battery system will be of greater use for the customer in delivering reliable power service. Economically, the level of regulatory reform engaged by the utility to provide price signals to customer. The increasingly reliance by customers of PV systems will provide greater penetration for the deployment of PV/storage units. Tangential applications able to be supported by the existing assets (such as additional reserve emergency capacity for utility reliability programs) stand as the next easiest application to engage, driving value growth of these systems.

1.2. Financing Sources

The availability and cost of capital impact the scale and growth of the market. Typical project developers rely on equity and debt financing, with markets with scant operating experience relying on greater equity than debt for financing. As experience is gained in operation, more lenders are willing to provide financing for the equipment sales. Different segments of the market—residential, commercial and industrial, and front of the meter, will all have their own financing source makeup, as well as highlighting differences in different markets around the globe. Over the last few years, the amount of debt making up the financing for equipment has grown and is expected to continue to make up an ever-larger component of the financing sources for the market.

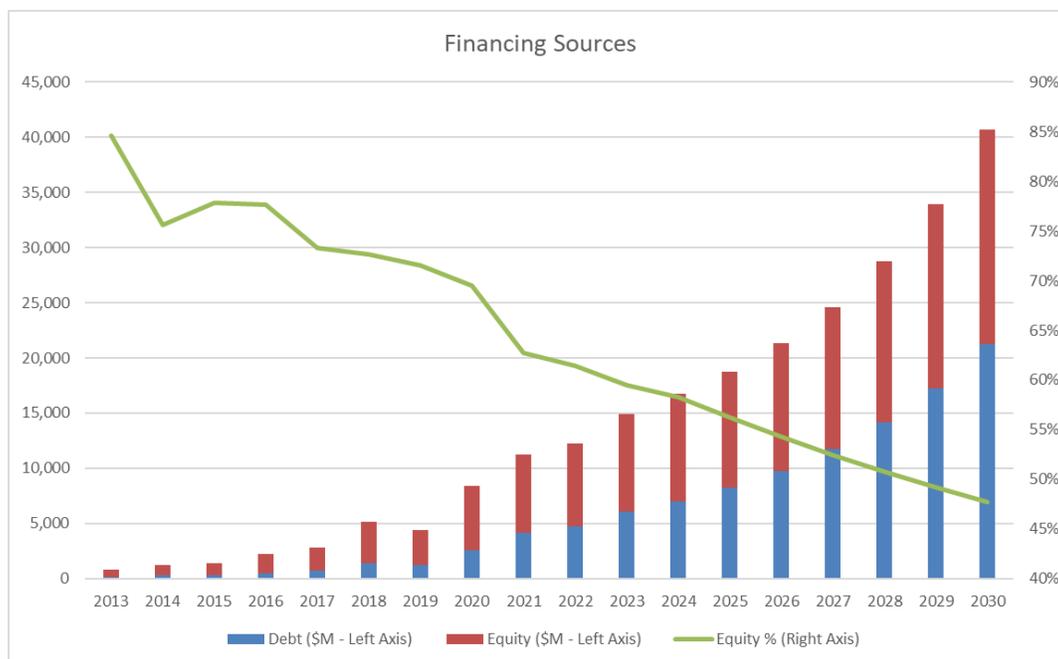


Figure 1-5. Global Energy Storage Financing Sources (Estimate)

Source: Mustang Prairie Energy

1.3. Non-Lithium Technologies

The value ascribed to non-lithium energy storage technologies is critical is having developers and lenders interested in utilizing these systems for market deployment. Unfortunately, the capabilities of energy storage systems vary widely, supporting a myriad of possible uses that have not all been proven in the market. Faced with a known value for a lithium-ion system for a known application, it is not surprising that groups entering the market only see lithium ion systems as the most valuable—or even viable—option for applications that conform to the technologies capabilities.

For these reasons, setting the valuation approaches are critically important for non-lithium energy storage technologies. Defining how the valuation will be done—methodology, assumptions, metrics, etc.—is arguably more important to non-lithium technology developers, than the value ascribed to a technology for a particular application—especially if the application definition has a bias towards lithium-ion built into the framework of the question. The bias by the participants in the market is not intended to harm the prospects of these non-lithium technologies, but developers and capital providers are interested in getting projects done and choosing which one has the greatest return on

investment. Market operators and regulatory groups also fall into this pattern as well when faced with a need for supporting energy storage technologies but have only lithium ion systems available as the widely accepted commercial option. Within that framework, it is thus not hard to understand that the method for choosing the best option for the customer's needs is based on the capabilities and availability of lithium ion—both at the market rules for the applications, and which ones are easiest to finance.

Over the last decade lithium ion energy storage technologies have captured an increasingly larger percentage of the grid scale energy storage market as compared with other energy storage technologies. In part, this is due to the rapid technological advances in lithium ion batteries leveraging the advances stemming from their use in the transportation market. The capability of these systems was suited to fill the need of emerging applications in the electrical power market, such as frequency regulation and capacity reserves which prioritized performance over low cost arbitrage. This family of storage technologies quickly became the most deployed on a large scale and based on the accompanying track record of performance was able to be incorporated into projects through 3rd party financing.

The history of grid scale energy storage technologies has only recently been one of primarily lithium ion. For many decades, energy storage needs in the power sector primarily revolved around the use of pumped hydro systems at the utility scale level, and lead acid batteries for either UPS systems at power facilities and substations or supporting off-grid applications. The performance requirements of both applications for lead acid batteries were well understood, leading to efforts at refining the technology. The sheer market size of these applications dwarfed other potential uses, fixating in the minds of utility planners and executives what “battery energy storage” meant. A variety of other technologies continued to be developed, but as the economics of the power grid were well understood and highly regulated, improvements were evolutionary, not revolutionary.

Faced against an incumbent technology, non-lithium systems must find a way to create not just a track record of operation, but one in an applications that is valuable in new ways to customers. As mentioned earlier, the first step is to have the definition of the applications themselves be focused on the customer's needs. Maintaining this focus can be difficult, as the result of an honest evaluation is that the applications is developed, but no technology option exists. In response, regulators and market operators often write the rules for crucial applications to utilize what is simply available. For instance, energy storage systems were able to make inroads into the frequency regulation market quickly because the existing rules were originally designed around the fastest response capability of thermal plants, not what the grid operators actually needed as a responsive tool. When energy storage systems became available for this use—and the market rules were re-written to provide a level playing field, batteries quickly came to dominate the fast reaction portion of the market.

Costs too are an important valuation component. Here again, biases in the metric used can thwart new entrants. Most energy storage systems are evaluated on a \$/kWh basis. However, this is a capital cost, not a project orientation. Embedded into this cost metric is a lifespan, based on what lithium-ion has. If a competing technology is able to last twice as long (or 5 times as long as in the case of pumped hydro), this has no impact. Other differences on the level of energy throughput that can be supported are not easily parsed into a simple capital cost framework, so migrating the evaluation—not just by project developers who craft detailed project proformas, but also lenders and policy makers—to something that focus' the valuation framework to something that is more application specific is needed.

2. PROJECT VALUATION

The approach to value a project is inherently based on how others view the asset. Since we are looking at potential projects, the approach used will utilize a standard project economic model to take into account all of the revenues and costs, with assumptions made to understand those parts of the model that are exogenous, allowing the developers to evaluate different design and operating strategies to support different applications.

It is important to recognize that all of the various actions of the project may not be valuable to all parties on the same basis. Some applications like asset deferral are quite valuable to a utility, but unless there is a contract for the full value of the performance of the duty to a 3rd party, a developer will not value it as the utility does. For this reason, when we discuss value streams for the applications for modeling purposes, we will be assuming they are revenue streams, unless identified later.

Finally, 3rd party valuation models have proliferated recently and have improved significantly to account for the myriad possible design and operating regimes of the system. These tools have been matched by improved risk management products by the insurance industry to improve the revenue assurance of the facility.

2.1. Valuation Approach

There are three general approaches to value an energy storage project: net income, market, or replacement. Each approach has its own merits and is appropriate under different conditions.

- **Net Income:** The net-income valuation approach is the most straight-forward, being derived from the revenue, costs, and producer margins incorporated into the final price. This is the general bottom-up approach commonly developed through a project economic model. This approach has the benefit of being able to incorporate the many variable aspects of revenues and costs that are common when evaluating an energy storage asset. This approach also has the detriment if the data, assumptions, or analysis is not correct—lending credence to “rules-of-thumb” unless the analytical capabilities are available and reliable. This is the approach that most valuation models follow and will be discussed in this chapter. Although the model is generally a structured NPV calculation, the goal of the exercise is to obtain an IRR for the project.
- **Market:** The market valuation approach is simply to evaluate the current value attributed to the asset in the competitive bidding market. Generally, this approach requires a competitive market for like-assets, and some amount of trading history for the market clearing price to be based off of. Stock prices are good example of this. Fundamentally stocks are based on a bottom-up approach, but the actual clearing price of a transaction is based on the last exchange of the asset (or like).
- **Replacement:** The replacement valuation approach is based on the cost to replace the asset in questions with one of similar qualities and capabilities. This approach will take into account locational and other qualifications that may affect the price of the facility. For instance, the exact same capital equipment set-up will have two distinct values due to locational impacts on the revenue. Of greater importance, however, are the limitations based on ownership or control of land, assets, or regulatory clearances that impact the value of an asset if it were to be replaced.

This chapter will be primarily concerned with the net-income valuation method for a number of reasons. Energy storage projects are still relatively new, so there is not a long operation track record or large number of like facilities that are transacted on the secondary market to establish viable alternative pricing levels. As more projects are developed and transactions occur, transaction review from the secondary market will become an important aspect of setting the project's valuation. Until that time, however, the project economic model, and different valuation metrics will be used to determine the value of individual projects, and to provide a basis for comparison.

2.2. Project Economic Model

The Project Economic Model—also known as the Project Financial Model—provides a structured framework for the integrated economic valuation of an energy storage project. The model generally takes the form of a proforma model structure, taking into account the present and forecast of all of the expected discounted cash flows, expenses, and the impact of financial accounting such as taxes, depreciation, and other fees. The goal is to provide transparency and visibility into both the assumptions and analytics of the model.

The modeling framework is generally straightforward, even for energy storage projects with complicated operation usage profiles. The complication in the modeling arises from how closely the framework will track the actual economic operation of the facility. Because of the differing capital and operating characteristics of different energy storage technologies, a critical issue is to separate any technical biases from impacting the comparison of a particular project's economic analysis that is based on one technology versus another. Evaluating these differences in equipment costs and system capabilities comes into play when financiers and developers need to replicate their market models in order to optimize multiple project revenues.

The model provides benefits to multiple parties. Developers can use them to evaluate the sensitivity of a proposed project as it relates to a variety of assumptions and possible market conditions, designs, and operating strategies. They will also provide insight to potential lenders as to the financial viability of a proposed project—the soundness of a project's ability to provide the required return, and the project developer's assumption and approach. Through evaluating the sensitivity of the model to the potential range of input conditions, the equity and debt providers can gain a better understanding of the risk-adjusted return for the project. Once agreed on, it will serve as the basis for structuring the project's financing agreement.

Project economic models themselves are relatively straightforward, so the critical challenge is providing visibility into their economic and operating assumptions, making sure to consider changes resulting from supporting multiple applications

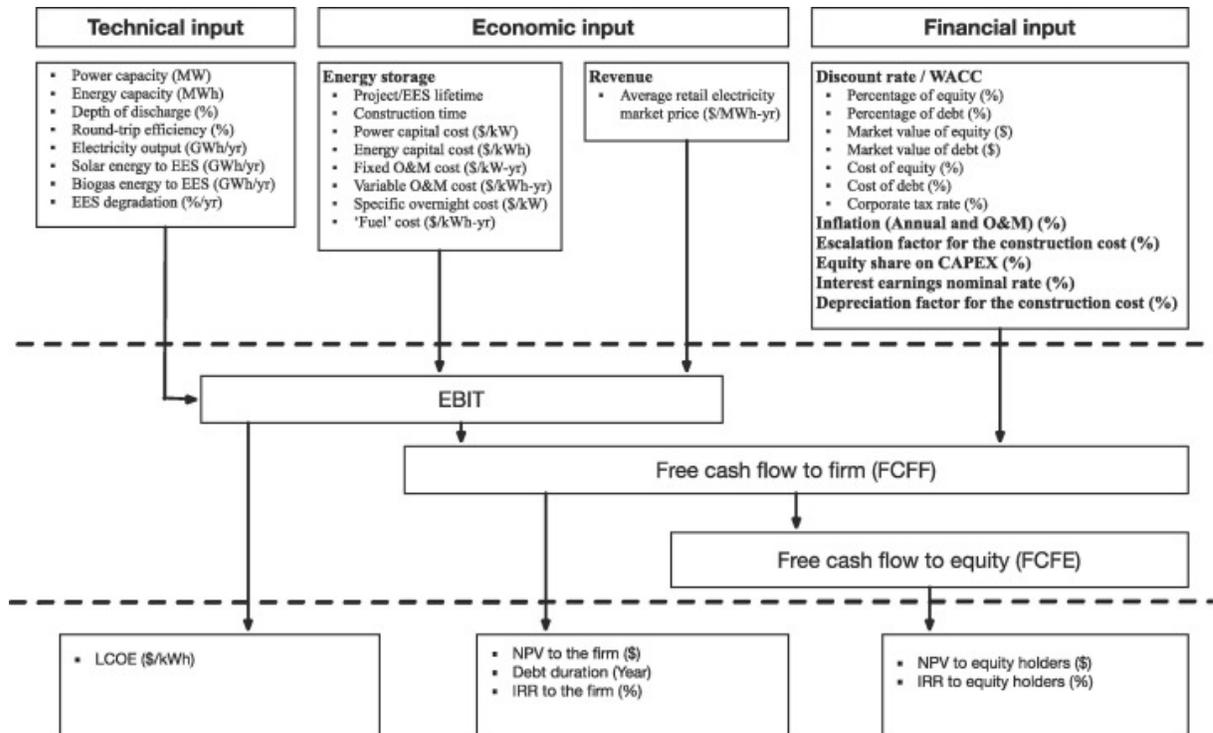


Figure 2-1. Project Economic Model

Source: Applied Energy¹

It is important to recognize that the audience for the project economic model—outside the project developer that uses it as a tool—are capital providers. In general, many in the investing community continue to be surprised by the variability in the modeling capability and quality upon which energy storage investment decisions are based. But this group is quick to add that they are seeing a marked improvement recently and believe this trend will continue. They do, however insist they must still review the models (if homegrown by the developer) for mistakes in coding and market assumptions. The latter review need is based on evaluating the developer’s understanding of market data and assumptions, and then understanding the impact these assumptions have on the model.

For this reason, having a scenario approach for the market modeling is useful as it gives greater credence to the strength of the analysis. What some investors are many times looking for is not necessarily the right answer (at least initially), but the right thought process. Many investors have worried that the models sometimes feel that they were worked in reverse—starting with a financially successful project, and then working back toward the beginning of the modeling analyses with some unrealistic initial assumptions tucked away in an out of the way part of the assumptions.

A developer’s ability to robustly defend the whole spectrum of proforma assumptions will strengthen the case being made to his financiers. In particular, the understanding of the impact of existing and possible market price drivers, and the ability to highlight where a project can be at an advantage vis-a-vis others, is important. As the number of applications grows, the requirements to support them become fundamental to any modeling framework. Both third-party models and models internal to a project development team are rapidly gaining in capability and fidelity.

2.2.1. Technical Input

The technical inputs into the model will define the power and energy rating of the facility, as well as cover the operating and performance capabilities that will impact the operating costs. This will include a wide range of inputs, such as economic, market, financial, and baseline assumptions.

2.2.2. Economic Input

The economic inputs into the model will include both the revenue and costs for the project.

Revenue for the energy storage project will either be expressed as a contracted revenue stream from a PPA (Power Purchase Agreement), derived from merchant activity by the facility, or some combination thereof. Depending on the services provided, the revenue will be based on the capacity (kW) or energy (kWh), with resulting implications for operation as capacity can simply be standby reserves, whereas energy throughput requires cycling the energy through the system.

System capital costs have become less of an unknown over time as familiarity with energy storage systems increases. The variable component remains with the operating costs. Greater familiarity with these operations is reducing the variability, but this understanding still lags that of the initial costs due to the time required to create a sufficient base of operating time and experience.

2.2.3. Market Input

A number of market-based inputs are also incorporated into the model structure. Electricity prices can have a significant impact on overall operating costs as they will express themselves in both the station power loads (HVAC, controls, etc.) and the efficiency losses that occur when charging and discharging. The rates for these costs may vary by jurisdiction, especially for behind-the-meter deployments. The relevant electricity prices will experience variability in both market segmentation and regional differences. This is another area of direct interest for developers as they typically have to contract separately for the station power needs of the facility. The system can be designed to also utilize the energy from the battery banks, but that will negatively impact the round-trip efficiency of the system.

2.2.4. Financial Input

There are a number of financial assumptions that impact the project economic model. The cost of capital—equity and debt costs—is critical to the profitability of a project. The cost of capital is many times a reflection on the riskiness of the developer and the design of the project. This is an important consideration as the resulting weighted average cost of capital (WACC) will have a direct impact on the financial profitability of the project. The cost of capital is many times impacted by the standing of the developer with lenders, and the thoroughness of the project development plan. The cost of capital can be reduced if the investor has better familiarity with the business model and related market variables.

Tax issues impact the project through a number of avenues. Depreciation expenses on federal and state taxes for the project generally has the largest impact. Over time the depreciation schedule for energy storage projects has allowed for greater acceleration, improving the financial viability of the project. There is more of an opportunity for variability expected and evolution at State and Local jurisdictions over time, although local governments have little experience to date with these facilities generally so these costs can be quite variable. Depending on the location, property tax incentives can also be used, as in CA, to promote the deployment of energy storage systems.

2.2.5. Baseline Assumptions

Although economic and financial assumptions do not typically drive the profitability determination of a project, poor choices and usage may increase volatility, raising the level of risk adjusted cost of capital. Economic and financial assumptions stem from the project developer but must be defensible for presentation to the lenders. The source of any data should be reputable, consistent, and provide a clear methodology for its own assumptions to provide guidance for any group using the data in their analysis.

The U.S. Energy Information Administration publishes the widely used Annual Energy Outlook and a variety of other market databases for markets across the United States based on existing regulatory, economic, and technical assumptions and trends. For groups developing their own drivers, the EIA provides a comprehensive and integrated analysis to promote a well-grounded baseline. For project developers, the EIA's analysis system provides comprehensive and detailed economic pricing drivers with ample supporting methodology for a project located in different parts of the United States.

2.3. Revenue

Revenue is the main determinate in establishing project valuation as it is more variable than the capital cost for a project (even though capital costs for batteries have been declining dramatically over the years, once the decision to price out a project cost, there is little variation in the price once the provider has been selected an usage profile agreed upon). The revenue can be either structured as a contract, purely merchant, or some combination of the two.

Successful project financing is based on ensuring that the project in question will be able to generate reliable revenues to cover the debt service, operating costs, and earn an acceptable return for the equity providers. The financing contract structure used will be the most financeable for a particular market; straightforward generation can operate with a simple offtake structure, while a complex operational profile will require a structure that can manage a more complex risk hedging strategy for the facility.

Even if a contract exists, there can be variable aspects to the payment structure. For instance, most capacity payments are priced in the \$/kW metric whereas an application that relies on the amount of throughput will generally be priced in the \$/kWh metric, but there may be some base capacity payment as well.

Revenue opportunities for energy storage assets have risen over time for a number of reasons. The scope of applications that energy storage assets can address have risen in number and have become more formalized. This has allowed the value of the applications to rise as they become more integrated into the overall market.

2.3.1. Revenue Recognition

Not all applications that energy storage systems are able to provide have easily identifiable revenue streams associated with them. This is a challenge as the profitability of the project relies on generating reliable revenue from operations. Some applications have formalized definitions in power markets, and thus are easily monetized (although the scale of the monetization will vary), while others have been identified as useful, but the magnitude varies according to time and place with value based on customer's internal value.

Over time, we have seen more applications that energy storage system support become more formalized and/or have greater clarity, allowing the project to recognize more revenue from the

different actions it provides. This continued growth in revenue recognition supports the greater profitability in the future for energy storage projects, not because the value of the services will increase, but rather because revenue can finally be recognized from a variety of services that the facility could provide all along.

To complicate matters, not all the different applications, although valuable, are translatable into easily definable revenue streams. In general, these fall into 3 categories:

- **Discrete:** Some value streams for energy storage facilities are tied to actual services or products in formal electricity markets, allowing the potential revenue stream for that application to be easily and publicly contracted provided that the facility adheres to all qualifying conditions. Examples of this type are frequency regulation and spinning reserves.
- **Definable:** Another set of value streams have value to another market participant, but are typically locationally specific for price, making any attempt at crafting a market-wide rule of thumb for value difficult at best. If the energy storage developer can contract for one of these services, it is generally on a bilateral basis or is consolidated into a purchase price (asset purchase). An example of this type is black start.
- **Indeterminate:** The final set of value streams are not easily (or widely) quantifiable and there is little hope for a near-term systematic valuation basis—yet they are often mentioned as a driver for near-term energy storage market growth. If you cannot contract for something or systematically value it, it cannot be a fundamental market driver for a competitive market until people begin to devise a means to provide a basis for its value so vendors know how to price a risk adjusted solution. An example of this type would be resiliency.

2.3.2. **Value Stacking**

Energy storage projects, except for some highly specialized applications like frequency regulation, are typically designed around generating multiple revenue streams in order to devise a profitable operating profile for the facility. This is typically termed as value stacking. It is similar to how many existing thermal power plants operate, producing a basket of power and grid products and services depending on what is the most valuable product for the facility to produce.

As one might imagine, determining what basket of products would be the most profitable for a given energy storage facility can be daunting, even as we use existing power systems as a guide. First, energy storage has a significantly limited discharge capacity. As one application is provided, it reduces the ability of the facility to provide other services if they require significant time operations. Associated with this is the ability to operate in a charging mode, shifting the concept of the application being provided from one of a discharge product, to one of a balancing operation service.

Secondly, the location where the system operates will impact the structure of the revenue streams available. For instance, not all applications are available to generate revenue across all areas of the country. Energy storage facilities in formalized wholesale markets can provide frequency regulation in the ISO markets, but energy storage system not located in an ISO/RTO market cannot. These facilities must develop bilateral contracts with the local utility. Overall, PPA type contracts are obviously much more stable—and generally produce overall greater revenue—than trying to operate the facility in a purely merchant strategy. It is important to remember that a PPA does not guarantee profitability, just reliable revenue streams.

Finally, the boundary limitations of the market strategy must be taken into account. As mentioned earlier, choosing one application reduces the energy available to perform other applications. From a contractual perspective, choosing one application also typically precludes choosing another application because they are mutually exclusive in the market. In addition, there might be some standby or timing requirement that also impacts the operation of the facility in choosing one application vs another. However, some applications can be provided simultaneously. For instance, providing a black-start service to the grid does not conflict with the unit providing load following services to the grid, assuming that the facility maintains sufficient reserves to provide the black-start capability at all times. Since black-start and load following cannot occur at the same time, it is possible to have contracts for both services.

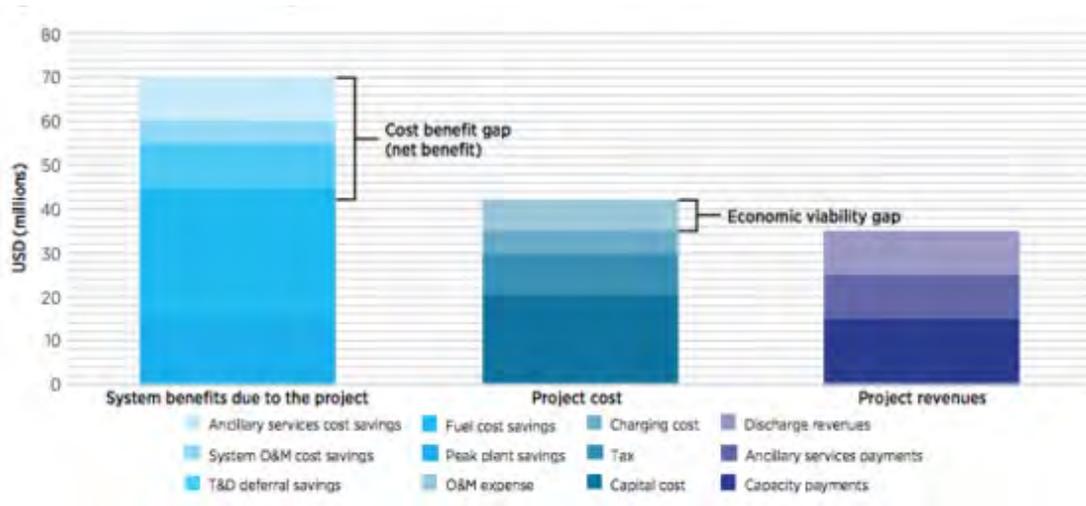


Figure 2-2. Economic Viability Gap

Source: IRENA

2.3.3. Applications

Energy storage systems are able to provide a wide range of services across the power grid. This chapter will provide a description of a number of applications currently being envisioned for energy storage technologies. As the technology continues to improve, and as market participants learn how to utilize these systems in the market, additional applications continue to be explored and would be added to the list.

These applications may or may not have a widely accepted or clear way to generate value or revenue, however. Also, although we typically divide these into different market segments, the evolving nature of how energy storage assets in different parts of the power grid interact with the market continues to blur, such as the growth in BTM assets becoming active in ISO markets for wholesale services. The following is a description of how energy storage systems can operate.²

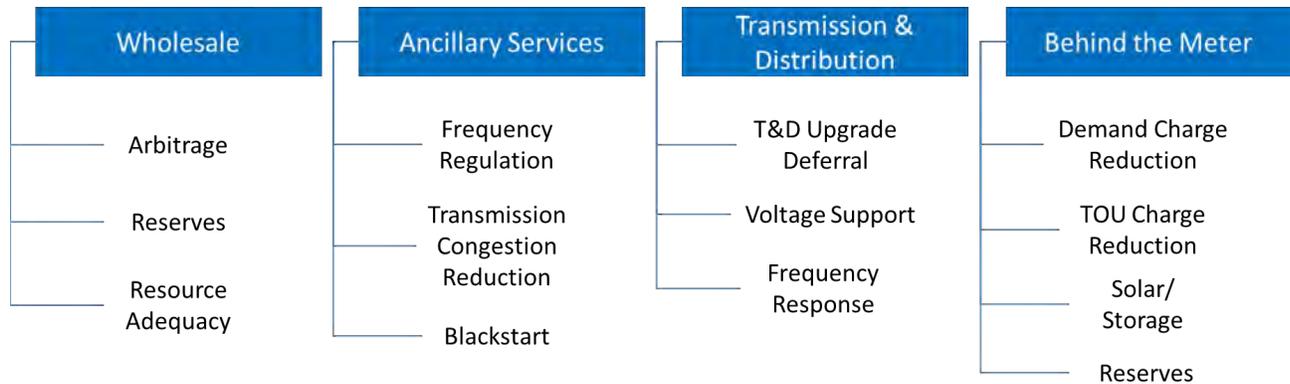


Figure 2-3. Energy Storage Applications

Source: Mustang Prairie Energy

2.3.3.1. Arbitrage

Arbitrage is the act of absorbing low-cost, off-peak power and selling it during peak demand periods when its value is highest. This application is typically provided as a product in an organized market. Arbitrage would compete against generation resource. Because of this, arbitrage for energy storage systems is considered a low value product.

If an energy storage system were to engage in this, it would be more appropriate for larger scale systems measuring in the 10s or 100s of MWs and many hours of endurance that have the lowest \$/kWh levelized operating cost. As with power sales, arbitrated energy would be paid on a \$/kWh basis. The usage profile envisioned for this application could occur whenever the value of the electricity is the highest.

Because the goal of the application is to cycle the greatest amount of energy through the system for sale, this will mean that the energy storage system must be operated at the most efficient rate possible. For most energy storage of the charging cycle requirements of the storage system, however, this will typically mean a charging period slightly longer than the discharging period.

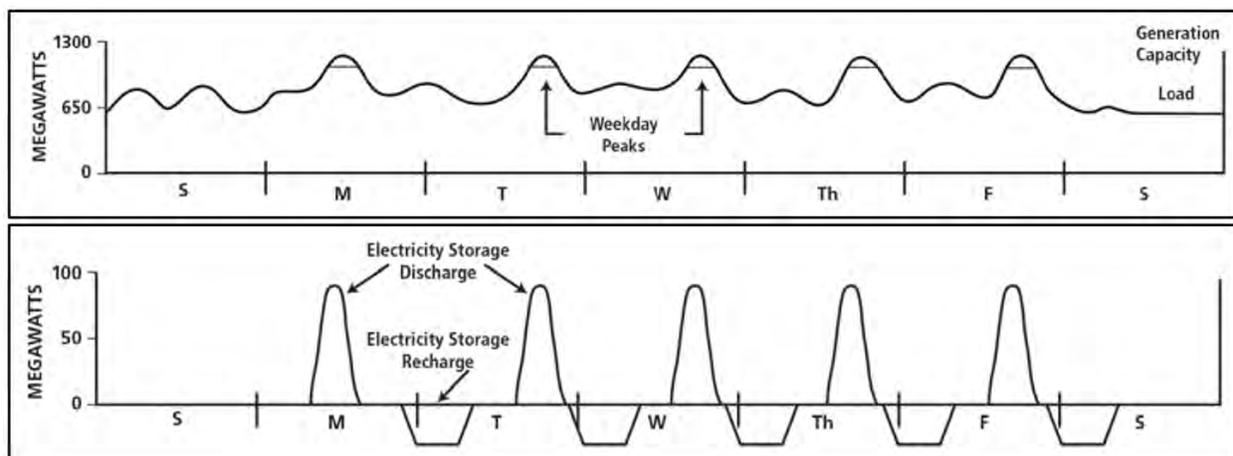


Figure 2-4. Arbitrage – Time Shift

Source: DOE/EPRI Electricity Storage Handbook

2.3.3.2. Reserves

Reserves are energy resources from facilities that are online and operational but not at full load. Reserve resources are the first tier of resiliency for regional power grids and are required to operate the grid effectively. There are different types of reserve resources, generally divided by the speed of response. Spinning reserves are able to react immediately and have typically been sized to support the largest single generator or resource on the grid and replace it in the event of a fault. Non-spinning reserves are generally fast reacting resources that are able to react at a slightly longer timeline. There are also categories for longer term replacement reserves that are envisioned to be available for multiple hours. Depending on the resource mix and the reliability of different generating resources, the total reserve capacity will vary but can represent 15%-20% of the total generating supply capacity, with spinning and non-spinning representing approximately 10%. Each of these values will vary depending on the ISO/RTOs requirements.

Most energy storage technologies are fast reacting enough to provide the spinning reserve level service, even if only in standby. The scale (MW) necessary would be determined by the scale and need in the ISO/RTO market, but most energy storage systems operating in the wholesale power market would easily be applicable. The service is paid on a MW basis, with the usage profile of a reserve asset being in standby mode while under contract.

Because the goal of these applications is to have sufficient energy in reserve in order to provide the contracted service to the ISO/RTO, some portion of the energy storage capacity at the facility may not be used for other applications. Because this is an infrequent service, the charging of the facility would come at the most opportune time after the grid interruption is over.

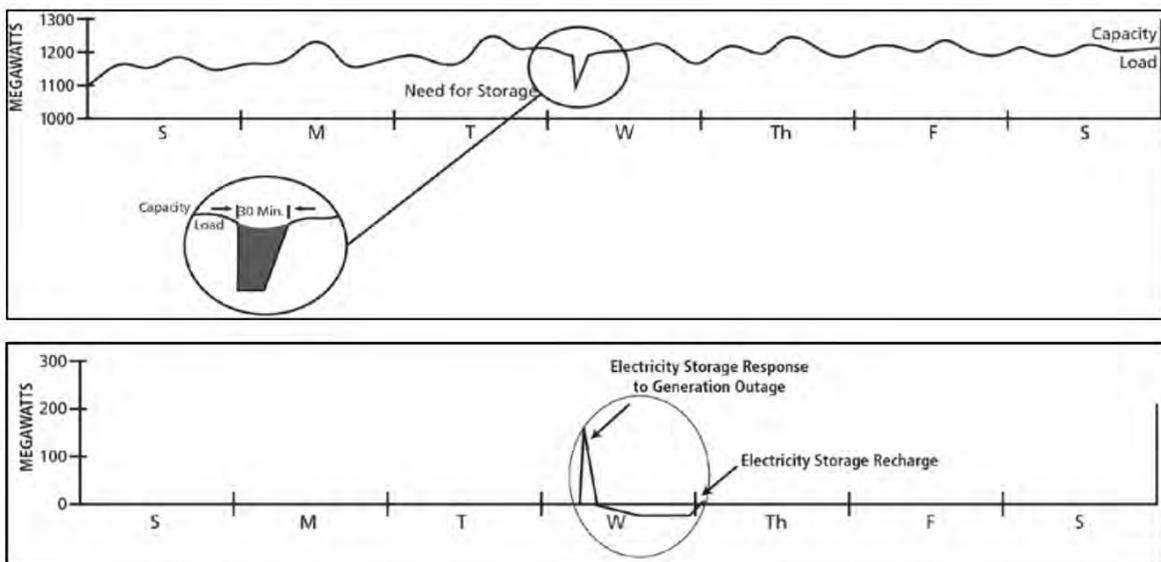


Figure 2-5. Reserves – Spinning & Non-Spinning

Source: DOE/EPRI Electricity Storage Handbook

2.3.3.3. Resource Adequacy

Resource adequacy (RA) is similar to reserves but based on behind the meter resources. In the California ISO (CAISO) area, utilities or other load serving entities (LSEs) are required to have available (own or contract for) sufficient resources to meet their share of the CAISO system's peak demand, plus a Planning Reserve Margin (PRM), currently 15% of demand. Owners of BTM assets are able to bid these resources into an auction to provide these resources in the event of a resource need. The RA auction is designed to provide appropriate incentives to private developers for the siting and construction of new reliability resources for the power grid. Many resources are able to provide RA resources, with energy storage finding it one of the more important markets for deployment in the CAISO system.

The RA contract ensures that those resources will be available to serve the needed requirement for capacity when needed. This capacity can either be a generator or a load that commits to provide RA resource into the CAISO market. The dispatch for the RA resources is coordinated at the CAISO on an economic ranking, selecting the lowest cost resources first. These services are paid according to the MW bid into the market.

2.3.3.4. Frequency Regulation

Frequency regulation (a.k.a. regulation) acts to stabilize the power grid by managing the moment-to-moment changes in the demand or supply balance of the power grid. The frequency of the AC power in North America is 60 Hz and is primarily maintained by the system inertia from the rotating mass of power generators. As load changes, excess generation causes a frequency increase above 60 Hz; insufficient generation causes a decline. Small shifts in frequency (load) do not degrade reliability, but large ones can damage equipment, degrade system efficiency, or even lead to a system collapse. These changes are first counteracted by the rotational inertia inherent in the connected synchronous generators. As the variation continues, regulation can also be provided through generating units operating under automatic generator control or participating in manual frequency control, both of which can change output quickly (on the order of MWs/min).

This service is contracted by ISOs/RTOs in the ancillary services markets. Although the concept is the same across the different organizations, the markets vary as to the structure of the contracted service, which is priced in \$/kW. These ISOs/RTOs provide market-based compensation to sources, which can be provided by either generators, variable loads, or storage. Historically, the need for frequency regulation was roughly one percent of the power system generating capacity. With faster reacting storage resources, this percentage has dropped, although the magnitude depends upon the type of local generation and load.

Energy storage facilities providing this service are designed with fast power ramping ability rather than longer duration. Originally requiring only a minimum of 15 minutes of discharge duration, regulatory changes have increased the requirements of the service to 30-minutes to 1-hour, depending on jurisdiction. Many facilities providing this service have been stand-alone facilities, but a number of units have also been designed for multiple applications, including providing frequency regulation. Because of the cycling nature of the service, any facility providing frequency regulation will need to reserve a portion of the capacity for the potential cycling range contracted, even if not used to its full extent each cycle.

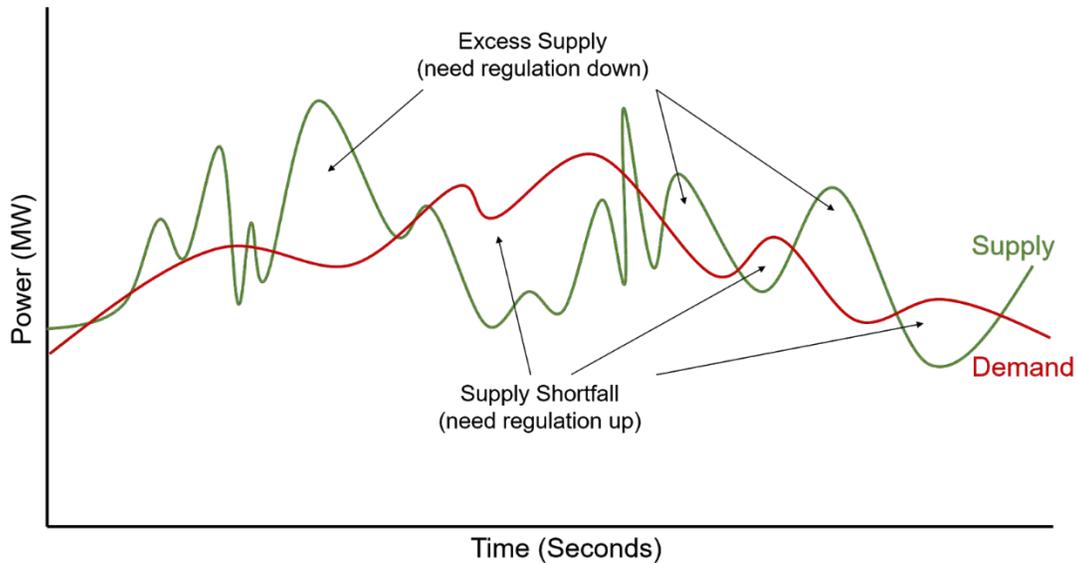


Figure 2-6. Frequency Regulation

Source: VLI-EV.com

2.3.3.5. Transmission Congestion Reduction

Transmission line congestion occurs when energy cannot be delivered across one or more transmission lines to the intended loads because the transmission capacity is not sufficient to deliver the requested energy. This condition can present a number of challenges to the power grid: the potential for physical damage from overburdened powerlines and increase wholesale electric costs (typically in the form of higher locational marginal pricing).

There are a number of solutions. The most direct is to increase transmission capacity—but this is generally a long-term solution, and a very costly one. A related issue here is that since the transmission system is generally a network and not a radial system, increasing the carrying capacity of a particular powerline does not necessarily correspond to a one-for-one uplift in carrying capacity. Much like adding a new lane to an existing highway—other traffic on other routes moves to the lane, reducing the net new additional capacity. The second solution to transmission congestion relief is for the utility / load serving entity to have a dispatchable load reduction program which would allow them to shed load as the grid's transmission capacity became burdened. A third solution is to incorporate an energy storage facility. In most instances, this unit would be positioned past the congestion point. During low demand periods, energy would be moved to the storage facility, and then during peak periods, the energy would be discharged to supplement the energy being provided through the transmission line. If ISO/RTOs have a program like PJM Interconnection, then the energy storage system would be compensated for providing this congestion relief by paying the unit with incremental capacity transfer rights as the congestion-relief payments.

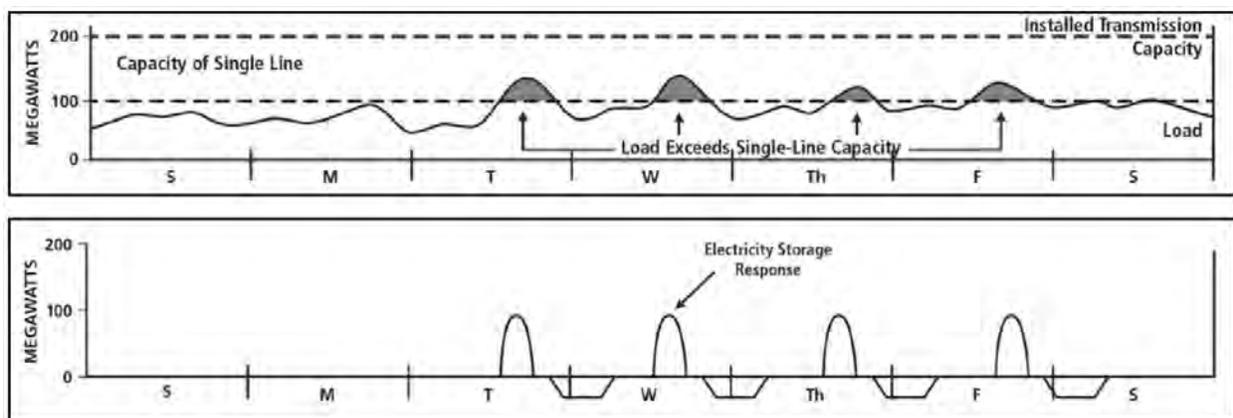


Figure 2-7. Transmission Congestion Reduction

Source: DOE/EPRI Electricity Storage Handbook

2.3.3.6. Blackstart

Blackstart services are used as the starting point for the grid’s restoration after a blackout. After a blackout occurs, most power generating facilities self-isolate and begin a shutdown process as there is nowhere for the power output to go. Blackstart units are able to self-start and stabilize independent of the power grid. These power facilities with self-starting capabilities are needed after a power grid shutdown since most generation facilities require system power from an outside source to begin operation (provide auxiliary plant-load and cranking power for the generator) and export power. In addition to self-starting, these units have the capability to maintain frequency and voltage under varying load while the system is restored since most of the system inertia (rotating mass of the major power generators) will not be available.

The locations of these units are very important. They are generally co-located with a key power generation facility, while others are dispersed throughout the transmission system at important interconnection points to support key transmission line become energized in a stable manner. Once operating, black start units help the generating unit begin the process of starting up. Recovery from a blackout follows this pattern of individual units coming online, synchronizing, and then expanding the connected network until all of the power grid is back online. The entire restoration process is slow and methodical, so ISOs/RTOs require that Blackstart generation units have the ability to operate for many hours to restore the system.

Blackstart services have traditionally been paid for through a cost-based service, but some ISOs/RTOs are beginning to provide an escalating incentive payment to entice additional units provide the service if there are insufficient resources.

2.3.3.7. Voltage Support

Utilities manage the carrying capacity of the transmission and distribution system through maintaining the voltage level within a preset range; this effort also protects utility and customer equipment from damage. Traditionally, conventional generation provides the majority of the voltage support to the electric systems, with some specialized power electronic equipment also providing some voltage injection or absorption to maintain voltage levels within the desired range.

Besides the production of voltage support from the generators, the need for voltage support/management is very localized. Much like frequency regulation instabilities, system voltage

can also be impacted by swings in power use by customers—especially heavy motive equipment. Low voltage conditions arise on power systems from two main sources: highly loaded powerlines and long, unsupported distribution lines. Uncompensated for, both of these situations can negatively impact the amount of power able to be transmitted through the powerline.

Energy storage can provide voltage support by controlling the injection of energy and reactive power. This capability makes them a beneficial asset to utilities in a distributed deployment at substations or along problem powerlines. Four quadrant inverters incorporated into the energy storage system are able provide or absorb real and reactive power, whereas the act of managing the energy flows on the powerline can also impact the powerline’s voltage levels.

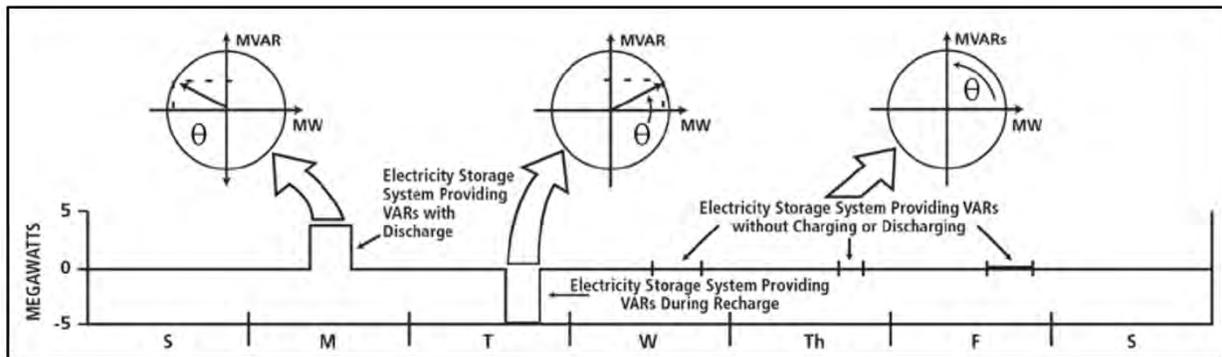


Figure 2-8. Voltage Support

Source: DOE/EPRI Electricity Storage Handbook

2.3.3.8. T&D Upgrade Deferral

Transmission and Distribution lines are upgraded over time as needed to support the increasing load from customers. Deferring the upgrade by a few years will enable the utility to delay a large capital expense and maintain a higher utilization rate for its transmission and distribution assets.

Utilities upgrade individual power lines on the distribution system based on the experienced and planned load growth. Typically, load growth is in the 1%-3% annual growth range, but sometimes can be as high a 5% if significant new customer growth is experience. With the increasing load, a bottleneck on the line will eventually emerge where the carrying capacity of a portion of the line, typically after leaving the substation, becomes insufficient to transmit all of the power demanded along to entire powerline. As the peak demand begins to near the carrying capacity of the powerline, the utility will commence an upgrade of the line, generally higher voltage transformers and related equipment but could include restringing of the line if needed.

A typical power line upgrade adds upwards of 33% new carrying capacity to the line, to ensure no need to upgrade the line again for a significant amount of time. Unfortunately, this strategy leaves the resulting powerline significantly underutilized for many years. Upgrade deferral refers to adding energy storage past the bottleneck, allowing the utility to effectively pre-position energy past the bottleneck. Some T&D upgrades are needed for voltage support. Others are needed due to congestion or peak demand that exceeds the ability to supply adequate voltage from existing wires. T&D upgrades are inherently specific to locations.

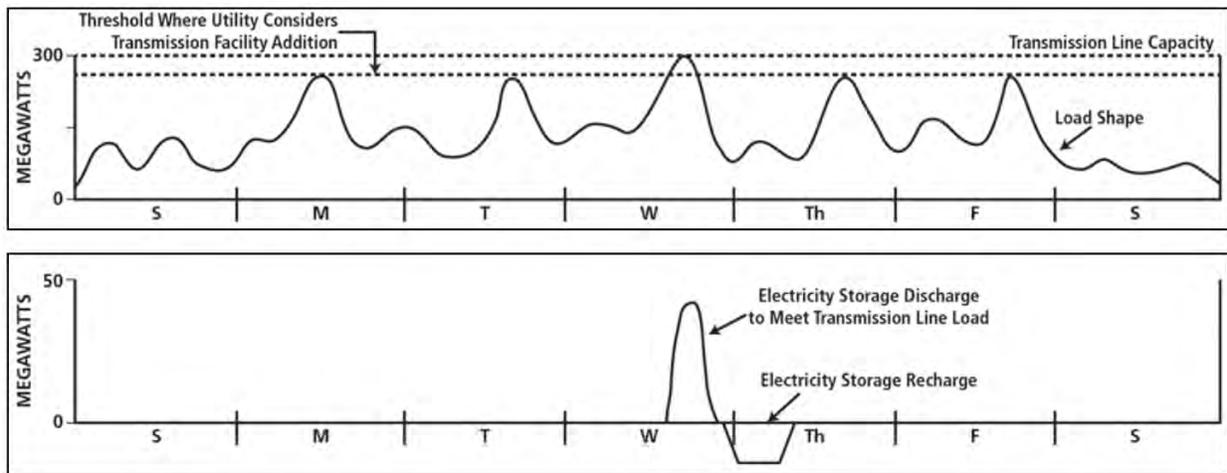


Figure 2-9. T&D Upgrade Deferral

Source: DOE/EPRI Electricity Storage Handbook

2.3.3.9. Frequency Response

Frequency response is very similar to frequency regulation, except it reacts to system changes in even shorter time periods of seconds to less than a minute. The frequency of the AC power in North America is 60 Hz and is primarily maintained by the system inertia from the rotating mass of power generators. As load changes, excess generation causes a frequency increase above 60 Hz; insufficient generation causes a decline. Small shifts in frequency (load) do not degrade reliability, but large ones can damage equipment, degrade system efficiency, or even lead to a system collapse.

These changes in frequency are first counteracted immediately by the rotational inertia inherent in the connected synchronous generators and the associated governor response. As the variation continues, secondary frequency control response regulation can be provided within 10s of seconds through generating units operating under automatic generator control which can change output quickly (on the order of MWs/min). Automatic generator governors act to restore frequency if it deviates more than 0.036 Hz from normal (normal control bands of ± 0.05 Hz). If the variance in frequency continues to grow, the power facility may lose their synchronization from the grid at ± 1.5 Hz to prevent significant equipment damage, which can begin to occur at ± 3.0 Hz. The combined effect of inertia and the governor actions determines the rate of frequency decay and recovery shown in the arresting and rebound periods in the upper portion of Figure 10. It is important to note that the rate at which the frequency decays after the triggering event – loss of generator or transmission – is directly proportional to the aggregate inertia within the grid at that instant.

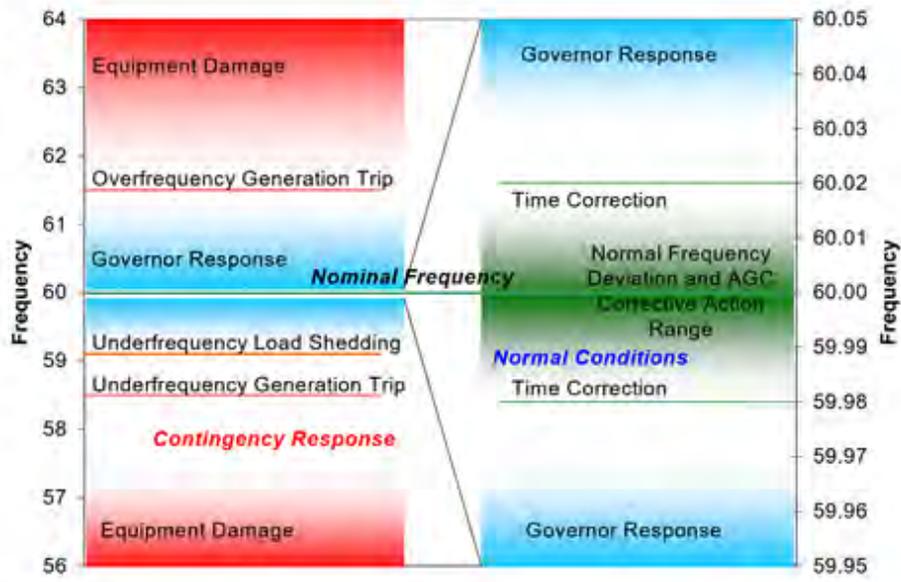


Figure 2-10. Frequency Response

Source: Brendan Kirby, ORNL

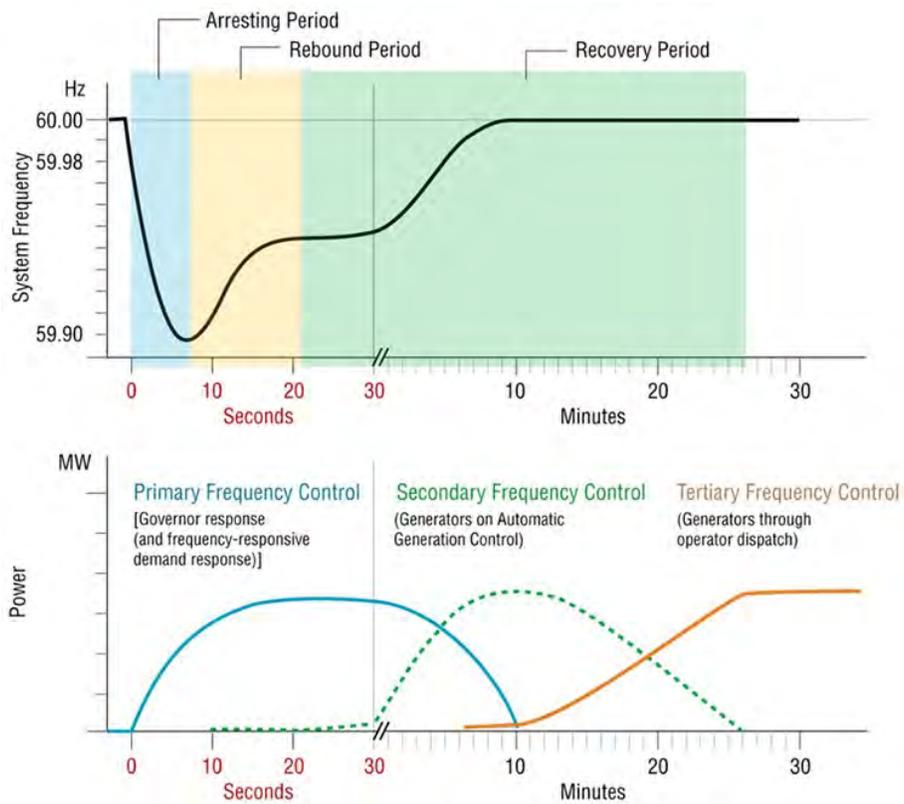


Figure 2-11. Frequency Control & Recovery

Source: Joe Eto, LBNL

2.3.3.10. Demand Charge Reduction

Utilities typically apply a demand charge to customers in addition to the cost of the commodity energy. The rationale is to provide feedback to the customers as to what is the most expensive portion of the service period for the utility, and hence, provide incentives to customers to reduce their demand, and thus the most expensive portion of the cost of service for the utility. More prevalent historically in larger customers, this is becoming more widespread with all customer classes as time of Use (TOU) rates are introduced. The demand charge is based on the utility measurement of the highest demand during any 15-minute period in a billing period. These charges are billed to the customer in \$/kW. Originally a relatively small portion of the bill, the demand charge has grown to be significant, even sometimes half of the total dollar value of the bill.

Energy storage located on the customer side of the meter can reduce the measured demand during these peak demand periods, reducing the demand charge applies to that customer. The basic requirement for this application is to supply from behind the meter a portion of the customer load or demand during this peak demand period. The shape and duration of the load may not be constant and will be affected by the prior installation of storage or other load-modifying resources such as solar. Distribution entities and/or small utilities which pay a transmission demand charge can also value this application and provide additional incentives to their customers.

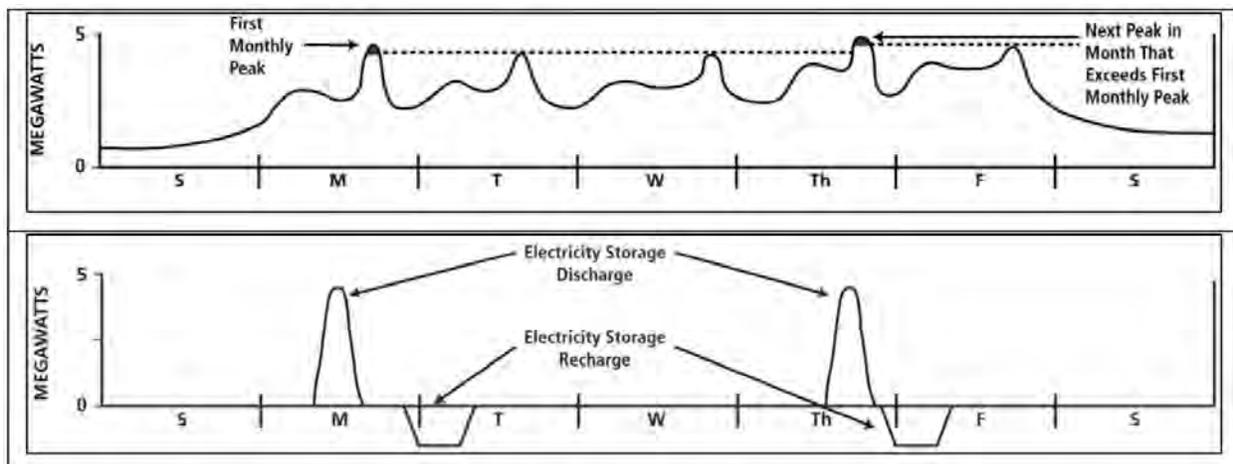


Figure 2-12. Demand Charge Reduction

Source: DOE/EPRI Electricity Storage Handbook

2.3.3.11. BTM - Time-of-Use Charge Reduction

Similar in nature to the Demand Charge Reduction, the Time of Use Charge reduction is based on the provision of energy from an energy storage system situated behind the meter. Customers are increasingly being subjected to time of use (TOU) rate for the commodity energy charge (\$/kWh). Although the level difference between peak and non-peak rates is generally not significant, making the economics of pursuing this operational strategy directly generally uneconomical, the direction is for continued divergence. Thus, customers that are utilizing energy storage to reduce their demand charge reduction could also then benefit from shifting their import of power (through the meter) from a higher cost period to a lower cost one.

2.3.3.12. BTM Solar/Storage

Energy storage is fast becoming a standard component of BTM residential and commercial solar deployment. The energy storage system provides the owner a variety of uses, the relative value of each depends on the type of deployment envisioned. For instance, residential users on time-of-use rates in areas with high electricity rates may see as their primary value shifting some of the on-site generated power to an evening peak to reduce the cost of their utility bills, whereas residential users in remote areas may see the primary value in powering the house through semi-frequent power disruptions or even allowing the house to go off grid when desired.

Typically, the energy storage system is positioned behind the inverter, on the DC circuit connected to the solar panels. Power generated from the solar panels can then be directed to the inverter and the load, or to the battery on the DC circuit for later discharge to the inverter and the load. The energy storage asset can be a great benefit to homeowners if their load is lower than the production level of the solar panels, allowing the excess energy to be shunted there. Generally, power from a household can be exported to the grid but will only remain on the local powerline below the local transformer which is only unidirectional. Depending on how the utility wants to manage the power-flow among the 5-10 houses connected below the transformer, the storage asset may be required / designed to absorb all of the excess output of the homeowner's PV system, allowing more flexibility in the design of the PV system. As the home demand increases past the production of the PV panels, the energy storage system discharges, reducing the import of power from the grid.

2.3.3.13. Reserve Power

Energy storage systems have a key role to play in ensuring reliable, high quality power for BTM sensitive or mission critical loads and maintain operation and/or bridge to backup generators in the event of a service disruption. Historically the realm of uninterruptible power supply market, the growing use of distributed resources allows for additional opportunities for these assets.

The core operation of these assets is to provide power during an outage either to bridge to longer duration backup generator, or to allow for an orderly shutdown of operations. Because of this wide range of uses, the amount of energy required onsite will vary greatly due to the intended usage profile. A BTM battery storage can provide back-up power at various scales, ranging from sub-second-level power supply for important industrial operations, to 24-hour back-up by pairing with an on-site solar PV system.

Because of the inherent nature of this operation—activity due to a blackout—this application can be included as part of the usage profile of many energy storage installations that are designed to either support renewable power onsite generation, or as BTM reliability asset that will sell services into the wholesale market. The critical issue will typically be the power delivery requirements of the mission critical load, versus the storage asset for the alternative application. Generally, energy storage assets to provide highly reliable power supply for short periods of time are far more expensive than those for longer duration at lower power levels—even if the total energy (kWh) rating of the asset is the same. Therefore, the ability of the inverter to manage multiple storage resources—or even onsite generation—will be key in utilizing these assets for multiple market strategies.

2.4. Costs

Energy storage system costs have been declining steadily for over a decade, with additional declines expected across all technologies. As different technologies are at a different point in their technological development, there are different drivers affecting their respective price decline. For instance, early stage technologies experience price declines from improving chemistry/physics. As energy storage technologies enter commercialization, material selection, manufacturing improvement and scale drive price declines. As technologies enter a more mature commercial market, competition and greater manufacturing scale drive further cost declines.

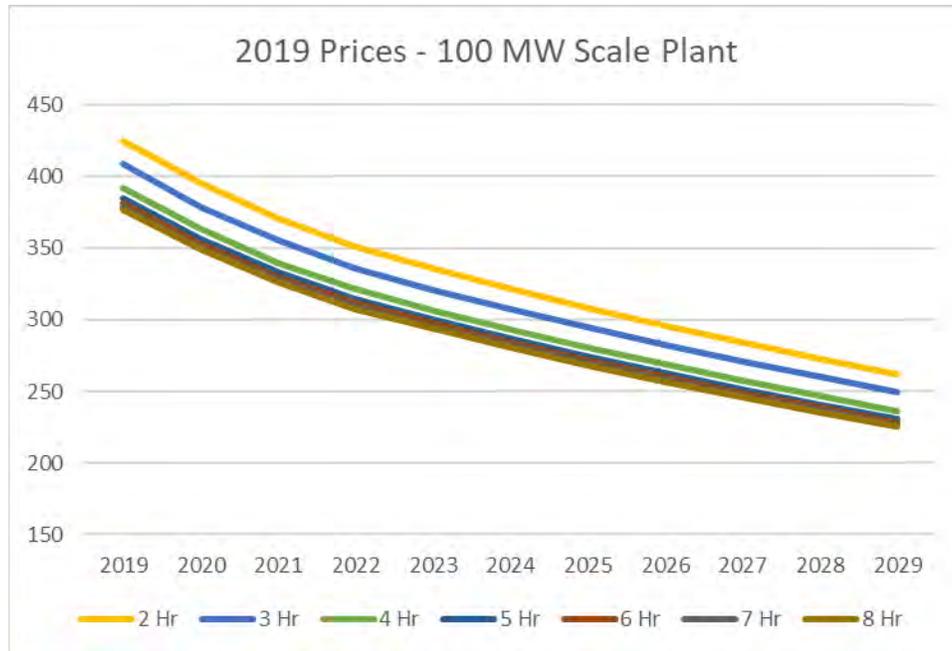


Figure 2-13. ESS Pricing

Source: 2019 Energy Storage Pricing Survey

System costs are becoming more visible with the increased competition have become less of an unknown over time as familiarity with energy storage systems increase. The variable component remains with the operating costs. Familiarity with these are also reducing the variability, but lags that of the initial costs due to the time required to experience sufficient operating time. An important aspect of determining the costs is the need for replacement batteries. The degradation of the initial batteries is based on the usage profile and environmental operating conditions of the system. Therefore, there is an iterative nature to the cost calculations on evaluating different usage profiles in that the replacement battery needs will be based on the number and degree of applications envisioned.

Electricity prices can have a significant impact on overall operating costs as they will express themselves in both the station power loads (HVAC, controls, etc.) and the efficiency losses that occur when charging and discharging. The rates for these costs may vary by jurisdiction, especially for Behind the Meter deployments. The relevant electricity prices will experience variability in both market segmentation and regional differences. This is another area of direct interest for developers as they typically have to contract for the station power needs of the facility separately.

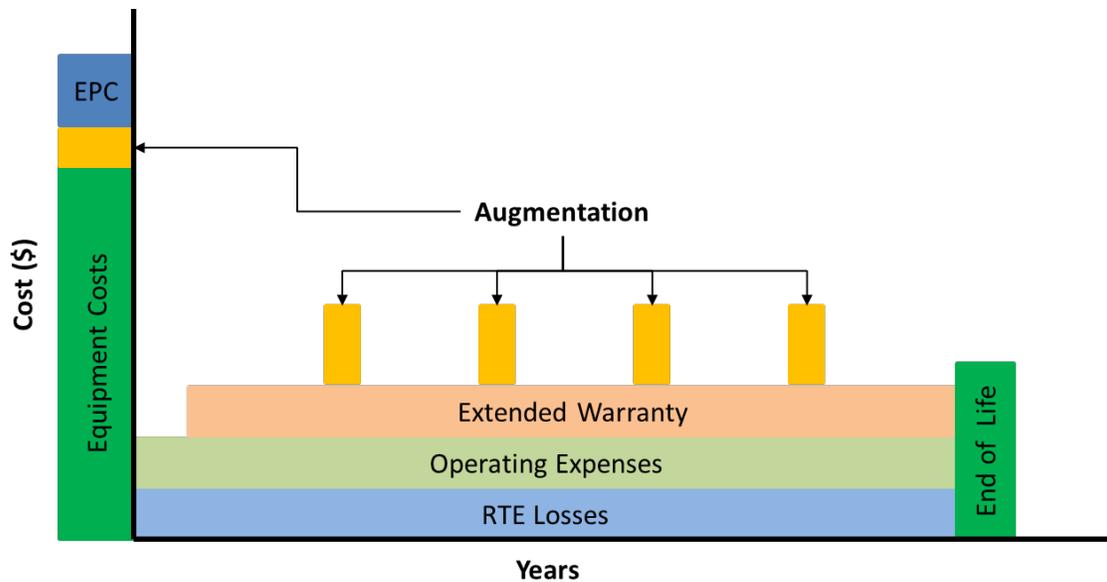


Figure 2-14. ESS Cost Budget

Source: Mustang Prairie Energy

2.4.1. **Capital Costs**

The capital cost of an energy storage system is the total value of all of the initial equipment purchased for the project. This is derived from adding the cost of all of the subassemblies and components needed to construct the final version of the product, many times described internally as a Bill of Material (BOM). This will vary most directly based on the variations of an energy storage system's particular power and energy rating. Incorporated into the equipment costs are services and overhead charges needed to keep the various OEM and system integrator firms in operation.

An important caveat is that due to the modular nature of energy storage systems (varying power and energy ratings) the same dollar value of the system (\$) could look significantly different if provided in \$/kWh or \$/kW metric depending upon the weighting of the different power or energy components.

The general cost structure of energy storage systems used across all energy storage technologies include the following components:³

- Storage Module (SM):** The storage module is the most basic component, typically an assembly of energy storage medium systems (battery) built into a modular unit to construct the energy storage capacity (kWh) of an energy storage system. For a lithium ion system, for example, it would be the complete rack (or tower, or cabinet), consisting of the battery modules, battery management system (BMS), and the rack and associated electrical cabling. Most cell-based energy storage technologies will have a similar unit block but may have different costs structures for each sub-component; for instance, lead acid battery systems do not require a BMS system as sophisticated as that of a lithium-ion system.

- **Balance of System (BOS):** The Balance of System is the equipment needed to combine a series of the storage modules into a complete DC level system. This will include electrical cabling, switchgear, thermal management, fire suppression, plus the enclosure, ranging from a special purpose enclosure, standard container, or a building.
- **Battery Energy Storage System (BESS):** The Battery Energy Storage System is the complete DC level energy storage system and is comprised of one or more storage modules with the accompanying Balance of System equipment so the unit can be electrically connected with other electrical components, safety of integration being a high priority. For many energy storage systems, these other electrical systems would be an inverter to provide AC power, but increasingly, there is interest for DC level storage equipment to be connected on a DC system distribution system using a DC:DC converter—for instance connecting on a solar array behind the solar field inverter.
- **Power Conversion System (PCS):** The Power Conversion System is responsible for converting and managing the power (kW) flow between the Battery Energy Storage System's DC power output and connects that to an external AC power circuit—typically a step-up transformer to an AC distribution system. Components within the PCS would include the bi-directional inverter, any protection equipment to help isolate the DC system if needed, and the required cabling or busbar.
- **Energy Management Software (EMS):** The Energy Management System is the software used to control the operations of the energy storage system, especially with regards to the import and export of energy according to predetermined operating strategies. The degree of the sophistication of this system is dictated generally by the range of expected market roles or applications the unit is expected to perform, and at what level in the market. For instance, a simple residential energy storage system only providing a few support functions will be significantly less robust than the EMS of a large utility levels system interconnected at the transmission level and expected to operate in a multifunctional role. Typically, large scale systems will include the communication equipment to connect to the utility SCADA and DMS systems.
- **Energy Storage System (ESS):** The Energy Storage System is the complete equipment list for an AC level energy storage system. This will include all of the equipment up to, but not including the step-up transformer. For ease of comparison, this will not include some electrical equipment such as metering equipment which can vary from location.
- **Grid Integration (GI):** Step-up transformer and required power electronics /switchgear required to integrate and provide protection for the energy storage system with the power grid. This will also incorporate any metering and physical security required. This component can vary widely based on scale, usage profile, and location of the energy storage system.
- **Engineering, Procurement, and Construction (EPC):** The Engineering, Procurement, and Construction component of the system costs deals with all components related to project construction and commissioning. This aspect of the system cost can vary widely due to a number of factors: experience level of the developer and EPC providers, the scale and

complexity of the system, and the deployment location of the unit. Aspects of this cost component include any engineering and permitting studies, equipment procurement logistics and shipping, site preparation and construction, and commissioning.

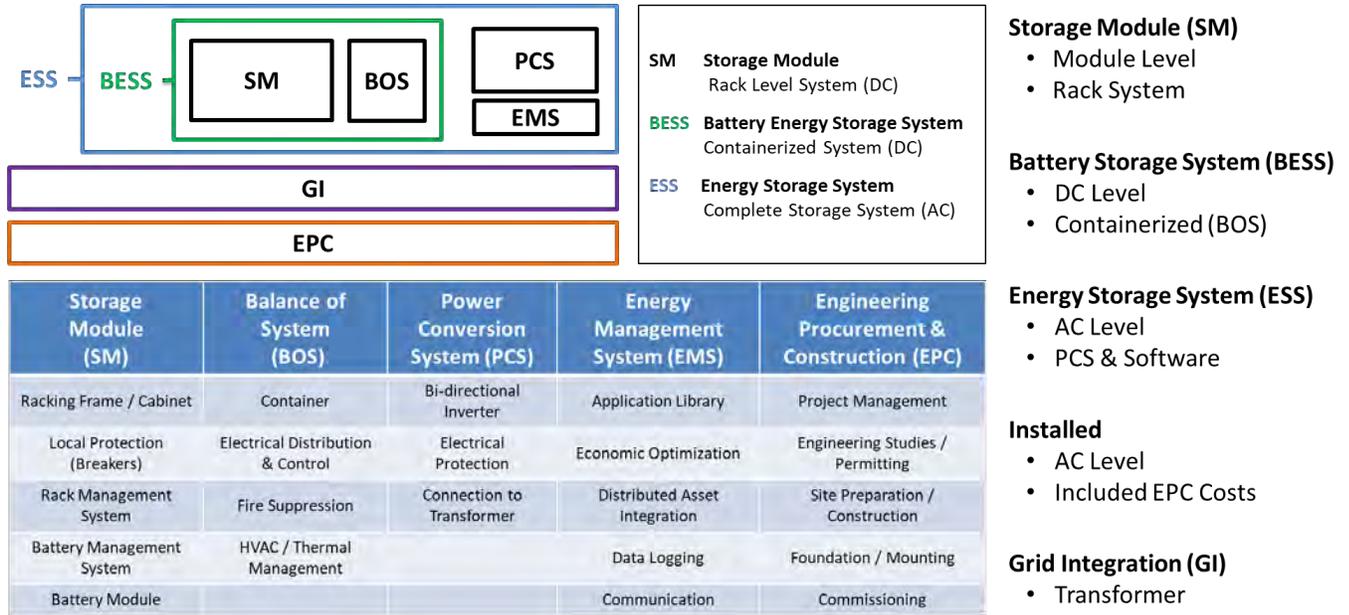


Figure 2-15. ESS Capital Equipment

Source: Mustang Prairie Energy

2.4.2. Capacity Maintenance

Some energy storage technologies lose capability over their operating life; this is called degradation. This will vary by technology. For instance, for mechanical systems, this loss can be rectified by maintenance or small component replacement as part of a service plan, whereas other, typically chemical based systems, have a long-term and irreversible transformation of the energy storage device itself.

In order to maintain either the amount of energy storage capability (kWh) or the rate at which the system can charge and/or recharge (kW/min) it may be necessary to add additional energy storage capacity to the system; this is called augmentation. The amount of augmentation required will depend upon the type of energy storage technology (lifespans of technologies differ) and the usage profile assumed for the facility.

2.4.2.1. Degradation

Degradation (sometimes referred to a fade) is the reduction in capacity (kWh) of the battery’s energy storage capacity over set period of time. Different energy storage technologies will experience degradation at different rates, with some technologies showing little or no degradation while others experience significantly more. This impact is based on the technology; technologies relying on electrostatic, mechanical, or purely reversible chemical reaction will experience little or no degradation during the transformation of the electrical energy. Chemical energy systems—

batteries—do undergo physical change, and thus degrade during operation, thereby losing some portion of initial battery capacity over their operating life. However, this is not true of all chemical storage systems; flow batteries are generally designed for limited to no degradation of energy storage capacity during operation.

Degradation comes through two pathways: calendar aging and cycle life. Calendar aging accounts for the eventual capacity loss resulting from the slow chemical changes to the battery material itself, reducing or eliminating its reactivity for the reversible storage process. The cycle life aging of the battery is driven by operational factors. They include operating temperature, operating range for the state of charge, charging rate, discharging rate, etc. Therefore, over the life of the system, how much energy can be cycled through will decline. The amount of decline will depend on under what conditions the battery is stored, and how the battery is used; depending on these factors, the degradation rate will be faster or slower.

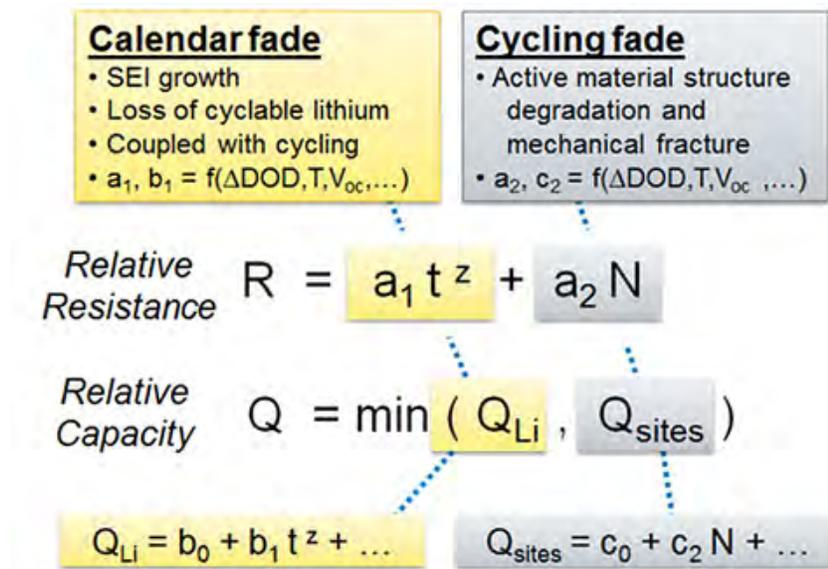


Figure 2-16. Energy Storage Degradation

Source: NREL

The cycle life of a battery depends on a number of factors; two important ones related to a chosen usage profile are the Depth of Discharge (DOD), and the cycling range of charging and discharging in each cycle. For instance, a battery will have a cycle life of X cycles when cycled at 100% DOD for each cycle. If the cycle life—X—of the battery at 100% DOD is less than the desired lifespan, the cycle lifespan of the battery can be extended by reducing the range of the DOD for each cycle. Therefore, by adjusting the DOD from 0% to a 100% state of charge (SOC) on each cycle to then cycle between 10% SOC and 90% SOC (80% DOD for each cycle), the cycle life of the battery is extended.

Degradation schedules are a foundational component of warranties from the different battery OEMs. As with many chemical cell technologies, degradation of lithium-ion systems depends upon a variety of usage factors to determine the degradation the system will experience. In addition, each OEM within a storage technology family (NCM, LFP, etc.) has a slightly different chemistry and manufacturing process, which requires different capabilities from one vendor to the next. A further

challenge for project developers is the constantly evolving—and improving—quality and capability of these systems, especially with respect to a potential variable usage profile. This leaves the developer with the need for a very clear and detailed understanding of the degradation of the system and the limitations this will imply for various usage profiles.

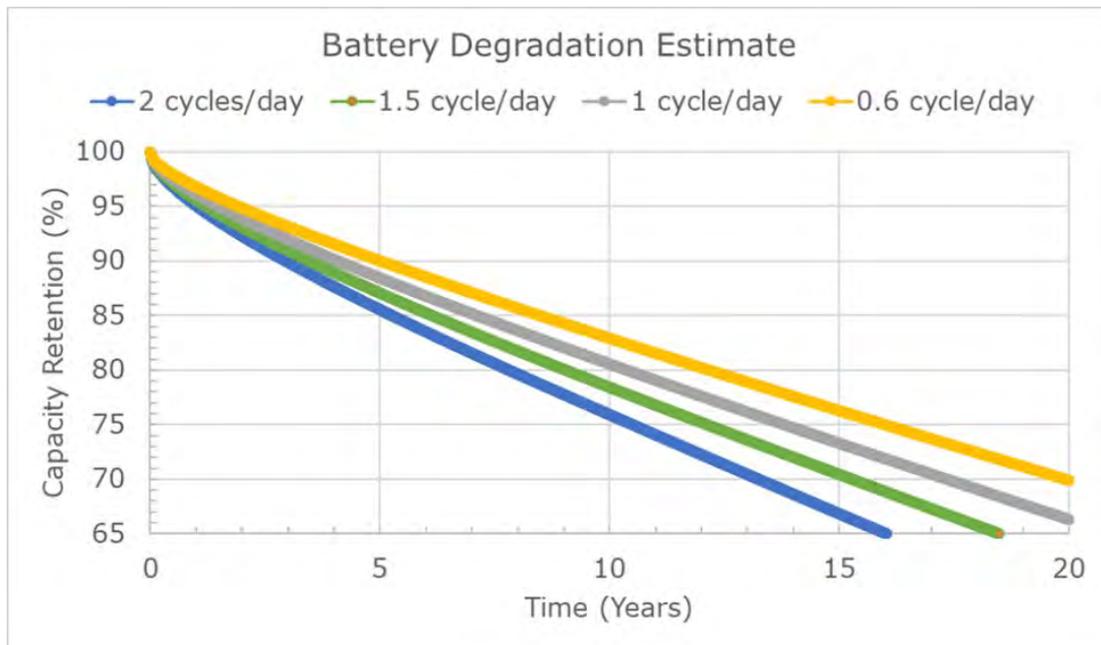


Figure 2-17. Battery Degradation Estimate

Source: DNVGL

Successfully managing degradation of the energy storage module over the project term relies on system integrators who are able to balance the designed capability of the technology with the hoped-for application profile requirements. This typically starts with a detailed understanding of the degradation profile of the cells, including the environmental and usage impacts under different usage profiles. For instance, running the system at an elevated temperature saves on both the cooling and parasitic load requirement, but shortens the lifespan of the cells and, if allowed to operate at too high a temperature, would violate the warranty. Knowledge of the different equipment OEMs is also critical as one vendor's equipment capabilities will differ from another.

By integrating the capabilities of storage technologies and least-cost strategy, OEMs and integrators can provide solutions for specific usage profiles that deliver stable, usable energy capability over the life of the system or, alternatively, a declining, but assured capability over time. Typically, projects needing assured energy capability such as asset deferral or renewable time shift will need to ensure full usable energy over the system's lifespan. Projects that can manage with a declining usable energy capability will generally be more focused on power availability and ramping capabilities.

2.4.2.2. Augmentation

Augmentation represents the additional energy storage equipment needed for the system over its lifespan in order to maintain the capability agreed to under the performance guarantee or support a specific usage profile. This calculated minimum is often described as usable energy (kWh) capacity,

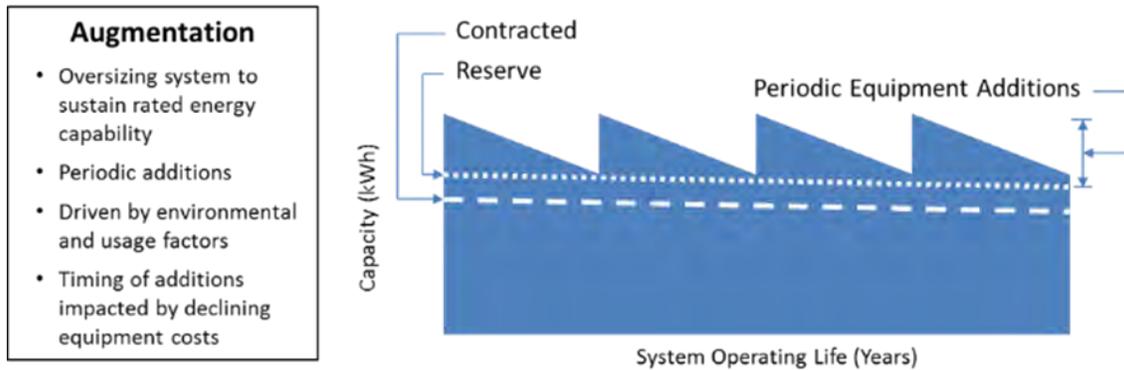
which is the amount of energy targeted or required to be cycled daily through the system throughout the system's lifespan. However, if the energy storage system is slated for providing capacity (kW) instead of energy (kWh), then a different (and lower requirement) augmentation schedule would be required to ensure the cycling capability for the energy needed.

A variety of augmentation strategies exist, each with their own benefits and costs. The goal of all of these strategies is to best the cycle life of the resulting energy storage system with its intended usage profile. First: initially oversizing of the system pushes the costs up front but saves on future installation costs. Secondly: periodic augmentation allows for a lower-cost approach to match the capacity needs, but it requires additional balance of system cost to absorb additional modules and increased labor costs if done too frequently. Third: the replacement of individual modules at the end of their operating life to reducing capital outlays while benefitting from reduced battery costs. However, to date, this approach has not been utilized due to the technical needs involved in balancing the varying voltage of the different modules on a particular battery string (below the inverter).

Augmentation requirements are based largely on the performance capabilities of the energy storage technology in question, and the usage profile of the energy storage system during operation. This impact on the battery's cycle life varies by technology. Technologies such as flow batteries and flywheels are designed to cycle their entire energy range without degradation. Chemical batteries such as lithium-ion or lead will experience an increase in their cycle life as the range of charging and discharging of energy per cycle is reduced. (Changes also vary by cathode chemistry in lithium-ion cells.) Additional attributes that will impact the life of the battery include operating temperature and the rate of charging/discharging.

Augmentation schedules attempt to find the least-cost approach to obtain the required capability of the system over its lifespan. The challenge is to map the declining cost of batteries (and improving capabilities) with the expected usage profile over time—leaving sufficient capacity in the battery to provision the needed usage requirements (and avoid penalties), but not have excessive amounts of spare capacity. To easily ensure sufficient capability over the life of the system, the project developer could simply overbuild the energy storage system, but that strategy can be needlessly expensive as batteries today cost more than they will in the future. Due to the declining cost of the equipment, the typical cost minimization strategy is to push off into the future as much of the augmentation as possible as future batteries are expected to cost less. Determining the least-cost augmentation schedule will continue to vex many project developers who desire to use the energy storage facility for a number of applications. Thus, the result is typically some mixture of initial oversizing—with augmentation occurring a few years into the future, but as infrequently as possible in order to minimize the labor component.

Augmenting the energy storage capacity of a facility often means adding more than just additional battery modules. Historically, for lithium-ion batteries this question manifests as to whether the project is only required to added DC battery modules, or complete AC level systems. The issue is based on the ability to add new battery modules in line with existing, older battery modules tied to a common inverter—which had been the practice for many cost-conscious developers. As the modules will have different electrical properties (due to age), balancing them becomes more difficult, thus the earlier strategy of simply adding new modules to strings with older battery modules has been proven not to work well. However, if the modules are instead added to the overall system with a new inverter (at the AC level), or with a DC-DC converter, then the new modules can be electrically isolated from the older ones and run with more reliable performance over time, albeit at a slightly higher capital cost.



System Degradation Drivers

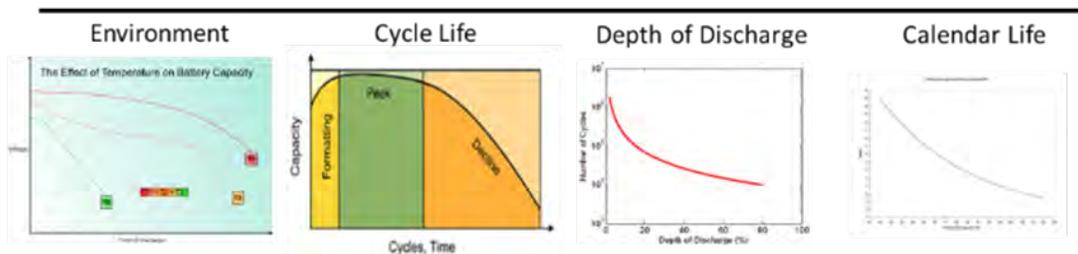


Figure 2-18. Energy Storage Augmentation

Source: Mustang Prairie Energy

2.4.3. Operation Costs

Operating costs are critical to understanding project’s actual value over its operating life. Over the life of the unit, the ability of the facility to reliably dispatch and react to signals is directly proportional to the quality of the equipment, and how it is maintained. Although decried sometimes as excessive expenses, experience with maintaining units actually in the field at a high state of readiness are quickly highlighting the importance of maintaining the system in good working order – lessons taken to heart by both operations, and lenders who are cautious of systems not being able to repay their loans due to the system not being able to operate when contracted. Operating costs for energy storage assets include:

- charging/operating losses,
- operating and maintenance costs, and
- warranty costs.

2.4.3.1. Charging / Operating Losses

Losses from charging and standby operation are a central expense for energy storage facilities. For this reason, the round-trip efficiency (RTE) of the unit is very important to the strategy envisioned for the unit—especially for more actively usage profiles. As one would imagine, different energy storage technologies have different round trip efficiencies based on the method needed to convert the electrical energy into a form for storage, and back again.

Since RTE can impact total operating costs, it is an important input into economic modeling calculations. These charging costs will also vary between technologies as the round trip efficiencies vary widely—flow batteries can achieve into the 80% range for round-trip-efficiency (DC:DC), whereas lithium-ion modules routinely state 95%+ round trip efficiency (DC:DC). In reality, average RTE values based on real-world experience are lower than the optimal values provided by manufacturers. For instance, lithium ion system is typically given an 85% round trip efficiency for the entire system.

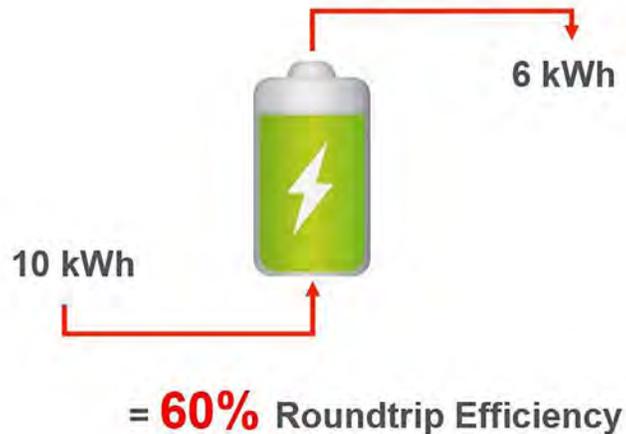


Figure 2-19. Round Trip Efficiency

Source Simplifi Power

System level should be the metric used, but that is sometimes difficult to obtain as OEMs may only provide the cell or module level data (what they have). It is important to use the complete round trip efficiency (RTE) of a system, which (for cell based systems like lithium-ion) includes the DC battery modules, the power conversion system (primarily inverter), the parasitic load from the HVAC (Heating, Ventilation and Air Conditioning) equipment, and the station power needed to power the electrical controls of the facility (not significant, but should be taken into account).

Because the HVAC can vary significantly based on the geographical location of the system, and to the degree of how actively used is the energy storage system, this location specific variance is not typically added to the station power load estimate provided by manufacturers. The impact of HVAC is becoming more important as operating data becomes more widely published. This HVAC loads will always vary as different seasons and regions of the country require different cooling loads, and different applications require different usage levels, requiring different cooling loads.

2.4.3.2. Operation & Maintenance

Maintaining energy storage systems in a good working order is essential in order to have the facility operate as planned or contracted —both on time and according to the usage profile required. Estimating the actual operation and maintenance (O&M) costs are thus central to properly calculating the total cost of ownership of the system. O&M costs will cover monitoring and scheduled maintenance of both the battery system, HVAC, and power electronics. Chemical batteries such as lithium ion systems are typically a low-maintenance cost technology as compared to others with a moving parts that require more frequent maintenance. On average, higher usage of the

system will require a larger degree of maintenance for all technologies. Because of the lack of significant experience with any storage system over the long-term (decade plus), there remains open questions as the O&M needs to maintain expected performance levels for a wide variety of applications—especially when operating in multiple modes simultaneously.

Traditionally, typical maintenance costs have been expressed as the annual maintenance contract that is sold by OEMs—but generally undertaken by a service group certified by the OEM. These generally cover one or two visits per year to visually inspect the system and change out consumables such as air filters for the cooling systems; some contracts also provide for one or two unscheduled visits. Increasingly, remote monitoring is being used to improve overall monitoring, and reduce these on-site visit requirements. Remote monitoring in particular helps lower the cost to inspect the units. It also provides an opportunity to gather data for predictive maintenance, as the body of operating experience grows. Operation and maintenance concerns have grown with the push toward longer-lived systems, driving a focus on the operation of the facility over time, rather than maintenance of the initially installed equipment and hopes that it will operate whole life without incident. Historically these O&M charges were effectively 1% - 1.5% of the capital costs of the system for chemical cell-based systems like lithium ion—slightly higher for systems like flow batteries with more moving parts.

With the growing number of units deployed, the focus is now turning to developing an O&M cost structure that is based on a fixed and variable pricing component. Currently some anecdotal information for a few applications have become available, and the expectation is that additional information from a wider set of vendors covering a wider set of applications will allow for a reliable and systematic breakout of O&M costs for all energy storage technologies that would cover a variety of usage profiles. This would allow for a clearer costs structure differentiating passive and active operating modes. In addition, environmental conditions should also be taken into account as energy storage systems in some extreme environments are expected to have a higher O&M cost structure than those in a more temperate climate.

2.4.3.3. Warranty Costs

Warranty costs are another important component of a projects operating costs⁴. Although technically optional, they are in fact many times of requirement of lenders, as these groups view having the capital equipment of the project covered under warranty essential to protecting their assets and their ability to generate the requisite revenue. Warranty coverage is typically focused on two areas: manufacturing defect, and performance. The limited warranty covering manufacturing defect guarantees the battery system to be free from defects in material and workmanship and provides relief in the event only that there were defects in the manufacturing of the product with the vendor required to repair or replace the defective components. This warranty is not extended to any design issues of the product and does not reimburse for economic loss resulting from downtime.

The warranty period can vary depending upon the market and/or usage profile under which the battery is intended to operate. Typically, manufacturing warranties and performance warranties are provided with differing coverage periods. Generally, the manufactures warranty can be upwards of 15 to 20 years, while performance warranty is provided for a much shorter period of time, and requires the operator to keep the operation of the system between certain parameters (temperature, Depth of Discharge, C-Rate, etc.) For larger systems, performance warranties of 2-3 years can be

provided with purchase, and annual renewal is available. For smaller commercial and residential systems, many times a 10-year warranty is capitalized into the purchase price.

Performance warranty periods are also highly dependent upon the usage profile expected for the facility, and the market where it is being sold. For instance, in the commercial and residential market with a simplistic usage assumption, the warranty period would be listed in years, with 10 years being typical now, which is simply capitalized into purchase. Increasingly, this time period is being supplemented by an energy throughput level not to be exceeded. For larger utility scale systems that will define coverage in more detail depending on the usage, typical original equipment warranty coverage is 1-3 years, with the ability for the customer to buy an extended warranty on a year by year basis.

The performance warranty is a growing area of focus for developers and lenders. The performance warranty will cover the technical rating of the unit, with respect to such issues as: power, energy, efficiency, duration, and availability. Performance warranties vary by OEM provider but are generally centered on energy storage capacity (kWh) or energy throughput (kWh) provisions over the life of the unit. Using storage capacity as a framework, the performance warranty is typically described as a specified schedule of guaranteed energy capacity (kWh) of at least X% of the rated energy capacity for a specific number of years (or cycles) after the date of the initial installation. The rated capacity under the warranty is typically either step down every few years or be a straight-line annual reduction. Using energy throughput as a framework, the performance warranty is typically described as a certain amount of energy throughput over the life, generally according to a specific table per annual usage while the system is operated under normal conditions and can include such issues as temperature, charging/discharging rates, state of charge operating range.

Some aspects related to warranty coverage, however, are not expected to ever be covered freely by the OEM, however. For instance, warranties cover the cost of the equipment, and not the labor to replace the unit, or shipping it back for repair or replacement. This is an important issue with price conscious customer—such as residential—who are primarily concerned with up front capital costs and not total life operating expenses.

2.4.4. Project Costs

Project costs are another area that contribute to the total system cost for customers⁵. Two areas in particular are of note: project development, and engineering, procurement, and construction (EPC). Project development costs are those generated by the project development team need to launch the project and encompass many of the soft costs that are sometimes difficult to specify. Engineering, Procurement, and Construction (EPC) costs have historically been subject to significant over-runs due to the small body of experience deploying energy storage systems. Overall, the base expense and the variance in possible costs ranges are expected to continue to decline as experience grows.

2.4.4.1. Project Development

Project development costs center around structuring the project entity, and the financial and legal relationships it has with external organizations. Better clarity on these issues reduces the risk to creditors of being repaid. These costs have declines through leveraging the expertise in solar and wind project development. Particular areas of concern are:

- **Real Estate:** Property rights are important for any power industry project, and energy storage projects are no different. It is critical to ensure that the site is suitable for its use as an energy storage facility, including size, layout, and access. It is also important to secure long-term access and control of site for all necessary uses to construct, operate, maintain, and finally decommission the facility.
- **Permitting.** Permitting ensures that the activities and intended uses on the property are allowed according to safety and land use rules. For this reason, permitting requirements are very site and project specific. It is also important to understand which permitting requirements apply, as the relevant Authority Having Jurisdiction (AHJ) that are involved can include local, state, regional and federal agencies.
- **Regulatory.** Energy storage projects are covered by a variety of regulatory entities at both the local, State, and Federal levels. Because of the relative newness of the industry, it continues to be a dynamic environment.
- **Incentives:** Incentives for energy storage technology investment are available at the federal, state, and local levels. They are embedded in the tax code, paid as direct benefits from states and utilities, and/or encapsulated in mandates or utility requirements.
- **Off-Take Agreements:** Off-take agreements cover the revenue contracts underpinning the financial viability of the project. Their structure for Front of the Meter projects will depend on if the revenue contract is a PPA (FTM) or energy savings (BTM) arrangement, or if the facility is operating in a merchant role. For this reason, the counterparty and its credit worthiness are important.
- **Tax:** Tax incentives have played an important role in developing conventional and renewable energy facilities, and it holds out promise to support energy storage projects as well. This includes developing investment incentives such as the Investment Tax Credit (ITC) or the Production Tax Credit (PTC). Ensuring energy storage projects qualify for the accelerated (5-year) Modified Accelerated Cost Recovery System (MACRS) instead of the typical (7-year) schedule is also beneficial.
- **Profit Margin:** Project developers engaged in the energy storage market must make a profit on their business activity in order to stay in business over the long-term. This profit is expressed in a number of ways, including management fees, success fees, etc. Depending on the level of competition in the market, this may be smaller than expected. However, it should be noted that some portion of the project developer profit margin is the equity built up in the firm itself, including capabilities of the firm and ownership stakes in the various projects.

2.4.4.2. Engineering Procurement Construction

For the majority of project developers, the construction and delivery of their individual energy storage facility is coordinated via a contract with an engineering firm providing the engineering, procurement, and construction (EPC) services.⁶ The EPC firm must be capable of providing highly specialized engineering, procurement, installation, construction, and commissioning services, either directly, or through a number of subcontractors (electrical contractors, etc.) and suppliers who will undertake specific aspects of the scope of work. EPC contracts are designed to clearly allocate the division of responsibilities between the developer of the energy storage projects and the firm

responsible for the energy storage systems installation. These contracts lay the foundation for a successful project's operation by clearly allocating the primary areas of project responsibility.

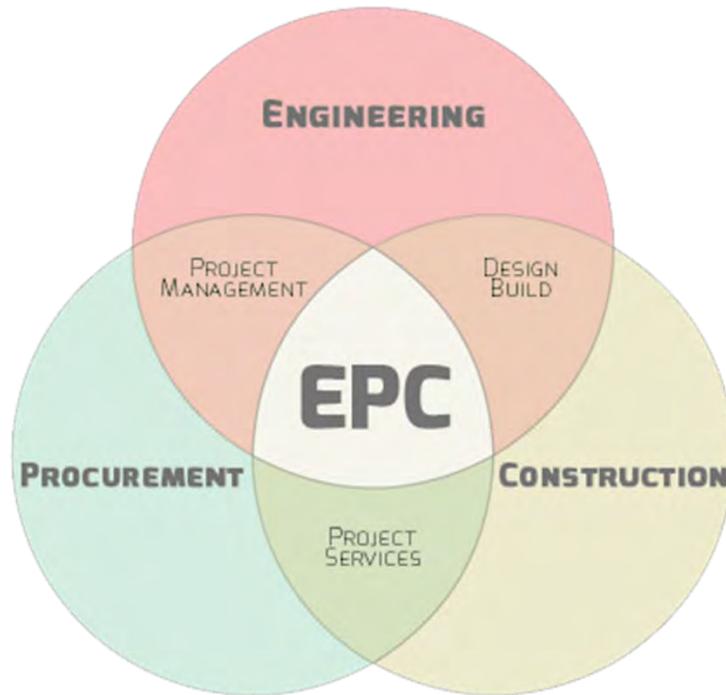


Figure 2-20. EPC – Engineering, Procurement & Construction

Source: Enerray

The EPC firm is responsible for integrating all of the engineering designs of the system into an integrated whole for use in the project's site layout, engineering, and integration studies, and required permitting. Site-specific engineering costs remain a major concern for the EPC budget. Overruns in these site-engineering costs is driven by non-repeatable engineering work, generally described as Non-Recurring Engineering (NRE) costs. These can be significant due to the variability in locations, customer class of facility, and whether the facility is a retrofit or a green-field location. EPC firms are trying hard to leverage lessons learned from previous deployments to lower the learning cost curve, but challenges remain. Leaders at EPC firms have cited the lack in continuity in partners, both on the OEM and customer sides, for driving up NRE costs. Continuity of relationships between EPC and project developer in other solar and wind markets have proven to lower the cost and time required through increasing the familiarity with work processes.

The EPC firm is also responsible for procuring (with purchases either flowing through the firm or simply in coordination with it) all the components of the energy storage system according to the product specifications listed in the system design. Increasingly, system integrators are providing a complete equipment stack, but some developers and customers still procure the AC and DC components separately. As more vendors and system integrators enter the field, the EPC firm must be versed in a growing number of OEMs to ensure good integration and construction. The EPC firm is also responsible for contracting the shipping and transportation of equipment to the

construction site. Procurement cost overruns can be driven by multiple factors, but those most unique to the energy storage industry relate to OEM supplier reliability on delivery timeliness. While a slippage in schedule can incur penalties for missing schedule milestones, this risk is of heightened importance for energy storage projects intended for summer peak capacity, since they typically need to be in service (Commercial Operation Date - COD) by a particular date. These risks to the developer's schedule can be somewhat mitigated by utilizing liquidated damages clauses in the OEM equipment supply contracts.

The EPC firm is also responsible for coordinating the construction of the energy storage facility. This will require the use of their own staff, plus selecting subsidiary electrical contractors to assist with the installation and commissioning. Due to the increasing scale and complexity of energy storage systems, the need for demonstrated experience by the electrical contractors is becoming expected, as this leads to lower cost over-runs and higher quality work. One of the critical risks for construction overruns is in the site engineering, so experience with site assessment and development, environmental management, and foundation construction is imperative in order to maintain cost containment.

EPC contracts are typically “turnkey”—requiring the EPC firm to deliver a facility ready for commercial operation by a specified date (COD) and within a specified budget, subject to customary change order provisions for unknown conditions, force majeure, developer-caused delays, and other factors. Through detailing the different parties' responsibilities with regard to the project, the EPC contract aims to both deliver the project according to the schedule while also limiting opportunities for the different parties to claim cost overruns. For these reasons, an experienced EPC firm is quickly becoming an indispensable partner for project developers, lenders, and site-owners/customers. The EPC firm works closely with the developer during deployment and is for solving technical challenges as they arise while knitting together all of the technical details of the equipment and the project. Since the industry is rapidly expanding with multiple vendors of different components, EPC firms must expand their technical knowledgebase to multiple OEMS in order to win contracts.

Payment terms for EPC contracts are typically a fixed amount, helpful for the project developer to craft a reliable project budget. Because there are a number of fixed costs that favor larger facilities, construction costs generally decline as a percentage of capital costs as the system size increases. As with engineering costs, there are also large site-specific factors that can drive up costs, especially for smaller systems where the energy storage unit is being installed into an existing structure with limited space and pre-existing electrical systems.

A critical issue raised by many industry leaders concerns who is responsible for cost over-runs when the inevitable change-orders happen to the original plan. The wording in the contract is thus of high importance for both developers and EPC firm. As with any construction project, EPC firm building into their bid sufficient space for some cost over-runs. When significant changes to the contract occur, change order agreements dealing with these scope changes are negotiated separately.

Finally, EPC costs are also impacted by exposure to the equipment warranty and any possible liquidated damages for delay or performance caused by facility construction issues. Project owners and lenders increasingly require a “fully wrapped” warranty from the EPC firm, thus making it responsible for all defects in design, equipment, and performance in the event the system fails performance tests. Lenders want to know that the project can perform to expected performance metrics (availability, round-trip efficiency, capacity) backed by liquidated damages (agreed upon compensation for a specific breach of a contract). For these issues, there will continue to be an

evolution in the limits for EPC firm responsibility and liability as, over time, the full extent of system operations and reliability continue to emerge.

Developers interviewed maintain that there remains a wide range of experience when it comes to EPC firms (although the average quality is rising rapidly), but that some projects continue to be impacted by the site preparation and construction in particular. EPC firms interviewed also agreed that the construction component can be far more expensive than originally thought, but that cost-overruns were driven by earlier changes in design that necessitated alternations in the construction and installation segment. Both parties agreed that specially built enclosures or containerized systems allow for ease of construction and installation.

Finally, developers are looking to EPC firms to help manage the design, construction, and operational risk of these projects. Since energy storage systems are comprised of multiple components from multiple vendors, it is difficult to understand the overlapping warranty coverage (for usage, environment, etc.) of all of the components once they are connected and operate as a unit. EPC firms are unique in understanding the technologies they deploy, but also the impact of deployment on the design and operation, especially of large systems. By layering all of the component warranties with their understanding of the impact of deployment and operation, EPC firms are able to calculate the total warranty coverage (warranty wrap) of the system under different operating modes, including possible manufacturing defects, capacity, performance warranties (i.e., reliability), etc. From that knowledge, they can provide a complete warranty coverage for the entire system in operation under the assumed usage profile. The willingness of a particular EPC firm to provide this coverage will be based on their familiarity and confidence with the various components (battery modules, BMS, controls, PCS, HVAC etc.), and with its own engineered, designed, and integrated energy storage system.

2.4.5. End of Life

As the number of energy storage projects grow in scale and age, developing a responsible and scalable end of life process will rise in importance: for government regulators (reduce landfill totals), project developers, lenders, and insurance providers (reduce cost and liability exposure), and OEMs (increase possible raw material source).⁷

While most energy storage facilities will be powered by lithium-ion facilities, it is critical to be aware that there exist a variety of additional energy storage technologies—all of which will all need to have a comprehensive end of life set of procedures as well. Overall, end of life operations entails three requisite activity stages: Decommissioning, Transportation, and Disposal.

2.4.5.1. Decommissioning

Decommissioning of the energy storage facility is the act of dismantling of the equipment and returning the site/location back to a brownfield state. This can roughly be described as the construction/commissioning process in reverse, including the removal of the battery systems and then the housing and balance of systems. In this stage, systems comprised of containerized system components would have some advantages over specially built housing solutions as they are more easily handled for moving in discrete units.

Overall system designs vary between different energy storage technologies—leading to different requirements for the decommissioning of a facility.

- For cell-based chemical systems, the length of the container determines the ease of the decommissioning process. If in a containerized solution, typically the weight of a fully loaded unit (with lithium ion battery modules) is under the weight restriction for on-road travel, thus allowing the entire unit to be removed whole. For containers over 20', the lithium ion battery modules are typically removed from the racking systems and transported separately. This is similar to the commissioning approach where the racking and system envelope/container is shipped to the site separately and then the modules are placed into the racks onsite. For cell-based battery systems other than lithium, the same weight restriction strategy applies.
- For liquid-based systems such as flow batteries, the electrolytes must be removed from the system in order to reduce the weight and remove any possible reagent from the system prior to movement. Once removed, many of the modern flow battery systems are designed around modular, containerized solutions which can be removed from the pilings and hauled away. For mechanical systems such as flywheels, the system is typically removed in the same manner that it was brought on-site and constructed.
- For mechanical systems such as CAES and PHS, since the system is typically constructed on-site, the decommission process will entail significant deconstruction of the unit on-site prior to removal. In the extreme, removing something like a concrete dam would require actual demolition.

After the energy storage equipment and related housing have been removed from the site, the site itself must be returned to the agreed-upon status, as stated in the contract. The requirements here will be driven in large part by how the system was installed and housed. A purpose-built building can, in many instances, outlast the energy storage system, and so poses an opportunity for repowering, or re-using, for another purpose. For systems installed on pylons or concrete slabs, deconstruction teams have the choice of either removing these footings or leaving them for other uses.

Although there have not been a large number of commercial energy storage facilities that have gone through an end-of-life process, there have been a few demonstration systems that have undergone the process. These have not only provided the industry with valuable decommissioning experience but have been helpful primarily in driving the development of those decommissioning guidelines that are acceptable to utilities and state public utility/service commissions (PUCs).

More importantly, there have been, for many decades, uninterruptible power supply (UPS) deployments at a variety of locations. These deployments have required the removal of battery banks from a variety of commercial and industrial establishments. This activity has laid the groundwork for the proper procedures required to decommission a previously active facility that contains both electrical and chemical components.

2.4.5.2. Transportation

The complexity of transporting the retiring energy storage system components from the project site to a disposal location is based largely on the design and degree of containerization of the system. If some components were constructed onsite, these could be removed in larger segments rather than broken down like the components originally shipped to the site.

After decommissioning the site, the components of the energy storage system will be transported to a facility for disposal. The transportation of the various components will need to be done in

accordance with the controls and regulations of these systems, and with the understanding that regulations in the future will probably be more stringent for the transportation of caustic chemicals, along with partially energetic chemical devices.

The transportation of energy storage system components will generally conform to a reversal of the original equipment's initial transportation to the site.

There are a number of regulations currently governing the safe transportation of batteries. An important resource for understanding these regulations for transportation, both to and from the site, is the Rechargeable Battery Association (PRBA). The PRBA was formed in 1991 and has remained at the forefront of helping organizations craft safe regulations for the handling and transportation of batteries.

In 2004, the PRBA was granted official observer status by the United Nations Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Chemical Classification and Labeling, making the organization an important global resource for firms dealing with energy storage system transportation issues.

Within the United States, a number of federal regulations apply for the transportation of batteries. According to PRBA they include:

- 49 CFR Subchapter C – U.S. Hazardous Materials Regulations.
- 49 CFR 173.185 – U.S. Lithium Battery Regulations.
- 49 CFR 172.102 – Special Provisions 130 and 340 applicable to dry cell batteries and nickel metal hydride batteries.
- 49 CFR 173.159, 173.159a – U.S. Lead Acid Battery Regulations.

2.4.5.3. Disposal

Disposal of the energy storage system's equipment is the final end-of-life decision. There are essentially three areas of focus here: second life (re-use) issues, recycling, and the disposal of waste to an appropriate final location.

Second life is an increasingly popular idea for trying to take advantage of the remaining usefulness of a battery by transitioning it from one application into another. Typically, this has referred to transferring lithium-ion cells from vehicles into stationary applications that do not require a demanding usage profile, thereby extending their usefulness and significantly increasing the cell's lifecycle value.

But challenges exist, stemming from a variety of application requirements. Chemical cells age differently, so if the priority is to reuse, the cells must be tested, sorted, and re-packaged into modules of like capability. Next, the second life application usage profile must match the capability of the remaining life in the cells, typically, a less strenuous usage profile. Finally, the cost of all of this handling, testing, and refurbishment must be made cost-effective. Regulatory approvals also pose a challenge. Many battery systems for vehicles conform to ASME standards, but systems that will be deployed in stationary applications require the systems ascribe to IEEE, UL, etc. standards.

Recycling has been part of the battery industry for many decades. The lead acid battery industry currently recycles approximately 98% of all lead batteries, which represents a significant resource stream for newly manufactured lead acid batteries. Recycling for lithium-ion batteries is an emerging opportunity driven both by the expected growing volume of "spent" lithium-ion batteries, and the

opportunity to reclaim some of the valuable metals found in those batteries. Recapturing the most valuable components of an energy storage system can impact the longevity of other energy storage technologies dramatically, such as the vanadium in the vanadium flow battery. Recycling, especially of lithium-ion cells, has garnered a significant level of interest by the industry as it looks toward a vast future array of “used” cells from both vehicles and stationary systems. Depending on the chemistry of the cell, different types of metals are the primary target of the recycling efforts. Since much of the different materials must undergo significant chemical transformation and processing prior to going into the cell, not all of the material is easily retrievable. Outside of the materials in a cell, however, the equipment that was part of the balance of a plant—housing, inverters, etc.—and is targeted for recycling, is much easier to process—especially where the focus is on metal recycling.

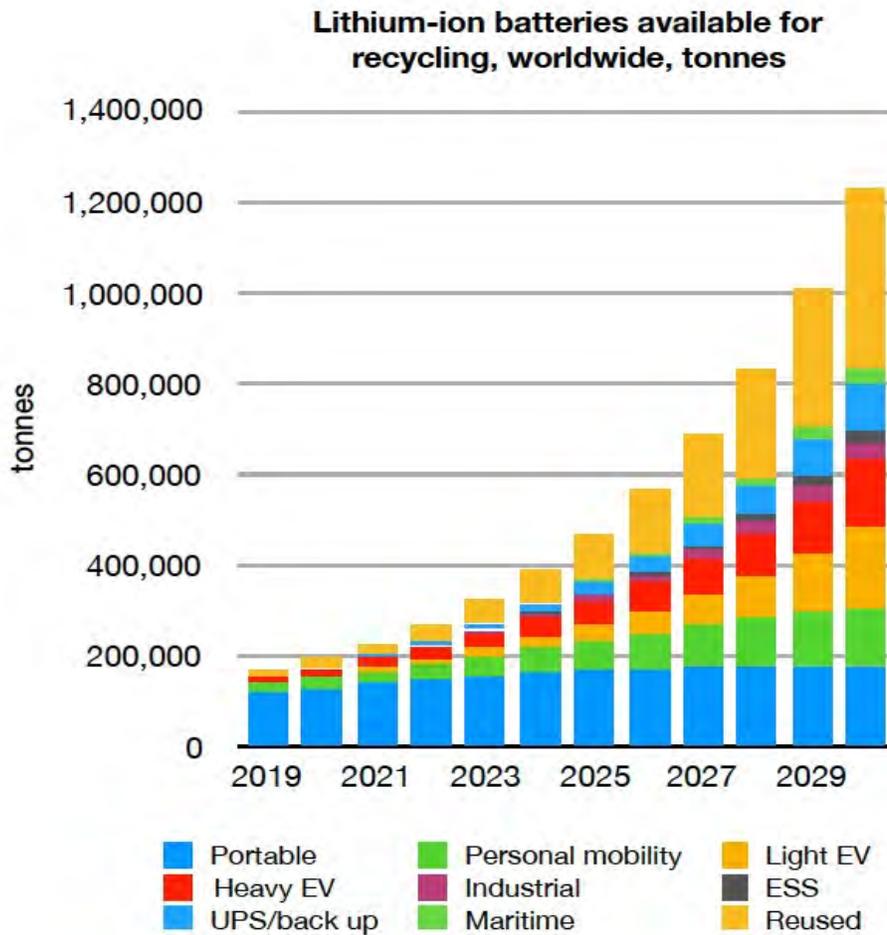


Figure 2-21. Recycling Tonnage

Source: Circular Energy Storage

Waste disposal represents an important component that must be addressed for the expanding battery industry — especially the lithium-ion segment. Although much of the material in a lithium-ion battery can technically be re-used, there may or may not be the economic justification for reuse

outside of a regulatory requirement. In addition, some parts of a lithium-ion battery may not be recyclable. Thus, some way to address these parts must be determined. Other types of energy storage technologies have their own waste disposal issues, and these too must be addressed. Disposal of materials remaining after the initial recycling effort must be done with proper handling methods, based on the type of material remaining. For some of the material, it may require disposal into a landfill capable of handling hazardous waste from chemical and industrial facilities. Some of the material could possibly be sent to municipal landfills. But only if it falls within the safety guidelines of that particular disposal site.

2.5. Project Valuation Models

The central tool for valuing an energy storage project is the project valuation model. Many still use simple Excel models to evaluate projects, but to capture the opportunities in the power market, it is increasingly required to utilize something with far greater granularity in time and manage multiple aspects of the hardware. For this reason, this report will focus on purpose-built software models. This software structures the project economic model so that variable aspects of operating the facility in a power market can be modeled to provide project developers and owners a better understanding of potential profitability and rank possible usage profiles. The development of economic models for energy storage project valuation has advanced greatly in the last few years. To take account of the complexity, these models need to take into account 3 key issues, technology, economics, and finance.

- First, the valuation models must have a sound basis in the technical design and performance of the energy storage technology. Most are designed for lithium ion, but variations between different vendors requires incorporating a number of different technical assumptions. If the models are able to support a variety of energy storage technologies, then the complexity increases.
- Secondly, based on the technical specifications of the equipment, the valuation model will determine the operating economics of the unit. Revenue opportunities are constructed from incorporating the various applications that the unit can perform. This required a clear understanding of the market rules and how one or more can be supported by the facility's performance capability. Costs will include both capital and operating, so a clear understanding of the dynamic impact on costs from varying the level of operation is key.
- Finally financing the project needs to take into account the cost of the available capital and what are the contractual requirements for it to be available. For instance, most lenders require that the operator maintain and operate the equipment under the OEM warranty. Other requirements include such rules as prohibiting 2 applications from being selected if their requirement for energy for the first precludes the use of the second application that same day.

A critical challenge for any energy storage valuation model is to provide visibility into the economic and operating assumptions as there are generally many more variables at play for these projects as compared to other power projects. Sensitivity analysis is thus helpful to incorporate into the modeling framework to highlight the degree of importance different inputs have into the modeling analysis. Because of the complexity inherent in modeling the economic performance of energy storage systems, it is sometimes best to view the modeling framework for an energy storage project as a series of layers to provide a clearer approach to the analysis. In general, there are three

components of project valuation modeling that are used to ascertain the project's value. Not all modeling packages use these steps or defines them in the same way.

The first layer is to optimize the choice of technologies for the desired usage profile. This provides the different capital and operating costs and different capabilities of the different technologies. Besides the modeling approach, specific covering the revenues, costs, and financing inputs for the economic analysis in the valuation model need to be addressed. Because of the different capital and operating characteristics of different energy storage technologies, it is important to ensure that the design requirement calculation be a separate module which will be re-run each time the usage profile is altered in a modeling run. This ensures that the focus is on optimizing the cost of supporting a customer's application requirement, not the best approach for any given system.

The core effort is to optimize the operation of a given energy storage technology and design to produce the most cost-effective operation. Here, the goal is to optimize the operations of the system for a set usage profile (application stack) under different market conditions through iterative analysis for varying conditions. The variables here would include the revenue streams which vary by market, scale, and duration, and the various tariff or charging costs of electricity. An expansion of this evaluation is to then extend the optimization of the analysis to the choice and ranking of applications.

The final effort is the optimization of the system design to support the chosen usage profile most economically. This would entail running a series of scenarios to determine the proper design incorporating different power and energy capabilities. This effort allows for a sensitivity analysis once the applications are set. A similar expansion of this evaluation would also require re-analyzing the different application stacks for the different system designs to obtain the relationship map of what designs work best for which applications (and then also evaluating the different regional economic inputs).

It should be noted that the level of sophistication in these models has grown significantly, and the expectation exists that the rate will continue for some time. Whereas solar and wind have a few key drivers for value generation (solar irradiance at a site, average winds speed, etc.) energy storage systems typically have many more critical factors. Many times, these factors are inter-related, and comprise a feed-back loop (use of system verses lifespan, etc.). Because of this heightened complexity, the assumptions and data feeds for the model are also critical. This is especially true where modeling complex value streams.

A growing number of energy storage valuation models have been developed by different groups of the last few years, and more are expected to emerge with all of the growing in sophistication. Although they all look to model the cost and behavior of an energy storage system operating in a particular market, care should be taken to focus on exactly what question the model is attempting to answer, and what approach the model is using. For instance, determining the "value" of a facility assumes a particular vantage point when summing the value stream—different players ascribe different values to different applications if the application is not one of the few that is a discretely defined market role. Therefore, it is critical when evaluating a valuation model for use to ensure that you are using the right one for your needs: what they are trying to calculate—revenue generation, or cost avoidance, etc.

2.5.1. QuEst – Sandia National Laboratories

Sandia National Laboratories has developed QuEst, an energy storage project simulation model to evaluate the economic impact of various market applications.⁸ The model is open source, allowing

users the freedom to add additional modules, or change the base code in order to tailor the model more closely to their needs. QuEST is designed to be used in system planning activities by running a variety of simulations to determine the maximum possible revenue from a specific system.

According to Sandia National Laboratories, the current application list includes:

- QuEST Data Manager — Manages acquisition of ISO market data, US utility rate data, commercial and residential load profiles, etc.
- QuEST Valuation — Estimates potential revenue generated by energy storage systems providing multiple services in the electricity markets of ISOs/RTOs
- QuEST BTM - Estimates the cost savings for time-of-use/net energy metering customers using behind-the-meter energy storage systems

The first analytical module of QuEST—QuEST Valuation—was focused on performing front of the meter project valuation analysis based on a variety of application inputs. For these projects, QuEST can perform analysis of the maximum revenue achievable from a project based on historical market data. It does this by evaluating and optimizing the application stack to maximize revenue based on the operational limitations for choosing different applications based on the remaining state of charge in the energy storage system for a specific historical dataset. The goal is to optimize the value stacking application strategy for a particular ISO for different systems, based on their power and energy rating. Data for QuEST is obtained from the different ISOs/RTOs market data, U.S. utility FERC forms, etc.

A follow-on analytical module—QuEST BTM—is focused on performing behind the meter project valuation analysis based on evaluating time of use and net-energy metering strategies. The QuEST model is designed to assist customers to evaluate reducing their time-of-use energy charges or demand charges through peak shaving. The model is able to evaluate both independent, and solar integrated supply in order to reduce the customer's monthly bill by time shifting. QuEST BTM uses simulated load profiles based on governmental database of a variety of commercial and residential buildings located in different geographical areas of the United States. It also incorporates data from U.S. utility rate structures to allow users to select the appropriate rate structure most pertinent to their project. Through simulating different configurations of the energy storage system (power / energy), QuEST BTM can help users determine the appropriate energy storage system for their particular needs.

2.5.2. Battery Storage Evaluation Tool – Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) has developed two models designed to identify the sizing and usage of energy storage systems in order to support the greater deployment of energy storage technologies.⁹ The two models are the Battery Storage Evaluation Tool, and the Optimal sizing Tool for Battery Storage. These tools are designed to be used by a variety of users supporting policy and utility planning, project developers, and customers to evaluate the cost effectiveness of energy storage at locations on the power grid.

The Battery Storage Evaluation Tool is a computer model that simulates the use of an energy storage system to support a variety of applications on a utility distribution system. It is designed to support utilities evaluating energy storage technologies in order to improve the reliability and flexibility of their power systems. The model simulates a complete year of operating an energy storage system to evaluate the use of the technology and provide a means to optimize both the design and control of the unit to maximize benefits based on local market rules and conditions. The

model uses a variety of battery system and market conditions to set the technical operating parameters of the iterative calculations done to arrive at the optimal solution.

The Optimal Sizing Tool evaluates energy storage deployments sited behind the meter at the consumer location. The tool was designed to address two key challenges of behind the meter energy storage deployment, its design and operation. The first challenge is to determine the economic optimization of a system’s design and sizing (power and energy) based on the technology’s capability and cost. The second challenge refers to the identifying the most cost-effective operation of the unit to provide cost of service reduction through demand charge reduction. The results of this analysis are designed to support the informed purchase of these systems by commercial and residential customers.



Figure 2-22. PNNL - Battery Storage Evaluation Tool

Source: PNNL

2.5.3. REopt™ – National Renewable Energy Laboratory

The National Renewable Energy Laboratory (NREL) developed the REopt model to evaluate the project economics of solar plus storage deployments in different regions of the United States.¹⁰ REopt is a decision support tool for optimizing energy systems in behind the meter situations such as commercial buildings, campuses, communities, and microgrids. REopt develops the optimal selection of system sizing and capability among a series of choices based on specific electrical and thermal loads required for the building. The pool of potential technologies includes a variety of distributed energy sources and incorporates both their economics and technical performance capabilities.

REopt’s economic analysis of the potential project includes a variety of value/revenue streams available for the behind the meter distributed resource deployment. The results show where solar and storage may be cost-effective in the near-term and long-term. Through this analysis, building

owners and their agents can identify the most economically optimal solution for distributed resource deployment to meet the owner’s needs.

To calculate the optimal design and operation of the chosen distributed energy resource for the desired demand load, REopt runs thousands of evaluations on the economic viability of the technology choice for the building type, climate zone, and utility tariff. Through the use of REopt, developers can better characterize the market potential for specific energy technologies under different policy choices and market conditions.

Technologies Evaluated 	Business as Usual 	Add PV 	Add PV and Battery Storage 
Additional PV Size	n/a	3 MW	3 MW
Battery Size	n/a	n/a	0.58 MW:3.2 MWh
Total Cost	n/a	\$5.6 million	\$7.8 million
Annual Energy Costs	\$487,000	\$269,000 (\$218,000 savings)	\$292,000 (\$195,000 savings)
Annual Demand Costs	\$679,000	\$652,000 (\$28,000 savings)	\$522,000 (\$157,000 savings)
Life Cycle Cost	\$29.0 million	\$27.1 million	\$25.6 million
Net Present Value	n/a	\$1.9 million	\$3.4 million

Figure 2-23. NREL - REopt

Source: NREL

2.5.4. System Advisor Model (SAM) – National Renewable Energy Laboratory

The System Advisor Model (SAM) was developed by the National Renewable Energy Laboratory (NREL) as a project-based performance and financial model to facilitate decision making for groups involved in the renewable energy industry.¹¹ Groups intended to benefit from the model include project managers and engineers, policy analysts, technology developers, and researchers. According to the SAM model website, the System Advisor Model “makes performance predictions and cost of energy estimates for grid-connected power projects based on installation and operating costs and system design parameters that you specify as inputs to the model.”

The System Advisory Model was originally developed by NREL in collaboration with Sandia National Laboratories (SNL) in 2005. The System Advisory Model evaluates the cost and performance of renewable energy projects that can be situated on either side of the meter. Specific design and operating parameters can be specified, including the impact of possible incentive structures. Different system configurations can be modeled to optimize electricity revenues. The System Advisor model is able to provide financial insight into a number of different projects, including behind the meter renewable projects, renewable energy projects structured with a PPA, and third-party ownership of a project with a PPA or lease arrangement.

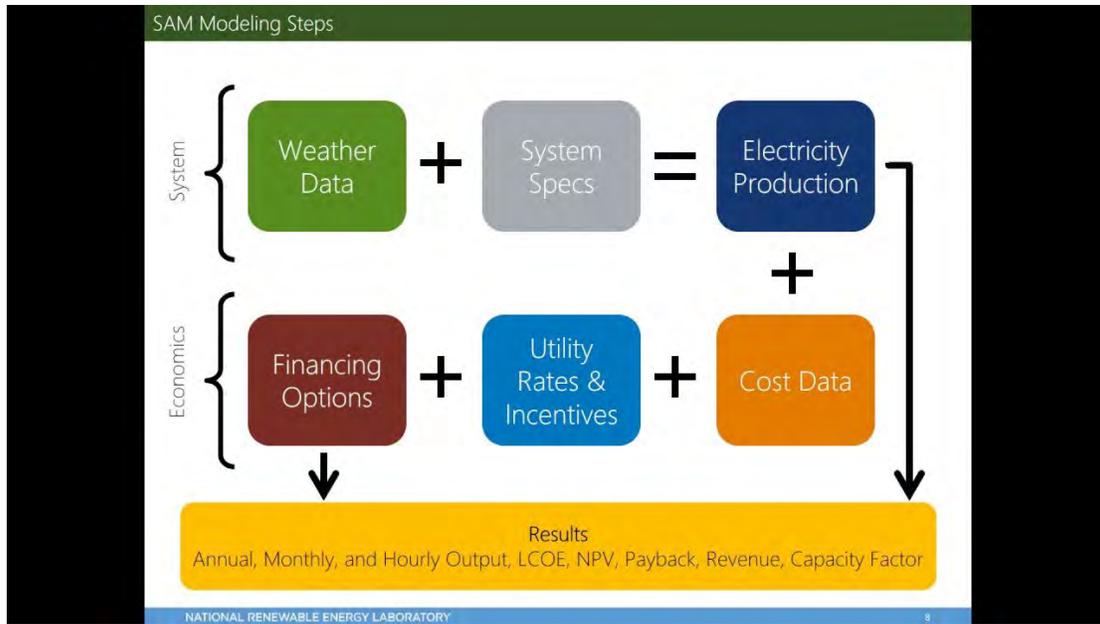


Figure 2-24. NREL's System Advisor Model (SAM)

Source: NREL

The System Advisory Model is not intended for stand-alone storage, but rather incorporates energy storage technologies as a component of a solar storage system. Energy storage technologies incorporated for evaluation include lithium ion, lead acid, and flow batteries. According to the System Advisor Model website, a number of renewable energy systems can be evaluated, including:

- Photovoltaic systems, from small residential rooftop to large utility-scale systems
- Battery storage with Lithium ion, lead acid, or flow batteries
- Concentrating Solar Power systems for electric power generation, including parabolic trough, power tower, and linear Fresnel
- Industrial process heat from parabolic trough and linear Fresnel systems
- Wind power, from individual turbines to large wind farms
- Solar water heating
- Geothermal power generation
- Biomass combustion for power generation
- High concentration photovoltaic systems

2.5.5. **HOMER Energy**

The HOMER (Hybrid Optimization Model for Multiple Energy Resources) model evaluates distributed generation and microgrids and is globally accepted as a standard in modeling and optimization software for microgrids.¹² The software assists in design and optimization for

microgrid systems with a variety of power generation and load profiles ranging in size from village power to grid connected microgrids.

Originally developed by the National Renewable Energy Laboratory (NREL) in 2000, the HOMER (Hybrid Optimization Model for Multiple Energy Resources) model software was licensed to Homer Energy, LLC in 2009 to further promote its use and widespread adoption. Subsequently in December of 2019, UL purchased the firm to expand its services across the renewable energy value chain.

Microgrid Value Proposition

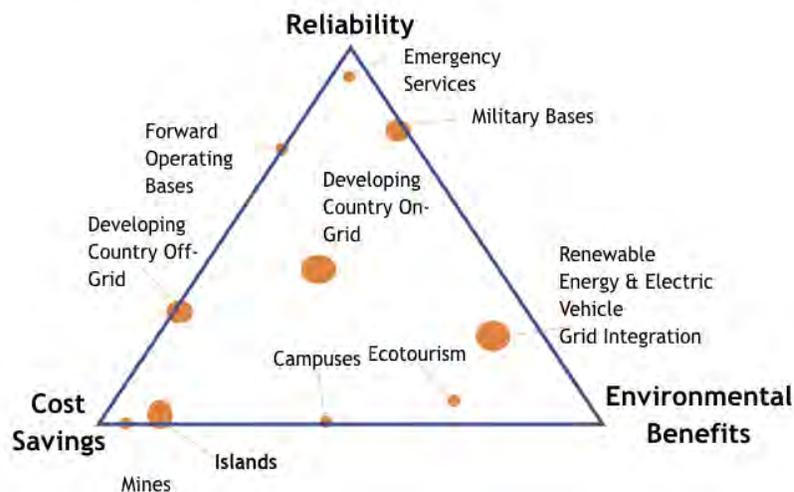


Figure 2-25. Homer Energy – Microgrid Value Proposition

Source: UL

The HOMER Pro software is the core software offering for optimizing microgrids and distributed energy resources, and is comprised of three components:

- **Simulation:** HOMER will simulate all possible combinations of the equipment selected and simulates the operation of these different setups for an entire year.
- **Optimization:** The model can sort the results of all of the different system combination choices in a single run to identify the least-cost options for the Microgrid.
- **Sensitivity Analysis:** HOMER can evaluate the impact of certain variables or options to showcase the impact of variables in and out of your control have on the final, low-cost design.

A recent addition to the suite is Homer Grid, used to support behind the meter customers model their energy usage and evaluated energy management strategies to reduce their service costs. This includes:

- Minimize demand charges,
- Model tariffs and time-of-use rates, and
- Take advantage of utility incentive programs.

Homer Energy modeling platform incorporates energy storage assets into the microgrid optimization software through a separate module that simulates the technical performance characteristics of a number of different energy storage technologies including rate dependent losses, changes in capacity with temperature, variable depth-of-discharge for cycle life, and increased degradation rate at higher temperatures. Utilizing this module, the user can develop a hybrid microgrid to evaluate the inclusion of an energy storage asset into a microgrid environment under different usage patterns.

2.5.6. EPRI - Storage Value Estimation Tool (StorageVET®)

The Electric Power Research Institute (EPRI) has developed the Storage Value Estimation Tool (StorageVET) 2.0 as a free, open source tool for the development of energy storage project development.¹³ StorageVET 2.0 is a publicly available energy storage project simulation tool which builds on EPRI's previous efforts, the Energy Storage Valuation Tool, and the Storage Valuation Estimation Tool (StorageVET) 1.0—which was developed with initial support from the California Energy Commission for the California energy storage market. Storage VET 2.0 has been expanded to provide support for utilities, regulators, and vendors for projects in all regions in the U.S. The model is supported with the input from EPRI's open technical forum, the Energy Storage Integration Council (ESIC).

StorageVET®

Storage Value Estimation Tool: www.storagevet.com

- Web-hosted tool, free to the public
- Project cost-benefit analysis
- Time-series constraints and dispatch optimization simulation
- Multi-services optimization and stacked services
- Customizable for location, technology, sizing, use cases
- Made possible through funding support from the California Energy Commission (CEC)



Figure 2-26. EPRI - StorageVET

Source: EPRI

StorageVET 2.0 is a valuation model for the analysis of energy storage technologies alone or paired with other power systems for a cost-benefit analysis of the project. The model can be used as a standalone simulator or integrated with existing power system models. StorageVET 2.0 develops an estimation of the costs and revenue streams for an energy storage project through evaluating possible grid products and services available, with input based on the energy storage technology choice, system scale (power/energy), and specific location deployment for both front of the meter and behind the meter applications utilizing a stacked services approach. The model can run the analysis at hourly or sub-hourly, depending on the application and data availability.

The system can assist in both location and value stacking optimization for project usage strategy and valuation. For instance, the scenario analysis features assist in determining the best site and rating (power / energy) for a specific market's rules and revenue streams. By comparing the perfect foresight dispatch results versus real world data and dispatch, the system owners can learn where additional value can be obtained during operation. Through this analysis, StorageVET 2.0 helps project developers identify high value locations for energy storage deployment.

The fundamental use of StorageVET 2.0 is to understand energy storage project economics and operations. The tool is adaptable to many settings, including research, policy or regulatory analysis, commercial decisions (by a range of actors), infrastructure planning and research. StorageVET 2.0 incorporates realistic financial pro forma outputs which support analysis of project finance. With respect to benefits, it can calculate optimal market revenues or avoided costs associated with alternative infrastructure or resources. StorageVET 2.0 can analyze many variations on storage value streams across a range of applications.

2.5.7. Lazard Levelized Cost of Storage (LCOS)

The investment bank Lazard produces an annual Levelized Cost of Storage (LCOS) report based on a general power project proforma model to provide a basis for comparing projects from differing energy storage technologies for specific usage profiles. The analysis is based on a survey of observed costs and general project financial assumptions.¹⁴

The report provides an estimate of what a PPA price needs to be in order to provide for a specified return on investment for the project. This approach is useful in project feasibility to determine what energy storage technology would provide the most competitive project, given the same starting market conditions and project return expectations. For this reason, the use cases are as clearly defined as possible so the technical requirements for the different energy storage technologies can be used to size the different systems accordingly in order to support the specified use case. The downside is that the approach does not allow for optimization of operating strategy or performance characteristics. It provides a snapshot as to the competitiveness of the different technologies, and thus must hold varying the capabilities of the different systems constant in order to provide the static snapshot for competition.

The report also provides a set of results on what the current conditions facing project developers now. This analysis uses the inputs of the LCOS study and provide an illustrative snapshot of an expected financial project return utilizing the available value stacking of available applications in different areas of the United States.

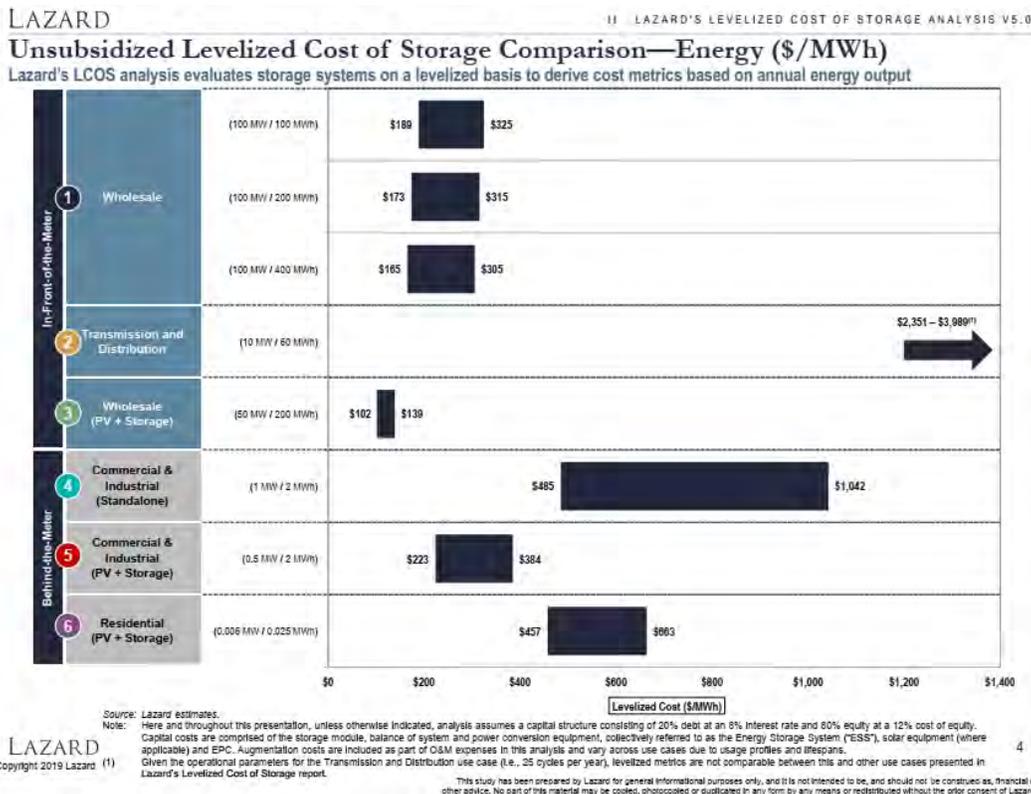


Figure 2-27. Lazard Levelized Cost of Storage (LCOS)

Source: Lazard

2.5.8. Fractal Model X™

Fractal Energy Storage Consultants have developed Fractal Model X to support energy storage project development.¹⁵ The firm provides project finance models for storage and solar/storage projects for utilities, developers, and investors.

Their energy storage model, Fractal Model X™, simulated an energy storage system and allows the user to evaluate both technical and financial factors to evaluate the project. Technical factors included such issues as design, configuration by OEM design, and a slew of technical parameter that affect operation such as state of charge (SOC), round trip efficiency (RTE), degradation, and augmentation.

Financial analysis on the projects includes the ability to evaluate the revenue from operation in formal markets (ISO/RTOs) or bilateral contracts, stacking application or custom application usage profile, and the simulation of performance under the varying technical modeling options. In this way, the model evaluates the total cost of ownership and IRR for RFP bidding and investment returns.

2.5.9. Ascend Analytics - BatterySIMM™

Ascend Analytics has developed BatterySIMM to help developers and investors value energy storage projects in the wholesale power market. Ascend Analytics develops advanced simulation models that capture the full range of portfolio exposures and options.¹⁶

The model is designed to optimize battery charge and discharge strategy across different power and ancillary service markets incorporating and modeling a variety of battery performance attributes over time. The evaluation will take into account time periods from 1 month to 20 years, optimize revenue given both physical characteristics and ISO market rules, and evaluate either energy storage or renewables + energy storage options. The model is designed to help determine the optimal location, project size, and revenue options in order to assist with different RFP bidding strategies.

2.5.10. E3 - RESTORE

Energy and Environmental Economists (E3) has developed the valuation model RESTORE to ascertain the costs and benefits of energy storage.¹⁷ The model is designed to optimize project valuation, maximize multiple revenue streams, minimize net costs, incorporating specific battery technology and market constraints. E3 is a consulting firm supporting utilities, regulators, policy makers, developers, and investors make the strategic decisions surrounding new public policies, technological advances, and customer purchasing.

The RESTORE model is designed to optimizing the dispatch of energy storage systems in the wholesale (contract and merchant sales), utility support (T&D Deferment and avoided costs), and behind the meter applications (minimize customer costs). E3 developed the capability to assess multiple technologies, including, Li-ion flow batteries, compressed-air energy storage, and pumped hydro for utilities and commercial customers in the RESTORE model. For energy storage systems active in front of the meter operation, RESTORE can provide bidding strategies for project developers. For energy storage systems active in behind the meter operation, RESTORE incorporates E3’s expertise in distributed energy resource planning to capture tariff impacts

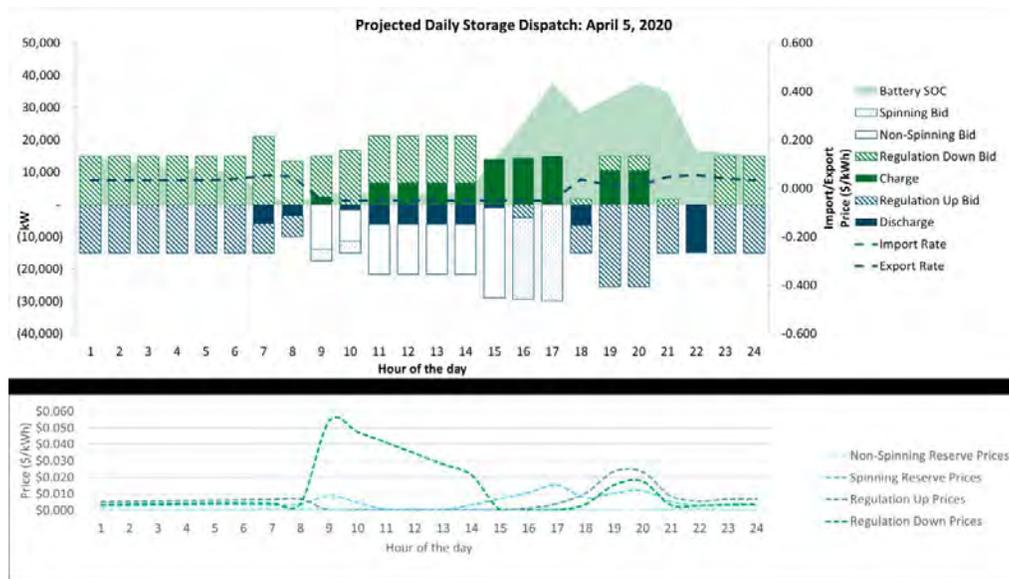


Figure 2-28. E3 - RESTORE

Source: E3

2.5.11. **Energy toolbase**

Energy toolbase is a valuation tool that provides cost-analysis for BTM peak demand shaving with energy storage systems, coupled with solar PV or stand alone.¹⁸ The software is designed to evaluate residential and commercial market systems.

Energy toolbase is designed to calculate the existing utility bill as a baseline, and then evaluate a number of different options for potential savings. The software utilizes a large library of utility rates to develop the avoided costs estimate and is compatible with a number of solar PV production models to estimate the possible solar production. To support the significant California market, the software can evaluate California NEM opportunity scenarios on the economics of exporting power back to the grid under a variety of scenarios.

Energy toolbase is designed to develop the optimal system size based on the dollar savings. This analysis will incorporate the new rate structure after installation, and can evaluate a solar/storage system, or simply a stand-alone storage. The software is also able to arrive at the optimal economic benefit by running a series of scenario analyses based on equipment choice, pricing, financing terms, etc.

2.6. **Risk Management**

Most groups involved with project development usually agree that energy storage projects are not necessarily different than a typical power industry project finance transaction, especially with regards to risk allocation. The financing for the project will not close until the identified risks have been addressed, and safeguards have been put in place for the unidentified ones. However, energy storage project development does bring with it a greater number of moving parts to the projects, so developers must consider storage's unique technology, policy and regulatory mandates, and market issues—as they exist now, and as the market continues to evolve.

Three areas have important impacts on risk management strategies in the energy storage industry: Insurance, liquidated damages, and codes and standards. Insurance and professional service firms put forth significant effort to design risk management strategies that expand opportunities at a lower cost through leveraging the financial assets of the insurance firms. Groups engaged in codes and standards development ensure that through devising clear guidelines for equipment, operation, technical and market guidelines, developers, investors, and customers will have a basis for quality and operability that will aide those looking to minimize the project risks.

2.6.1. **Insurance**

Insurance is typically thought of as a means for protecting against financial loss, but these products can also be used to enhance the reliability and thus value of a variable revenue stream.¹⁹ Insurance companies reduce their risk through a detailed understanding of the technology, its operation, and its interaction with the power market. Insurance policies are increasingly important to the energy storage lenders and, as the industry scales in both number and size of projects. The improvement of coverage for general insurance for energy storage projects, project continuation strategies, and performance insurance to augment existing product warranties for lenders. Many industry experts believe the underlying requirements for improved insurance will positively impact energy storage by reducing risk, limiting liability, and helping with financing by removing financial liabilities from weak balance sheets.

As the industry matures through a growing body of project development and operational history, the cost of insurance should continue to decline as additional performance data and loss experience help refine the loss potential evaluation of these projects. Lacking sufficient data in emerging industries like energy storage, insurance firms have long been a driver in promoting better testing and standards development (in both equipment, installation, and operation) in order to reduce insured loss through performance degradation or failure. Better information provides these firms with the ability to determine the actual risk premium cost for a variety of project development choices. As the industry gains more experience, re-insurers (insurance for insurance firms) will get involved, reducing further the cost for insurance coverage.

Of most interest to many lenders is the credit enhancement products focusing on improving the credit worthiness of the financing. This can come in a number of ways, from enhancing the security of the revenue streams of the application if the contract is variable, as there is still not any interest in providing a revenue guarantee for merchant only roles. Much work has accomplished on improving the credit worthiness of un-rated customer payments as revenues, allowing for some groups to begin developing securitization of payment for solar/storage projects where the storage asset is not the only actor. With experience, this too may change to allow support for storage only assets acting in the market. Finally, some insurance firms also provide support for equipment by providing an insurance support for operation of the equipment, enhancing the OEM warranty for the system.

2.6.2. *Liquidated Damages*

Liquidated damages are clauses in the project contract that estimates generally difficult to define losses to one of the parties. These clauses provide for the payment of an agreed upon amount to address the losses to one of the parties if the other party is found in breach of contract. These are common in the power sector to address such issues such as losses stemming from the termination of a PPA, scheduling delays, or equipment damages. The goal is to impose a penalty to address to loss to one of the parties, but not price the damages high enough to make them onerous and material impact. Items not to be covered would be the loss of revenue for potential activity.

2.6.3. *Codes & Standards*

Codes and Standards impact both the cost and revenue side of the valuation equation. For costs, standards cover how energy storage systems will be designed, equipment selection, and manufactured. Ensuring that systems comply with the relevant Standards can be expensive for OEMS, but if they do not build their products to the required Standards, they run the risk of not being able to sell the product at all. When concerning revenue, standards also cover how energy storage systems are integrated into the power system, operated, and disposed of. Failure to comply with existing product standards and local Codes and regulations can cause delay in operation, and possibly impacting the operational range of the facility. Therefore, ensuring that the system is in compliance with the relevant codes and standards, but also maintaining the proper documentation of this compliance, is of critical importance to the developer, and subsequent operator of the facility. Areas where Codes & Standards impact the valuation of energy storage projects include Safety, Reliability & Performance, and Business Practices.

2.6.3.1. *Safety*

The U.S. Department of Energy has been a key driver for safety standards development in the energy storage market, coordinating ongoing work by manufacturers and SDO groups. The Safety development effort continues to be development and coordinated through the Energy Storage (ES)

Safety Collaborative. Through Sandia National Laboratories, the U.S. Government has published a number of safety related publications, with *Energy Storage System Guide for Compliance with Safety Codes and Standards*²⁰ being the one of the most important collection. As the report states, “This Compliance Guide (CG) is intended to help address the acceptability of the design and construction of stationary ESSs, their component parts and the siting, installation, commissioning, operations, maintenance, and repair/renovation of ESS within the built environment.” Because of the continuing change in the environment, a periodic update is provided, with the March 2019 publication of the Codes & Standards Update from the Energy Storage Safety Collaborative being the most current as of the publication date of this report.

2.6.3.2. Reliability & Performance

The U.S. Department of Energy has recently initiated a program to develop reliability and performance standards for energy storage industry. There is currently only a limited number of published standards exclusively on reliability & performance of energy storage systems. Because the operation of energy storage systems typically interacts with a number of existing power grid operations, much of the existing standards structure is based on standards governing closely related equipment or operational processes. As reliability and performance is critical to improving performance-based contracting for energy storage systems, there is a significant amount of effort being focused on measuring and expressing energy storage system performance.

A number of governmental and industry trade groups have supported the development of standards in this area, including EPRI-ESIC Working Group to develop technical references on application metrics. The Energy Storage Association published a White Paper, *Updating Distribution Interconnection Procedures to Incorporate Energy Storage*²¹ as a guide to policymakers looking to update distribution interconnection rules to better incorporate energy storage technology. These and other efforts have provided fundamental support towards defining formal standards concerning reliability and performance of energy storage systems.

A critical development for reliability and performance standards is the update of IEEE-1547 which is the Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces. Specifically, the envisioned IEEE 1547.9 Guide for ESS interconnection will provide guidance for distribution level equipment. Supporting the Working Group for 1547.9 is a critical path for the US Department of Energy.

2.6.3.3. Business Practice

The third area of where standards development will support better project valuation is business practices. Model business practices promote a streamlined transactional process in a mature commercial market. The energy storage industry has been held back in developing many commercial market roles because of the inability for the governing bodies of these different markets to easily incorporate energy storage’s flexibility into existing market rules. The development of business practices that address the ability of energy storage systems capability will support the integration of energy storage into existing market roles with more secure revenue streams available to them.

An example of a Standards Development Organization for developing business practices is the North American Energy Standards Board (NAESB). NAESB’s standards and model business practices support both the wholesale market—by providing documentation for the Federal Energy Regulatory Commission (FERC) orders—and the retail market by providing documentation for the National Association of Regulatory Utility Commissioners (NARUC) among other groups. Much of NAESB’s business practice standards development are focused on streamlining transaction

processes. This includes electronic data interchange in support of a variety of market transactions, including billing and payments and electronic retail billing transactions. Such standards improve transparency, accountability, and efficiency and provide greater reliability, lower costs, and greater flexibility of the market transactions—ensuring a more stable revenue stream for the different application, leading to more reliable products and services.

3. PORTFOLIO VALUATION

Developing a portfolio of assets can be seen as the inevitable evolution for energy storage project developers and private equity investors who are interested in leveraging their knowledge of the technology, expertise in project development, and access to capital. Having completed a few projects, it is natural to continue with the effort to leverage these more intangible capabilities into ownership and operation of valuable assets. This also dovetails nicely with the need of institutional investors to find investment opportunities for larger sums of capital, while lowering their investment risk. These portfolios—at least the successful ones—should not be seen as simply a larger collection of assets, but a planned portfolio to generate higher returns on the investment.

Portfolio theory follows a simple concept, a group of like assets can provide more stable, and thus a higher risk adjusted return than a single, large individual one. Portfolio theory comes from the investment industry, but is applicable to assets in the power sector, especially when some of the generating resources follow different patterns. This theory thus plays a component of least cost planning strategies for integrated resource planning.

Portfolio theory has proven to be very applicable to renewable assets as their resource base is typically highly variable from one location to the next. This also provides insights into how other factors impact the development of assets. Although New Mexico and Arizona have better solar resources than California, it was the regulatory support and higher power prices in the later promising greater returns which drove many developers to that State initially.

Developing portfolios of energy storage-based assets is an obviously emerging trend for the industry. To undertake this strategy successfully, developers need to leverage important lessons learned from the renewable sector which has developed advanced asset management and operational strategies for these renewable project. The development of energy management software is seen as a critical development due to the complexity of operating energy storage systems. Other strategies for risk management are also important to reduce potential areas of loss.

3.1. Lessons Learned in Other Markets

Successful portfolio development and operation in the energy storage market will rely on the existing procedures and specifications of portfolio evaluation in other power industry markets. As the energy storage industry matures, the experience in how individual project design and operation in these other markets will help the growth of successful portfolios of energy storage ones.

3.1.1. *Portfolio Management*

The growth of power project portfolio assets has spawned the development of portfolio management tools and strategies to support and drive the investment value of the assets. A well-thought out strategy is important. These power generation project assets are complex by themselves and coupled together require an oversight to provide support for the management's goals. As fleets grow in size and complexity, an oversight approach is necessary to both ensure continues successful operation, but also to content with any potential negative impacts. Whatever the basis of generation, these assets have high capital costs, operate with sometimes complex cost and revenue schedules, leverage a variety of financial and tax details, and must contend with multiple investors and lenders over their entire operating lifetimes. Therefore, it is critical for investors to proactively manage each site's operational, financial, and ESG metrics as granularly as possible.

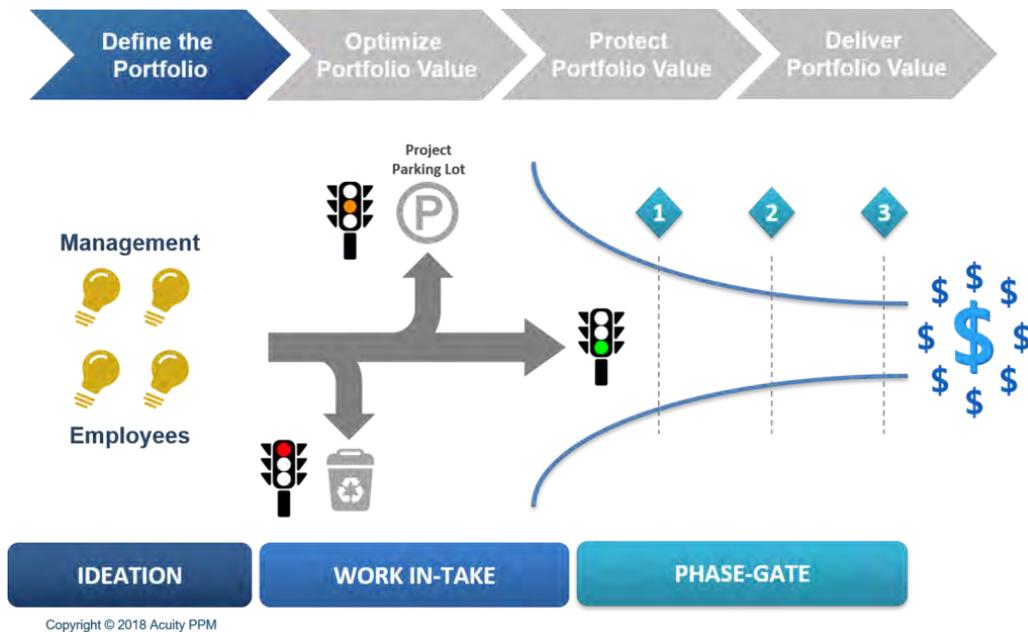


Figure 3-1. Project Portfolio Process

Source: Acuity PPM

- New Projects:** In addition to evaluating new projects on their own merit (unit valuation), it is important to evaluate potential new projects as they impact the existing portfolio. Depending on the location, scale and technology choice, new projects can leverage the existing investment and capabilities of the portfolio. Once added, the new project could also provide additional market strategy benefits.
- Asset Management:** Owning and managing a fleet of assets requires not just the operational market strategy software suites (described in the next section) but also a strategy for managing the operation costs. From the portfolio owner’s perspective, this means not just lowering current costs (monitoring, O&M, warranty, etc.) as much as possible in the short term, but minimizing these costs in the long-term—over not just the life of the project, but of the portfolio. Assuring higher availability relies on the equipment to be in good working order, so the value generation capacity of the assets in the portfolio is directly tied to the investment in operation management.
- Portfolio Monitoring:** In addition to the operational management of the portfolio, the portfolio managers also need to monitor the relative health and competitiveness of the portfolio in the market. This is critical as the goal of building and maintaining the portfolio is to generate value which either produces returns from operations if maintain ownership or positioning the portfolio for a sale. Issues that should be taken into account for this evaluation including the impact on the portfolio by market forces (pricing, regulatory), new technology entrance into the market, and the competitive positioning of the portfolio with regards to competing portfolios.
- Deal Management:** A portfolio is not just a group of assets, but a collect of strategic investments where the hope is the ever mythical “one plus one equals three.” For this reason, in addition to the new projects being built by the developer / IPP group managing

the portfolio, strategic changes will be expected where one or more projects may be bought or sold to optimize the strategy and hopeful return of the portfolio directors. Currently, the amount of operational experience and wide range in technology and unknown longevity has curtailed such activity. However, as the energy storage industry continues to expand and mature, the value of projects at different stages of life and in different areas of the country will begin to exhibit variation in value from the simplistic slow decline. Only after sufficient information and analysis has been collected will this stage of development commence, but once it does, it will add to the complexity of valuing energy storage systems in a portfolio.

- **Investor Management:** Investors in the project portfolio must be kept apprised of their investments. Investors in the portfolio will have a variety of needs for updates, especially for their own investors to whom they have to report. Providing updates for investors as many will have like-investments, may be a source of information, resources, and opportunities for the operators of the portfolio.
- **ESG Management:** The growth of SRI/ESG (Socially Responsible Investing / Environment, Social Justice, Corporate Governance) has become a significant theme in the investment community, and all development groups looking to develop capital assets into a portfolio for investor's capital should strongly consider how their activity is viewed through this lens. This aspect of investing has not had a significant impact on energy storage projects to date, but as it is becoming a mainstream component of all power industry investing, should be assumed that it will play into the development at some point in the near term.

3.1.2. *Thermal Power*

Thermal power plants have been the basis of multi-technology power project portfolios for decades, and thus can provide a great deal of insight for the developers of energy storage projects, especially if they intend on taking advantage of more than one energy storage technologies.

- **Technology Mix:** Existing portfolios of power generation assets have grown to encompass a number of different technologies. This typically came about earlier from coal-based groups adding natural gas, or natural gas units adding wind and solar asset. This experience has provided most of the power asset portfolio operators with the comfort of maintaining multiple technologies in their portfolio, including differing operating and support strategies.
- **Policy Change:** Thermal power generation facilities have a significant lifespan and have lived through a variety of policy changes that impact their industry. Emission limitations have been some of the most significant, requiring a series of capital equipment and operating cost additions. The policy changes also resulted in operating strategy changes to adjust to the new economics of the market.
- **Market Impact:** Thermal power facilities have long had supporting industries that have significant pricing impacts. For instance, the coal industry has long relied on the rail industry to provide coal resources for power plants. This impacts the price, but also the availability of the resource. The low-sulfur coal in the Powder River Basin was not able to be transported to all of the interested markets until rail capacity was expanded. Natural gas also had limitations due to pipeline capacity and location. Some project development strategies even relied on shutting down older power plants so a newer one could be built to take advantage of the natural gas reservations on the pipeline.

- Regional Impacts** Power facilities face a variety of challenges based on the region where they operate, typically based on resource differences. For instance, the Southwest has typically a lower cost of generation for solar due, whereas the Pacific Northwest has abundant hydropower. These impact the clearing price for electricity, and hence value of the assets based on the same technology standard.
- Coordinated Dispatch:** As the development of multi-fuel technology portfolios continued, strategies were proposed, and sometimes engaged to coordinate the dispatch between fossil and renewable energy facilities. Some if this was in support of utility integrated resource planning, while other strategies have been for market activity at the ISO level.
- Hybrid Power Production:** Combining multiple technologies to provide a coordinated service is one of the first areas were energy storage is actively coordinated with other assets of a portfolio. Most instances have been with co-located assets with renewable assets such as solar and wind, but an early deployment of storage by AES Energy Storage in Chile (AES Energy Storage Angamos Battery Energy Storage System) was coordinated with a thermal facility. This deployment allowed the storage to provide required grid services for the transmission system so the fossil facility could generate increased revenue.



Figure 4 Assessment of relative benefit/impact of coal, coal with CCS, natural gas, nuclear, hydro, wind, biomass, geothermal and solar photovoltaic electricity generating technologies (EPRI, 2012)

Figure 3-2. Thermal Power Portfolio Evaluation

Source: EPRI

3.1.3. Renewable Power

Renewable power portfolios have risen over the last decade to significant as those projects grow to many multiple hundreds of Megawatts, and the number of projects being completed and incorporated into the portfolios grows apace. Because of the variability of the resource—wind and solar—individual projects always have some degree of variability in generation. This has been mitigated sometimes through overbuilding the generating resource, so each site increases the minimum output. Portfolios of these projects avoid the pitfall that individual projects may perform poorly on a given day or part of a day – other projects in the portfolio do better, balancing out the overall performance. Investors have shown a preference for these project portfolios as they are able to provide a more reliable overall return, reducing the risk of their investment.

Beyond the overall strategy, specific issues have also been proven out that impact the performance of the portfolio. For instance, performance of the wind farm will rely on the quality of the resource data; not just the windiness of the site verses that found in the typical resource base, but the periodicity of the resource, such as the daily, season, annual, and multi-annual cycles for each location. Modeling with this data can also incorporate some unintended bias as valuation software packages approach the challenge in a slightly different manner, impacting some systematic bias in the estimation of the potential value for the project. Wind turbine technology also impacts performance. For instance, choosing to standardize on one OEM or model for all locations, or purchasing system from different vendors based on the relative strength of an OEM’s technology in one market over the other.

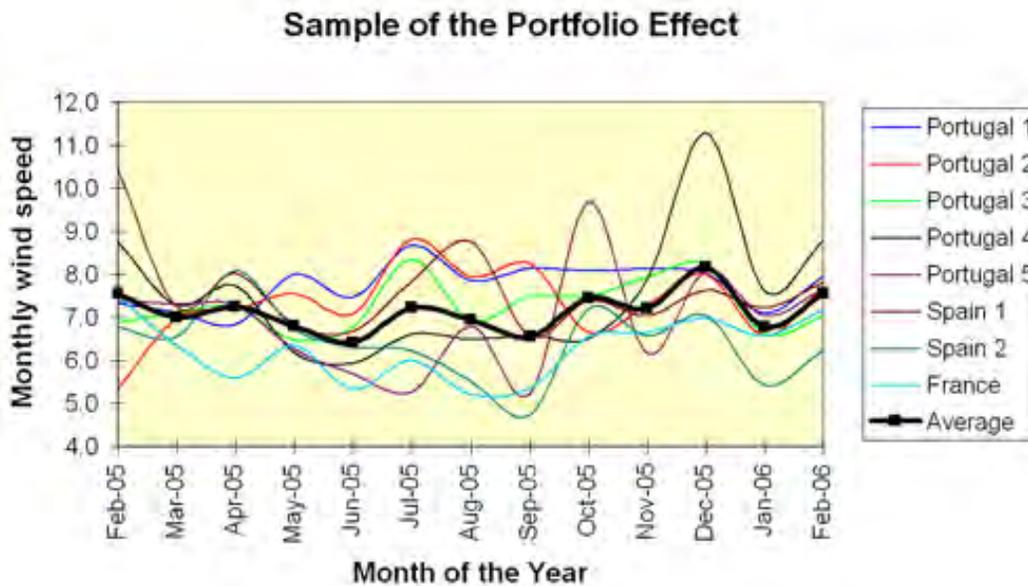


Figure 3-3. Wind Projects & Portfolio Impact

Source: Wind Energy, The Facts

3.2. Energy Storage

In this section we describe four general market strategies for energy storage portfolio investment and operation. Due to the nascent state of the energy storage market, these are all undoubtedly incorrect, but stand as a ready framework to describe how portfolios of energy storage assets can be

positioned. These business models include FTM Operation, FTM Asset Management, BTM Operation, and BTM Asset Management.

These four business strategies are primarily focused on the energy storage assets and related strategy. Many current business strategies incorporate some type of hybrid power generation. This other strategies will not be covered directly here, as they rely upon those other markets for the majority of the value generation and strategy. However, because of the utilization of energy storage assets, these other market strategies can leverage some of the framework analysis describe here.

It should also be noted that different groups can develop strategies that would incorporate components of different groups depending on the conditions for the proposed facility, access to capital, and access to customers.

3.2.1. *FTM Operation*

The first market strategy is termed front of the meter operations. This operation is most analogous to the traditional independent power producers that own a variety of generating asset and operation them for the greatest return on those assets. These projects are individually designed to provide a variety of products and services, based on the region. For example, some facilities are the well-known stand-alone frequency regulation units in the PJM Interconnection region. Others provide products and services to utilities or ancillary services for utilities. These groups will of course look for contracted revenue, but there is increasingly an agreement that some portion of the capability of the unit will be run in a merchant role, requiring some significant access to or investment in trading operations in order to maximize the value of the unit's capabilities. An area of expected growth will include those energy storage facilities co-located with large renewable power generation facilities. These last types are included here is this business strategy if they provide additional market services in addition to supporting the renewable energy facility, such as the AES Laurel Mountain facility.

This market strategy is seen to work best in formal markets where there is the ability to contract for a variety of services for different customer groups. This approach allows for sales through the local RTO, the incumbent utility, and potentially a bilateral contract with a 3rd party organization. A number of groups have begun to develop portfolios of energy storage assets following this market strategy. Leveraging experience from other power sector markets, but in renewable generation, but also thermal generation and utility operation. These groups are looking to take advantage of opportunities in the wholesale power market where the price visibility allows for financeable contracts to be obtained. As experience with storage continues, some groups are looking to incorporate storage in strategies to take advantage of transmission market opportunities as well.

3.2.2. *FTM Asset Management*

The second market strategy is termed front of the meter asset management. This strategy operates in the same wholesale markets as the FTM Operation strategy, but this strategy approaches the operation of energy storage assets as service to the utility, or other entity. This approach can also support a number of ownership models, with the portfolios either being owned by the operator and selling a service, or the asset being owned by a 3rd party (or even the customer) and the systems being operated as a service. Therefore, this strategy relies on obtaining contract and operating the facility for the client, with no focus on being active in the wholesale power market outside of the contract with the primary contract.

Because this strategy relies on the operating contract with the customer, this market strategy can be located in any area of the country. However, if the client is a utility, the deployment of the system can have some significant advantages. For instance, the utility may already have a site the project can use, making the contracting and siting effort significantly easier. To date, there have not been entire portfolios developed to explore this strategy, but individual project activity has shown interest towards this approach.

3.2.3. *BTM Operation*

The third market strategy is termed behind the meter operations. This strategy is best exemplified as the energy storage as a service offerings that have become prevalent in the commercial and industrial market. These projects have been primarily designed to provide cost of service reduction for customer's electricity bills. These are increasingly many times connected to solar arrays, leveraging this on-site resource to further extend cost reduction opportunities. As these systems have been deployed and proven their capability, the entire commercial energy management sphered has continued to increase in complexity, both from additional equipment such as on-site EV charging stations, and more advanced building management systems. The companies providing BTM energy storage systems have responded by expanding the software capabilities of their system to support additional cost savings—and revenue generation—capabilities for customers. Capital providers have supported this strategy by providing credit facilities for the firms to offer better and more flexible deployment opportunities, increasing the number and type of potential customers.

This market strategy is seen to work best where commercial and industrial electricity tariff structures have seen increasing demand charges and a growing disparity of on and off-peak power pricing. This approach benefits from having potential customers experiencing increasing electricity cost of service for many years. Even though they may have already incorporated a number of energy efficiency and on-site PV systems to reduce their cost of service, BTM energy storage assets hold out the potential to further reduce their electricity costs. If these customers take advantage of the energy storage as a service offering, they have the opportunity of contracting for their electricity costs, removing the variability in the costs of service to either a flat or a known cost escalation that can be securely budgeted. The growth of this market has allowed these providers to continue to scale their offerings, creating national providers for commercial and development customers. The deployed assets of these providers have already received interest from institutional investors looking to buy portfolios of contracts from the providers. This trend is expected to continue and will be an important component of the evolving “Grid Edge” market strategy in the electric power industry both in the U.S. and globally.

3.2.4. *BTM Asset Management*

The fourth market strategy is termed behind the meter asset management. This strategy is best exemplified by some of the residential energy storage providers. Residential customers are interested in the capabilities that energy storage promise—ability to time-shift self-generated PV energy, EV charge management, reserve power for emergencies, and enhanced power quality. These applications are easily handled by the software provided by the system, so there is no need for the customer to be engaged on operating the unit at a very involved level. Though a contract, these customers are able to have the residential energy storage provides manage the onsite storage asset

for them through the license of the energy management software, and integration with the centralized analytical software hub of the firm. In this strategy, the owners of the asset can vary, while the management of the device can remain with the storage provider.

Because this strategy relies on rising prices, increasing complexity of residential power systems, and the need for better power quality, this, market strategy can be located in any area of the country. Because residential tariffs are controlled by State PUCs, the market opportunities tend to follow State deregulation and incentive payments by the State government for customers to deploy the batteries, PV, and EV charging equipment. The strategy for portfolio developers is to utilize this growing desire of residential customers to utilize the capabilities of energy storage systems and leverage the financing capacity of capital providers to expand the number of potential customers. This flexibility allows the residential energy storage providers a variety of deployment strategies. This can include both direct sales of the system with a contract for operation, leasing of the asset, or event having the energy storage provider manage a portfolio of residential systems for a utility to provide reliability services such as the Green Mountain Power / Tesla program that offers a subsidized lease for customers.

3.3. Energy Management Software

Energy management software has emerged as the most critical aspect of achieving successful energy system operation (assuming of course a well-designed and capable energy storage technology) for individual systems and fleets of units in a portfolio. Typically, there are three components of the energy management software, market analytics, the operating system, and communication and control. Individual vendors may incorporate one or more of these components into a single platform when providing the Suite to clients as they are all critical to a successful operation.

The market analytics provides critical insights into the physical and economic conditions where the energy storage asset(s) operate. Here, data feeds from the software provider's central hub are evaluated to discern what would be the most profitable and valuable operation in both the short term and long term. This may be one of the most specific and complicated differences between energy storage and other power sector market analytics. Due the inherent limitation of storage capacity and lifespan of the energy storage system, there is always a feedback loop between market strategy, and lifespan/capability of the unit.

The operating system manages the real-time operation of the energy storage unit(s) and is generally the heart of the software suite. This suite or platform incorporates the different algorithms to operate according to different modes for a variety of applications. While doing this, the unit also monitors performance and online conditions of the system to analyze the health and safety of the unit. The data from operation provides the basis for the machine learning capabilities to improve the operation of the unit through predictive learning in operation strategy and maintenance. The extensive monitoring allows for safety protocols to protect the system and surrounding environment.

The communication and controls component is the area seeing the most native expansion in capability. Originally the communication system allowed simply for the integration of the system into the local utility distribution management system for dispatch. Recent advances in paralleling units for coordinated activity has grown from simply reaching sufficient scale in order to bid into markets, to now supporting the growth in fleet operation in support of a market strategy. This communication capability also supports the ability of the energy storage system to be tied into

wholesale trading desks, increasingly relevant as the portfolios of energy storage systems grows and market trading strategies lie at the heart of portfolio performance and valuation. Based on all of this communication and coordination activity, secure and robust cyber-security protocols are essential.

3.3.1. **NEC - AEROS®**

AEROS Controls Suite is provided by NEC Energy Solutions provides analysis and management for either single asset or a portfolio of energy storage projects.²² The software suite enables a better and more accurate integrated command and control functionality. There are three parts of the AEROS software: AEROS Core, AEROS Controls, and AEROS Command Services.

AEROS Core: This is the software suite’s energy storage operating system. The tiered software control system allows for independent site level management of the different components of the energy storage system (PCS, ESS, Meters, Protections, Cooling, etc.) and plant level management either on-site or remotely.

AEROS Controls: This is the software’s integrated controls for on-site system operation. This software allows autonomous activity based on an external signal such as the utility market dispatch signal. The software manages components of the energy storage system with regards to availability, safety, and system life.

AEROS Command Services: This is the software’s remote management platform to enhance distributed control, dispatch, monitoring and maintenance either a single energy storage facility or an entire portfolio. These tools assist with warranty monitoring, data logging, and remote support from NEC staff.

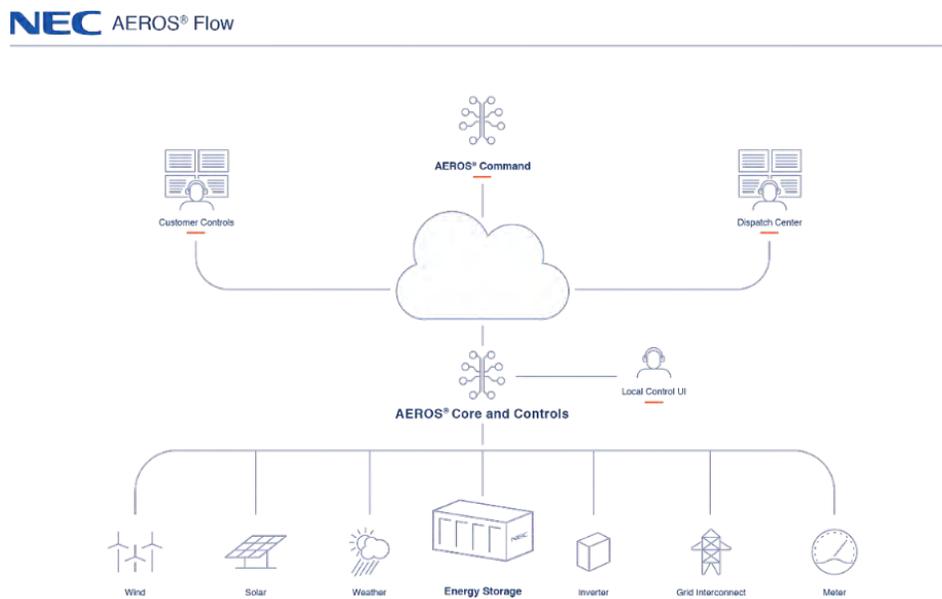


Figure 3-4. AEROS Control Suite

Source: NEC

3.3.2. **Enel X – DER Optimization Software**

Enel X's DER Optimization Software supports commercial and industrial customers reduce their electricity usage costs.²³ The software is able to utilize machine learning to learn about the customer's specific energy usage profile so it can optimize the interaction of the battery system at the optimal time to provide the greatest value possible. The software allows commercial customers a number of key benefits:

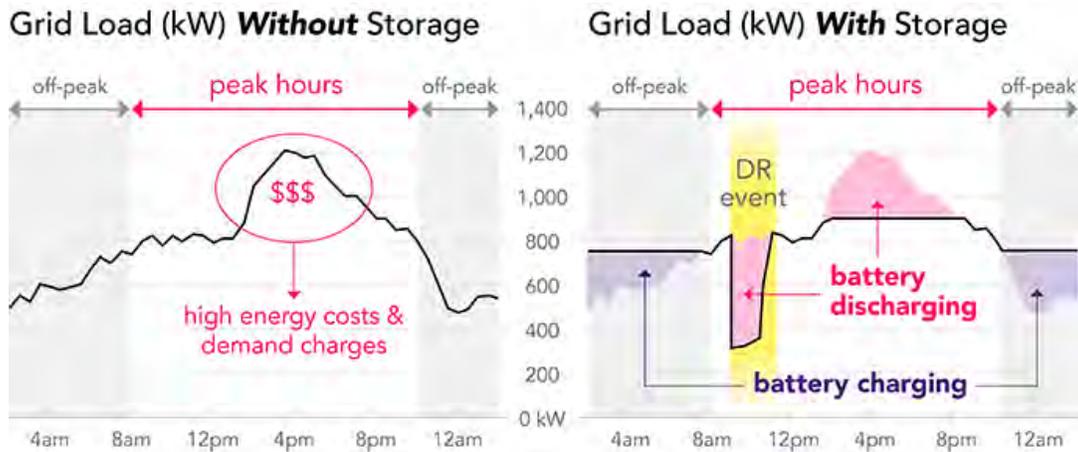


Figure 3-5. Enel X DER Optimization Software

Source: Enel X

The DER software is governed by a local site controller for the energy storage asset. This site controller manages the onsite asset, and is able to be paralleled with a large number of other DER systems to bid larger blocks of power into the market for grid services (these are sometimes not available for individual unit involvement due to minimum power rating for some grid services). The DER software manages the operation based on a variety of factors, including real-time demand, time of use tariffs, and solar production. The software is able to integrate with customer's existing building management software, PV system, and EV charging systems. Through this integration, the DER software is able to support a number of applications, including peak shaving, energy time shifting, renewables integration, EV charging, voltage/frequency support, critical load support and back-up, and microgrid operations.

The software allows customers to manage demand charges and avoid high time-base electricity costs and become involved in utility demand response programs to earn additional payments. The software is also able to support the customer's involvement in and to take advantage of other market program and incentives.

The software also supports added flexibility to the customers energy needs. The software is able to support the integration of on-site solar with the battery system, provide enhanced grid stability and reliability by enhancing the utility's power delivery, and providing an additional level of operational security through maintaining some on-site energy for back-up power.

3.3.3. **Tesla - Autobidder**

Tesla provides a software suite called Autobidder to manage the operations of its energy storage systems.²⁴ The software was developed to support all levels of Tesla equipment, from small behind

the meter systems to a 100MW front of the meter systems. The software was also designed for the owner of either one or multiple facilities and autonomously determines the cost and benefit of every potential action, inclusive of revenues streams, warranties, and maintenance agreements, to maximize net present value of the asset.

Autobidder operates as a real-time control platform enabling operators to easily configure operational strategies for maximum value creation. The software can support a number of applications utilizing different value stacking operations during real-time operation. The advanced algorithms allow for complex co-optimization calculations needed to successfully stack multiple applications successfully.

The software suite was designed to support a variety of market roles. In the wholesale market, the system can support including energy and capacity products, ancillary services, transmission and distribution services, renewable firming and shaping, and bilateral contract arrangements. Autobidder also ensures owners that equipment warranties will not be impacted by operational choices by the operation.

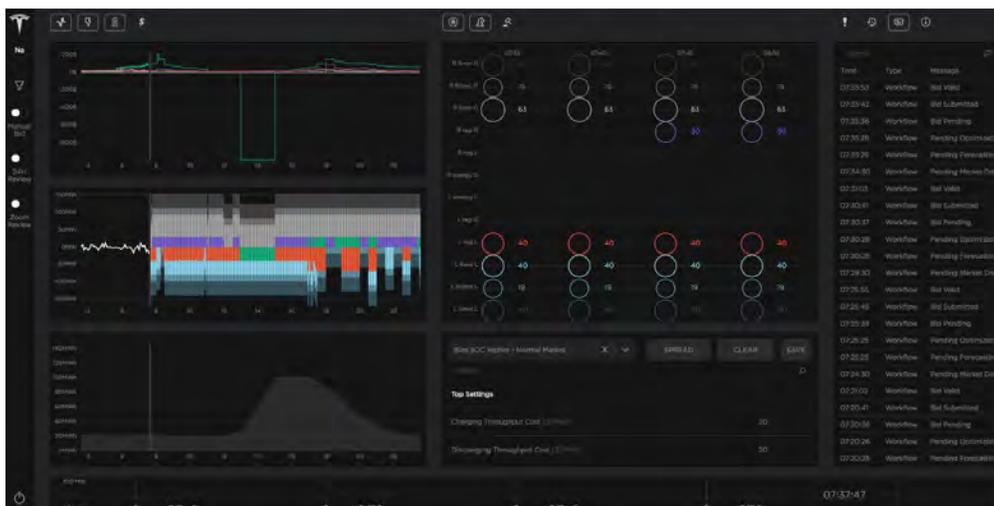


Figure 3-6. Tesla Autobidder Software

Source: Tesla

3.3.4. **Fluence Operating System**

Fluence provides an advanced software suite to manage and operate the energy storage systems it develops for its clients.²⁵ This energy management software incorporates advanced decision control, optimization, and control capabilities. The software suite is comprised of two components: Fluence IQ and Fluence Operating System.

The Fluence IQ software product provides intelligent decision-making support and optimization is for the energy storage asset, or a portfolio. The software is able to enhance performance and lower operating costs of the system through existing dispatch algorithms developed based on some of the widest and longest running systems in the field. The report capabilities provide a quick view into the status of availability, round trip efficiency, system state of health, etc. while providing insights into how the system is operating with respect to the offtake contracts and warranty limitations.

The Fluence Operating System (OS) software provides the control capabilities for the energy storage asset. This software platform provides an integrated control and asset management to provide deep visibility into the operations of a single facility, or entire portfolio. The software manages the assets for a variety of scheduled applications through active management of the facility to adjust to actual operating conditions. Monitoring of the system also allows deep insight to multiple areas to detect and alert operators in the event of safety concerns.

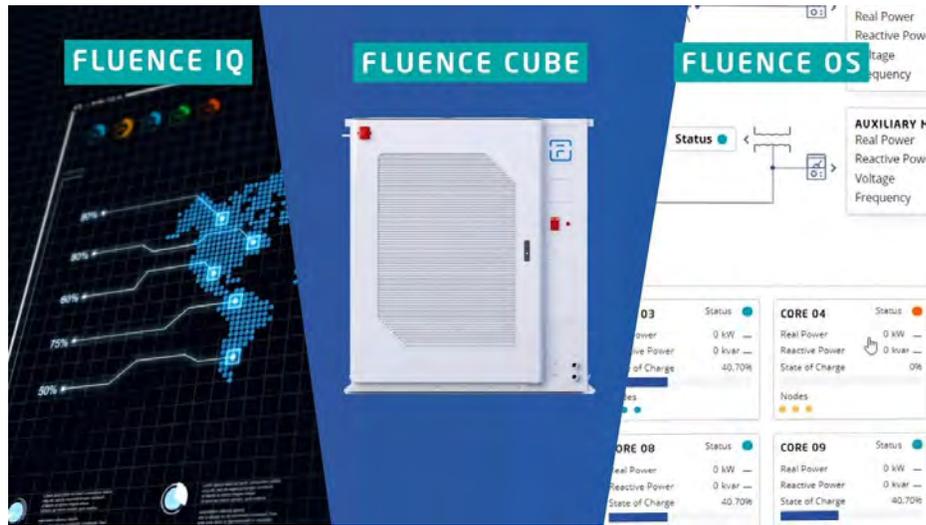


Figure 3-7. Fluence Energy Storage Offering

Source: Fluence

3.3.5. **Wartsila – GEMS OS**

Wartsila provides the GEMS software to monitor, control, and optimize energy storage projects for its customers.²⁶ Instead of simply being energy storage specific, GEMS is designed to control a number of energy project assets, including storage, renewable, and thermal generation in a hybrid power environment. GEMS was designed to be technology neutral and has been integrated with 16 different batteries and 12 power conversion systems. The software supports multiple value streams for energy storage system operation, including frequency regulation, spinning reserves, and VAR support while optimizing an efficient O&M schedule for the facility.

The GEMS software provides a deep view into the operation of the storage asset. The depth of experience with energy storage systems provides a wealth of advance algorithms to maximize battery performance and longevity, in real time, and over the expected life of the system.

The GEMS software is designed to give operators a deep view into the system operation, allowing them to optimize the system performance, reduce costs and provide proactive warranty protection through limiting excessive operation when needed. Through its machine learning capability, the software can adapt and learn from market changes. Incorporated into this learning behavior is the ability to incorporate safety features and operation into the unit strategy.



Figure 3-8. Wartsila GEMS OS

Source: Wartsila

3.3.6. **STEM - Athena™**

STEM provides its Athena software to operate and manage commercial and industrial customer’s energy storage assets in real time. STEM provides its customers with real-time local and regional demand and pricing forecasts for better operation. ²⁷

The Athena software suite accurately forecasts energy demand onsite and energy demand on the grid, providing actionable data for customers to act on advantageous pricing opportunities. The software does this by optimizing activity across multiple applications, including demand charge management, energy arbitrage, wholesale market participation, and backup power.

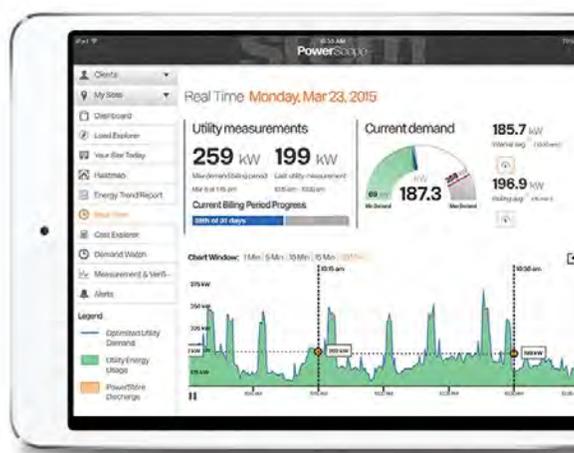


Figure 3-9. Athena Software Suite

Source: STEM

The Athena software is designed to operate in an autonomous mode for its customers, managing the market complexity and real-time data from the STEM support network to provide real-time decision making to create value for the customer. While doing this, the system is also cognizant of the health of the battery and is designed to maximize the system's lifecycle health and capability to maintain availability over the life of the unit while providing accurate, reliable, and flexible operation.

3.4. Risk Management

Developing a project portfolio of energy storage systems faces a number of operational challenges. External risks also will potentially impact the profitability, and hence valuation of the portfolio. These include market level changes (policy, etc.) the access to low cost capital, and supply chain concerns. Although these risks are shared by owners of individual units, they are possibly magnified when owning a fleet of systems as risk management techniques to mitigate individual risks becomes more difficult when the portfolio of projects operates in a variety of market, utilizes multiple technologies, etc.

3.4.1. Market Changes

Exogenous factors will have a large impact on the valuation of the energy storage projects. Significant market changes can take a long time to fully evolve and are not typically seen as a major risk for a project as typically projects do not move forward without off-take contracts, etc. fixed for the life of the facility—or enough to pay off an appreciable component of the debt.

This is not the case for portfolios, which have lifespans longer in length than even the full project life. Therefore, changes in policy, or the pricing of electricity / power products and services are important to incorporate into the portfolio strategy.

3.4.1.1. Policy Changes

Public policy changes can impact the underlying factors that drive the valuation of the portfolio, and their possible change and evolutions should be taken into account. These changes can come in a number of forms, such as market rule changes, Greenhouse Gas limitations, Tax issues, Safety rules and regulation, etc. Unfortunately, a crystal ball does not exist that can provide complete clarity into the magnitude and direction of policy changes that can impact the capital-intensive portfolio of energy storage projects. However, care should be maintained to be aware that change will continue to happen, and that contingencies should be ready to be put into place if certain major changes in the policy arena occur.

3.4.1.2. Electricity Pricing

An important exogenous input to the project economic model is the cost of electricity. This presents itself in a number of ways. Obviously, the cost of electricity used to charge and discharge the unit drives the charging costs, but the market price for electricity also impacts the cost of products and services the energy storage system uses to drive value for the unit. Therefore, not only the current pricing level, but its volatility, rate of change, and fixed charges such as demand and capacity charges stem in some measure from the equilibrium pricing of electricity. This is even more true for ancillary services such as frequency regulation that shadow the spot price of power.

3.4.2. Access to Capital

Accessing low cost capital is critical to the development of portfolios of energy storage assets. This access will utilize the same financial tools, programs, and structures other power industry assets have utilized; promising ones in the near-term include investment tax credits, Master Limited Partnerships, and securitizations.

3.4.2.1. Stand-Alone Energy Storage ITC

The development of an investment tax credit for stand-alone energy projects continues to be a goal of the industry. Experience has shown energy storage system to be covered under the Solar ITC, but only as a supporting piece of equipment, and precluding the use of the true potential of the energy storage asset. A separate stand-alone energy storage ITC would entice additional capital for energy storage projects and has been a mainstay of solar and wind project portfolio investments.

In the 116th Congress, the Energy Storage Tax Incentive and Deployment Act (S. 1142 & H.R. 2096) offers an ITC for stand-alone energy storage systems. These legislation would make energy storage technologies eligible for the ITC under IRC Sec. 48 and 25D, with the option to elect “direct payment.” The ITC for stand-alone energy storage should either be refundable or allow taxpayers to elect “direct payment” of the credit as tax already paid (as in Sec. 104 of the House Ways & Means GREEN Act discussion draft). Since tax equity is likely to become scarce in the near term and due to the pull-back in economic activity, the ITC should allow businesses to reduce reliance on costly and time-consuming tax equity transactions.²⁸

3.4.2.2. Master Limited Partnerships

A master limited partnership (MLP) is a type of limited partnership that trades on an exchange. This combines the liquidity of a publicly traded security (equity) with the tax benefits of a limited partnership. Through this structure, groups are able to raise low cost capital for project investments through IPOs and secondary offerings. Master Limited Partnerships typically attract more capital investment, lowering the cost to develop the sector and increasing available equity. This structure would significantly benefit the energy storage market as MLPs increase private investment in technology markets. These markets deliver greater benefits since the investor base is much larger. More investors add liquidity to these companies and ultimately a higher valuation and return for the owners.

MLP's are considered a Pass-Through structure by the IRS, and thus MLPs do not pay State or Federal corporate tax. Instead, they pass through the majority of their income to investors in the form of regular quarterly distributions which are tax deferred. This allows MLPs to avoid paying to regular corporate taxation on its income—typically 35% before being providing it to shareholders. In a typical corporate structure, another tax is levied on dividends by the shareholders. The MLP structure allows the organization's income to be directly reported through the owner's taxable income at the personal tax rate rather than the corporate rate. To qualify as an MLP, the partnership must generate more than 90% its income from activities related to the infrastructure investments in the production, processing, and transportation of natural resource industries, such as timber, oil, natural gas and coal.

To date, only fossil fuel development has been able to take advantage of this tax structure; renewable energy is excluded from the statute. Recent legislation specifically mentioning energy storage (in addition to renewable energy projects) opening up Master Limited Partnerships (MLPs) to include energy storage was reintroduced during the 113th Congress in the House (H.R. 1696) and

Senate (S. 795). These bills simply expand the definition to include renewable resources and energy storage in addition to fossil exploration and resources.

3.4.2.3. Securitization

As a capital-intensive project industry expands, the need for ever larger pools of lower cost capital are needed to allow for developers to maintain a sufficient margin on the project even as the overall revenue of the contract declines due to competition. Asset backed securities (ABS) have played that role in many industries and promises to support the continued growth of the energy storage market, if the energy storage industry can provide the constant and reliable cash streams from the projects that are required.

The use of ABS has grown in the solar industry, allowing issuers to remove the assets from their balance sheets, and isolate investors from operating the asset directly. ABS allows these deeper capital markets to fund projects in these emerging markets with longer term, lower cost funds. Investors in ABS want simple, reliable returns from the project's operation. This is a challenge for energy storage projects to date, but experience is being driven by including storage into solar/storage projects placed into the pools of financing. This experience will provide significant experience as to how the rest of the energy storage industry would be able to tap into these capital markets and support the growth of energy storage project portfolios.

3.4.3. Supply Chain

Managing the supply chain for the energy storage industry is a critical aspect of minimizing industry risk, and something that investors consider as they make plans for significant investments needed to develop or support a portfolio of energy storage projects. There are typically four areas that receive a deeper dive of investigation: materials supply, manufacturing, construction, and operations.

3.4.3.1. Material Supply

The first component of any supply chain is the material supply. This typically has two aspects, mining the raw materials from specific mineral deposits, and processing that raw material into industry grade material ready for manufacturing.

There are a number of reasons for concern in this stage of the supply chain. As energy storage technologies are moving towards commonplace and possibly being an integral component of the electrical power and transportation industry, the availability of materials becomes a strategic concern for the U.S. Redundancy of available mineral deposits becomes a goal that many countries and regions of the world can agree on an contribute.

It must also be noted that battery factories do not simply use raw ore in the manufacturing process. For any industry, raw ores must be processed into higher grade materials, and then combinations of different materials into composite materials that are more typically used in precise manufacturing. This is of significant importance for the lithium ion battery industry where purity of specific combinations of components has become essential.

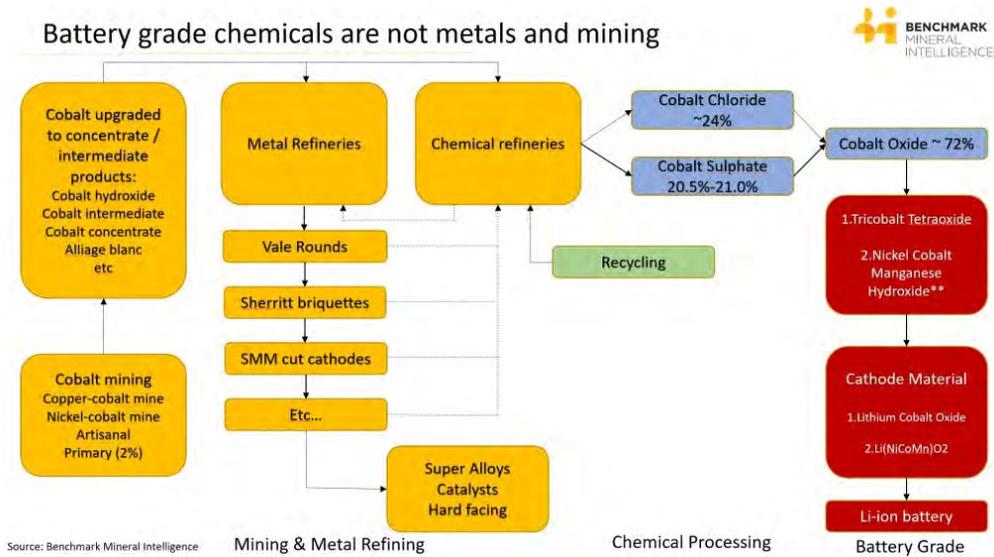


Figure 3-10. Battery Materials Supply Chain

Source: Benchmark Mineral Intelligence

Recycling of used batteries has increased as a potential source of refined materials. As mentioned earlier, the lead acid battery industry recycles virtually all of the batteries produced, allowing recycled materials to be a significant component of the input into the manufacturing process, reducing costs. This same strategy is envisioned for the lithium-ion industry. Estimates vary but reducing materials costs by 10% to 30% have been widely expected, according the Argonne National Laboratory. Because of the different components of the battery, recycling and processing efforts take specific tracks. This effort can also impact the manufacturing design and processing, by highlighting options to make manufacturing and reprocessing easier.

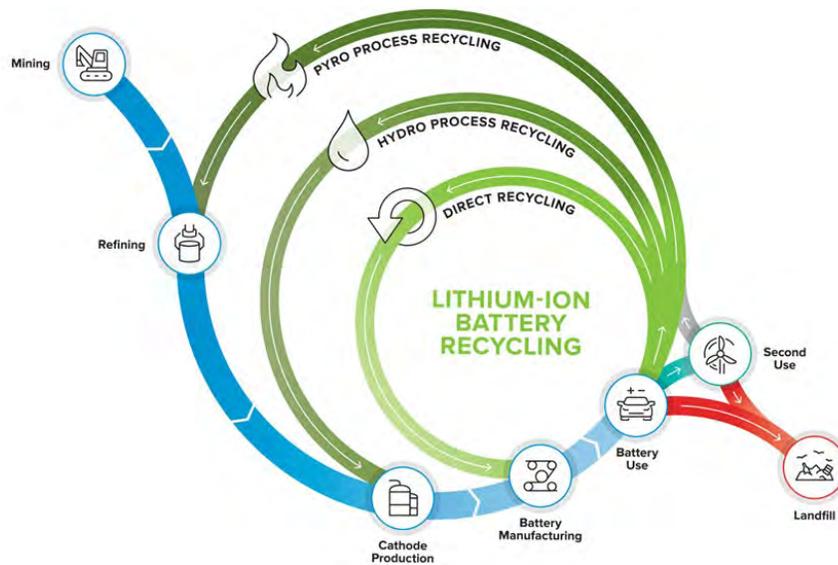


Figure 3-11. Lithium Ion Battery Recycling

Source: ANL

Although the lithium ion battery industry currently dominates manufacture and deployment of energy storage systems for grid applications, there are over a dozen families of other energy storage companies, each with their own material supply chain. Many leverage other key industrial materials as nickel, zinc, or vanadium, so there exists the capability to develop a refinement capability for battery grade material for those technologies.

3.4.3.2. Manufacturing

Manufacturing capabilities for batteries and other energy storage technologies is another key aspect of the supply chain. Because the capabilities, scale, and design of the capabilities rely on this stage of the supply chain, this is typically of interest by project developers and the financial backers of the projects. Because of the scale of the growing lithium ion manufacturing segment, consultancy groups such as Benchmark Minerals Intelligence track the growth of different manufacturing facilities as part of their focus on the lithium-ion battery supply chain.

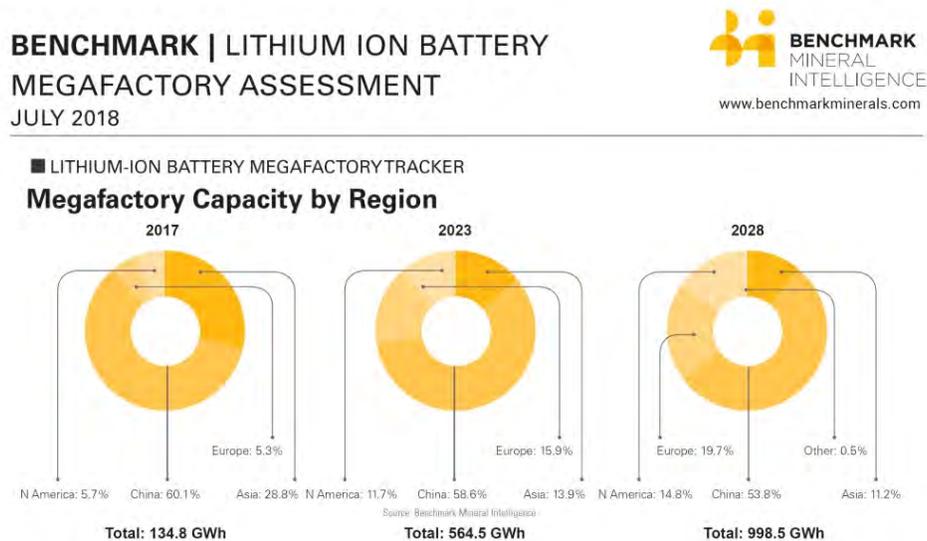


Figure 3-12. Megafactory Capacity by Region

Source: Benchmark Mineral Intelligence

3.4.3.3. Construction

The construction of energy storage facilities is another component of the supply chain that has risen to prominence by investors as an area of concern, as although systems can be well designed, construction errors or faults can impact the performance of energy storage facilities over their entire lifespan. EPC firms are responsible for the engineering and construction of the facilities, but it is electrical contracts that do the actual construction. Therefore, it is their capability and expertise that will impact the quality of the project. As the industry grows, more and more electrical contractors will become involved in deploying energy storage systems. For the contractor who has had infrequent—or no—exposure to ESS technologies and operations, the essential challenge for the project developer is ensuring that the electrical contractor is up to date and trained in the latest ESS codes. Additionally, since these codes are still rapidly evolving, the contractor needs to be aware of impending updates that may occur during the course of the project.

The installation of energy storage systems (ESS) is a critical milestone in a project’s development, safety, and long-term optimum performance. Because of the nature and evolution of ESS technologies and systems, it is particularly important to select the right electrical contractor. A well-chosen electrical contractor will help ensure that numerous components are installed, commissioned, and maintained properly—even when physically incorporating new components and systems of the different OEMs.

Issues can arise, however, when developers, integrators and EPCs are not completely familiar with best practices for electrical contractor selection. The National Electrical Contractors Association (NECA) published an ANSI-approved standard NECA 416-2016 titled, “Recommended Practice for Installing Energy Storage Systems (ESS)”. It describes the methods, procedures and best practices that should be used for installing multiple types of energy storage systems.

NECA 416 provides valuable insights and important provisions for those involved in installing and providing energy storage system services for their customers. This quality performance standard not only addresses the essentials of good workmanship and best practices that are common to energy storage system installations, but also provides important guidelines for addressing the commissioning and maintenance of such systems. The content of NECA 416 is also aligned directly with the minimum requirements in new Article 706 of the 2017 National Electrical Code® (NEC®).

3.4.3.4. Operation

A well thought out operations plan for a portfolio of energy storage assets is essential. If it is true that the growing energy storage project industry is mirroring the experience of the early solar market, then it is useful to review the experience there. What we find is that O&M execution ranked among the top concerns of equipment manufacturers, project developers, and investors. This is becoming even more of an area of concern for energy storage portfolio owners. There exists a wider variety of energy storage technologies, and even within lithium, there exists significant differences in design from one OEM to another. Generally, energy storage systems are designed to be more interactive and at varying power charging and discharging rates (and rate of change for these power levels), giving rise to increased O&M requirements. Finally, safety issues rank high in the operational concerns of any energy storage facility, and it becomes of an even greater concern as the invest level rises as with large portfolios of assets operating under similar plans.

Developing an operation program for energy storage assets will encompass a number of components. A central components will be a centralized Network Operating Center (NOC) that provides insights leveraging the energy management system that is used to manage and control the different assets in the portfolio. Because cybersecurity concerns are fundamental to the operating of the power grid, all communication and control interfaces through with the different energy storage units through the EMS suites must utilize secure cybersecurity protocols.

The operations program for the energy storage portfolio is one of the most important investments the owner of the portfolio can make to ensure the proper availability and capability of the assets. Since there are a number of moving parts to operating a number of energy storage assets, it is common to see groups looking to standardize as much as possible. This can include purchasing only a few (or one) type of energy storage technology from a single system integrator. The more different types of technologies and operating systems a group has, the greater the investment in training and different O&M procedures they must contend with.

The O&M expenses must be part of an O&M strategy that reduces not just current, but also lifetime costs while maximizing availability and capability of the units. There continues to be significant cost

pressures on reducing annual expenditures but short-changing the O&M budget is a precarious choice for operators, potentially leading to catastrophic damage from an untended asset. A critical choice these operators will have to make is to either provide the O&M services themselves or contract it out to engineering support firms.

In some ways this decision is not based on a choice, but rather as to the type of firm operating the portfolio. If the firm is based on engineering capabilities, developing an O&M program internally is simply an organic growth to the enterprise. If the group is more contract and finance based, then contracting out the O&M program to a firm is probably the best choice. If the portfolio manager does contract with an O&M services firm, then a number of considerations must be taken into account, such as the experience and capability of the firm. Of importance also is the bankability of the O&M services firm, meaning the available bonding or insurance policies held by the firm to cover any instances that arise from a failure at a facility.

4. ROLE FOR THE U.S. DOE

The U.S. Department of Energy has an important role in establishing a foundation of resources, analytics, metrics, and commonality among definitions to supporting improved project and portfolio valuations. As the U.S. Department of Energy puts more resources toward improving the development of energy storage technologies, new and innovative programs are being developed, and existing programs are gaining additional support. Together, this will enable to U.S. Department of Energy to play a crucial role by providing a greater availability of data on the market, more powerful analytics, resulting in improved confidence for those looking to evaluate opportunities and invest in energy storage project assets.

4.1. Energy Storage Grand Challenge

The U.S. Department of Energy launched the Energy Storage Grand Challenge on January 8th, 2020 to set goals for energy storage technology development and deployment. The vision for the program is for the DOE to foster the same type of advancement and use of energy storage technologies as was the result of other DOE programs supporting solar and wind technologies. Through the Energy Storage Grand Challenge effort, the U.S. DOE will coordinate efforts towards a series of goals by 2030 that are grouped into 5 pillars:

- **Technology Development:** Establish ambitious, achievable performance goals, and a comprehensive R&D portfolio to achieve them.
- **Technology Transfer:** Accelerate the technology pipeline from research to system design to private sector adoption through rigorous system evaluation, performance validation, siting tools, and targeted collaborations.
- **Policy and Valuation:** Develop best-in-class models, data, and analysis to inform the most effective value proposition and use cases for storage technologies.
- **Manufacturing and Supply Chain:** Design new technologies to strengthen U.S. manufacturing and recyclability, and to reduce dependence on foreign sources of critical materials; and
- **Workforce:** Train the next generation of American workers to meet the needs of the 21st century electric grid and energy storage value chain.

This effort will provide clarity on the valuation of both individual projects and portfolios of assets. Better performance, lower cost, and the capability for more granular analysis market opportunities all improve the effort towards crafting realistic values for energy storage projects.

4.2. Readiness Levels

The U.S. Department of Energy plays an essential role through formalizing a series of readiness level metrics to describe the stage of progress for energy storage technologies along a variety of critical development paths. These readiness levels are used by groups inside the government and out to describe the status of different aspects of an energy storage technology's progress towards commercialization. Governments use them to identify and segment products from different vendors for R&D funding opportunities, for instance.

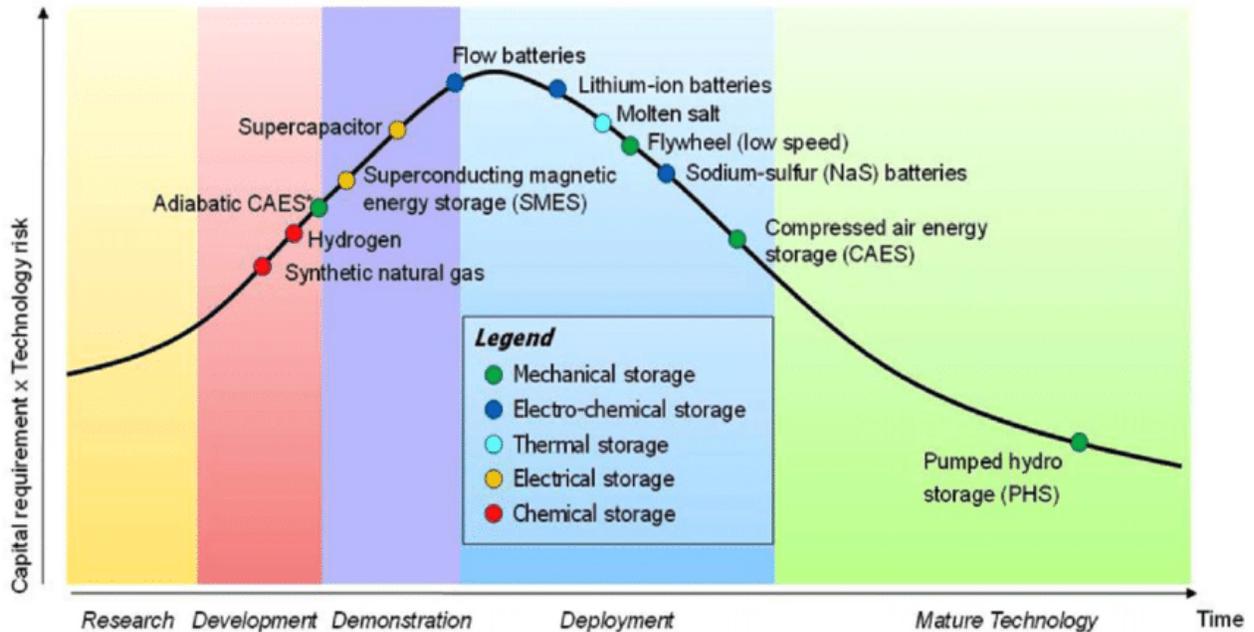


Figure 4-1. Readiness Levels for Energy Storage

Source: Schlumberger Business Consulting (SBC) Energy Institute, 2015

It should be understood, however that these metrics are typically just one-dimensional issues—describing how far along something is along the line between 1 and 9 based on a variety of conditions and milestones. For that reason, it should be remembered that they are very helpful, but deeper insights into the value of the technology should not be read into the rating; it is simply a status check of the technology along a particular developmental spectrum.

Existing technology readiness metrics include:

- Technology Readiness Level (TRL)
- Commercial Readiness Level (CRL)
- Manufacturing Readiness Level (MRL)

As the market for energy storage technologies advances, an additional readiness level should be developed, the Project Readiness Level (PRL). This would serve to highlight and provide insight into number project deployment specific issues.

4.2.1. **TRL – Technology Readiness Level**

The Technology Readiness Level (TRL) scale is widely used to track the early stage development for various technologies and has been used extensively in the energy storage market in various government funding programs. The TRL scale was developed by the National Aeronautics and Space Administration (NASA) in the 1980s to assist that governmental agency in managing its R&D efforts.

The TRL scale encompasses a range from 1 (basic principles observed) through 9 (total system used successfully in project operations). Over time, this scale was adopted by other U.S. Federal government agencies as it proved superior in identifying the actual technology maturity and preventing premature deployment by the federal government. The TRL scale is important as the rating implies adherence to a set of standardized technological progress milestones giving comfort to users that there will be continual progress toward a working prototype.

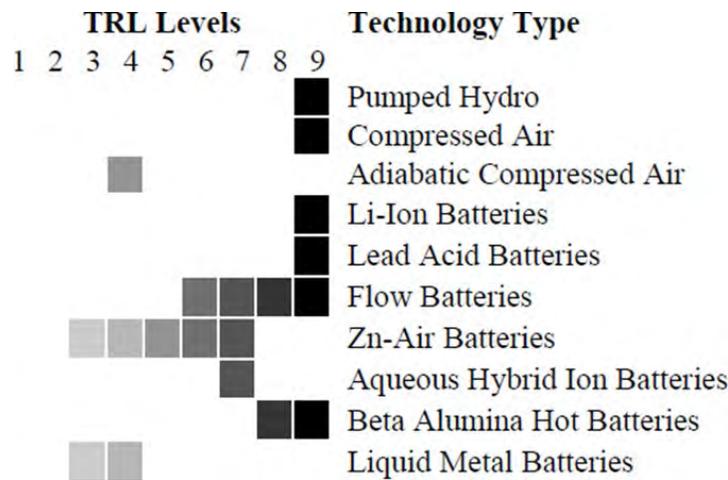


Figure 4-2. TRL – Technology Readiness Levels (TRL) for Energy Storage Technologies

Source: National Academic Press

4.2.2. **CRL – Commercial Readiness Level**

To provide a common framework to define the spectrum of maturity for technologies as they enter commercial readiness, the U.S. Department of Energy’s ARPA-E (Advanced Research Projects Agency—Energy) has followed suit with a commercial readiness level (CRL) that provides a means for all parties to discuss the commercial development of a technology.

Like the TRL, the CRL is important as the rating implies adherence to a set of standardized commercial milestones giving comfort to users that there will be continual progress toward a commercially ready solution. As the TRL and CRL scales describe two different attributes of the system they are not directly comparable, and typically overlap. As with the TRL, the CRL scale ranges go from 1 (knowledge of applications, etc.) to 9 (widespread deployment).

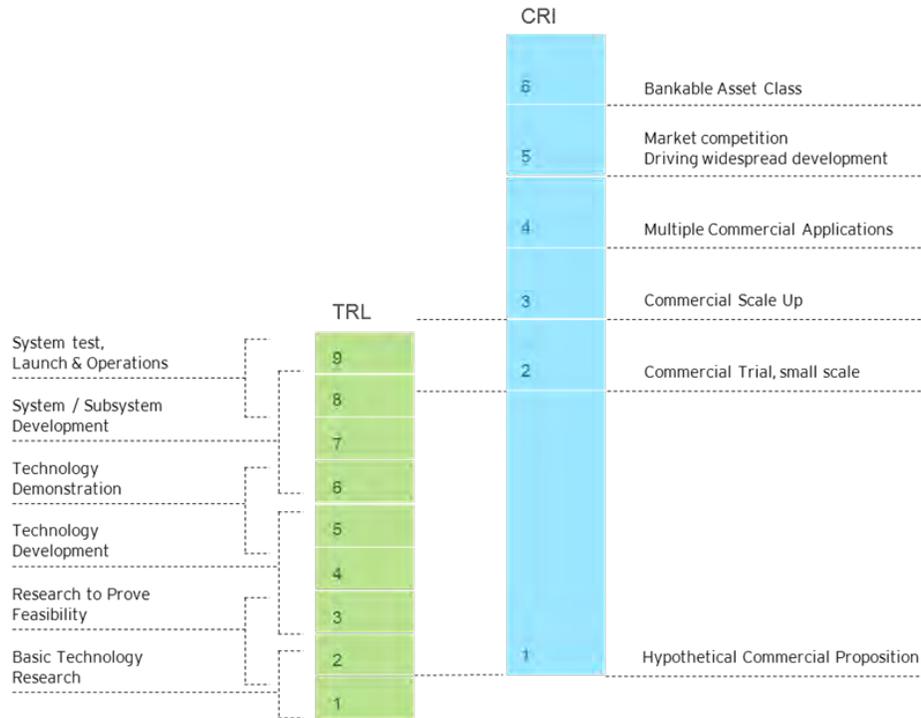


Figure 4-3. CRL – Technology (TRL) and Commercial (CRL) Readiness Levels

Source: Australian Renewable Energy Agency (ARENA)

4.2.3. **MRL – Manufacturing Readiness Level**

Manufacturing readiness is the third area of readiness that is gaining interest as investors try and gauge the readiness of emerging manufacturing for energy storage technologies. The Manufacturing Readiness Level (MRL) was developed by the U.S. Department of Defense²⁹ and provides a measure to define when a technology or process is maturing. MRLs provide an assessment of the maturity of the manufacturing process for a given component, sub-assembly, or complete system. Areas of related interest include material resource availability, supply chain, and production capacity.

The MRL rating system will help improve the manufacturing process and supply chain to address a number of key issues for the industry.

- **Scale manufacturing to meet demand.** Most production processes are limited by gating steps in the production process, with cost effective production scale-up coming in discrete step changes. This is also linked to the ability to support manufacturing expansion with sufficient numbers of trained manufacturing workers, especially skilled ones.
- **Refine the manufacturing process to improve yield.** With experience, manufacturing production can reduce waste and inefficiencies, improving gross margins for the manufacturer. This is typically an iterative step, including redesign of the product for better operation while also improving the ability to manufacture it.
- **Product Lines.** Design the product and components to support the development of a full product line family. Manufacturers many times utilize a modular component design approach in order to support multiple platforms to serve different markets while keeping the

number of components needed to be developed small. For interoperability, manufacturer look to product standards so that they can continue to focus on the overall design of the system while giving them the possibility to purchase sub-components from outside vendors while still ensuring these new components would fit and operate properly with the rest of the system.

- **Emerging Technologies.** Manufacturing of emerging technologies like energy storage typically suffers from a gap in innovation and funding as OEMs transition from low volume production as the technology emerges from R&D labs to higher volume during commercial production. This is another aspect of the much touted “Valley of Death” as early stage firms emerge with new and innovative technologies. Not just in raw manufacturing capacity, but also in design capability to scale production while maintaining high quality and stable margins. Often over-looked, the ability to—or a believable plan to get to—manufacture at scale, with a high yield, and in a cost-effective manner is important for the Bankability Study to allay the concerns of investors, partners, and customers.

Table 4-1. Manufacturing Readiness Levels

MRL - 1	Manufacturing Feasibility Assessed
MRL - 2	Manufacturing Concepts Defined
MRL - 3	Manufacturing Concepts Developed
MRL - 4	Laboratory Manufacturing Process Demonstration
MRL - 5	Manufacturing Process Development
MRL - 6	Critical Manufacturing Process Prototyped
MRL - 7	Prototype Manufacturing System
MRL - 8	Manufacturing Process Maturity Demonstration
MRL - 9	Manufacturing Processes Proven
MRL - 10	Full Rate Production demonstrated and lean production practices in place

Source: NREL/TP-560-45406

4.2.4. **PRL – Project Readiness Level**

As the energy storage market moves further into deployment of different energy storage technologies, understanding their readiness to be utilized by a standard project developer in real-world situations is becoming critical. The proposed Project Readiness Level (PRL) would act as a tool for early adopters to provide insights into the readiness of a technology for financing for a project.

Lenders typically obtain independent engineering reports as part of their risk management process in their credit approval process for project development. These reports ensure the suitability of the equipment choices for the chosen application. Independent Engineering Reports are thus project specific. The proposed PRL would need to be technology or OEM specific to provide assurance that the technology in questions would be ready a project. The PRL is thus designed to lay the groundwork for an independent engineering report. In this way, the PRL would operate in a similar to a Bankability Study that evaluates the ability of a technology to be ready for project deployment; an independent engineering report assumes that the technology is deployable, and focuses on whether the project design and intended operation is appropriate for the lender's capital. A few of the issues would include:

- **OEM Review:** Ascertain good corporate performance to support the emerging technology offering.
- **Technology Evaluation:** Review of performance capabilities of technology, and possible development paths that would support wider market roles.
- **Manufacturing Process:** Deeper dive into the manufacturing process of the OEM (or its contract manufacturer), as well as visibility into the firm's production life cycle.
- **Supply Chain:** A deeper dive into the OEM's supply chain can show exposure to production risk.
- **Competition:** Evaluate the competing vendors of a particular technology in order to provide some baseline capability index.

4.3. Analytics

One of the most important areas of support for improved project and portfolio valuation for the U.S. Department of Energy is the area of analytical tools for energy storage project evaluation. Three areas in particular are of interest:

- **Valuation Models:** Continuing to improve publicly available valuation models will benefit a variety of groups in the project development arena. Project developers need tools they can adapt to evaluate unique business operations. Groups in the lending community needs to know that financial models of project developers are sound and would also like to know there is a 3rd party capability to evaluate project proposals.
- **Standardized Duty Cycles:** Evaluating project costs relies on designing a system capable of supporting specific duty cycles. As customers are looking to compare the offering from different vendors—and even different technologies—it is imperative that a set of standardized duty cycles are developed to provide a performance metric to use as a first comparison basis.
- **System Pricing:** Developing and publishing a standard reference price for different energy storage technologies will help set expectations for what battery prices should be. Currently, many groups only have a narrow view into the pricing of systems, giving rise to confusion over expectations for differently sized systems or different technologies.

4.3.1. Valuation Models

A critical role for the U.S. Department of Energy to improve the understanding of energy storage project and portfolio valuation is to continue to develop and make publicly available valuation models that serve the upcoming need of new and innovative roles in the energy storage market. In particular, Sandia National Laboratory's QuESt valuation model has a number of planned improvements. These include supporting integrated solar + storage, enhanced capabilities for projects active in the wholesale market in front of the meter, and Integrated Resource planning for State and utility planners.

As energy storage becomes more widespread, the evaluation of energy storage for integrated resource planning is of especial need. For example, QuESt was used recently to evaluate the addition of solar, wind and energy storage in support of the State goal of 100% carbon free energy. Through modeling energy storage into the mix, generation resources can be reduced somewhat while increasing the reliability of the supply to utility customers. To ensure that the modeling tool supports the actual need of State planners, transmission constraints and load flows are also to be incorporated into the analysis. As this experience is gained with New Mexico, other States could be supported.

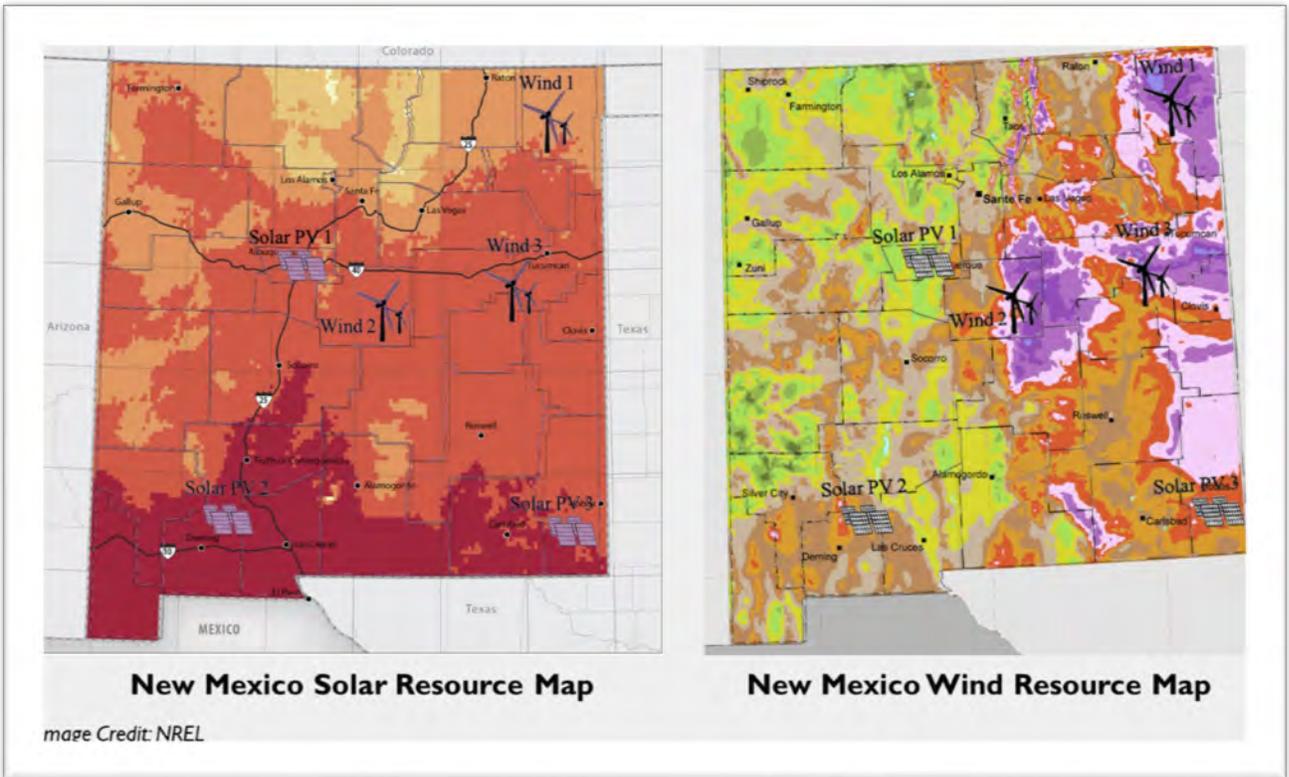


Figure 4-4. QuEst – Integrated Resource Planning Support

Source: SNL

4.3.2. **Standardized Duty Cycles**

Standardized duty cycles important for developing a valuation for energy storage systems. A duty cycle helps define the technical performance requirements for the usage profile for the applications that are the basis for revenue generation. This metric can then be used by groups such as utilities and ISO/RTOs to define the application for energy storage community. The performance requirements are also useful for developers and to determine the technical requirements, and hence, capital costs for the system.

The U.S. Department of Energy has led in this effort for years through such efforts as the report PNNL-22010 *Protocols for Uniformly Measuring and Expressing the Performance of Energy Storage Systems* (the “Protocols Report”) and PNNL-233090 *Determination of Duty Cycle for Energy Storage Systems Integrated with Microgrids*. These reports were developed to define the technical characteristics of an operating energy storage system through effective testing measures. The reports define a number of representative duty cycles for different applications based on real-world data. The duty cycles are designed to model realistic usage patterns, and range from energy to power intensive, and include attributes of stacked use cases.

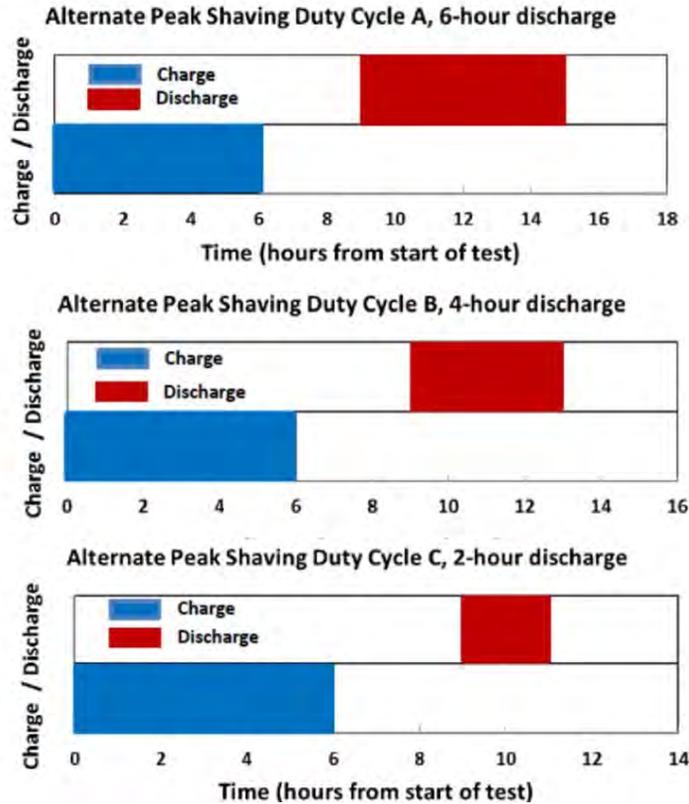


Figure 4-5. Alternate Peak-Shaving Duty Cycles

Source: PNNL³⁰

4.3.3. System Pricing

Developing a database of reference energy storage system prices to customers for various energy storage technologies at different power and energy sizes is an important role for the US. Department of Energy to provide the industry. The system price provided is the total expected installed cost (capital plus EPC) of an energy storage system to a customer. Because the capital cost of these system will vary depending on the power (kW) and energy (kWh) rating of the system, a range of system prices should be provided. A good example of this type of publication is the *Energy Storage Pricing Survey*, published annually through Sandia National Laboratories.

The goal of publishing this data is to set expectations for customers of the cost of energy storage systems at different power and energy levels. Estimating the system price of an energy storage can be difficult as there is no “standard” system configuration, and due to the nascent nature of the industry and the ongoing scarcity of equipment, different system sizes. These, and other reasons, make it difficult for customers to use the available published pricing for specific energy storage systems to extrapolate to a system that fits their needs. To ensure that the results are useful for customers as they evaluate systems at different scales, a key part of such a database would be to make the analysis internally consistent which allows for a reliable comparison of different system pricing.

This approach benefits the results in a number of ways.

1. First, all technologies are broken down into the most basic component possible, allowing the different technologies to have a similar frame of evaluation where possible.
2. Secondly, this approach allows a greater amount of precision on the components that are similar across technologies—balance of systems, power electronics, construction—using the same cost structure where appropriate.
3. Third, the forecasted prices are thus developed at the component level which supports greater precision for each price estimate as the future costs for the different components will change at different rates.
4. Finally, this structure also allows for a systematic evaluation of systems at different power and energy ratings. By have a component level pricing relationship for power electronics (for example), then the overall system price for the same technology will have a more accurate relationship to other systems at different power and energy ratings.

4.4. Data Sources

Reliable, comprehensive, and easily accessed data source are an imperative component of improving the valuation of energy storage projects and portfolios. The energy storage industry can benefit from the prior experience and investment by effort to support the solar industry in designing and executing on the needed data sources. In a number of instances, these same resources already developed for the solar, wind, and the greater power industry in general can be leveraged to support energy storage projected development.

4.4.1. Global Energy Storage Database

A critical requirement to improving reliable project and portfolio valuation is to expand the amount of comparable data on existing projects operating in the marketplace.³¹ There are a number of proprietary energy storage project databases on the market, but the U.S. Department of Energy has provided a publicly available database on projects operating across the globe, establishing a basis for improving pricing visibility for energy storage projects.

The *DOE Global Energy Storage Database* provides free, up-to-date information on grid-connected energy storage projects worldwide. Users can search the database by using a host of attributes, including region, technology, service territory, benefit stream, and other project statistics. As the database has grown, data visualization tools have been added to help users analyze the data. Competing project database offerings exist from various consulting firms, but the Global Energy Storage Database remains the most widely available resource to the public.

The U.S. Department of Energy's planned path forward for the *DOE Global Energy Storage Database* is to continue to expand the number of projects included, deepen the level of information available on each project, and add additional analysis capabilities to make the database more usable and effective. Through this continuing effort, the *DOE Global Energy Storage Database* will maintain its status as the primary basis for the analysis of energy storage projects.

Many survey participants stated it is critical for the continual expansion and development of this database. As the industry matures, decision making is increasingly being based on the growing body of real-world knowledge that stems from the *DOE Global Energy Storage Database*. Cost and performance benchmarking of existing projects—and their improving capability over time—would

be the basis to provide lenders the confidence in to extend more and cost-effective capital to this growing market.

According the Sandia National Laboratory, the *DOE Global Energy Storage Database* is the go-to source for unbiased, accurate, and up-to-date information on energy-storage projects and policies. The database is publicly accessible and simple to use, providing an open-access resource for detailed energy-storage project and policy information, and allowing users to contribute data through a third-party vetting process.



Figure 4-6. DOE OE Global Energy Storage Database: Project Coverage

Source: U.S. Department of Energy

The database-driven website is maintained by the DOE Office of Electricity Delivery & Energy Reliability at the Sandia National Laboratory website. All data can be exported to Excel or PDF.

Energy storage projects and policies can be searched in through basic and advanced selection criteria, including via interactive data visualizations. Further, users can submit project and policy information for inclusion in the database. The database supports such function as:

- Database Map search
- Project Details
- Data Visualization

Data visualization is an especially important capability of the analytics embedded in the database software. As the volume of projects grow, and as the level of details on each project expands, spotting trends in the data and teasing out key points that can support deployment and operating strategies by developers and asset owners will rise in value.

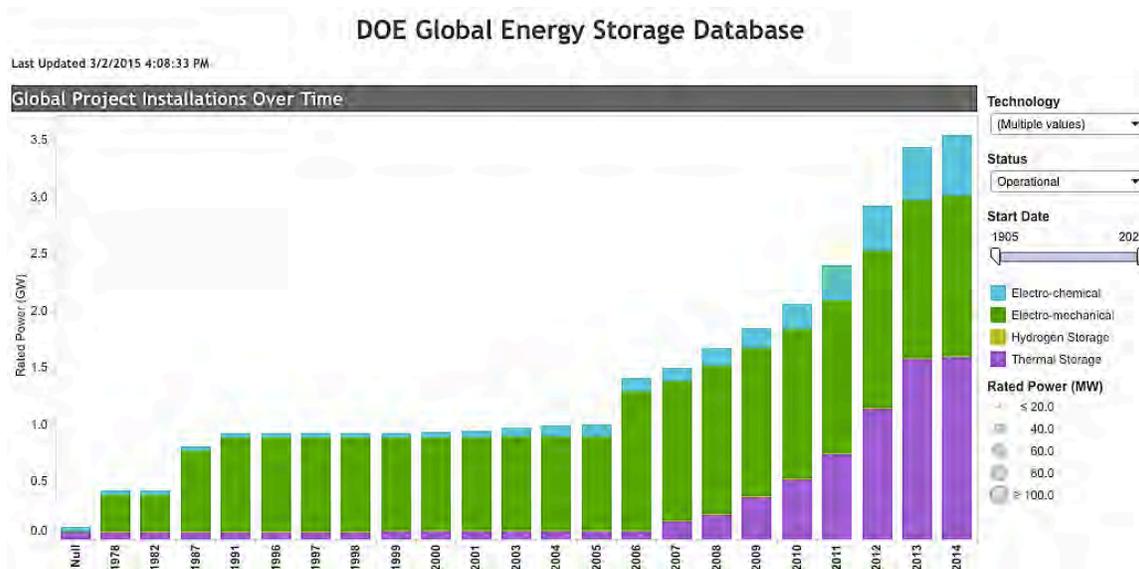


Figure 4-7. DOE OE Global Energy Storage Database: Data Visualization

Source: U.S. Department of Energy

4.4.2. Utility Rate Database (URDB)

An essential input to any Behind the Meter energy storage project valuation is a clear understanding of the current tariff rate structure for the location of the asset in question.³² The U.S. Department of Energy publishes the Utility Rate Database (URDB) as part of the OpenEI, an open repository of energy information, data, and resources. The URDB is a storehouse of rate structure information from utilities in the United States. The URDB includes rates for utilities based on the authoritative list of U.S. utility companies maintained by the U.S. Department of Energy’s Energy Information Administration. The current URDB holds 52,461 utility rate structures from 3,817 EIA-recognized utility companies.

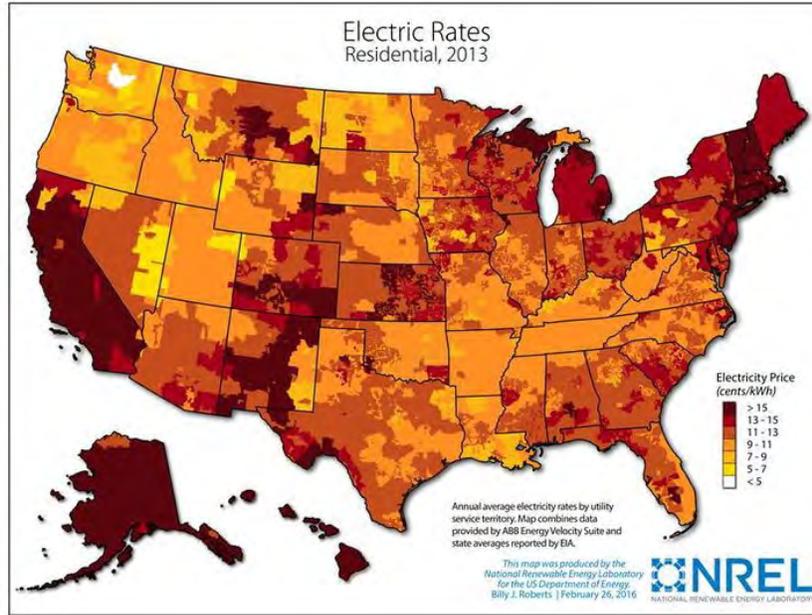


Figure 4-8. Utility Rate Database (URDB)

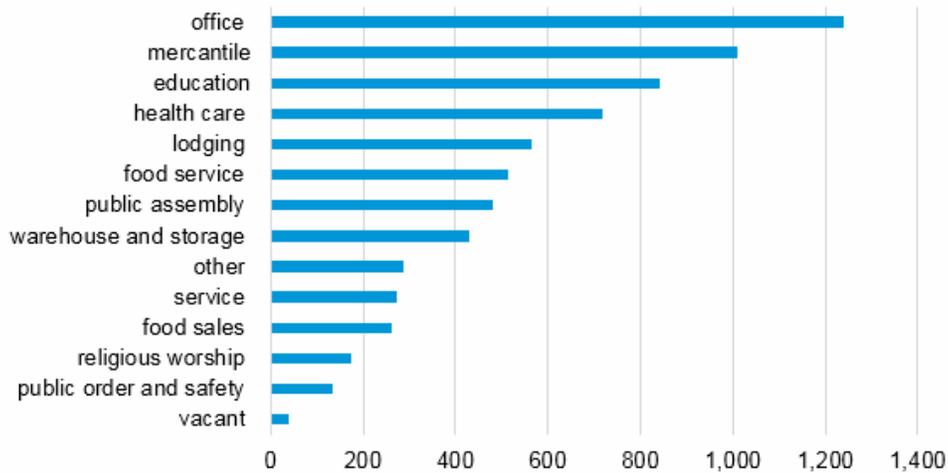
Source: NREL

The availability of a reliable, comprehensive, and publicly available resource is critical to Behind the Meter project valuation. This becomes even more important for projects that incorporate renewable resource that increase the complexity of the available energy resources for the customer. The URDB was designed for easy access to the data, with the availability to access the information through full download, single selection web interface, or automated Application Programming Interface (API) for use in more comprehensive analysis tools and models.

4.4.3. ***U.S. Department of Energy Commercial Reference Building Model***

Evaluating behind the meter energy storage deployment opportunities calls for not just an understanding of the rate structures, but also the building electrical loads. To support a better understanding of commercial building energy usage, the U.S. Department of Energy provides a set of energy usage characteristics for a common set of reference commercial building to serve as a starting points for analysis related to building energy usage research and modeling. These models represent realistic building characteristics and construction practices that represent approximately two-thirds of the existing commercial building stock. ³³

Total = 6,963 trillion British thermal units (Btu)



Source: U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey, Consumption and Expenditures, Table C1, May 2016



Figure 4-9. Energy Use by Commercial Building Type

Source: U.S. EIA

Table 4-2. Commercial Building Reference Model Locations

Number	Climate Zone	Representative City	TMY2 Weather file location
1	1A	Miami, Florida	Miami, Florida
2	2A	Houston, Texas	Houston, Texas
3	2B	Phoenix, Arizona	Phoenix, Arizona
4	3A	Atlanta, Georgia	Atlanta, Georgia
5	3B-CA	Los Angeles, California	Los Angeles, California
6	3B-other	Las Vegas, Nevada	Las Vegas, Nevada
7	3C	San Francisco, California	San Francisco, California
8	4A	Baltimore, Maryland	Baltimore, Maryland
9	4B	Albuquerque, New Mexico	Albuquerque, New Mexico
10	4C	Seattle, Washington	Seattle, Washington
11	5A	Chicago, Illinois	Chicago-O'Hare, Illinois
12	5B	Denver, Colorado	Boulder, Colorado
13	6A	Minneapolis, Minnesota	Minneapolis, Minnesota
14	6B	Helena, Montana	Helena, Montana
15	7	Duluth, Minnesota	Duluth, Minnesota
16	8	Fairbanks, Alaska	Fairbanks, Alaska

Source: U.S. Department of Energy

Fifteen commercial building types and one multifamily residential building were determined by consensus between DOE, the National Renewable Energy Laboratory (NREL), Pacific Northwest National Laboratory (PNNL), and Lawrence Berkeley National Laboratory (LBNL). The remaining one-third of U.S. building stock—although not exactly defined by the reference set—is typically similar enough to one of the 16 reference building as to make the reference building set usable for all evaluation purposes for U.S. commercial building energy modeling.

4.4.4. EIA Data Forms

The U.S. Department of Energy maintains survey form to collect asset and operational data about the U.S. energy industry. Two series in particular have been important for reporting on energy storage projects. The EIA-860 survey family collects generator-level data about existing and planned units at electric power plants with 1 megawatt or greater nameplate capacity. Data from this survey is used in the Electric Power Annual. The EIA-861 survey family collects utility information such as peak load, generation, electric purchases, sales, revenues, customer counts, energy efficiency, demand response, net metering programs, and distributed generation capacity.

The U.S. Department of Energy began tracking energy storage assets as part of the Energy Information Agency’s (EIA) monthly inventory survey (EIA-860M). By incorporating energy storage assets into these standard reporting forms, developers can gain some information about the current state of the market in the specific region they are contemplating the development of an energy storage project.

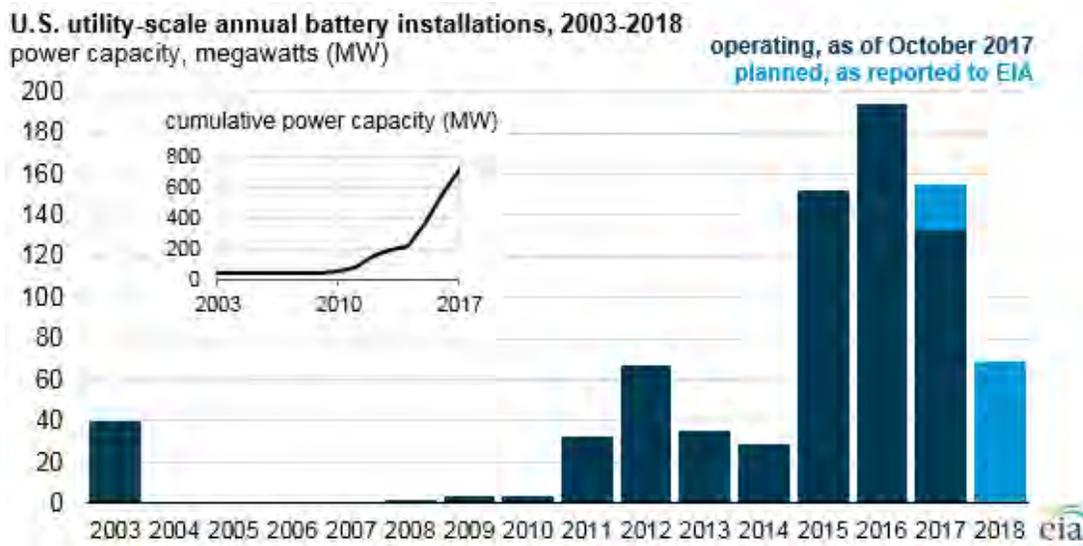


Figure 4-10. U.S. DOE Inventory of Generators.

Source: U.S. EIA

Based off of data from EIA-860, The U.S. EIA produced the report “U.S. Battery Storage Market Trends” in May 2018. The “U.S. Battery Storage Market Trends” report examines trends in U.S. battery storage capacity installations and describes the current state of the market, including information on applications, cost, as well as market and policy drivers for recent battery storage installations.

This report provided an update on trends in U.S. battery storage capacity additions and describes the current state of the market, including information on applications, cost, and market and policy drivers. Not all energy storage technologies are covered in this report, however, which is only limited to lithium-ion, nickel-based, sodium-based, lead acid, and flow batteries. Other technologies, Flywheel, CAES, Pumped Hydro Storage (PHS) not covered.



Figure 4-11. EIA’s U.S. Battery Storage Market Trends

Source: U.S. EIA

It should be noted that the Energy Information Agency (EIA) is the statistical and analytical agency within the U.S. Department of Energy. By law, EIA’s data, analyses, and forecasts are independent of approval by any other officer or employee of the U.S. Department of Energy, or other parts of the Federal Government. Therefore, the report stresses that the views in this report therefore should not be construed as representing those of the U.S. Department of Energy or other federal agencies.

Data for the report is derived from existing EIA surveys, the aforementioned EIA-860 and EIA-861. The reporting cut-offs for these surveys are based entirely on the power capacity of the generator and not on location with respect to the customer meter, distribution network, or wholesale grid.

According to the EIA, EIA's Annual Electric Generator Report (Form EIA-860) collects data on the status of existing utility-scale battery storage units in the United States, along with proposed utility-scale battery storage projects scheduled for initial commercial operation within the next five years. The monthly version of this survey, the Preliminary Monthly Electric Generator Inventory (Form EIA-860M), collects the updated status of any projects scheduled to come online within the next 12 months.

Table 4-3. Form EIA-860 Fields

	Field		Field
1	Utility ID	19	Storage Technology 1
2	Utility Name	20	Storage Technology 2
3	Plant Code	21	Storage Technology 3
4	Plant Name	22	Storage Technology 4
5	State	23	Nameplate Reactive Power Rating
6	County	24	Storage Enclosure Type
7	Generator ID	25	Arbitrage
8	Status	26	Frequency Regulation
9	Technology	27	Load Following
10	Prime Mover	28	Ramping / Spinning Reserve
11	Sector Name	29	Co-Located Renewable Firming
12	Sector	30	Transmission and Distribution Deferral
13	Nameplate Capacity (MW)	31	System Peak Shaving
14	Summer Capacity (MW)	32	Load Management
15	Winter Capacity (MW)	33	Voltage or Reactive Power Support
16	Operating Year	34	Backup Power
17	Maximum Charge Rate (MW)	35	Excess Wind and Solar Generation
18	Maximum Discharge Rate (MW)		

4.5. Project Financing

The U.S. Department of Energy has established a number of Offices that are designed to support project financing for energy storage projects. As the different Departments within the U.S. DOE have different roles, so too will be the approach in supporting the market differ. Although these will range from developing innovative financing strategies to financing project connected to the transmission network, all of the programs are designed to reduce the eventual cost and expand the opportunity for developers and customers to successfully develop successful energy storage projects.

4.5.1. U.S. DOE Loan Programs Office

The U.S. Department of Energy established the Loan Programs Office to accelerate the deployment of innovative clean energy projects across the United States. The Loan Program Office traces its beginning to the Energy Policy Act of 2005, which included Title XVII (Incentives for Innovated Technologies) that created the Section 1703 loan program and the Loan Program Office. The Loan Program Office targets projects that improve the integration of renewable energy generation into the power grid by enhancing the capability for renewable energy variability, dispatchability, congestion, and control.

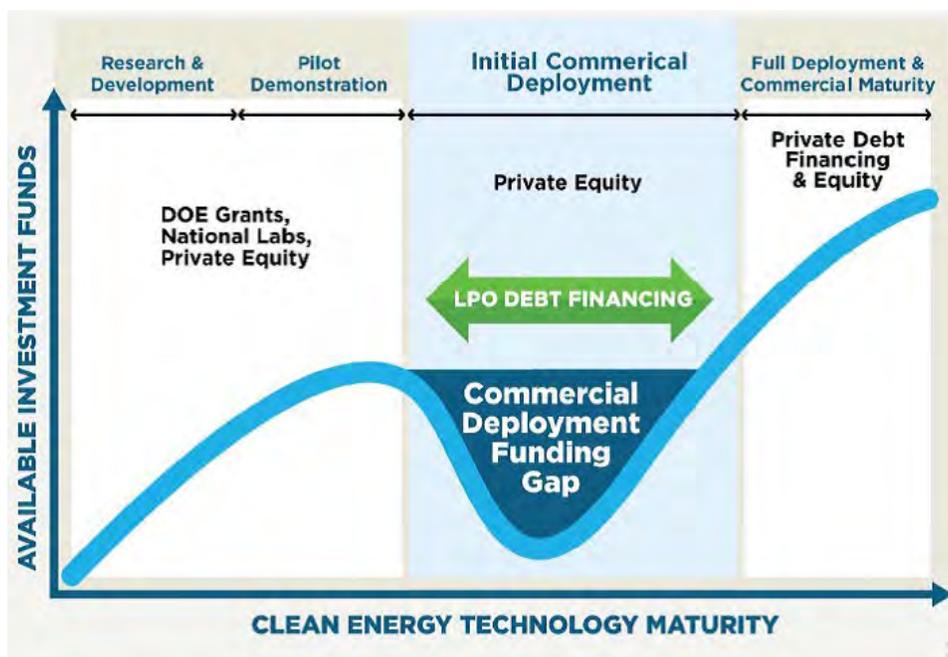


Figure 4-12. Bridging the Gap

Source: U.S. DOE Loan Program Office

The DOE Loan Program Office was developed to promote innovative financing alternative to support emerging energy technologies such as energy storage. The Loan Programs Office can support the energy storage industry significantly by working with the financial community to educate it on the value proposition of energy storage. Through co-lending or working with other lenders on the securitization of asset, the Loan Program's office can leverage relatively small amounts of its financing ability to greatly expand the market.

4.5.2. U.S. Office of Electricity

The U.S. Office of Electricity now hosts a number of federal power marketing agencies such as the Bonneville Power Administration (BPA), Southeastern Power Administration (SEPA), Southwestern Power Administration, (SWPA), and the Western Area Power Administration (WAPA). These Administrations operate and maintains electric transmission lines and associated facilities in accordance with the Federal Power Act, Section 211, and our Open Access Transmission Service Tariff.

The Western Area Power Administration is a good example of how one of these groups can support energy storage project financing of large projects. Through an infrastructure financing program aimed at expanding and modernizing the electric grid, WAPA's Transmission Infrastructure Program (TIP) can make loans to project. According to the WAPA website, the TIP's primary goal is to leverage federal funds and attract private and other non-federal co-investment to support the development of critical transmission and related infrastructure. Through this program, WAPA is working with AES Energy Storage LLC to support the proposed Arizona Peaking Capacity Energy Storage Project. This proposed project is a 100-megawatt (MW) battery energy storage facility adjacent to the existing Arizona Public Service Company's (APS) Westwing Substation within Maricopa County, Arizona.

REFERENCES

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- [3] 2019 Energy Storage Pricing Survey, Sandia National Laboratories, Albuquerque, NM, (unpublished)
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- [6] Ibid. Best Practice Guide 5: Construction, Chapter 2: EPC Contract
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APPENDIX A. U.S. DOE ENERGY STORAGE FINANCING RESOURCES

Energy Storage Grand Challenge

- <https://www.energy.gov/energy-storage-grand-challenge/energy-storage-grand-challenge>

Funding and Financing for Energy Projects

- Funding & Financing for Energy Projects: <https://energy.gov/funding-financing-energy-projects>
- Federal Financing Facilities Available for Energy Efficiency Upgrades and Clean Energy Deployment:
<https://www.energy.gov/sites/prod/files/2013/08/f2/Federal%20Finance%20Facilities%20Available%20for%20Energy%20Efficiency%20Upgrades%20and%20Clean%20Energy%20Deployment.pdf>
- Federal Financing Programs for Clean Energy:
<https://energy.gov/sites/prod/files/2016/05/f32/Federal%20Financing%20Programs%20for%20Clean%20Energy.pdf>

Loan Programs Office

- <https://energy.gov/funding-financing-energy-projects>

Office of Electricity (OE)

Energy Storage Program

- <https://www.energy.gov/oe/activities/technology-development/energy-storage>
- Fact Sheet: [Energy Storage Program Fact Sheets](#)

Database

- Global U.S. DOE Energy Storage Database: <https://www.energystorageexchange.org/>

Reports

- [Energy Storage System Guide for Compliance with Safety Codes and Standards](#)
- [DOE/EPRI 2015 Electricity Storage Handbook in Collaboration with NRECA](#)

Energy Storage Technology Advancement Partnership (ESTAP)

- The Energy Storage Technology Advancement Partnership (ESTAP) is a federal-state funding and information sharing project, managed by the Clean Energy States Alliance (CESA), which aims to accelerate the deployment of electrical energy storage technologies in the U.S.
<https://www.cesa.org/projects/energy-storage-technology-advancement-partnership/>
- Energy Storage Procurement Guidance Documents for Municipalities:
<http://www.cesa.org/assets/2016-Files/Energy-Storage-Procurement-Guidance-Document.pdf>
- Commissioning Energy Storage: <http://www.cesa.org/assets/Uploads/ESTAP-Webinar-Slides-5.20.14.pdf>

Fossil Energy (FE)

- <https://netl.doe.gov/coal/crosscutting/energy-storage>

Energy Efficiency and Renewable Energy (EERE)

- State Energy Program: <https://energy.gov/eere/wipo/state-energy-program>

Energy Information Agency (EIA)

Key Reports

- **U.S. Battery Storage Market Trends**
https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf

Articles

- <https://www.eia.gov/todayinenergy/detail.php?id=40072>
- <https://www.eia.gov/todayinenergy/detail.php?id=42995>
- <https://www.eia.gov/todayinenergy/detail.php?id=41833>

Sandia National Laboratory (SNL)

Energy Storage Program

- U.S. Department of Energy, Energy Storage Systems
<https://www.sandia.gov/ess-ssl/>
- U.S. Department of Energy, Energy Storage Systems: Publications:
<http://www.sandia.gov/ess/sandia-national-laboratories-publications/>

Energy Storage Valuation Modeling

- QuESt Model, <https://energy.sandia.gov/tag/quest/>

Key Reports

- DOE/EPRI Electricity Storage Handbook with NRECA:
<http://www.sandia.gov/ess/publications/SAND2015-1002.pdf>
- DOE OE Energy Storage Systems Safety Roadmap Focus on Codes and Standards—
SAND2017-9147R: <http://www.sandia.gov/energystoragesafety/wp-content/uploads/2017/08/Roadmap-CS-report-August-2017-final.pdf>
- Energy Storage Financing: *A Roadmap for Accelerating Market Growth*
<http://www.sandia.gov/ess/publications/SAND2016-8109.pdf>
- Energy Storage Financing: *Performance Impacts on Project Financing*,
https://www.sandia.gov/ess-ssl/wp-content/uploads/2018/12/ESF2-MustangPrairie_SAND2018-10110_final.pdf
- DOE OE Energy Storage Systems Safety Roadmap,
http://www.sandia.gov/ess/publications/EnergyStorage_safetyroadmap_2017.pdf
- Energy Storage Procurement - Guidance Documents for Municipalities,
<http://www.sandia.gov/ess/publications/SAND2016-8544O.pdf>

- Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems, <http://www.sandia.gov/ess/publications/SAND2016-3078R.pdf>
- Methodology to Determine the Technical Performance and Value Proposition for Grid-Scale Energy Storage Systems: A Study for the DOE Energy Storage Systems Program, <http://www.sandia.gov/ess/publications/SAND2012-10639.pdf>

Pacific Northwest National Laboratory (PNNL)

Energy Storage Program

- PNNL Stationary Energy Storage Reports- DOE OE Energy Storage Program, <https://energymaterials.pnnl.gov/esp/reports.stm>

Energy Storage Valuation Modeling

- Energy Storage Optimization Tools
<https://availabletechnologies.pnnl.gov/technology.asp?id=413>

Key Reports

- Energy Storage System Safety: Plan Review and Inspection Checklist, <https://energymaterials.pnnl.gov/pdf/PNNL-SA-124486.pdf>
- Measuring and Expressing the Performance of Energy Storage Systems (Presentation) <https://energymaterials.pnnl.gov/pdf/PNNL-SA-118995.pdf>
- Energy Storage System Guide for Compliance with Safety Codes and Standards; <http://www.sandia.gov/ess/publications/SAND2016-5977R.pdf>
- Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems, <https://energymaterials.pnnl.gov/pdf/PNNL-22010Rev2.pdf>
- Overview of Development and Deployment of Codes, Standards and Regulations Affecting Energy Storage System Safety in the United States; http://www.sandia.gov/ess/docs/safety/Codes_101_PNNL_23578.pdf
- Inventory of Safety-related Codes and Standards for Energy Storage Systems with some Experiences related to Approval and Acceptance; <https://energymaterials.pnnl.gov/pdf/PNNL-23618.pdf>

National Renewable Energy Laboratory (NREL)

Renewable Energy Finance

- Renewable Energy Project Finance, <https://financere.nrel.gov/finance/>

Energy Storage Valuation Modeling

- REopt: Renewable Energy Integration & Optimization, <https://reopt.nrel.gov/tool>

Key Reports

- Installed Cost Benchmarks and Deployment Barriers for Residential Solar Photovoltaics with Energy Storage: Q1 2016, <https://www.nrel.gov/docs/fy17osti/67474.pdf>
- Identifying Potential Markets for Behind-the-Meter Battery Energy Storage: A Survey of U.S. Demand Charges, <https://www.nrel.gov/docs/fy17osti/68963.pdf>

- Battery Energy Storage Market: Commercial Scale, Lithium-ion Projects in the U.S., <https://www.nrel.gov/docs/fy17osti/67235.pdf>

Argonne National Laboratory (ANL)

Energy Storage Program

- <https://www.anl.gov/pse/energy-storage>

Joint Center for Energy Storage Research (JCESR)

Energy Storage Program

- <http://www.jcesr.org/>

Idaho National Laboratory (INL)

Energy Storage Program

- Clean Energy & Transportation, <https://at.inl.gov/SitePages/Energy%20Storage.aspx>

Energy Storage Publications

- <https://avt.inl.gov/project-type/advanced-energy-storage-publications>

National Energy Technology Laboratory (NETL)

- <https://netl.doe.gov/coal/crosscutting/energy-storage>

APPENDIX B. 2019 U.S. DOE ENERGY STORAGE FINANCING SUMMIT (SAN FRANCISCO, CA)



Please join us for this event focused on valuing individual systems and entire portfolios of energy storage projects, enabling financial institutions greater transparency and a deeper insights into this emerging asset class in preparation for investments. These studies are part of the U.S. DOE's outreach effort to the financial industry to promote market development through reducing barriers to entry, reducing transaction costs, and promoting wider access to low cost capital. Speakers will include representatives from the U.S. DOE and industry experts who have experience with the challenges and opportunities of investing in energy storage projects.

This complimentary event is by invitation only, and you must be registered to attend; only those people receiving this email directly and registering will be assured a spot while there is space available. Please note that this event is closed to the media.



This year's first keynote speaker is Janea Scott, Commission of the California Energy Commission



This year's second keynote speaker is Troy Miller, Chairman of the Board of the Energy Storage Association, and North American Sales Leader for Energy Storage at GE Power.

Tuesday, October 22nd, 2019
11:30AM – 6:00PM ET

Kirkland & Ellis, LLP
555 California St, 27th floor, San Francisco, CA 94104



KIRKLAND & ELLIS LLP





U.S. DOE ENERGY STORAGE VALUATION WORKSHOP | 9:00-11:00 a.m.

Moderator Ray Byrne, *Manager of the Electric Power System Research Department, Sandia National Laboratories*

Panelists Patrick Balducci, *Pacific Northwest National Laboratory* Giovanni Damato, *Electric Power Research Institute Inc.*
 Ricky Concepcion, *Sandia National Laboratories* Tu Nguyen, *Sandia National Laboratories*

U.S. DOE ENERGY STORAGE FINANCING SUMMIT | 12:00-5:00 p.m.*

Chairman Richard Baxter, *President, Mustang Prairie Energy*

DOE Energy Storage Program Imre Guk, *Energy Storage Program Director, U.S. Department of Energy*

Welcome Remarks Paul Tanaka, *Kirkland & Ellis LLP*

Keynote Speakers Janea Scott, *Vice Chair - Commissioner, California Energy Commission*
 Troy Miller, *Chairman of the Board, Energy Storage Association*

Panel 1: Wholesale Markets

Moderator

Robert Fleishman
Kirkland & Ellis LLP

Panelists

Ali Amirali, *Starwood Energy*
 Jay Goldin, *Munich Re*
 Luke Hansen, *8Minute*
 Randy Mann, *esVolta*
 Sean Yovan, *174 Power Global*

Panel 2: BTM and Emerging Opportunities

Moderator

Bill Tarantino
Morrison & Foerster LLP

Panelists

David Cieminis, *Able Grid Energy Solutions*
 Joe Eisenberg, *Sunrun*
 Erik Richardson, *Enel X*
 Josh Rogol, *Strata Solar*
 Russ Weed, *ARES North America*

Panel 3: Investors View

Moderator

Danny Kennedy
New Energy Nexus

Panelist

Gustavo Coito, *SUSI Partners*
 Scott Jacobs, *Generate Capital*
 Matt Koenig, *DNV GL*

* Networking reception to follow.

Keynote Speakers

Imre Gyuk, Manager, U.S. DOE Energy Storage Program



Dr. Imre Gyuk is the Energy Storage Program Manager for the U.S. Department of Energy Office of Electricity Delivery and Energy Reliability. He holds a B.S. from Fordham University, and a Ph.D. in Theoretical Particle Physics from Purdue University. He has been responsible for the DOE's energy storage program for 20 years, including directing the \$185 million program for the ARRA stimulus funding.

Janea Scott, Vice Chair, Commissioner, California Energy Commission



Vice Chair Janea A. Scott is serving in her second term on the California Energy Commission. She was appointed Vice Chair in 2019. Scott is one of five commissioners on the Energy Commission, which is the state's primary energy policy and planning agency. Scott was appointed by Governor Edmund G. Brown Jr. in February 2013 and reappointed by Governor Brown in January 2016 to serve as the Energy Commission's public member.

Troy Miller, GE Power and Energy Storage Association



Troy Miller is the North American Sales Leader for Energy Storage at GE Power. He has over 25 years of experience in the Power Engineering industry. Mr. Miller has lengthy experience in the application and implementation of all aspects of energy storage, renewable energy, and microgrids. Mr. Miller is the Chairman of the Board of Directors at the Energy Storage Association (ESA), and serves as a Vice President of the National Alliance for Advanced Technology Batteries (NAATBatt).

Host

Paul Tanaka, Partner, Kirkland & Ellis LLP



Paul Tanaka leads Kirkland's Global Environmental Practice, serving as head environmental counsel for a large number of private equity firms and public companies. Paul's clients rely on him to identify and strategically manage environmental regulatory compliance and other environmental liabilities.

Summit Chairman

Richard Baxter, President, Mustang Prairie Energy



Richard Baxter is President of Mustang Prairie Energy where he bridges the financial and technical sides of the market. He is the author of the book "*Energy Storage: A Nontechnical Guide*" (PennWell), and author of the Energy Storage Financing report series for Sandia National Laboratories. He has been active in the energy storage industry for 20 years, and served on the Board of Directors for the Energy Storage Association (ESA), and was Chairman of the Board for NovoCarbon (TSX-V: GLK)

DOE Energy Storage Valuation Workshop

Ricky Concepcion, Sandia National Laboratories



Ricky Concepcion joined the Electric Power Systems Research group at Sandia National Laboratories as a member of technical staff in 2014. He has conducted research in the areas of electric transmission systems and energy storage system valuation. He is the lead developer of QuESt, Sandia's open source software tool for energy storage valuation and related applications. His other research interests include signal processing, optimization, and related fields.

Tu Nguyen, Sandia National Laboratories



Tu A. Nguyen is a Senior Member of the Technical Staff at Sandia National Laboratories. He received his B.S degree in Power Systems from Hanoi University of Science and Technology, Vietnam in 2007. He worked as a Power Transformer Test Engineer in ABB High Voltage Test Department in Vietnam from 2008 to 2009. He received his Ph.D. degree from Missouri University of Science and Technology in December 2014.

Patrick Balducci, Pacific Northwest National Laboratories



Patrick Balducci has 20 years of professional experience as an economist and project manager. He is a Chief Economist at the Pacific Northwest National Laboratory (PNNL) where he has been employed since 2001. He is currently leading the industrial acceptance areas of the PNNL Energy Storage Program. He has extensive experience in modeling the benefits of energy infrastructure and in leading research and development efforts supporting the U.S. Department of Energy (DOE) and the electric power industry.

Giovanni Damato, Electric Power Research Institute



Giovanni Damato serves as Principal Project Manager in the Energy Storage and Distributed Energy Resource Program at the Electric Power Research Institute (EPRI). Giovanni has nearly fifteen years of professional experience leading the exploration of distributed energy resources (DER), including grid-connected energy storage. Giovanni provides innovative grid storage and DER techno-economic analyses with strategic recommendations to energy industry stakeholders.

Moderator

Ray Byrne, Sandia National Laboratories



Ray Byrne is manager of the Electric Power System Research department at Sandia National Laboratories, where he has been employed since 1989. He holds a Ph.D. in electrical engineering from the University of New Mexico, an M.S. in electrical engineering from the University of Colorado, Boulder, and a B.S. in electrical engineering from the University of Virginia. He also completed an M.S. in financial mathematics at the University of Chicago. Previously, he was a distinguished member of the technical staff at Sandia.

Panel 1: Wholesale Markets

Jay Goldin, Munich RE



Jay Goldin is the Vice President of Green Tech Solutions for Munich Re America. In this role, he works with energy system manufacturers, developers and financiers to support solar, wind, energy storage and bioenergy project development. Prior to Munich Re, Jay led business development at Enphase Energy and received his MBA and AB from Stanford University.

Ali Amirali, Starwood Energy Group



Ali Amirali is a Senior Vice President of Starwood Energy Group. In this role, Mr. Amirali is responsible for the expansion of Starwood Energy Group's StarTrans high-voltage transmission assets. He also supports the origination, development and acquisition activities associated with utility-scale power generation and storage projects.

Krish Koomar, esVolta



Krish Koomar is the CFO of esVolta. He oversees all financial aspects of the company, manages shareholder relationships & reporting as well as the overall company strategy. Krish has 20+ years of treasury & finance experience in the renewable/conventional power and banking sectors. He brings significant transactional experience - closed transactions exceeding \$10 billion (via Corporate, Project & vendor financings & M&A transactions) in the U.S as well as internationally.

Sean Yovan, 174 Global



Sean has over 10 years of utility power procurement experience, mostly leading the short-term planning and bidding strategy functions at Southern California Edison. More recently he pivoted to utility scale project development, and contract origination with a move to Southern Company where he was responsible for growing Southern Company's business in the western region of the U.S.

Luke Hansen, 8Minute



Luke has been with 8minute Solar Energy for two years where he is the Senior Director for Storage and has three announced PPA's totaling 435 MW and nearly 2 GWh of energy in solar plus storage systems. Prior to 8minute, Luke was a Senior Battery System Engineer at General Electric for 5 years, where he designed, built and commissioned more than a dozen Battery Energy Storage Systems totaling over 80 MW and earned 10 U.S. patents

Moderator

Bob Fleishman, Sr. Of Counsel, Morrison & Foerster, LLP [Moderator]



Robert Fleishman is senior of counsel in the firm's corporate department, resident in the Washington, D.C. office. Mr. Fleishman has a leading reputation defending energy and financial industry participants and individuals in energy markets against charges of market manipulation, particularly before the Federal Energy Regulatory Commission (FERC), the Commodity Futures Trading Commission (CFTC), and other regulatory bodies, and advising companies on the energy regulatory and compliance aspects of transactions and other energy market activities.

Panel 2: BTM and Emerging Opportunities

Joe Eisenberg, SunRun



Joe Eisenberg is a Director in the Project Finance group at Sunrun, where he works on a variety of structured finance transactions in tax equity, debt and securitization. In this capacity, Joe has overseen the launch of Sunrun's energy storage products to the capital markets. He has been with Sunrun for six years, having previously worked at Renewable Analytics, an investment research and consulting firm, and Susquehanna International Group, a multinational financial firm.

David Cieminis, Able Grid Energy Solutions



David's ten years in renewable energy include roles in origination, development and finance. Prior to founding Able Grid, David led origination efforts for 8minutenergy in the West and Southwest with a focus on development and storage contracting. During his five years at SunEdison, he held a variety of roles on both utility and DG projects that enabled the financing and construction of hundreds of MWs of new solar projects.

Erik Richardson, EnelX



Erik Richardson is a Senior Manager leading West Coast Business Development for Enel X North America's Flexibility Solutions team. In his role Erik is responsible for the development of new markets, commercial offerings, and strategic partnerships for energy storage and flexible energy solutions. Prior to joining Enel X, Erik worked in community solar project acquisition and development at NRG Renewables (now Clearway Energy Group).

Russ Weed, Cleantech Strategies



Russ is a seasoned business developer, marketing and sales executive, and legal manager, with 28 years of experience in the energy and electronics industries. He has a track record of success at GE, UET, and leading law firms when an attorney in private practice. In 2018, Russ established a cleantech consultancy, CleanTech Strategies.

Josh Rogol, Strata Solar



Joshua Rogol serves as Senior Vice President of Energy Storage at Strata Solar, leading origination and development of stand-alone and solar plus storage projects across the US, and responsible for contracting over 500MWh. Previous experience includes VP of Sales at ViZn Energy, VP of Business Development for Urban Green Energy (UGE) and was a founding member of PHOTON Consulting.

Moderator

Bill Tarantino, Morrison & Foerster LLP



Mr. Tarantino also has broad experience in consumer class action and false advertising litigation, particularly with respect to claims of health or environmental benefits. Prior to joining Morrison & Foerster, Mr. Tarantino clerked at the U.S. Environmental Protection Agency, Region IX Office of Regional Counsel, where he assisted in the prosecution and resolution of cases brought by the U.S. Department of Justice for violation of hazardous waste and water quality laws

Panel 3: Investor's View

Gustavo Coito, SUSI Partners



Gustavo focuses on the origination, structuring and execution of energy storage infrastructure deals globally. He has worked on over ten billion euros of energy and infrastructure transactions in more than ten countries across five continents. He has 11 years of relevant finance experience, six of which he spent in the Natural Resources M&A team at Goldman Sachs in London, followed by his tenure at Actis, a leading growth markets private equity investor.

Scott Jacobs, Generate Capital



Scott Jacobs is the CEO and Co-Founder of Generate Capital. Scott's long-standing emphasis on innovative approaches to thematic investing focus broadly on the "resource revolution." Prior to Generate, Scott served as a Managing Director and Co-Founder of EFW Partners, an investment firm focused on the world's critical resources: energy, food, and water.

Matt Koenig, DNVGL



Matt was a Co-Founder of Corvus Energy, a manufacturer of integrated energy storage modules for commercial marine electric and hybrid propulsion storage solutions. He worked as a director of sales for Princeton Power System where he led development and sales of energy storage and microgrid projects, a founding team member of the sales and BD team as a senior manager at Lockheed Martin Energy Storage, and most recently as principal consultant for ESS and DER at DNVGL.

Danny Seagraves, Willis Towers Watson



Danny Seagraves is recognized globally as a leading expert in the creation and implementation of sophisticated risk finance and risk management solutions whose primary purpose is to allow his clients to achieve superior bankability for their cutting-edge investments. He is also on the alternative energy bankability global leadership team at Willis Towers Watson.

Herschel Salan, NEC Financial



Herschel Salan, President of NEC Financial Services, provides enhanced financing solutions for diverse industry clients. With over 30 years of experience in leasing and financial services, Herschel and his team are focusing their efforts on providing energy storage project financing in the United States and emerging markets in the United Kingdom and Europe

Moderator

Danny Kennedy, Managing Director of CalCEF & CalCharge



Danny Kennedy leads the California Clean Energy Fund, connecting entrepreneurs everywhere to capital to build an abundant clean energy economy that benefits all. He is also the President of CalCharge, a public private partnership with the National Labs and universities of California, unions, and companies, working to advance energy storage.

Attendee List

	Company	First	Last	Title
1	174 Power Global Corporation	Sean	Yovan	
2	8minutenergy Renewables, LLC	Dan	Myers	Manager
3	8minutenergy Renewables, LLC	Luke	Hansen	
4	Able Grid Energy Solutions	David	Cieminis	Chief Commercial Officer
5	CEC	Janea	Scott	
6	CES	Pramod	Kulkarnie	
7	Clean Path Ventures	Matt	Cheney	CEO
8	Cleantech Strategies	Russ	Weed	
9	Coronal Energy	Yaron	Glazer	Vice President Strategy
10	DNVGL	Matt	Koenig	
11	DOE	Imre	Gyuk	
12	EnelX	Erik	Richardson	
13	Energy Vault	Marco	Terruzzin	Chief Product Officer
14	Engie Storage	Tim	Larrison	CFO
15	EPRI	Giovanni	Damato	
16	EPRI	Ben	Kaun	Program Manager, Energy Storage and Distributed Generation Program
17	ESA	Troy	Miller	
18	EsVolta	Krish	Koomar	
19	FlexEnergy	Pedro	Elizondo	Senior Manager, Business Development
20	GELI	Ben	Brown	CFO
21	Generate Capital Inc	Michael	Huerta	
22	Generate Capital, Inc.	Ed	Bossange	
23	Hareon Solar	Rubin	Sidhu	Deputy Technology Director
24	Hitachi Capital America Corp	Tom	Waters	Vice President - Energy Solutions
25	Kirkland & Ellis LLP	Paul	Tanaka	Partner
26	Kirkland & Ellis LLP	Michael	Saretsky	Associate
27	Kirkland & Ellis LLP	Ashton	Starr	Business Development Coordinator
28	Kirkland & Ellis LLP	Robert	Fleishman	Partner
29	Kohlberg Kravis Roberts & Co. L.P.	Cav	Walters	Principal
30	kWh Analytics	Hai	Shen	Chief of Staff
31	LS Power Development, LLC	Cody	Hill	Director, Energy Storage
32	Macquarie	Andres	Pacheco	
33	Morrison & Foerster LLP	William	Tarantino	
34	Munich Re	Josef	Pommerening	Green Tech Solutions
35	Munich Reinsurance America, Inc.	Jay	Goldin	Vice President
36	Mustang Prairie	Richard	Baxter	President
37	New Energy Nexus	David	Kennedy	
38	New Energy Risk	Tom	Dickson	CEO
39	Pacific Northwest National Laboratory	Patrick	Balducci	
40	Pvel	Alex	Mayer	Technologist
41	Renewance	David	Mauer	VP, Sales and Services
42	Sandia National Laboratories	Raymond	Byrne	
43	Sandia National Laboratories	Babu	Chalamala	
44	Sandia National Laboratories	Alexander	Headley	
45	Sandia National Laboratories	Joseph William	McNamara	
46	Sandia National Laboratories	Howard	Passell	
47	Sandia National Laboratories	Sharon Ann	Ruiz	
48	Sandia National Laboratories	Ricky	Concepcion	
49	Sandia National Laboratories	Tu	Nguyen	
50	Silicon Valley Bank	Troy	Ault	Vice President

Attendee List (Cont.)

	Company	First	Last	Title
51	SK E&S Americas	Deokyong	Kang	
52	SK E&S Americas	Bryan	Lee	
53	Starwood Energy Group	Ali	Amirali	
54	STEM	Prakesh	Patel	VP Strategy and Capital Markets
55	Stem	William	Hanley	Project Finance Manager
56	Stem, Inc.	Charlotte	Schmidlapp	Director, Finance
57	Strata Solar	Joshua	Rogol	
58	Sunrun Inc.	Joseph	Eisenberg	Senior Associate
59	Sunrun Inc.	Sean	Dimeo	Associate
60	SUSI Partners AG	Gustavo	Coito	
61	Swinerton Renewable Energy	Craig	Horne	
62	UET	Rick	Winter	President & CEO
63	USI Insurance Services	Dixon	Wright	Senior Vice President
64	Veridity Energy Solutions, Inc.	Mark	Stout	Director, Business Development
65	Voltaiq	Cicely	Li	Sr Analyst, Business Development
66	Willis Towers Watson	Danny	Seagraves	

Synopsis

On October 22nd, 2019, Kirkland & Ellis, and Mustang Prairie Energy in partnership with the U.S. Department of Energy and Sandia National Laboratory presented a one-day Energy Storage Finance Advisory Committee Meeting at Kirkland & Ellis' San Francisco that had 66 attendees. Speakers included representatives from the U.S. Department of Energy, the California Energy Commission, and industry experts who have experience with the challenges and opportunities of investing in energy storage projects.

The Summit was the first Energy Storage Finance Advisory Committee Meeting for a U.S. Department of Energy sponsored study to issues and challenges surrounding project and portfolio valuation. This series of studies are part of the U.S. Department of Energy's effort to promote market development through reducing barriers to entry, reducing transaction costs, and promoting wider access to low cost capital in order to promote development across the energy storage industry.

In the morning prior to the Summit, the 2019 U.S. Department of Energy's Energy Storage Valuation Workshop was held to provide an overview of project valuation model development. Parties from Sandia National Laboratories, Pacific Northwest National Laboratory, and the Electric Power Research Institute presented their models and examples of the type of project evaluation capable from the different approaches.

The first Keynote address was given by Janea Scott, Vice Chair, Commissioner, California Energy Commission. Her presentation showcased the efforts of the State of California's effort to promote the development of energy storage project development at all levels of the electrical power sector to promote customer choice, improved service, and a more resilient power grid.

The second Keynote address was given by Troy Miller, Chairman of the Board of the Energy Storage Association, and North American Sales Lead for GE Power. His presentation showcased the efforts of the Energy Storage Association and one of the leading system integrators to promote policy and economic development that will benefit the entire industry.

The final Keynote was given by Dr. Imre Gyuk of the Office of Electricity of the U.S. Department of Energy. His presentation showcased the efforts of the U.S. DOE to support energy storage technology and market development. The presentation highlighted all of the areas where the U.S. DOE is supporting the market and showcased how all of the different parts support the Department's other efforts.

The first panel of the day focused on Wholesale Markets. The discussion focused on the current state of project financing for large scale energy storage projects currently, how the market is changing, and included expectations for where it will go in the next two to three years. The panelists shared their insights into the current competition driving down system costs and the stubbornly low expected profit margins on projects. As many project sizes continue to rise, competition for these marquee projects will continue to be fierce. However, recent fires at battery facilities have caused safety requirements to rise, adding costs to customer requirements to meet more stringent codes and inspections. Panelists continue to believe therefore that is a significant amount of unpriced market risk from a variety of unknowns as these relatively new technologies are applied to emerging applications. The sheer number of new entrants entering the market and aggressively bidding low to win contracts has been hiding some of this price risk the panelists believe. Although all agreed that NMC Lithium Ion technologies are the established standard, all were interested in the prospects for other technologies, both technological capability, but more importantly, their bankability for a project. To address the market risk, operational knowledge and expertise was mentioned as essential.

A key part of this strategy is the software used to analyze the health of the unit and make operational decisions based on market conditions. A deeper level of market understanding was considered important as contracts continue to decline in length, with a merchant tail becoming a regular part of the operational assumption for storage facilities in the future.

The second panel of the day focused on Behind the Meter and Emerging Opportunities. The discussion focused on emerging retail applications, and the fast rising solar/storage opportunities. In order to ensure successful operation of the unit, the importance of the balance of plan for system design and operation were highlighted as areas of importance. Many system failures have their point of origin in a faulty support system, not just the battery component. This question as to the system engineering of the unit also extended into the available engineering and technical support. Having available 3rd party expertise was deemed essential as some panelists wondered how the different project and operating costs affect the project design and operation planning. Obviously, spending the time to get this part right will have an impact on the partners chosen, and if quality wins out, financial partners will be more comfortable, and thus have a larger risk appetite knowing the project is as fundamentally sound as is possible.

The final panel of the day focused on the Investor's Viewpoint. Here, investors were able to discuss what type of investment risks that are willing, and not willing to take. Many explained their answers based on the type of investor they were – debt provider for large projects, leases for BTM commercial units, or equity capital provider. It was also mentioned that there was a difference in the pricing of technical and project risks. Some of the panelists discussed their ongoing challenge of improving the credit worthiness of revenue streams for investors to support the economic models of the developers. This panel took up the conversation about safety and describe the issue of insurance firms and their approach to energy storage systems with the prospect of fires and other potential calamities. The group in general then discussed ways their felt could make Lithium safer, and convince the public of this safety?

APPENDIX C. 2020 U.S. DOE ENERGY STORAGE FINANCING SUMMIT (NEW YORK, NY)



Please join us for this event focused on valuing individual systems and entire portfolios of energy storage projects, enabling financial institutions greater transparency and a deeper insights into this emerging asset class in preparation for investments. These studies are part of the U.S. DOE's outreach effort to the financial industry to promote market development through reducing barriers to entry, reducing transaction costs, and promoting wider access to low cost capital. Speakers will include representatives from the U.S. DOE and industry experts who have experience with the challenges and opportunities of investing in energy storage projects.

This complimentary event is by invitation only, and you must be registered to attend; only those people receiving this email directly and registering will be assured a spot while there is space available. Please note that this event is closed to the media.



This year's first keynote speaker is Chandrasekar Govindarajalu, World Bank



This year's second keynote is Alicia Barton, President & CEO of NYSERDA

Tuesday, January 14th, 2020
11:30AM – 6:00PM ET

Kirkland & Ellis, LLP
601 Lexington Ave, New York, NY 10022



KIRKLAND & ELLIS LLP





U.S. DOE ENERGY STORAGE VALUATION WORKSHOP | 9:00-11:00 a.m.

Moderator Ray Byrne, *Sandia National Laboratories*

Panelists Patrick Balducci, *Pacific Northwest National Laboratory* Giovanni Damato, *Electric Power Research Institute Inc.*
 Ricky Concepcion, *Sandia National Laboratories* Alex Headley, *Sandia National Laboratories*

U.S. DOE ENERGY STORAGE & FINANCING SUMMIT | 12:00-5:00 p.m.*

Chairman Richard Baxter, *Mustang Prairie Energy*

DOE Energy Storage Program Imre Gyuk, *U.S. Department of Energy*

Welcome Remarks Robert Fleishman, *Kirkland & Ellis LLP*

Keynote Speakers Alicia Barton, *NYSERDA*
 Chandrasekar Govindarajalu, *Energy Climate Finance, The World Bank*

Panel 1: Market Outlook

Moderator
 Robert Fleishman
Kirkland & Ellis LLP

Panelists
 Jeff Bishop, *Key Capture Energy*
 Geoff Brown, *Powin Energy*
 Kelly Sarve, *Strategic Management Group*
 Michael Schrempp, *Munich Re*
 Dan Wishnick, *Fluence*

Panel 2: Capital Providers

Moderator
 Kelann Stirling
Kirkland & Ellis LLP

Panelists
 Amy McCartin, *NY Green Bank*
 John O'Brien, *Siemens Financial*
 Chris Pagano, *Hitachi Capital*
 Herschel Salan, *NEC Financial*
 Dan Tobin, *U.S. DOE Loan Program Office*

Panel 3: International Opportunities

Moderator
 Ali Zaidi
Kirkland & Ellis LLP

Panelists
 Peter Mockel, *IFC*
 Nick Sangermano, *Rubicon Capital Advisors*
 Paul Smith, *Wartsila Development Finance Services*
 Matt Tappin, *Shell New Energies*

* Networking reception to follow.

Presented by:

KIRKLAND & ELLIS



In partnership with:



Keynote Speakers

Imre Gyuk, Manager, U.S. DOE Energy Storage Program



Dr. Imre Gyuk is the Energy Storage Program Manager for the U.S. Department of Energy Office of Electricity Delivery and Energy Reliability. He holds a B.S. from Fordham University, and a Ph.D. in Theoretical Particle Physics from Purdue University. He has been responsible for the DOE's energy storage program for 20 years.

Chandrasekar Govindarajalu, World Bank



Chandra Govindarajalu leads the global battery storage program at the World Bank. The World Bank has made commitment to accelerate deployment of battery storage in the developing world with an aim to finance 17.5 GWh of new battery storage in developing countries by 2025. He also leads the energy climate finance team which is responsible for mobilizing climate finance from Climate Investment Funds (CIFs), and the Green Climate Funds (GCF).

Alicia Barton, NYSERDA



Alicia Barton is President and CEO of the New York State Energy Research and Development Authority. Ms. Barton has held public and private sector leadership roles advancing clean energy projects and companies for over a decade. Immediately prior to her appointment, Ms. Barton served as co-chair of the Energy and Cleantech Practice at Foley Hoag, LLP, a global law firm based in Boston).

Host

Bob Fleishman, Sr. Of Counsel, Morrison & Foerster, LLP [Moderator]



Robert Fleishman is senior of counsel in the firm's corporate department, resident in the Washington, D.C. office. Mr. Fleishman has a leading reputation defending energy and financial industry participants and individuals in energy markets against charges of market manipulation, particularly before the Federal Energy Regulatory Commission (FERC), the Commodity Futures Trading Commission (CFTC), and other regulatory bodies, and advising companies on the energy regulatory and compliance aspects of transactions and other energy market activities.

Summit Chairman

Richard Baxter, President, Mustang Prairie Energy



Richard Baxter is President of Mustang Prairie Energy where he bridges the financial and technical sides of the market. He is the author of the book "*Energy Storage: A Nontechnical Guide*" (PennWell), and author of the Energy Storage Financing report series for Sandia National Laboratories. He has been active in the energy storage industry for 20 years, and served on the Board of Directors for the Energy Storage Association (ESA), and was Chairman of the Board for NovoCarbon (TSX-V: GLK)

DOE Energy Storage Valuation Workshop

Ricky Concepcion, Sandia National Laboratories



Ricky Concepcion joined the Electric Power Systems Research group at Sandia National Laboratories as a member of technical staff in 2014. He has conducted research in the areas of electric transmission systems and energy storage system valuation. He is the lead developer of QuESt, Sandia's open source software tool for energy storage valuation and related applications. His other research interests include signal processing, optimization, and related fields.

Tu Nguyen, Sandia National Laboratories



Tu A. Nguyen is a Senior Member of the Technical Staff at Sandia National Laboratories. He received his B.S degree in Power Systems from Hanoi University of Science and Technology, Vietnam in 2007. He worked as a Power Transformer Test Engineer in ABB High Voltage Test Department in Vietnam from 2008 to 2009. He received his Ph.D. degree from Missouri University of Science and Technology in December 2014.

Patrick Balducci, Pacific Northwest National Laboratories



Patrick Balducci has 20 years of professional experience as an economist and project manager. He is a Chief Economist at the Pacific Northwest National Laboratory (PNNL) where he has been employed since 2001. He is currently leading the industrial acceptance areas of the PNNL Energy Storage Program. He has extensive experience in modeling the benefits of energy infrastructure and in leading research and development efforts supporting the U.S. Department of Energy (DOE) and the electric power industry.

Giovanni Damato, Electric Power Research Institute



Giovanni Damato serves as Principal Project Manager in the Energy Storage and Distributed Energy Resource Program at the Electric Power Research Institute (EPRI). Giovanni has nearly fifteen years of professional experience leading the exploration of distributed energy resources (DER), including grid-connected energy storage. Giovanni provides innovative grid storage and DER techno-economic analyses with strategic recommendations to energy industry stakeholders.

Moderator

Ray Byrne, Sandia National Laboratories



Ray Byrne is manager of the Electric Power System Research department at Sandia National Laboratories, where he has been employed since 1989. He holds a Ph.D. in electrical engineering from the University of New Mexico, an M.S. in electrical engineering from the University of Colorado, Boulder, and a B.S. in electrical engineering from the University of Virginia. He also completed an M.S. in financial mathematics at the University of Chicago. Previously, he was a distinguished member of the technical staff at Sandia.

Panel 1: International Opportunities

Nick Sangermano, Rubicon Capital Advisors



Nick is a Managing Director with Rubicon Capital Advisors (“Rubicon”) and is based in the New York office. His focus within the firm ranges from corporate finance to project finance and private placements across the energy and sustainability sectors globally. Nick has over 15 years of experience in the energy finance industry, having raised more than USD \$2 billion in capital

Peter Mockel, IFC



Peter is a Senior Industry Specialist for embedded systems with IFC’s Climate Business Department. This includes grid scale energy storage (battery) systems, as well as smart utility meters, building management systems, and lighting systems. He has also built and managed R&D labs in Berlin, Beer Sheva and Los Altos. Peter also spent consulting with Booz, Allen & Hamilton

Matt Tappin, Shell New Energies



Matt is a member of the corporate development team at Shell New Energies, where he is involved in acquisitions, investments, partnerships and other complex transactions for Shell’s power-related businesses. Prior to joining Shell, Matt was most recently Vice President of Corporate Business Development at Centrica Business Solutions, the distributed energy business of UK-based utility Centrica plc.

Paul Smith, Wartsila Development Finance Services



Mr. Smith is responsible for Wärtsilä Development Financial Services (WDFS) activities in the Americas. Mr. Smith joined Wärtsilä in 1989 and was a founding member of the Wartsila Development Financial Services team. Wartsila Development Financial Services, Inc. is responsible for green field development of projects using Wartsila equipment since 1991.

Al Berkeley, UN GII



Al is the Former Director of the World Economic Forum USA, Alfred Berkeley was committed to improving the state of the world by engaging industry leaders in partnerships to shape global, regional and industry agendas. He came to the position with a wealth of experience in the financial sector, which culminated in his role as President and subsequently Vice Chairman of NASDAQ Stock Market, Inc.

Moderator

Ali Zaidi, Kirkland & Ellis, LLP



Ali Zaidi is Of Counsel at Kirkland & Ellis LLP and a leader in its Sustainable Investment and Global Impact Group. Ali focuses his practice on identifying, mitigating, and managing environmental, social, and governance risks. He also counsels clients on complex regulatory matters related to climate change and frontier technologies in energy, water, and mobility, including on standards governing artificial intelligence and autonomous systems like drones and driverless vehicles.

Panel 2: Capital Providers

John O'Brien, Siemens Financial



John O'Brien is a Director within Siemens Financial Services' Energy Finance team. John joined the team right after its inception in 2008 and is responsible for originating and structuring renewable (wind, solar) and traditional thermal (CCGT and CT) power transactions. Prior to Siemens, John worked in the utility investment banking groups for Wachovia Securities and KeyBanc Capital Markets.

Chris Pagano, Hitachi Capital



Chris Pagano leads a national team focused on the origination, structuring and execution of project and structured finance solutions within the clean technology, information technology, and commercial and industrial sectors. His experience in the clean technology sector includes the financing of commercial and industrial energy projects, and lender finance facilities for finance companies and project developers.

Andrew Cleary, CIBC



Andrew Cleary has 13 years of experience and provides advisory services for M&A, recapitalizations and capital raise transactions with a focus on the North American power, utilities and energy storage markets. Andrew has worked on transactions involving a variety of generation technologies, including solar, wind, hydro, pumped storage, geothermal and thermal assets.

Cherian Thomas, Nord/LB



Cherian Thomas has over 25 years of experience in the Project Finance space, approximately half in Engineering and half in Finance. He graduated from the University of Texas at Austin with a Bachelor's Degree in Mechanical Engineering in 1992 and transitioned to banking after an MBA at NYU in 2004.

Amy McCartin, NY Green Bank



Amy McCartin is a Director at NY Green Bank on the Investment & Portfolio Management team, working to expand financing markets for clean energy and energy efficiency investments by facilitating transactions with clients and partners. Ms. McCartin holds a bachelor's degree in business administration from University of Michigan Ross School of Business with a concentration in finance and strategy.

Moderator

Kelann Stirling, Kirkland & Ellis LLP



Kelann Stirling has represented sponsors, lenders, and governmental entities in connection with financings of the following types of projects: Oil and gas, LNG, Conventional and renewable power, and Infrastructure. She has experience in all aspects of structuring international and domestic project financings and negotiating and drafting finance and project development documents

Panel 3: Market Outlook

Michael Schrempp, Munich RE



Michael is Global Head of Munich Re's Green Tech Solutions Team with offices in Munich, San Francisco, Hong Kong, and Tokyo. Green Tech Solutions (GTS) develops and offers innovative insurance solutions for Renewable Energy and Energy Efficiency Technologies. Major achievements are innovative performance warranty solutions for green to support bankability, improve financing and enable large projects.

Dan Wishnick, Fluence



Dan Wishnick is a Managing Director at Fluence – A Siemens and AES Company. Siemens and AES have joined forces to form Fluence, a new energy storage technology and services firm that combines the expertise, vision, and financial backing of the two most experienced icons in energy storage. Dan has more than 25 years of experience in sales, marketing, engineering, business development and managing operations.

Jeff Bishop, Key Capture Energy



As co-founder and CEO, Jeff Bishop oversees all aspects of Key Capture Energy and has grown the company from a concept in 2016 to a market leader in building large-scale energy storage projects. He primarily focuses his attention on capital fundraising and allocation, commercial and regulatory strategy, and building a best-in-class team of energy professionals.

Mike Wietecki, Power Energy



Mike serves as the General Counsel and VP: Business Operations of Powin Energy. In that role he oversees all legal, operational, and commercial aspects of the business. Mike has a diverse background covering securities, litigation and risk management, M&A, sustainability, regulatory compliance, and operations. Prior to helping form Powin Energy he held a variety of roles at several financial firms in Minnesota and Oregon.

Kelly Sarber, Strategic Management Group



Kelly Sarber is the CEO of Strategic Management Group and is an expert in sourcing opportunities and building enterprise value around companies and projects in the renewable energy, waste and wastewater industries. Sarber is currently sourcing utility scale battery project sites in NY and CA using a market advantage honed over many decades working with utilities, solid waste companies and other heavy industrial centric businesses.

Moderator

Bob Fleishman, Sr. Of Counsel, Morrison & Foerster, LLP [Moderator]



Robert Fleishman is senior of counsel in the firm's corporate department, resident in the Washington, D.C. office. Mr. Fleishman has a leading reputation defending energy and financial industry participants and individuals in energy markets against charges of market manipulation, particularly before the Federal Energy Regulatory Commission (FERC), the Commodity Futures Trading Commission (CFTC), and other regulatory bodies, and advising companies on the energy regulatory and compliance aspects of transactions and other energy market activities.

Attendee List

	Company_Name	First_Name	Last_Name	Job_Title
1	127 Energy, LLC	Ken	McCauley	Partner & Co-Founder
2	Able Grid	Casey	Keller	
3	Able Grid Energy Solutions	David	Cieminis	Chief Commercial Officer
4	AES	Manish	Kumar	
5	Amazon Web Services, Inc.	Peter	Hirschoeck	
6	Argo Group US	Frank	Petrocelli	Senior Risk Analyst
7	Argo Group US	George	Schulz	Vice President
8	ARPA-E	Rakesh	Radhakrishnan	Technology to Market Advisor
9	Bank Of America	Allison	Saegh-Fleming	Director - Energy Structured Solutions
10	BlackRock, Inc.	Anmay	Dittman	Director
11	BlackRock, Inc.	Rael	McNally	Director, Infrastructure / Renewable Power
12	BlackRock, Inc.	Martin	Torres	
13	Bloomberg New Energy Finance	Yayoi	Sekine	Analyst, Energy Storage
14	BQ Energy	Alicia	Scott	Project Manager
15	BYD America	Kyle	Burak	Director
16	Calpine Corporation	Josh	Farkas	Senior Counsel
17	Calpine Corporation	Krish	Raju	Director
18	Canadian Imperial Bank of Commerce	Andrew	Cleary	Executive Director - Global Infrastructure & Power
19	CIT Bank	Mike	Bonafide	Vice President
20	Coalition for Green Capital	Abraham	Wapner	Associate
21	CohnReznick Capital	Nick	Sangermano	Managing Director
22	ConnectGen, LLC	Colleen	Nash	
23	Constellation	Shane	Smith	MD Project Finance and GenCo Strategy
24	Convergent Energy and Power LP	Toby	Tiktinsky	Vice President Project Development
25	Credit Suisse LLC	John	Cavalier	Managing Director
26	Customized Energy Solutions	Michele	Kaufman	Director of Business Development
27	Customized Energy Solutions	Jed	Trott	Vice President
28	Delorean Power LLC	Rory	Jones	
29	Department of Energy	Eric	Hsieh	Office of Director, EPSA
30	DNV GL	Davion	Hill	Energy Storage Leader, North America
31	DNVGL	Matt	Koenig	
32	DOE	Imre	Gyuk	
33	EDP Renewable North America	Phillip	Westerby	EVP Technical
34	Educational & Cultural Trust Fund	Michael	Yee	Director
35	Electric Power Research Institute (EPRI)	Peggy	Lp	Engineer Scientist
36	Energy Intelligence Partners	Edward	May	Managing Partner
37	Energy Storage Association	Sharon	Thomas	Policy Manager
38	Energy Storage Response Group	Paul	Rogers	
39	Energy Storage Response Group	Nick	Warner	
40	Energy Vault	Marco	Terruzzin	
41	EPRI	Giovanni	Damato	
42	EPRI	Eva	Gardow	Principal Tech Lead
43	Exergy Energy	David	March	CEO
44	Fire & Risk Alliance	Scott	Bryant	Managing Director
45	FlexEnergy	Pedro	Elizondo	Senior Manager, Business Development
46	Fluence Energy	Dan	Wishnick	Managing Director
47	Galehead Development	Michael	McNeley	Project Development Manager
48	GE Power	Troy	Miller	
49	Gee Strategies Group, LLC	Robert	Gee	President
50	Generate Capital Inc	Ed	Bossange	Capital Markets

Attendee List (Cont.)

	Company_Name	First_Name	Last_Name	Job_Title
51	Geronimo Energy	Ken-Ichi	Hino	Director, Energy Storage
52	Global Change Associates	Peter	Fusaro	Chief Commercial Officer
53	Go Electric	Steven	Lichtin	
54	Goldman, Sachs & Co.	Harry	Singh	Vice President
55	GSPP	Jason	Kuflik	Partner
56	Guggenheim Securities, LLC	Mayank	Jain	Managing Director
57	Hartford Steam Boiler	John	Roach	Assistant Vice President
58	Hartford Steam Boiler	David	Tine	New Product Development, Energy
59	Helaba Landesbank Hessen-Thüringen	Erica	Egan	Senior Vice President
60	Helix Power	Frank	Di Luna	Advisor
61	Helix Power	Laura	Sapien-Grabski	Communication & Government Affairs
62	Highview Power	Salvatore	Minopoli	Vice President
63	Highview Power Storage	Jamie	Hussman	System Optimization & Analytics
64	Hitachi Capital America Corp	Chris	Pagano	Vice President and General Manager of Structured Finance
65	Hitachi Capital America Corp	Tom	Waters	Vice President - Energy Solutions
66	ICON Infrastructure Canada	Jamie	Manson	
67	International Finance Corp (IFC)	Peter	Mockel	Senior Industry Specialist
68	Japan Electric Power information Center, USA	Hiroyuki	Yomori	General Manager
69	Javelin Capital	Emily	Arches	Senior Analyst
70	Javelin Capital	Ashton	Whitcomb	Senior Associate
71	Kansai Electric Power	Yoshiko	Takeda	Deputy Chief Representative
72	Key Capture Energy	Ann	Anthony	
73	Key Capture Energy	Jeff	Bishop	Co-Founder and Chief Executive Officer
74	Kirkland & Ellis LLP	Scott	Cockerham	Partner
75	Kirkland & Ellis LLP	Robert	Fleishman	Partner
76	Kirkland & Ellis LLP	Nicholas	Gladd	Of Counsel
77	Kirkland & Ellis LLP	Brian	Greene	Partner
78	Kirkland & Ellis LLP	Kristin	Mendoza	Partner
79	Kirkland & Ellis LLP	Toochi	Ngwangwa	Associate
80	Kirkland & Ellis LLP	Nathan	Santamaria	Partner
81	Kirkland & Ellis LLP	Ashton	Starr	Business Development Coordinator
82	Kirkland & Ellis LLP	Kelann	Stirling	Partner
83	Kirkland & Ellis LLP	Ali	Zaidi	Of Counsel
84	KPMG LLP	Nate	Gabig	Managing Director, Risk Analytics
85	Lazard	Samuel	Scroggins	Power, Energy & Infrastructure M&A at Lazard
86	LG Chem	Peter	Gibson	Sales Director
87	Longroad Energy Partners	Thomas	Siegel	VP Transmission
88	LSIS USA	David	Nickerson	Director of Business Development
89	Marsh Insurance	Fredrick	Wass	
90	METI/ JETRO NY	Shinjiro	Takeda	Special Advisor/ Director
91	Miller Brothers	Gerard	deLisser	VP Development
92	Munich RE	Michael	Schrempp	Head of GreenTech Solutions
93	Munich Reinsurance America, Inc.	Jay	Goldin	Vice President
94	Mustang Prairie	Richard	Baxter	President
95	NAATBatt International (NAATBatt)	Jim	Greenberger	Executive Director
96	NEC Financial Services	Herschel	Salan	President
97	New Energy Capital Partners LLC	Adam	Bernstein	Managing Partner
98	New Energy Fund II, LP	Mark Townsend	Cox	Partner and Chief Investment Officer
99	New Energy Fund LP	Olushola	Ashiru	Partner and PM
100	NY-BEST	Bill	Acker	Executive Director

Attendee List (Cont.)

	Company_Name	First_Name	Last_Name	Job_Title
101	New York Energy Week	Rona	Banai	
102	New York Power Authority	Vennela	Yadhavi	Business Development Engineer, Renewable Energy
103	New York Power Authority	Michael	Midden	Director
104	NYSERDA	Alicia	Barton	President and CEO
105	NYSERDA	Scott	Egbert	Program Manager
106	NYSERDA	John	Joshi	Director, Financing Solutions
107	NYSERDA	Scott	Larsen	Project Manager, Renewables Optimization and Energy Storage
108	NYSERDA	John	Lochner	Vice President
109	NYSERDA	David	Sandbank	VP Distributed Energy Resources
110	Nexus Infrastructure	Alan	Dash	
111	Nord/LB	Sondra	Martinez	Senior Director
112	Nord/LB	Cherian	Thomas	Senior Director
113	NOV	Assad	Mohanna	
114	NRStor C&I	Moe	Hajabed	President
115	NRStor C&I	Christie	Kneteman	Vice President & General Counsel
116	NY Green Bank	Alfred	Griffin	President
117	NY Green Bank	Andrew	Kessler	Managing Director, Investment & Portfolio Management
118	NY Green Bank	Amy	McCartin	VP Investment and Portfolio Management
119	NY Green Bank	Nicholas	Whitcombe	Managing Director, Investment & Portfolio Management
120	Origis Energy	Dries	Bruyland	Managing Director
121	Osaka Gas USA Corporation	Shunsuke	Inoue	Manager
122	Pacific Northwest National Laboratory	Patrick	Balducci	
123	Pacific Northwest National Laboratory	Vince	Sprenkle	
124	Pacific Northwest National Laboratory	Charlie	Vartanian	Sr. Technical Advisor
125	Panasonic	Janet	Lin	Director, Energy & Digital
126	Power Edison	Yazan	Harasis	
127	Power Edison	Shihab	Kuran	Chief Executive Officer
128	Powin Energy	Geoffrey	Brown	President
129	PPL Corporation	Vijay	Singh	Vice President - Renewables and Energy Storage, President - I
130	Rabobank	Brian	Han	AVP, Project Finance
131	Rabobank	Hemani	Jadhav	Executive Director, Project Finance, Renewable Energy
132	Rabobank	Sylvie	Morvan	VP, Project Finance
133	Renewance	Dave	Mauer	VP Sales and Services
134	Rhynland	Patrick	Verdonck	
135	Rocky Mountain Institute	Rachit	Kansal	Senior Associate
136	ROTH Capital Partners	Craig	Irwin	Storage Analyst
137	Roth Capital Partners, LLC	Jesse	Pichel	Managing Director, Investment Banking
138	Rubicon Capital	Nick	Sangermano	
139	Rubicon Infrastructure Advisors	Tom	Weirich	Director - Global Marketing
140	S&P Global Inc.	Tom	Thornton	
141	Saginaw Chippewa Indian Tribe of Michigan	Kevin	Blaser	Energy Buyer
142	Sandia National Laboratories	Raymond	Byrne	
143	Sandia National Laboratories	Babu	Chalamala	Manager
144	Sandia National Laboratory	Alexander	Headley	
145	Schneider Electric SA	Scott	Daniels	Technology & Innovation, Office of the CTO
146	Seal Rock Group LLC	Bev	Corbin	Managing Member
147	Shell New Energies	Matt	Tappin	
148	Siemens Financial Services	John	O'Brien	Director
149	SNL / QuEST	Ricky	Concepcion	
150	Solar USA Power	Cliff	Henry	President & CEO

Attendee List (Cont.)

	Company_Name	First_Name	Last_Name	Job_Title
151	Soltage LLC	Dirk	Van Ouwkerk	SVP of Storage Development
152	Sound Grid Partners	Tess	Williams	Principal
153	Sound Grid Partners, LLC	Dan	Sowder	Principal
154	Sparkplug Power	Sean	Becker	President
155	Starwood Energy Group	Ali	Amirali	
156	Starwood Energy Group	Anik	Gandhi	
157	Starwood Energy Group	Martha	Kammoun	Co-General Counsel
158	Statoil UK Limited	Bala	Nagarajan	Investment Director
159	Strata Solar	Joshua	Rogol	Vice President, Energy Storage
160	Strategic Management Group	Kelly	Sarber	
161	Summit Ridge Energy	Will	Fischer	VP, Business Development
162	Tortoise Infrastructure Partners	Jerry	Polacek	
163	Torys LLP	Milosz	Zemanek	Partner
164	Traxys North America LLC	Erez	Ichilov	
165	Traxys North America LLC	Kevin	Smith	
166	True Green Capital Management LLC	Chris	Kirkman	Managing Director and Head of Project Finance
167	US DOE - LPO	Douglas	Schultz	
168	U.S. DOE Loan Program Office	Dan	Tobin	Senior Investment Officer
169	UN Global Sustainability Impact Institute	Alfred	Berkeley	Advisory Board
170	US DOE	Dan	Nicholas	
171	US DOE Loan Program Office	Andrzej	Potasinski	
172	USI Insurance Services	Dixon	Wright	Senior Vice President
173	VDE	John	Sedgwick	
174	Wartsila Development Financial Services	Paul	Smith	
175	Wartsila NA Inc.	Christopher	Kuhl	Dir of Sales - Storage Systems
176	Willis Towers Watson	Michael	Perron	SVP
177	Willis Towers Watson	Danny	Seagraves	
178	Willis Towers Watson Northeast	Dick	Merbaum	EVP
179	World Bank	Fernando	De Sisternes	Energy Specialist
180	World Bank	Slavena	Georgieva	Energy Consultant
181	World Bank	Chandrasekar	Govindarajalu	Team Leader, Energy Climate Finance
182	World Bank	Sandeep	Kohli	Senior Energy Specialist
183	World-Wide Holdings	J.	Wailes	
184	World-Wide Holdings Corp.	Niko	Elmaleh	Owner
185		Chet	Lyons	
186		Russ	Weed	Independent Consultant

Synopsis

On January 14th, 2020, Kirkland & Ellis, and Mustang Prairie Energy in partnership with the U.S. Department of Energy and Sandia National Laboratory presented a one-day Energy Storage Finance Advisory Committee Meeting at Kirkland & Ellis' New York City office that had 170 attendees. Speakers included representatives from the U.S. Department of Energy, the World Bank, and the New York State Energy Research and Development Authority, and industry experts who have experience with the challenges and opportunities of investing in energy storage projects.

The Summit was the second Energy Storage Finance Advisory Committee Meeting for a U.S. Department of Energy sponsored study to issues and challenges surrounding project and portfolio valuation. This series of studies are part of the U.S. Department of Energy's effort to promote market development through reducing barriers to entry, reducing transaction costs, and promoting wider access to low cost capital in order to promote development across the energy storage industry.

In the morning prior to the Summit, the 2020 U.S. Department of Energy's Energy Storage Valuation Workshop was held to provide an overview of project valuation model development. Parties from Sandia National Laboratories, Pacific Northwest National Laboratory, and the Electric Power Research Institute presented their models and examples of the type of project evaluation capable from the different approaches.

The first Keynote address was given by J Chandra Govindarajalu, who leads the global battery storage program at the World Bank. R. Govindarajalu's presentation showcased the efforts of the World Bank's new \$1 Billion funding to promote energy storage system globally.

The second Keynote address was given by Alicia Barton, President and CEO of the New York State Energy Research and Development Authority (NYSERDA). Barton's presentation highlighted the long efforts NYSEERDA has undertaken to support energy storage technology and project development and highlighted many of the success stories of energy storage development in New York State.

The final Keynote was given by Dr. Imre Gyuk of the Office of Electricity of the U.S. Department of Energy. His presentation showcased the efforts of the U.S. DOE to support energy storage technology and market development. The presentation highlighted all of the areas where the U.S. DOE is supporting the market and showcased how all of the different parts support the Department's other efforts.

The first panel focused on the International Opportunities. This panel approaches the market from a number of directions and provided the attendees with a deep understanding of the complexity of dealing with the international aspect of the energy storage market. The panelists compared different energy storage development strategies in the North America, and Europe. They were able to describe how global energy firms are looking to energy storage as a component of their market strategy going forward. This would include many different market components, from project development to project financing. A key focus for the speakers was the need to reduce transaction costs for international projects as determining the bankability of storage projects outside of North America and Europe is more challenging.

The second panel focused on the Capital Providers. Here, investors were able to discuss what type of investment risks they are willing, and not willing to take. Key to this discussion was a discussion as to why the individual speaker thought about and why they were interested in the energy storage sector. Some of the panelists were able to provide some insights into leasing opportunities, as well as

the expected returns for debt and equity providers looking at the energy storage market. Of key interest here was the perspective of the overall debt market, and how they are approaching the energy storage opportunity and what they need to see to become more deeply engaged. Some of the panelists discussed their ongoing challenge of structuring the project deals to reduce operational risk and improve the bankability of the project. An important caveat brought out was that it is important to structure the projects on a sound technical and legal footing at the very beginning of the process. Many of the panelists highlighted that developers that short-changed the early diligence phase of the project will have to deal with significantly higher costs later.

The final panel of the day focused on Wholesale Markets. The discussion centered on the current state of project financing for large scale energy storage projects currently, how the market is changing, and included expectations for where it will go in the next two to three years. The growth of software as a key factor in project profitability is also allowing commercial and industrial assets to be promoted for wholesale applications in formal ISO markets, making them a potentially significant source of capacity. System integrators also highlighted the aspect of software as critical to a well operating facility. A key theme throughout many of the panelists' discussion was the educational level and perspective of capital providers. Many on the panel have spent significant time educating the capital providers they work with on the complexity of energy storage projects, and what aspects are similar, and which are different, from solar and wind project financing. One interesting aspect of lenders was that a number of the panelists described meeting lenders that "needed" a storage project in the portfolio, and thus willing to overpay for a potentially uneconomic or even poorly designed facility.

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Name	Org.	Sandia Email Address
Babu Chalamala	08811	bchalam@sandia.gov
Joseph McNamara	08811	jwmcnam@sandia.gov
Howard Passell	08811	hdpasse@sandia.gov
Tu Nguyen	08811	tunguy@sandia.gov
Raymond Byrne	08813	rhbyrne@sandia.gov
Technical Library	01177	libref@sandia.gov

Email—External (encrypt for OOU)

Name	Company Email Address	Company Name
Dr. Imre Gyuk	imre.gyuk@hq.doe.gov	US DOE
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