SANDIA REPORT
SAND2018-10110
Unlimited Release
Printed September 2018

Energy Storage Financing:

Performance Impacts on Project Financing

Richard Baxter
Mustang Prairie Energy

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

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

Printed in the United States of America. This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Telephone: (865) 576-8401
Facsimile: (865) 576-5728
E-Mail: reports@osti.gov
Online ordering: http://www.osti.gov/scitech

Available to the public from
U.S. Department of Commerce
National Technical Information Service
5301 Shawnee Rd
Alexandria, VA 22312

Telephone: (800) 553-6847
Facsimile: (703) 605-6900
E-Mail: orders@ntis.gov
Online order: http://www.ntis.gov/search

SAND2018-10110
Unlimited Release
Printed September 2018

Energy Storage Financing:

Performance Impacts on Project Financing

Richard Baxter
Mustang Prairie Energy

Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185-MS1140

Abstract

Understanding performance is the key to risk management in energy storage project financing. Technical performance underlies both capital and operating costs, directly impacting the system's economic performance. Since project development is an exercise in risk management, financing costs are the clearest view into how lenders' perceive a project's riskiness. Addressing this perception is the challenge facing the energy storage industry today. Growth in the early solar market was hindered until OEMs and project developers used verifiable performance to allay lenders' apprehension about the long-term viability of those projects. The energy storage industry is similarly laying the groundwork for sustained growth through better technical Standards and best practices. However, the storage industry remains far more complex than other markets, leading lenders to need better data, analytical tools, and performance metrics to invest not only to maximize returns, but also safely—through incorporating more precise performance metrics into the project's documents.

ACKNOWLEDGMENTS

The author would like to acknowledge the support and guidance of Dr. Imre Gyuk, Director of the U.S. Department of Energy's Office of Electricity Delivery and Energy Reliability's Energy Storage Program, and Dr. Babu Chalamala and Dr. Ray Byrne of the Energy Storage Systems Program of Sandia National Laboratories.

The author would also like to thank all those who made the three Stakeholder Meetings possible:

January 11th, 2017

Location	New York, NY
Keynote	Imre Gyuk, Director of the U.S. Department of Energy's Office of Electricity Delivery and Energy Reliability's Energy Storage Program
Keynote	Alfred Griffin, President of the NY Green Bank
Host	Sutherland Asbill & Brennan LLP and Mustang Prairie Energy
Sponsors	Enovation Partners and S&C Electric Company

April 19th, 2017

Location	Denver, CO
Co-located:	2017 Energy Storage Association Conference & Expo
Host	Energy Storage Association

June 7th, 2017

Location	Washington, D.C.
Keynote	Imre Gyuk, Director of the U.S. Department of Energy's Office of Electricity Delivery and Energy Reliability's Energy Storage Program
Keynote	Reed Hundt, CEO of the Coalition for Green Capital
Host	Eversheds Sutherland LLP and Mustang Prairie Energy
Sponsors	Mitsubishi Electric, CSA Group, UniEnergy Technologies, Roth Capital Partners, and Enovation Partners

CONTENTS

Contents ... 7

Figures ... 11

Tables ... 13

Nomenclature ... 15

Executive Summary ... 17

1. Energy Storage & Performance ... 25
    - 1.1. Why Performance Matters ... 25
        - 1.1.1. Understanding Performance ... 26
        - 1.1.2. Application Stacking ... 26
    - 1.2. What Is Performance? ... 28
        - 1.2.1. System Rating ... 28
        - 1.2.2. Technical Performance ... 29
        - 1.2.3. System Performance ... 30
    - 1.3. Financing & Performance ... 31
        - 1.3.1. Utility ... 31
        - 1.3.2. Merchant ... 32
        - 1.3.4. Commercial ... 33
        - 1.3.5. Residential ... 34

2. Technology Factors ... 35
    - 2.1. Design Review ... 35
        - 2.1.1. Bankability Studies ... 36
        - 2.1.2. Independent Engineering Report ... 41
    - 2.2. Integration and Deployment ... 44
        - 2.2.1. System Integration ... 45
        - 2.2.2. Engineering Procurement & Construction (EPC) ... 46
        - 2.2.3. Commissioning ... 48
    - 2.3. Operation ... 49
        - 2.3.1. 3rd Party Monitoring ... 49
        - 2.3.2. Operation & Maintenance (O&M) ... 50
        - 2.3.3. Warranty ... 52

3. Economic Factors ... 55
    - 3.1. Costs ... 55
        - 3.1.1. Equipment Costs ... 56
        - 3.1.2. Augmentation ... 59
        - 3.1.3. Operating Costs ... 61
        - 3.1.4. Warranty ... 62
        - 3.1.5. Round-Trip Efficiency (Losses) ... 62
        - 3.1.6. Engineering, Procurement & Construction (EPC) ... 63
        - 3.1.7. End of Life ... 64
        - 3.1.8. Total Cost of Ownership (TCO) ... 64
    - 3.2. Revenue ... 65

3.2.1. Value Streams 65
3.2.2. Value Stacking 66
3.2.3. Design Implications 68
3.3. Project Economics 68
3.3.2. Permitting 68
3.3.3. Interconnection 69
3.3.4. Financing Costs 69
3.3.6. Valuation 69

4. Contractual Factors 71
4.1. Project Documents 71
4.1.1. Corporate Organization Documents 72
4.1.2. Real Estate Agreements 72
4.1.3. Entitlement 73
4.1.4. Project Design 73
4.1.5. Warranty Documentation 74
4.1.6. Construction Documents 74
4.1.7. Engineering Review Documents 74
4.1.8. Interconnection Study 75
4.1.9. Project Operation Documents 75
4.1.10. Off-Take Agreement 75
4.1.11. Performance Guarantee 76
4.2. Financing Documents 78
4.2.1. Project Economic Documents 78
4.2.2. Project Insurance Documents 78
4.2.3. Funding Agreement 79
4.2.4. Security Agreement 79
4.2.5. Direct Agreement 79
4.3. Insurance & Risk Management 80
4.3.1. General Insurance 80
4.3.2. Project Continuation 81
4.3.3. Credit Enhancements 82
4.3.4. Performance Insurance 82

5. Next Steps 85
5.1. Data 86
5.1.1. Engineering & Technical Services 86
5.1.2. Safety & Standards 89
5.1.3. Performance Testing & Verification 90
5.1.4. Data Formatting 91
5.2. Project Modeling 93
5.2.1. Economic & Financial Assumptions 94
5.2.2. Project Economic Model 95
5.2.2. Simulation Models 95
5.2.3. Data Sources 99
5.3. Financial Performance Metrics 103
5.3.1. Grid Services 104
5.3.2. Utility 106

5.3.3. Residential ... 107
References ... 110
Appendix A: U.S. Department of energy Resources Supporting Energy Storage Financing.... 112
Appendix B: List of Interviewees ... 114
Appendix C: Stakeholder Meeting: 2017 U.S. DOE Energy Storage Financing Summit (NYC) ... 116
Appendix D: Stakeholder Meeting: 2017 Energy Storage Asociation Conference & EXPO ... 126
Appendix E: Stakeholder Meeting: 2017 U.S. DOE Energy Storage Financing Summit (DC) 132
Distribution ... 142

FIGURES

Figure 1. Energy Storage System Ratings. 17
Figure 2. Making Energy Storage Financeable.. 18
Figure 3. Market Applications for Energy Storage.. 27
Figure 4. Usable Energy. 28
Figure 5. Energy Storage System Ratings. 29
Figure 6. Making Energy Storage Financeable.. 36
Figure 7. Technology Readiness of Energy Storage Technologies. 38
Figure 8. Technology & Commercial Readiness Levels. 39
Figure 9. Remote Monitoring. 49
Figure 10. Energy Storage System Costs.. 56
Figure 11. Energy Storage System Diagram.. 58
Figure 12. Augmentation Costs 60
Figure 13. Value Stacking.. 67
Figure 14. Orange Button Initiative. 92
Figure 15. NREL’s System Advisory Model (SAM). 96
Figure 16. Example of HOMER Model Output.. 97
Figure 17. StorageVET® Model Architecture... 98
Figure 18. Sample results from QuESt Valuation's wizard. 99
Figure 19. DOE Global Energy Storage Database.. 100
Figure 20. U.S. DOE Inventory of Generators. 100
Figure 21. Utility Rate Database URDB). 101
Figure 22. Energy Use by Commercial Building Type. 102
Figure 23. PJM Average Performance Score.. 105
Figure 24. Residential Equipment Performance Rating. 108

TABLES

Table 1. Energy Storage Applications. 20
Table 2. Energy Storage Project Contracts. 21
Table 3. Energy Storage Applications. 65
Table 4. Energy Storage Project Documents. 72
Table 5. Commercial Building Reference Model Locations. 102

NOMENCLATURE

AC	Alternating Current
ARPA-E	Advanced Research Projects Agency-Energy
ARRA	American Recovery and Reinvestment Act
BOMA	Building Owners and Managers Association
BTM	Behind the Meter
CAFD	Cash Available For Distribution
CEC	California Energy Commission
CEFIA	Clean Energy Finance Investment Authority
CESA	Clean Energy States Alliance
CPUC	California Public Utility Commission
CRL	Commercial Readiness Level
CSR	Codes, Standards, and Regulations
DC	Direct Current
DCSA	Demand Charge Savings Account
DER	Distributed Energy Resources
DOE	Department of Energy
DRESA	Demand Response Energy Storage Agreement
EES	Electrical Energy Storage
ECI	Electrical Construction Industry
EPC	Engineering Procurement and Construction
EPRI	Electric Power Research Institute
ESA	Energy Storage Association
ESIC	Energy Storage Integration Council
ESCO	Energy Services Company
ESPC	Energy Savings Performance Contract
FERC	Federal Energy Regulatory Commission
FTM	Front of the Meter
HVAC	Heating Ventilation and Air Conditioning
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
INL	Idaho National Laboratory
IPO	Initial Public Offering
IRP	Integrated Resource Plan
IRS	Internal Revenue Service
ISO	Independent System Operator
ITC	Investment Tax Credit
kW	Kilowatt
kWh	Kilowatt hour
LBL	Lawrence Berkeley Laboratory
LCOE	Levelized Cost of Energy
LCOS	Levelized Cost of Storage
LPO	Loan Programs Office
MACRS	Modified Accelerated Cost Recovery System
MBTF	Mean Time Between Failure

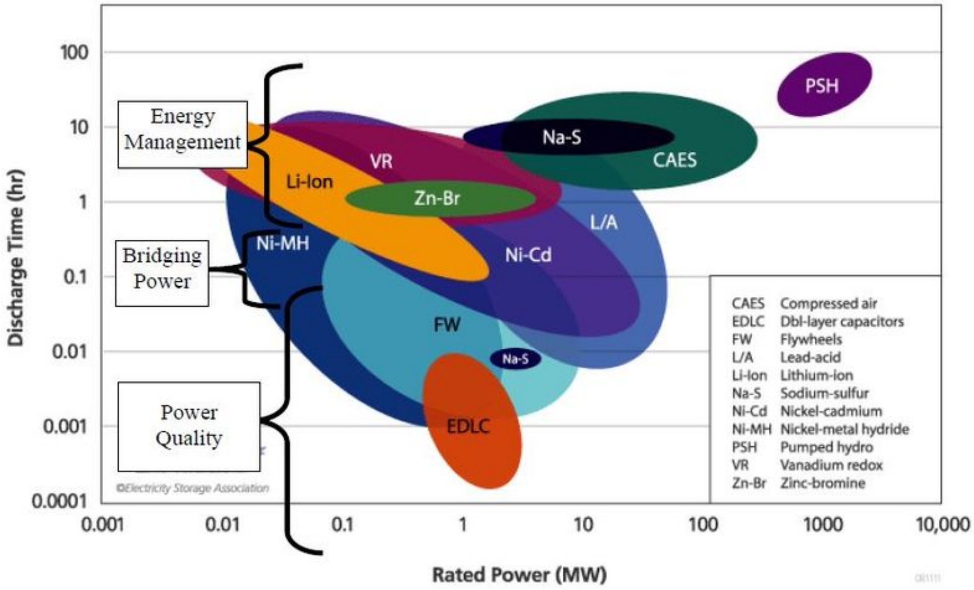
MESA	Modular Energy Storage Architecture
MLP	Master Limited Partnership
MW	Megawatt
MWh	Megawatt hour
NEC	National Electrical Code
NECA	National Electrical Contractors Association
NEIS	National Electrical Installation Standards
NEMA	Association of Electrical Equipment Manufacturers and Medical Imaging Manufacturers
NFPA	National Fire Prevention Association
NRECA	National Rural Electric Cooperative Association
NREL	National Renewable Energy Laboratory
NY-BEST	New York Battery and Energy Storage Technology
NYSE	New York Stock Exchange
NYSERDA	New York State Energy Research and Development Authority
O&M	Operation & Maintenance
OEM	Original Equipment Manufacturer
ORNL	Oak Ridge National Laboratory
PACE	Property Assessed Clean Energy
PG&E	Pacific Gas & Electric
PLR	Private Letter Ruling
PNNL	Pacific Northwest National Laboratory
PPA	Power Purchase Agreement
PUC	Public Utility Commission
PV	Photovoltaic
R&D	Research & Development
REIT	Real Estate Investment Trust
REV	Reforming the Energy Vision
RFP	Request for Proposal
RTE	Round-Trip Efficiency
RTO	Regional Transmission Organization
SBIR	Small Business Innovation Research
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SGIP	Small Generator Interconnection Procedures (FERC)
SGIP	Small Generator Incentive Program (CPUC)
SNL	Sandia National Laboratories
SPE	Special Purpose Entity
TRL	Technology Readiness Level
UL	Underwriters Laboratories

EXECUTIVE SUMMARY

Understanding performance is the key to risk management in energy storage project financing. Technical performance underlies both capital and operating costs, directly impacting the system's economic performance. Since project development is an exercise in risk management, financing costs are the clearest view into how lenders perceive a project's riskiness. Addressing this perception is the challenge facing the energy storage industry today. Growth in the early solar market was hindered until OEMs and project developers used verifiable performance to allay lenders' apprehension about the long-term viability of those projects. The energy storage industry is similarly laying the groundwork for sustained growth through better technical Standards and best practices. However, the storage industry remains far more complex than other markets, leading lenders to need better data, analytical tools, and performance metrics to invest not only to maximize returns, but also safely—through incorporating more precise performance metrics into the project's documents.

Energy Storage & Performance

Energy storage systems are not simply reversible energy sinks; they are a highly engineered system with the innate ability to be the most flexible and valuable asset on the power grid. Their great ability to undertake so many market roles comes with the challenge of understanding what the best applications are for a particular energy storage technology to craft a profitable system.



Source: Energy Storage Association

Figure 1. Energy Storage System Ratings.

The key to unlocking their value is understanding their performance. The answer to that lies in understanding why performance matters to energy storage systems, understanding what performance metrics mean, and how they can be leveraged to obtain lower cost lending to drive more project development.

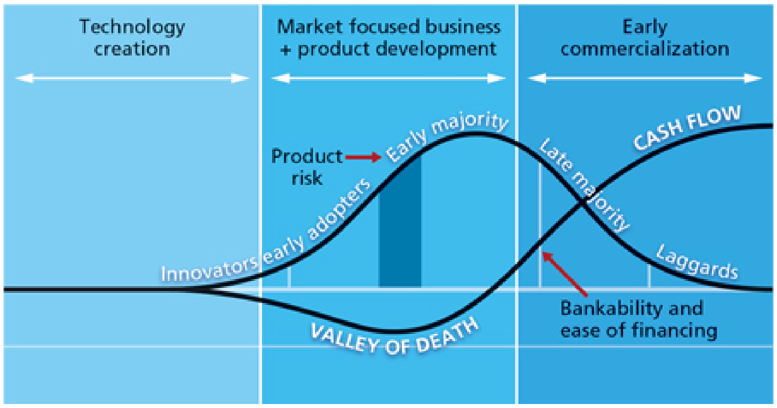
- **Why Performance Matters:** Successful project development is based on managing risks. Typically, this means incorporating all the known risks and managing the projects costs and revenues to generate a project with an acceptable IRR. Skill (or luck) is required to also incorporate the ability to manage unknown risks. Understanding the performance of the system is crucial to manage the cost effectiveness of different solutions to manage the projects risks.

- **What is Performance?** Energy storage system performance is the measured level of how well the unit operates against a subjective set of metrics. To understand how these measurements of the different characteristics of an energy storage system can be used, it is important to showcase their differences—which range from static features, operating results about single technical characteristics, or outcomes dependent upon multiple parameters. The adoption of common description is essential as these metrics are the foundation for describing the performance of the unit.

- **Financing & Performance:** Project financing is based on ensuring that the project in question will be able to generate sufficient revenues to cover the debt service and earn an acceptable return for the equity providers. The structure used will be the most financeable for a particular market; the one that can mitigate the risks in the most cost-effective manner. An effective method to mitigate the project risks is to tie the key cost and operating requirements of the projects tightly to performance metrics.

Technology Factors

Technology evaluation is the basis for understanding the performance capabilities of energy storage technologies. Performance requirements are fundamental to the design, integration and deployment, and operation of the system to ensure successful operation and thus profitable returns for owners and lenders.



Source: DNV GL

Figure 2. Making Energy Storage Financeable.

The impact of performance is evident throughout technology evaluation process:

- The design review will focus both on the performance of the technology, and performance of the system. This evaluation helps to determine financeability of the technology and project design. An energy storage system has many more operating variables than a comparably sized solar PV or wind project, thus a review of the appropriateness of the equipment selection and project design is critical for a lender on its funding decision, and thus the basis for the financeability of the project. This design review will focus both on the estimated performance of the technology, and the system as a whole. Evaluating the technology offering is not just a critical decision for a lender, but for everyone associated with the project. Evaluating the system offering focuses on the effectiveness of design, with relation to cost and performance with a primary focus on whether the system can operate successfully to repay the lender, sponsor, and project developer.

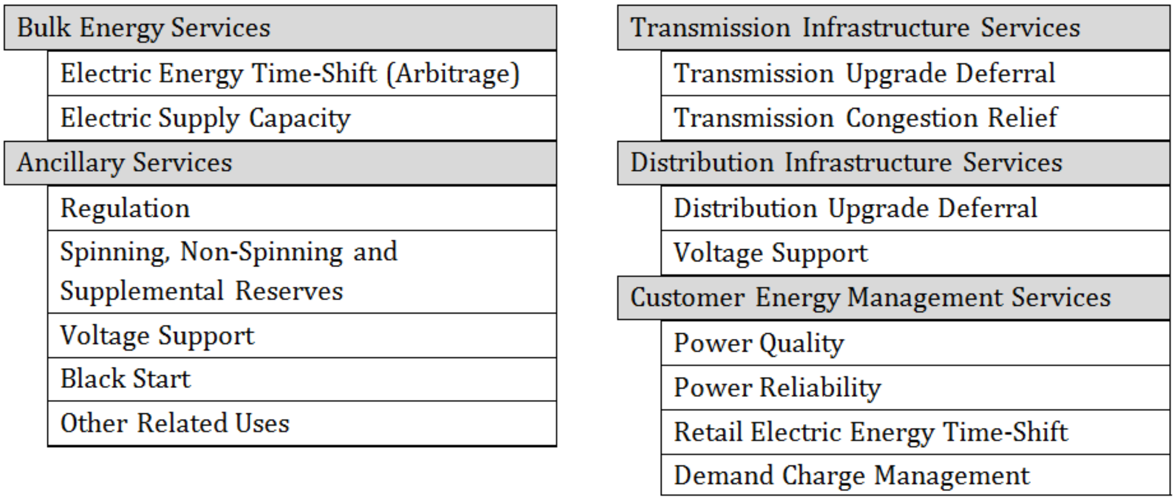
- Integration and deployment of energy storage focuses not just on the performance of the individual components themselves, but also understanding how they all interact as a complete system, taking into account local environmental conditions to ensure that the desired performance level can be achieved. Three areas in particular: system integration, EPC (Engineering, Procurement, and Construction), and Commissioning.

- The proper operation of the system is obviously important, and so too is the monitoring and verification of the system’s performance. To ensure unbiased measurement, obtaining 3rd party monitoring services provides the lenders assurance that the system will remain physically able to perform as expected, and thus ensure reliable servicing of the debt. Operation and maintenance remains critical to obtaining a long running operation.

Economic Factors

The economic performance of an energy storage system is a balance between the most cost-effective design and its operating strategy for a chosen market role. What makes energy storage project development challenging is that choices on either side of the equation can have significant impacts on the other, and thus an iterative exercise. A key in this decision is that energy storage systems have a limited duration capability to charge or discharge, and thus the marginal value of the remaining charging and discharge capacity at any given time is of prime importance to the system value, but this balance is always changing. To develop an energy storage project with long term flexibility (and hence value), the project developer must incorporate this understanding of changing marginal values into their design operating plan from the start. For this reason, the performance of the energy storage system is paramount to its ability to create value for the owners.

Table 1. Energy Storage Applications.



Bulk Energy Services	
	Electric Energy Time-Shift (Arbitrage)
	Electric Supply Capacity
Ancillary Services	
	Regulation
	Spinning, Non-Spinning and Supplemental Reserves
	Voltage Support
	Black Start
	Other Related Uses
Transmission Infrastructure Services	
	Transmission Upgrade Deferral
	Transmission Congestion Relief
Distribution Infrastructure Services	
	Distribution Upgrade Deferral
	Voltage Support
Customer Energy Management Services	
	Power Quality
	Power Reliability
	Retail Electric Energy Time-Shift
	Demand Charge Management

Source: U.S. DOE Energy Storage Handbook

The impact of performance is evident throughout the economic assessment process:

- For costs, performance explains the balance of upfront vs. lifetime costs. Some technologies may cost more initially, but could cost less to operate over the system life. When replacement cells are required, project developers attempt to push out required augmentation to allow the ongoing declining cost trends to produce lower future costs for batteries. Finally, ensuring high availability for the system through proper operation and maintenance is only possible through performance monitoring and verification.

- For revenue, performance helps us understand which application can be stacked. Balancing higher value operation with performance requirements that affect other revenue operation requires an understanding of the different performance requirements, and choosing which mix produces the highest and most reliable revenue stream.

- For project economics, performance is key for understanding how all aspects of system design, operation, and market strategy are interconnected. Impacting one area of the system will have follow-on impacts elsewhere, so the entire project needs to be evaluated as a whole for overall, integrated value generation.

Contractual Factors

Contracts are essential for structuring energy storage project deals. They are used to define stable and secure revenue streams, they help secure the equipment necessary for the project company and define compensation for performance and damages for non-performance. Importantly, they are able to identify the performance required for each of the steps involved in the intricate dance of project developers having everything show up and installed properly while paying for it with the lowest cost financing available. Showcasing responsibility for each step allows the inclusion of 3rd party services such as equipment monitoring and performance verification to validate requirements in the contracts. Most important for the risk management perspective, contracts provide a framework do deal with contingencies.

Table 2. Energy Storage Project Contracts.

Project Documents	Financing Documents
Corporate Organization	Project Economics
Real Estate	Project Insurance
Entitlements	Funding Agreement
Project Design	Security Agreement
Warranty	Direct Agreement
Construction	
Engineering Review	
Interconnection Study	
Project Operation	
Off-Take Agreements	
Performance Guarantee	

Source: Mustang Prairie Energy

Project development financing is complex and relies on a myriad of documentation to ensure parties both receive what they want while specifying performance requirements. This includes:

- Project documents are used to define, construct and operate the project. A series of project documents are required that will define the organization and operation of the energy storage project. These are typically similar to other power industry project documents, but with variations in order to cover the differences in the energy storage market. As the industry is still evolving, different groups may group the project documents differently than this description.

- Financing documents set the terms and conditions upon which the lenders will lend to the project company. These are typically similar to other power industry project documents, but with variations in order to cover the differences in the energy storage market. In more mature project development markets, there can be significant complexity. As the industry evolves, these documents will also undergo optimization. As the industry is still evolving, different groups may group the project documents differently than this description.

- Insurance is a means for protecting against financial loss. For a complex and highly integrated issue such as energy storage project development, it is also a means to design risk management strategies that expand opportunities at a lower cost through leveraging the financial assets of the insurance firms. This risk management and allocation focus is especially important for energy storage project development. As energy storage is somewhat different that other power projects, and so the risk management strategy will need to take account of unique technology, policy and regulatory, and market issues.

Next Steps

The energy storage industry today is in a similar situations as in the early stages of the wind and solar markets. The cost of equipment was declining, but undertaking project development continued to be slowed through hesitancy by lenders and investors' understanding the long-term ability of these projects to reliably service their debts and provide a possible return for investors. Manufacturers, EPCs, and insurance firms in the solar industry with deep understanding of the products were able to provide warranty assurance based on their knowledge of their products performance to ensure the sale of their systems. As momentum in project developer and operation picked up, this risk reduction reduced the cost of offered capital, reinforcing the growth trend.

Energy storage systems are unfortunately more complicated than solar and wind projects, but the same efforts will be needed to ensure the financeability of energy storage projects.

- Improved sources of data are needed for better decision making. This data will provide the foundation of what applications and market roles these systems can reliably perform. Through expanding the scope of data availability, plus improved Standards, lenders and project developers can be more assured of the comparability and linkage of performance and financial returns.

- More detailed analytical modeling tools will support more reliable project financing proposals. The heart of the evaluation of the viability of a project is a project economic model for the facility that will account for all of the projected cash flows and costs over the life of the facility. Interviewees stressed the need for better and more transparent market models and system simulator tools and capabilities to cover all of the varying applications where an energy storage facility can operate. The lending community in particular noted that when evaluating a project, they are left many times having to evaluate differing project models from different developers, and many of the models used do not fully capture the dynamic capabilities of energy storage systems impact on revenue generation in the same way leaving them uncertain as to the differences in projects.

- Financial performance metrics are the basis for payment and penalty terms within contracts; these can be technology or system performance metrics such as capacity retention or availability, or they can be derived metrics based on the system's performance in the market. Performance ratings have been instrumental in the development of the wind and solar markets, and will be critical to the commercial success of energy storage the energy storage market. However, because of the more complex usage in energy storage system profiles, the performance metrics will need to also be more tailored to specific applications in order to align what the systems can do with what they are being paid for. Because of these differences, no single financial performance metric will be universal, but generally has specific applicability for different market rules. Whatever financial performance metric is chosen, the measurement of it needs to be transparent, so 3rd party monitoring can be undertaken.

1. ENERGY STORAGE & PERFORMANCE

Energy storage systems are not simply reversible energy sinks; they are a highly engineered system with the innate ability to be the most flexible and valuable asset on the power grid. Their great ability to undertake so many market roles comes with the challenge of understanding what the best applications are for a particular energy storage technology to craft a profitable system.

The key to unlocking their value is understanding their performance. The answer to that lies in understanding why performance matters to energy storage systems, understanding what performance metrics mean, and how they can be leveraged to obtain lower cost lending to drive more project development.

- **Why Performance Matters:** Successful project development is based on managing risks. Typically, this means incorporating all the known risks and managing the projects costs and revenues to generate a project with an acceptable IRR. Skill (or luck) is required to also incorporate the ability to manage unknown risks. Understanding the performance of the system is crucial to manage the cost effectiveness of different solutions to manage the projects risks.

- **What is Performance?** Energy storage system performance is the measured level of how well the unit operates against a subjective set of metrics. To understand how these measurements of the different characteristics of an energy storage system can be used, it is important to showcase their differences—which range from static features, operating results about single technical characteristics, or outcomes dependent upon multiple parameters. The adoption of common description is essential as these metrics are the foundation for describing the performance of the unit.

- **Financing & Performance:** Project financing is based on ensuring that the project in question will be able to generate sufficient revenues to cover the debt service and earn an acceptable return for the equity providers. The structure used will be the most financeable for a particular market; the one that can mitigate the risks in the most cost-effective manner. An effective method to mitigate the project risks is to tie the key cost and operating requirements of the projects tightly to performance metrics.

1.1. Why Performance Matters

Successful project development is based on managing risks. Typically, this means incorporating all the known risks and managing the projects costs and revenues to generate a project with an acceptable IRR. Skill (or luck) is required to also incorporate the ability to manage unknown risks. Understanding the performance of the system is crucial to manage the cost effectiveness of different solutions to manage the projects risks. In this way, a clearer understanding of the risk adjusted profit potential of the system, can be established, and how operational choices affect the ability of the system to maintain profitability over the unit’s operating life.

1.1.1. Understanding Performance

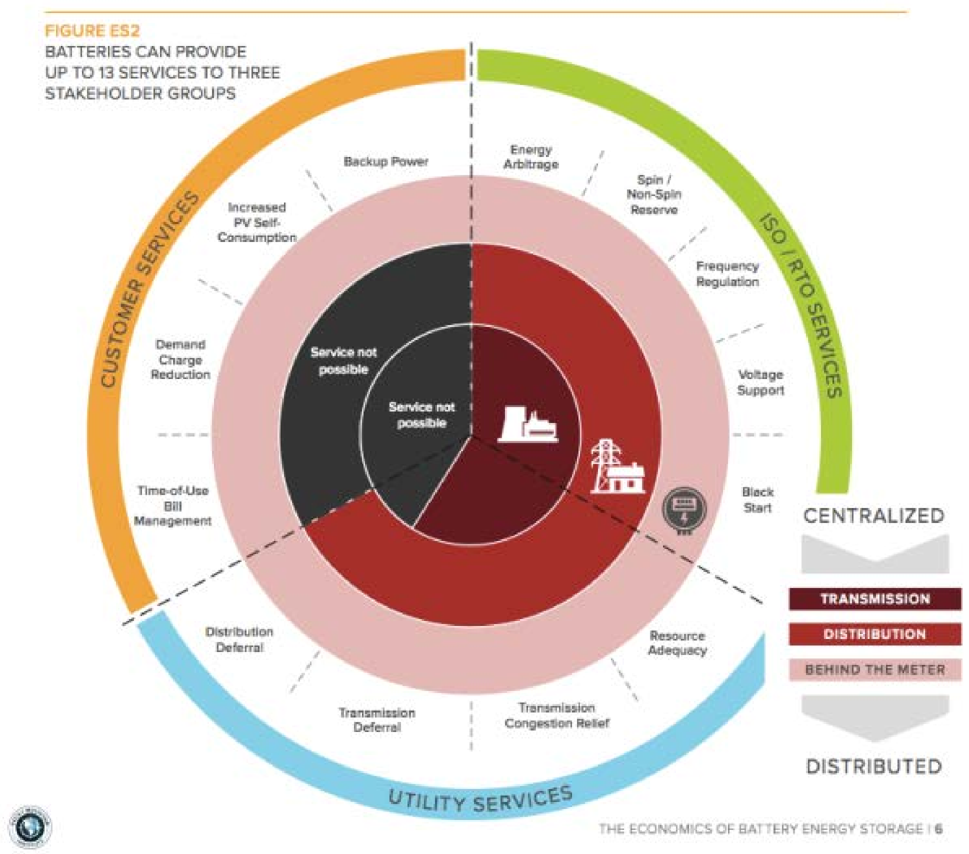
Understanding performance is at the heart of performance management, which states that you must be able to measure something before you can monitor it, and monitor it before you can manage it. Energy storage system can perform a variety of tasks under an even wider set of market conditions. Only by understanding the equipment’s performance capability can you understand the system’s potential; without understanding how to leverage that potential, you can’t understand the value of energy storage system.

A better understanding of performance—and its implications—is vital for people across the energy storage industry; it’s the most important method to understand the value of their products and services in the development of an energy storage project. By incorporating risk management into supplier selection, system design, and market strategy, project developers are using verifiable performance to lower their own exposure to loss, while working to hold on to some of the upside revenue generation potential. For OEMs, performance allows them to differentiate their products, and—if superior to the competition—gain a competitive and pricing advantage against others. If the OEMs are confident about their product’s performance, they will be able to better manage the performance requirements being push back up the supply chain. Understanding the performance of equipment, suppliers, and market strategies allows lenders to properly price each project’s risk adjusted value. Finally, engineering and insurance firms are using deep dives into the products and projects design and operations to position themselves as much needed allies in the fast-growing market as new competitors without deep experience with these systems enter the market.

Another role for performance is to provide an early warning service against possible outsized losses. Projects being developed now are profitable, but many project developers interviewed agreed that the range of possible outcomes when operating these systems is still possibly weighted more negatively than positive due to the lack of extensive experience operating these systems in the market. Luckily, this situation is changing rapidly, and with the continued decline in costs—and improvement in capability, the range of possible outcomes for profitability is tightening and rising. However, a saying I think fits the energy storage industry at this juncture well—“it’s not what you don’t know that gets you in trouble, it’s what you know that just isn’t so.” Therefore, utilizing performance metric evaluation will help keep what we know to focus on in front of us but their use will also help the industry test for false assumptions with key drivers to ensure continued successful operation of the facilities.

1.1.2. Application Stacking

A core tenant of energy storage operational strategy is to perform a number of applications concurrently, as it is difficult to operate an energy storage facility profitably while only performing one market role. The Rocky Mountain Institute’s (RMI) *The Economics of Battery Energy Storage* study outlined 13 applications suitable for energy storage, which are widely agreed upon as the important core applications for energy storage systems. The RMI study recommended the stacking of multiple applications to extract the most value from the energy storage system.

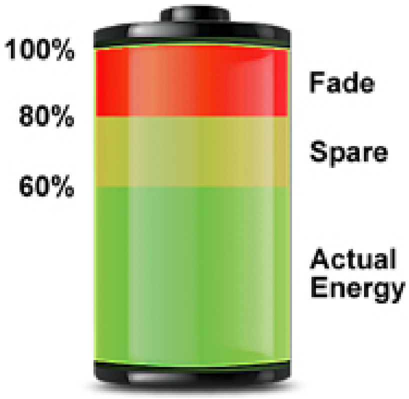


Source: Rocky Mountain Institute (RMI)

Figure 3. Market Applications for Energy Storage

Unfortunately, the capability of lithium-ion batteries—the most prevalent type of energy storage available today—degrades over time due to usage. The degradation is driven by both the amount, type, and conditions under which the batteries are used. Therefore, when deciding upon the type of applications desired to be supported, the operating requirements must also be considered when stacking the different applications to make sure the battery is technically capable of providing that levels of service. Secondly, a cost-effectiveness choice must be made as to which applications are worth investing the batteries' capability. There is not an exact linkage between usage (for an energy storage system) and compensation for these market services, as many were originally designed to be provided for by fossil power facilities. Finally, there is also a time element to the degradation of the battery, so the choice to undertake one set of applications may be cost-effective when the unit is new, but over time, a different set of applications may be more cost effective given the remaining capacity in the battery. It depends on the level of degradation or fade in the cells at the particular time. Knowing the proper usage of the battery depends on understanding how the battery is meeting the original expectations for it capacity over its lifespan—its performance.

Battery capacity fades from the day the unit is manufactured. As they are used, they slowly lose capacity, with the unusable portion termed the fade of the battery. The End of Life (EOL) for a chemical battery has traditionally (based on lead acid batteries) been when the battery fade has reached 20% of the original capacity (80% original capacity remaining) when the rate of fade accelerates. More recent chemical battery systems (now primarily lithium-ion) have extended the EOL to a fade of up to 40% (60% of original capacity remaining) without a significant change in the rate of capacity loss up to that point. This extension allows project developers to push out the need for additional battery capacity, making the system more cost effective.



Source: Battery University, Cadex Electronics, Inc.

Figure 4. Usable Energy.

1.2. What Is Performance?

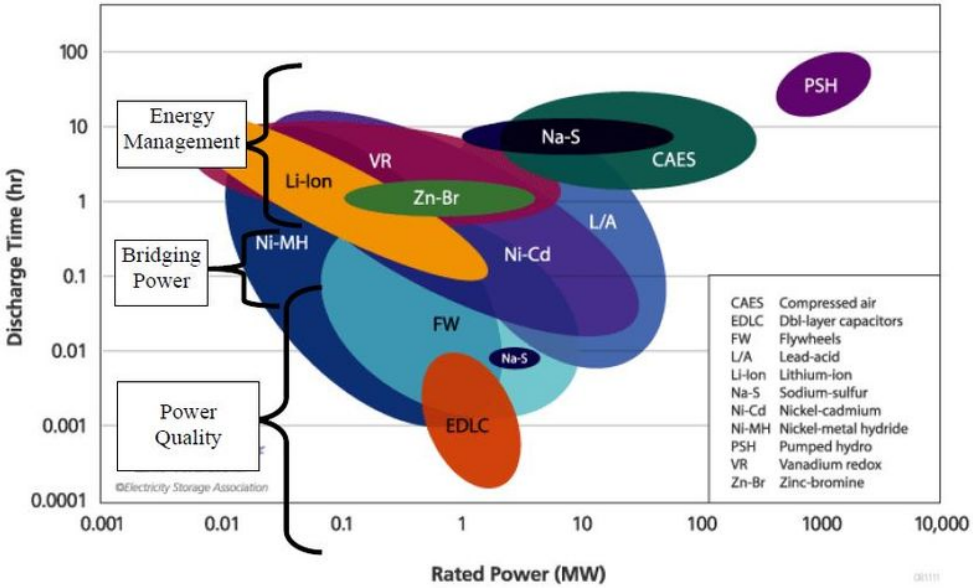
Energy storage system performance is the measured level of how well the unit operates against a subjective set of metrics. To understand how these measurements of the different characteristics of an energy storage system can be used, it is important to showcase their differences—which range from static features, operating results about single technical characteristics, or outcomes dependent upon multiple parameters. The adoption of common description is essential for the industry as these metrics are the foundation for describing the performance of the unit. The U.S. Department of Energy has worked to harmonize industry consensus definitions of these energy storage system characteristics to support the use of performance metrics in financing projects. The following list, based off the U.S. Department of Energy’s efforts in this area[1] is indicative, and by no means complete.

1.2.1. System Rating

The most basic level of describing an energy storage system is the initial system ratings of the unit. These do not change through usage, but are set or devised by the manufacturer, and form the basis of other performance measurements. These ratings will vary by technology, but since they are at the system level, can vary depending upon to type of product being sold by the manufacturer.

- **Initial Energy Capacity:** The amount of electrical energy (kWh) capable of being stored by an energy storage system and expressed as the product of rated power of the energy storage system and the discharge time at rated power.

- **Initial Rated Power:** The typical power (kW) that the energy storage facility is designed to charge or discharge on a regular basis.



Source: Energy Storage Association

Figure 5. Energy Storage System Ratings.

These parameters discuss full energy storage systems. Cell level parameters, such as specific energy density (Wh/L), specific energy (Wh/kg), power density (W/L), and specific power (W/kg) are not covered here as the performance levels described are for the system level.

1.2.2. Technical Performance

Technical performance metrics describe the operating results with regard to a single technical characteristic. These characteristics describe aspects of the energy technology's design that manifest in the operation of the unit.

- **Internal Resistance:** The resistance to power flow of the energy storage system during charging and discharging cycles.

- **Lifespan:** This can be measured in cycle-life (one full charge and discharge cycle), energy throughput (kWh), or calendar life (years). The length of the lifespan is dependent upon outside factors—the type and degree of usage, and the environmental conditions under which the unit operates.

- **Ramp Rate:** The rate of change of power delivered to or absorbed by an energy storage system over time, expressed in megawatts per second or as a percentage change in rated power over time (% per second).

- **Response Time:** The time in seconds it takes an energy storage system to reach 100% of rated power starting when the unit is online, but not active.

- **Reactive Power Ramp Rate:** The rate of change of reactive power delivered to (inductive) or absorbed by (capacitive) by an energy storage system over time expressed as MVAr per second or as a percentage change in rated apparent power over time (% per second).

- **Reactive Power Response:** The time in seconds it takes an energy storage system to reach 100% of rated apparent power (var) during reactive power absorption (inductive) and sourcing (capacitive) measured from when the unit is in standby.

- **Reference Signal Tracking:** The ability of the energy storage system to respond to a reference signal.

- **Round-Trip Efficiency:** The energy output from an energy storage system divided by the energy input into the unit over one duty cycle under normal operating conditions, expressed as a percentage (%).

- **Scheduled Downtime:** The time set aside for energy storage system for maintenance or other non-operational schedule activity. (This downtime can be minimized for some modular energy storage systems by pulling off-line only one energy storage module at a time. This can allow the system to retain its original power rating, but the energy capacity would be diminished, and the batteries remaining on-line would be taxed more so than in normal operations—affecting their lifespan.)

- **Self-Discharge Rate:** The rate at which an energy storage system loses energy when it is in stand-by mode. This can change depending upon the environmental conditions of the battery.

- **Standby Energy Loss:** The rate at which an energy storage system loses energy when it is in an activated state but not producing or absorbing energy, including self-discharge rates and hotel loads from auxiliary systems (power electronics, software, HVAC, etc.)

1.2.3. System Performance

System performance metrics are operating results based on multiple technical performance measurements during operation. By coupling a number of these technical operating characteristics, the system performance metrics are more useful as an operating parameter to ascertain how well the energy storage system is achieving its operational target.

- **Availability:** The degree to which an energy storage system is in an operable and dispatchable state. Availability is calculated as the reciprocal of unscheduled downtime, with scheduled downtime for maintenance subtracted first and not affects this performance attribute.

- **Available Capacity:** The energy storage holding capability (kWh) of the energy storage system at any given time ready for use. This value is calculated from adding any additional energy capacity additions to the initial energy capacity and subtracting the capacity degradation of the energy storage system.

- **Capacity Degradation:** The reduction is the energy storage holding capability (kWh) of the energy storage system over the life of the unit.

- **Duty-Cycle Round-Trip Efficiency:** The useful energy output from an energy storage system divided by the energy input into the energy storage system over a charge/discharge profile that represents the demands associated with a specific application that is placed on an energy storage system, expressed as a percentage (%).

1.3. Financing & Performance

Project financing is based on ensuring that the project in question will be able to generate sufficient revenues to cover the debt service and earn an acceptable return for the equity providers. The structure used will be the most financeable for a particular market; the one that can mitigate the risks in the most cost-effective manner.

An effective method to mitigate the project risks is to tie the compensation of the project to performance metrics (beyond other business risk management strategies). These generally fall within two groups cost and revenue. Cost related project risks are typically mitigated through the selection of only mature technology in widespread commercial deployment that is proven and reliable. The choice of OEM supplier for that technology is selected from those with an effective product warranty backed up by a strong balance sheet. Revenue risk mitigation is best served by the project developer obtaining a long-term off-take contract for services, with a credit worthy counter-party, and with performance guarantee for the operation of the facility. Since this is the energy storage market, no one strategy fits all situations, and different strategies are used in different markets.

1.3.1. Utility

Utilities have described many potential uses for energy storage systems on their network, with many utilities looking to structures that allow them the opportunity to contract for capacity and other grid services without owning the facilities. These agreements are typically described as Power Purchase Agreements (PPA) to define to long-term off take agreements. Project developers like then as they represent contracted revenue with a good counter-party—meaning a highly financeable project.

Two types of PPAs are most common for energy storage projects so far, a tolling agreement, and a capacity service agreement. In the tolling agreement, the developer is responsible for project ownership and operation. The utility owns the electricity used to charge the energy storage system, and has the right to dispatch the charging or discharging of the system for its own benefit (energy, or grid services) within specified operating parameters. For operating the facility, the project developer receives a capacity payment (adjusted by availability and round-trip efficiency) and a variable O&M payment based on the amount of energy throughput. Energy needed for station service is separately billed to the developer. The capacity service agreement is similar to the tolling agreement, but the developer is the owner of the electricity, and is responsible for all costs, including the charging cost. The utility pays a straight capacity payment for the ability to utilize the output of the system for energy and grid services. These capacity service agreements transfer more of the project risk to the developer, but also provide more of a possible upside—if the developer truly understands the performance of his system.

1.3.2. Merchant

Without a viable single PPA to ensure contracted revenue for a wholesale facility, the developer will look to stack a number of value streams in order to generate sufficient revenue to pay for the facility. Technically, these facilities could be located anywhere, but developers have typically looked in formal wholesale markets (ISO/RTO regions) where the facility can engage in open market grid service sales. The challenge for merchant energy storage projects is that initially the only revenue stream lenders would recognize for lending purposes were fixed capacity payments. The only other option for project owners is to sell electricity or services into the wholesale market in a merchant role. With growing experience, some lenders are signaling that some revenue to support these facility’s debt service can be derived from these merchant activities, as long as there are some fixed revenue contracts in the mix.

Another application of energy storage in the wholesale market is to combine it with a fossil unit and operate it as a hybrid facility; to date, projects utilizing gas turbines (GE) and MW-scale reciprocal engines (Wartsila) have been announced. The benefit of this arrangement is to augment the gas turbine’s operational range in the wholesale market in order to offer more services such as a longer duration of services for spinning reserves, etc. Financing for these facilities is expected to be based primarily on the capabilities of the fossil facility, but enough of the units have not be developed yet to ascertain the impact of the storage asset on the financing of the entire facility. The impact of the energy storage on project financing on a hybrid facility is typically just the net difference of the output capabilities of the fossil generator by itself, and the output of the hybrid operation.

The final application for energy storage in the wholesale market is to be coupled with a renewable asset to construct a different type of hybrid facility. Typically, renewable projects are compensated based on total production (kWh) over a period of a month or year. Only when the output of the facility is either compensated for dispatchability, or penalized for lack of ramp control over the output would the addition of an energy storage component be warranted. Since the renewable system will remain the bulk of the project assets, the financing for the hybrid project will be structured around that, with the impact of the energy storage component being limited to the risk exposure of the hybrid facility not fulfilling the expanded facilities. Another important strategy of utilizing energy storage assets in combination with large wind and solar facilities is to alleviate the interconnection limitations. Typically, these projects are located in remote locations, requiring addition transmission investment. Though utilizing energy storage, it is possible to overbuild the renewable asset for the related transmission line, and store the excess energy locally in the storage facility, so that the hybrid asset could continue to produce the full amount of output of the rated interconnection for some time after the renewable resource peaked (sundown, low-wind).

1.3.4. Commercial

Behind the meter (BTM) energy storage project development is typically geared toward providing peak demand capabilities, although grid services and on-site services are growing in importance. These BTM energy storage systems are typically offered by developers as a 10-year operating lease, keeping them off the balance sheet of the commercial customer. This lease ensures that the commercial customer has no direct capital or operating costs as the unit is owned and operated by the developer. Lenders and developers interviewed stressed the number of challenges still facing this market, including; software solutions to model complex building load profiles and site-specific tariff requirements, hardware solutions that integrate the building's load, possibly onsite generation units, and the existing building control software, and financing solutions to support standardized agreements that reduce the internal processing of bundled contracts with the lender providing the financing facility for the developer. As project developers gain confidence and experience, combinations of the different programs described here can be supported cost effectively with only marginally additional capital equipment. Since the energy storage systems themselves are not being pushed beyond their typical operating range, the performance risk exposure in this market is migrating toward the enabling software system. Proven performance capabilities here, will translate into greater access to lower cost capital from third party lenders, extending those firms advantageous positions in the market.

Two of the most widely used energy savings performance contracts between project developers and their customers are the Demand Response Energy Storage Agreement (DRESA) and the Demand Charge Savings Agreement (DCSA). In the DRESA, a developer is compensated by the local utility for providing capacity for demand response programs through aggregating a number of customer sited energy storage assets operating as a virtual power plant (VPP). These contracts are highly sought after as the capacity contract with a utility provides virtually no counter-party risk, leaving the performance of the system—aggregating software and energy storage hardware—as the area of operational risk in the contract. The DCSA contract follows more closely to the typical energy savings performance contract used to finance energy efficiency building retrofit contracts. These contracts provide for service cost reductions based on the performance of the energy storage system. Here, the energy storage asset is used to reduce demand charges. Due to the rapidly maturing nature of the industry, there has been a wide range of service bill reduction promises and guarantees, with the trend being towards firmer guarantees of cost reduction as experience has taught the developers what the systems are capable of, and their ability to understand customer load profiles. As this area of the market continues to grow rapidly, other applications are being contemplated, such as providing cost reduction strategies for on-site electric vehicle chargers, which would typically exacerbate the peak load of the facility.

Onsite usage is the final area of usage for a BTM energy storage system. Historically this has meant back-up power, but increasingly interest is focusing on coupling with onsite solar for self-generation. Back-up power strategies have often targeted mission critical applications. Normally this type of applications has centered around uninterruptible power system (UPS) systems, but the increase in deployment of energy storage systems for bill reduction has highlighted the idea of combining these two functions in behind the meter deployments. However, integrating the energy storage system to remediate these problems has technical and contractual issues. Technically, the placement of the UPS on the customer's system is designed to provide direct support for the most critical sub-loads, whereas the peak shaving systems are typically integrated near the customer's point of connection with the utility. Resolving the needs of the two deployment locations while minimizing the capital equipment needed is a challenge. Secondly, and possibly more importantly, the contractual focus of the two applications are different, leading to competing risk management priorities. Whereas the peak shaving strategy's risk exposure is to the electrical bill alone, the UPS risk exposure is to business interruption and possible equipment damage (from poor power quality). It is not impossible to provide both applications from the same energy storage asset, but the two issues should be recognized as the project is contemplated.

The solar industry has aggressively looked to utilizing energy storage systems to augment the deployment of solar PV assets for commercial users. The Solar Energy Industries Association (SEIA) has recently included energy storage language into the Solar Power Purchase Agreements they publish in recognition of the direction of the industry. Since the solar asset is the primary asset in this deployment, the financing of the storage system will be incorporated with the solar PV asset and its solar PPA.

1.3.5. Residential

There are few, individually monetizable value streams for residential energy storage systems, so the deployment strategy has typically relied upon multiple value streams, plus leveraging discrete market opportunities such as home solar installations and directed economic incentives. The opportunity for utilizing energy storage in the residential market stem from coupling with solar systems, providing grid services to utilities, and stand-alone back-up power services. Coupling with residential solar systems for consumer self-generation has been one of the primary deployment avenues to date in this market. The storage system here is not the primary driver for sales and financing, so structuring the contract is based on the solar asset; the requirements for the storage asset are based largely on what is stated in the warranty. Grid services are another opportunity for residential energy storage deployment. These virtual power plant (VPP) contracts with utilities are compensated through capacity contracts, providing certainty of payback. Examples of residential energy storage pilots are occurring at a number of utilities, such as Green Mountain Power in VT and in South Australia. Finally, stand-alone storage can provide back-up power for residential owners as well. This value stream is hard to calculate and even harder to monetize, especially for all the potential storage owners.

The current belief by many in the energy storage industry is that the residential market will continue to expand, but only driven by a number of external economic factors. Since this is inherently a retail market, a different approach is needed to make progress here. Many believe that residential solar deployment and utility VPP programs will continue to drive deployments here, so performance metrics that help to highlight the usability of energy storage for those roles will have the greatest impact in the residential market.

2. TECHNOLOGY FACTORS

Technology evaluation is the basis for understanding the performance capabilities of energy storage technologies. Performance requirements are fundamental to the design, integration and deployment, and operation of the system to ensure successful operation and thus profitable returns for owners and lenders.

The impact of performance is evident throughout technology evaluation process:

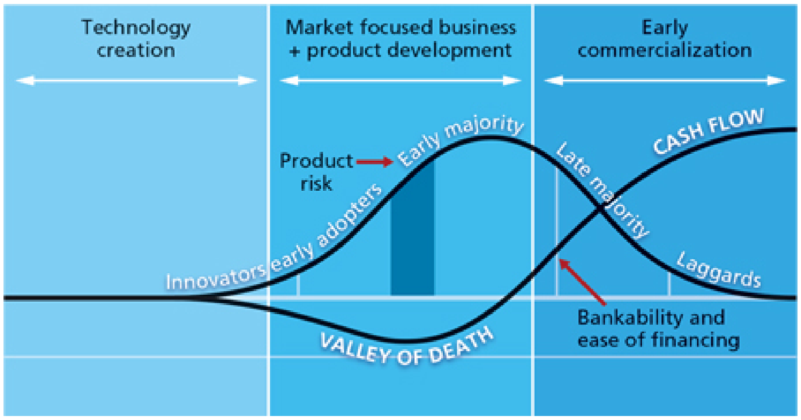
- The design review will focus both on the performance of the technology, and performance of the system. This evaluation helps to determine financeability of the technology and project design. An energy storage system has many more operating variables than a comparably sized solar PV or wind project, thus a review of the appropriateness of the equipment selection and project design is critical for a lender on its funding decision, and thus the basis for the financeability of the project. This design review will focus both on the estimated performance of the technology, and the system as a whole. Evaluating the technology offering is not just a critical decision for a lender, but for everyone associated with the project. Evaluating the system offering focuses on the effectiveness of design, with relation to cost and performance with a primary focus on whether the system can operate successfully to repay the lender, sponsor, and project developer.

- Integration and deployment of energy storage focuses not just on the performance of the individual components themselves, but also understanding how they all interact as a complete system, considering local environmental conditions to ensure that the desired performance level can be achieved. Three areas in particular: system integration, EPC (Engineering, Procurement, and Construction), and Commissioning.

- The proper operation of the system is obviously important, and so too is the monitoring and verification of the system's performance. To ensure unbiased measurement, obtaining 3rd party monitoring services provides the lenders assurance that the system will remain physically able to perform as expected, and thus ensure reliable servicing of the debt. Operation and maintenance remains critical to obtaining a long running operation.

2.1. Design Review

An energy storage system has many more operating variables than a comparably sized solar PV or wind project, thus a review of the appropriateness of the equipment selection and project design is critical for a lender on its funding decision, and thus the basis for the financeability of the project. This design review will focus both on the estimated performance of the technology, and the system as a whole. Evaluating the technology offering is not just a critical decision for a lender, but for everyone associated with the project. Evaluating the system offering focuses on the effectiveness of design, with relation to cost and performance with a primary focus on whether the system can operate successfully to repay the lender, sponsor, and project developer.



Source: DNV GL

Figure 6. Making Energy Storage Financeable.

2.1.1. Bankability Studies

Proving a storage technology is bankable has been a significant hurdle for many companies with emerging energy storage development technology companies. In this report, a Bankability Study will refer to the evaluation of the technology or company developing the technology, and the Independent Engineering Report will focus on aspects of the project's viability, which will include the bankability of the technology and/or company providing the technology. For those technologies that are widely available and assumed to be sufficiently mature—lithium-ion—the input of the Bankability Study is typically covered largely by the warranty. As energy storage technologies become widely deployed with substantial operational experience, the Bankability Study becomes less necessary as a stand-alone requirement.

Time and again, study participants stressed the need for Bankability Studies to ensure financeability of an energy storage project utilizing an emerging technology. Bankability Studies have been widely used in the solar PV industry, and provide a 3rd party project risk assessment to determine if the equipment will perform as predicted by the manufacturer over the project life. However, a Bankability Study is more than just an engineering equipment report, they are a process to understand the potential risks from utilizing a technology from an emerging technology provider, and set in place the knowledge on how to deal with them by evaluating the full supply chain. These Bankability Studies can be designed to provide a full due diligence review on the OEM, including the OEMs position as going concern, its technology, manufacturing process and capability, supply chain, and potential competitors to ensure the security of cash flow from the project.

The Bankability Study will also contain an evaluation of the technology vendor to ascertain default risks. Many study participants believed that through these deeper dives into the supply chain, the Bankability Study can provide a clearer insight into other projects undertaken by the developer; have they developed a robust enough set of internal controls to ensure that the project developer will be able to consistently develop high quality systems? This last part is crucial as when unexpected problems arise—and they always arise—especially in emerging markets like energy storage. Lenders want to know there is capability to fix the problem, and that there are solid companies standing behind the product or workmanship.

Bankability Studies are important for both lenders and manufacturers. For the lenders and other financial firm interested in participating in energy storage projects, the rapid advancement in the technology has left little common knowledge about energy storage technologies. These reports can also provide a deeper visibility into the capabilities of the technology and its value chain for the lending community. As the industry expands, the challenge for lenders grows, as the number of global manufacturers active in the market grows, each with a possible divers supply chain. For manufacturers, engineering firms providing Bankability Studies act as an impartial technical evaluator who has had experience with other OEM firms in the market; the Bankability Study can help the firm incorporate industry best-practices by identify gaps in the manufacturer's product design, reliability, manufacturing and installation and maintenance. Other groups can also benefit from Bankability Studies—particularly EPC (Engineering, Procurement, and Construction) firms who are increasingly being called upon to provide some level of warranty wrap. Bankability Studies can have all or only part of (or more) of the components listed here as warranted to provide the technical understanding for a lender. A prerequisite for an engineering firm to undertake a Bankability Study is to have deep domain knowledge on the energy storage technology in question.

2.1.1.1. Original Equipment Manufacturer (OEM) Corporate Review

Bankability Studies cover many of the same aspects of a Due Diligence review undertaken for a capital raise on the firm in order to ascertain good corporate performance to support the emerging technology offering. These will cover a wide range of issues for the firm (with the degree to which these are covered will vary as needed):

- **Corporate & Financial Documents**: This would include the firm's Articles of Incorporation, bylaws, and Board of Directors legal agreements, financial statements, auditor's reports, income tax returns, listing of subsidiaries and partnerships, current or pending litigation, and professional services currently or recently retained.

- **Corporate Assets:** This would include a list of all physical assets, major process equipment, real estate holdings, and intellectual property, including general description of trade secrets and process knowledge.

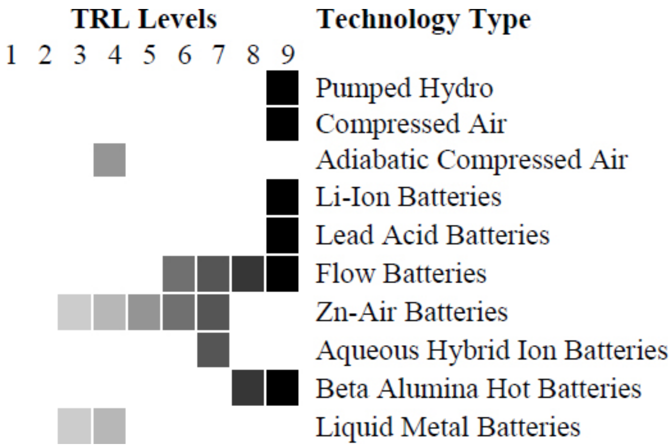
- **Products & Services:** This would include a list of all products or services existing now or in development, major customers over the last 3 years, and a description of the markets where the firm is active and major competitors in each one.

- **Operations:** This would include a list of all employees (contracts & benefits), government licenses, environmental audits, and all insurance coverage.

2.1.1.2. Technology Evaluation

Undertaking a technical evaluation of the energy storage technology is the core of a Bankability Study and the first stage in estimating the financeability of the energy storage technology development company for a project. This is of more concern for companies developing emerging energy storage technology companies than those manufacturing widely commercially available products.

A standard measure of technology development is the Technology Readiness Level (TRL). The TRL scale is 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 NASA in the 1980s and ranges from 1 (basic principles observed) through 9 (total system used successfully in project operations). 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.
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.

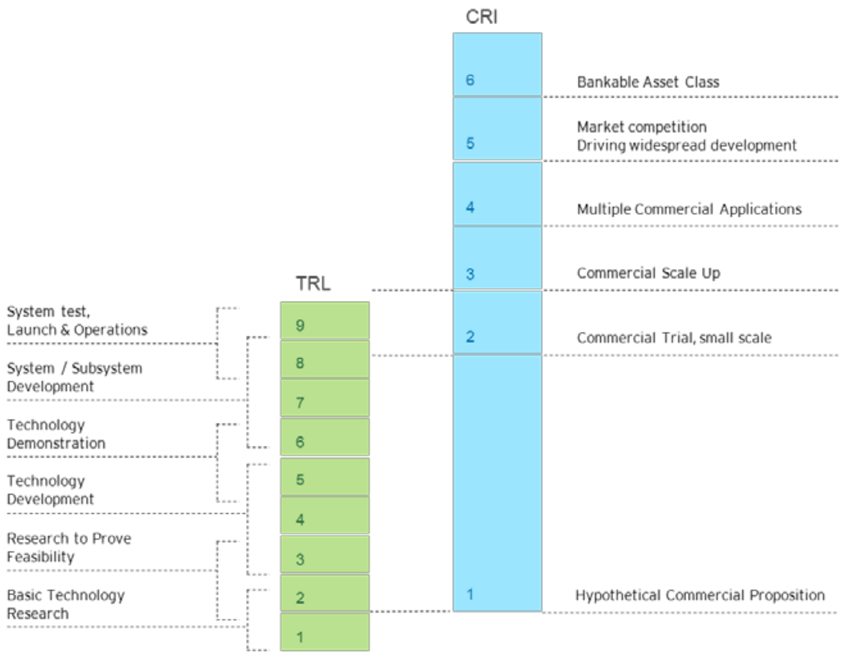


Source: National Academic Press

Figure 7. Technology Readiness of Energy Storage Technologies.

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 goes from 1 to 9.



Source: Australian Renewable Energy Agency (ARENA)

Figure 8. Technology & Commercial Readiness Levels.

2.1.1.3. Manufacturing Process

After the technology has been proven ready for commercialization, a Bankability Study will also provide a deeper dive into the manufacturing process of the OEM (or its contract manufacturer), and visibility into the firm's production life-cycle, including design work in progress. This is done to establish that that the manufacturing process is able to support the expected commercial development of the product. This would include the ability to:

- 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.

- 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.

- 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.

The growing level of interest and activity by contract manufacturers in the energy storage industry is another key signpost of the market’s maturity. A number of partnerships between contract manufacturers and energy storage technology developers have been announced, bringing more interest by other groups. Some still profess that the market still remains fuzzy, but it is moving quickly and they want to establish themselves in the industry before all the good partners are taken as they notice many of their competitors already in motion. The establishment of product Standards over the next few years will help to define the role of this group of firms, many of whom are already key to energy storage technology developer’s business plans.

As the OEM expands its operation to support very large capacity, customers will insist on their suppliers adhere to industry standard guidelines. This includes the ISO 9000 family of management system standards that are designed to provide a framework of quality management systems in the firm. ISO 9001 deals with the requirements that firms wishing to meet the Standard must fulfill. Third-party certification bodies provide independent confirmation that organizations meet the requirements of ISO 9001.

2.1.1.4. Supply Chain

Building off the evaluation of the manufacturing process, a deeper dive into the OEM’s supply chain can show exposure to production risk. Here, the Bankability Study reviews how the OEM manages its supply chain, including any raw materials and components from suppliers in inventory.

For suppliers in general, the Bankability Study looks to determine the risk management strategy employed by the OEM to highlight potential disruptions in manufacturing. Reviewing supplier arrangements allow the study to determine issues such as the geographical distribution of suppliers, the level of sole sourcing for components and what alternatives exist, the process of validating new suppliers and the process of switching, etc. The Bankability Study can also look into recent history for any supply disruptions, and the general health of the OEM’s supplier network.

2.1.1.5. Competition

Finally, a Bankability Study will evaluate the competing vendors of the particular technology in question in order to provide some baseline capability index. Competitor intelligence is typically part of a due diligence process, but can also be undertaken as a separate endeavor to obtain information such as sales numbers and details, marketing strategy, partnerships and vendors, etc.

- **Press Analysis:** Significant amount of information on competitors can be found in the public domain, including press releases, public presentations, financial statements (if public), etc. Increasingly, competitor websites hold invaluable information about products, services, and market strategies.

- **Pricing Research:** Determining the current price of a competitor's product or service offering can be determined in a number of ways. These would range from simply searching through public online listings, press analysis, or from other firms or individuals in the industry. Typically, the complete price you are looking for is not available, requiring the development of a pricing model that will take disparate data points plus a methodology to combine the data into a complete price, based on your own proprietary knowledge of the product.

- **Competitors:** Interaction with the target company's competitors is a key avenue for market intelligence. Especially in emerging industries such as energy storage, there are common areas where competitors will share information on the market to advance to industry. Trade groups like the Energy Storage Association or NAATBatt are also helpful.

- **Customer Interviews:** Reaching out to existing and potential customers is a reliable, valuable, and often overlooked approach to determine competitor offering and market positioning. Typically, customers are far more willing to share insights with other vendors who compete with their own supplier in the hope of securing a superior product at a cheaper price.

- **Industry Interviews:** Beyond customers, peers in the industry can provide significant insights and data on competitors. These other sources include suppliers, distributers, and other experts in the industry who can provide insight into the supply chain for manufacturers of a certain technology.

2.1.2. Independent Engineering Report

The Independent Engineering Report (IER) has long been a requirement by lenders as part of electric power industry project financing in order to make investment decisions with confidence. The independent technical assessment provided by the IER is a central part of the lenders risk management process in their credit approval process for project development. IERs cover the design, engineering, construction, contracting and performance predictions for the facility.

By definition, the IER would cover most of the aspects of the aforementioned Bankability Study. However, as many of the systems deployed now are based on lithium ion, a widely accepted and proven technology, the need of the IER is more geared toward system design and acceptance as the market moves towards a more commercial level, the market needs more IER support than Bankability Study insight.

2.1.2.1. Project Documentation & Contract Review

A first step in project evaluation is to review all of the existing project documentation and contracts with regards to the technical aspects and performance requirements for the project. This review is to ensure the technical adequacy and consistency of contracts, while conforming to good engineering and construction standards practices. Documents and contracts for review would include the: EPC Contract, OEM equipment supply, O&M contract, warranty contract, utility interconnection (if applicable), construction (civil and electrical work), Power Purchase Agreement (PPA), etc.

2.1.2.2. Regulatory & Revenue Evaluation

Evaluating the existing market rules under which the facility would operate and its expected revenue generation potential is critical to proper debt service coverage and positive returns for sponsors in the project. Done in part to fact-check the assumptions in the above mentioned contracts. Depending on the market segment where the facility will operate, there may be a number of different regulatory jurisdictions that will have oversight or impact. This review takes on additional importance due to the changing natures of the market rules for energy storage, and the resulting potential for revenue generation (or loss of opportunity). For energy storage projects, the regulatory & market rule reviews would cover a similar area as the resource assessment typical of wind and solar projects.

2.1.2.3. Safety, Permitting, & Local Ordinances

Safety is an area of increasing focus across all portions of the energy storage industry—manufacturing, installation, and operation. The U.S. Department of Energy's Energy Storage program has made safety a focus for a number of years now, in effort to highlight its critical component of both successful operation, and also as underpinning of risk management to lower the cost of equity capital raising and project development finance. A key description of the layout of the U.S. DOE's safety program can be found in the *Energy Storage Safety Strategic Plan*[2], published in December, 2014.

Permitting and local ordinances are designed to promote the safe installations and operation of deployed equipment, The National Electrical Code (NEC), or NFPA 70, is a regionally adoptable standard for the safe installation of electrical wiring and equipment in the United States and has recently added Article 706, covering energy storage assets, to the 2017 edition. Complying with these local regulations is a component of the overall safety program of any energy storage project. The IER will focus its review on the technical aspects of the required permits and local consents. These might entail environmental, soil, construction and/or building permits, etc.

2.1.2.4. Plant Design and Performance

A core function of the IER is to review the system design, with regards to key metrics such as energy rating (kWh) power rating (kW), charge / discharge rate and temperature characteristics. The system design will cover all major components of the energy storage system: the storage module (battery), balance of system (containerization), thermal management, power conversion system, energy management system (software and communication). If the IER also includes the grid integration component, this would include the additional electrical interconnection equipment and SCADA system interface, etc. For these components, the IER will review their integration, and evaluate the track record of the different OEMs. Beyond simply the manufacturing quality of the equipment, the IER will also review their rated performance capability and estimated lifespan (individually, and integrated) against the stated usage profile for the system. This can also include independently verifying the expected performance through testing

2.1.2.5. Performance Testing & Valuation

A key aspect of validating IER findings is the ability to independently test the equipment against the expected performance requirements. This validates that the chosen technology is truly suitable for the target application. The results of the testing process can be used in both the equipment acceptance test prior to commissioning and validate the operating lifespan and capability assumptions in the financial model. If the engineering firm is not able to undertake the testing themselves, they must cite 3rd party test results undertaken at another testing lab.

The energy storage industry has been supporting the efforts of firms to evaluate and define the performance of energy storage technologies in different applications through the development of tests and metrics for these technologies in different market applications. Much of this effort has been included in a joint PNNL / SNL report *Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems* (PNNL-22010) (the “Protocols Report”). As the industry continues to advance its understanding of the operation of these assets, this report will be updated (currently on revision 2), and provide the foundational basis for developing an initial standard for the uniform measurement and expression of energy storage system (ESS) performance.

2.1.2.6. Construction and Commissioning

The IER will review the construction and commissioning plans so that they adhere to best practices and reasonableness of costs and so that the effort will stay on schedule and adhere to stated completion milestones. As the project progresses, the engineering firm can also audit the work in progress. This will include civil, and electrical construction work. Site conditions is always one of the critical issues with regards to cost and schedule over-runs, so the geotechnical survey remains critical.

The commissioning and start-up plan is important to ensure the unit operates as planned. Review of the commissioning and start-up plan including performance testing and acceptance criteria will be compared to independent testing performed by the 3rd party testing facility. Typically, the

IER will include an estimation of the project completion date, with recommendations for potential delay contingencies, so the engineering firm has an incentive to be accurate in estimating the Commercial Operation Date (COD) date. Critical to this review will be ascertaining that the facility will be in compliance with local codes and ordinances; as evidence of the maturing of the industry, these issues have recently been compiled and integrated into the new Article 706 of the 2017 edition of the National Electrical Code that covers energy storage systems.

2.1.2.7. Warranty

Equipment warranties are a critical component of project financing risk management, and thus their review with consideration of the usage requirements is one of the key aspect of the IER. As the level of technology is still evolving rapidly, and the usage opportunities expand, OEMs are challenged to provide clearer guidelines for what performance can be expected from the product, and what cannot. Critically then, this review must contain an analysis of the stated warranties for components that make up the storage asset and confirm that the expected usage profile can safely be performed by the proposed project.

2.1.2.8. Operation & Maintenance

Review of the Operation & Maintenance plan will allow the IER to ascertain if sufficient monitoring, field maintenance, and preventive maintenance effects are included. The levels of this maintenance will bear directly on the adequacy of the preventive maintenance and scheduled equipment replacement program to support the unit lasting through the term of the contract; a well thought out and executed O&M program reduces total project costs. This will include estimation of the cost of routine and unscheduled maintenance and on-site inspection and replacement parts.

2.1.2.9. Project Economic Model Assumptions

The value of a project economic model to provide a useful financial projection for the project is based heavily on the market data and technology costs assumptions that are used. The IER does not typically review the project economic model itself, but it does review many of the fixed and variable technology related costs that drive the project economic model. By clearly presenting the results of the different cost related items that are used, lenders and project developers can see the reasonableness of the parameters, and their impact on the project's financeability. If the engineering company is able to provide comparative data for each of the cost segments (equipment, O&M, etc.) than the lenders and project developers will be able to have more confidence in the relative competitive position this particular energy storage project will have vs. other energy storage projects, and alternatives in the market in general.

2.2. Integration and Deployment

The goal of an energy storage system designer is to create something that is greater than the sum of its parts. Evaluating the integration focuses not just on the performance of the individual components themselves, but also understanding how they all interact as a complete system. This also requires taking into account local environmental conditions to ensure that the desired performance level can be achieved. Three areas in particular: system integration, EPC (Engineering, Procurement, and Construction), and Commissioning.

2.2.1. System Integration

Integrating all of the various components is an important step in ensuring operational reliability of the system over the unit's lifespan. Great strides in technological advancement in both battery and inverter technology have resulted in better quality at lower prices for the components, and a growing body of experience is helping improve the state of the art for system integration. A key part of the improvement in system integration is the advancement of technical standards for components, allowing multiple manufacturers build with confidence of plug & play capacity. The importance of improving the quality of system integration cannot be overstated. As the quality and reliability of the system integration improves, it has a direct impact on reducing the NRE (Non-Recoverable Engineering) expenses that drive variability and volatility in EPC costs.

Within system integration, two areas of specialization are rising as essential for improving performance: electrical manufacturing, and software development. In the early days of the energy storage industry, many OEMs or project developers were forced to step into the role of system integrator as there were scant firms with significant technical experience coupling the equipment into workable solutions. As the industry has grown, professional electrical manufacturers are entering the industry. These firms bring their experience in electrical manufacturing to the energy storage market and see it as the next growth market. They are bringing their expertise on the assembly of the unit, based on their in-house equipment, or using external electrical manufacturers. Some integrators are able to use a globally integrated supply chain from multiple OEM vendors to develop a standardized energy storage platform that is scalable for commercial, industrial, and utility markets. By supporting project developers with in-house design and engineering support, they are able to support a wide variety of clients. By building to the emerging industry standards for products, they are able to provide interoperability, safety, and reliability.

Software is the second critical component of system integration for energy storage systems. The key value in energy storage systems is not just their ability to store energy, but in the flexibility they bring to the system in how they provide benefits for the power grid. The software—commonly described as the Energy Management System (EMS)—are literally the controls of this effort. They are responsible for managing the performance of the system. For that reason, the EMS must be designed with respect to the hardware's actual capability in order to have the system perform to its best ability.

Finally, safety is a critical design element that must be incorporated into the system integration—both for the well-being of personnel, but also for the operational risk to developers. Energy storage systems that are not designed safely are not designed for successful operation. Through the efforts of the U.S. Department of Energy, a safety mindset is becoming entrenched at the core of systems designing to preclude failures, but also to design for system failure. Trying to design a system that will never suffer a failure is extremely difficult and inherently expensive. Therefore, it is better to design the system so that when a failure does occur, the fault can be isolated quickly, and not allowed to cascade into other systems where greater damage and possible injury occurs.

2.2.2. Engineering Procurement & Construction (EPC)

Specialized engineering firms provide EPC (Engineering, Procurement, & Construction) services for energy storage projects. These contracts are designed to clearly state the requirements from the parties involved in the development of the energy storage projects; they support successful execution of deployment, lay the foundation for profitable operation, and are a key component of attracting lenders through clearly stating and dealing with the primary areas of project risk.

EPC contracts are typically a turnkey contract – contracting to deliver a completed facility for a developer by a specified date and within a specified budget. Besides expertise and experience, increasingly EPCs provide another key project essential—a warranty wrap for the entire energy storage facility. This warranty wrap will typically cover all equipment and operating performance of the complete system against their combined product warranties. In order to provide this coverage, the EPC reviews the warranties and operating experience of the different components in order to be comfortable in how each operates individually, and as part of a complete system. Obviously, the willingness of a particular EPC to provide this coverage will be based on the familiarity and confidence of the EPC with the various components, and the system integrator that designed and assembled the unit. The performance level covered would simply be the technical performance of the different components in their spec sheets—it would NOT cover revenue generation and the performance of the unit economically in the market.

For all of these reasons, an experienced EPC is quickly becoming an indispensable partner for project developers and lenders. The EPC is the group responsible to the developer for knitting together all of the technical details of the equipment and the project. As it is quickly becoming apparent, the multifunctional operational capabilities of an energy storage system are a central area of concern—will all of the components of the energy storage system still be able to perform to their full stated operational range when coupled together. For many multi-component systems both in and out of the energy storage industry, the answer is no (sometimes only slightly, other times to a large degree). By working closely with the developer, the EPC can therefore be the single point of management for the technical challenges of deployed energy storage system. As the industry is rapidly expanding with multiple vendors of different components, the EPCs are facing potentially large performance risk acceptance in order to win the contracts. In response, it is natural for EPCs to then look for avenues to reduce these risks they are requested to cover, such as down-selecting vendors to a smaller pool so there is a greater working relationship with OEMs of key components.

Payment term for EPC contracts are typically a fixed amount, essential for the project developer to craft a reliable budget for the project. A critical issue raise by many interviewees is on who is responsible for cost over-runs when the inevitable changes happen to the original plan. On the surface, cost over-runs would be typically be covered by the EPC as agreed to in the contract, as well as benefitting from any potential cost savings (although since the market is still relatively early, most EPCs interviewed for the study believed that typical movement would be towards cost over-runs). In reality, significant negotiations happen to cover as may contingencies as possible with the EPC building into their bid sufficient space for some cost-over runs. When significant changes to the contract occurred, change order agreements dealing with these scope changes are negotiated separately.

Key areas of EPC firm coverage where performance issues arise include:

- **Project Management:** The EPC is a single point of contact and responsible for staying on budget and following the project timetable. The firm is also responsible for adhering to local ordinances and regulations in the permitting process.

  Project developers interviewed highlighted the need for the EPC to have a good working relationship and communication with the developer during the process to highlight any concerns for impending issues so they can be dealt with in a timely was together. EPCs with significant project development experience, especially in similarly sized energy storage projects are greatly desired.

- **Engineering**: The EPC provides the system engineering design and documentation for the facility for use during construction, including project site layout, engineering and integration studies, and required permitting. The design is based by the EPC matching the required usage profile of the system with the technical capability of the equipment, with respect to the overall cost. This covers understanding the difference between the stated capabilities of the components separately, and integrated into a system.

  Project developers interviewed highlighted site-specific engineering costs as a major concern for project budget overruns. Although much of the industry players with experience continue to focus on leveraging lessons learned from previous deployments, site specific requirements continue to drive up NRE (Non-Recurring Engineering) costs, and most project developers are trying hard to not pay for the EPC experience curve.

- **Procurement**: The EPC is responsible for procuring all of the components of the energy storage system according the product specifications list in the engineering design. As more vendors and system integrators enter the field, the EPC must base the selection against vendor evaluations for quality and responsiveness, not simply price. The firm is also responsible for contracting the shipping and transportation of the equipment to the construction site.

  Project developers interviewed listed the recent tightening of availability for lithium-ion system as another concern, including the possibility of existing orders being canceled due to inability to deliver. As the market grows rapidly in the next few years, nearly all respondents stated that they believed there will be a number of periods where supply issues that will directly impact their availability to deliver a project on time.

- **Construction:** The EPC is responsible for coordinating the construction of the facility. One of the critical risks for construction over-runs is in the site engineering, so experience with site assessment and development, environmental management, and foundation construction is imperative to maintain cost containment. The firm including selection of subsidiary electrical contractors who will assist with the installation and commissioning.

Project developers interviewed for the study stated that there still remains a wide range of experience when it comes to EPC firms, and that many of the projects continue to be impacted by the site preparation and construction. EPC firms interviewed also agreed that the construction component can be far more expensive than originally thought, but these cost-overruns were driven by earlier changes in design that necessitated alternations in the construction and installation segment. All agreed that specialty built enclosures or containerized systems allow for ease of construction and installation.

2.2.3. Commissioning

Commissioning an energy storage system ensures that all components and the integrated system itself are installed, tested, and ready for operation according to the OEM's and system integrator's checklists. This process does not simply start when the construction is completed, but reaches back into the design phase where the commissioning team becomes familiar and comfortable with the equipment vendors commissioning procedures. They do this by reviewing the equipment specifications and applicable codes and standards that the system is required to meet, and review (if provided by the integrator) or develop an integrated Sequence of Operations (SOO) for the commissioning process. As part of the commissioning plan, safety is critical, and will be incorporated in the commissioning process through identifying the safety systems (fire suppression, sub-module containment or physical separation) that need to be installed, and the site incident prevention plan.

During construction, the commissioning team tracks the Factory Acceptance Tests prior to shipment to the site, and reviews the installation procedures and inspections. The team also uses the time to ensure that the training and emergency response procedures are adequate, as well as the on-site testing and startup procedures for the unit.

The Operational Acceptance Test will verify and test that that all electrical and mechanical components of the system are ready for start-up. After each component passes the test, the system will be ready to operate. To ensure validation of the procedures, some 3rd party testing is emerging to provide developers and lenders a second critical look at the system so they have confidence in its successful operation.

Finally, the Functional Acceptance Test will ensure that the equipment and controls are operating successfully and that the system is ready for its design operation according to the planned usage profile. Increasingly, this has a special focus on the software, controls, and communication that are rapidly expanding their capability as to how the system will operate. Training continues to need to be updated as equipment and control systems are updated by different vendors. Prior to signing off, operation and maintenance procedures and warranties must be reviewed to ensure that the equipment's capability matches the intended operational requirements for the intended market role of the unit. This last step is critical as varying market roles may unintentionally force the system out of compliance with the warranty, violating clear tenants of the lender's requirements.

2.3. Operation

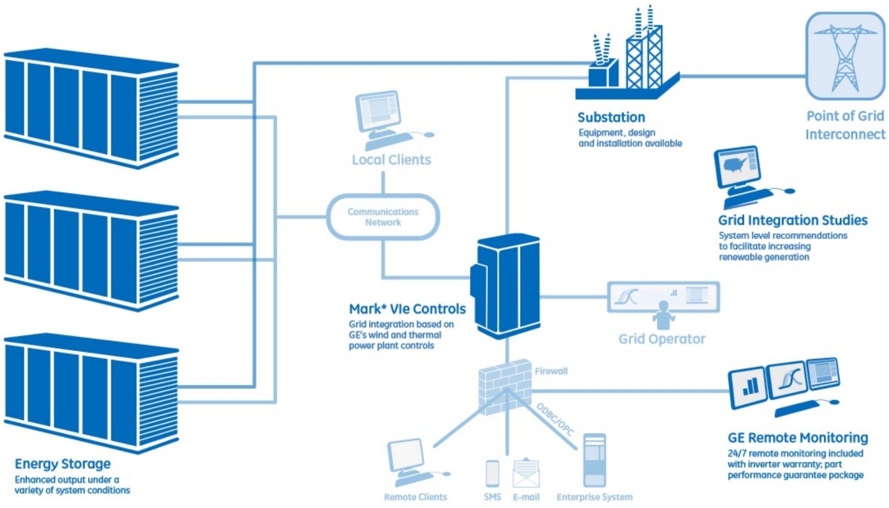
The proper operation of the system is obviously important, and so too is the monitoring and verification of the systems performance. To ensure unbiased measurement, obtaining 3rd party monitoring services provides the lenders assurance that the system will remain physically able to perform as expected, and thus ensure servicing of the debt. Operation and maintenance remains critical to obtaining a long running operation.

2.3.1. 3rd Party Monitoring

To ensure both quality and validity of the operational data, a number of operators are looking to 3rd party monitoring options for energy storage systems. These services are being offered by engineering firms specializing in testing, inspection and certification services, which provide the owner and lender with the option to ensure a neutral 3rd party to be tasked with verifying performance results.

2.3.1.1. Remote Monitoring

Remote monitoring of energy storage asset is commonplace now, and the practice is expected to continue as the industry grows. Remote monitoring is both useful for preventive maintenance scheduling, but also for the collection of operating data. Energy storage assets are designed to be able to operate and react in a variety of way. By collecting the data, risk management strategies based on properly operating the system are possible.



Source: GE Energy Storage

Figure 9. Remote Monitoring.

2.3.1.2. Operating Performance Verification

It is commonplace in the solar industry to utilize field evaluation and testing of the panels to confirm compliance of the equipment against performance guarantees. Performance testing answers the question at project design, project commissioning, and in a continual maintenance function to make sure that the product, as a whole, is performing as engineering and specified now, and in the future after 5, 10 or even 15 years of operation. Performance testing answers questions such as what is the round-trip efficiency, what is the response time to a market signal, what is the ramp rate, what is the standby energy loss rate, and what type of state-of-charge excursions are taking place?

Performance testing supports developing and validating the ability of an energy storage system to meet contract obligations. Energy storage financing is hampered by the high cost of capital. Third-party performance verification helps to assure that the system is designed and functions as it supposed to, but also produces useful information about the capacity degradation.

Third party performance verification can support better financial contracts. Standards for performance testing—such as found in PNNL-22010 (Protocols Report)—support greater commonality between contracts as they represent an industry accepted and increasingly adopted method for verifying performance. Financial models and insurance contracts are, in essence, expressions of assumptions on future performance. By providing data on real projects, these assumptions can be verified and improved, resulting in lower cost due to a higher degree of accuracy of forecast. These results will also tighten the range of assumptions that various actors make, tightening the band of expectations from these systems towards and industry norm based on best practices.

Third party performance testing can also reduce insurance cost and improve financeability through greater understanding of future performance under real conditions. Real data will help reduce downtime, and improve preventive maintenance O&M procedures and costs. Performance testing can also alleviate fears of over-taxing the operating capacity of energy storage systems in order to achieve the sufficient value stacking. Field evaluation would help demystify the question of the operating performance of energy storage systems in real-world applications, and make performance of battery systems far more predictable. In order to make the lessons learned easily transferable, the testing regimes need to be standardized and become a routine part of energy storage system operation.

2.3.2. Operation & Maintenance (O&M)

Operation and Maintenance procedures are a critical component of a successful energy storage facility operating in the market. In the solar PV market, O&M execution risks had ranked amongst the top three concerns of equipment manufacturers, rating agencies, and investors when this industry was young. O&M procedures in the energy storage market will be affected by different geographical and market operation variations. Some variation will also exist by chemistry – flow batteries vs. lithium ion—but other parts are more similar across the industry, such as inverters and HVAC systems.

Lowering O&M costs will require a focus on shared best practices by the energy storage industry, incorporating better field data, performance measurement, failure analysis, and reliability scoring to understand the impact of usage patterns on equipment. This work lowered the financing costs associated with solar installations.

O&M cost models estimate the costs of delivering an O&M program that considers system characteristics and which conditions determine the optimal inspection and repair schedules. More robust O&M cost models will enable financial firms to easily categorize, predict, and support energy storage projects, resulting in lower financing costs. Better models will also increase the effectiveness of O&M procedures, preventative maintenance, and reduce the cost of maintaining energy storage systems. This would require standardized maintenance protocols.

As the energy storage market expands, the O&M component is expected to follow the evolutionary patterns of the solar industry. Some key issues are expected to include:

- **O&M Price Pressure:** Revenue stress puts pressure on all aspects of the projects, especially those that deal with actual cash outlays. For this reason, there will be always be a constant balancing of what cost effective balance between different levels of O&M services are needed, and what people will pay for.

- **Fleet Managers:** even though market is relatively nascent, those groups with a plan to become operators of systems are planning out their operational plan, including O&M. This can either entail bringing those roles in-house, or lining up vendors for the services. This in turn could affect the purchase choice of new units as operators down-select to a fewer set of providers for commonalty of operation.

- **Solar / Storage:** One of the largest area for growth in the storage market is through coupling with solar assets. As these systems already have extensive operational experience—many operators here see storage a simply an extension of the electrical balance of plant for the solar field, and plan on the O&M for the battery system to be incorporated into the O&M procedure of the solar field overall.

- **Grid Services:** The degree to which the energy storage system operates—rate of charging and discharging, amount of energy cycled—in order to perform specified grid services will have a direct bearing on the O&M requirement of the system. Systems requiring more operation will require additional O&M services over their lifespan than others that play more of a reserve capacity role.

- **O&M Innovation:** The energy storage industry is just beginning its commercial market expansion, so we can be confident that a number of existing methods of providing O&M services will change and adapt as the market expands. As operators manage systems is different areas, remote monitoring will be utilized to reduce required staffing levels and improve preventive maintenance practices. Other adaptation and changes to the equipment themselves. For instance, if there are components that have a specified operational life, design just the core of that component to be easily replaces (and a minimum cost) so there is less field maintenance required.

- **Cybersecurity:** As energy storage assets become more widespread and integrated into the electrical grid, cybersecurity will need to extend to all aspects of the control systems, especially the O&M monitoring systems that touch on all aspects of the system. This will be of even more importance at smaller, more remote facilities that will not have a maintenance staff on site.

2.3.3. Warranty

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. 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. For larger utility scale systems that will define coverage in more detail depending on the usage, typical original equipment warranty coverage is 1-2 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 warranty 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 can 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.

Going forward, the growth in warranty coverage expansion is expected to improve with the advancement in energy storage technology. More specifically, warranties will improve with the greater understanding of the performance capabilities and limitations of the technologies, which is based on operating experience. Feedback from the market is also important and impactful as to what OEMs provide as a warranty. For example, utility contracts qualifying for resource adequacy require warranty coverage for duration of the contract term. Therefore, OEMs have a good insight into the types/length of warranties that project developers are looking for. Even with greater understanding of the performance expectations for storage systems, this does not mean that OEMs will start to provide extensive warranties free of charge; smaller technology development companies do not have the balance sheet to back such claims, and larger companies do not do that for existing products for the simple reason that they do not want to build up such a large liability on their balance sheet.

As the different OEMs become more confident with the operational capabilities of their products, competitive pricing pressure is expected to drive enhancement to the warranty offerings—primarily driven by the operating lifespan of systems that could be measured in years or kWh throughput. For instance, in many commercial and residential markets, 10 year operating lifespans is the extent of expectations. In the larger wholesale and utility markets, however, some projects are looking to extend the operating lifespan to 20 years for the facility. Depending on the usage profile and product, there may be alterations to what is covered over the outer years of a warranty, or some equipment would require an increase in the cost of the warranty in the outer years. Since battery cell operating life does not easily meet these extended lifespan expectations, warranty coverage must be balanced with the need for module augmentation to cover the operating life of the system (one of the reasons it's been easier for larger developers to find internal financing than smaller ones needing 3rd party lenders). As battery technology continues to advance, the definition of warranty coverage is continuing to move from a simple length of time warranty, to energy throughput.

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. 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. Instead of OEM warranties, other groups—EPC, electrical contractors—are better positioned to directly provide such a re-installation coverage.

3. ECONOMIC FACTORS

The economic performance of an energy storage system is a balance between the most cost-effective design and its operating strategy for a chosen market role. What makes energy storage project development challenging is that choices on either side of the equation can have significant impacts on the other, and thus an iterative exercise. A key in this decision is that energy storage systems have a limited duration capability to charge or discharge, and thus the marginal value of the remaining charging and discharge capacity at any given time is of prime importance to the system value, but this balance is always changing. To develop an energy storage project with long term flexibility (and hence value), the project developer must incorporate this understanding of changing marginal values into their design operating plan from the start. For this reason, the performance of the energy storage system is paramount to its ability to create value for the owners.

The impact of performance is evident throughout the economic assessment process:

- For costs, performance explains the balance of upfront vs. lifetime costs. Some technologies may cost more initially, but could cost less to operate over the system life. When replacement cells are required, project developers attempt to push out required augmentation to allow the ongoing declining cost trends to produce lower future costs for batteries. Finally, ensuring high availability for the system through proper operation and maintenance is only possible through performance monitoring and verification.

- For revenue, performance helps us understand which application can be stacked. Balancing higher value operation with performance requirements that affect other revenue operation requires an understanding of the different performance requirements, and choosing which mix produces the highest and most reliable revenue stream.

- For project economics, performance is key for understanding how all aspects of system design, operation, and market strategy are interconnected. Impacting one area of the system will have follow-on impacts elsewhere, so the entire project needs to be evaluated as a whole for overall, integrated value generation.

3.1. Costs

As the market for energy storage technologies expands, the understanding by project developers for the equipment costs has improved. However, this understanding is somewhat misleading as it typically pertains only to the initial equipment costs. The true cost of an energy storage system must take into account the intended usage profile and lifespan of the system, highlighting the need for good visibility into equipment costs, but also augmentation (additional equipment over the lifespan) and operation & maintenance costs, warranties, efficiency losses, end of life, and EPC costs in order to ascertain the total project level costs to provide a reliable level of service over the lifetime of the unit.

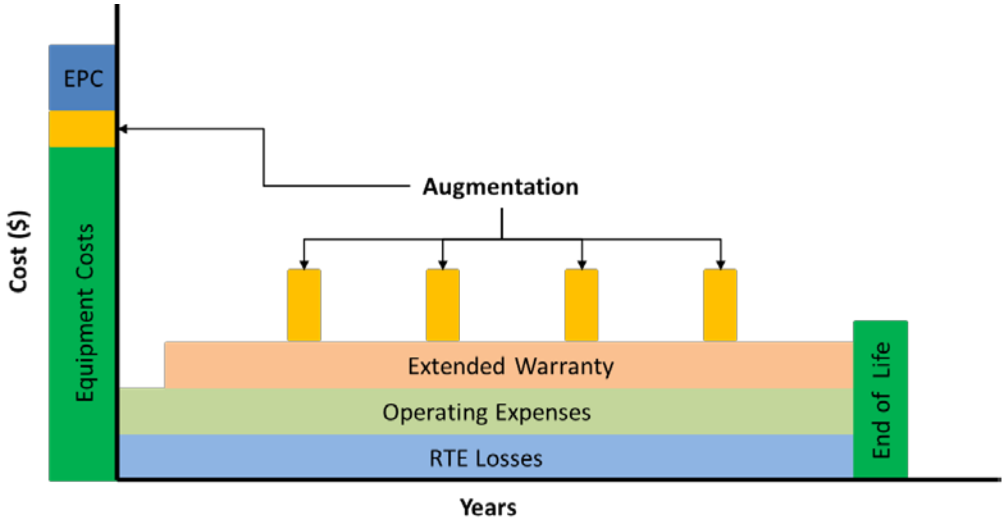


Figure 10. Energy Storage System Costs.

Source: Mustang Prairie Energy

3.1.1. Equipment Costs

The cost of capital equipment for energy storage systems is based on the usage profile envisioned for the system. For instance, if a storage system is designed to provide frequency regulation, the system will be more power (kW) centric with less energy capacity (kWh) onsite, this will represent a larger share of the price, whereas a system designed for long duration of low discharge will be more energy (kWh) centric and have a proportionally larger share of total cost attributed to the energy storage module. The confidence of equipment costs estimates of various storage technologies is based largely on the scale off production of various technologies, and what type of external engineering and manufacturing base can be leveraged.

Another important issue to highlight is the distinction between cost and price. As the energy storage industry expands, intense competition for the available tenders has driven down the bid price of systems offered. As competition is expected to remain fierce, the prices being offered by the absolute lowest bidders continue to be seen by some as “below cost.” This is good for project developers but bad for OEMs; more importantly, this situation is distinctly bad for lenders for two reasons. First, if the situation persists, then only OEMs backed with large balance sheets and focused on (and only possibly temporary) predatory market practices will be left—not necessarily the ones with the best product. Secondly, and more importantly, these prices give lenders an incorrect price signal to the relative riskiness of choosing a particular vendor, leaving them in a position of unknowingly higher risk if their low-cost vendor they use for many of their projects either exists the market or suddenly raises prices to a sustainable level.

For that reason, it’s important to remember that the price offered to customers includes a number of non-technical unique attributes specific to each system integrator that increase in importance as the base equipment—assuming the typical lithium-ion based system from a Tier-1 provider—becomes increasingly similar. First, profit margins or markups are included on some pass-through equipment from other vendors, such as the battery modules. Secondly, the unit cost per unit—primarily of batteries, but also inverters, etc. is driven by purchasing power of the integrator—lower per-unit prices (price breaks) at larger volume. Finally, a lower internal cost of capital for the self-funded developer can permit a lower project bid as compared to developers that turn to 3rd party capital. Different choices in these (and other) pricing strategies allow for the different pricing structure for project utilizing similar products.

Structurally, in order to discuss equipment costs between different energy storage technologies, we need a common system architecture framework to describe structurally the different components of an energy storage system. Different system architectures exist, but we will describe here an emerging general consensus that is used in the future U.S. DOE Energy Storage Handbook and the Lazard Levelized Cost of Storage (LCOS) survey.

- **Storage Module (SM**): The storage module is an assembly of energy storage medium components (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 need a BMS system as sophisticated as that of a lithium-ion system.

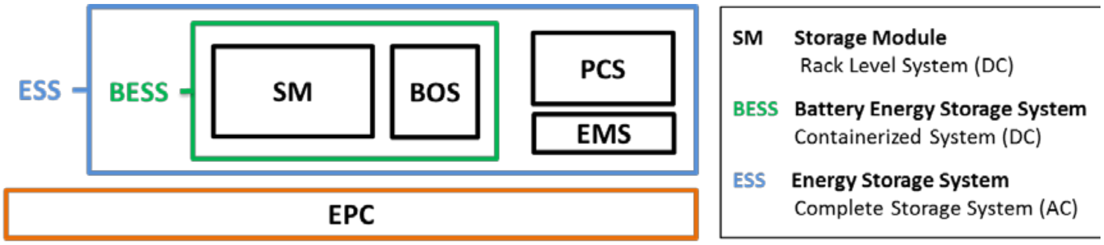
- **Balance of System (BOS):** The Balance of System is the equipment needed to combine a series of the storage modules into a complete DC level system. This will include electrical cabling, switchgear, thermal management, fire suppression, plus the enclosure, ranging from a special purpose enclosure, 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. For many energy storage systems, this 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—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. 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, this also 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.



Storage Module (SM)	Balance of System (BOS)	Power Conversion System (PCS)	Energy Management System (EMS)	Engineering Procurement & Construction (EPC)
Racking Frame / Cabinet	Container	Bi-directional Inverter	Application Library	Project Management
Local Protection (Breakers)	Electrical Distribution & Control	Electrical Protection	Economic Optimization	Engineering Studies / Permitting
Rack Management System	Fire Suppression	Connection to Transformer	Distributed Asset Integration	Site Preparation / Construction
Battery Management System	HVAC / Thermal Management		Data Logging	Foundation / Mounting
Battery Module			Communication	Commissioning

Source: Mustang Prairie Energy

Figure 11. Energy Storage System Diagram.

Besides the discrete equipment costs, there are system engineering and integration costs built into the BESS and ESS system levels to account for the engineering and design efforts to couple the different components from different manufacturers. The improvement of Standards in equipment safety and interconnection has changed this the integrator role where different integrators developed their own architecture towards commercial scale (in the early days of the industry) towards one where there is much greater interoperability. This shift has resulted in more robust, higher quality systems increasingly being sourced from larger-scale electrical manufacturing firms who can leverage their expertise in other fields. It should be noted, however, that increased interoperability does not mean immediate plug & play—many developers mentioned that there is still significant value to working with integrators with significant experience, and this is expected to be the norm for quite a while.

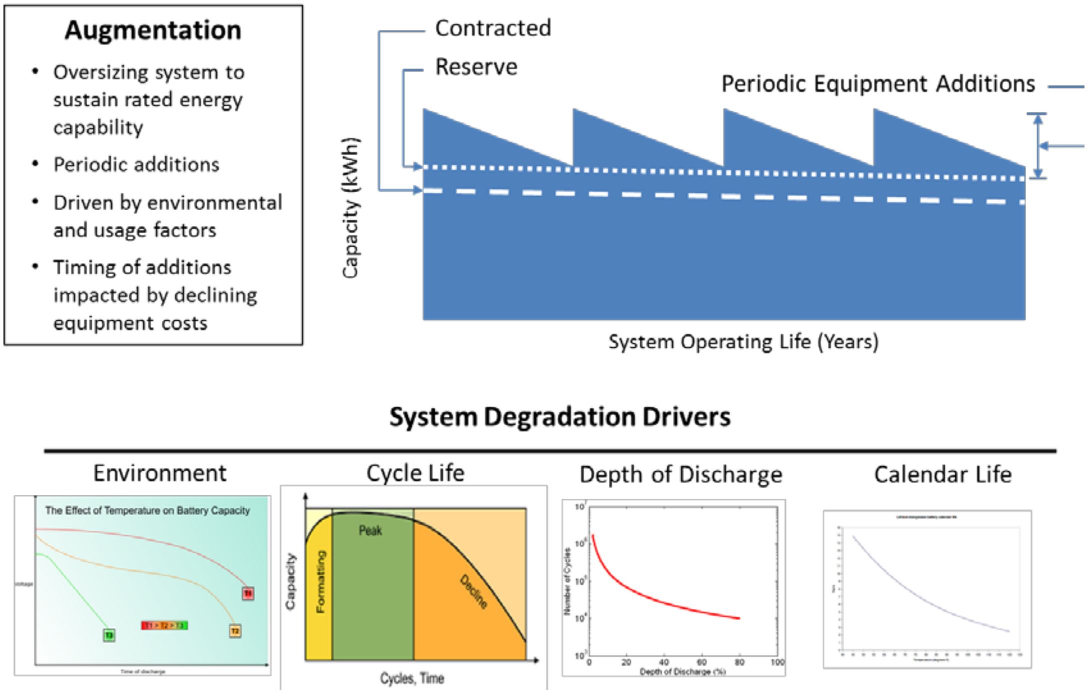
This expertise in design and manufacturing is incredibly valuable to the overall performance of the energy storage system over its lifespan; benefits include lower capital costs, lower EPC costs, and lower operating costs. Equipment costs are reduced as volume manufactures can manufacture or source better quality components at a lower cost than early, low volume energy storage pioneer OEMs who sometimes also operated as system integrators. Operating costs—especially O&M expenses—can benefit, ranging from longer-life components to lower manpower costs from better access designs. With better performing components, the system will experience lower downtime, resulting in higher availability. Round-trip efficiencies can also experience a slight improvement as better designs using more appropriate components can be operated more properly. Finally, as the initial equipment costs decline, and lifespan and availability improve, costs shift from up-front costs to be spread over the life of the system, especially inclusive of augmentation costs (next section). The longevity of the system is critical to the lifetime cost calculation—the longer the lifespan of the unit the lower the overall cost for service will be.

3.1.2. Augmentation

Augmentation costs represent the additional energy storage equipment needed to be added to the system over its lifespan to maintain the capability agreed to under the performance guarantee. This is many times described as a usable energy (kWh) capacity, which is the amount of energy targeted or required to be cycled through the system on a daily basis 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. This aspect of energy storage project budgeting is the most clearly dependent upon matching the performance requirements for the intended market role, and the performance capabilities of the energy storage technology which forms the basis of the system. To easily ensure sufficient capability, the project developer could simply overbuild the energy storage system, but that strategy would be needlessly expensive; the project developer's goal is to find the most cost effective solution to having only the minimally sufficient capability over the system's contracted lifespan. This has proven difficult, but the industry has made great strides on both aspects of this quandary. Unfortunately, this analysis will continue to vex many project developers interviewed who desire to use the energy storage facility for a number of applications—and possibly change the list of applications over the life of the system—without altering any capital requirements set down in the original project contracts.

The amount of augmentation required is highly dependent on the type of energy storage technology chosen, the usage profile under which the system will be operated, and the desired length of operating lifespan. In general, chemical storage systems—batteries—will typically experience degradation while mechanical or electrostatic have little to no degradation. This need for additional storage is driven primarily by two issues—oversizing the system in order to match the operational life of the batteries to the system project life, and the physical degradation of the storage module over the life of the unit.

The requirement for the initial oversizing of the battery system arises from the need to match the cycle life of a battery with the intended usage profile of the energy storage system; this is especially true for chemical batteries. The cycle life of a battery depends on a number of factors, but an important one is the Depth of Discharge (DOD)—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 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 100% state of charge (SOC) on each cycle, to then cycle between 90% SOC and 10% SOC (80% DOD for each cycle), the cycle life of the battery is extended. This impact on the battery's cycle life varies by technology—some like flow batteries and flywheels—are designed to cycle their entire energy range without degradation. Chemical batteries, like lithium-ion or lead, will experience an increase in their cycle life as you reduce the range of charging and discharging of energy per cycle, and changes also vary by cathode chemistry in lithium-ion cells.



Source: Mustang Prairie Energy

Figure 12. Augmentation Costs

The second issue–degradation—is the reduction in capacity (kWh) of the battery due to use or age in normal output over the operating life. Here too, different energy storage technologies will experience degradation at different rates, with some technologies showing little or no degradation, while others experiencing significantly more. The degradation is driven by how the energy is transformed into the storage medium for storage; 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 degradation during the charging and discharging process, and so require additional battery capacity to be added periodically over the life of the unit. Due to the declining cost of the equipment, the 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.

Focusing on just chemical batteries such as lithium-ion, degradation comes through two pathways—calendar aging, and cycle life. Calendar aging accounts for the eventual capacity loss resulting from the slow chemical changes of the batteries. The cycle life aging of the battery is driven by a number of factors that can reduce the cycle life—operating temperature, the operating range for the state of charge, the charging rate, the discharging rate, etc. Therefore, over the life of the system the amount of energy that can by cycled through a battery will decline. Depending on how it is used, this decline will be faster or slower.

The initial capacity reduction and the slow reduction in storage capacity drive the need to augment the initial energy storage capacity over the life of the energy storage system so it can maintain the target or contractual usable energy over the entire life of the system. The resulting augmentation schedule will then typically consist of some initial oversizing, and equipment additions (or replacements) on some schedule during the operating life of the system.

As the agreement for what usable energy level should be is still evolving, so too has been the definition of the equipment needed to be added. This is important as it goes to the cost and long-term performance. Specifically, for lithium-ion batteries, this question manifests as whether one 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 has been the practice for many cost-conscious developers. As the modules will have different electrical properties (due to age), balancing them becomes more difficult. However, if the modules are instead added to the overall system with a new inverter (at the AC level), then the new modules can be electrically isolated from the older ones and run with more reliable performance over time, but at a slightly higher capital cost.

3.1.3. Operating Costs

Operating costs also play a large role in the financial success of an energy storage project. Primarily, this consists of operation and maintenance (O&M), warranties, and efficiency losses. A variety of smaller operating costs—software licenses, etc.—are not yet uniformly applied, but warrant continued review. O&M costs will be discussed here, with the latter two primary issues (warranties, and efficiency losses) will be covered in later sections.

Operation and maintenance costs are important, and representing a growing area of interest, if not outright concern for developers and potential lenders. Because the technology is still maturing—and there are a number of types of energy storage technologies—the exact cost of O&M for these facilities is still to be determined based on more actual field experience. A growing area of interest for the O&M arena is the definition of fixed and variable costs as utilities look to understand and plan for the structuring of costs associated with this new class of grid resource. Lithium ion systems are typically a low-maintenance cost technology as compared to others with a significant amount of moving parts that require maintenance. However, energy storage technologies without a significant deployment base and operating experience are at a disadvantage lacking 3rd party data to prove the costs. 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, 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.

Typical maintenance cost is expressed as the annual maintenance contract that is sold by OEMs. 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 included to reduce these 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.

3.1.4. Warranty

Warranty extension costs are a closely related issue to O&M costs, as the extent of the warranty will typically be based on an ongoing maintenance coverage. As more understanding of failure rates for equipment grows, some escalation in costs have been introduced for components that operate extensively. For a more detailed description of warranty considerations, please see Chapter 2.3.3.

3.1.5. Round-Trip Efficiency (Losses)

Efficiency loss represents an important related operating cost for energy storage facilities, and can lead to significant operating impact—especially for more active usage profiles. As one would imagine, different energy storage technologies have different round-trip efficiencies (RTE) 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 round-trip-efficiency (DC:DC), whereas lithium-ion modules routinely state 95-97% round-trip efficiency (DC:DC).

Typically, the cell (or module) efficiency is highlighted, but 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 total is not typically added to the station power load estimate. 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.

Design improvements can be made to improve the round-trip efficiency, chief among these is to take advantage of more effective, or even free cooling. For instance, many early fully containerized designs typically included the inverters inside the container which provided a clean integrated design, especially for installation purposes, but led to additional heat removal requirements. Many system designs now typically call for the inverter to be housed in an outside container. In addition, many designs utilize a modular approach of special purpose enclosures for the battery modules on individual pads making for cheaper installs. These enclosures were small enough to promote pass through air cooling using only a small cooling unit, a simple fan, or even simple passive cooling (pass through air). In this way, the smaller purpose built enclosure can reduce the cooling equipment required, which reduces the electrical load on the storage module, improving battery performance and expanding the space in the container for additional batteries.

3.1.6. Engineering, Procurement & Construction (EPC)

EPC costs have proven to be the most fluctuating component of project costs. These costs vary significantly by market segment, with engineering and construction areas showing the greatest variability.

The engineering costs variability is driven by non-repeatable engineering work, generally described as NRE (Non-Recurring Engineering) costs. These can be significant due to the variability in locations, customer class of facility, and whether the facility is a retrofit of green-field location. These NRE costs has so far been generally non-translatable from one deployment to another. Leaders at EPC firms also cited the lack in continuity in partners, both on the OEM side and customers, as driving up the costs as they felt that having the opportunity to perform a number of jobs with a particular project developer would allow the two firms the chance to lower costs through familiarity of work process.

Procurement costs are derived from the purchasing and delivery of the needed equipment from the suppliers to the project site for construction. Procurement costs overruns can be driven by a number of factors, but those most unique to the energy storage industry would be OEM supplier reliability on delivery or slippage of schedule. This can incur penalties for missing schedule milestones, but this risk is of a heightened importance for energy storage projects intended for summer peak capacity as they typically need to be in service (COD) by June 1st or before or they run the risk of losing out on participating as a resource for that summer.

Construction costs generally decline as a percentage of capital costs as the system size increases as there are a number of fixed costs that larger facilities can benefit from. As with engineering costs, there is also a large site-specific impact and variability that can drive up costs, especially for smaller systems especially where the energy storage unit is being installed into an existing structure with limited space.

Overall, performance impacts on EPC costs derive from equipment warranty and the performance guarantee exposure to possible damages from issues related to the construction of the facility. Project owners and lenders increasingly require a “fully wrapped” warranty from the EPC, making it responsible for all defects in design, equipment and performance in the event the system fails the performance tests. Lenders want to know the project can perform to expected performance metrics (availability, RTE, capacity), backed by liquidation damages (agreed upon compensation for a specific breach of a contract).

3.1.7. End of Life

The End of Life (sometimes referred to as (EOL) costs have generally not received a high level of priority to date, and any estimates will greatly depend upon the technology choice. These costs generally fall within the decommissioning phase and the dispensing of the remaining equipment. The decommission costs are greatly influenced by the original design and installation choices—containerized solutions that can be transported to a central decommissioning site can prove much cheaper than deconstructing a purpose-built installation on site. Dispensing of the equipment still varies tremendously by technology, with the effort of recycling more of the materials a high priority.

This effort to address EOL costs comes both from the global effort of manufacturers to deal with their products on a full life-cycle spectrum, and the push to include all cost components in the energy storage system life cycle. Sometimes this can be beneficial to a particular technology in deployment. For example, lead-based batteries operate in an industry where nearly all lead-acid batteries are recycled, providing a credit at the end of life on materials cost. Other technologies such as vanadium based flow batteries also can recycle their vanadium electrolyte, allowing for a reduced total cost for materials. Some providers even lease the vanadium content of the vanadium flow battery, changing a portion of the capital cost of the system to a lease payment. Finally, depending on the project design lifetime, the end of life costs themselves could be pushed out to 20 years from now, significantly reducing their financial impact on from a NPV perspective.

3.1.8. Total Cost of Ownership (TCO)

A Total Cost of Ownership (TCO) calculation combines all project related costs, and allows for comparisons of costs needed to provide a specific level of service. By incorporating the operational performance requirements, the different aspects of the cost component—initial costs, augmentation, operation—can be understood within the context of system design.

One prominent TCO analysis can provide an example. The Lazard Levelized Cost of Storage (LCOS) compares a variety of energy storage technologies through the use of “Use Cases” that hold a number of inputs fixed—power rating (kW), energy rating (kWh), lifespan (10 or 20 years) environmental conditions and usage profile (typically 1 cycle per day). By choosing a number of these Use Cases, the Lazard LCOS is able to showcase the different costs requirements to support the particular Use Case with different technologies. However, by holding a number of these input parameters fixed in each Use Case, it is therefore inappropriate to compare the cost of a particular technology with another technology from a different Use Case as the input parameters are different.

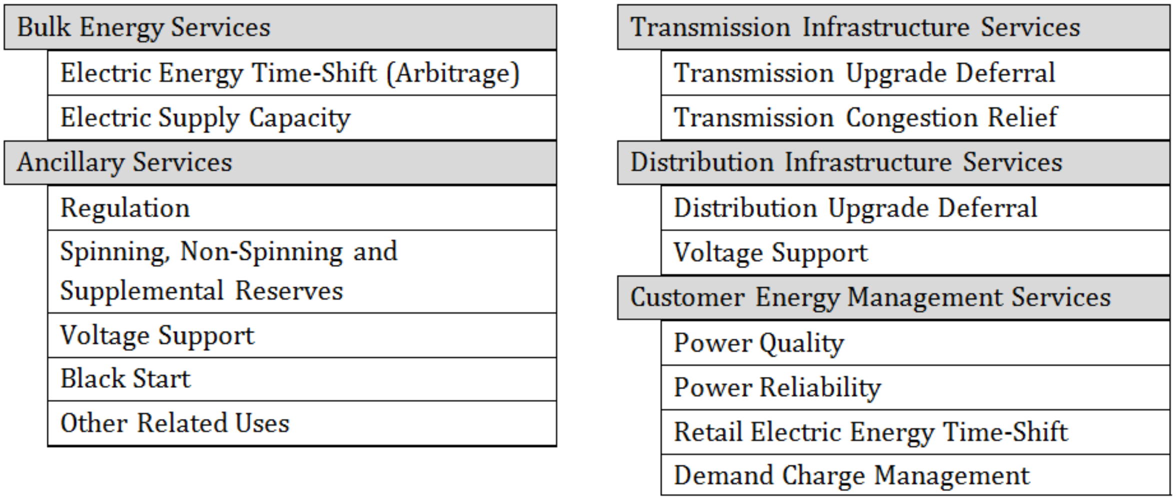
This last part is critical, as the framework that is used to compare the different units can lead to a bias and a possible misappropriate comparison. For example, using $/MWh as a basis for the TCO is appropriate if you are focused on pricing systems based on the amount of energy throughput on the system. However, if the systems are primarily bid into capacity markets, than the more common \$/kW-yr. would be appropriate. The underlying cost (\$) would be the same, but using one pricing metric over the other will lead to biases when comparing different systems to different uses. This an issue that project developers interviewed for this Study highlighted repeatedly. Many developers noted that they'd like to evaluate different technologies for applications they are looking at, yet confess that they are concerned that the underlying assumptions are sufficiently solid enough to make a proper comparison. You do need to understand how you're looking at a project in order to understand how you can compare it and what question you're actually asking.

3.2. Revenue

Any successful project must have sufficient revenue over its operating life to cover its construction and operating costs and meet the required hurdle rate of the project developer. Lenders, and thus project developers, would prefer a contracted revenue stream in the form of a Power Purchase Agreement (PPA) for wholesale market projects which would provide a stable and secure revenue stream. In the behind the meter (BTM) market, contracts have been primarily based on the amount of savings potential for the customer. In the front of the meter energy storage market, although some PPAs are becoming available from utilities, these remain few, with excessive competition in the RFP bidding process, which drives down the potential revenue available from the contract. Typically, revenue streams are driven by policy and regulatory changes, which are outside the purview of this report. We will deal here with what value streams are achievable, and which ones are the most highly correlated with performance.

3.2.1. Value Streams

Table 3. Energy Storage Applications.



- Bulk Energy Services
  - Electric Energy Time-Shift (Arbitrage)
  - Electric Supply Capacity
- Ancillary Services
  - Regulation
  - Spinning, Non-Spinning and Supplemental Reserves
  - Voltage Support
  - Black Start
  - Other Related Uses
- Transmission Infrastructure Services
  - Transmission Upgrade Deferral
  - Transmission Congestion Relief
- Distribution Infrastructure Services
  - Distribution Upgrade Deferral
  - Voltage Support
- Customer Energy Management Services
  - Power Quality
  - Power Reliability
  - Retail Electric Energy Time-Shift
  - Demand Charge Management

Source: U.S. DOE Energy Storage Handbook

Energy storage technologies are capable of a myriad of market roles. All of these provide value, yet not all of them can be easily associated with a specific revenue stream. The U.S. Department of Energy Storage Handbook[3] provides a good guide to the most common applications attributed to energy storage market strategy.

It is important to understand that when it comes to creating value through the use of energy storage, there is still much work to be done. With the energy storage market still evolving, regulatory development in many ways lags the technological development.

These applications and potential others fall into 3 general categories of value streams.

- **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 location specific for price, making any attempt at crafting a market-wide rule of thumb for value difficult at best. If the energy storage developer is able to contract for one of these services, it is generally on a bilateral basis or in a consolidated into a purchase price (asset purchase). An example of this type is black-start.

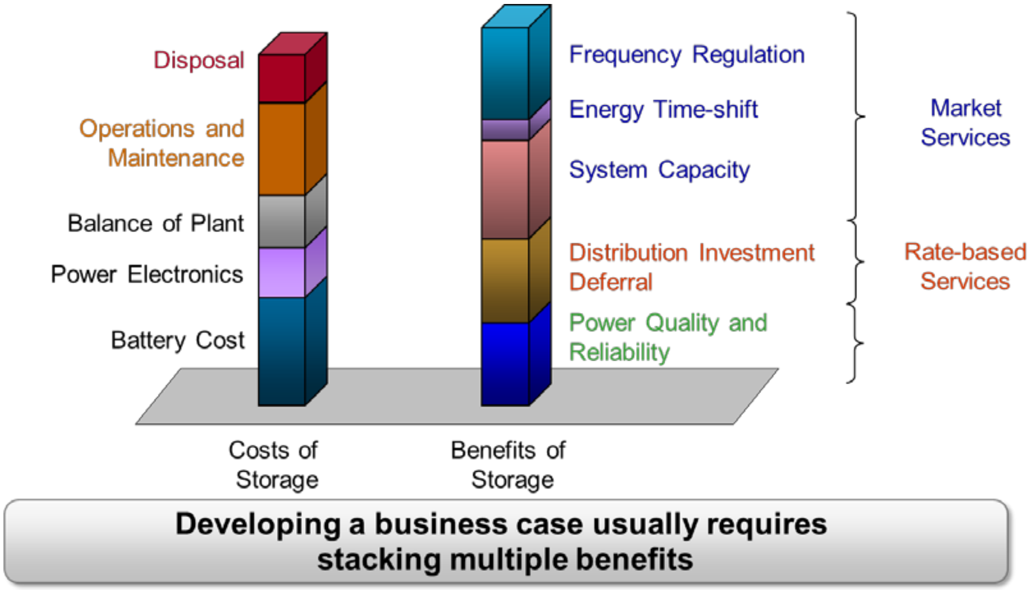
- **Indeterminate:** The final set of value streams are not easily quantifiable with little hope of a near-term systematic valuation basis, yet often mentioned as a driver for near-term energy storage market growth. If you cannot contract for something or systematically value it, it cannot be a fundamental market driver for an economic system until people begin to devise a means to provide a basis for its value so vendors know how to price a solution. An example of this type would be resiliency.

As the capability of energy storage technologies improve, we are able to understand more of what they can do, and map that to possible applications. As the energy storage industry's ability to map these capabilities to market roles, new values are created. As the electric power market structure evolves to incorporate these new valuable roles, the energy storage market opportunity will increase. In order to incorporate these new market values correctly, understanding their performance requirements and the technical capabilities of the possible energy storage technologies is fundamental.

3.2.2. Value Stacking

For most energy storage installations, a number of different revenue streams are needed to provide the expected return on the project. As each individual revenue stream is not sufficient in itself to economically support the facility, combining a number of these applications is the typical approach and is commonly referred to as value stacking.

Optimizing the mix of possible applications for maximum gain can easily be quite complex, increasingly so as higher numbers of applications are needed to cover the project costs and the control algorithm has to decide which pattern of application support provides the greatest return at the lowest risk. For instance, the straightforward approach to value stacking is to target the highest value applications first, and then the second most valuable, etc. Unfortunately, this is not necessarily the strategy that will provide for the greatest value creation for the system in the real world. Understanding the performance requirements of the different possible vs. potential applications requires a multi-faceted approach. By incorporating the performance requirements of the application with the technical capabilities of the energy storage system being evaluated, you can determine what the most valuable overall operational strategy with respect to operational requirements is a part of an integrated operation. This means not just focusing on revenue generation, but performance and cost-based usage evaluation.



Source: EPRI

Figure 13. Value Stacking.

A value-stacking strategy relies on deeply understanding system performance to balance the technical, operational, and economic impacts from different dispatch choices. If the operator does not truly understand the performance characteristics and capabilities of the system, significant risk to the ongoing viability of the project are raised. This issue will increasingly be a part of energy storage project operation as system operations will be dominated by a multi-application strategy situated in a market where the changing value of the applications will dictate a changing usage profile to maintain profitability. For this reason, covenants in lending agreements will eventually need to take into account and permit various and possibly changing usage profiles over the life of the system as contracts evolve to match usage. Most covenants are based on technical performance now, but the use of application specific performance metrics is expected to rise in order to more closely link compensation to economic performance. For instance, choosing an application the provides high revenue—such as frequency regulation, is taxing on the energy storage system, so although you might generate more revenue than say arbitrage, the impact on the storage system—especially if they are chemical batteries—could be that the equipment's useful operating life is short, leading to a poor choice from a project value generation perspective.

3.2.3. Design Implications

The design of an energy storage system is based on the most cost effective technical capabilities to perform a set of applications. Other aspects of the design choice is the scale of the intended market, and the degree of specialization required. These last two items will have a nontrivial impact on the design, and their impacts are related.

The issue rests on the choice of customization vs. standardization. For instance, a highly customized design can be better suited for a particular application, but lacks the flexibility for multiple applications. Depending on the degree of specialization required, the components may also be highly customized. The degree of this customization will impact the manufacturing costs of the unit. Units designed for a mass market will target components that can be purchased in large volume, which can translate into low price from OEMs looking for the large purchase orders. Highly customized units are typically targeted at smaller, niche markets with only moderate sales opportunity at best, translating into higher cost per piece from the OEM.

3.3. Project Economics

The complete project economics for energy storage facilities incorporate a variety of other factors that are required for a project to be undertaken successfully. As the complexity of the projects becomes more understood, these costs are expected to fall into line comparable to similarly sized power projects. The key differential will remain the performance requirements on the system.

3.3.2. Permitting

Permitting procedures and costs for energy utility scale storage projects are falling typically in-line with other power projects of similar size and scope. A major driver for reducing these are the important of standards and local ordinances. Local ordinances for behind the meter facilities can vary, primarily based on the familiarity of the local inspectors with energy storage equipment. The release of the 2017 National Electrical Code (NEC) is supporting local inspectors to engage with energy storage projects, but it depends on the local groups to update to these updated standards (Frequently, local jurisdictions do not update to the latest NEC immediately when it is updated on its 3-year cycle).

Project developers aim for a straightforward permitting process, so anything that supports the local jurisdiction treating the energy storage asset as a known and uncomplicated asset to be installed is beneficial. This means that the storage system needs to comply with local zoning and building codes and any expected environmental review.

3.3.3. Interconnection

The interconnection process for energy storage systems follows the same process as similarly sized resources wanting to be connected to the grid. As part of the interconnection agreement, this would require an interconnection study, and to pay for any system upgrades necessary to ensure deliverability of energy on the affected part of the local power grid. The effort and cost of this undertaking scales with the size of the system for front of the meter systems, and over a number of years to complete as the complexity of the operation increases. The interconnection for behind the meter (BTM) projects is typically shorter due to the smaller grid impact, allowing for a shorter interconnection procedure, with some States developing a specific interconnection process for energy storage assets.

If the energy storage asset is being installed as a retrofit to an existing facility, it is important to note that if the new hybrid facility exceeds the original interconnection agreement (from a MW rating) then a new interconnection is required. If the new hybrid system is the same or less, a full interconnection study in not necessarily needed, depending on the ISO/RTO in question and the market role expected for the facility. Many developers mentioned that they are reviewing many older facilities with existing interconnection agreements for possible upgrades as this can be a simpler and less expensive means to site an energy storage facility.

3.3.4. Financing Costs

As lenders are becoming more familiar and comfortable with energy storage projects (technology and system integration), the cost of capital is declining as lenders see these projects as lower risk. This can impact not just the financing of the capital equipment, but also reduce the rate for construction loans and potentially allow for lower deposits—both important inputs for developers. The cost of capital is obviously a key input to the total cost of an energy storage facility. The effective cost varies depending on the cost of equity, debt, and the amount of debt able to be obtained by the developer.

Access to capital has also become a strategic advantage for some developers. Access to low cost capital, especially if internal, give developers an advantage over others who get it from 3rd party providers. It should be noted that with the growing interest in the energy storage market, many lenders are looking to become more active in this market, but many of these groups are coming from more mature industries where the risks are lower. These new lenders are rapidly working up the learning curve, with some looking to simply keep the same relationships with developers that are also new to the energy storage market too. Without sufficient understanding of the risks involved, these lenders run the risk of providing capital for a project that is riskier that they understand, and thus they are providing capital without the appropriate risk premium.

3.3.6. Valuation

In the end, it is the project developer who incorporates all of the forecasted cash flows, expenses, and taxes and other fees into the project economic model of the facility to determine if the project will be viable. The most common framework is the project pro-forma, which is the common structure for other power industry project evaluations. Lenders also require such analysis to validate economic feasibility of the project, and to determine that it will generate sufficient cash flows to cover all operating and debt-servicing expenses and any required reserves over the lifespan of the facility.

The key to any of this valuation analysis is that the modeling must be far more flexible than other frameworks of comparable power projects to handle the iterative nature of the evaluation for energy storage systems. System costs impact design choices, which impact application choices, which in turn directs revenue generation. Because of the impact of performance on equipment cost design and revenue generation, even small operational changes made to improve revenue potential has the possibility of shifting the design requirements more than just slightly, requiring a revaluation of the applications targeted—and their capability requirements.

4. CONTRACTUAL FACTORS

Contracts are essential for structuring energy storage project deals. They are used to define stable and secure revenue streams, they help secure the equipment necessary for the project company and define compensation for performance and damages for non-performance. Importantly, they are able to identify the performance required for each of the steps involved in the intricate dance of project developers having everything show up and installed properly while paying for it with the lowest cost financing available. Showcasing responsibility for each step allows the inclusion of 3rd party services such as equipment monitoring and performance verification to validate requirements in the contracts. Most important for the risk management perspective, contracts provide a framework do deal with contingencies.

Project development financing is complex and relies on a myriad of documentation to ensure parties both receive what they want while specifying performance requirements. This includes:

- Project documents are used to define, construct and operate the project. A series of project documents are required that will define the organization and operation of the energy storage project. These are typically similar to other power industry project documents, but with variations in order to cover the differences in the energy storage market. As the industry is still evolving, different groups may group the project documents differently than this description.

- Financing documents set the terms and conditions upon which the lenders will lend to the project company. These are typically similar to other power industry project documents, but with variations in order to cover the differences in the energy storage market. In more mature project development markets, there can be significant complexity. As the industry evolves, these documents will also undergo optimization. As the industry is still evolving, different groups may group the project documents differently than this description.

- Insurance is a means for protecting against financial loss. For a complex and highly integrated issue such as energy storage project development, it is also a means to design risk management strategies that expand opportunities at a lower cost through leveraging the financial assets of the insurance firms. This risk management and allocation focus is especially important for energy storage project development. As energy storage is somewhat different that other power projects, and so the risk management strategy will need to take account of unique technology, policy and regulatory, and market issues.

4.1. Project Documents

A series of project documents are required that will define the organization and operation of the energy storage project. These are typically similar to other power industry project documents, but with variations in order to cover the differences in the energy storage market. As the industry is still evolving, different groups may group the project documents differently than this description.

Table 4. Energy Storage Project Documents.

Project Documents	Financing Documents
Corporate Organization	Project Economics
Real Estate	Project Insurance
Entitlements	Funding Agreement
Project Design	Security Agreement
Warranty	Direct Agreement
Construction	
Engineering Review	
Interconnection Study	
Project Operation	
Off-Take Agreements	
Performance Guarantee	

Source: Mustang Prairie Energy

4.1.1. Corporate Organization Documents

These documents will include the corporate formation documents for the project company which describe the relationship among the project sponsors (equity investors); this is commonly done in a jurisdiction such as Delaware with favorable regulatory oversight. Other documents include all management contracts for the project company, and any host community agreement with the local jurisdiction. Besides the technology readiness, the corporate stability of the OEMs providing key components for the project developer are crucial to the project developers obtaining financing for the project.

Project developers highlight these documents as the core descriptors of the project, with the eventual structure showcasing the lengths to which developers lacking extensive financial backing have to stretch and contort themselves and their projects to get funding.

4.1.2. Real Estate Agreements

These agreements cover real estate issues and provide the right of the project company to utilize a designated property to build the energy storage project. These agreements will include the lease agreement or deed, the title report (and clean of liens) and an environmental assessment. The scale of project will play a role in the extent of these concerns, as behind-the-meter storage systems do not generally raise significant material concerns due to their smaller size and are typically at a client’s site. Larger projects built on a stand-alone basis will require a review of local laws and regulations.

Project developers in particular mentioned that it is critical to understand all of the local land-right uses. The energy storage industry is revealing itself to be quite similar to other markets with many local peculiarities with respect to project development. Land use laws and local property taxes are often mentioned by project developers as items that can vary quite widely from location to location.

4.1.3. Entitlement

Entitlements are legal rights conveyed by approvals from governmental entities to develop a property for a certain use, building type or building placement. These rights will include local and State permits required, special use or zoning approval, etc. Local permitting and approval for energy storage projects continue to be an area of concern for groups involved in energy storage project development. This is of particular issue for areas where energy storage projects are still relatively new.

Project developers have long known that local governments are sometimes slow to adopt new regulations and ordinances that are important in quickly changing market. For instance, local jurisdictions do not typically update to the newest National Electrical Code every three years when updated by the NFPA (National Fire Protection Association). Energy storage deployment received a major update in the 2017 edition, and the faster local inspectors have this resource, the more streamlined energy storage project developers (especially for behind the meter deployments) will be.

4.1.4. Project Design

The overall project design, which will include the general plan sets from the developer (with support from the system integrator, etc.) and the site analysis. The power and energy rating is increasingly being specified by customers, but the developers and integrators are responsible for providing a design that will maintain the deliverability, availability, and capacity desired by the customer over the unit's life. Depending on the work involved, the site analysis can be quite extensive, including the site design, and where the site sits with regards to other overlays, such as floodplains and nearby infrastructure, and the geotechnical report of the underlying surface and hydrology of the site. Project development in other power markets gets more complex when siting near existing population centers or commercial facilities in other markets, it is the same with energy storage.

According to a number of interviewees, coordinating small changes that typically creep into a project once construction begins was essential to maintain the capability of the system upon completion within the original budget. This starts with the actual capability of the energy storage system and stretches to site preparation and foundation construction was typically highlighted where changes occurred due what conditions were found underground. This is the say that the project would generally continue, but as one EPC stated, you only know what lies beneath after you dig. For this reason, a quote for a specific project necessitates a specific project specification, yet project developers are hesitant to not be restricted for the unit to be used for alternative applications in the future as the market continues to evolve.

4.1.5. Warranty Documentation

The documentation for the product warranties for the varying components are essential for the development of the project. These typically take the form of performance and manufacturing components of the warranties, with the description of each spelled out clearly. Documents included here would be warranties for the major components such as the energy storage system, inverter, and key parts of the balance of system such as the HVAC system.

Project developers view OEM warranties as essential for successful, yet sometimes find it difficult to translate the coverage to operational use of a facility that is expected to evolve its operational strategy with the growth and changes in the market.

4.1.6. Construction Documents

The construction documents center on the EPC contract for the facility. The EPC contract provides for the complete engineering, procurement, and construction of a facility by a certain date (the Commercial Operation Date, or COD), typically for a fixed price. It is also common for the commissioning of the facility to be included in this turnkey contract, and thus use the COD as the delivery date. Increasingly, EPC contracts are including a warranty wrap as a means for the EPC to incorporate its engineering capabilities in a way that developers need. Lenders are also interested in the warranty wrap in order to isolate any technology risk. These warranty wraps also allow engineering firms to differentiate themselves from others with less technical expertise willingness to take on the performance risk of the technology.

Many groups interviewed the construction documents as something that should be relatively straightforward once the project design is finalized, yet maintain a healthy level of concern as to the ability to meet the COD requirements, while incorporating the alterations that invariably arise in construction projects. To ensure continuity of the project under a variety of circumstances, the financial strength of the EPC itself has become of growing concern, in addition to its experience in order to control for cost and schedule over-runs, etc.

4.1.7. Engineering Review Documents

The Independent Engineering Report (IER) is to provide an independent technical assessment or due diligence for an energy storage project. If the energy storage technology in question does not have significant operating experience or a wide base of providers, a Bankability Study which would provide a deeper review (audit) of the technology and manufacturer is possibly required.

Project developers rely on IERs to answer technical due diligence questions from lenders and allay their concerns about the project being able to support a profitable operation of the facility. As the complexity of the project expands when a more multi-functional approach is desired, the need to rely on these reports grows, highlighting concern for what can be proven out. Lenders as well highlight the need for independent engineering firms to understand complex market modeling for them in order to guide them to what are the areas of most concern, now and in the future, for energy storage projects at different points in the market.

4.1.8. Interconnection Study

For larger energy storage projects, an interconnection study is typically required. This will review the deliverability of the proposed system, and the potential impacts on the neighboring system and budget money for remediation. This can take a significant amount of time and resources, so timing of this component is important for the overall completion schedule.

Most project developers view an interconnection study for a storage project on the same level as one for a large generation project—potentially very involved and capital intensive, but not an insurmountable undertaking if you have chosen the right EPC partner. An approved interconnection agreement has value in and of itself, so investment into a study will provide a separately valuable asset of the project.

4.1.9. Project Operation Documents

This will include the documents covering the management and operation of the energy storage facility over its designed operating life. These documents will include documents covering operation and maintenance, communications with utility/ISO, 3rd party monitoring and performance verification, etc. If possible, especially with the O&M contract, the goal would be to have the contract with the OEM or an authorized agent is preferred for familiarity and proper training with the equipment. This familiarity with the equipment in question is of growing importance as performance levels are becoming more discretely specified in the contract.

With more deployments providing valuable experience to developers, the operations contract as the proper operation of the facility is also being recognized as critical for achieving low cost, long-term profitability of the project in order to ensure repayment for lenders. Increasingly, project developers were unanimous in looking to groups with strong track records of performance as liquidated damage provisions are being incorporated in the event of poor performance stemming from poor operation.

4.1.10. Off-Take Agreement

Off-take agreements typically cover the relationship between the energy storage facility and a 3rd party that will pay for all or part of the services of the energy storage facility. These agreements provide the stable, contracted revenue stream critical for low cost financing of energy storage project. The type of contract depends on the product or services sold (see Chapter 1 for a list of the contract types), with the typical provisions in the contract being term (duration), price, and creditworthiness of the off-taker. For energy storage projects, this typically means some type of PPA structure (tolling, etc.) for from of the meter projects, and some type of energy savings performance contracts for behind the meter projects. Included in this would be the required any performance requirement for the facility during its operating lifespan.

Project developers interviewed were typically quite focused on obtaining some type of PPA or contracted revenue source in order to obtain lower cost financing for the project. In previous years, many described the need for a contract that provided for 100% of expected revenue for the project. As this remains elusive, many project developers mentioned that lenders have relaxed the original requirement as they too have gained experience. Although there is no "average" response, many lenders have moved towards being more comfortable with only a partial amount of the output / capability of the facility under contract, with the target of debt coverage the requisite first step. If only some of the output of the facility is contracted for, then the remainder would operate in a merchant role. As more projects gain experience in the market performing this role, this aspect of revenue generation will gain familiarity, and potential credibility. Under current conditions, however, it is not generally feasible to develop an energy storage project without an off-take agreement of some magnitude by operating the facility wholly in a merchant role.

4.1.11. Performance Guarantee

Performance guarantees are a means to ensure that projects meet the performance requirements found within off-take agreements. These requirements have long been a part of other renewable energy markets, but primarily been centered on energy production. In the early stages of solar and wind projects, lenders required cash reserves if they were not confident in the technology's performance capability and longevity, or if operational history was inadequate. In response, some solar panel manufacturers began providing a performance guarantees covering the efficiency of the solar panels throughout the life of the system. This allowed for the provision of different products—better equipment and maintenance would be qualified for an improved performance level—at different cost levels based on the added value that could be guaranteed. It should be remembered though, that this was a much simpler construct, the only performance focus was energy (kWh) production.

As the energy storage industry begins to emulate the solar and wind commercial markets, customers and lenders are requiring assurances that energy storage systems perform as promised, especially over the full life of the system. The difference between energy storage and these other technologies, however is that there are many more degradation factors involved in the operation of an energy storage system, making the definition of the application extremely important, but also highly dependent upon the assumptions made as the different degradation factors interact with each other. For instance, some derived metrics (efficiency, cycle-life, etc.) greatly depends on how the system is operated (depth of discharge, charge/discharge rate, etc.), and under what conditions it is operated (temperature, etc.), which leaves performance guarantee difficult to define for a range for a customer's multiple market role needs in order to respond to variable market conditions.

Performance guarantees are an increasingly common requirement by customers (to fulfill off-take agreement requirements) and lenders (to maintain payment) for the energy storage project to maintain specific capability performance levels over the life of the system. These agreements require the developer (which then many times falls to the EPC) to be responsible for developing the least cost strategy to maintain the facilities rated performance capability over the life of the contract. This system level performance during operation focus is different than the component warranty level, or EPC level warranty "wrap" that ensures that the facility as a whole will operate according to the warranted level. Although many times overlapping, the performance guarantee is designed to match what the customer wants—not what the OEM has written down on a spec sheet. As the market continues to evolve and people look to do more and varied operations with the systems, the definition of these two requirements is expected to vary.

The specifics of the performance guarantee will depend on the application required of the system in operation. However, from the perspective of coverage, you can describe Performance Guarantees along the lines of Technical, System, or Operational metrics.[4]

- **Technical Guarantees:** Typically focused on equipment capabilities such as capacity guarantees, which guarantee an annual available energy capacity over the life of the system. This will generally follow the warrantied capacity from the OEM, and will take into account constraints to issues such as cycle limits or energy throughput constraints. Energy capacity requirements are typically set annually (but more frequent checks have been noted in existing contracts) with cycle life constraints on a more frequent limitation, depending on the application.

- **Availability Guarantee:** Typically focused on achieving a guarantee to operate a minimum percentage of time in the market. Generally, this is requested to be at 98% or greater. When reviewing this guarantee, care should be made to understand the impact or inclusion of scheduled downtime for maintenance or other plant needs.

- **Demand Reductions:** Typically focused on behind the meter commercial applications where peak shaving is used to reduce consumer bill service cost. Because of the variability in both tariff and consumer load profile, the exact amount offered will always be site specific. Since this has an economic aspect to the operation, the cost, round-trip efficiency, and responsiveness of the storage technology are important inputs.

In order to provide these performance guarantees, the project manager (or realistically, the EPC or other groups with engineering capabilities) will have to determine the least cost method of matching its technical system modeling to its market modeling efforts. For energy storage technologies that suffer from degradation from usage, this means that understanding the operational performance of the technology and the augmentation schedule required, including initial oversizing, augmentation, and possible replacement of the storage modules.

The inclusion of performance guarantees will benefit all involved by increasing transparency on this critical issue. Lenders will be able to lower their risk exposure to energy storage projects by obtaining some coverage for both technology and operation risk–two areas with they have limited experience with regards to energy storage projects. Project developers will also benefit by ensuring access to lower cost capital costs for the project through getting deeper technical analysis backing from the EPC and OEMs. Those OEMs able to either absorb the credit risk on their balance sheet or purchase 3rd party insurance will benefit and be able to utilize this capability to their advantage for marketing purposes. Finally, EPCs will also benefit with the increase in the need for market performance analysis for the units to prove out the market strategy of the system.

Many leading energy storage OEMs are confident that their technology is able to meet the desire for ever-improving performance targets as this is increasingly a key market differentiator among

OEMs. Over time, they are raising the minimal operating performance guarantees—albeit within a specific operating range—as they gain more operational experience in commercial settings. Although lenders were clear for the need for performance guarantees from energy storage providers, many admit they did not understand the technical challenges involved, and thus the risk level they were requiring the OEMs to take on. The question then remains, how close are these OEM guarantees to ones the lenders and customer's actual want? Matching and coordinating the performance metrics that OEMs want to back with what lenders want in the contract remains the crux of this critical issue.

4.2. Financing Documents

A series of financing documents set the terms and conditions upon which the lenders will lend to the project company. These are typically similar to other power industry project documents, but with variations in order to cover the differences in the energy storage market. In more mature project development markets, there can be significant complexity. As the industry evolves, these documents will also undergo optimization. As the industry is still evolving, different groups may group the project documents differently than this description.

4.2.1. Project Economic Documents

These documents validate the economic viability of the project for lenders. The centerpiece of this effort is the project economic model for the facility and supporting market assumptions that power the project financial analysis for the project. This modeling framework includes the market assumptions, but also provides the framework for the project's capital costs, operating budget, and financial statements for the project firm. Standardized project economic models to ensure that developers have a template of what to include in the project financial analysis.

Lenders interviewed for the study highlight a clear project economic modeling framework is key for any discussion with project developers. Besides confirming that the basic math is correct, it should clearly lay out the assumptions used, and so that a clearer evaluation of where potential risks for the project lay.

Project developers interviewed for the study also view the project economic model as central to their strategy of developing a profitable and financeable energy storage project. A robust modeling framework supports their own team to be honest with themselves and truly understand where their particular strengths manifest in the economic analyst, and how best to leverage their assets and capabilities to maximum effect.

4.2.2. Project Insurance Documents

Insurance coverage requirements for energy storage projects is tracking that of similarly sized electrical power projects, with a number of property insurance providers quickly looking to expand into the market. These policies cover general liability, property, construction, business interruption, and environmental risks. Business interruption typically includes strict limitations to equipment issues and not market operational risk. Depending on the energy storage technology in question, the environmental impact coverage can be somewhat different depending on the electrolyte spill impact potential.

Project developers interviewed typically based their assumption for the coverage needed on standard coverage policies for related power projects of similar size. As the developers look towards less common energy storage technologies, insurance firms do not seem to have a problem per-se about providing coverage, but quickly lack internal experience with these alternatives to lithium-ion look to Bankability Studies. To stay competitive, policies from inexperienced groups may cost a similar amount, but with more limitations than those who have more experience in the market.

4.2.3. Funding Agreement

The funding agreement for the project firm will vary based on the type of financing structure used, and will set the terms and conditions upon which financial institutions will provide the equity and debt financing for the project. The equity contribution agreement covers the amount and timing of equity contributions from the project sponsor into the holding company for the project. A similar agreement covers the debt financing to be provided by the lender.

Project developers interviewed generally agree that the funding agreement are the key set of documents for project finance. The document structure is typically similar to other power industry projects; one important area of concern for lenders is the variations due to newness of the technology and the performance requirements. As one developer described this hurdle, everything falls into place once you have the funding document signed, but you don’t get the funding document signed until everything is in place.

4.2.4. Security Agreement

A security agreement is put into place between the borrower and the collateral agent to allow for continued operation of the project. In the event that the borrower defaults, the lender has the right to foreclose on the collateral (the project) in order to operate the facility so that the debt can be repaid. This include both the capital assets, and all of the operating contracts and agreements, including the EPC contract, O&M contracts, insurance policies, warranties, licenses, and property agreements.

As the number of project developers grow, more developers with fewer resources are entering the market, giving pause to lenders. Even if the team has experience, a lack of financial capacity has made the focus on this aspect of increasing concern in the eventuality of default.

4.2.5. Direct Agreement

The direct agreement is the specific agreement that allows the lenders (or their designated agent, etc.) to assume control of the project company if it defaults on its obligations to the lenders. These agreements are entered into among the same groups that conduct security agreements in order to obtain consent and rights from these groups to approve the transfer of control if required.

4.3. Insurance & Risk Management

Insurance is a means for protecting against financial loss. For a complex and highly integrated issue such as energy storage project development, it is also a means to design risk management strategies that expand opportunities at a lower cost through leveraging the financial assets of the insurance firms. This risk management and allocation focus is especially important for energy storage project development. Project developers and lenders both generally agree that energy storage projects are not fundamentally different than a typical power industry project finance transaction, especially with relation to risk allocation; the deal will not close until the known risks have been addressed, and safeguards in place for unknown risks. However, energy storage is somewhat different that other power projects, and so the risk management strategy will need to take account of unique technology, policy and regulatory, and market issues.

Insurance companies reduce their own risk through detailed understanding of the technology, its operation, and interaction in the power market. Insurance policies are increasingly important to the energy storage industry, and as the industry scales in both number and size of projects, many study participants believed the underlying requirements for improved insurance will impact energy storage by reducing risk, limiting liability, and help with financing through 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 firms. Lacking sufficient data in emerging industries like energy storage, insurance firms have long been a driver to promote better testing and Standards development (in both equipment, installation, and operation) to reduce insured loss through performance degradation or failure. Better information provides these firms the ability to determine what 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.

Four areas showcase the development of the insurance and risk management industry in the energy storage industry. First, the improvement of coverage for general insurance for energy storage projects, project continuation strategies, and performance insurance to augment existing product warranties for lenders. Secondly, the project continuation risk management product that provides a technical backstop for projects using emerging technologies. Thirdly, credit enhancements for OEMs and customers. Lastly, performance insurance to provide a financial backstop for the project.

4.3.1. General Insurance

Like other power industry projects, energy storage projects will need general insurance coverage for protection against financial losses. Project developers interviewed highlighted that typical project insurance is increasingly available from different providers, but the variability in offers highlights the insurance industry’s lack of experience with energy storage. Risk tends to be showcased in reduction in coverage rather than higher rates. Typical insurance coverage areas include:

- **General Liability Insurance:** This policy provides coverage for bodily injury, personal injury and property damage caused by the approved project company's operation or injury to a 3rd party that occurs on the project company's premises.

- **Property Risk Insurance:** This policy protects the physical property and equipment of the project company against loss from theft, fire or other threats.

- **Environmental Risk Insurance:** This policy cover gaps in coverage created by pollution exclusions in liability and property insurance policies. This type of coverage will be driven by both the chemicals used in different energy storage technologies, and the familiarity with them of different insurance firms and local inspectors. Batteries with electrolytes that could possibly produce a hazardous spill face the most scrutiny here, but impact from battery fires will also potentially expose many other chemistries to enhanced scrutiny and exposure.

- **Business Interruption Insurance:** This policy covers the loss of income that a business suffers after a disruption in operation. The income loss covered would typically include all time during operational interruptions, including any reconstruction time to get the facility back on-line. A number of insurance providers stressed that this coverage did not cover losses from merchant activity, or from inappropriate operation of the facility that caused the facility to be off-line. This type of insurance is greatly impacted by the level of knowledge by the insurance provider, with some study participants relating the hesitancy of insurers to get too involved with operational impacts without getting to know the technology and market better.

- **Construction Risk Management:** The construction of an energy storage project carries multiple risks. It is the responsibility of the EPC to recognize and manage those risks to prevent exposure to the Project Company and possible loss. One area where additional insurance could be needed is contractor insurance, which covers gaps in contractor's banding capacity and/or coverage which protects the property owners from mishaps during construction caused by the contractor.

4.3.2. Project Continuation

Project continuation risk management strategies are similar to security and direct agreements designed to ensure the continuation of an energy storage project, but much more detailed and targeted at the underlying technology know-how. These strategies are designed to put all of the documentation needed to ensure continuation of operations into a "Project Lockbox."

This type of risk management solution is more geared toward emerging technologies with a smaller manufacturing base for replacement options. Here, the project continuation insurance first addresses any proprietary material or equipment needed for the project that could be put at risk if the company backing the project were to cease operation. In addition, any process knowledge needed continue operating the plant by a 3rd party would also be secured in the

Lockbox. Through this process, lenders would have a greater level of assurance that if there was a potential business disruption at either the parent OEM or project company the project company could continue operation through access to proprietary equipment or knowhow to ensure continuity.

4.3.3. Credit Enhancements

Credit enhancement is used to obtain better terms for an outstanding debt by improving the credit profile of a firm. Credit enhancement reduces the default risk of a non-servicing the debt; with additional resources available to the lender, the lender is many times not only willing to provide the debt, but also with a lower interest rate. This will remain an issue in the energy storage market for some time as many lenders still consider the energy storage market immature. An often-overlooked issue is that credit risk assessment in this industry extends well beyond the project developer to include other critical providers up the supply chain such as various essential subcomponent equipment suppliers that the project would be relying on for warranties, guarantees, and operation & maintenance services of the project.

Through the use of credit enhancements, the borrower reassures the lender of their ability to honor its loan obligation through posting additional collateral, getting a 3rd party guarantee (letter of credit), or obtaining insurance. The insurance policy is on the payments to guarantee that interest payments and principal repayments will be made. Lenders are concerned of the expanding number of project developers in the energy storage market that are thinly capitalized. Insurance for credit enhancement solves some of the key problems of project developers not obtaining addition capital (if they had sufficient capital, they would not need credit enhancement).

Credit enhancements can alleviate credit risk for a variety of other participants surrounding an energy storage project. For small OEMs with an emerging technology, they can help provide a financial backstop for corporate and technology risk. For project developers, they can enhance project execution risk management, allowing them to go after riskier and more lucrative projects. For customers, they can provide assurance and allow them to sign cost reducing contracts if they don’t have sufficient collateral.

4.3.4. Performance Insurance

Performance insurance provides a financial backstop for energy storage projects needing to meet specific performance guarantees. Performance insurance has been initially targeted at projects using energy storage technologies firms without a large balance sheet since large firms can leverage balance sheets for exposure; effectively, without some way to ensure the belief in the self-provided performance guarantee, they are unable to compete. As performance requirements continue to build, other applications of performance insurance will increase.

Insurance providers interviewed for the study stressed that there is no universal performance insurance; each policy is based on the technology option chosen and the intended application requirement. It is designed to bridging gap in what lenders want and what OEMs can provide.

The solar industry also had performance insurance for projects, but again this was for energy (kWh) production, a less complex challenge than what awaits in the energy storage market.

Mentioned many times by insurance providers, key to any continued conversation is a Bankability Study for energy technology and IER report for the project. In order to provide this policy, the insurance firm must undertake a deep due diligence dive on the technology and OEM so that the technology is able to able to maintain its capacity rating (and other required performance ratings) under expected usage profile, and the firm can support the deployment of the technology over the life of the project, and if not, what steps are required to that there is no technology risk for the lender.

5. NEXT STEPS

The energy storage industry today is in a similar situations as in the early stages of the wind and solar markets. The cost of equipment was declining, but undertaking project development continued to be slowed through hesitancy by lenders and investors' understanding the long-term ability of these projects to reliably service their debts and provide a possible return for investors. Manufacturers, EPCs, and insurance firms in the solar industry with deep understanding of the products were able to provide warranty assurance based on their knowledge of their products performance to ensure the sale of their systems. As momentum in project developer and operation picked up, this risk reduction reduced the cost of offered capital, reinforcing the growth trend.

Energy storage systems are unfortunately more complicated than solar and wind projects, but the same efforts will be needed to ensure the financeability of energy storage projects.

- Improved sources of data are needed for better decision making. This data will provide the foundation of what applications and market roles these systems can reliably perform. Through expanding the scope of data availability, plus improved Standards, lenders and project developers can be more assured of the comparability and linkage of performance and financial returns.

- More detailed analytical modeling tools will support more reliable project financing proposals. The heart of the evaluation of the viability of a project is a project economic model for the facility that will account for all of the projected cash flows and costs over the life of the facility. Interviewees stressed the need for better and more transparent market models and system simulator tools and capabilities to cover all of the varying applications where an energy storage facility can operate. The lending community in particular noted that when evaluating a project, they are left many times having to evaluate differing project models from different developers, and many of the models used do not fully capture the dynamic capabilities of energy storage systems impact on revenue generation in the same way leaving them uncertain as to the differences in projects.

- Financial performance metrics are the basis for payment and penalty terms within contracts; these can be technology or system performance metrics such as capacity retention or availability, or they can be derived metrics based on the system's performance in the market. Performance ratings have been instrumental in the development of the wind and solar markets, and will be critical to the commercial success of energy storage the energy storage market. However, because of the more complex usage in energy storage system profiles, the performance metrics will need to also be more tailored to specific applications in order to align what the systems can do with what they are being paid for. Because of these differences, no single financial performance metric will be universal, but generally has specific applicability for different market rules. Whatever financial performance metric is chosen, the measurement of it needs to be transparent, so 3rd party monitoring can be undertaken.

5.1. Data

Improved sources of data are important for better decision making by both project developers and lenders. Many interviewees hoped for both an expansion in the scope of data availability, and a coalescence on Standards or best practices so the comparability and linkage of performance and financial returns would be more accessible.

5.1.1. Engineering & Technical Services

Engineering services are essential for setting and answering the technical risks and capabilities of energy storage systems. The goal for the industry is to harmonize analysis process between firms so customers will have assurance that any Bankability Study or Independent Engineering Report will meet some minimum list that lenders feel is sufficient according to generally accepted best practices. By supporting the development of a more knowledge and experience based mature engineering services, the U.S. Department of Energy can support the acceleration of a mature energy storage market to benefit customer at all levels in society.

5.1.1.1. Independent Engineering Reports

Independent Engineering Reports (IER) have been basis for reducing technology and design risk in the wind and solar markets for lenders, and will be likewise essential in the far more complicated energy storage market. Engineering firms active in the solar and wind project development are rapidly entering the energy storage industry, and will bring with them the best practices learned in these other industries. However, the level of complexity of energy storage projects is far greater, and the type of deployments continue to prove out new and innovative uses—meaning that that it is difficult for these engineering firms to move up the learning curve easily as the domain knowledge requirements keep growing. The experience curve for some engineering firms has indeed been steep. One OEMs tell of an early experience with an engineering firm conducting an IER for a project only a few years ago where the engineering firm required a financial guarantee for each and every line item on their inverter's spec sheet, including the decibel level (Inverters do not normally make significant noise during operation; if they do, there are significant problems with the inverter that will become evident quickly).

A harmonization of IERs would assist in the further development of the energy storage industry. This would not need be a formal "Standardization" in the technical sense (ANSI-Standards, etc.), but an agreement of generally accepted best practices in the development of independent engineering reports. Having engineering firms agree to a common core list of components a depth in degree of coverage that lenders feel is sufficient, would go a long way in helping lenders and insurance firms gain familiarity through ease of comparison with energy storage project development.

Engineering firms develop their own style of IERs to showcase their competency in the area to differentiate their competency. By harmonizing the portions of the reports that are similar across all IERs, lenders would have greater visibility into comparing the different engineering firms' capabilities. For instance, does the engineering firm undertake its own testing, or does it rely on performance data from outside sources? By providing the results in a more common and systematic way, and with the domain knowledge more clearly defined, lenders will have more confidence in the reports, and be able to better compare engineering services between firms.

5.1.1.2. Testing—Codes & Standards

Codes and Standards provide a risk mitigation framework for energy storage systems to operate safely, allow for design interoperability, and ensure that equipment does not injure people, or interfere or damage other equipment on the power grid. Testing by manufacturers and testing companies is a key part of the certification process, and can validate that the equipment adheres to the guidelines outlined in the Standard. These testing procedures will include mechanical and electrical tests on the components and then systems. A variety of Standards for energy storage equipment exist, including UL 9540 *Standard for Energy Storage Systems and Equipment*, and IEEE 2030.3 - *IEEE Standard Test Procedures for Electric Energy Storage Equipment and Systems for Electric Power Systems Applications*: The U.S. DOE supports the efforts of these and other Standards bodies through efforts like PNNL-23618 *Inventory of Safety Codes and Standards.*

A central role of the IER is to ensure that all of the equipment to be used in the project will adhere to these industry standards. Manufactures and 3rd party testing facilities are expanding their capability to evaluate these products. An ongoing challenge will be for developers and lenders to ensure that these groups have the experience to do to testing properly so the results are valid, but that real issue can be addressed with certifications of the testing facilities themselves. A benefit of all of these testing efforts will be a growing body of real capability data on the components and systems; increased data allows for better predictive estimation, which is the basis for performance metrics.

The U.S. Department of Energy has an important role here to both maintain support and harmonize the ongoing efforts across different industry Standards and technical groups, but to also continue its educational efforts for the wider industry. By maintaining its own efforts at Sandia National Laboratories and other locations, the U.S. Department of Energy can maintain its ability to provide the much-needed testing capability to the industry, but also have a hand in understanding what is needed to operate testing facilities for customers to provide a 3rd party validation of system's performance levels in order to ensure a bankable project.

5.1.1.3. Installation & Commissioning

To improve the installation challenges for its members, the National Electrical Contractors Association (NECA) develops NECA 416–2016, *Recommended Practice for Installing Energy Storage Systems (ESS).* This is the latest in a series of installation guidelines from the National Electrical Installation Standards (NEIS®) group within NECA. Energy storage systems are increasingly important to electrical contractors in utility, wind and solar systems. NECA 416-2016 describes methods and procedures used for installing, commissioning, and maintaining energy storage systems with installer and inspector checklists. This publication includes good workmanship elements and guidelines for installation, commissioning, and maintenance of energy storage systems. NECA 416-2016 is aligned with the minimum requirements in the new Article 706 of the 2017 National Electrical Code (NEC®) (see below).

Standardizing for commissioning guidelines has also received support from the U.S. Department of Energy through Sandia National Laboratory, a compilation of such given through *Electrical Energy Storage Start-up & Commissioning Overview*[5] presentation. In this Clean Energy States Alliance (CESA) webinar, the key parts of the project implementation and commissioning process are reviewed, including:

- Commissioning Activities During Design and Construction
- Team and Commissioning Program Development
- Factory testing/Procedures/Inspections/Training
- Electrical Energy Storage System Commissioning Process
- Operational Acceptance testing (OAT)
- Start-up
- Function Acceptance testing (FAT)
- Shakedown

The 2017 National Electrical Code (NEC®) has been updated recently to address energy storage systems. Article 706, *Energy Storage Systems,* provides requirements covering permanently installed systems that can be stand-alone or interactive with other electric power production sources. Prior to this new Article, lead acid and some other battery technologies were covered in Article 480 which covered emergency backup power for UPS applications. With the advent of both more types of energy storage technologies—Flow batteries, capacitors, flywheels, etc.—and a myriad of new uses, an expanded coverage of energy storage systems was needed. This new Article centralizes the requirements for all stationary energy storage systems, into a single NEC® Article.

To ensure proper training for installers, NECA has established the *Energy Storage and Microgrid Training and Certification (ESAMTAC).* This program is designed to develop training and certification programs for energy storage installation at local electrical training centers. It formalizes and standardizes training program, and highlights the specialty skills and knowledge needed to work safely on energy storage and microgrid projects. The ESAMTAC program is designed to benefit developers, lenders, and insurance firms by allowing them to identify and utilize skilled installers. This has the benefit of not only reducing the time required to install system, but also ensuring that these systems are installed properly, reducing damages during install, and supporting the longevity and viability of the system.

5.1.1.4. Operation & Maintenance Procedures

With more experience being gained by groups designing, building and maintaining the growing number of deployed energy storage systems, operation and maintenance procedures are rapidly being standardized across a number of owner & operators based on input from OEMs. Some of these procedures will have some technology specific differentiation, but as market focused applications become standardized, there is an increasingly amount of similarity in monitoring, servicing and repairing these assets for optimizing the performance of these energy storage assets.

Common features of operations focus on a Network Operating Center (NOC) where all critical information on the facility is easily monitored. This is helpful for any facility, but quickly becomes critical for managing multiple sites. The NOC allows for local dispatch of the units, either independently, or via automated dispatch from the utility or balancing authority. Remote monitoring of the facility allows for testing at regular intervals to ensure specified operating availabilities, capabilities, and efficiencies. As operational experience is gained, additional performance data—from individual components and at the system level, can be captured to improve the analytics in the controls software.

A strong operations plan is the basis for a strong maintenance plan. Utilizing experience from other markets, a reliability centric maintenance plan will promote more uptime and higher availability. Preventative and predictive maintenance – especially on mission critical components—is a key element of these efforts. Also essential is a strong focus on safety– including policies, procedures, and action plans in place (See next section). Increasing modular designs of energy storage facilities—helpful for design, construction, and augmentation over a long life—allows for the facility to remain in operation while portion is down for maintenance. The use of well trained and certified electricians and technicians will result in lower operating costs, fewer safety issues, and lower risk for events that could damage the facility.

5.1.2. Safety & Standards

The U.S. Department of Energy was consistently mentioned by survey participants as the trusted actor to ensure the industry continues to focus on the safe and effective design, manufacture, and operation of energy storage systems. It was felt by many that these issues—although not normally prominent when discussing financing challenges—were fundamental to having energy storage projects be established as bankable assets.

The U.S. Department of Energy has been the prime agent in promoting the safe design, manufacturing, and operation of energy storage system. An overview of the effort can be found in the U.S. *DOE Energy Storage Safety Strategic Plan* which many groups from across the energy storage industry participated. This Program is designed to prevent both injury and property loss through better design, operation, and measurement and verification efforts.

Another related aspect is the process for managing the eventual system failures, and putting in place a process to ensure the safety of personnel, and to ensure that the same failures will not happen again. Three examples in particular showcase lessons learned that lenders want to see.

- In 2011, a module design issue was determined after a fire in a sodium sulfur battery from NGK Insulators in Joso City, Ibaraki Prefecture NGK. The company redesigned the module and fixed the units in the field at considerable expense. Because of the action by the firm, no one has ever doubted the bankability of NGK technology after that.

- In 2011, a flywheel system operating by Beacon Power in Stephentown, NY failed during operation. A root cause analysis led to an issue with the manufacturing of the unit which the company then fixed. Key lessons learned were that a single unit could fail without pulling down the rest of the system. After the issue was fixed, the flywheel systems have continued to operate successfully.

- In 2012, a fire at an Xtreme Power battery system at the Kahuka Wind Farm on Oahu, HI, consumed the battery building and temporarily disrupted the output from the wind farm to the Oahu grid. The wind & storage facility had been designed with all power flow through the battery building, leaving the wind farm unable to operate until a grid connection for the wind farm was re-established.

Going forward, many simply desire the U.S. Department of Energy to continue executing on the U.S. DOE Energy Storage Safety Strategic Plan. In order to keep the efforts of the Energy Storage Systems Safety (ESS-S) program relevant, the U.S. Department of Energy holds an annual Safety and Reliability workshop to support the evolving industry. One key role the U.S. Department of Energy can leverage its position is to continue to work with Standards groups in the development and inclusion of safety issues as industry Standards are developed, such as the recently issued UL 9540–*Safety of Energy Storage Systems*.

5.1.3. Performance Testing & Verification

Performance testing and verification of the energy storage system's operating track record is a direct means to gather essential data about how these energy storage systems perform in real life circumstances. Ongoing performance testing allows for the unit's ability to be measured against performance requirements in the operating contract. The U.S. Department of Energy has been central in supporting a centralizing program to guide these efforts. 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* 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. Other Standards groups have endorsed this effort and show signs of adopting this methodology globally.

Onsite performance testing and verification by 3rd party providers, offers the energy storage industry a means to monitor this performance and capture much needed operational data to bolster the chain of custody for the data. A 3rd party providers introduces a skilled, neutral party as a service provider to the project developer that can operate alongside any existing on-going monitoring. By having a 3rd party testing firm review the actual status of the equipment as it ages, lenders will have an unbiased look into the status of the equipment. These insights will touch on a number of key issues, such as design, commissioning, and operation. It will also be able to provide a guide to the efficacy of degradation models for the equipment, and provide other insights into OEM issues such as round-trip efficiency, response time, stand-by losses, etc. The data can also be used to improve predictive maintenance and reduce downtime and O&M

costs. By assuring lenders of the proper functioning of the system, their confidence in the ability of the system to service the debt is enhanced, and can help lower the cost of capital for other projects with a higher confidence of good operation.

5.1.4. Data Formatting

The energy storage industry needs common data formatting to reduce transactional costs throughout the business processes of energy storage project operations. Data formatting is not the same as a communications protocol such as the MESA Standards Alliance (MESA) has released, which is a protocol for data exchange for communication between utility control centers and energy storage systems. These address the storage systems configuration and operational states within the IEEE 1815 *Standard for Electric Power Systems Communications-Distributed Network Protocol (DNP3).* Common data formatting, in contrast, supports better data quality, accessibility, and improved efficiency on the use of the data for business processes.

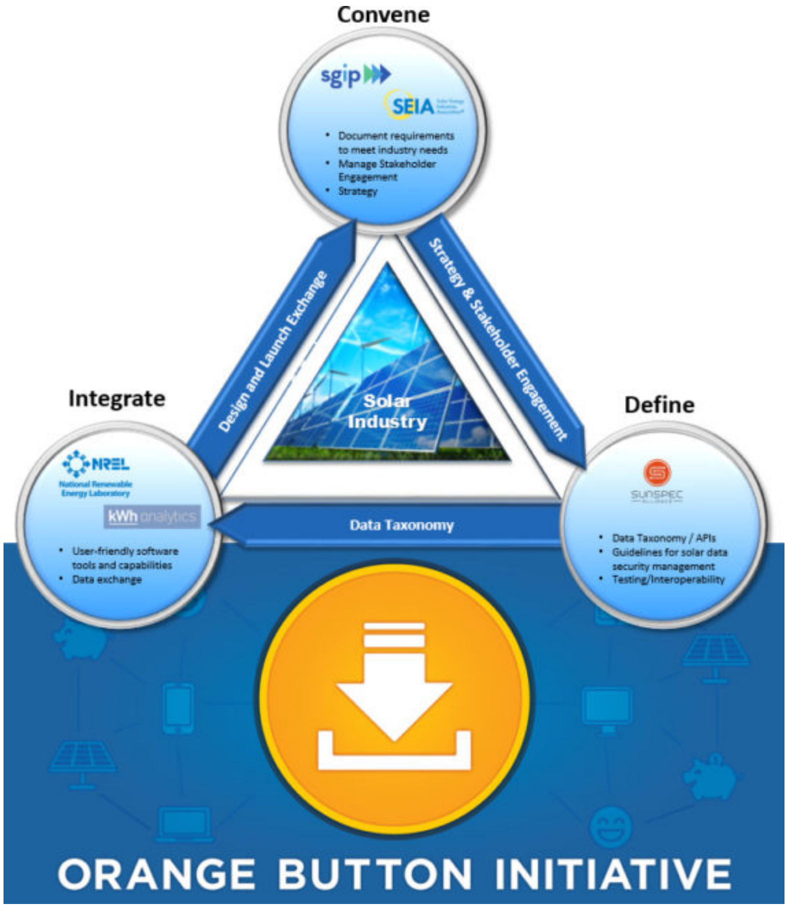
5.1.4.1. Orange Button

We can look to the solar industry for an example of an industry-wide effort to address the need for improved data formatting to drive an emerging industry forward—the Orange Button℠. The Orange Button℠ effort grew out of U.S. Department of Energy Sunshot Initiative and was originally named *Solar Bankability Data to Advance Transactions and Access*, as it “targets a reduction in soft costs by streamlining the collection, security, management, exchange, and monetizing of solar datasets across the value chain of solar.”

These actions are aimed at making the transfer and use of the data better in order to standardize the data-landscape for solar industry. By supporting the efforts to use the data better, transactional costs decline by improving quality, accessibility and efficiency of the exchange of data across the industry’s value chain. Project developer in particular benefit, by lowering the cost of customer acquisition, and lowering the cost of capital due to improved lenders’ understanding of the project offerings. Finally, this also improved the development of risk management strategies through the increase of data sharing, and improves the use of analytical tools by increasing the data available for analysis.

The Orange Button accomplishes this by:[6]

- Defines the data requirements, formulates data taxonomies interoperability standards, and data exchange process.
- Supports the creation and adoption of industry-led open data standards for rapid and seamless data exchange across value chain from origination to decommissioning.
- Promotes the reduction in soft costs (project development) by making it easier to share solar data and speeding up processes like financing.
- Helps reduce market inefficiencies, lower costs for consumers, and facilitates the growth and expansion of distributed solar.



Source: NREL

Figure 14. Orange Button Initiative.

We can look to the Orange Button Working Groups to see where the energy storage industry should focus its efforts. These include:

- **Deployment:** Data needed for permitting concerning structural and electrical safety.
- **Financial:** Efficient project financing and financial reporting during project operations. Streamline data exchange between banks and developers to assess development risk.
- **Real Estate:** Data requirements of the real estate industry to deploy projects at various types of commercial real estate categories.
- **Solar O&M**: Focused on all data requirements behind project operations and maintenance practices and cost models.
- **Grid Integration:** Focused on the data needs for utilities, ISOs, and solar developers with regard to new utility-scale and behind-the-meter connections.

5.1.4.2. Energy Storage

The U.S. Department of Energy has some experience promoting the formatting of operational data from energy storage demonstration projects it has funded, with the result appearing in the Technology Performance Report for the project.

The data included would contain:

- **System Characteristics**: Profiles of the prototype system and usage profile.
- **Data Measurements:** Definition of what components to be monitored and frequency of recording during operation.
- **System Performance Parameters:** List of technical, economic, and safety performance characteristics to be measured.
- **Projected Performance Parameters:** List of performance characteristics that must be forecasting based on data collected. Examples include life cycle cost information and long-term capacity degradation.

The U.S. Department of Energy can support the industry's push to provide a consistent formatting of the data through its experience managing demonstration programs. Part of the program was to be able to compare characteristics and performance between projects, so although the projects would have different performance results, the formatting of the data needed to be supportive of analysis across all projects lies.

5.2. Project Modeling

The heart of the evaluation of the viability of a project is a project economic model for the facility that will account for all of the projected cash flows and costs over the life of the facility. Project economic models themselves are relatively straightforward, so the critical part is the clear visibility into the economic and operating assumptions, making sure to take into account changes from supporting multiple applications. Also, because of the still emerging nature of the market for storage assets, an ability to showcase the key market drives is helpful to understand where the operations leverage lies.

Interviewees stressed the need for better and more transparent market models, system simulator tools, and capabilities to cover all of the varying applications where an energy storage facility can operate. The lending community in particular noted that when evaluating a project, they are left many times having to evaluate differing project models from different developers, and many of the models used do not fully capture the dynamic capabilities of energy storage systems impact on revenue generation in the same way leaving them uncertain as to the differences in projects.

Some participants suggest that the U.S. Department of Energy could contribute to better analytical tools and information for energy storage project development analysis, with a key ask being for better data as many developers are viewing integrated market models as an area of competitive advantage. Project developers did highlight the desire for 3rd party analysis of system performance of energy storage technologies and systems as a check to their own assumptions.

5.2.1. Economic & Financial Assumptions

Although economic and financial assumptions do not typically drive the profitability decision for a project, poor choices and usage many times may accentuate volatility and increase the level of uncertainty needlessly.

The cost of capital is critical to the profitability of a project. This will include the cost of debt, the cost of equity, and the debt/equity ratio. These values are typically specific to the developer as elevated levels are proxies for the level of risk that the lender feels for a specific developer or project. The debt to equity ratio can have a noticeable impact on the overall return for the project.

Tax rates will typically not change at the Federal level, but as you move to State and local jurisdictions, there is more of an opportunity for variability expected and evolution over time. The annual inflation rate projections do change, so must also be reviewed periodically over the life of the facility. Local property taxes have come to also impact energy storage facilities as to how these facilities will be treated has a large impact on the decision, and local governments have little experience to date with these facilities generally.

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.

The choice of economic and financial assumptions for project modeling is the purview of the project developer. The source should be reputable, consistent, and provide a clear methodology on its assumptions so the developer can answer questions from lenders on these key drivers. The U.S. Department of Energy publishes the Annual Energy Outlook[7] which provides long-term energy projections for the United States based on existing regulatory, economic, and technical assumptions and trends. For project developers, this modeling system provides a comprehensive and detailed economic pricing drivers with ample supporting methodology for a project located in different parts of the United States. In addition to the central report, there is an appendix containing all of the output for the various components of the model.[8] Most useful, is a complete set of excel spreadsheets of the entire modeling system output.[9]

5.2.2. Project Economic Model

The project economic model is structured as to take into account the forecast of all of the expected cash flows, expenses, and taxes or other fees. These are a typical analytical tool developed by project developers to decide to financial viability of a proposed project. Lenders require such analysis to validate economic feasibility of the project, and that it will generate sufficient cash flows to cover all operating and debt-servicing expenses and any required reserves over the lifespan of the facility. Once agreed on, it will serve as the basis for structuring the project finance deal.

The modeling framework of a project economic model is generally straight-forward, 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 different capital and operating characteristics of different energy storage technologies, a critical issue here is always to separate any technical biases from impacting the comparison of a particular project economic analysis based on one technology vs. another. Matching these differences in equipment costs and system capabilities comes into play when needing to iterate with market models that optimize potential project revenues.

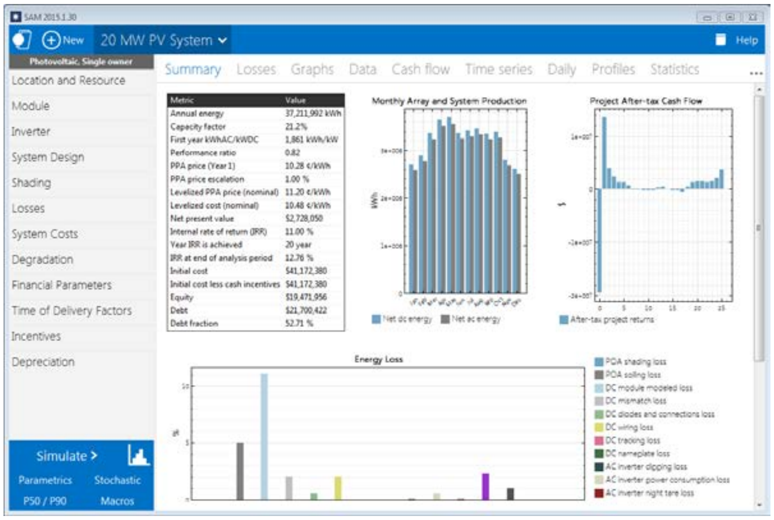
5.2.2. Simulation Models

The strength of a project economic model is its ability to pull all of the relevant information and assumptions into a common framework for evaluation and analysis. Because of the complexity of operating the system in a real-world market environment, it is difficult to incorporate into the project economic model the system simulation model and the related market modeling components for highly complex markets. For that need, more sophisticated and specific modeling simulation engines are required. The U.S. Department of Energy and State Governments has supported the development of a number of energy storage modeling efforts that can support project developers and lenders. Many of these models will provide the project economic model on top of the core system simulation work to offer a complete modeling package. Some developers noted that they would like the flexibility to structure the project differently than using only the framework provided by the model.

The lending community in particular is eager for improved and standardized modeling tools so they can evaluate projects from different developers more easily; currently they must invest the time to understand the intricacies of each developer’s project economic model, and many are not able fully capture the dynamic capabilities of energy storage systems. Although there was no stated implication of distrust in these models, the lenders nevertheless stated that they would prefer to have some type of standard, 3rd-party modeling framework to provide a check when analyzing the performance of energy storage systems.

5.2.2.1. System Advisor Model (SAM)

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. 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 model was developed by NREL in collaboration with Sandia National Laboratories in 2005. SAM 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.



Metric	Value
Annual energy	37,211,992 kWh
Capacity factor	21.2%
First year kWhAC/kWDC	1,861 kWh/kW
Performance ratio	0.82
PPA price (Year 1)	10.28 ¢/kWh
PPA price escalation	1.00 %
Levelized PPA price (nominal)	11.20 ¢/kWh
Levelized cost (nominal)	10.48 ¢/kWh
Net present value	$2,728,050
Internal rate of return (IRR)	11.00 %
Year IRR is achieved	20 year
IRR at end of analysis period	12.76 %
Initial cost	$41,172,380
Initial cost less cash incentives	$41,172,380
Equity	$19,471,956
Debt	$21,700,422
Debt fraction	52.71 %

Source: National Renewable Energy Laboratory (NREL)

Figure 15. NREL’s System Advisory Model (SAM).

SAM does not model hybrid power systems, but the model does incorporate energy storage assets within a renewable project; it is not intended for a stand-alone wholesale energy storage asset. Since the focus of the model is for the renewable energy, any further energy storage modeling capability will support the widening use of energy storage assets for renewable energy projects.

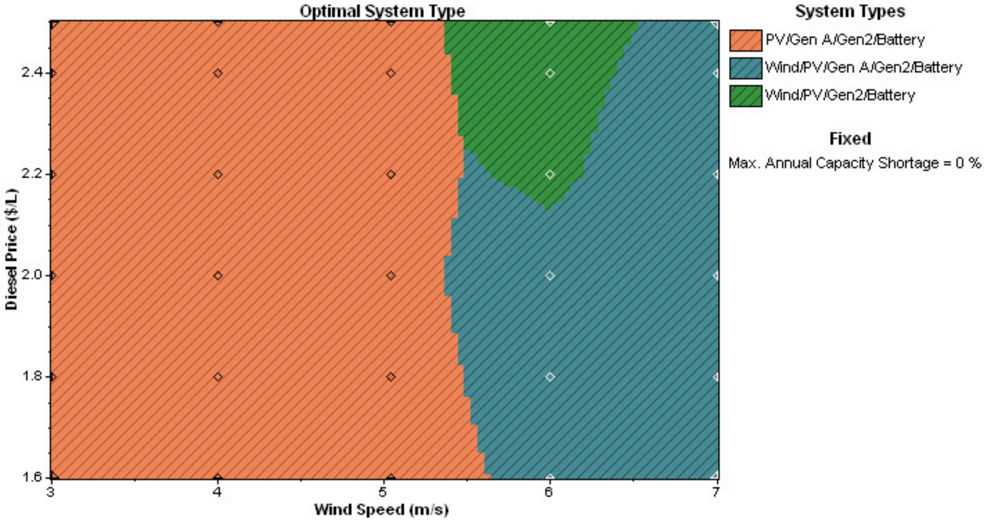
5.2.2.2. HOMER

Originally developed by NREL in 2000, the HOMER (Hybrid Optimization Model for Multiple Energy Resources) model is globally accepted as the standard microgrid modeling software. The software was licensed to Homer Energy, LLC in 2009 to further promote its use. 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. The software has 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.



Source: Techno-economic analysis of a hybrid mini-grid system for Fiji islands, Sandeep LalAtul Raturi, International Journal of Energy & Environmental Engineering, December 2012, 3:10

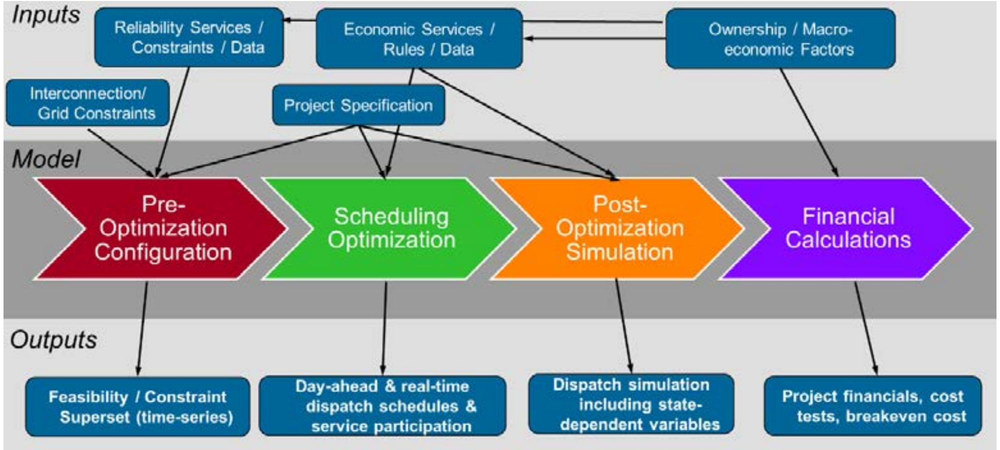
Figure 16. Example of HOMER Model Output.

Homer incorporates energy storage assets into the microgrid 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, you can develop a hybrid microgrid to evaluate the inclusion of an energy storage asset into a microgrid environment.

5.2.2.3. Storage Value Estimation Tool (Storage VET®)

The Electric Power Research Institute (EPRI) has recently developed the Storage Value Estimation Tool (StorageVET®), a free, and online publicly available energy storage simulation tool. Initially developed with support from the California Energy Commission (CEC) for the California market, StorageVET® is being expanded for use in other parts of the United States with the inclusion of different data sets, and the ability to provide your own.

The model was designed to be used by utilities, regulators, and vendors for site-specific energy storage projects. It estimates the costs and benefits of energy storage projects, supporting the analysis of a variety of Grid Services, technologies, system sizes, and locations for both front of the meter and behind the meter applications. StorageVET® helps identify high value locations for energy storage deployment. The model is supported with the input from EPRI’s open technical forum, the Energy Storage Integration Council.



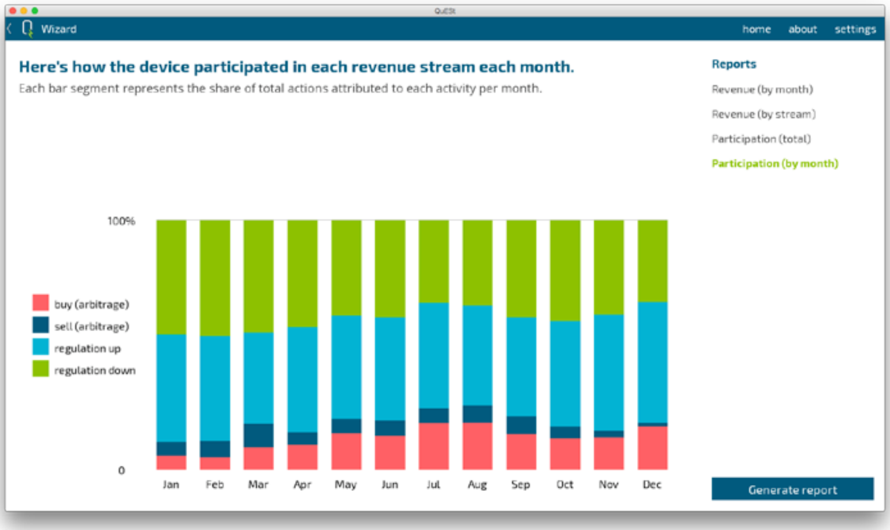
Source: EPRI

Figure 17. StorageVET® Model Architecture.

5.2.2.4. QuESt

Sandia National Laboratories has recently released QuESt, a free, publicly available, open source software application suite for energy storage simulation and analysis. The initial release version includes two applications:

- **QuESt Valuation:** This application estimates an upper bound on the amount of revenue a front of the meter energy storage system can generate over a given month in a specific ISO/RTO. Using historical data from ISO/RTOs such as hourly day ahead LMP and frequency regulation movement and capacity credits, QuESt Valuation solves for the optimal policy of energy arbitrage and frequency regulation participation that results in the maximum gross revenue generated by the energy storage system. Different energy storage systems can be modeled according to characteristics such as energy capacity, power rating, and round-trip efficiency. This analysis gives insight into the value of the energy storage system based on its revenue generating potential. The initial release includes support for the ERCOT, PJM, and MISO markets but support for the remaining markets in the USA is under development.
- **QuESt Data Manager:** This application is designed to retrieve historical data shared by ISO/RTOs on their websites or through their APIs for use in other applications, such as QuESt Valuation. The purpose is to remove the need for locating and appropriately formatting data.



Here's how the device participated in each revenue stream each month.

Each bar segment represents the share of total actions attributed to each activity per month.

Source: Sandia National Laboratories

Figure 18. Sample results from QuESt Valuation's wizard.

5.2.3. Data Sources

In order to make the most from these and other potential simulation models, detailed market information on the electrical power market is needed. The U.S. Department of Energy has been expanding the number and type of resources to improve the modeling of existing and proposed projects.

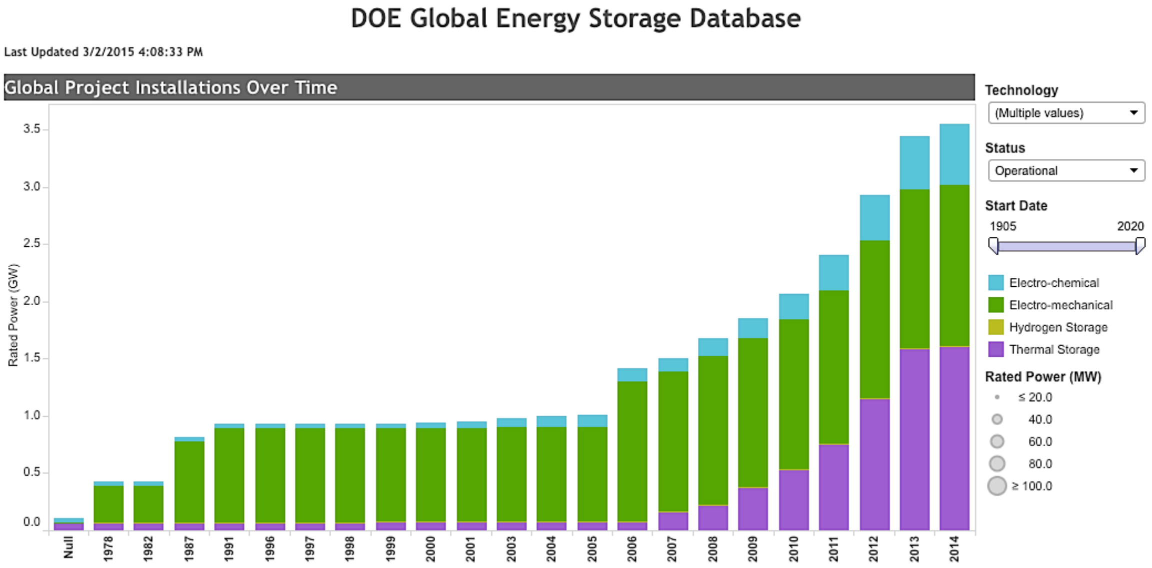
5.2.3.1. Global Energy Storage Database

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—

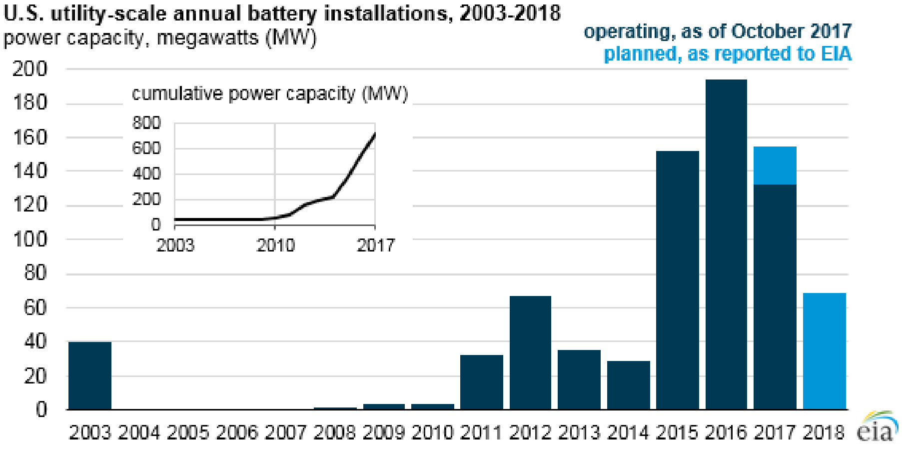
would be the basis to provide lenders the confidence in to extend more and cost-effective capital to this growing market.



Source: U.S. Department of Energy

Figure 19. DOE Global Energy Storage Database.

5.2.3.2. Inventory of Generators, EIA-860

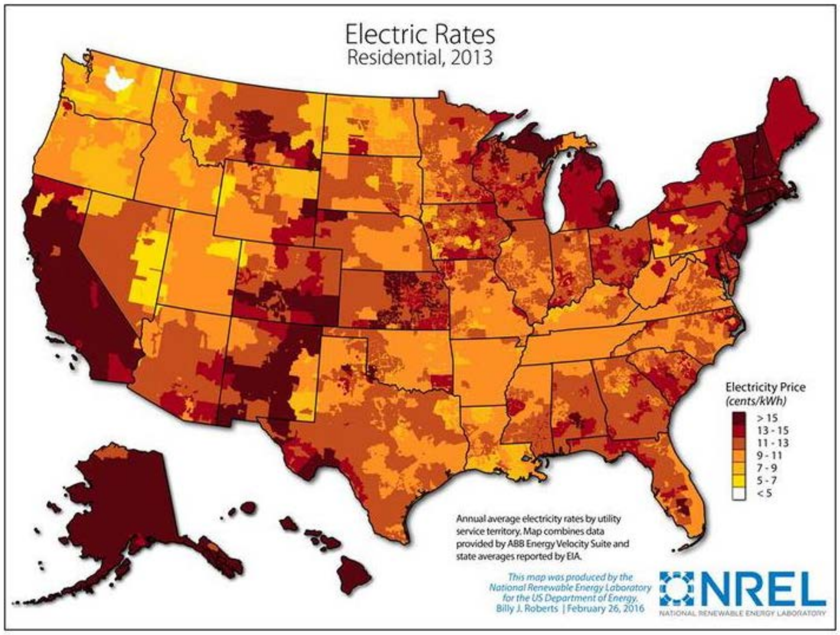


Source: U.S. Energy Information Administration, Form EIA-860M, Preliminary Monthly Electric Generator Inventory

Figure 20. U.S. DOE Inventory of Generators.

The U.S. Department of Energy has begun tracking energy storage assets as part of the Energy Information Agency's (EIA) monthly inventory survey. Each month, utilities and other asset owners provide information on the current status of existing and proposed generating units at electric power plants with 1 megawatt or greater of combined nameplate capacity through the Monthly Update to Annual Electric Generator Report, Form EIA-860M. The final inventory of generators is published each year with the annual EIA-860. By incorporating energy storage assets into these standard reporting forms, developers can gains some information about the current state of the market in the specific region they are contemplating the development of an energy storage project.

5.2.3.3. Open EI – Utility Rate Database (URDB)



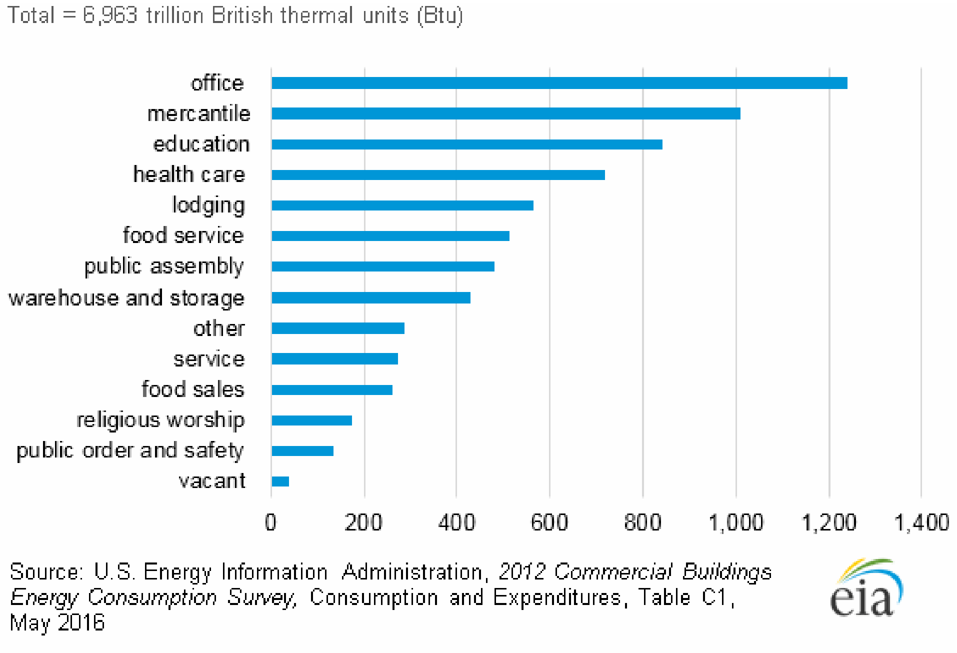
Source: NREL

Figure 21. Utility Rate Database URDB).

An important input to any Behind the Meter energy storage modeling is a clear understanding of the current tariff rate structure for the location in question. The U.S. Department of Energy published the Utility Rate Database[10] (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 list of U.S. utility companies maintained by the U.S. Department of Energy's Energy Information Administration.

5.2.3.4. 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.



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

Figure 22. Energy Use by Commercial Building Type.

Table 5. 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.[11]

5.3. Financial Performance Metrics

Financial performance metrics are the basis for payment and penalty terms within contracts; these can be technology or system performance metrics such as capacity retention or availability, or they can be derived metrics based on the system's performance in the market. Performance ratings have been instrumental in the development of the wind and solar markets, and will be critical to the commercial success of energy storage the energy storage market. However, because of the more complex usage in energy storage system profiles, the performance metrics will need to also be more tailored to specific applications in order to align what the systems can do with what they are being paid for. Because of these differences, no single financial performance metric will be universal, but generally has specific applicability for different market rules. Whatever financial performance metric is chosen, the measurement of it needs to be transparent, so 3rd party monitoring can be undertaken.

Examples of performance ratings already in use in the energy storage market are instructive as to how performance ratings could be adopted in other settings to support the wider adoption of energy storage system based on a provable measurement of their performance capabilities. Many industry participants welcome the development of performance ratings, and want some aspect of them incorporated into project contracts to ensure a better chance of the project's ability to generate revenue in return for guaranteed performance. A reliable performance rating would allow lenders to structure the funding for a project based on an agreed upon market driven metrics, significantly reducing their risk and thus allowing them to safely offer increasing amounts capital for projects. Many lenders that were interviewed were interested in a tighter linkage of performance to compensation; although the possibility of a loose tie-up allows for the possibility of a high performing system to have a higher reliability of debt repayment, it also means that the higher performing system is not being totally compensated for the capital being put to use in the project. The performance rating would also benefit project developers as they would know more closely what the performance requirements would be, and thus be able to not overbuy the capital equipment.

Financeable performance metrics are key to our capability to improve contracts in the market. We can base contracts on simple technical metrics now, but as market operation gets more complex, we need contracts that can handle that cleanly, and that means better metrics that can better highlight performance metrics germane to the application.

Three approaches for imparting performance metrics into contracts in particular will be important: performance scoring, technical and system performance metrics, and benchmarking.

- Performance scoring defines how the energy storage asset operates against a market signal.

- Performance metrics defines how the energy storage asset operates against its own technical potential, and

- Performance benchmarking defines how the energy storage asset operates as compared to other energy storage assets (or other resources).

All approaches provide insight into the operations of a particular energy storage asset, and thus can be a reliable metric to be used in compensating an energy storage system, or when comparing one asset vs another for purchase.

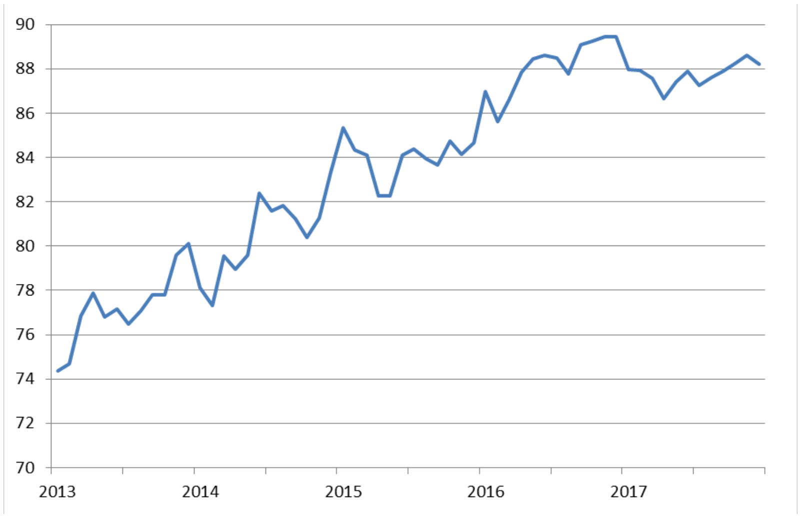
The U.S. Department of Energy has a unique opportunity to play a key role in ensuring that the performance of energy storage systems become more understood, widely adopted, and transparent. Once the financial industry understands the linkage between the technical performance of the storage asset and the financial application, the use of performance ratings to further the growth of the energy storage market will be possible. The goal is to provide the performance data in a clear and useful format so the market can utilize the information as needed.

5.3.1. Grid Services

Energy storage assets have the opportunity to provide a wide range of flexible grid services across the transmission and distribution system. Grid Services—inclusive of ancillary services—are essential for maintaining a stable grid to provide low cost and reliable power to customers, both during normal operations and ensuring resiliency of the grid during interruptions. As energy storage assets have been able to showcase their performance capacity, they have been able to make inroads into the formal ISO/RTO markets for these services, based largely on their performance capability. Frequency regulation has been the best example to date of the beneficial use of energy storage assets in this role.

Frequency regulation has been a clear early example of how energy storage can perform a key function in the wholesale power market, with compensation being based on performance. This focus on performance stems from the Federal Energy Regulatory Commission (FERC). At the core of FERC Order No. 755's pay-for-performance based frequency regulation service is the performance measurement. All market assets providing frequency regulation services in formal wholesale markets are to be evaluated through this process, so it has become an insightful indicator of how energy storage assets perform in a real and very competitive market. Individual ISO markets approach the performance measurement calculation differently, depending on the structure of their market calculations, but generally have some type of hourly evaluation process where they score the resources providing frequency regulation services in the compensation calculation.

The PJM Interconnection's (PJM) use of a Performance Score is central to payment for frequency regulation services in that region. The Performance Score is calculated by measuring the accuracy, delay, and precision of the asset in following the market signal. Based on enhanced performance pay opportunity, nearly 250 MW of energy storage systems have been installed in the region to provide frequency regulation services. (After the initial development of the RegD market, subsequent change to the qualification and payment structure altered the market prospects for energy storage assets and made it less advantageous for existing facilities).



Source: Mustang Prairie Energy

Figure 23. PJM Average Performance Score.

Prior to the change in the market rules (which affected how the performance score was tallied), the confidence is the performance score by lenders was sufficient to support financing of two energy storage facilities designed to provide frequency regulation. In 2015[12], RES America developed and constructed the Jake Energy Storage Center (Joliet, IL) and the Elwood Energy Storage Center (West Chicago, IL), each with 39.6 megawatt (MW) of operating capacity and the ability to store 7.8 megawatt-hours (MWh) of energy. Financing was arranged through Prudential Capital Group and Lincoln National Life Insurance Co. What makes this financing unique was that it was the first non-recourse debt financing that used the two units' performance score as part of ensuring revenue generation. The financing for the facility was linked to a hedge on the frequency regulation forward market price, with a requirement of a performance score sufficient to maintain operation of the units in the market, and thus to receive payment based on the hedged frequency regulation forward prices; the debt repayment was structured with the length of the hedge.

The U.S. Department of Energy can support the further expansion of energy storage assets into other wholesale power market roles through leveraging the experience of the lenders utilizing performance to enable lower cost project financing. Performance metrics have a place in underpinning other services in the wholesale power market, which will support the use of energy storage assets in these applications. As the confidence in a performance rating increases with other lenders, the metric will become a more reliable and established input into ensuring the financeability of projects.

Another benefit of the market performance metrics like the PJM Performance Score is that unit performance is presented in a way that shields the underlying unit's technical performance by measuring the performance (in this case, its accuracy, delay, and precision) against the regulation signal. Since the resulting market performance metric is a based off of the relationship to these three criteria, the technical operation of the underlying unit can remain proprietary to the project owners and equipment OEMs—who do not want their product's detailed technical performance made public. This ability to shield proprietary operational information will be important in the push to utilize this approach in other markets to garner the support of project developers and battery OEMs. The introduction of these market performance metrics should be beneficial to those looking for flexibility in structuring the financing of these projects as other market performance metrics for different market services could be used along the lines of the hedges used to finance the RES America facilities.

5.3.2. Utility

Utilities are at the forefront of evaluating energy storage systems at various location and applications, and much of the use of performance scoring within contracts for payment will stem from experience here. Because of the variety of deployment opportunities that span varying usage profiles, many examples of how performance parameters can be integrated into payment contracts.

One example is from a utility who has recently installed a MW-scale energy storage system at a substation, and incorporated performance into their payment structure. The utility structured payment to be quarterly, with 50% of the payment being tied to the system maintaining the performance guarantee provided by the developer. The performance metrics was centered on the capacity maintenance laid out in the warranty, with a separate test administered each quarter. The other 50% of the quarterly payment is based on a capacity payment for what services the unit provides. This compensation methodology highlights the utility's tying of payment for the system directly to a previously agreed to performance. As these systems get more complex, the industry will combine more in-depth system metrics to gauge performance, especially as increasingly multiple—and dynamic—applications drive compensation arrangements.

Another point of input came from a separate utility executive interviewed for the Study, with the keen insight of not to over-think the problem. This example dealt with smaller, feeder level energy storage assets used to provide resiliency and reliability for the system. Since these are difficult applications to quantify in a contract, the utility began rethinking the problem—especially if they wanted to promote the ability of vendors to provide the storage systems on a contract basis service agreement for the utility. Since the goal was to have distributed resources on the grid, one solution proposed was simply to pay the vendor a service fee for the capacity (kWh) in the storage asset to always have some minimum capacity (50%) available that would be callable by the utility. The goal of this was slightly different than a Resource Adequacy program, as instead of addressing peak load periods, this potential need was for a far more infrequent interaction. To promote visibility, the systems could be "pinged" by a 3rd party monitoring vendor to relieve any potential conflicts of interest if either the utility or storage vendor provided the monitoring.

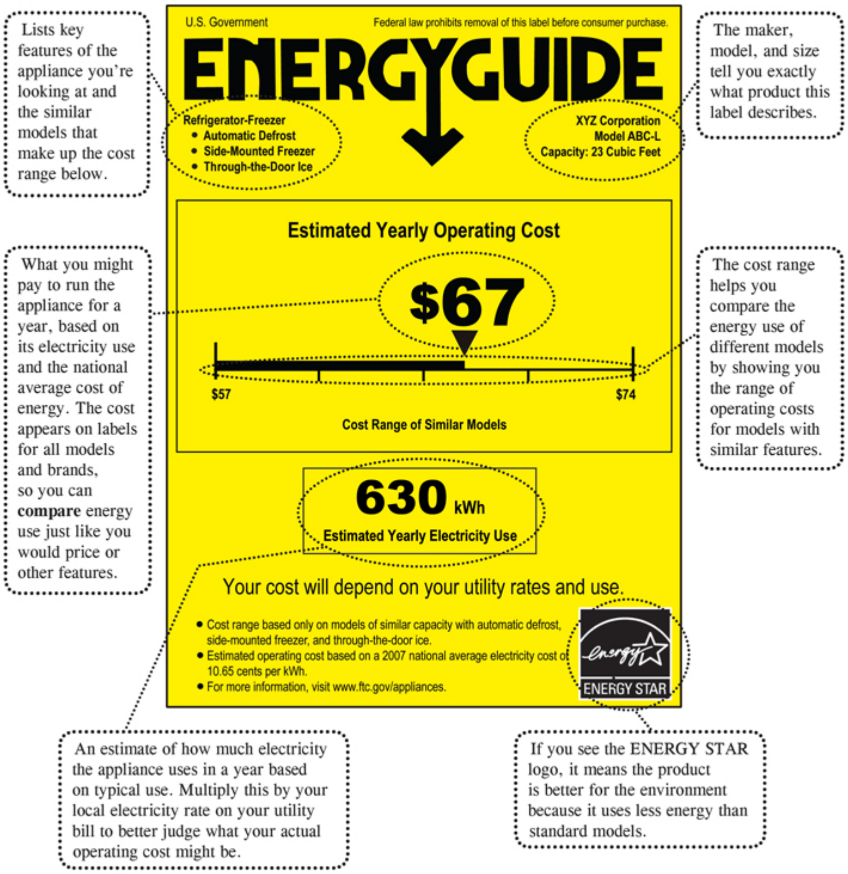
These and other examples show that the utility industry is already starting to incorporate performance for energy storage services into contract planning. Although contracting for capacity could also be seen as a performance (no pay for non-performance) what we are also seeing is that utilities are looking deeper into operational performance metrics in an attempt to ensure that good operation of the unit not only now, but also over the future of the contract.

5.3.3. Residential

Performance benchmarking can provide residential customers a desperately needed insight into their choices of home energy storage systems. The energy storage options for residential customers is growing rapidly, and it is quickly becoming apparent that the average homeowner does not have the information nor ability to understand the economics of their choice—even if nearly all are based on lithium-ion batteries. Unfortunately, this task will become even more complex as additional home energy storage systems—and of varying technologies—enter the market. Many providers of these residential energy storage solutions tout the low initial cost of the system, or some isolated performance metric such as round-trip efficiency, without giving the customer sufficient information with respect to overall costs and savings. By supporting the development of an integrated benchmark rating system, the U.S. Department of Energy could help customers more easily determine the cost effectiveness of a residential energy storage system. For working purposes, we will call this potential benchmark rating system for residential energy storage systems “GridStar.”

The potential GridStar rating would be loosely based on the U.S. Government’s existing “Energy Star” program. The ENERGY STAR™ rating is the leading international standard for energy efficient consumer products. The program was created in 1992 by the U.S. Department of Energy and U.S. Environmental Protection Agency. Equipment that showcases the Energy Star service mark typically 20% to 30% less energy than required by federal standards. The program is typically focused on consumer products, but commercial and industrial buildings are also included in a benchmarking rating, to provide a means for the energy efficiency of individual commercial buildings and industrial facilities against the energy efficiency performance of similar buildings.

A possible example of the GridStar rating would be a simple cost calculation of savings using a particular home energy storage system, and placing that unit’s savings in relation to other competing models. At its most simple would be a net present value (NPV) calculation for the purchase. The key point in setting up the methodology is that it would be open enough to work with a variety of vendors who will have a range of systems with different attributes: power, energy, round-trip efficiency, lifespan, etc. while also providing a specific metric for consumers to compare answer. Therefore, some of the inputs to the calculations would be fixed; structure the analysis of the unit over a 10-year lifespan, calculate the unit to undertake one complete charge and discharge cycle per day, etc. This would penalize any developer who designed a system with a longer life, but it would be flexible enough to compare units of different power and energy ratings.


U.S. Government

Federal law prohibits removal of this label before consumer purchase.

ENERGYGUIDE

Refrigerator-Freezer
- Automatic Defrost
- Side-Mounted Freezer
- Through-the-Door Ice

XYZ Corporation
Model ABC-L
Capacity: 23 Cubic Feet

Estimated Yearly Operating Cost

$67

$57 $74

Cost Range of Similar Models

630 kWh

Estimated Yearly Electricity Use

Your cost will depend on your utility rates and use.

- Cost range based only on models of similar capacity with automatic defrost, side-mounted freezer, and through-the-door ice.
- Estimated operating cost based on a 2007 national average electricity cost of 10.65 cents per kWh.
- For more information, visit www.ftc.gov/appliances.

Lists key features of the appliance you're looking at and the similar models that make up the cost range below.

The maker, model, and size tell you exactly what product this label describes.

What you might pay to run the appliance for a year, based on its electricity use and the national average cost of energy. The cost appears on labels for all models and brands, so you can **compare** energy use just like you would price or other features.

The cost range helps you compare the energy use of different models by showing you the range of operating costs for models with similar features.

An estimate of how much electricity the appliance uses in a year based on typical use. Multiply this by your local electricity rate on your utility bill to better judge what your actual operating cost might be.

If you see the ENERGY STAR logo, it means the product is better for the environment because it uses less energy than standard models.

Source: Energy Star (U.S. Environmental Protection Agency)

Figure 24. Residential Equipment Performance Rating.

An important underlying issue would be the financial and economic inputs; discount rate, cost of electricity, etc. For the most part, much of this could be taken from the U.S. Department of Energy's Annual Energy Outlook publication and utility rate database. Location specific issues could also be incorporated such as rebates in particular States, or utility. Since the price of electricity and the relevant tariff vary tremendously from location to location, a decision needs to be how exact (and thus helpful) the calculation would be. Ease of calculation would rely on State level average prices and sacrifice accuracy. Utility level calculation would be more precise for customers, but then limit the usefulness of a particular calculation to customers of only one utility, and thus potentially promote confusion in a region. As the point of the rating is to provide customers with more information about their purchases, specifically with the relative position of the units among one another, a State level average might be the most useful for the most people.

This like other issues are important, and input from consumer groups and retailers would weigh heavily on the final decision.

The success of any development like the GridStar program would not rely on new programs, but rather could be an extension of efforts already underway under the U.S. Department of Energy's Energy Storage Program by coupling together a number of Testing, Analysis, and Standards efforts. As with other Standards efforts, the focus of the U.S. Department of Energy would be to work with private industry to first design an appropriate (and agreed upon) benchmarking analysis, and then promote the acceptance of these protocols so that any accredited testing facility could provide the testing for verifying the different manufacturer's storage system's adherence to the rating methodology. The Grid Star program could start with relatively simple applications such as residential energy storage systems, with other, more complex evaluations such as solar/storage and storage coupled with vehicle fast charging as potentially later options.

REFERENCES

1. *Measuring and Expressing the Performance of Energy Storage Systems*, Update on and Overview of Revision 2 to the PNNL/SNL Protocol, Pacific Northwest National Laboratory (PNNL), Richland, WA, PNNL-SA-118995/SAND2016-6155 PE, June 30, 2016, https://energymaterials.pnnl.gov/pdf/PNNL-SA-118995.pdf

2. *Energy Storage Safety Strategic Plan*, U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability, Washington, D.C., December, 2014, https://www.energy.gov/oe/downloads/energy-storage-safety-strategic-plan-december-2014

3. *DOE/EPRI Electricity Storage Handbook, in Collaboration with NRECA*, Abbas A. Akhil, Georgianne Huff, Aileen B. Currier, Benjamin C. Kaun, Dan M. Rastler, Stella Bingqing Chen, Andrew L. Cotter, Dale T. Bradshaw, and William D. Gauntlett, Sandia National Laboratories, Albuquerque, New Mexico, SAND2015-1002, http://www.sandia.gov/ess/publications/SAND2015-1002.pdf

4. *Energy Storage Warranties and Performance Guarantees*, Michael Kleinberg, DNV GL, NAATBatt Annual Meeting 2016, March 3rd, 2016, http://naatbatt.org/wp-content/uploads/2016/03/DNVGL.pdf

5. *Electrical Energy Storage Start-up & Commissioning Overview*, Dan Borneo, Sandia National Laboratories, May, 2014, https://www.cesa.org/assets/Uploads/ESTAP-Webinar-Slides-5.20.14.pdf

6. *Orange Button – Solar Bankability Data to Advance Transactions and Access (SB-DATA), U.S. Department of Energy*, (website), https://www.energy.gov/eere/solar/orange-button-solar-bankability-data-advance-transactions-and-access-sb-data

7. *Annual Energy Outlook 2018 – Final Report*, U.S. Department of Energy, Energy Information Agency, Washington D.C., Feb 6, 2018, https://www.eia.gov/outlooks/aeo/pdf/AEO2018_FINAL_PDF.pdf

8. *Annual Energy Outlook 2018 – Appendix A: Reference Case*, U.S. Department of Energy, Energy Information Agency, Washington D.C., Feb 6, 2018, https://www.eia.gov/outlooks/aeo/pdf/appa.pdf

9. *Annual Energy Outlook 2018 – Projection Tables by Case*, U.S. Department of Energy, Energy Information Agency, Washington D.C., Feb 6, 2018, https://www.eia.gov/outlooks/aeo/tables_ref.php

10. U.S. Utility Rate Database, U.S. Department of Energy, OpenEI, (website), https://openei.org/apps/USURDB/

11. *U.S. Department of Energy Commercial Reference, Building Models of the National Building Stock*, Michael Deru, Kristin Field, Daniel Studer, Kyle Benne, Brent Griffith, and Paul

Torcellini (National Renewable Energy Laboratory), Bing Liu, Mark Halverson, Dave Winiarski, and Michael Rosenberg (Pacific Northwest National Laboratory), Mehry Yazdanian (Lawrence Berkeley National Laboratory), Joe Huang (Formerly of Lawrence Berkeley National Laboratory), Drury Crawley (Formerly of the U.S. Department of Energy), National Renewable Energy Laboratory, Golden, CO, NREL/TP-5500-46861, February 2011, https://www.nrel.gov/docs/fy11osti/46861.pdf

12. *RES Announces Substantial Completion and Project Financing of Chicago Area Energy Storage Centers*, Press Release, Renewable Energy Systems Americas Inc., Nov 10, 2015, https://www.prnewswire.com/news-releases/res-announces-substantial-completion-and-project-financing-of-chicago-area-energy-storage-centers-300175915.html

APPENDIX A: U.S. DEPARTMENT OF ENERGY RESOURCES SUPPORTING ENERGY STORAGE FINANCING

ESS Program

- U.S. Department of Energy, Energy Storage Systems: Publications: http://www.sandia.gov/ess/publication/

Sandia National Laboratory (SNL)

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

Database

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

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
- 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)

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

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 Project Finance, https://financere.nrel.gov/finance/

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

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/

Key Reports

- 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

U.S. DOE Funding and Financing for Energy Projects

- Funding & Financing for Energy Projects: https://energy.gov/funding-financing-energy-projects

Areas of Support:

- Loan Programs Office: https://energy.gov/funding-financing-energy-projects
- State Energy Program: https://energy.gov/eere/wipo/state-energy-program
- Federal Financing Facilities Available for Energy Efficiency Upgrades and Clean Energy Deployment: Link to Report
- Federal Financing Programs for Clean Energy: https://energy.gov/sites/prod/files/2016/05/f32/Federal%20Financing%20Programs%20for%20Clean%20Energy.pdf

APPENDIX B: LIST OF INTERVIEWEES

	Company	First	Last	Title
1	127 Energy	Ken	McCauley	Partner & Co-Founder
2	ABB	Pat	Hayes	Bus Dev Manager, Energy Storage
3	ADARA Power	Neil	Maguire	Founder & CEO
4	Anbaric	Dan	Dobbs	Vice President
5	Ardour Capital Investments, LLC	Brian	Greenstein	Managing Partner
6	Black & Veatch	Mark	Manley	Manager, Consulting
7	Cairn ERA	Sam	Jaffe	Managing Director
8	Canadian Solar	Chet	Lyons	Director, Energy Storage & Related Markets
9	Carnegie Hudson Resources	Charles	Gassenheimer	President
10	CIT Group Inc.	Rhys	Marsh	Director, Energy
11	CleanCapital	Thomas	Byrne	Co-Founder
12	Coalition for Green Capital	Reed	Hundt	Founder & CEO
13	CSA Group	Ryan	Franks	Manager, Energy Storage Group
14	DNV GL	Davion	Hill	Energy Storage Leader
15	Eaton Corporation	Chris	Thompson	Grid Power Business Unit Manager
16	Energi Insurance	Chris	Lohmann	VP, Alternative Energy Solutions
17	Energy Impact Parners	Steve	Hellman	Managing Paratner
18	EnStorage	Itai	Karelic	VP Bus Development
19	EOS Energy	Chris	Gerlach	CFO
20	EPRI	Giovanni	Damato	Sr. Project Manager
21	Eversheds-Sutherland	Michael	Stosser	Of Council
22	Exponent	Richard	Finovarti	Prncipal Consultant
23	Flextronics International	Pedro	Elizondo	Senior Manager / Business Development
24	G.C. Andersen Partners, LLC.	Thomas	Blum	Sr. Advisor
25	GE Research	Rick	Cutright	Director, Energy Storage
26	Generate Capital	Ed	Bossange	Capital Markets
27	Google-X	Julian	Green	Moonshot Pilot
28	Greentech Media	Brett	Simon	Analyst, Energy Storage
29	Hartford Steam Boiler (HSB)	John	Stokes	Vice President, Energy Practice Leader
30	Helaba	Erica	Egan	Senior Vice President
31	Helix Power Corporation	Matt	Lazarewicz	President
32	Independent	Marc	Aube	President
33	International Finance Corporation (IFC)	Peter	Mockel	Senior Industry Specialist
34	JLT Specialty Limited	Sabbir	Khandokar	Lenders Insurance Advisor
35	Key Capture Energy	Jeff	Bishop	Managing Partner
36	Key Capture Energy	Dan	Fitzgerald	Chief Development Officer
37	Kilpatrick Townsend	Mark	Reidy	Partner
38	Lazard LLC	Garrett	Haddad	Associate
39	LED.Finance	Ross	Reida	Chief Sales Officer
40	Macquarie Bank Limited	Prashant	Mupparapu	Senior Managing Director
41	Mission Critical Sales	Larry	Goldberg	President
42	Mitsubishi Electric Power Products, Inc	Charlie	Vartanian	Advanced Technologies Advisor
43	Morrison & Foerster	Robert	Fleishman	Senior Of Counsel

List of Interviewees (Cont.)

	Company	First	Last	Title
44	Mortenson Construction	Brent	Bergland	General Manager
45	MUFG	Andrew	Axel	Sr. Vice President
46	NAATBatt International (NAATBatt)	James	Greenberger	Executive Director
47	New Energy Capital	Nick	Devonshire	Associate
48	New Energy Risk	Jon	Cozens	Managing Director
49	NextWave Energy	Richard	Steubi	President
50	Nuveen	Vickrum	Singh	Principal, Energy & Infrastructure Investments
51	NY Green Bank	Alfred	Griffin	President
52	NYBEST	Bill	Acker	Executive Director
53	On Demand Energy	Steve	Levey	CEO
54	Orion Energy Partners	Timothy	Mister	Senior Associate
55	ORIX Infrastructure	Barry	Gold	Managing Director
56	Parker Hannifin	Jim	Hoelscher	General Manager
57	Pearl Street	Jason	Makansi	President
58	Pendernales Electric Cooperative	Peter	Muhuro	Chief Strategy Officer
59	Pickwick Capital Partners	Kevin	Blackman	Managing Directors
60	Potomac Energy Fund	Norm	Allen	Operating Partner
61	Power Edison LLC	Shihab	Kuran	President & CEO
62	Prudential Capital Group	Ric	Abel	Managing Director
63	RES America	Craig	Horne	VP - Business Development
64	Roth Capital	Craig	Irwin	Sr. Research Analyst
65	Roth Capital	Brian	Kremer	Director, Cleantech Investment Banking
66	S&C Electric Company	Troy	Miller	Director, Grid Solutions
67	Schneider Electric	Scott	Daniels	Technology & Innovation, Office of the CTO
68	SEIA	Michael	Mendolson	Sr. Director of Project Finance & Capital Markets
69	Sentry Financial	Mark	Nelson	Managing Director
70	Siemens Corporation	Dan	Wishnick	Business Manager
71	Siemens Financial Services	John	O'Brien	Director
72	Silicon Valley Bank	Matt	Maloney	Head of Energy & Resource Innovation
73	Sparkplug Power	Sean	Becker	President
74	Starwood Energy Group Global LLC	Ali	Amirali	Senior Vice President
75	Starwood Energy Group Global LLC	Patrick	Verdonck	Vice President
76	SUSI Partners AG	Asif	Rafique	Managing Director, Energy Storage Infrastructure
77	UK Power Reserve	Jeni	Oppenheimer	Chief Strategist
78	UniEnergy Technologies (UET)	Russ	Weed	VP Business Development & General Counsel
79	V-Charge	Bob	Chatham	Managing Director
80	Vector Advisors	Brett	Perlman	President
81	Vionx Energy	Alan	Dash	Board Member
82	WattJoule	Greg	Cipriano	VP of Business Development
83	Wells Fargo Insurance	Dixon	Wright	Senior Vice President
84	Wells Fargo Insurance Services	Nick	Blaine	SVP
85	Willis Towers Watson	Danny	Seagraves	Vice President

APPENDIX C: STAKEHOLDER MEETING: 2017 U.S. DOE ENERGY STORAGE FINANCING SUMMIT (NYC)

Performance Impacts on Project Finance and Insurance

Please mark your calendars for this event focusing on identifying the impact of performance on project financing for energy storage projects. This event is stakeholder meeting targeting the financial community and project developers and is part of a U.S. Department of Energy sponsored study.

This study's goal is to understand the current challenges facing energy storage project financing, and gain insights into how de-risking the performance issues in the solar, wind and energy efficiency markets benefited these markets, and what strategies could be successful in the energy storage market.

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.

Speakers will include representatives from the U.S. Department of Energy and industry experts who have experience with the challenges and opportunities of investing in energy storage projects. The Keynote speaker is Alfred Griffin, President of the NY Green Bank.

The event will be held at the New York City offices of the law firm Sutherland Asbill & Brennan LLP on January 11th, 2017.

This event is held Partnership with the U.S. Department of Energy, with event Hosts Sutherland Asbill & Brennan LLP and Mustang Prairie Energy; sponsorship is provided by Enovation Partners and S&C Electric.

AGENDA

2017 U.S. DOE Energy Storage Financing Summit:

Performance Impacts on Project Financing and Insurance

1:30-2:00pm	**Registration**
2:00-2:10pm	**Welcome** Michael Stosser, Sutherland Asbill & Brennan LLP
2:10-2:30pm	**U.S. DOE Energy Storage Financing Study: Introduction** Richard Baxter, Mustang Prairie Energy
2:30-2:45pm	**U.S. DOE Energy Storage Program** Imre Gyuk, Manager, U.S. DOE Energy Storage Program
2:45-3:15pm	**Keynote** Alfred Griffin, President, New York Green Bank
3:15-3:30pm	**Networking Break**
3:30-4:15pm	**Panel 1 – Financing Energy Storage Projects** Dan Gabaldon, Enovation Partners [Moderator] Asif Rafique, SUSI Partners Patrick Verdonck, Starwood Energy Prashant Mupparapu, Macquarie Bank
4:15-4:30pm	**Networking Break**
4:30-5:15pm	**Panel 2—Performance Impacts on Project Financing** Troy Miller, S&C Electric [Moderator] John Stokes, Hartford Steam Boiler (Munich Re) Danny Seagraves, Willis Towers Watson Sabbir Khandokar, JLT Specialty
5:15-5:15pm	**Closing** Richard Baxter, Mustang Prairie Energy
5:15-7:00pm	**Reception**

Hosts

SUTHERLAND

MUSTANG PRAIRIE

Sponsors

Enovation Partners

Cleantech Group

S&C ELECTRIC COMPANY
Excellence Through Innovation

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. He is internationally recognized as a leader in the energy storage field.

Alfred Griffin, President, NY Green Bank

Alfred Griffin is an industry leader in developing innovative solutions in support of the financing of renewable energy generation and energy efficiency projects, and brings 25 years of experience in banking and finance to the NY Green Bank. As President, Mr. Griffin oversees partnerships with private sector capital providers and other clean energy market participants to address barriers that limit private investment into attractive renewable energy and energy efficiency project.

Host

Michael Stosser, Of Counsel, Sutherland

With more than 34 years of experience, Michael guides clients in the development and finance of renewable and alternative energy projects and clean tech. He also represents traditional energy—natural gas, oil and power—clients in negotiations and transactions, including export matters, mergers, acquisitions and arbitrations. Michael's broad experience—in both the public and private sectors—makes him uniquely qualified to represent clients in state and regulatory matters, before Congress and in the development of energy legislation.

Chairman

Richard Baxter, President, Mustang Prairie Energy

Richard Baxter is President of Mustang Prairie Energy where he bridges the financial and technical arenas of the storage industry for investors, project developers, and manufacturers. He is the author of the book "*Energy Storage: A Nontechnical Guide*" (Pennwell), and the U.S. DOE report, "Energy Storage Financing: A Roadmap for Accelerating Market Growth." [SAND2016-8109]. He has been active in the energy storage industry for 18 years, as an investment banker, equity analyst, economist, and consultant, and served on the Board of Directors for the Energy Storage Association (ESA).

Panel 1: Financing Energy Storage Projects

Asif Rafique, SUSI Partners

Before joining SUSI Partners, Asif worked for over 10 years at Ecofin in London, a leading investment manager in renewable energy and infrastructure. He was key to investing, managing and exiting a variety of transactions across renewable sectors, representing an aggregate value of over three billion Euros. Prior to this, he worked in the energy and infrastructure sector at Deutsche Bank in London and Houston.

Patrick Verdonck, Starwood Energy Group

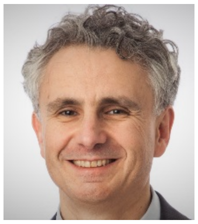
Patrick Verdonck is a Principal of Starwood Energy Group. In this role, he is responsible for making principal investments in the power sector. He was actively involved in the acquisition of Quail Run and Berlin Station. He has an observer role on the board of Nautilus Solar Energy and has worked on several transmission development projects. Prior to joining Starwood, Mr. Verdonck was an investment banker in Citigroup's London-based Energy Power and Chemicals team where he worked on financing transactions throughout Europe, Middle-East and South Asia.

Prashant Mupparapu, Macquarie Bank

Prashant Mupparapu is Senior Managing Director in Macquarie's Commodities and Global Markets division, based in New York. He lead the Commodity Solutions group, which provides trade finance, asset based loans, project finance, mezzanine debt and off-balance sheet commodity financing. In addition, we offer a full suite of risk management/hedging products to enhance our bespoke private lending solutions. Prashant has over 20 years of experience providing financing and risk management solutions in the Energy, Commodities and Industrial sectors.

Moderator

Dan Gabaldon, Partner, Enovation Partners



Over the past two decades, Dan has served leading companies across the energy value chain in many of their most critical strategic and operational improvement challenges. At Enovation, he has focused particularly on DER and Energy Storage, serving energy companies, OEMs and investors seeking to benefit from the rapid changes in this area. He has served a similar mix of clients in the natural gas sector on M&A and operational improvement issues. His work usually involves leveraging Enovation's growing set of proprietary analytic tools and datasets.

Panel 2: Performance Impact on Project Financing

John Stokes, Hartford Steam Boiler (Munich Re)

John Stokes has been the U.S. Energy Practice Leader with Hartford Steam Boiler (HSB) since 2013. John's areas of current responsibility include managing underwriting and business development operations, and delivering HSB's products and services in the areas of Energy and Natural Resource Sustainability. Prior to his current role, John managed a large territory of Equipment Breakdown business covering a variety of customers including agencies, national and regional brokers, and HSB's transactional client companies.

Danny Seagraves, Willis Towers Watson

Since 1988 Danny has delivered unique and customized risk management and risk finance solutions for his clients; empowering them to achieve optimum balance sheet protection while maximizing their risk-adjusted returns. Danny has earned a reputation of serving his clients from an enterprise risk management perspective. Because of the breadth of his experiences and his ability to analyze situations from multiple perspectives, Danny has become a critical member of his clients' strategic planning teams.

Sabbir Khandokar, JLT Specialty

Sabbir provides insurance advice to financiers on projects through initial procurement, construction and operational phases, international and domestic. Sabbir has extensive practical knowledge in various insurance specialisms: notably in areas of Construction "All Risk" insurance, Property Damage "All Risk" insurance, Marine Transit insurance, Delay in start-up insurance, Business Interruption insurance, Third Party Liability insurance, Pollution Liability insurance, Professional Indemnity insurance, Political Violence insurance and Terrorism insurance.

Moderator

Troy Miller, S&C Electric Company

Troy Miller is Director of Grid Solutions at S&C Electric Company, where he has global responsibility for the Grid Solutions market segment that includes energy storage, var compensation, and microgrids. With more than 25 years in the Power Engineering industry, Troy has lengthy experience in the application and implementation of all aspects of power electronics and power quality.

Attendee List

	First	Last	Company_Name	Job_Title
1	Ken	McCauley	127 Energy	Partner & Co-Founder
2	Brian	Greenstein	Ardour Capital Investments, LLC	Managing Partner
3	Yulia	Michael	Aspen Insurance	AVP Underwriter
4	Chester	Lyons	Canadian Solar	Director, Energy Storage & Related Markets
5	Charles	Gassenheimer	Carnegie Hudson Resources, LLC (CHR)	President
6	Drew	Carleton	CIT Group	Director
7	Marc	Theisinger	CIT Group Inc.	Managing Director
8	Joel	Meister	Deloitte Tax LLP	Tax Manager, Washington National Tax
9	Brian	Asparro	Demand Energy	
10	Chris	Thompson	Eaton Corporation	Grid Power Business Unit Manager
11	Chris	Lohmann	Energi Insurance	VP, Alternative Energy Solutions
12	Matt	Roberts	Energy Storage Association	Executive Director
13	Dan	Gabaldon	Enovation Partners	Director
14	Mike	Nolan	Enovation Partners	
15	Bob	Zabors	Enovation Partners	Founding Partner & CEO
16	Pedro	Elizondo	Flextronics International	Senior Manager / Business Development
17	Thomas	Blum	G.C. Andersen Partners, LLC.	
18	Jigar	Shah	Generate Capital	President
19	Harry	Singh	Goldman, Sachs & Co.	Vice President
20	Chris	Cadwell	Green Peak Solar	Principal
21	John	Stokes	Hartford Steam Boiler (HSB)	Vice President, Energy Practice Leader
22	Erica	Egan	Helaba (Landesbank Hessen Thueringen)	Senior Vice President
23	Kevin	Blackman	Helix Power Corporation	Founder
24	Matt	Lazarewicz	Helix Power Corporation	President
25	Jim	Lavelle	Houlihan Lokey	Managing Director, Co-Head, Industrials
26	Michael	Morabito	Houlihan Lokey	Director
27	Peter	Mockel	IFC	Senior Industry Specialist
28	Sabbir	Khandokar	JLT Specialty Limited	Lenders Insurance Advisor
29	Peter	Gibson	LG Chem	
30	Prashant	Mupparrapu	Macquarie Group Limited	Sr. Managing Director
31	Charlie	Vartanian	Mitsubishi Electric Power Products, Inc	Advanced Technologies Advisor
32	Richard	Baxter	Mustang Prairie Energy	President
33	James	Greenberger	NAATBatt International (NAATBatt)	Executive Director
34	Tom	Dickson	New Energy Risk	CEO
35	Bill	Acker	New York Battery & Energy Storage Technology	Executive Director
36	Sarah	Davidson	NY Green Bank	External Affairs
37	Alfred	Griffin	NY Green Bank	President
38	Timothy	Mister	Orion Energy Partners	Senior Associate
39	Joshua	Herlands	ORIX	
40	Barry	Gold	ORIX Infrastructure	Managing Director
41	Kristin	Daur	Perse	Underwriter
42	Patrick	Stumbras	Perse	President
43	David	Chiesa	S&C Electric Company	Senior Director of Business Development
44	Dan	Girard	S&C Electric Company	Director of EPC
45	Troy	Miller	S&C Electric Company	Director, Grid Solutions
46	Ray	Byrne	Sandia National Laboratories	
47	Scott	Daniels	Schneider Electric	Technology & Innovation, Office of the CTO
48	Daniel	Wishnick	Siemens Corporation	Business Manager
49	Matt	Maloney	Silicon Valley Bank	Head of Energy & Resource Innovation

Attendee List (Cont.)

	First	Last	Company_Name	Job_Title
50	Catherine	Helleux	Societe Generale	SVP
51	Sean	Becker	Sparkplug Power	President
52	Ali	Amirali	Starwood Energy Group Global LLC	Senior Vice President
53	Alan	Dash	Starwood Energy Group Global LLC	Sr Vice President
54	Patrick	Verdonck	Starwood Energy Group Global LLC	Vice President
55	Prakesh	Patel	Stem, Inc.	Vice President
56	Asif	Rafique	SUSI Partners AG	Managing Director, Energy Storage Infrastructure
57	Lara	Cooley	Sutherland Asbill & Brennan LLP	Manager
58	Dorothy	Franzoni	Sutherland Asbill & Brennan LLP	Partner
59	Damian	Georgino	Sutherland Asbill & Brennan LLP	Special Counsel
60	Jonathan	Gottlieb	Sutherland Asbill & Brennan LLP	Partner
61	Michael	Stosser	Sutherland Asbill & Brennan LLP	Of Counsel
62	Madeleine	Tan	Sutherland Asbill & Brennan LLP	Partner
63	Kyle	Wamstad	Sutherland Asbill & Brennan LLP	Associate
64	Gary	Yang	UniEnergy Technologies	CEO
65	Russ	Weed	UniEnergy Technologies (UET)	VP Business Development & General Counsel
66	Imre	Gyuk	US Department of Energy	Energy Storage Program Manager
67	Dixon	Wright	Wells Fargo Insurance	Senior Vice President
68	Nick	Blaine	Wells Fargo Insurance Services	SVP

Synopsis

On January 11th, 2017 Sutherland Asbill & Brennan LLP, Mustang Prairie Energy in Partnership with the U.S. Department of Energy presented a one-day financial summit at Sutherland's New York office in Manhattan where 68 people were in attendance. Sponsors for the event were Enovation Partners and S&C Electric Company. Speakers included representatives from the U.S. Department of Energy, the NY Green Bank, and industry experts who have experience with the challenges and opportunities of investing in energy storage projects.

The summit was the kickoff for a new U.S. Department of Energy sponsored study to identifying the impact of performance on project financing for energy storage projects. This study's goal is to understand the current challenges facing energy storage project financing, and gain insights into how de-risking the performance issues in the solar, wind and energy efficiency markets benefited these markets, and what strategies could be successful in the energy storage market. 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.

The summit began with an overview of the Study by Richard Baxter of Mustang Prairie Energy, followed by Imre Gyuk, the Program Manager of the DOE Energy Storage Program who gave an overview of federal support for energy storage technology development, and explained how that support is extending into the commercialization of these systems.

The Keynote address was given by Alfred Griffin, President of the NY Green Bank. His presentation showcased the efforts of the NY Green Bank in addressing current financing gaps and barriers for clean energy projects in New York State, and how that support can benefit energy storage projects.

The first panel of the day focused Financing Energy Storage Projects, with panelists from private equity and investment banking firms. The discussion focused on how third party financers are emerging as the source of new project development capital driving the growth of the energy storage industry. These lenders shared insights into how they evaluate the investment opportunities in the energy market. The panelists also discussed their investment strategies, how they see the energy storage market evolving, and how system performance impacts a project's value and risk profile. Insights included how typically in new technology markets, there is a yield premium for early projects; in energy storage now, there is little to none as excessive interest by many lenders reduces yields obtainable on investments. Some panelists thought it was difficult to see sustainable financing and deployment model for the U.S. without better revenue streams and returns that take into account any risk in the project.

The second panel of the day focused on performance impacts on energy storage project financing and evaluating other key drivers that incorporate performance measures to determine a project's bankability. The panelists reviewed current financing models and considered which ones would emerge in the future, and discussed whether lessons could be learned and adapted from the solar, wind and energy efficiency industries. Many of the panelists noted that performance of energy storage systems affect project development in many ways, including revenue and insurance coverage/needs. A key point agreed to is that when measuring performance, it is the entire systems that needs to be measured in concert, not just single components alone.

APPENDIX D: STAKEHOLDER MEETING: 2017 ENERGY STORAGE ASOCIATION CONFERENCE & EXPO

27th ANNUAL ENERGY STORAGE ASSOCIATION CONFERENCE AND EXPO
APRIL 18-20, 2017
DENVER, COLORADO

Energy Storage Financing: *Reducing Risk for Project Financing*

Please come and share your insights into the challenges of securing financing for energy storage projects, and what steps would be helpful to move the industry forward.

This stakeholder meeting is part of a U.S. Department of Energy sponsored study evaluating ways to reduce the contract risks for energy storage project financing. This study's goal is to understand the current challenges facing energy storage project financing, and gain insights into how de-risking the performance issues in the solar, wind and energy efficiency markets benefited these markets, and what strategies could be successful in the energy storage market. Three financial industry leaders will participate to share their insights, and help lead the discussion on key challenges facing the industry today.

Discussion points will include:

- Criteria for debt financing
- Revenue certainty
- Technology acceptance
- Challenges of financing long vs. short duration systems

We look forward to your participation and input into the discussion.

Panelists

Ali Amirali, Starwood Energy Group

Barry Gold, Orix Infrastructure

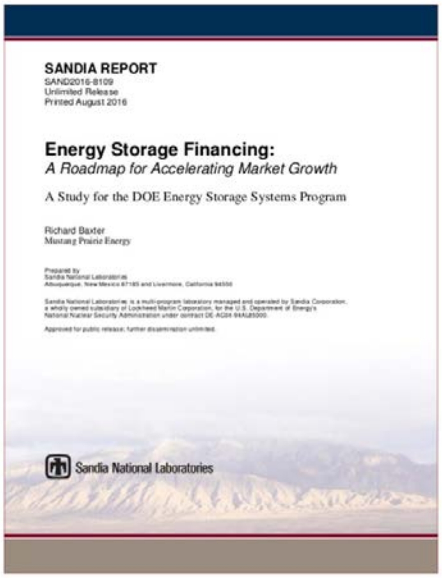
Rhys Marsh, CIT

Schedule

Wednesday, April 19th, 2017

Four Seasons Ballroom, #1

2pm – 3pm


SANDIA REPORT
SAND2016-8109
Unlimited Release
Printed August 2016

Energy Storage Financing:
A Roadmap for Accelerating Market Growth

A Study for the DOE Energy Storage Systems Program

Richard Baxter
Mustang Prairie Energy

Sandia National Laboratories

Panelists

We have arranged for 3 senior financial industry leaders to take part in the stakeholder meeting to assist in the discussion.

Ali Amirali, Senior Vice President, 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, as well as for new business/project opportunities in the transmission and distribution arena in North America. He also supports the origination, development and acquisition activities associated with utility-scale power generation and storage projects.

Barry Gold, Head of Orix Infrastructure

Barry Gold is the Head of ORIX Infrastructure and is based in New York. Mr. Gold has over 30 years of experience in private equity, debt financing and advisory in power, energy, transport, water and other infrastructure sectors. Prior to joining ORIX, Mr. Gold was a Senior Advisor to a private equity infrastructure fund, co-founder and co-head of The Carlyle Group's infrastructure fund, co-head of Citigroup's structured and infrastructure finance group, and head of Asian project finance at Lehman Brothers. Mr. Gold has led the financings or investments for infrastructure investments, public-private partnerships and project financings in excess of $30 billion of transaction value. Mr. Gold holds a BS and an MBA from New York University.

Rhys Marsh, Vice President, CIT

A seasoned financial professional, Mr. Marsh is currently a Vice President at CIT. He is responsible for originating, structuring and underwriting project finance transactions in the energy space with a focus on power and renewables. He is responsible for over $500 million of capital commitments to more than a dozen power projects across the United States. Mr. Marsh is currently arranging financings for several solar power projects, that combined represent more than 55 MW of capacity and $200 million in total costs.

Moderator

Richard Baxter, President, Mustang Prairie Energy

Richard Baxter is President of Mustang Prairie Energy where he bridges the financial and technical arenas of the storage industry for investors, project developers, and manufacturers. He is the author of the book "*Energy Storage: A Nontechnical Guide*" (Pennwell), and the U.S. DOE report, "Energy Storage Financing: A Roadmap for Accelerating Market Growth." [SAND2016-8109]. He has been active in the energy storage industry for 18 years, as an investment banker, equity analyst, economist, and consultant, and served on the Board of Directors for the Energy Storage Association (ESA).

Attendees

	Company	First	Last	Title
1	127 Energy	Ken	McCauley	Partner, Co-Founder
2	AIM	Matt	Kestenbaum	Associate
3	Blackrock, Inc.	Rael	McNally	Director, Blackrock Infrastructure
4	CEA Greentech	Jim	Delaney	Sales Manager
5	CIT Group	Rhys	Marsh	
6	CMS Energy	Tim	Mehl	Director of Development
7	CoBank	Stephanie	Smith	Relationship Manager, Product Development
8	Consumers Energy	Chuck	Hookham	Project Developers
9	DC Systems	Matt	Koenig	Director of Sales
10	Enovation Partners	Dan	Gabaldon	Founding Partner
11	Enstorage	Arnon	Blum	CEO
12	Enstorage	Itai	Karelic	VP Business Development
13	EUCI	Laxmi	Mrig	Principal
14	Fiemens Financial	Eric	Anderson	Sr. Manager
15	First Solar, Inc.	Rob	van Harren	PVS Lead Analyst
16	Future Energy Advisors	Richard	Steubi	President
17	Hartford Steam Boiler (Munich Re)	John	Stokes	Energy Practice Leader
18	Kilpatrick Townsend	Robert	Edwards Jr	Patner - Co-Head Energy Tean
19	Kilpatrick Townsend	Mark	Reidy	Patner - Co-Head Energy Tean
20	Mitsubishi Lease (MUL)	Andrew	Axel	Sr. Vice President
21	Mortenson	Mark	Donahue	Vice President
22	Mustang Prairie Energy	Richard	Baxter	President
23	NRECA	Doug	Danley	Tech Liason - Renewables
24	Panasonic	Janet	Lin	Director
25	RES	Caroline	Twitchell	Manager
26	Siemens Financial	John	O'Brien	Director
27	Starwood Energy Group	Ali	Amirali	Sr. Vice President
28	Travelers Capital Corp	Dmitri	Kotlarov	AVP
29	UniEnergy Technologies (UET)	Russ	Weed	VP Business Development & General Cousel
30	Union Concerned Scientists	Mike	Jacobs	Sr. Energy Analyst
31	Willis Towers Watson	Danny	Seagraves	Vice President
32	Xcel Energy	Chris	Barba	Analyst
33	- Unsigned -			
34	- Unsigned -			
35	- Unsigned -			
36	- Unsigned -			

Synopsis

This Stakeholder Meeting was held to provide the audience at the 2017 Energy Storage Association the ability to provide input into the current study: Energy Storage: Performance Impacts on Project Financing. A total of 36 people were present to listen to the industry thought leaders provide their insight, and discuss market developments with the audience. Key Issues covered included Technology Risk, Revenue Risk, and how to integrate Risk Management strategies into financing new projects.

The first topic of discussion was the need for a more standardized approach by the industry for evaluating technology risk. Independent Engineering Reports (IER) are a standard tool in other power industry project development efforts, and so are being looked to for answers as to the technological risk of these projects. However, there is not a lot of experience with these projects yet, leaving significant variance from one engineering firm to another. This in turn hampers lenders ability to evaluate different projects if the IER is provided by different firms. Other technical inputs to the project development process were covered, including warranties and commissioning acceptance tests. These items were also mentioned as critical, but still lacking the standardization across vendors.

The second topic discussed was the issue of revenue risk. Revenue certainty is an obviously critical item for accessing cost effective capital, yet there are few firm revenue contracts available for energy storage projects. Some do exist through utility RFPs, but these are typically not negotiated significantly, leaving the developer to deal with what the utility offers. Many on the panel and audience were looking forward to when bilateral contracts would emerge in a larger fashion in the wholesale market, but that then raised the issue of counterpart-risk and credit-worthiness. These issues become especially acute in the Behind the Meter (BTM) market where small customer firms lack the ability to provide sufficient credit for large capital purchases. This line of discussion opened up the discussion to the criteria for debt financing, and what type of risk management strategies could help bridge the current gap. Many agreed that if the project developer was able to get some contracted revenue, then the cost of the debt would be dramatically reduced.

The incorporation of risk management strategies into project development efforts was highlighted as critical; in addition, it was evident that all participants approached the goal differently. Representatives from the insurance industry highlighted that in a properly working market, risk is allocated to the group that can handle it the best, and that is also best suited to pay for it. A suggestion was proffered that better performance metrics could help create better contracts to improve risk management. Other methods that were raise to de-risk the project development process included EPC wraps on the project equipment and construction, and insurance products that wrap warranty risks. These two approaches address a similar issue, but come at it from different avenues – technical or insurance. In the end, they both leverage knowledge of battery life and performance.

Parts of the discussion delved into end-use markets, to discuss practical issues of energy storage project development improvement. The first area discussed concerned solar storage project development at the utility scale. Here, some representatives of the solar industry provided an update as to the status and direction of utility scale solar RFPs, and the opportunity to incorporate storage into the offerings. One issue brought to the fore was the need to help educate utilities to write RFPs that will not just utilize stand-alone energy storage assets, but how incorporating energy storage into a solar RFP can allow the utility to target a result that more cost effective than either asset alone. This discussion of utility education also raised the need for better incorporation of storage into the utility IRP process.

Finally, the last topic covered focused on Behind the Meter (BTM) deployment of energy storage assets. Here, project financing for service providers moves toward funding facilities that can fund multiple projects in tranches over time as contracts are signed. This financing many times is targeted at providing the storage as a service to the customer rather than have them purchase it. Many issues on sustaining the effort were raised, including issues such as the difference in the permitting process from jurisdiction to jurisdiction. On the financing side, the idea of eventually needing to structure the project debt for securitization was raised as an issue, but most agreed that that step will only come after more of the financial industry becomes familiar with and comfortable with financing and operating energy storage projects at all levels of the market.

APPENDIX E: STAKEHOLDER MEETING: 2017 U.S. DOE ENERGY STORAGE FINANCING SUMMIT (DC)

Reducing Risk for Project Financing

Please mark your calendars for this event focusing on identifying the impact of performance on project financing for energy storage projects. This event is stakeholder meeting targeting the financial community and project developers and is part of a U.S. Department of Energy sponsored study.

This study's goal is to understand the current challenges facing energy storage project financing, and gain insights into how de-risking the performance issues in the solar, wind and energy efficiency markets benefited these markets, and what strategies could be successful in the energy storage market.

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.

Speakers will include representatives from the U.S. Department of Energy and industry experts who have experience with the challenges and opportunities of investing in energy storage projects. The Keynote speaker is Reed Hundt, CEO of the Coalition for Green Capital.
The event will be held at the Washington DC offices of the law firm Eversheds Sutherland on June 7th, 2017.

This event is held Partnership with the U.S. Department of Energy, with event Hosts Eversheds Sutherland LLP and Mustang Prairie Energy; sponsorship is provided by Mitsubishi Electric, CSA Group, UniEnergy Technologies, Roth Capital Partners, and Enovation Partners.

AGENDA

2017 U.S. DOE Energy Storage Financing Summit (DC):

Performance Impacts on Project Financing

11:30-12:00pm	**Registration / Lunch**
12:00-12:05pm	**Welcome** Dorothy Franzoni, Eversheds-Sutherland LLP
12:05-12:20pm	**Energy Storage Financing Study: Overview** Richard Baxter, Mustang Prairie Energy
12:20-12:45pm	**U.S. DOE Energy Storage Program** Imre Gyuk, Manager, U.S. DOE Energy Storage Program
12:45-1:15pm	**Keynote** Reed Hundt, CEO, Coalition for Green Capital
1:15-1:45pm	**Networking Break**
1:45-2:30pm	**Panel 1—Investor Perspective** Dan Gabaldon, Enovation Partners [Moderator] Ali Amirali, Starwood Energy Group Craig Irwin, Roth Capital John O'Brien, Siemens Financial Services Joshua Herlands, Orix
2:30-2:45pm	**Networking Break**
2:45-3:30pm	**Panel 2—De-Risking the Project** Joshua Belcher, Eversheds Sutherland (US) LLP [Moderator] Patrick Strubras, Power Energy Risk (PERse) Chris Lohmann, Energi Insurance Services Tom Dickson, New Energy Risk
3:30-3:45pm	**Networking Break**
3:45-4:30pm	**Panel 3—OEMs & Operators Perspective** Catherine Krupka, Eversheds Sutherland (US) LLP [Moderator] Russ Weed, UniEnergy Technologies (UET) Charlie Vartanian, Mitsubishi Electric Power Products, Inc. (MEPPI) John Rimac, CSA Group John Zahurancik, AES Energy Storage
4:30pm	**Closing** Richard Baxter, Mustang Prairie Energy
4:30-6:00pm	**Reception**

Hosts

EVERSHEDS SUTHERLAND

MUSTANG PRAIRIE

Sponsors

MITSUBISHI ELECTRIC

UET UniEnergy Technologies

CSA Group

ROTH Capital Partners

Enovation Partners

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. He is internationally recognized as a leader in the energy storage field

Reed Hundt, CEO, Coalition for Green Capital

Mr. Hundt imagined the Green Bank concept in 2009, while he was working on the Obama Transition Team. After working for several years on federal Green Bank legislation, including the Green Bank Act of 2009 and the 2010 Senate Energy Committee Bill, Mr. Hundt decided to focus on state Green Banks. He founded the Coalition for Green Capital in 2012 and currently serves as the Chief Executive Officer.

Host

Dorothy Franzoni, Partner, Eversheds Sutherland

Dorothy Black Franzoni is Chair of Eversheds Sutherland (US)'s Renewable and Alternative Energy team. She counsels clients regarding project development for electric generating plants, power purchase and sale arrangements, power plant joint-ownership arrangements, power delivery scheduling and bulk system operations matters, federal loan and loan guarantee programs, secured and unsecured loan arrangements, tax-advantaged leasing transactions, and publicly issued and privately placed debt financings.

Conference Chairman

Richard Baxter, President, Mustang Prairie Energy

Richard Baxter is President of Mustang Prairie Energy where he bridges the financial and technical arenas of the storage industry for investors, project developers, and manufacturers. He is the author of the book "*Energy Storage: A Nontechnical Guide*" (Pennwell), and the U.S. DOE report, "Energy Storage Financing: A Roadmap for Accelerating Market Growth." [SAND2016-8109]. He has been active in the energy storage industry for 18 years, as an investment banker, equity analyst, economist, and consultant, and served on the Board of Directors for the Energy Storage Association (ESA).

Panel 1: Investor Perspective

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, as well as for new business/project opportunities in the transmission and distribution arena in North America. He also supports the origination, development and acquisition activities associated with utility-scale power generation and storage projects.

Craig Irwin, Roth Capital Partners

Craig Irwin is a Senior Research Analyst leading ROTH's Cleantech coverage in biofuels, advanced lighting, and the companies providing products and services that enable the Utility of The Future, including batteries and electric vehicles. Prior to joining ROTH Capital Partners, Craig covered Cleantech companies at Wedbush, Merriman Curhan Ford, and First Albany, where his equity research experience in the sector reaches back to 2001.

John Obrien, Siemens Financial Services

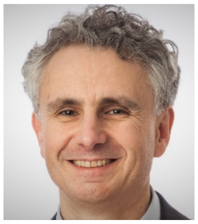
John O'Brien is a Director within Siemens Financial Services' Energy Finance team. John joined the team right after its inception in 2008 and is responsible for originating and structuring renewable (wind, solar, and storage) and traditional thermal (CCGT and CT) power transactions. Since 2008 SFS EF has lent in excess of $10 billion to power projects and currently has a portfolio of over $5.5 billion split roughly between renewable and thermal transactions.

Josh Herlands, Orix Infrastructure

Josh Herlands focuses on investing in energy and infrastructure projects and platforms. Mr. Herlands has 10+ years of experience in energy finance, law, and project development. Prior to ORIX, he worked with a boutique investment and advisory firm that focuses on energy projects, as well as a venture investment firm that funds renewable energy development across the U.S. Mr. Herlands began his career in the Power and Project Finance group at Lehman Brothers.

Moderator

Dan Gabaldon, Enovation Partners



Over the past two decades, Dan has served leading companies across the energy value chain in many of their most critical strategic and operational improvement challenges. At Enovation, he has focused particularly on DER and Energy Storage, serving energy companies, OEMs and investors seeking to benefit from the rapid changes in this area. He has served a similar mix of clients in the natural gas sector on M&A and operational improvement issues. His work usually involves leveraging Enovation's growing set of proprietary analytic tools and datasets.

Panel 2: De-Risking the Project

Patrick Strumbras, Power Energy Risk (PERSe)

Patrick Stumbras has 31 years of experience in the insurance industry, with a primary focus on power generation. Before joining RSG, Pat served as Executive Vice President and Branch Manager for the New York City offices of one of the largest underwriting managers of renewable projects worldwide. Prior to that, he held senior level positions with a number of major brokerage firms in the U.S.

Chris Lohman, Energi Insurance Services

Chris Lohmann is Vice President of the Alternative Energy Solutions group at Energi Insurance Services. Energi specializes in delivering risk management solutions to the energy industry, and Chris is responsible for leading innovation for emerging markets in renewable, distributed, and smart energy. In addition to General Liability, Property, and Casualty insurance, Energi offers Performance and Product Warranties that guarantee the engineering productivity of energy storage projects.

Tom Dickson, New Energy Risk

Currently Tom is the CEO of New Energy Risk, a venture-backed managing general underwriter specializing in sourcing, underwriting and structuring performance insurance policies for new and renewable energy technology. Prior to leading New Energy Risk, Tom held a variety of senior executive positions in leading innovative insurers and reinsurers in the US and internationally, notably as CEO and Chief Underwriting Officer of the Centre Group that grew to approximately $1 billion in surplus and $10 billion in assets.

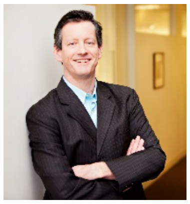
Moderator

Joshua Belcher, Eversheds Sutherland

Joshua Belcher has a national, multidisciplinary practice counseling clients in the utility, power and pipelines sectors. He guides clients through mergers and acquisitions, financings, project development and energy commodities transactions, with a focus on helping companies identify and manage complex environmental business risks in the context of the transaction and ongoing operational compliance.

Panel 3: OEMs and Operators Perspectives

Russ Weed, UET



Russ Weed is VP Business Development & Marketing for UniEnergy Technologies. Russ has more than 25 years of experience as a VP business development and general counsel, including at the General Electric Company. At UET, Russ is responsible for business strategy activities; channel partnerships; outbound marketing including public relations and branding; government relations; negotiations and contracting; intellectual property and other legal matters; mergers & acquisitions; and fundraising.

Charlie Vartanian, Mitsubishi Electric Power Products, Inc.

Charlie Vartanian has over 25 years of power industry experience in electric utility planning, technical standards development, policy analysis, and the marketing and sales of advanced energy systems. Charlie is a licensed Professional Engineer in California, and is a senior member of the IEEE.

John Rimac, CSA Group

John Rimac joined CSA Group in 2011 and holds the position of Business Manager Field Evaluations and Verifications. John is based in CSA Group's U.S. headquarters in Cleveland, OH, and manages technical staff tasked with verifying products to end user requirements as well as field evaluators who work with both customers and local Authorities Having Jurisdictions (AHJs) to ensure electrical equipment meets safety requirements and is compliant with applicable codes and standards.

John Zahurancik, AES Energy Storage

John Zahurancik leads the Energy Storage group at The AES Corporation, operating the world's largest fleet of grid connected batteries. As a co-founder of the AES storage team, he has developed advanced, grid scale storage projects in Chile, and the United States. This includes the first power purchase agreement for a storage project for Southern California Edison, the largest existing grid connected li-ion battery system in West Virginia, and the first commercial battery classified as a wholesale generator.

Moderator

Catherine Krupka, Eversheds-Sutherland

Catherine Krupka advises commodities trading companies, including financial services companies, energy marketers and asset owners, on compliance and enforcement, agency regulation and business transaction issues arising from trading physical and financial power, natural gas, emissions, crude and refined products. Catherine advises clients on energy transactions, including mergers, company and asset acquisitions/dispositions, energy/asset management and tolling arrangements and transmission and scheduling services agreements.

Attendee List

	First	Last	Company	Title
1	Mark	Crowdis	127 Energy	Partner & Co-Founder
2	Steve	O'Rourke	APL Renewables	Managing Director
3	Kiran	Gill	APL Renewables	North American Renewables
4	John	Zahurancik	AES Energy Storage	President
5	Johann	Rayappu	BlackRock Inc.	Vice President, Energy Infrastructure
6	Tony	Richardson	Bradley Electro	Territory Manager
7	Rhys	Marsh	CIT Energy	Director
8	Jim	Goldinger	ClearSky Power & Technology Fund	Managing Director
9	Reed	Hundt	Coalition for Green Capital	CEO
10	Alex	Kragie	Coalition for Green Capital	Program Director, Coalition for Green Capital
11	Jim	Green	CSA Group	Global Manager Energy Storage
12	John	Rimac	CSA Group	North American Verifications Manager
13	Brian	Knowles	Cypress Creek Renewables	Director of Energy Storage
14	Davion	Hill	DNVGL	Energy Storage Leader
15	Spencer	Hanes	Duke Energy Renewables	Managing Director of Business Development
16	Chris	Thompson	Eaton	Grid Power Business Unit Manager
17	Marc	Aubé	EFS Consulting	Principal
18	Chris	Lohmann	Energi Insurance	VP Alternative Energy Solutions
19	Dan	Gabaldon	Enovation Partners	Founding Partner
20	Bob	Zabors	Enovation Partners	Founding Partner & CEO
21	Itai	Karelic	Enstorage	VP, Business Development
22	Kateryna	Krasynska	EOS Energy Storage	Director, Corporate Finance and Strategy
23	Scott	Rackey	First Solar	Head of PVS Development
24	Rob	van Haaren	First Solar	Lead Analyst - PVS
25	Pedro	Elizondo	Flex Energy	Business Development Director
26	Richard	Stuebi	Future Energy Advisors	President
27	Matthew	Koenig	GenTech Marketing	President
28	Dan	Dobbs	Greensmith	Director of Product Management
29	Michael	Hastings	Half Moon Power	CEO
30	Doug	Akerson	Hartford Steam Boiler (Muich Re)	VP Energy Products
31	John	Stokes	Hartford Steam Boiler (Muich Re)	Energy Practice Leader
32	Brett	Perlman	Harvard University	Fellow
33	Erica	Egan	Helaba (Landesbank Hessen Thuringen)	Senior Vice President
34	Matt	Lazarewicz	Helix Power	President
35	Jamie	Fergusson	International Finance Corp. (IFC)	Manager
36	Rory	Jones	International Finance Corp. (IFC)	Investment Officer
37	William	MEUNIER	International Finance Corp. (IFC)	Consultant
38	Stratos	Tavoulareas	International Finance Corp. (IFC)	Principal Energy Advisor
39	Jeff	Bishop	Key Capture Energy	Managing Director
40	Dan	Fitzgerald	Key Capture Energy	Chief Development Officer
41	Vani	Dantam	Landis + Gyr	V.P. Business Development
42	Garrett	Haddad	Lazard	Associate
43	Samuel	Scroggins	Lazard	Associate
44	Jonathan	Silver	Marathon Capital	Senior Advisor
45	David	Gianamore	Mitsubishi Electric Power Products, Inc.	Assistant General Manager
46	Robert	Misback	Mitsubishi Electric Power Products, Inc.	COO
47	Charalie	Vartanian	Mitsubishi Electric Power Products, Inc.	Northwest Territory Manager
48	Andrew	Axel	Mitsubishi UFG Lease & Finance	SVP, Director of Sales
49	Richard	Baxter	Mustang Prairie Energy	President

Attendee List (Cont.)

	First	Last	Company	Title
50	Joey	Shorter	National Electrical Contractors Association	NECA Director, Research / Executive Director, ELECT
51	Brendan	Endicott	NEC Energy Solutions	Director, Business Development
52	Nick	Devonshire	New Energy Capital	Associate
53	Adam	Bernstein	New Energy Capital	Managing Partner
54	Tom	Dickson	New Energy Risk	CEO
55	Joshua	Herlands	ORIX USA	Director
56	Patrick	Strumbras	Power Energy Risk	President
57	Geoff	Brown	Powin Energy	President
58	Ric	Abel	Prudential Capital Energy Partners	Managing Director
59	Craig	Irwin	ROTH Capital Partners	Senior Analyst
60	Brian	Kremer	ROTH Capital Partners	Director, Cleantech Investment Banking
61	Jesse	Pichel	ROTH Capital Partners	Managing Director
62	Troy	Miller	S&C Electric Company	Director, Grid Solutions
63	Ray	Byrne	Sandia National Laboratories	Distinguished Member of the Technical Staff
64	Scott	Daniels	Schneider Electric	Office of the CTO
65	Michael	Maiello	Schneider Electric	Senior Vice President
66	Daniel	Wishnick	Siemens	Sales & Business Development Manager
67	John	O'Brien	Siemens Financial Services	Director
68	Amir	Yazdi	Solar Energy Industries Association	Assistant General Counsel
69	Sean	Becker	Sparkplug Power, Inc.	President
70	Ali	Amirali	Starwood Energy Group	Senior Vice President
71	Patrick	Verdonck	Starwood Energy Group	Senior Vice President
72	Imre	Gyuk	U.S. Department of Energy	Manager, Energy Storage Program
73	Jeni	Oppenheimer	UK Power Reserve	Chief Strategist
74	Sean	Greany	UK Power Reserve	Project Development Director
75	Cody	Beck	UK Power Reserve	Strategic Development Advisor
76	Michael	Carr	UniEnergy Technologies (UET)	VP of Strategic & Western Sales
77	Russ	Weed	UniEnergy Technologies (UET)	VP BD & Marketing, General Counsel
78	Rick	Winter	UniEnergy Technologies (UET)	President & COO
79	Mike	Jacobs	Union of Concerned Scientists	Senior Energy Analyst
80	Waydal	Sanderson	Universal Renewables Holdings LLC	Managing Director
81	Alan	Dash	Vionx Energy	Board Member
82	Chris	Murray	WGL Energy	Senior Business Development Manager
83	Danny	Seagraves	Willis Towers Watson	Vice President

Synopsis

On June 7th, 2017 Eversheds Sutherland LLP and Mustang Prairie Energy in Partnership with the U.S. Department of Energy presented a one-day financial summit at Eversheds Sutherland's Washington D.C. that had 83 attendees. Sponsors for the event were Mitsubishi Electric Power Products, Inc. (MEPPI), CSA Group, UniEnergy Technologies, Roth Capital Partners, and Enovation Partners. Speakers included representatives from the U.S. Department of Energy, the Coalition for Green Capital, and industry experts who have experience with the challenges and opportunities of investing in energy storage projects.

The Summit was the third stakeholder meeting for a U.S. Department of Energy sponsored study series to identifying the impact of performance on project financing for energy storage projects. This study's goal is to understand the current challenges facing energy storage project financing, and gain insights into how de-risking the performance issues in the solar, wind and energy efficiency markets benefited these markets, and what strategies could be successful in the energy storage market. 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.

The summit began with an overview of the Study by Richard Baxter of Mustang Prairie Energy, followed by Imre Gyuk, the Program Manager of the DOE Energy Storage Program who gave an overview of federal support for energy storage technology development, and explained how that support is extending into the commercialization of these systems.

The Keynote address was given by Reed Hundt, CEO of the Coalition for Green Capital. His presentation showcased the efforts of State governments to promoted innovative project development financing, and how the experience in the wind, solar, and energy efficiency markets could be leveraged in the energy storage industry.

The first panel of the day focused investor perspectives. The discussion focused on the current state of project financing for energy storage projects currently, and how the market is changing, with expectations for where it will go in the next 2 years. The speakers shared insights into how currently there is significant competition driving down the expected profit margins on projects. Panelists believed there are a number of players buying market share, and that competition for larger public bids will continue. The panelists also discussed how capital costs are expected to continue to decline rapidly, helping these aggressive players continue to bid very aggressively. Insights included a discussion as to how most people underestimate the complexity of operating an energy storage facility in a wholesale market setting. Instead of it operating against one driving metric (wind speed for wind turbines, solar irradiance for solar PV), there are a whole host of interconnected issues that drive the operational strategy; it's more like a gas turbine with multiple market roles, which has implications for financing. Panelists believe that the best revenue model for storage is still up for grabs, especially as regional variation will drive opportunistic approached both based on peak / off-peak pricing, varying electricity costs, and T&D investment levels. The Panelists all agreed what was needed now was for the continuing development of Standards (equipment, engineering, & performance) and for the regulatory environment to catch up to the technology development.

The second panel of the day focused on de-risking project financing. The rapidly evolving insurance offerings for energy storage systems was a key area of discussion. A key point noted was that standard insurance policies cover most asset and liability issues, but would improve with additional experience, while performance insurance needs significantly more operational data to price the performance risk properly. It was believed that insurance products would evolve with the market as the experience became available. A key point was noted that there will be a clear limit to the liability—for example, insurance would cover a manufacturing defect, but insurance will not cover a failure in the design. This is important when dealing with performance insurance—those policies are intended to cover the possibly of the unit not performing to stated specification—not that the energy storage system did not generate sufficient profits in the market. The panelists agreed that insurance policies will continue to mature, and as energy storage system are integrated into other assets—especially solar—that the insurance policies covering those projects will also need to evolve.

The final panel of the day focused on OEM and operator perspectives. The panelists reviewed many examples of how performance expectations and requirements have already been integrating into the markets, with the expectation that this trend will continue. Most of the panelists saw this as an opportunity to differentiate their hard-won experience from the growing number of new entrants in the market. Many of the panelists noted that most contracts with utilities (customers) were focusing on availability and efficiency as key operational metrics, while developers had to contend with OEM performance warranties. Operators agreed that performance insurance seems like a good idea, but were concerned about the cost and thus had to weight the risk carefully as profit margins were typically low.

DISTRIBUTION

1 Dr. Imre Gyuk
Program Manager, Energy Storage Research
Office of Electricity Delivery and Energy Reliability
U.S. Dept. of Energy
Washington, DC 20585

1	MS1108	Babu R. Chalamala	8811
1	MS1108	Tu. A. Nguyen	8811
1	MS1108	David Copp	8811
1	MS1138	Charles J. Hanley	8810
1	MS1140	Raymond H. Byrne	8813
1	MS1140	Ricky J. Concepcion	8813
1	MS1140	Felipe Wilches-Bernal	8813

1	MS0899	Technical Library	9536 (electronic copy)

Sandia National Laboratories