Westmoreland Fire Department

Westmoreland Town Hall – next to Fire Department

Westmoreland Post Office – in Town Hall Building

Community Church – across from Town Hall

Westmoreland Village Store – next to Town Hall

Consolidated Communications Building – near Village Store

Westmoreland School – down the street from Town Hall, Village Store and Fire Department

Eversource NH
Estimates of Energy Efficiency Opportunity in Westmoreland

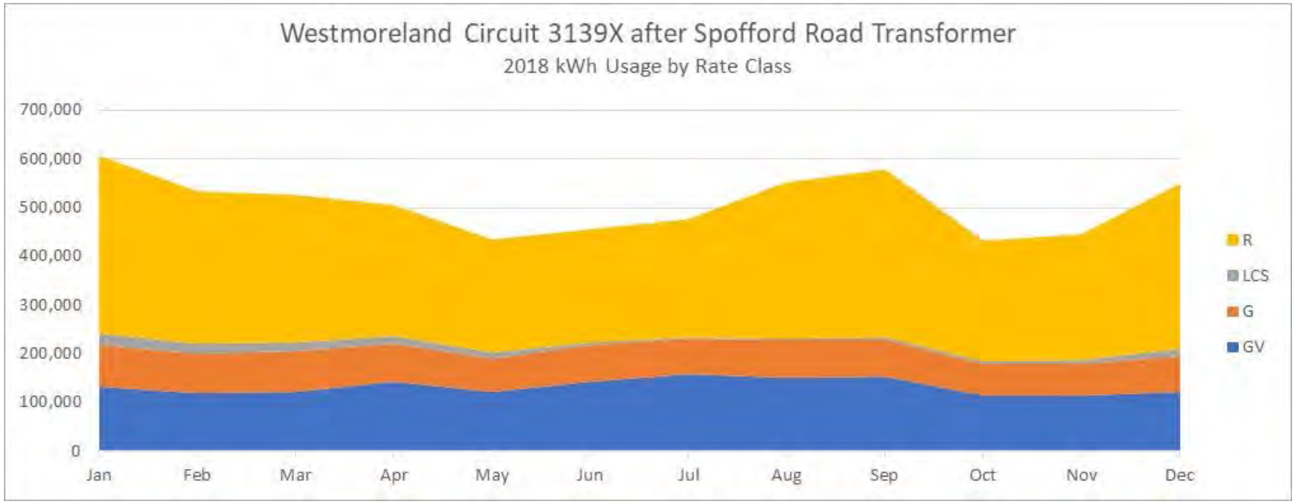
Westmoreland

3139X

EE Related Energy Efficiency

- NH RSA Section 374-F:4, below.
- (e) Targeted conservation, energy efficiency, and load management programs and incentives that are part of a strategy to minimize distribution costs may be included in the distribution charge or the system benefits charge, provided that system benefits charge funds are only used for customer-based energy efficiency measures, and such funding shall not exceed 10 percent of the energy efficiency portion of a utility's annual system benefits charge funds. A proposal for such use of system benefits charge funds shall be presented to the commission for approval. Any such approval shall initially be on a pilot program basis and the results of each pilot program proposal shall be subject to evaluation by the commission.

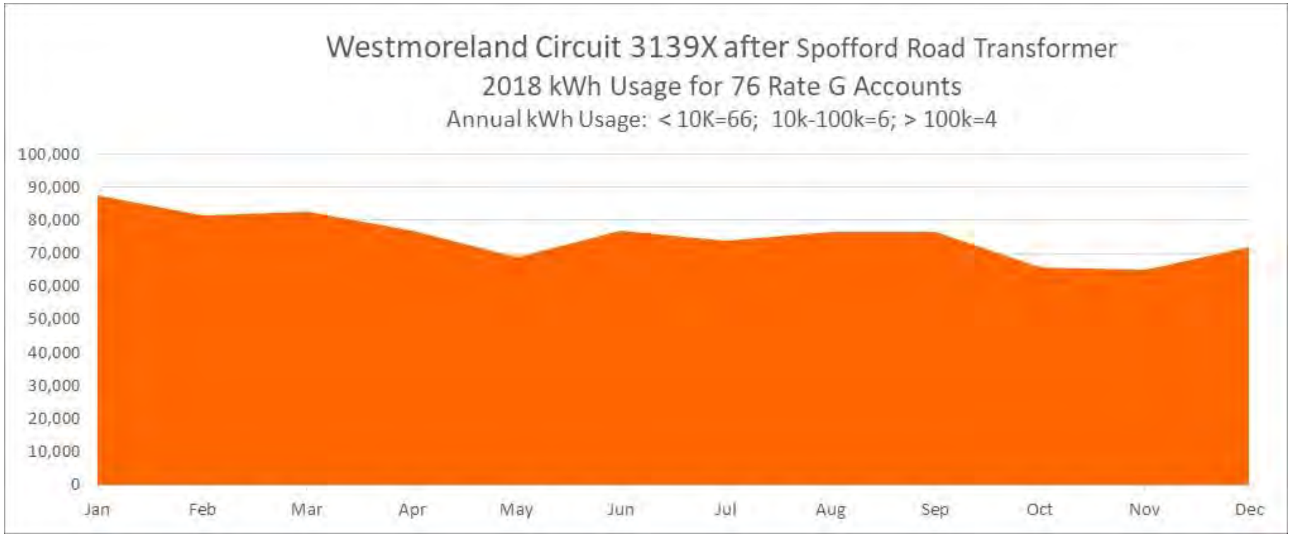
Stacked Usage



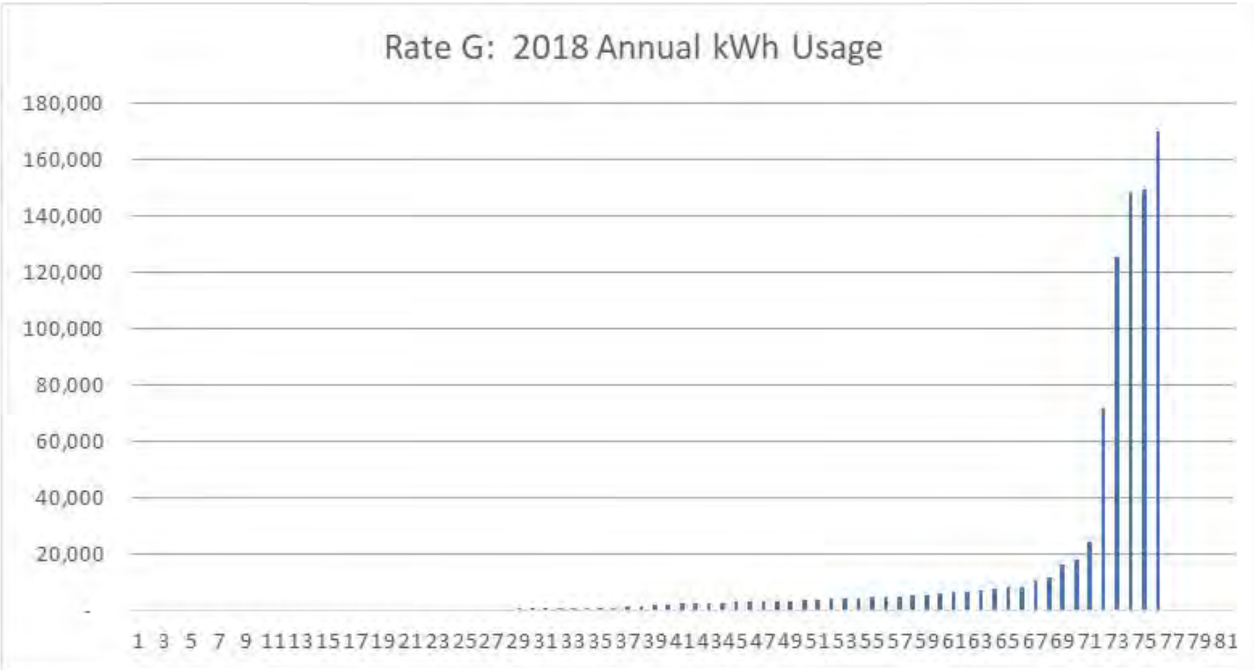
GV Account EE Opportunity

- There is one primary GV Account in Westmoreland
- This account is currently going through an expansion, which will increase usage.
- Energy efficiency staff are currently working with this account on potential EE projects.
- GV Account Estimated Participation = 1

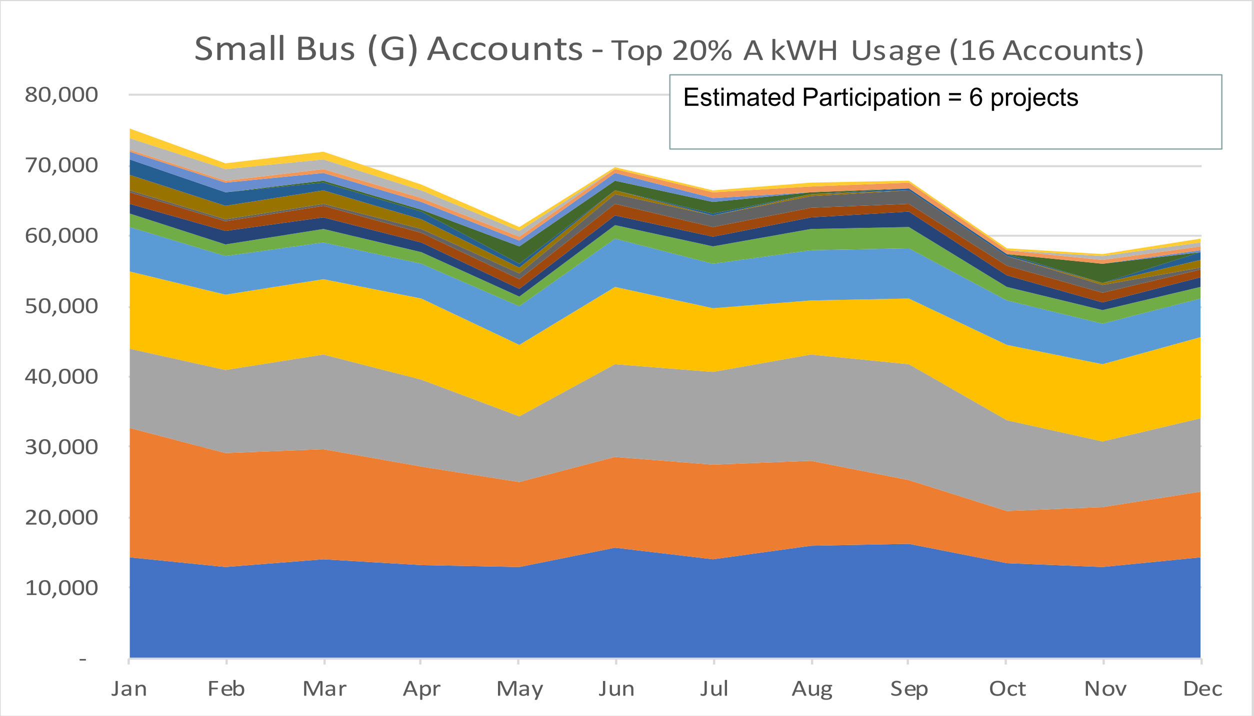
G Accounts (< 100 kW)



G Accounts (< 100 kW)

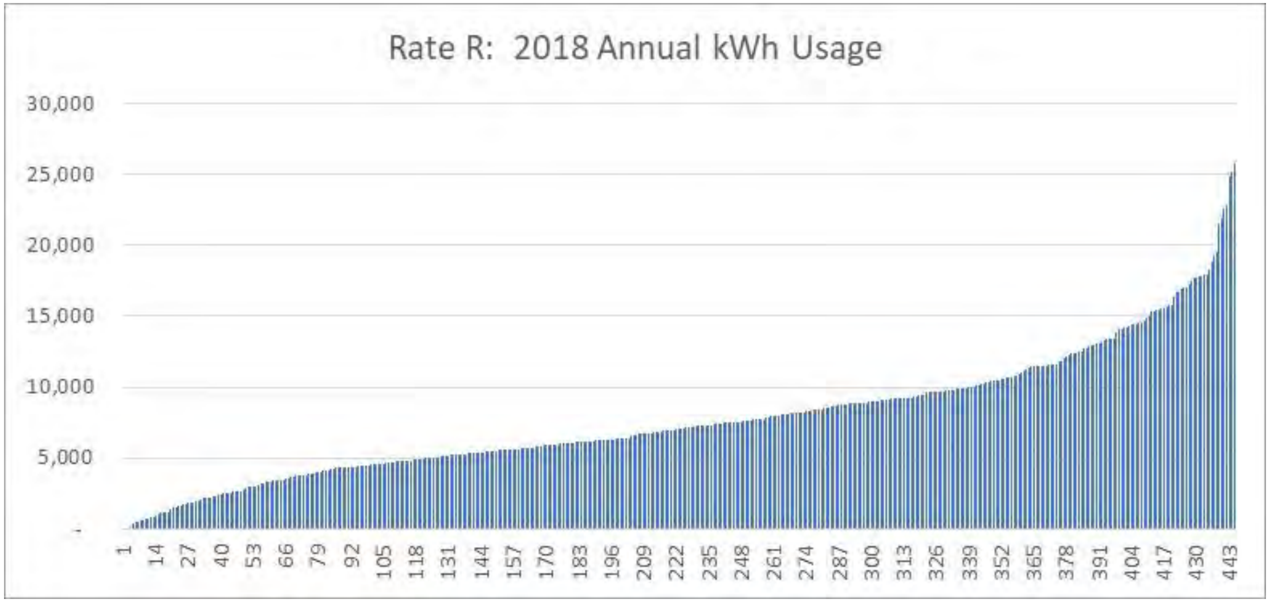


G Account EE Opportunity

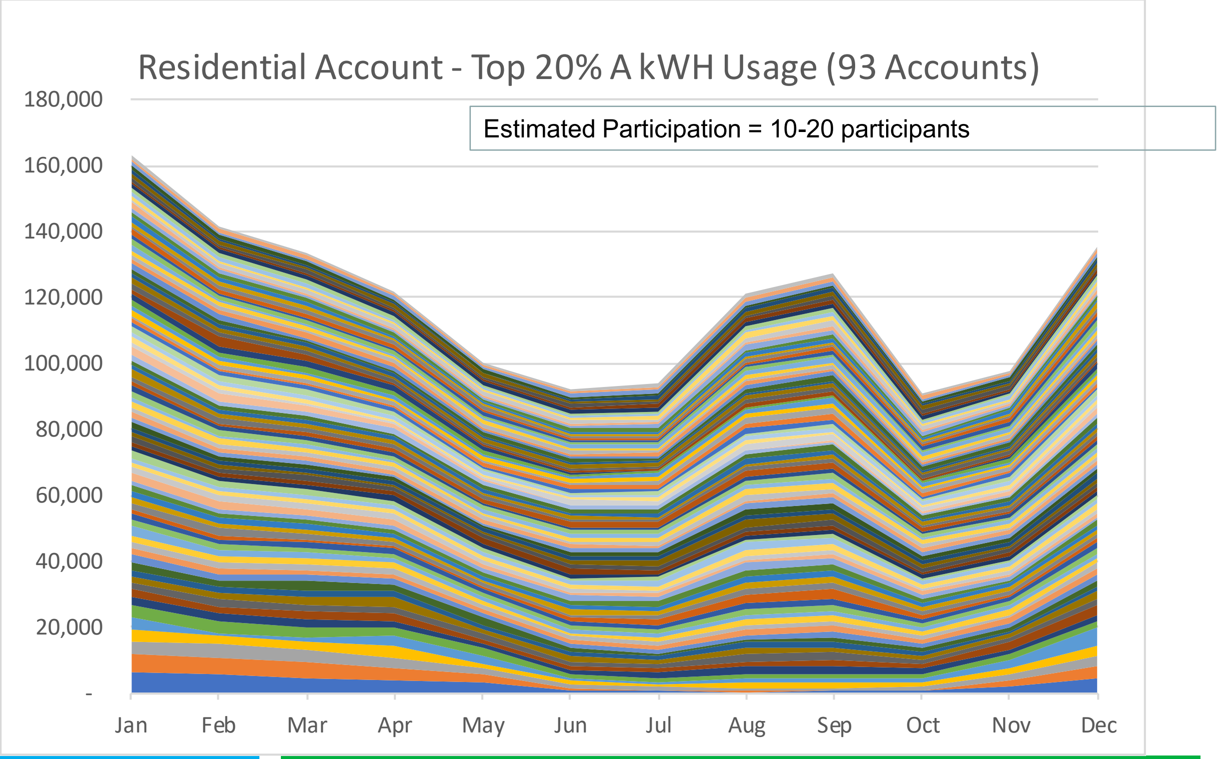


Residential Accounts (448)

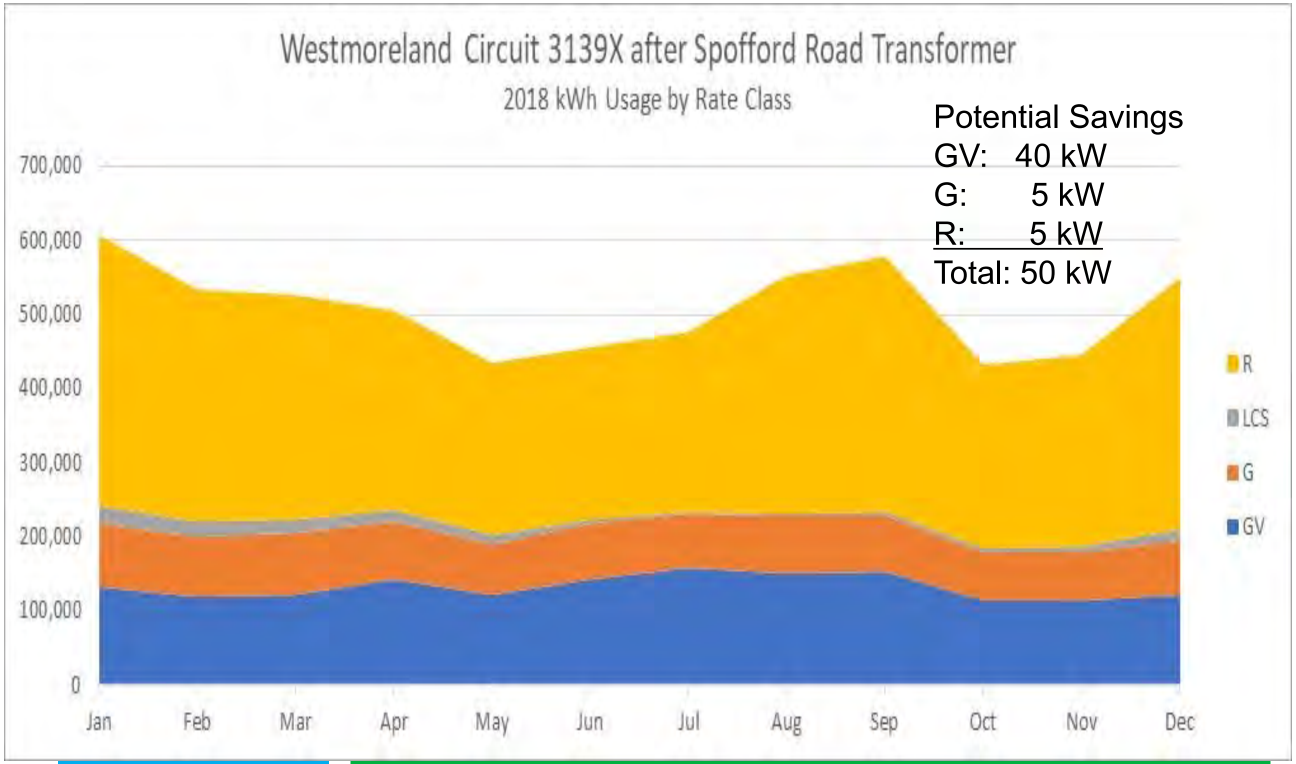
EVERSOURCE ENERGY



Residential Account EE Opportunity



Stacked Usage (600,000/744= 806 kW)



Residential Demand Response

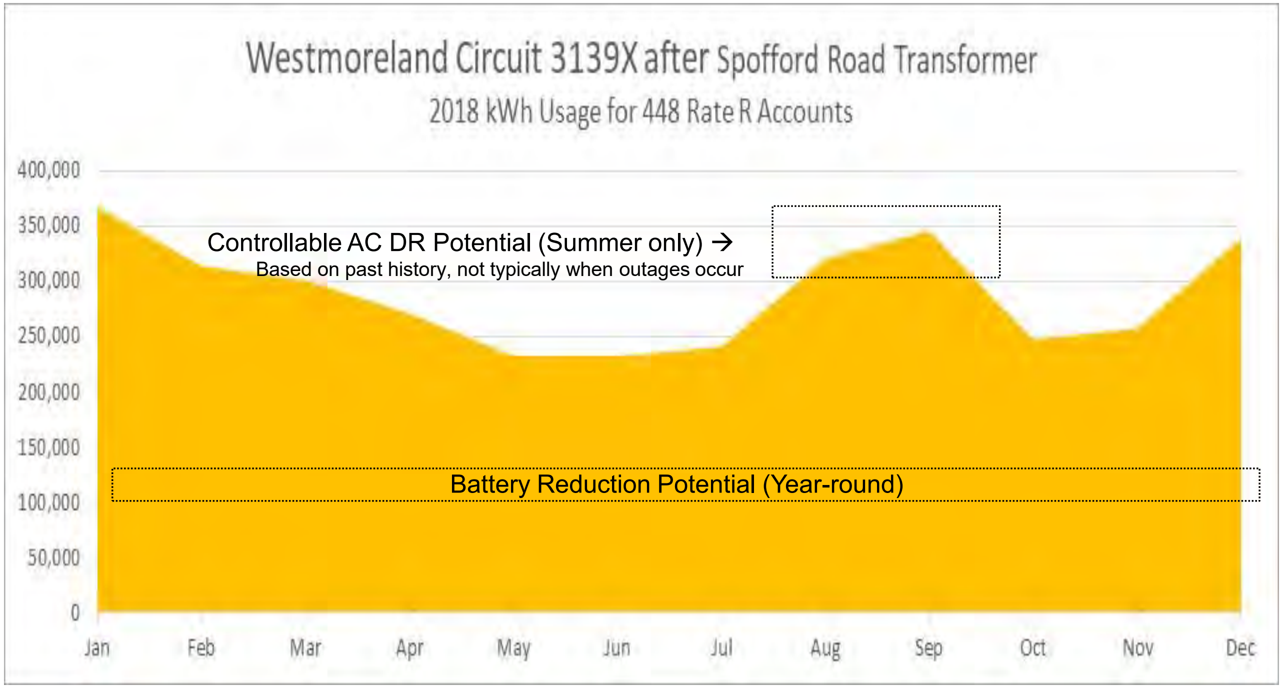
Residential Demand Response

1. **Batteries**
   4-5 kW / Account
   Up to 10 on Circuit 3139x
   10 x 5 kW = 50 kW
   Year-round

2. **Controllable Air Conditioning**
   0.5 kW / Account
   Up to 30 on Circuit 3139x
   AC: 30 x 0.5 kW = 15 kW
   Summer only

Residential Accounts (of 448 Accounts)

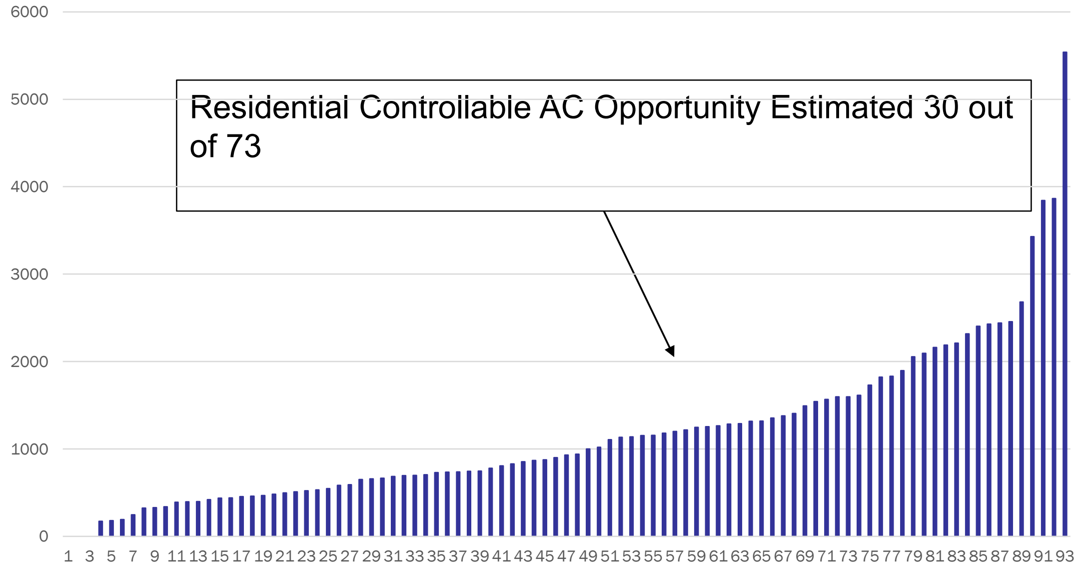
Batteries: up to 10 Homes
Controllable AC: up to 30 Homes



DR: 73 Customers with Estimated Cooling > 1,000 kWh during Summer

EVERSOURCE ENERGY

Residential Customers (20% high users)
73 Customers with Higher Summer Load kWH > 1,000 kWh



Westmoreland: Est. EE & DR Savings

EVERSOURCE ENERGY

1. Estimated Energy Efficiency

Customer Class	Qty	Est kW	When?
Large Business	1	40 kW	year-round
Small Business	6	5 kW	year-round
Residential	10-20	5 kW	winter
Total Est. Savings	17-27	**50 kW**	

2. Estimated Demand Reduction

Battery Storage	10	50 kW	year-round
Controllable AC	30	15 kW	summer
Total Est. Savings	40	**65 kW**	

Eversource Energy

Conceptual Design Report for Eversource Westmoreland Energy Storage System

May 2019

Doosan GridTech
71 Columbia St, Suite 300, Seattle, Washington, 98104

Section 1 Executive Summary

The Eversource engineering team reviewed its New Hampshire service territory for energy storage use cases that, combined with efficiency and demand response, could cost-effectively defer traditional solutions. Eversource commissioned Doosan GridTech to review and evaluate the feasibility of the leading storage component candidate on its selection matrix: the 3139X circuit in the area of Westmoreland, New Hampshire, which presents with significant reliability challenges. This feasibility study examines the 3139X electrical system, presents a conceptual design for an energy storage system (ESS), and assesses the benefits achievable through an ESS connected in Westmoreland.

The primary goals of the Westmoreland ESS are to improve reliability on an isolated and vulnerable section of the 3139X feeder, demonstrate the ability to provide value for customers through peak shaving and other ESS use cases, and develop best practices for the deployment and control of energy storage.

A 1.7MW / 7.1MWh lithium ion ESS is recommended to meet these goals.

a. The recommended primary use cases are islanding to improve distribution reliability and peak shaving to achieve Regional Network Service (RNS), Local Network Service (LNS) and ISO-NE capacity cost savings.
b. Lithium ion battery technology is recommended based on its technological maturity and suitability to perform the recommended use cases.
c. A 1.7MW/ 7.1MWh ESS is recommended as a cost-effective size that enables primary use cases. Detailed sizing analysis is documented in Section 5. A 1.7MW/7.1MWh system:
    i. supports all commercial and residential load downstream of the Spofford step transformers through all upstream outages up to 4 hours in duration based on projected load through 2028
    ii. achieves approximately $485K in average annual projected RNS, LNS, and ISO-NE capacity charge reduction through peak shaving

The analysis resulted in the following findings:

- The Westmoreland site is uniquely well-suited to use energy storage to cost-effectively defer traditional solutions to address reliability issues while also providing additional cost savings to customers by means of peak shaving.
    a. The section of the 3139X circuit downstream of the Spofford step transformers is a rural, radial feeder prone to outages.
    b. Critical loads in the town center of Westmoreland (an elementary school and town emergency shelter, a fire station, a nursing home, a town hall, a post office, and a communications building) are located on this radial section and currently cannot be served during loss of supply on 3139X upstream of the town center.
    c. An ESS located near the Westmoreland town center could island the 3139X circuit downstream of the Spofford step transformers and maintain service to residential and critical loads during upstream outages for up to 4 hours under peak conditions based on projected load through 2028.

d. If existing or future sectionalizing switchgear lies between a fault on 3139X downstream of the Spofford step transformers and an ESS located near the Westmoreland town center, the ESS could maintain service to critical and residential loads downstream of the sectionalizing switchgear for more than 4 hours at peak load based on projected load through 2028.

- Several distinct ESS applications were studied and technical and economic benefits were quantified.
    a. The ESS will provide backup power to support the 3139X circuit downstream of the Spofford step transformers, improving reliability and maintaining service to customers and critical loads in the event of an upstream outage. A wires alternative would cost $6 million.

    b. The ESS will shave peak load on the 3139X circuit, reducing RNS, LNS and ISO-NE capacity charges for customers.
    The demonstration of peak shaving will allow Eversource staff to develop best practices for control and operations and ensure that future ESS deployed to defer capacity upgrades will be operated with high reliability and performance. More details on the peak shaving application can be found in Section 0

    c. The ESS will demonstrate primary frequency response. While currently provided by traditional generation, FERC Order 842 (Feb. 2018) requires all new interconnecting distributed energy resources to demonstrate capability of providing this service. This application is discussed further in Section 5.3.

- The costs and benefits of the recommended 1.7MW / 7.1MWh ESS are:

    a. The total capital cost of the ESS is $7.0M which includes a 20% contingency. This includes a fully loaded EPC project budget of $4.3M; the remainder is fully loaded direct expenditures by Eversource. Assumptions, cost breakdown, battery replacement plan, and more cost estimate details are discussed in Section 7.1.

Table 1-1: Total project budget estimate in $000s

Budget Elements		2020
Total EPC capital budget, fully loaded		$4,328
Eversource Direct Capital Expenditures (line items fully loaded)	Eversource staff labor including EE, PM, legal	$1,491
	Permitting	$176
	Systems Integration	$171
	Site Development and Building	$562
	Interconnection Switchgear, Aux Power Equipment, and Communication	$273
	Total Eversource direct spend, fully loaded	$2,674
Project Capital budget total, fully loaded		$7,002

b. The operating and maintenance cost of the ESS is given in Table 1-2. A detailed breakdown of the elements included in this estimate is provided in Section 7.1.3.

Table 1-2: Annual O+M Costs

Operating and Maintenance ($000)	
Average Annual Costs	$140

c. The quantifiable economic benefits associated with the Westmoreland ESS are shown in Table 1-3. The values in Table 1-3 for RNS and Capacity benefits assume that 10 of 12 monthly peaks are hit for RNS savings and the yearly Capacity peak is hit with the ESS. A detailed discussion of potential economic benefits and additional revenue scenarios can be found in Section 5.2.2.

Table 1-3: Benefit Summary

One-time Benefits	Value ($000)
Deferred Distribution Upgrades	$ 6,000
Annual Benefits	**Average Annual Value ($000/yr)**
RNS Charge Reduction	$ 348
ISO-NE Forward Capacity	$ 120
LNS Charge Reduction	$ 19

d. The following list provides a qualitative overview of the potential benefits realized through the Westmoreland ESS.

i. Improved customer power quality

ii. Improved customer reliability

iii. Development and demonstration of best practices for peak shaving when there is a power flow constraint in the system to maintain power quality or avoid equipment damage, and to reduce RNS and ISO-NE capacity costs

iv. Development and demonstration of best practices for primary frequency response

v. Experience in designing, deploying, operating, and maintaining a utility-scale, utility-owned and -operated ESS

vi. Help demonstrating and articulating the value of grid-side enhancements and assisting in increased transparency with customers and other stakeholders

vii. Integration of a new distributed asset type into the Eversource New Hampshire control and operations software

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Section 2 Background

Energy storage has unique flexibility through its ability to serve as generation or load and to produce or absorb both real and reactive power. ESS can be used to address the full range of real and reactive power needs, performing discrete grid services at the generation, transmission and distribution levels of the electricity system.

The challenge of this flexibility and range comes in two areas: 1) determining the most valuable use of the ESS resource at each moment of each day; and 2) developing new organizational control and communication practices that may require the coordination of groups that have historically operated independently.

Grid-scale, utility-integrated energy storage is a relatively new technology for electric utilities. For ESS to serve as multi-purpose grid management tools requires energy systems to be tightly integrated with distribution operations. Energy storage controls need to perform multiple, simultaneous tasks:

-dispatch both real and reactive power;
-factoring in local circuit conditions and bulk power system opportunities;
-coordinating with the DSCADA software that controls the overall distribution system.

These challenges are best addressed through the deployment of demonstration projects and the development of best practices around energy storage application prioritization and control.

Eversource has engaged Doosan GridTech to provide a conceptual design report that evaluates the feasibility of using an ESS to provide customer reliability benefits, manage the impacts of DERs and support the integration of additional DER, along with a quantitative analysis of the benefits and costs over the project's life. The design study evaluates technical feasibility and determines an optimal strategy of deployment.

Doosan's power systems integration team has years of experience providing storage system engineering and conceptual design work to utilities across the country. Doosan has worked closely with Eversource to determine the optimal ESS deployment strategy and to quantitatively analyze benefits and costs. This work has been performed with an eye towards scalability and setting processes and strategies in place that can inform future expansion of Eversource's storage fleet to cost-effectively bring value to customers.

Section 3 Goals and Objectives

The following goals and objectives have been identified for the Westmoreland ESS demonstration project:

3.1 GENERAL: Eversource ESS Projects and ESS Scalability

1. Safely install, operate, and maintain a utility-scale ESS within Eversource's New Hampshire service territory.
2. Provide an ESS control and monitoring capability that can be managed by the appropriate local field operations personnel as well as the regional bulk power control center with minimum impact on the day-to-day operations of other operational entities within Eversource.
3. Demonstrate and evaluate metrics and techniques that enhance Eversource's ability to design and model the appropriate ESS capacities (energy and power) in future ESS deployment efforts.

4. Demonstrate and evaluate the benefits of open standards, including the Modular Energy Storage Architecture (MESA), in enhancing the scalability of energy storage integration with utility operations.[2]
5. Utilize field measurements from demonstrated ESS performance to quantify technical and economic benefits of each individual ESS use case as well as the sum of combined use cases.

3.2 GENERAL: Design study

1. Conduct an energy storage design process that engages and educates the Eversource engineering team and results in an approved ESS design that is compliant with Eversource engineering standards.
2. Design and demonstrate a control and dispatch architecture that achieves the maximum value for an ESS/ESS fleet by:
    a. Optimally blending distribution and bulk system applications to meet local circuit reliability and power quality goals while capturing value from bulk system applications
    b. Implementing the necessary interfaces with existing Eversource distribution and transmission control platforms to make ESS optimization decisions across multiple potential applications
    c. Executing autonomous ESS dispatch while also providing awareness and control to Eversource operators
3. Calculate project budget, costs and benefits, schedule, system design, and risk assessment to evaluate the value of an ESS facility to customers. Provide quantitative analysis to support Eversource’s proposal to their regulators.

3.3 ESS VALUE: Westmoreland

1. Deploy utility-scale, utility-owned and -operated ESS to enhance customer reliability and reduce peaks.
2. Help demonstrate and articulate the value of grid-side enhancements and assist in increased transparency with customers and other stakeholders.
3. Identify and understand technical aspects of ESS integration and impacts on system planning, design, and operations.
4. Provide clear economic benefit to customers.
5. Support the development of the broader electric power system in a clean energy future by widespread dissemination of the findings of the demonstration project, by sharing a summary of performance data annually with regulators, the public, and other stakeholders.

Section 4 Site Selection and Westmoreland Electrical System

Westmoreland was selected as one of the best sites for an energy storage demonstration project by a cross-functional team at Eversource after a process that compared multiple candidate locations across a range of criteria. The site selection process is summarized in Section 4.1 and the Westmoreland electric distribution system is described in Section 4.2.

[2] http://mesastandards.org/

4.1 Site selection

The site selection process resulted in the selection of one of the best locations for demonstrating energy storage. A cross-functional team at Eversource generated a prioritized list of benefits that could be realized by an energy storage system, including DER integration, the possibility of multiple stackable benefits, ability to defer equipment upgrade expenditures, capability to provide backup power, and practical deployment considerations such as the availability of land and complexity of site preparation. Eversource created a locational decision matrix comparing potential New Hampshire ESS host distribution substations in each of these categories. Table 4-1 lists scoring criteria for each benefit category and includes the scale used to score each substation in each category.

Table 4-1: Locational decision matrix categories and scoring

1 = Low	2 = Acceptable	3 = Average	4 = Promising	5 = Excellent
DER Penetration: The more DER equipment connected on the feeder, the higher the point value.				
Stackable Benefits: The more benefits that can be stacked (DER Integration, Load shifting, Load smoothing, Voltage Regulation, Frequency regulation, etc.), the higher the point value. Feeders were examined to analyze specific problems that can be addressed/studied.				
Avoid / Defer System Upgrades: The closer the existing equipment is to its maximum rating, the higher the point value. The highest value between feeder loading and substation loading was chosen.				
Backup Capability: The capability of a load zone to have various forms of redundancy received a higher point value. The more deficiencies and lack of redundancy the higher the point value.				
Land Available / Site Prep: Point value based on amount of Company -owned land and how readily available and cleared it is.				

Table 4-2 shows the locational decision matrix for New Hampshire distribution substations. The scoring categories are weighted according to Eversource priorities for ESS demonstration in New Hampshire.

Table 4-2: Locational decision matrix for NH substations

Substation	DER Penetration		Stackable Benefits		Avoid / Defer System Upgrades		Backup Capability		Land Available, Site Prep		Total	
	Weighting		Weighting		Weighting		Weighting		Weighting			
	10%		25%		25%		35%		5%			
	SCORE	Weighted Score	SCORE	Weighted Score	SCORE	Weighted Score	SCORE	Weighted Score	SCORE	Weighted Score	Total (out of 5)	Rank
Chestnut Hill 3139X	1	0.1	5	1.25	4	1	4	1.4	5	0.25	4	1
Peterboro 313	1	0.1	4	1	5	1.25	3	1.05	3	0.15	3.55	2
Greenville 3155	1	0.1	4	1	5	1.25	3	1.05	2	0.1	3.5	3
Hanover Street 16W3	1	0.1	4	1	5	1.25	2	0.7	5	0.25	3.3	4
Mont Vernon 24X1	1	0.1	3	0.75	3	0.75	4	1.4	3	0.15	3.15	5
Errol 3525X5	1	0.1	3	0.75	4	1	3	1.05	5	0.25	3.15	5
Brentwood 3103	1	0.1	2	0.5	4	1	4	1.4	2	0.1	3.1	7
Pittsfield 319	1	0.1	3	0.75	4	1	3	1.05	2	0.1	3	8
Tuftonboro 346	1	0.1	3	0.75	5	1.25	2	0.7	2	0.1	2.9	9
Pittsburg 355X10	1	0.1	2	0.5	2	0.5	4	1.4	4	0.2	2.7	10
New London 316	1	0.1	2	0.5	3	0.75	2	0.7	2	0.1	2.15	11

The Chestnut Hill substation has the highest total score and was selected as the best location for an ESS demonstration project in New Hampshire. The 3139X circuit in the Westmoreland area commonly appears on lists of circuits with worst reliability in Eversource's New Hampshire service territory. The circuit loading downstream of the Spofford step transformers is well-suited to the ESS size and cost range Eversource is considering for this demonstration project. More details on the 3139X circuit and Westmoreland electrical system are provided in Section 4.2.

Doosan GridTech has advised other utilities in the process of screening a list of candidate sites and selecting the best site to meet objectives. The process that Eversource used to select the Chestnut Hill substation and 3139X circuit is similar to the process that Doosan would have recommended.

4.2 Westmoreland electrical system

Figure 4-1 presents a simplified one-line diagram of the 3139X circuit annotated with information on distribution of critical loads, sectionalizing switchgear, circuit distance, and more.

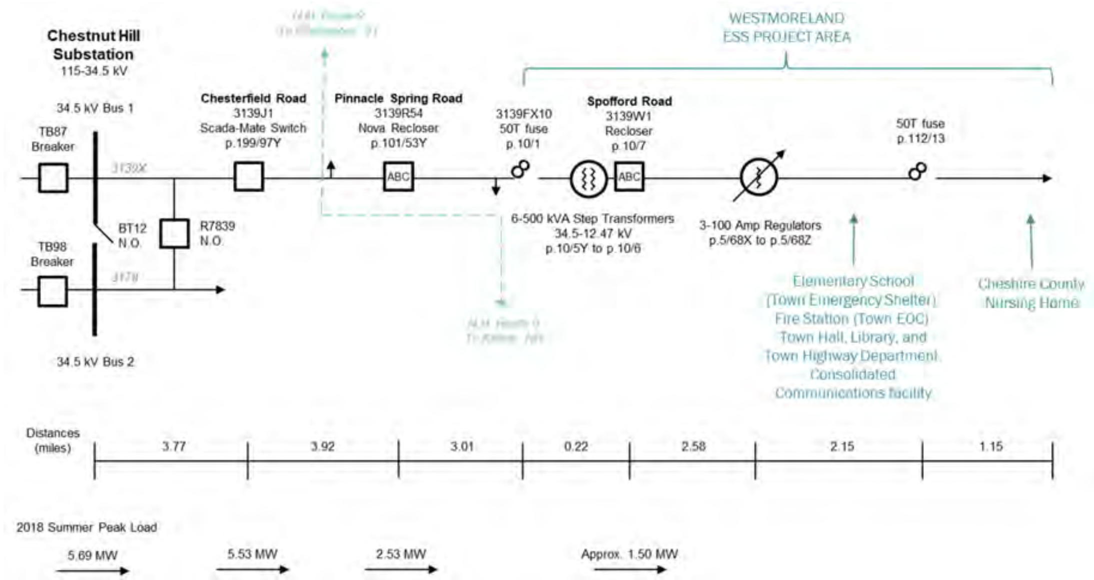

Figure 4-1: Annotated diagram of electrical system in Westmoreland environs

The Chestnut Hill substation serves the 3139X and 3178X circuits. 3139X is a radial 34.5kV feeder upstream of the Spofford Road transformers, which step voltage down from 34.5kV to 12.47kV. 3139X serves a load mix that consists primarily of rural residential loads with scattered light commercial loads.

The Westmoreland town center is located roughly 14 circuit miles of radial feeder from the Chestnut Hill substation and hosts critical loads including an elementary school (that serves as the town emergency shelter), the town fire station, Town Hall, the post office, a general store, and a Consolidated Communications building. The Cheshire County Nursing Home is located an additional 2 circuit miles downstream of the town center. Service to these critical loads is currently dropped during outages in the upstream distribution system and there are no alternate sources available through system reconfiguration today (see Section 5.1.2 for information on potential $6M circuit tie that would allow reconfiguration).

Table 4-3 lists the outages in the distribution system upstream of the Spofford step transformers that have caused loss of service to critical loads in the Westmoreland town center since 2012. There have been 13 such outages since November 2012 and these outages have an average duration of 2.2 hours and a maximum duration of 6.87 hours. Energy storage located in the Westmoreland town center can serve loads downstream of the Spofford step transformers during outages of this type.

Table 4-3: Outages in the upstream distribution system since 2012 that resulted in complete loss of service downstream of the Spofford Rd. step transformers

Date	Duration (hrs)
5/7/2018	0.32
4/4/2018	4.53
2/21/2018	0.97
12/12/2017	1.02
10/24/2017	0.67
10/27/2016	0.87
6/12/2016	2.83
11/27/2014	6.87
11/26/2014	1.78
3/22/2014	4.50
9/12/2013	1.40
6/28/2013	2.08
11/8/2012	1.15

Table 4-4 lists all outages on line 3139X downstream of the Spofford step transformers since 2012. There have been 24 such outages since November 2012 and these outages have an average duration of 2.8 hours and a maximum duration of 8.68 hours. Energy storage can serve some load downstream of the Spofford Rd. step transformers during outages of this type, depending on the location of the outage and sectionalizing switchgear. If the outage occurs upstream of the ESS and there is sectionalizing switchgear between the ESS and the outage location, then the ESS can form an electrical island and support loads downstream of the switchgear. If there is no sectionalizing switchgear between the outage location and the ESS, or the outage occurs downstream of the ESS, the ESS will not be able to perform islanding.

Table 4-4: 3139X outages downstream of the Spofford Rd. step transformers since 2012

Date	Duration (hrs)
7/25/2018	0.47
7/25/2018	1.53
6/18/2018	8.07
5/5/2018	0.55
12/23/2017	2.40
12/23/2017	6.73
12/12/2017	5.82
12/12/2017	4.82
12/12/2017	8.68
9/5/2017	6.22
9/5/2017	3.22
8/6/2017	2.93
8/6/2017	0.57
1/19/2017	2.23
1/19/2017	1.08
11/15/2016	0.87
6/14/2015	1.03
6/8/2015	1.82
6/8/2015	1.37
5/27/2015	1.50
11/2/2014	0.45
7/4/2014	2.98
10/6/2013	0.87
5/25/2013	1.97

While energy storage is capable of supplying power to critical Westmoreland loads during all outages of the type listed in Table 4-3 and some of the outages listed in Table 4-4, ESS ability to support an electrical island that includes all loads downstream of the Spofford step transformers throughout expected outage durations is dependent on ESS power and energy capacity. Outages downstream of the Spofford step transformers frequently occur in bunches during a single storm event. If long outages fall within a few hours of each other during a high-load period, the ESS recharge capability may be limited. ESS sizing analysis is detailed in Section 5.

Section 5 Valuation and Sizing Analysis

This section discusses sizing considerations and value streams associated with the primary use cases identified for the Westmoreland ESS.

5.1 Islanding

During loss of service in the upstream distribution system, an ESS can provide backup power to support an electrical island encompassing circuit 3139X downstream of the Spofford step transformers. The sizing goal for this use case is to set ESS power and energy capacities capable of supporting all load downstream of the Spofford step transformers through expected outage durations assuming 2028 projected load.

5.1.1 Islanding sizing methodology

ESS sizing for the islanding use case is based on the expected load profile of the electrical island and the target outage ride through duration. The electrical island in this case is the section of circuit 3139X downstream from the Spofford step transformers.

Load at the Spofford step transformers is measured manually at irregular intervals. Since no regular load metering occurs, the load profile of the electrical island must be estimated. Manual measurements show that load at the Spofford step transformers averages 27% of the total 3139X load. To account for load growth on the 3139X circuit, 2016 load data was scaled to projected 2028 values. Projected 2028 peak load at the Chestnut Hill substation (16.8MVA) is 112% of the measured 2016 peak (15.0MVA). Therefore, the equation used to estimate projected 2028 load at the Spofford step transformers is:

*Projected 2028 Spofford xfrmr load = 2016 3139X load * 0.27 * 1.12*

Figure 5-1 shows the resulting 2028 projected load profile at the Spofford step transformers. The average projected load is 1.0 MVA and the projected peak load is 1.7 MVA.

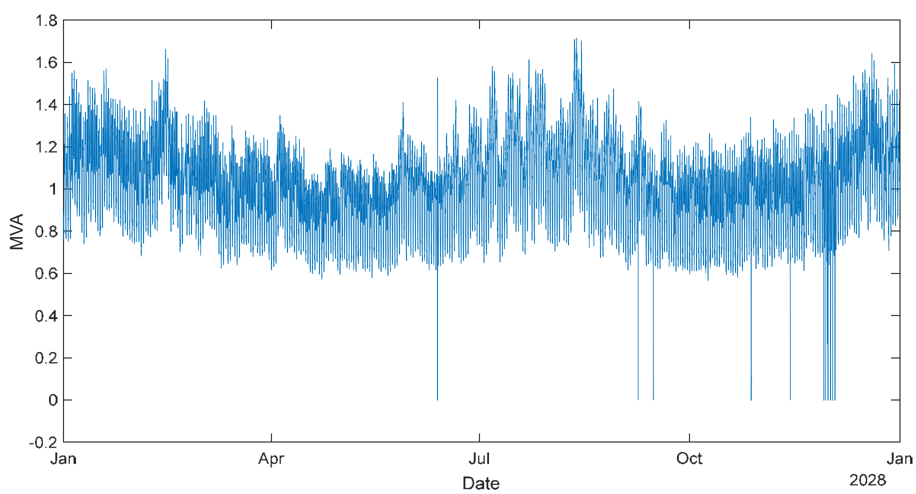

Figure 5-1: Projected 2028 load at the Spofford step transformers

The ESS power capacity necessary to support the electrical island during all possible outages is the island's peak load. Therefore, the recommended Westmoreland ESS power capacity is 1.7MW.

The ESS energy capacity necessary to ride through an outage is the area under the load profile curve over the duration of the outage. As an example, Figure 5-2 shows the projected 2028 load profile during an illustrative summer day. The shaded region shows the energy required to support projected load on 3139X during a 4-hour outage beginning at 4:30 P.M.

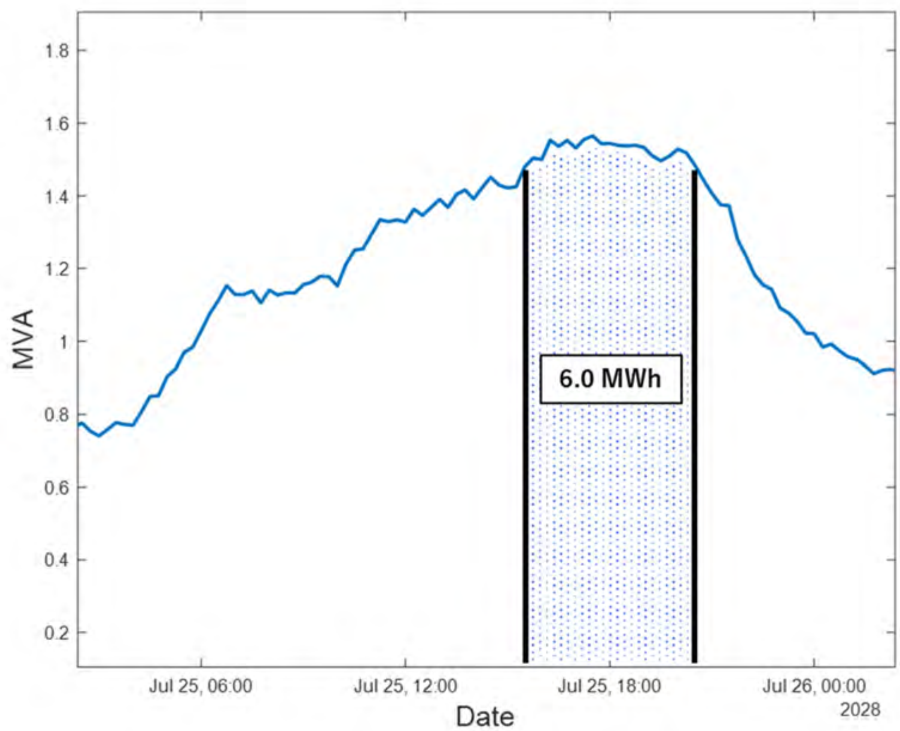

Figure 5-2: Illustrative 4-hour outage energy requirement

A comprehensive survey to determine the energy capacity required to ride through any outage of a certain duration can be carried out by evaluating outages starting at each 15-minute interval of the year. Figure 5-3 illustrates the power and energy requirements necessary to maintain service to line 3139X downstream from the Spofford step transformers during all potential 2-hour, 4-hour, and 7-hour outages, assuming the 2028 projected load profile. Each data point in Figure 5-3 represents the power and energy capacity necessary to ride through one simulated outage of the color-corresponding duration.

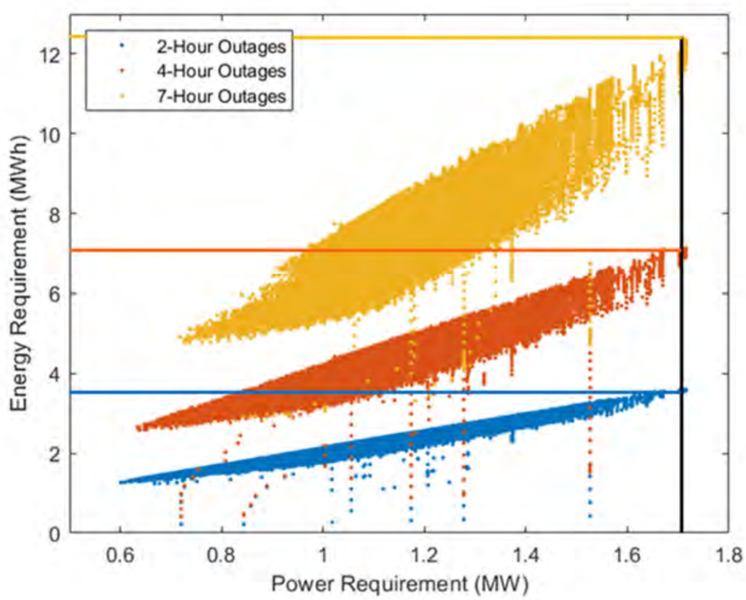

Figure 5-3: ESS power and energy requirements for simulated outages of different durations

The maximum power requirement for each duration is 1.7 MW, as this value is set by the annual peak load. The colored horizontal bars on the figure note the maximum energy requirement for each duration. The energy capacity required to maintain service to the electrical island throughout all 2-hour outages is 3.6 MWh, the energy capacity required to ride through all 4-hour outages is 7.1 MWh, and the energy capacity required to ride through all 7-hour outages is 12.4 MWh.

2-, 4-, and 7-hour durations were selected for this analysis based on historical outage durations recorded on the 3139X circuit. Outages experienced on the circuit since 2012 are listed in Section 4.2. Section 4.2 lists two types of outages: outages upstream of the Spofford step transformers that caused loss of service to the entire prospective electrical island and outages that occur downstream of the Spofford step transformers, within the prospective island. The primary focus for ESS sizing is the first of these types, as the ESS will be able to perform islanding during any of these outages. These outages average 2.2 hours and have a maximum duration of 6.9 hours.

2 hours was selected to illustrate average outage duration, 7 hours was selected to illustrate the maximum historical outage duration, and 4 hours was selected as a recommended target ride through duration, as 77% of historical outages on 3139X upstream of the Spofford step transformers have been 4 hours or shorter while the energy requirement reduction relative to the 7-hour outage energy requirement leads to significant system cost savings.

While a 12.4 MWh system is necessary to ride through any outage of the 7-hour maximum recorded historical outage duration, the recommended energy capacity is the 7.1 MWh necessary to ride through any 4-hour outage. The modest increase in potential outage ride through capability provided by the 12.4 MWh system is outweighed by the significant additional battery module cost.

5.1.2 Traditional alternative

To estimate the economic value that an ESS could provide through islanding, it is compared to traditional alternatives. Eversource engineers developed an alternative distribution solution to provide backup power to line 3139X downstream of the Spofford step transformers. This solution involves serving this portion of 3139X from the Emerald Street substation in Keene, NH via 10 miles of new spacer cable.

The estimated cost of this solution is $500,000 per mile with a 20% contingency, for a total cost of $6M.

The alternative solution would not have the duration restrictions inherent in a battery. However, the alternative solution would be vulnerable to storm-related outages and thus not be available at all times.

5.2 Peak shaving

5.2.1 Peak shaving for distribution system flexibility and reliability

The application of peak shaving may be valuable for a utility when there is a power flow constraint in the system to maintain power quality or avoid equipment damage, and it would be costly to upgrade equipment to remove the constraint. For example, when a distribution substation transformer nears its loading limit during high-load periods and load growth indicates that it will be necessary to replace the transformer with a higher-rated model before the end of its natural life.

An ESS connected such that by discharging the net load at the point of constraint is lowered can help to defer the transformer replacement. The same application may be applied to avoid upgrades to transformers, switchgear, or cables. To use an ESS for this purpose, a utility must have a very high degree of confidence in the availability and performance of the ESS, as well as practiced and high-functioning operational processes that ensure the ESS state of charge is managed to perform as needed, since failure to do so could result in equipment damage or loss of load. There are no existing constraints that require peak shaving to defer equipment upgrades on the 3139X circuit, but the Westmoreland ESS allows Eversource the opportunity to demonstrate and develop best peak shaving practices.

5.2.2 Peak shaving for RNS, LNS, and ISO-NE Capacity cost reduction

Peak shaving also has the potential to lower transmission and capacity costs, particularly by reducing costs on Regional Network Service (RNS), Local Network Service (LNS), and the ISO-NE capacity market. RNS charges are paid by transmission customers to transmission owners (ISO-NE Schedule 9) for transmission services and to the ISO (ISO-NE Schedule 1) for scheduling the movement of power through, out of, within and into the New England Control Area. RNS charges are calculated as the product of a transmission customer's Monthly Regional Network Load value (the hourly transmission customer network load coincident with the monthly system-wide peak load) and annually set Schedule 1 and Schedule 9 RNS rates. RNS rates have risen in recent years and 2018 ISO-NE Capacity, Energy, Loads, and Transmission (CELT) Report total RNS rate forecasts for 2019-2022 are provided in Table 5-1.

Table 5-1: ISO-NE RNS rate forecast

Year	Total RNS Rate ($/kW-yr)
2019	117
2020	123
2021	129
2022	135

Discharging an ESS during monthly network peak load hours will reduce RNS charges and result in customer savings.

This remainder of Section 5.2.2 is comprised of language provided by Eversource assessing RNS charge reduction and ISO-NE capacity savings opportunities:

Eversource has evaluated using generation, lithium-ion battery storage, and load controlled devices with a nameplate capacity of 5 MW or less for peak load reduction. This means that the assets will be called to put energy back onto the grid at peak times. Targeted peaks will include the monthly peaks used to determine RNS charges and the yearly summer peak that determines the ISO New England capacity supply obligation ("ISO Capacity") for load serving entities (LSE) serving our customers.

5.2.2.1 Using These Assets as Load Reducers Generally

Using generators as load reducers simply entails counting the generators' output as an offset to monthly or summer peaks instead of bidding the output into the wholesale market as a Settlement Only Generator ("SOG") and taking the market clearing price as compensation.

Using dispatchable batteries and controlled devices involves a similar practice. It is reasonable to expect that the company would need to discharge these assets several times per month, on average, to ensure that it hits the hours that will lower our system loads during monthly peak hours. In addition, the shape of the assumed peaks may require the assets to discharge for up to four hours during each peak shaving attempt to have reasonable confidence of lowering the monthly peak and not just shifting it to a nearby hour. Eversource expects that, through effective forecasting and deployment, it will be able to reduce our annual ISO-NE Forward Capacity Market coincident peak, which is the maximum hourly load on the ISO-NE system each year, and will be able, on average, to reduce ten of the twelve monthly RNS peaks each year. This estimate trends conservative; Eversource expects that it may be able to exceed it.

As a general matter, monthly and summer peaks are also well correlated with circuit peaking. This means that shaving peak to obtain ISO-NE Capacity and RNS cost savings will also at the same time relieve loading on circuits providing operational and infrastructure benefits. This provides additional value for customers.

5.2.2.2 RNS

Transmission facilities in ISO-NE are funded through a pool-wide "postage stamp" rate for regional network service. Under the RNS rate, the cost of a transmission project is allocated in proportion to each ISO-NE Transmission Provider's peak electricity demand (this is referred to as "network load").

To calculate RNS savings, Eversource utilized an ISO-NE forecast of RNS through 2022 (shown in Table 5-1), then assumed an increase of 4.66% year-over for the remaining years of the analysis. Eversource is also assuming it can use the storage to hit ten of the twelve annual peaks. Eversource estimates the average annual RNS charge reduction savings achievable by the Westmoreland ESS to $348k/yr.

5.2.2.3 ISO Capacity

Load serving entities (LSE) in the ISO-NE electricity market are responsible for their share of regional capacity requirements through ISO-New England's Forward Capacity market. This is a charge collected from load serving entities and paid to generators to ensure that ISO-NE has sufficient generating capacity and that new resources are sited in the optimal location. Each individual LSE's capacity charge is determined by their yearly capacity supply obligation, representing their pro-rata share of the New England energy market load at the yearly hourly peak for New England.

Eversource's FCM forecast includes Forward Capacity Auction (FCA) prices ranging from $100/kW-yr on the high end to $57.6/kW-yr on the low end, with year-over-year changes that vary. With respect to historical auction prices, the most recent auction, FCA 13, cleared at $45.6/kW-Yr, while previous auctions have been above $100/kW-Yr, with volatility from one auction to the next. The average of the last five auctions has been approximately $79.5/kW-Yr. Eversource's analysis uses the FCA 11 clearing price of $63.6/kW-yr and grows it at inflation (2%) as to represent a reasonable price given historical volatility. Eversource assumes it would successfully use the storage assets to hit the yearly ISO-NE peak (which has historically been in the summer). Eversource estimates the average annual ISO-NE Capacity savings achievable by the Westmoreland ESS to be $120k/yr.

5.2.2.4 LNS

Eversource LNS cost reduction analysis assumes an LNS rate starting at $10/kW-Yr and growing at inflation (2%). This is consistent with Eversource's review of internal historical data. While there is inherent uncertainty around LNS rates on a year-over basis, this analysis assumes a lesser rate as a conservative assumption. Eversource estimates the average LNS charge reduction achievable by the Westmoreland ESS to be $19k/yr.

5.3 Primary frequency response

There are multiple technical mechanisms to maintain system frequency at 60Hz. One is the frequency regulation market which acts to adjust the generation of participating assets on a 4s cycle. At faster timescales, there are additional mechanisms to stabilize the system after a contingency event that causes a deviation of system frequency away from 60Hz. There are requirements and mandates from FERC, and balancing authorities can choose how to supply the resource of responsive assets to meet their portion of the obligation. ISO-NE has obligations that flow down to requirements to member utilities. In February 2018, FERC issued Order 842 mandating that all new interconnecting synchronous and non-synchronous generation facilities demonstrate the capability to provide primary frequency response services.

For frequency deviations that are less severe, the requirement is as defined in NERC Standard BAL-003-1 Frequency Response and Frequency Bias Setting.[3] Traditionally the obligation has been met by thermal generators that have governors or the modern digital equivalent, which monitor frequency locally and moderate output according to a droop curve, which defines a ΔMW/Δf response, a modulation of power output for an observed frequency deviation. This regime applies to frequency deviations in the range of Δf<0.5Hz. Events of this magnitude occur regularly.

For more extreme frequency deviations, compensatory load shedding is required to balance DERs that are required to trip offline above the threshold illustrated by the black curve shown in Figure 5-4 as per PRC-006-NPCC-1. The way that Eversource implements this requirement is that 7% of load will be shed after frequency deviations <59.5Hz that are sustained for longer than 0.3s, an additional 7% at 59.3Hz, and an additional 7% at 59.1Hz. This regime of frequency deviation is reached only very rarely. In the Eastern Interconnect, which is a very large and stiff synchronous system, frequency deviations of this magnitude occur only when a portion of the system has separated in some fashion from the bulk system. For example, the two times that it occurred in Eversource territory in the past ten years involved loss of transmission line and an isolated, local pocket of the grid remaining energized briefly by local generation before experiencing an outage. In that circumstance, an energy storage system that attempted to stabilize frequency could cause safety concerns and it is not recommended that energy storage assets attempt to take any action to support system frequency. Anti-islanding protection would preclude participation.

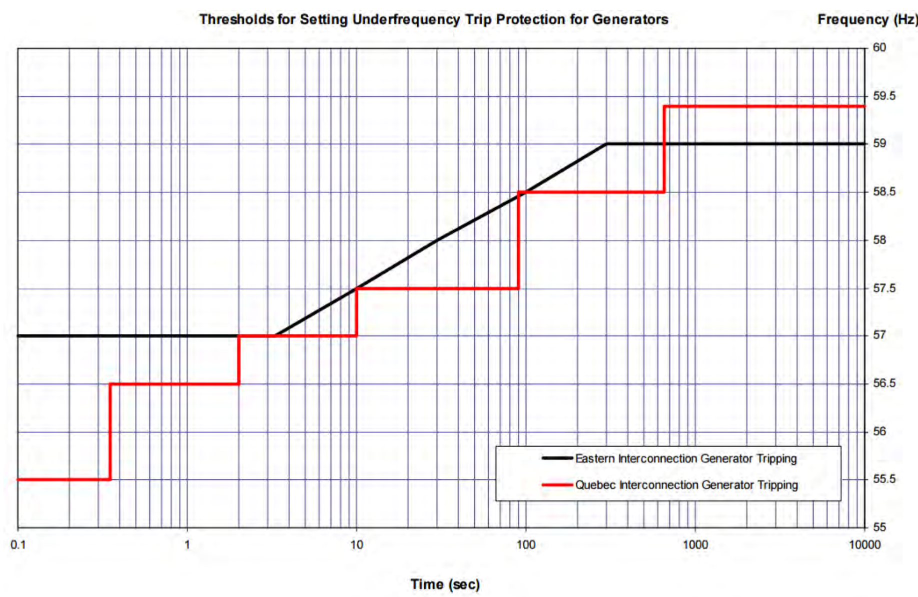

Figure 5-4 – Under frequency trip protection for generators from PRC-006-NPCC-1.

At present, there is not a shortage of governor-equipped power plants than can provide the necessary resource to respond to less severe frequency deviations, but it is anticipated that in a future energy system with very high

[3] http://www.nerc.com/pa/Stand/Project%20200712%20Frequency%20Response%20DL/BAL-003-1_clean_031213.pdf

levels of distributed and inverter-based generation, there will not be adequate supply of traditional responsive resources. FERC Order 842, issued in February 2018 in response to this expected shortage, requires energy storage assets to include primary frequency response capability. Energy storage is technically capable of providing this resource, but performance in operational conditions has not been well studied. It is recommended that the Westmoreland ESS demonstrate the application of primary frequency response using a droop-curve-like control. Demonstration of this application would establish performance expectations for inverter-based assets and provide an opportunity to develop best practices around the implementation of the control. It would allow for exploration of concerns about impact to local power quality when a frequency deviation event occurs and ESS output ramps quickly in response, and development of mitigation measures.

5.4 Sizing, costs, and benefits summary

The ESS applications discussed in Section 5 create multiple technical and economic benefits. The potential benefit must be weighed against cost and practical considerations such as risk, operational complexity, administrative overhead, and commercial availability to determine the optimal power and energy rating for the Westmoreland ESS. The valuation of each application discussed in this section is listed in Table 5-2. The primary considerations are as follows:

1. A 1.7MW / 7.1MWh ESS is recommended to operate the section of circuit 3139X downstream from the Spofford step tansformers as an electrical island during loss of service in the upstream distribution system. 1.7MW covers projected peak load on this circuit section through 2028 and, assuming the projected 2028 load profile, 7.1 MWh is a sufficient energy capacity to ride through any 4-hour outage.
2. The 1.7MW / 7.1MWh ESS that enables the above use cases is capable of achieving approximately $485k in average annual cost savings through peak shaving to reduce ISO-NE RNS, LNS and capacity charges.

For these reasons, a power and energy capacity of 1.7MW / 7.1MWh is recommended. The cost of the recommended system is discussed in further detail in Section 7.1.

Table 5-2: Benefit summary

One-time Benefits	Value ($000)
Deferred Distribution Upgrades	$ 6,000
Annual Benefits	**Average Annual Value ($000/yr)**
RNS Charge Reduction	$ 348
ISO-NE Forward Capacity	$ 120
LNS Charge Reduction	$ 19

In addition to benefits easily expressed as a dollar value, there are multiple technical benefits that have been discussed throughout this section. These include

- Gain experience designing, procuring, operating ESS
- Increase DER hosting capacity
- Develop peak shaving best practices
- Increased system reconfiguration flexibility

- Demonstrate primary frequency response
- Improve power quality
- Enhance coordination across utility functional groups

Section 6 Conceptual Design

6.1 Battery chemistry

Based on the use-cases and reliability objectives for the Eversource Westmoreland ESS project, Lithium ion was determined to be the most suitable energy storage technology for this project.

Table 6-1 shows a comprehensive comparison of considered technologies. Out of the mature and demonstrated technologies, Lithium ion is shown to be the most cost-effective and high-performing technology given the expected use-cases and duty cycles. Sodium-Sulphur (NAS) batteries perform at the low end of their efficiency scale in the long periods without charging and discharging as specified in expected use patterns due to heating requirements to maintain operating temperature. Additionally, NAS batteries are produced at scale by a single vendor, eliminating the benefits of cost competition between large vendors seen in the Li-ion market. Lead-acid batteries are suitable for many of the same use-cases as Lithium ion but have much lower energy density. They have not seen the same decrease in price over the last decade and don't offer a significantly lower cost to justify their lower performance in this application.

Commercially unproven technologies at the multimegawatt scale such as Zinc-hybrid cathode and flow batteries were determined to be unfit for this application due to factors that would increase risks to project completion and reliability. Flow batteries are not recommended at their current technology readiness level; there has not been a large-scale demonstrated high-reliability flow battery installation. Zinc hybrid cathode batteries are both commercially unproven and are produced by limited vendors with uncertain futures. Vendor quality uncertainty, bankruptcy or acquisition could cause delays, technological problems or project unfeasibility during any stage in the design or implementation process.

Lithium ion has rapidly become the chemistry of choice for megawatt-scale utility ESS's. With over 500 MW of installed Lithium ion projects in the U.S. to date,[4] Lithium ion batteries in stationary electric grid applications is well established. It has an extremely favorable cost-curve trajectory and, due to continuing manufacturing-scale additions, the cost is expected to continue its decline. Lithium ion technology continues to dominate the energy storage market and captured over 97% of market share in 2018, both driving and being driven by declines in prices.

Lithium ion also has the highest flexibility of all battery choices considered, making it an excellent choice to demonstrate a wide range of use cases. Lithium ion batteries typically achieve > 90% round-trip efficiency, making them well suited for energy applications, and they can support the ramping requirements (power/time) of all use-cases identified for this ESS. Like most electrochemical battery chemistries, Lithium ion batteries do suffer lifecycle degradation, but the degradation expected from a Lithium ion battery is no more significant than other battery chemistries offering the same degree of flexibility; and the modular nature of Lithium ion batteries

[4] Bloomberg New Energy Finance

makes it possible to maintain capacities over the lifetime of the ESS by replacing batteries as needed or augmenting energy capacity.

Table 6-1: Comparison of battery chemistry options

Technology	Example Vendors	Technological Maturity	Size	Round-trip efficiency	Advantages	Disadvantages
Li-ion	Samsung, LG Chem, Panasonic, BYD, CATL	Mature	5 kW – 100+ MW	80-92%	Relatively mature technology, high efficiency, fit for many use cases	High capital costs accelerated degradation with high cycling frequency
Flow Batteries	Sumitomo, UET, Primus Power	Limited commercial deployment	25 kW – 100+ MW	70-77%	Power and energy independently scalable, no degradation of capacity over thousands of cycles, no fire risk	Relatively high balance of system costs, reduced efficiency during rapid charge/discharge use cases (high auxiliary power load)
NAS	NGK (sole vendor)	Mature	1 MW – 100+ MW	75-90%	Relatively mature technology, high energy capacity and long duration	Maintaining high operating temperature leads to high auxiliary power costs in infrequent use cases, flammability issues
Zinc	Eos, Fluidic Energy	Unproven	5 kW – 100+ MW	75%	Projected low cost	Unproven cost from limited vendors, lower efficiency, unproven commercially
Lead Acid	GS Yuasa, Enersys, East Penn Mfg.	Mature	5 kW – 2 MW	63-90%	Established recycling infrastructure, low cost relative to li-ion	Poor depth of discharge, short lifespan, poor ability to operate at partial SOC

6.2 Major system components

The System design details that follow give a top-level overview of the components and design considerations for an ESS project at the Westmoreland site. The descriptions and diagrams presented are representative of typical systems and, once the component vendors have been selected and detailed designs have been established, may vary from what is eventually deployed.

The ESS is comprised of the following major components: Battery System; Power Conversion System (PCS); Control Cabinet; Step-Up Transformer; and other BOS components. Figure 6-1 shows the basic layout of a generic ESS with the major components identified. ESS design specific to the Westmoreland project is provided in the following sections.

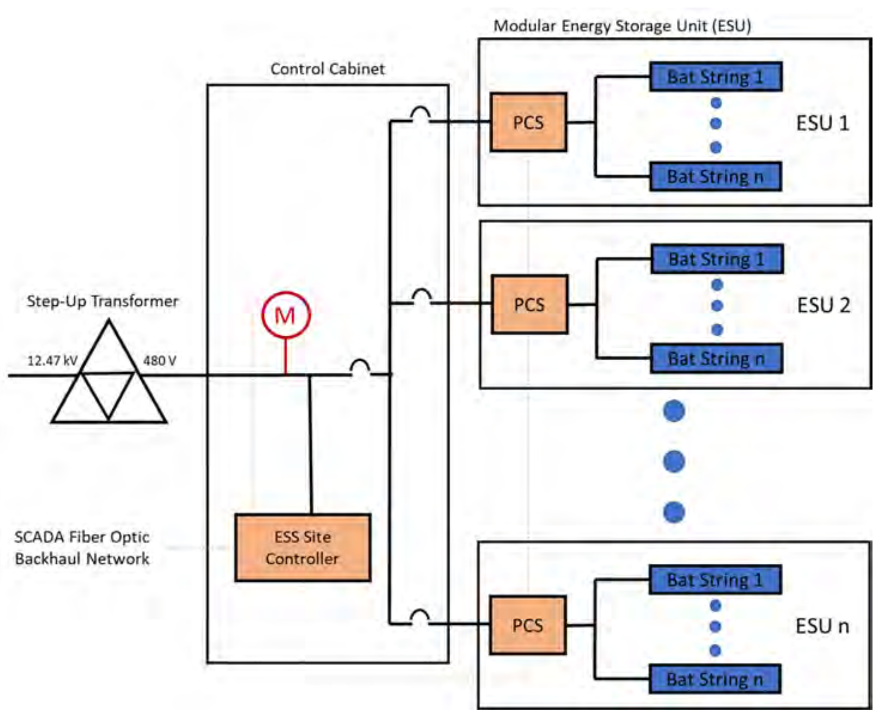

Figure 6-1 – ESS block diagram

The blue boxes (B1, B2, B3) in Figure 6-1 represent the battery racks in each Energy Storage Unit (ESU). The actual number of battery racks will vary depending on the vendor and system configuration.

6.2.1 Battery System

The battery system includes racks of battery modules, a Battery Management System (BMS) for monitoring and control, DC connections, and switchgear to connect each rack to the common DC bus. The battery container includes heat, ventilation, and air-conditioning (HVAC) systems that keep the batteries within their rated temperature range. The battery container will also be equipped with sensors, fire alarms, and fire-suppression equipment. Fire suppression systems for lithium ion batteries are triggered by a combination of heat and smoke detection. Alarms will alert any on-site personnel and operators in the control room. Fire suppression can be accomplished by a non-damaging clean agent type system, in which a fire suppressant gas is released to fill the container volume and suppress a fire so that it does not propagate from a faulty cell to adjacent battery cells. Alternatively, or additionally, a water-based fire suppression system may be used, which is non-toxic but has the disadvantage of destroying all equipment within a container.

Battery form factor can be in a modular format (e.g. Tesla layout) or in a containerized format (e.g. LG Chem, Samsung). Batteries should be enclosed in a NEMA 3R[4] container. Lithium ion battery modules are fully sealed and do not release any emissions under normal operation.

6.2.2 Power Conversion Systems (PCS)

The Power Conversion System (PCS) stands between the ESS and the grid, converting the ~1000VDC of the battery system to the 480VAC, 60 Hz of the electric grid, and vice versa. It also provides critical system protection and operating functionality, such as anti-islanding protection (to prevent unintentional islanding) and power conditioning. The PCS connects to the battery container using a DC connection at a voltage that varies according to battery SOC. The utility side of the PCS has a 480VAC, 3-phase AC output that connects to the ESS connection transformer.

Figure 6-2 – Typical 1.25MVA containerized PCS from S&C electric company

Inverter power quality should conform to UL-1741-SA requirements and standard utility requirements. Total Harmonic Distortion (THD) and Total Demand Distortion (TDD) are less than 5%. Inverters should be equipped with AC and DC disconnect switches as well as a DC contactor.

6.2.3 Control System Software and the MESA Standard

Eversource will operate the ESS as an integrated system with Control System Software that provides monitoring and alarm capabilities. The Modular Energy Storage Architecture (MESA) provides a standards-based communications network that enables Eversource to interact with this and any future ESS using a similar DNP3 communications profile, significantly reducing engineering costs. The MESA protocol also employs multiple advanced ESS control algorithms that dispatch the ESS to achieve the desired use cases on the grid.

[4] For NEMA 3R Definition: http://www.nema.org/Products/Documents/nema-enclosure-types.pdf

Information on the MESA standard can be found at www.mesastandards.org. By standardizing the communications interface between multiple components within the ESS, and between the ESS and Eversource's SCADA platform, the MESA Standard enables Eversource to control the ESS and subsequent ESSs that may be installed in a consistent manner. The MESA Standard also drives out non-recurring engineering costs as additional ESSs are deployed by standardizing system design.

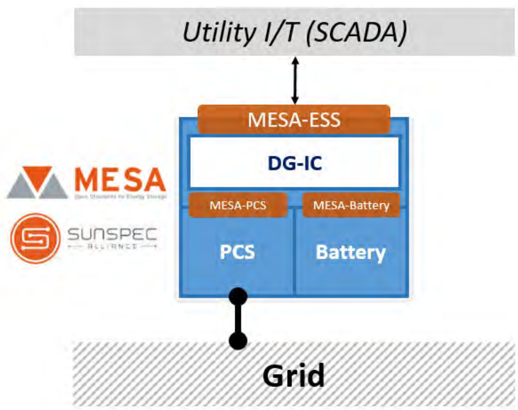

Figure 6-3 – MESA Standard block diagram between ESS components and utility

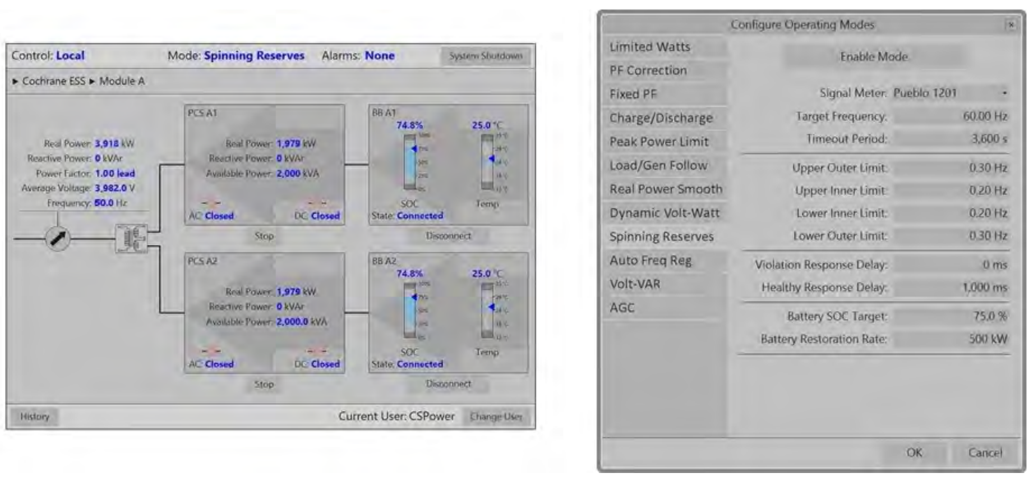

Figure 6-4 – Doosan GridTech Intelligent Controller (DG-IC) example control screens.

6.2.4 ESS Disconnect Switch Cabinet

To comply with Eversource safe work practices, a visible and lockable means of disconnecting the ESS from all components on the utility side of the point of common coupling (defined as the 480V terminals of the utility transformer) will be provided. The ESS Disconnect Switch will electrically isolate the ESS connection transformer. An ESS output meter and automatic tripping coordinated via installed relays may be installed if required. Exact specifications will be determined during the detailed design phase of the project.

The switch enclosure will be appropriately grounded to the ground grid and will be equipped with ground fault detection if required.

6.2.5 Control Cabinet

Utility personnel will locally control ESS operations via a Control Cabinet that houses the ESS networking and control hardware. The Control Cabinet will include the controller platform (typically an Advantech UNO 4600 series computer), the system display and control interface (typically a 19" touchscreen), and all equipment necessary to communicate with the PCS, batteries, and internal system meters, as well as external points, like solar output meter telemetry.

The Control Cabinet is typically an outdoor rated, pad-mounted cabinet. 120V AC auxiliary power is typical. The Control Cabinet will also include an uninterruptable power supply (UPS) to power critical control and monitoring components in the event of a grid outage. The UPS will be sized during the detailed design phase to achieve a minimum of 1 hour for a safe and controlled shutdown of ESS components during an outage. Longer back-up times are possible by adding additional UPS units. DC auxiliary power options are available and may be advantageous to include in addition to AC. Such a design may offer resiliency to lengthier loss of AC power, up to 8 hours, and would be consistent with substation designs that Eversource staff are accustomed to.

Figure 6-5 – Typical control cabinet

6.2.6 Step-up Transformer

The step-up transformer converts between the distribution voltage (12.47 kV nominal) to ESS inverter output voltage (480V). Typical ESS components are compatible with both WYE-WYE and DELTA-WYE transformers. Alternative transformer configurations are also possible, including Grd-Y/Grd-Y, and depending on Eversource's preference for distributed generation, may be evaluated and selected during the detailed design phase.

The detailed design phase will also consider the appropriate transformer K-factor, exact windings ratio, and tap position to ensure safety and reduced wear and tear on the transformer. Typically, the step-up transformer will include a no-load tap changer that can be adjusted +/-5% if required by change in substation design or load reconfiguration. ESS connection transformers are commonly over-sized due to the potential operation of the ESS across a wide range of its four-quadrant response capabilities. Lessons learned from early deployments of ESSs of this scale suggest that a larger transformer rating is advisable.

6.2.7 Site Enclosure and Access

The entirety of the ESS will be enclosed by a fence no shorter than 8 feet. The access should allow for service vehicles, e.g., a vehicle to add or remove battery modules, to access the ESS. All ESS components should have pad-lockable doors to prevent unauthorized access.

6.2.8 Metering

Metering is required within the ESS and the surrounding grid infrastructure to:

- Provide an input signal to the site controller of local grid conditions to dispatch various Modes of Operation;
- Provide indication of ESS system output (active and reactive power) to ensure system operation is as expected;
- Enable measurement of key performance parameters for ESS evaluation, and;
- Track usage of auxiliary power to factor in to ESS efficiency.

Table 6-2: Metering requirements

Meter	Purpose	Meter type
ESS output	Provides kW, kVAR, pf, voltage, and frequency at the ESS output. Used for multiple modes to control ESS performance.	3Φ Bi-directional or equivalent (ION 8650 or equivalent)
ESS auxiliary power	Records the auxiliary power used for internal ESS loads (such as HVAC). TBD depending upon the technology selected.	Revenue meter with modbus communications capability (ION-6200 or equivalent)
ISO-NE revenue meter	TBD, dependent on ISO-NE market requirements and Eversource market strategy.	TBD

6.2.9 Auxiliary Power

Auxiliary power for most battery and PCS components is powered from the 480V AC bus at the PCS output and therefore does not require a separate 480VAC service from Eversource. The 480V auxiliary power bus normally requires a 1:1 isolation transformer between the PCS output and the ESS components. Components in the control cabinet require a 120V 1Φ supply of auxiliary power that is typically sourced from the battery container. The control cabinet components will include an embedded UPS to provide short-term power if the normal source of auxiliary power is lost.

6.2.10 Grounding Protection

The ESS will connect to an underground grounding grid that will be connected to a newly constructed ground grid for the ESS. Additional grounding conductors, to be specified during the detailed design phase, will be installed within the ESS site. A detailed ground report will be provided during the detailed design phase, including grounding impedance requirements.

The chassis/enclosures of all ESS components will be connected to the grounding grid to reduce touch potential hazards. The PCS's and 480V disconnect enclosure will have neutral points connected to the ground grid. The battery modules will be chassis grounded, though batteries often operate with a floating DC system that is not grounded.

6.3 Interconnection and Protection

Based on a preliminary review of the existing 3139X infrastructure, and a consideration of intended use cases, the recommended interconnection approach is shown in Figure 6-6. A 480V / 12.47kV step-up transformer is used to transform the PCS output to 12.47kV. A three-phase recloser will be installed that can electrically isolate the ESS from the distribution line. The energy storage system will have a robust set of protective equipment that will protect the device from grid conditions such as overcurrent, under and overvoltage, for example.

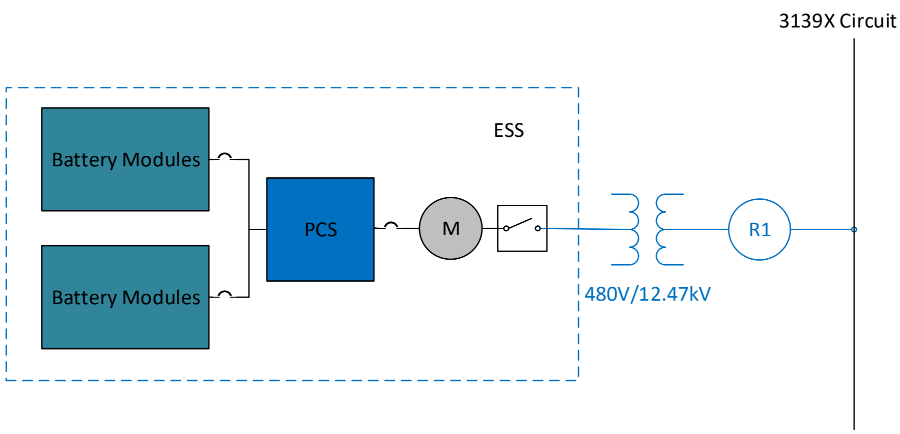

Figure 6-6 – Interconnection diagram

Standard protection used by Eversource allows reverse power flow under current settings. It is not anticipated that any existing protection equipment will have to be replaced or reconfigured to permit reverse power flow.

An interconnection and system protection study should be completed during the detailed design stage to verify configuration.

The system protection study during the detailed design phase should pay special attention to the protection scheme during islanding. The inverters spec'd in the conceptual design and project budget have a 200% short-term overload capacity (consistent with inverters Eversource is currently deploying for islanding-capable projects in the field). This can help with low fault current concerns, but a detailed study to identify necessary protection scheme changes should be performed.

6.4 Site and physical layout

6.4.1 Site characteristics

A strong candidate site for the Westmoreland ESS has been identified northwest of the Westmoreland town center near the Connecticut River. Figure 6-7 shows the identified parcel of land. This location is preferred due to its proximity to critical loads and expected ease of land acquisition. This plot is located adjacent to the Cheshire County nursing home critical load and is one mile from the concentrated critical loads in the Westmoreland town center. Indications from preliminary contact with the current owner are that the property is available.

Figure 6-7: ESS candidate location

The area to the northeast of the access road was identified as a floodplain, but the land marked in Figure 6-7 is viable for ESS construction.

The following image shows the candidate site in relation to the town center that includes the elementary school (that serves as the town emergency shelter), the town fire station, Town Hall, the post office, a general store, and a Consolidated Communications building.

Figure 6-8: Proposed site relation to critical loads

6.4.2 ESS physical layout

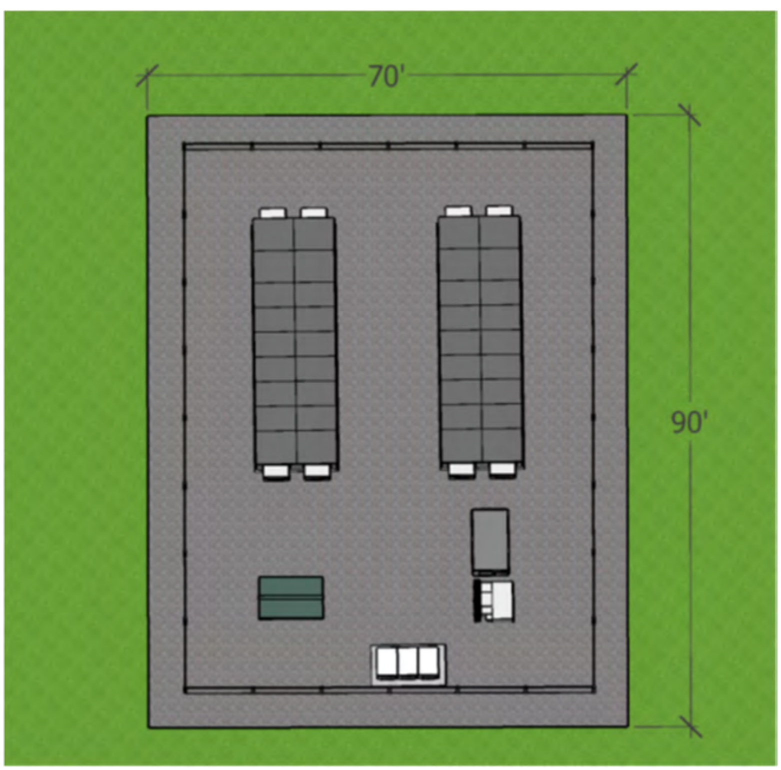

Figure 6-9: Westmoreland ESS physical layout and footprint dimensions

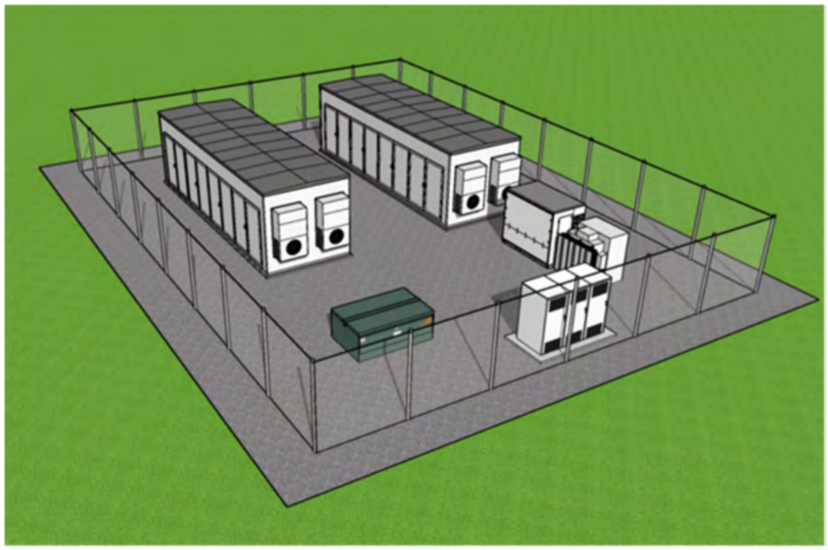

Figure 6-10: Angle view of ESS equipment layout

6.5 Communication

There is no existing communications infrastructure at the preferred Westmoreland site, so new communications equipment must be installed to implement the use cases of the demonstration ESS. Eversource uses a DSCADA system to remotely monitor and control equipment in other parts of the system; so, the Westmoreland ESS will be integrated into the existing system. A Remote Terminal Unit (RTU) will be installed at the site and data transmitted through wireless or radio link

The Westmoreland ESS site controller shall interface with the Eversource DSCADA system for indications, alarming, control and configuration parameters. A separate interface shall allow a remote user access for troubleshooting and monitoring. These interfaces will operate over a secure connection to Eversource's backhaul OT network.

All operational interaction with the site controller will be accomplished through an existing DSCADA platform. Interfaces between the DSCADA system and the site controller will leverage DNP3. All Eversource DNP3 interaction will be over IP connections regardless of the physical medium. The site controller implementation of the MESA-ESS DNP3 interface will be tested and certified. If Eversource chooses to pursue direct participation in ISO-NE markets in the future, these operations will be managed by a market services contractor.

Remote desktop protocol (RDP) or Internet Protocol Security (IPsec) will be available via a VPN connection to users external to Eversource's network for troubleshooting and remote monitoring. Such access may be continuous to allow for a permanent flow of data or may be limited instances (single-session) for troubleshooting or extracting log files. External remote control of the ESS will be allowed only if desired by Eversource. User accounts and permissions for the VPN tunnel will be configured and managed by Eversource.

Eversource will configure all network connectivity appliances (such as switches, routers, firewalls, etc.) as needed to establish IP connectivity to the site controller. Any network connectivity appliances supplied as part of the ESS will be subject to the approval of Eversource's Network Operations team to ensure interoperability with Eversource's existing network equipment.

The MESA-ESS interface will include the DNP3 points list that Eversource will use within the DSCADA system to monitor, dispatch and configure the ESS via the site controller. This list shall be submitted to Eversource as part of the "DNP Device Profile Document".

Operator control and decision-making between use cases needs to be determined at a later stage of detailed design.

6.6 Certification and Testing

6.6.1 Certifications

Because grid-tied energy storage systems are comprised of several different components, multiple Nationally Recognized Test Laboratory (NRTL) certifications apply to them. There are a significant number of certifications that can apply to utility-sited ESS.[5] An overview of recommended certifications and standards is included in Table 6-3.

Table 6-3: Recommended ESS standards and certifications

Number	Title	Notes	Link
IEEE 1547-2018	Standard for Interconnecting Distributed Resources with Electric Power Systems		https://standards.ieee.org/standard/1547-2018.html
IEEE 1547.1-2005	Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems		http://standards.ieee.org/findstds/standard/1547.1-2005.html
IEEE 1547.1a-2015	Amendment 1 to IEEE 1547.1-2005		https://standards.ieee.org/findstds/standard/1547.1a-2015.html
IEEE 2030.3-2016	Standard for Test Procedures for Electric Energy Storage Equipment and Systems for Electric Power Systems Applications		http://standards.ieee.org/findstds/standard/2030.3-2016.html
IEEE 2030.2-2015	Guide for the Interoperability of Energy Storage Systems Integrated with the Electric Power Infrastructure		http://standards.ieee.org/findstds/standard/2030.2-2015.html
IEEE P2030.2	Draft Guide for the Interoperability of Energy Storage Systems Integrated with the Electric Power Infrastructure	Draft	
IEEE 1679-2010	Recommended Practice for the Characterization and Evaluation of Emerging Energy Storage Technologies in Stationary Applications		https://standards.ieee.org/findstds/standard/1679-2010.html

[5] Inventory of Safety-Related Codes and Standards for Energy Storage Systems. Pacific Northwest National Laboratory (PNNL-23618), September 2014.

IEEE 519-2014	Recommended Practice and Requirements for Harmonic Control in Electrical Power Systems		https://standards.ieee.org/findstds/standard/519-2014.html
NFPA 70: NEC 2014	National Electric Code (applied to balance of system design principles, not applicable as an equipment standard)		http://catalog.nfpa.org/NFPA-70-National-Electrical-Code-NEC-Handbook-2014-Edition-P15728.aspx
IFC Section 608 2015	International Fire Code – Stationary Storage Battery Systems		http://sfmd.az.gov/documents/2016/03/2015-ifc.pdf
MESA-ESS 2016	MESA-ESS Draft Specification	Draft 1	http://mesastandards.org/mesa-ess-2016/
MESA-PCS Specification 2017	SunSpec Inverter Models 103, 113, 120, 121, 122, 123, 124, and MESA-PCS Extensions model 64800	Draft 2	http://mesastandards.org/mesa-device/
MESA-Storage 2016	SunSpec Energy Storage Models 802, 803, 804, 805	Draft 4	http://mesastandards.org/mesa-device/
MESA-Power Meter 2015	SunSpec Power Meter Models	Draft 4	http://mesastandards.org/mesa-device/
MESA-Device Model 64802	Example of a customized vendor model for a battery container	Other custom models can be created as necessary	
IEC 60086-4:2014	Primary batteries - Part 4: Safety of lithium batteries		https://webstore.iec.ch/publication/671
IEC 61000-6-3:2006	Electromagnetic compatibility (EMC) - Part 6-3: Generic standards - Emission standard for residential, commercial and light-industrial environments	Edition 2	https://webstore.iec.ch/preview/info_iec61000-6-3%7Bed2.0%7Den_d.pdf
UL 9540 2016	Standard for Energy Storage Systems and Equipment	Edition 1	https://standardscatalog.ul.com/standards/en/standard_9540
UL 1741-2010	Inverters, Converters, Controllers and interconnection System Equipment for Use with Distributed Energy Resources	Edition 2. Must comply with Supplement A (released 2017)	https://standardscatalog.ul.com/standards/en/standard_1741_2
UL 1642-2012	Standard for Lithium Batteries	Edition 5	https://standardscatalog.ul.com/standards/en/standard_1642_5
UL 1973 -2013	Standard for Batteries for Use in Light Electric Rail Applications and Stationary Applications	Edition 1	https://standardscatalog.ul.com/standards/en/standard_1973_1
UN Manual of Tests and Criteria, 6th Ed, 38.3	Recommendations on the Transport of Dangerous Goods, UN Manual of Tests and Criteria, Lithium metal and lithium ion batteries	Lithium-ion batteries classified as UN 3480 in Hazard Class 9	http://www.unece.org/trans/areas-of-work/dangerous-goods/legal-instruments-

			and-recommendations/un-manual-of-tests-and-criteria/rev6-files.html
49 CFR Subtitle B Chapter I (2017)	Code of Federal Regulations, Title 49 (Transportation), Pipeline and Hazardous Materials Safety Administration		https://www.ecfr.gov/cgi-bin/text-idx?SID=f2a9254e05937b161fab6ac647fd853c&mc=true&tpl=/ecfrbrowse/Title49/49tab_02.tpl
47 CFR, Chapter I, Part 15 (2017)	Code of Federal Regulations, Title 47 (Telecommunications), Radio Frequency Devices	Class A - Device marketed for use in business/industrial /commercial environments	https://www.ecfr.gov/cgi-bin/text-idx?SID=f2a9254e05937b161fab6ac647fd853c&mc=true&node=pt47.1.15&rgn=div5

6.6.2 Acceptance Testing Requirements

Testing of the ESS will be done in four phases between the design phase and the final turnover to Eversource, as follows:

1. Factory Integration Test. Occurs at the manufacturer's facility. The primary purpose is to witness the functionality, performance, controls, safety, and alarm communications of an Energy Storage Unit (ESU) prior to shipment. An Eversource-provided EMS/SCADA test set may be utilized for end-to-end communication checks.
2. Commissioning Testing. Designed to verify the proper installation, operation and interconnection of all components of the ESS after it is fully installed in the field. Ensure all components meet all contractual specifications and performance obligations. A third-party commissioning agent will be used.
3. Final System Acceptance. Final testing verifies proper functionality of the ESS under the full stack of controls from the utility SCADA system, through the site controller, to the individual components.
4. Field Performance Testing. Designed to evaluate the long-term performance of the ESS in various modes of operation. This may occur several weeks or months after commissioning.

Eversource and the EPC firm will jointly develop detailed plans for each stage of testing. Completion of each test, including the submission of a test report, is required prior to completing each milestone.

Test plans will, at a minimum, include the following:

1. Failure Modes and Effects Analysis
2. Non-operational Tests and Preparation
    a. Test insulation resistance.
    b. Check control power.
    c. Check protection and setpoints.
    d. Check control/communications wiring and signals.
    e. Check firmware load/software communications.
    f. Test E-stops and door interlocks.

   g. Test for loss of power.
   h. Test for restoration of power.
   i. Test subsystems (for example, the cooling system).
3. Local Operational Testing
   a. Verify operation of all protective functions specified in IEEE 1547 and UL1741-SA, including transfer trip and anti-islanding.
   b. Verify operation of all safety features and alarms (via actual or simulated trigger) that can be reasonably tested in the field.
   c. Shutdown testing: manual, emergency, site controller failure, PCS alarm, communications failure, HVAC failure.
   d. Verify operation of each PCS/battery module using local controls.
   e. Verify low power charge and discharge.
   f. Verify reactive power dispatch.
4. Site Controller Operational Test – Local System
   a. Verify that the site controller is configured and successfully communicates with the full ESS.
   b. Issue a system start and system stop command.
   c. Test charge, discharge, and reactive power dispatch, ramping from low to high power levels.
5. Performance Testing
   a. Operate the system at full charge and discharge capacities.
   b. Dispatch the system from 100% SOC to 0% SOC and the reverse.
   c. Operate the system at half power charge and discharge states, and document energy transferred.
   d. Evaluate round trip efficiency.
6. Eversource-site controller Operational Test – Full System
   a. Verify that the Eversource-site controller communications link is configured and successfully transmits commands and all SCADA points.
   b. Issue a system start and system stop command.
   c. Test/Demonstrate all operational modes of system by remote control via SCADA.

Eversource will be responsible for the following regarding Final System Acceptance testing of the ESS:

- Inspection and approval of final installation before initial energization
- Initial energization
- Measurement of equipment and site noise emissions

Section 7 Conceptual Project Plan

Eversource typically chooses to engage an Engineering, Procurement, and Construction (EPC) firm for new infrastructure such as transmission lines, solar PV farms, and, in future, energy storage systems. The conceptual project budget and project schedule discussed in this section have been developed with the assumption of an EPC procurement model. EPC firms take full responsibility for design and engineering (with input and review by Eversource in-house engineers), procurement of all hardware, management of all subcontractors, and oversee the construction process. The EPC procurement model provides the lowest risk and complexity for Eversource.

7.1 Project budget

The following budget is indicative of the budget that would be required to implement the recommended Westmoreland ESS using the preferred procurement and project execution structure. This section discusses 25-year lifetime expenditures in three categories: EPC capital budget in Section 7.1.1, Eversource direct capital expenditures in Section 7.1.2, and operating and maintenance budget in Section 7.1.3. Eversource typical overhead, and loaders were applied, with a contingency of 20%, and the total, loaded budget requirement is summarized in Table 7-1. The total beginning of life (BOL) capital budget is $7.0M, and the O&M budget is $140k/year. A $1.2M module replacement capital expenditure is expected after 12 years, though this number may change significantly due to market changes and evolving technical needs.

Table 7-1: Project Budget Summary in $000

Budget Elements		2020
Total EPC capital budget, fully loaded		$4,328
Eversource Direct Capital Expenditures (line items fully loaded)	Eversource staff labor including EE, PM, legal	$1,491
	Permitting	$176
	Systems Integration	$171
	Site Development and Building	$562
	Interconnection Switchgear, Aux Power Equipment, and Communication	$273
	Total Eversource direct spend, fully loaded	$2,674
Project Capital budget total, fully loaded		$7,002

7.1.1 EPC capital budget

The budget presented here provides externally sourced services and materials that fall under the EPC firm's responsibility. Estimates are based on recent market activities and assume a 1.7MW / 7.1MWh ESS is procured, installed, and implemented as per the recommendations in this report. Cost estimates are representative of multiple suppliers who meet recommended requirements.

Doosan recommends securing an unloaded BOL EPC project budget of $3.5M. Table 7-2 breaks down the EPC budget into major categories, and Figure 7-1 charts the allocation of the total budget among major categories. EPC project management, commissioning, and labor is spread evenly among the equipment categories.

Table 7-2: EPC budget (unloaded)

Description	Total Cost
Enclosure(s) including climate control equipment and fire suppression systems	$212
Battery Systems and Battery Management System	$2,088
Power Conversion Systems and Transformers	$354
Balance of System	$319
Contract Labor and PM	$566
Total ESS Budget (unloaded)	$3,539

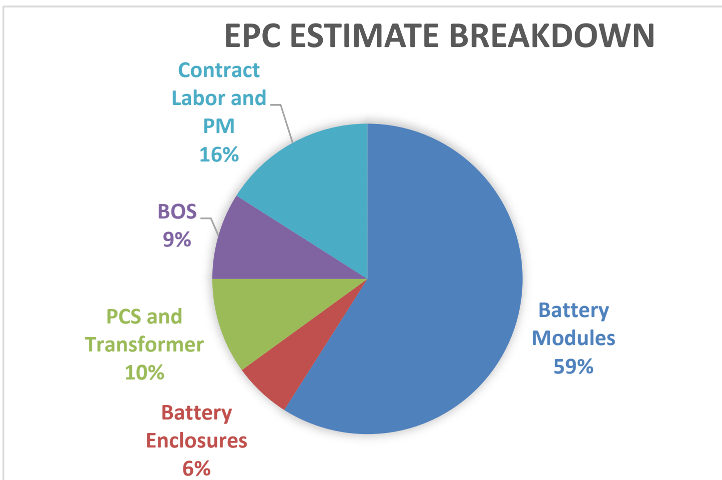

Figure 7-1 –EPC budget allocation among major project elements.

The EPC budget was developed with the design parameters and assumptions detailed in Table 7-3. The nameplate power and energy capacity drive the budget. The energy capacity of Lithium ion batteries degrades over the asset lifetime, due to a combination of factors including calendar life aging, the effect of cycling, and exposure to stressors such as high or low temperatures.

This estimate assumes the BOL system will be oversized to maintain a 7.1MWh AC energy capacity at the POI for 12 years. Battery module replacement at after 12 years will be required to maintain this 7.1MWh energy capacity for the 25-year project lifetime. Doosan currently projects this replacement to cost $1.2M, but this estimate is highly uncertain at this time. Eversource's ESS objectives and technical requirements may also evolve before within the first 12 years, and a different energy capacity or ESS technology may be implemented.

The training that is included in this budget estimate is substantial, since this this would be one of the first assets of this type in the Eversource NH service territory. It would include in-class, on-site, and interactive video training over six modules for operators, maintenance staff, engineering staff, utility first responders, and community first responders. The modules would cover an overview of the system, design and commissioning, operations, on-site safety and maintenance, on-site safety and emergency response, and technical library. Curriculum and interactive modules would be an enduring resource for Eversource for new staff.

Table 7-3: Design parameters used to create EPC budget

Parameter	Value
Electrical	
MW	1.7MW
MWh (AC) at interconnection at end of life	7.1MWh
Interconnection voltage (kV)	12.47kV
Interconnection switchgear	in Eversource scope
Aux power equipment	in Eversource scope
Performance	
DC efficiency (%)	90%
AC efficiency (%)	96%
Project life	25 years (module replacement after 12 years)
Cycle/day	Zero-one at 100% depth of discharge
Retention factor (%)	78%
Annual availability	97%
Augmentation	not in budget provided, possible if desired
O&M, Warranty	
Standard warranty	2 years
Maintenance	Included in O+M estimate
Extended warranty	annual over project lifetime after year 2
Other	
Training	in EPC scope
Site preparation	in Eversource scope
Permits	in Eversource scope
Civil Construction	in EPC scope
Electrical Construction	in EPC scope
Project start date (Award)	Jan-20
Project end date (COD)	Sep-21
Tax	not in budget
Shipping	included in budget
Performance bond	not in budget

7.1.2 Eversource direct capital spending

There are elements of an ESS that would not fall under the responsibility of the EPC firm, but rather require direct expenditure by Eversource in the form of labor and/or materials. Some of those items are indicated by blue background in Table 7-3. They are discussed in this section. The costs given in this section are unloaded budget estimates, and the fully loaded estimates are summarized in Table 7-1.

- Interconnection switchgear: $125k installed cost: Eversource purchases this equipment in volume and must interconnect DERs according to internal standards and guidelines, which require a three-phase recloser. This work falls under the purview of Eversource staff. The boundary line between the EPC firm's scope and Eversource scope is the high side of the step-up transformer.

- Auxiliary power equipment: $10k installed cost. Equipment required to power auxiliary loads such as the climate control system of the battery enclosures, auxiliary loads of the battery and PCS, and the control cabinet and site loads is most efficiently purchased and installed by Eversource. For a system of this size, the equipment would typically include a transformer rated at 100kVA, a revenue meter, and a panel with breakers at 480V and 120V.
- Radio equipment: $40k. Radio equipment required for secure communications between Eversource control center and ESS site.
- Site development: $460k. Work in this scope will consist of preparing the Westmoreland property, requiring some grading and retaining walls to provide a level yard. It will include tree clearing as necessary, trap rock, ground grid, and enclosure with substation fencing.
- Permitting and evaluation: $100k. Necessary permits include the Eversource interconnection study, wetlands delineation, endangered species review, archeological survey, civil site plan design, Federal, State and local permitting and environmental monitoring during construction. The assembly of materials for each application and submission will be managed by Eversource staff. Some design documents required for permit application packages will be produced by the EPC during detailed design phase 1.
- Systems integration: $100k. Includes work by Eversource IT staff to integrate control of ESS into the SCADA and operations systems. Because it is likely that polling will be required, a system with more bandwidth will be required, so a conservative estimate of $100k was used in the total budget.
- Eversource EE labor: $90k. Eversource engineering staff time will be required to carry out work within Eversource's scope, and to provide required system information to the EPC firm, review and approve design documents, and support testing and commissioning work. This effort is estimated as 9 months of full-time equivalent labor over the lifetime of the project.
- Eversource project development, project management, and program management: $675k. Eversource staffing to manage ESS program and individual projects from the development stage through commissioning. This estimate assumes that some of these costs will be split among multiple ESS projects
- Eversource legal: $94k. Eversource legal staff will assist in several stages of project development. These estimates all assume that this effort will be repeated across multiple ESS projects and common templates used where possible.
    - RFP development: $7.5k. Eversource legal staff will assist in developing a Request for Proposal for the EPC scope.
    - Contract template development: $7.5k. Eversource legal staff will assist in developing a template for the EPC contract.
    - Vendor negotiation: $19k. Eversource legal staff will negotiate contracts with vendors including the EPC firm.
    - Real estate transactions: $60k. Eversource legal staff will review and assist in completing the required real estate transaction.
-

7.1.3 Operating and maintenance

A total operating and maintenance (O&M) budget of $140k/year includes O&M for all components, software and troubleshooting services, plus an extended warranty on all system components in the EPC scope. It includes planned preventative maintenance for major system components: battery, PCS, containerization (HVAC, fire suppression), switchgear, and transformer. It would also include software updates, such as security patches and operating system updates. Finally, it would include troubleshooting services, so that if something goes wrong, assistance would be provided to ESS staff in interpreting alarms and identifying components in need or service or replacement.

This estimate is based on multiple recent quotes and is indicative of average costs in the industry. Because energy storage is a relatively nascent field, there is larger uncertainty in costs that will be incurred later in life than there is in upfront capital costs. Different vendors may quote O&M services with as much as 50% variance in cost for the same package of services. The O&M budget of $140k/year should be considered to have +/-50% uncertainty.

7.2 Project schedule

The project schedule described herein includes anticipated activities from the project start to the operation of the Westmoreland ESS.

Eversource plans to file the proposed demonstration project plan with NHPUC in 2019. NHPUC is expected to issue a ruling in early-mid 2020, and the project schedule shown in Figure 7-2 begins in May 2020. The major steps include the project initialization process, regulatory and permitting engagements, detailed design, procurement of ESS components, site preparation, ESS installation, ESS commissioning and acceptance testing, and final transition of the ESS to Eversource. The project schedule spans 18 months, with final acceptance and project closeout concluding in late 2021.

A summary of major project activities and dates is included in Figure 7-2 and in Table 7-4. This typical schedule is based on past project experiences and serves as an estimate and starting point for the Westmoreland ESS schedule. This schedule assumes a 1-month EPC contracting period. Doosan has experienced a wide range of contracting period durations with utilities (from well under a month to several months) and the final turnover to utility control could extend beyond 18 months from project initialization if the contracting period for this project is at the higher end of this range.

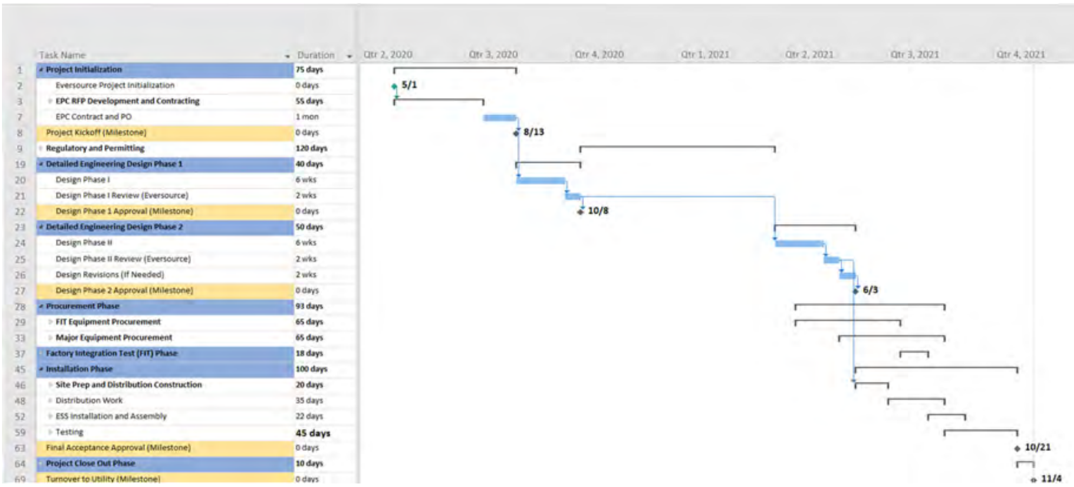

Figure 7-2 – Conceptual ESS project schedule.

Table 7-4: Major components of project schedule

Element	Average Duration	Description
Eversource project initialization: issue RFP		Send Request for Proposal (RFP) to EPC firms
EPC RFP submittals and Eversource review and selection	8 weeks	Collect RFP submissions from EPC firms, evaluate submissions according to criteria, and select preferred vendor and backup
EPC contract and PO	4 weeks	Finalize contract with EPC, issue PO and kick off project
Detailed Engineering Design Phase 1	8 weeks	Detailed engineering design resulting in design documents required for regulatory and permitting packages
Regulatory and permitting	17 weeks	Prepare, file, and receive approval on regulatory and permitting steps
Detailed Engineering Design Phase 2	10 weeks	Detailed engineering resulting in approved "For Construction" drawings from EPC to Eversource.
Procurement Phase	13 weeks	Issue PO's for equipment to begin lead times from suppliers.
Factory Integration Test	18 days (2-day Eversource visit to factory)	Test integrated components at supplier factory per FIT plan. Eversource witnesses testing for 2 days.
Site Preparation and Distribution Construction	3 weeks	Preparation of site by civil contractor and BOS electrical contractor. Construction of necessary distribution system additions/upgrades. All using "For Construction" drawings.
Distribution Work	5 weeks	Install transformers, install and connect medium voltage equipment, and interconnection process.
ESS Installation and Assembly	3 weeks	ESS equipment arrives on-site. Equipment is installed and electrically connected.

Communications integration, commissioning, and final acceptance testing	7 weeks	Connect ESS to utility network. Verify SCADA connection and points check. Progressively energize and test ESS components. Conduct first charge and discharge. Test all ESS functions. Document performance characteristics in Final Acceptance Report.
Project closeout and turnover to Eversource operations	2 weeks	Create as-built drawings, warranty documentation, punch list closeout, and personnel training. Place ESS in service. Provide all documentation to Eversource. Turn over to utility.

Public Service of New Hampshire d/b/a Eversource Energy
Proposed 1.7 MW / 7.1 MWh battery at Westmoreland, NH
Benefit/Cost Analysis
Utility Cost Test

[1]	Year Counter	Inv Year 1	Inv Year 2	Inv Year 3	Inv Year 4	Inv Year 5	Inv Year 6	Inv Year 7	Inv Year 8	Inv Year 9	Inv Year 10	Inv Year 11
[2]	Year Counter	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
[3]	Battery kW		1700									
	Benefits											
[4]	RNS Rate	$123.00	$129.00	$135.00	$141.29	$147.88	$154.77	$161.98	$169.53	$177.43	$185.69	$194.35
[5]	LNS Rate	$10.00	$10.20	$10.40	$10.61	$10.82	$11.04	$11.26	$11.49	$11.72	$11.95	$12.19
[6]	FCM Rate	$63.60	$64.87	$66.17	$67.49	$68.84	$70.22	$71.62	$73.06	$74.52	$76.01	$77.53
[7]	Peak Reduction Effectiveness	83.33%										
[8]	RNS Avoidance Benefit	$0	$0	$191,250	$200,162	$209,490	$219,252	$229,469	$240,162	$251,354	$263,067	$275,326
[9]	LNS Avoidance Benefit	$0	$0	$14,739	$15,034	$15,334	$15,641	$15,954	$16,273	$16,599	$16,930	$17,269
[10]	FCM Avoidance Benefit	$0	$0	$93,740	$95,615	$97,527	$99,478	$101,467	$103,497	$105,567	$107,678	$109,831
[11]	Asset Deferral Benefit	$0	$532,545	$888,987	$861,210	$834,257	$808,067	$782,581	$757,748	$733,517	$709,624	$685,779
[12]	Total Benefits	$0	$532,545	$1,188,716	$1,172,021	$1,156,609	$1,142,438	$1,129,471	$1,117,680	$1,107,036	$1,097,299	$1,088,205
	Costs											
[13]	Rev Req 25-Yr Assets	$0	($417,760)	($702,460)	($676,885)	($651,921)	($627,522)	($603,646)	($580,253)	($557,308)	($534,612)	($511,952)
[14]	Rev Req 12/13-Yr Assets	$0	($286,209)	($482,281)	($444,210)	($413,030)	($384,434)	($357,776)	($334,994)	($314,150)	($293,306)	($272,463)
[15]	O&M	$0	0	($79,406)	($79,667)	($149,976)	($150,287)	($150,624)	($150,987)	($151,377)	($151,795)	($152,240)
[16]	Total Costs	$0	($703,969)	($1,264,146)	($1,200,762)	($1,214,927)	($1,162,243)	($1,112,046)	($1,066,235)	($1,022,836)	($979,713)	($936,655)
[17]	Net Benefit to All Customers	$0	($171,425)	($75,430)	($28,741)	($58,318)	($19,806)	$17,425	$51,445	$84,201	$117,586	$151,550
	Net Present Value Calculation											
[18]	After-Tax WACC	7.09%										
[19]	Net Present Value of Benefits	$11,855,322										
[20]	Net Present Value of Costs	($9,956,354)										
[21]	Net Present Value Customer (Cost)/Benefit	$1,898,969										
[22]	Cost/Benefit Ratio	**1.19**										

[1] Investment year
[2] Calendar year
[3] kW installed
[4] Based on ISO-NE forecast
[5] Based on historic payments
[6] FCA 11 clearing price grown at inflation
[7] Assumption of 10/12 peaks hit, consistent with 4-hour battery
[8] [4] * [3] * [7]
[9] [5] * [3] * [7]
[10] [6] * [3] * [7]
[11] Revenue requirement of traditional poles-and-wires solution
[12] [8] + [9] + [10] + [11]
[13] Revenue requirement of 25-year assets
[14] Revenue requirement of 12/13-year assets (lithium ion cells)
[15] Estimated operations & maintenance
[16] [13] + [14] + [15]
[17] [12] + [16]
[18] After tax weighted average cost of capital
[19] Net present value calculation of [12] using [18] as discount rate
[20] Net present value calculation of [16] using [18] as discount rate
[21] Net present value calculation of [17] using [18] as discount rate
[22] -[19] / [20]

Public Service of New Hampshire d/b/a Eversource Energy
Proposed 1.7 MW / 7.1 MWh battery at Westmoreland, NH
Benefit/Cost Analysis
Utility Cost Test

Inv Year 12	Inv Year 13	Inv Year 14	Inv Year 15											
2031	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
$203.40	$212.88	$222.80	$233.19	$244.05	$255.43	$267.33	$279.79	$292.82	$306.47	$320.75	$335.70	$351.34	$367.71	$384.85
$12.43	$12.68	$12.94	$13.19	$13.46	$13.73	$14.00	$14.28	$14.57	$14.86	$15.16	$15.46	$15.77	$16.08	$16.41
$79.08	$80.66	$82.27	$83.92	$85.60	$87.31	$89.06	$90.84	$92.65	$94.51	$96.40	$98.32	$100.29	$102.30	$104.34
$288,156	$301,584	$315,638	$330,347	$345,741	$361,853	$378,715	$396,363	$414,834	$434,165	$454,397	$475,572	$497,733	$520,928	$545,203
$17,614	$17,967	$18,326	$18,693	$19,066	$19,448	$19,837	$20,233	$20,638	$21,051	$21,472	$21,901	$22,339	$22,786	$23,242
$112,028	$114,269	$116,554	$118,885	$121,263	$123,688	$126,162	$128,685	$131,259	$133,884	$136,562	$139,293	$142,079	$144,920	$147,819
$661,933	$638,088	$614,243	$590,398	$566,553	$542,707	$518,862	$495,017	$471,172	$447,326	$425,245	$406,690	$389,899	$373,108	$356,317
$1,079,732	$1,071,908	$1,064,761	$1,058,322	$1,052,623	$1,047,696	$1,043,576	$1,040,298	$1,037,902	$1,036,426	$1,037,675	$1,043,456	$1,052,050	$1,061,742	$1,072,580
($489,293)	($466,633)	($443,973)	($421,313)	($398,653)	($375,993)	($353,333)	($330,673)	($308,013)	($285,353)	($264,001)	($245,264)	($227,834)	($210,405)	($192,975)
($251,619)	($230,775)	($242,737)	($222,605)	($205,249)	($191,173)	($178,327)	($166,403)	($156,323)	($147,167)	($138,010)	($128,853)	($119,696)	($110,539)	($101,382)
($152,714)	($153,216)	($83,725)	($87,326)	($144,858)	($145,780)	($146,735)	($147,723)	($148,744)	($149,799)	($150,888)	($152,013)	($153,174)	($154,372)	($155,607)
($893,625)	($850,624)	($770,435)	($731,243)	($748,760)	($712,946)	($678,395)	($644,799)	($613,081)	($582,319)	($552,899)	($526,130)	($500,704)	($475,316)	($449,964)
$186,107	$221,284	$294,326	$327,079	$303,863	$334,749	$365,180	$395,499	$424,821	$454,107	$484,776	$517,326	$551,346	$586,426	$622,616

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2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056
$402.78										
$16.73										
$106.43										
$570,609	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$23,707	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$150,775	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$339,526	$ 322,734	$ 305,943	$ 289,152	$ 272,361	$ 255,570	$ 238,779	$ 221,988	$ 205,197	$ 188,405	$ 90,005
$1,084,617	$322,734	$305,943	$289,152	$272,361	$255,570	$238,779	$221,988	$205,197	$188,405	$90,005
($92,130)										
($48,402)										
($156,881)										
($297,413)										
$787,204	$322,734	$305,943	$289,152	$272,361	$255,570	$238,779	$221,988	$205,197	$188,405	$90,005