Energy Resilience Planning Framework

Efficiency Vermont R&D Project: Resilience

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Contents

Executive Summary

The energy resilience planning landscape contains a wide sampling of evaluation and planning strategies. Efficiency Vermont surveyed existing resources and developed a comprehensive planning strategy that is realistic and viable for Vermonters that limits administrative burden and maximizes utility.

The planning framework comprises six steps in a continuous cycle.

Step	Action
1	Define Energy Resilience
2	Conduct Hazard Analysis
3	Identify and Quantify Critical Loads
4	Develop Strategies to Meet Energy Resilience Goals
5	Implement Selected Energy Resilience Strategy
6	Evaluate Energy Resilience Plan at Regular Intervals

The framework guides planners to a comprehensive strategy to prepare for, adapt to, and recover from energy disruptions that risk life or severe economic loss. Each step provides the requisite platform to address the subsequent step resulting in economically achievable options to address and mitigate catastrophic risks.

The strategy developed ancillary tools for Efficiency Vermont to guide the process and produce reports for participants to include in implementation plans.

Efficiency Vermont's Energy Resilience Definition

Efficiency Vermont continues to evolve and adapt to Vermont's changing climate and energy landscape. In 2023, Efficiency Vermont defined energy resilience as:

> *Efficiency Vermont defines energy resilience as having access to affordable, reliable, low-carbon energy with the ongoing ability to prepare for, adapt to, and recover from power disruptions through establishing energy assurance to support critical loads protecting life and property.*

Resilience for an individual or community encompasses factors beyond energy, and Efficiency Vermont will consider energy resilience in the context of other factors that may impact overall ability to withstand and recover from events. Water and communications resilience as examples are equally important to overall resilience, and they cannot be divorced from energy resilience.

Efficiency Vermont tested the Energy Resilience Planning Framework with four demonstration projects. The energy resilience planning framework will guide site teams through evaluating and planning energy resilience requirements. The framework equips Efficiency Vermont to provide services and support to commercial customers in alignment with the adopted definition. Though components of the framework will enhance resilience support for residential customers, the framework in its entirety is excessive for their needs.

Efficiency Vermont Energy Resilience Planning Framework

The Energy Resilience Planning Framework comprises six steps to steer an executable plan to address defined energy resilience goals. Each step establishes a foundation to execute the subsequent step. The four demonstrations informed framework editing and adjustment, resulting in the final framework shown in Figure 1. Throughout the testing process, each site's experience effectuated the optimal framework configuration, confirmed each steps' relevancy and effectiveness, and developed and refined constructive planning tools to ensure foremost output. Participant feedback during the process informed the planning tools and the subtasks under each framework step.

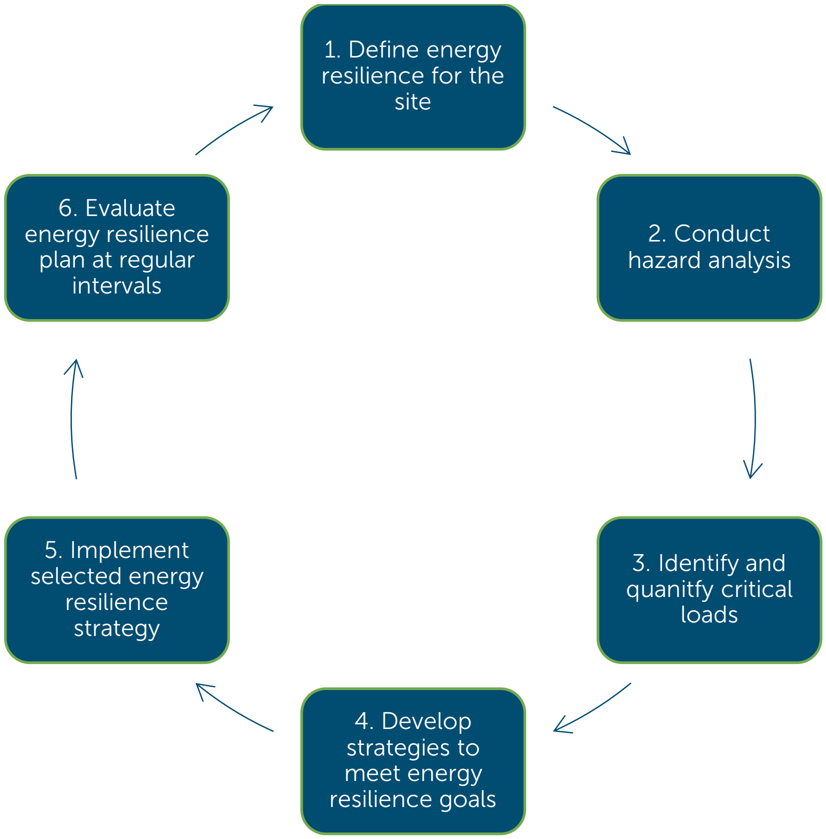

Figure 1. Efficiency Vermont's Energy Resilience Planning Framework

Preplanning

Successful energy resilience evaluation requires stakeholder engagement. Stakeholders are critical to comprehensive and decisive results. Internal stakeholders include facilities staff, tenants, information technology staff, and decisionmakers. External stakeholders include utilities, fuel providers, contractors, and local authorities. Excluding a relevant stakeholder risks developing an ineffective energy resilience plan, requiring further resources to correct.

Step 1: Define energy resilience

Defining energy resilience before making further decisions informs successive planning steps and direction. The definition encompasses three main components: physical boundaries in the scope, the function during an outage event, and the outage duration. NREL's Resilience Roadmap contains a list of federal, state, and organizational energy resilience examples to guide the step. The energy resilience definition can allow for economically acceptable property loss; however, it must protect life to be considered resilient.

The site's energy resilience definition establishes how to meet requirements for emergency activities, which could differ from normal operations. Energy resilience plans will serve occupant needs during a disruption, which might change the building's use. Operations might scale back or continue with partial processes. Some sites might adapt to a community service, such as evacuation shelter, medical site, or operations center. Some portions of a building might shut down while another continues to operate.[1]

The functional component of an energy resilience definition should describe what protecting life and property means for the site. Sites should consider their probable economic losses and risks to life and safety if they lose power or access to fuel deliveries. If the site's operations were crippled, who might suffer adverse consequences and what property might be destroyed? Unacceptable risks are those that resilience will mitigate or reduce. Risk to life is always unacceptable and needs to be mitigated. Risk that is acceptable does not need to be covered in resilience planning.

The resilience duration can be divided into increments, with differing resilience needs for various time intervals, as the risks to life and property shift with lengthening outages. Negative consequences compound as durations extend. The duration estimate will balance the costs to establish resilience to support systems in subsequent steps.

Step 2: Conduct hazard analysis

Outage event characteristics shape the risks to the site and control mitigation measure efficaciousness. A hazard has potential to disrupt energy access, and risks are the consequences to occupants or property. Energy

ENERGY RESILIENCE DEFINITIONS

The Winston Prouty campus defines energy resilience as the ability to support critical loads for outages lasting more than 4 hours and up to 3 days. Critical loads allow businesses to conduct an orderly operations shutdown that prevents product loss and allows occupants to safely secure and exit the building. Residential occupants can remain comfortably but austerely in their homes with baseline energy supply to serve loads that ensure minimum health and safety. Large gym or conference spaces with potential to provide broader community support and services can ensure minimum health and safety for occupants and critical humanitarian resources.

Peacham School defines energy resilience as the ability to support loads for outages lasting more than four hours and up to 3 days. Future plans will allow the building to serve as an emergency shelter for up to 7 days, but current use would last up to 3 days. Events 1 to 4 hours allow occupants to remain in the building until they can safely exit and leave the site. During events 4 hours to 3 days the school provides temporary daycare space for community volunteers for events effecting the entire community. Building systems should provide for occupant comfort and safety including lighting, heating, and food storage.

The community might establish the school as a long-term shelter location. Shelter activities would support 50 to 70 people for 5 to 7 days and require lighting and heating systems, small plug loads (laptop/cell phone charging), communications (telephones, computers, wifi internet access, other office equipment), water and wastewater services, and commercial kitchen equipment for food service.

[1] For example, the Illuminating Engineering Society's *Lighting Practice: Introduction to Resilient Lighting Systems* suggests a resilient lighting strategy should consider whether full illumination is necessary for activities. At a minimum, occupants need security, including access to sanitation and outdoor lighting. Light levels should follow IES guidance where possible, but function should be prioritized over aesthetics to maximize backup power capacity. Plan lighting levels for the space task(s) that will occur during an adverse event, not normal operations. Daylighting may also displace artificial illumination when available. Plans can also include portable and/or battery-operated lights for greater flexibility in the space during an event. Spaces containing occupancy sensors should maintain power to the occupancy sensor or to equipment controlling lighting such as networked lighting controls.

resilience addresses unlikely but severe events, shown below in a typical risk assessment matrix. Other risk classification quadrants are addressed separately because the changes of incurring costs due to them are greater or more likely.

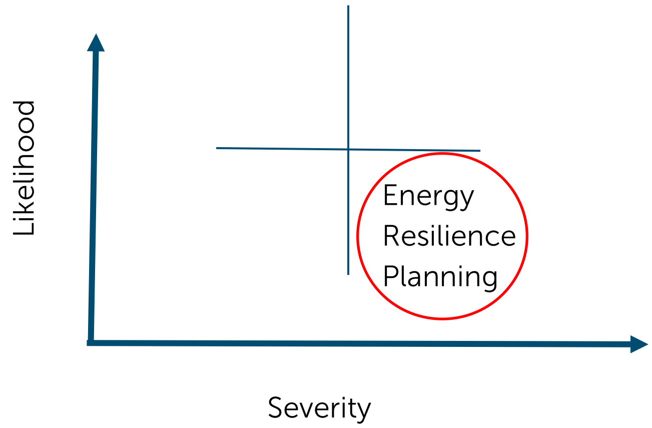

Figure 2. Energy resilience planning area of focus

Hazards fall into one of three categories: natural events, technological events, and threats as in Table 1. Natural events include weather events such as earthquakes, floods, wildfires. Technological events are equipment failures. Failures can result from human interference or mistakes, animal activity, wear and tear, or premature breakdown. Threats are malicious cyber or physical attacks. Some hazards might apply to multiple categories.

Natural Events	Technological Events	Threat Events
Flood	Substation failure	Targeted cyber attack
Snow or ice storm	System component failure	Active shooter
Hurricane	Power outage	Disgruntled actor sabotage
Earthquake	Internet outage	
Tornado	Downed power lines	
Extreme temperatures		

Table 1. Examples of events in the three hazard categories

The energy resilience plan establishes support for systems to prevent hazards from causing loss of life or catastrophic property damage. In this step, stakeholders identify the risks for each hazard and how they might threaten life or property (Figure 3).

Existing sites can use historic data to identify outage or fuel delivery disruption durations. Future business or environmental conditions could change disruption frequency due to weather conditions, local community development, or future growth plans. Sites implementing high-

Threat Identification	Category	Risk Type	Impact
internet outage	Technological	Property	inability to remotely access BMS
ice storm	Threat	Life	staff need to shutdown operations quickly so those who drive home can leave before roads are too risky
extreme heat - over 100F	Natural	Property	product spoilage during production
snowstorm	Natural	Life/Property	staff need to shutdown operations quickly so those who drive home can leave before roads are too risky outbound shipments may be delayed requiring product storage
vehicle hits utility pole	Threat	Property	could cause power outage damaging product during production prevents sales during outage prevents customers from leaving if walkway is blocked

Figure 3. Sample hazard analysis for a hypothetical coffee shop

cost resilience projects should plan for anticipated changes to limit costs to adjust. They should include anticipated expansion projects, planned equipment upgrades, or other foreseen changes in the energy resilience plan so that investments include those loads.

Step 3: Identify and quantify critical loads

The critical loads sustain functions necessary to protect life or property. Critical equipment can include HVAC pumps and fans, outlets for plug loads such as medical equipment, safety lighting, and process equipment that prevents product loss. All other loads can shut down during the outage. Determine critical load energy and power requirements and the loadshape to characterize risks across timelines. The analysis should consider planned equipment additions or upgrades and efficiency opportunities that reduce critical load.

Critical loads can change as an outage extends because longer events raise risks to life and property. Incremental energy resilience plans mitigate the risks in each time interval. If economic losses are less than costs to plan and implement a strategy, the risks will fall outside of the "energy resilience planning" quadrant in Figure 2 and do not require a resilience strategy. Note resilience must always protect life to be considered resilient, regardless of duration.

There are four critical load estimation methods, shown in Table 2. The bottom-up method is the most accurate because it uses metered, nameplate, or specification load data, but it requires the most time and effort. The percent of total load and percent floor area are quicker and less laborious than the bottom-up method but are less accurate. There is a risk of over- or underestimating critical load risking an insufficient energy resilience plan or higher costs. Err on overestimating critical load size because energy resilience must protect life, and overestimating mitigates risk to life during an adverse event. The generator-size method assumes an existing backup generator meets critical-load requirements, so the generator size is a proxy for critical-load size. The generator size method is quicker than the bottom-up method, but its accuracy depends on whether the assumption is true and remains true. It has a higher margin of error than the bottom-up method but can be more accurate than the percentage methods.

Critical Load Estimation Paths	
Bottom-Up	Equipment-level load size
Percent of Total Load	Percentage of the total site load
Floor Area Percent	Percentage of the total site floor area
Generator Size	Existing generator size proxy

Table 2. Critical load estimation strategies

Loads are unlikely to all operate concurrently, and equipment will not always operate at maximum capacity, so the critical load will not be the sum of all loads. The plan must identify what equipment can alternate to limit the load size. Energy resilience plans can call for cooler and freezer compressors to operate alternately, rooftop units could be alternated to prevent simultaneous power draw, and some plug loads can be allowed at preplanned times.

Critical equipment demand may not be easily identified by nameplate, and new sites will not have historic usage for reference. Examples include cell phone chargers, laptop computers, and residential refrigerators. These loads can use estimates from resources such as Reopt Critical Load Builder (located under the Resilience module), Commercial Buildings Energy Consumption Survey (CBECS) data, or reports from relevant industry bodies. The Illuminating Engineering Society's *Lighting Practice: Introduction to Resilient Lighting Systems* recommends that in spaces where occupants will shut down personal equipment and leave the building, safety lighting should be 1 lumen per square foot or one footcandle. Where occupants remain to complete a task or operation, IES recommends lighting levels meet IES task requirements.

Step 4. Develop strategies to meet energy resilience goals

Energy resilience strategies comprise plans, measures, or infrastructure investments that the site can implement or leverage to achieve the goals. Technical Resilience Navigator's Four Rs offer a rubric for defining effective measures. The four R's are: resourcefulness, redundancy, robustness, and recovery. Strategies should meet one or more of the Four Rs to achieve the energy resilience goals. Options grouped into no-cost, low-cost, and capital-cost categories will help identify the most attractive option or options.

In some cases, energy resilience goals require no action. If there is no risk to life, economic losses are not catastrophic, or functions can shift to elsewhere for the outage duration, there are no resilience investment benefits. A minimal cost plan to send staff home and remain without power is viable if the economic and life support implications favorable. Easily and cheaply replaced property would not need protection for resilience purposes.

photos courtesy of Iniu and Anker

Figure 4. Cell phone power banks

Energy that is not needed cannot be disrupted, so minimizing critical loads reinforces the energy resilience strategy and reduces the cost to support the remaining load. Identify energy efficiency options and implement critical load reduction. Any cost-effective efficiency measure offers economic benefits but focus on efficiency measures for critical loads to augment and maximize energy resilience.

No-cost and low-cost measures include coordinating equipment allowed to run. Allowing microwave use but not oven use or limiting lighting. Load shifting measures include low-cost purchases such as occupancy sensors or backup batteries for small electronics (Figure 4). Existing equipment that can integrate into the plan has no new additional costs, making the energy resilience goals more accessible. Existing backup generators or uninterruptible power supplies provide energy resilience capacity with no new cost. Emergency lighting with battery backup could provide sufficient light to negate additional lighting in some spaces (Figure 5). A strategy to maximize the time walk-in coolers and freezers are closed limits the energy required to support the load. Loads might be staged to limit the total concurrent power draw to reduce critical load and the required backup system size.

Capital projects require additional stakeholders, leadership buy in, and planning and implementation resources. Resilience needs and the costs might necessitate an incremental strategy to execute infrastructure investment in stages to make the goals achievable but lengthens the timeline to fully meeting the goals. The stakeholder team develops the strategy steps that are achievable.

Capital cost projects implement new infrastructure to meet critical loads for the outage duration. Common capital investments include electrochemical and thermal energy storage, renewable energy generation assets or fossil fuel generators, and control systems that can automate operation and detect events.

Photo courtesy of Lithonia

Figure 5. Emergency light fixture with battery backup

Step 5. Implement energy resilience strategy

The stakeholder team determines resource investment in the energy resilience strategy and creates an implementation plan. Options range from large capital projects to smaller, incremental steps that spread costs over time. Incremental step adoption might mean the energy resilience goals remain unmet until each incremental step is complete. Energy efficiency, particularly demand reduction, will help keep future costs to a minimum by lowering overall critical load and support energy resilience immediately by limiting the amount of power that can be disrupted.

Sites implementing large capital projects should include additional stakeholders, such as the utility, to ensure the plans and strategy are feasible, secure utility incentives, and comply with regulatory requirements. The energy industry continues a fast-paced advance, offering innovative financing, technology advancement, and ever-evolving functionality, so partner input on the latest options and strategy evaluation will bolster a realistic and attainable approach to optimize investment decisions.

Step 6. Evaluate energy resilience plan at regular intervals

Sites should reevaluate the energy resilience plan on a cyclical basis and in parallel with significant change in use or infrastructure. When businesses evolve and climate and economic conditions shift, the energy resilience definition changes, critical loads change with equipment upgrades or additions, and operations adjustments might change load sizes. Changes can negate the existing plan, and periodic reevaluation ensures the energy resilience strategy keeps pace with business changes while also containing energy costs.

Step six includes determining a reevaluation cadence. At a minimum, sites should reevaluate with significant changes including change of use, a building or equipment addition that adds new critical loads, personnel turnover that changes the decisionmakers, or substantial new load or load reduction. The reevaluation can be simple and consist of plan verification—or it might require reviewing each framework step to edit as necessary.

A cyclical reevaluation ensures small, negligible changes have not accumulated into a large shift in energy resilience requirements. The cadence depends on site size, the energy resilience plan complexity, and stakeholder agreement. Intervals can lengthen if there are few changes at each reevaluation. Start at a more frequent cadence and adjust as the team solidifies the energy resilience strategy, to ensure that newly developed strategies are effective. A one-year interval allows the energy resilience plan to run through all seasons, calendar events, business cycles, and community events. As the team refines and evaluates the strategy, the intervals can widen.

Energy Resilience Future

Volatile energy prices, global conflict, and greenhouse gas concerns drive technology exploration leading to advancements that address looming concerns while offering potential for more reliable energy access with greater local control. Technologies enabling energy resilience and strategies for meeting energy resilience goals continue to evolve while market players seek ways to innovate.

Electrification and renewable energy generation dominate discussion about addressing the world's pressing energy needs, but the exigencies at the local level include considerations unique to the locale and the owners. As more people take control over their resources and planning, the fundamentals of energy resilience planning and affiliated technologies have opportunity to innovate to meet growing and dynamic needs across the state.