Monetizing Energy Resilience Investment

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ABSTRACT

The amount of behind-the-meter renewable energy is increasing on the grid, and the Internet of Things is beginning to offer opportunities for greater energy efficiency and enhanced energy management. Both of these promising trends pose security risks and also offer a broad array of opportunities for owners to take control of their energy use and manage their costs while providing a level of energy assurance to secure their operations in the event of a catastrophic event.

Microgrids and owner-controlled energy offers compelling options for increasing the value of renewable assets to an energy system. These options also help assure energy supply and financial opportunities for the owner. The pace of such rapidly emerging technology in the market compels continuing research to refine options for energy production, storage, and control. These market and research developments, however, make it difficult for owners to determine the optimal choices that will meet their needs, and what investments make the most economic sense for them. All energy resilience investments must prioritize one overarching consideration above all others for the energy system and building owners alike: energy resilience.

Planning an energy resilience system at the building or campus level requires considerable thought and stakeholder input. But the process identifies the principal variables that form the system cost and revenue streams, not to mention those associated with structural and operational security. Therefore, asset configurations can be compared in terms of economic payback to help an owner determine which investment makes the most long-term economic sense—while also meeting energy resilience goals. This paper provides a mathematical method of comparison, using already-familiar net present value and time value of money concepts.

Introduction

Tropical storms, blizzards, tornadoes, hurricanes, and deliberate physical attacks, cyberattacks, or accidents can destroy the energy resources that communities need to support their basic needs. At a minimum, the expanding Internet of Things (IoT) is increasingly interconnecting infrastructure assets. Businesses, municipalities, public safety services, and critical service industries like health care increasingly must explore ways to take control of how they access their energy. This control enables them to mitigate financial effects from a disruption, and ultimately the impacts on life safety. Whether through cyberattack, acts of vandalism, or severe climate events, infrastructure is at risk of being damaged. In response, corporations and infrastructure operators are becoming increasingly interested in energy security.[1]

A single event can wipe out the energy and transportation infrastructure in a community. Residents of Houston, Texas, experienced this in 2017, when Hurricane Harvey devastated the city's infrastructure assets (Harrington 2018).[2] Most recently, the State of Texas experienced another climate crisis when sub-zero temperatures and freezing natural gas supply resulted in power outages that crippled

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[1] *Energy security,* as it is being used in this paper, refers to the relationship between national security and the availability of resources for energy use. This can involve balancing energy demand and supply to avoid economic constraints, and to make access to energy affordable. It can also involve securing the grid from disruptions.

[2] Hurricane Harvey lasted four days at the end of August 2017, hitting Houston heavily and costing $126.3 billion in property damage and killing 89 people. It is the 30th-worst flood in the history of the United States. (Harrington 2018).

the state (Cramton 2021).[3] In December 2016, the Burlington Electric Department in Burlington, Vermont, was the target of Russian hackers linked to presidential election interference. These hackers had installed malware on a utility laptop. Although the electric grid was not compromised at that time, such attackers are likely to continue to attempt to disrupt security and infrastructure assets (McCullum 2016). In a separate type of incident, in April 2020, a biker in Sheldon, Vermont, discovered and reported a transmission line fire that resulted in approximately $70,000 worth of damage to the Vermont Electric Cooperative. Investigators subsequently discovered that the line had been hit by a bullet in proximity to the fire (WCAX 2020).

Historically, diesel generators have provided backup power when systems are disrupted. An emergency backup generator meets the definition of *energy resilience* by providing energy to loads when grid resources are unavailable. This is the case with many residential and commercial buildings. An additional sector that is typically not singled out as a customer class in most utility programs, the military, also historically used backup generators as its approach to energy resilience. Energy managers typically connect critical loads to fossil-fuel-fired generators that can serve loads of approximately 20 MW (Marqusee 2017).

Regardless of sector, recent innovations have dramatically increased the number of technologies that can provide backup power for energy resilience. When energy resilience is treated as a decision-making pivot point for owners of energy systems and buildings, investments in backup power can also provide energy management and cost savings benefits during times of normal operations.

Given the increasing number of choices for energy resilience investments, owners must now determine what technologies make the most sense for their finances. But energy resilience asset configurations—ways in which assets critical to service delivery are effectively designed—are not directly comparable to each other. Further, their complexity makes it difficult to identify where the costs and savings might lie. Mathematics helps provide those answers. That is, the mathematical formulas this paper presents provide a framework for identifying where to look for system costs, where the savings and revenue streams might be, and how to determine comparable values for vastly differing system configurations to inform investment decisions.

Energy Hardening Versus Energy Resilience

It is important to distinguish between *energy hardening* and *energy resilience.* Energy hardening involves reinforcing assets to withstand and ride through an adverse event without downtime. Energy resilience involves keeping critical loads supported when an adverse event overcomes hardening efforts. In northern climates, drivers put snow tires on their cars to increase their ability to handle winter road conditions. In this way, they harden their cars against snow and slush on the roads. However, many drivers might be members of AAA or come from a two-car household that can provide assistance if snow tires are not enough to prevent the car from sliding off the road. These examples of a backup plan denote resilience. In hurricane-prone climates, homeowners can harden their homes by installing hurricane windows. However, they should also listen to and observe public safety recommendations if there is an order to evacuate from their homes; this strategy protects their safety if the storm strength is sufficient to overcome the hardening measures.

Energy resilience protects loads that support life or property during an adverse event that has eclipsed hardening efforts. Such events have a low likelihood of happening, but they carry a high risk if they do. It typically does not make economic sense to invest in hardening beyond high or medium likelihoods. Each enterprise must decide what risks to harden against and which

[3] The crisis resulted in more than 80 lives lost and tens of billions of dollars in property damage when the state experienced four days of below-average temperatures that strained the electrical system to the breaking point.

make less economic sense. Beyond energy hardening, the energy resilience plan protects life and property. The loss of that property would have to be profound enough to be unacceptable financially. Energy resilience would not seek to support energy loads that have no impact on life or property loss. Reducing the scope of protected loads keeps the energy resilience costs in check, and lends itself to creating a plan that positions operations to return to normal as quickly as possible.

Energy resilience is a system. On-site energy production, such as solar panels, or energy storage without on-site energy production, do not meet the definition of a *resilience system*. An energy resilience system provides all the components necessary to ensure continued power to critical loads for the duration of the owner's outage timeline, independent of external support. Such a system requires a means of energy production, storage, distribution, and controls that can automatically detect disturbances and isolate from the broader grid, to keep critical loads operational. Strictly speaking, *energy production* does not have to mean renewable sources, but it typically includes consideration for renewables.

Economic Analysis

Monetizing a resilience system uses net present value (NPV) to evaluate the economic implications of infrastructure investment and operation. NPV is a well-known financial evaluation metric, in common use across many industry sectors. The monetization equations allow owners and planners to compare unrelated asset configurations to determine which investment will provide the most resilience and economic benefit. For example, owners can compare the economic features of an existing diesel generator to a microgrid that combines photovoltaic production and electrochemical batteries to determine which offers the better value over the life of the equipment.

An important question for planners who must consider supporting equipment that preserves life concerns how to value the life being supported. Placing a monetary value on life is so problematic that there is no generally accepted method for doing so, and there is no ethical way to put a price on the effort to preserve life during an emergency. When determining the economic values associated with the mathematical variables discussed below, the value of life should therefore not be considered among them. The primary purpose of energy resilience is to protect life and property, and any purported energy resilience asset that cannot do that is not, in fact, providing energy resilience. Therefore, protecting life is a critical function of the investment, and it cannot be considered an effective resilience asset if it does not protect life, no matter what the economic analysis reveals about the benefits to the bottom line.

Resilience Planning Process

The energy resilience planning process is a critical exercise for identifying operational risks, actions necessary to protect against risks, and the level of investment needed. A system must foremost meet the owner's goals and support all loads critical to meeting those goals during an outage for the time period defined in the planning process. Calculating the costs and benefits for a system design meeting those needs will allow the owner to determine which system design, and investment choice, will provide for their needs and offer functionality that can deliver further economic benefits during normal operations.

The Energy Resilience Planning Process in Figure 1 is simplified from a process produced at Sandia National Laboratories to make the planning easier for small business owners or public-service organizations that do not have the in-house expertise to design energy resilience. Working through the planning process will orient the system design to ensure it is capable of meeting energy resilience goals. It also helps identify where there are opportunities to find cost savings and potential revenue streams when making decisions about asset investments. The results of the planning process will determine the energy resilience system design, the components required, and the overall capital costs necessary to meet goals and take advantage of the best financial opportunities in the energy market.

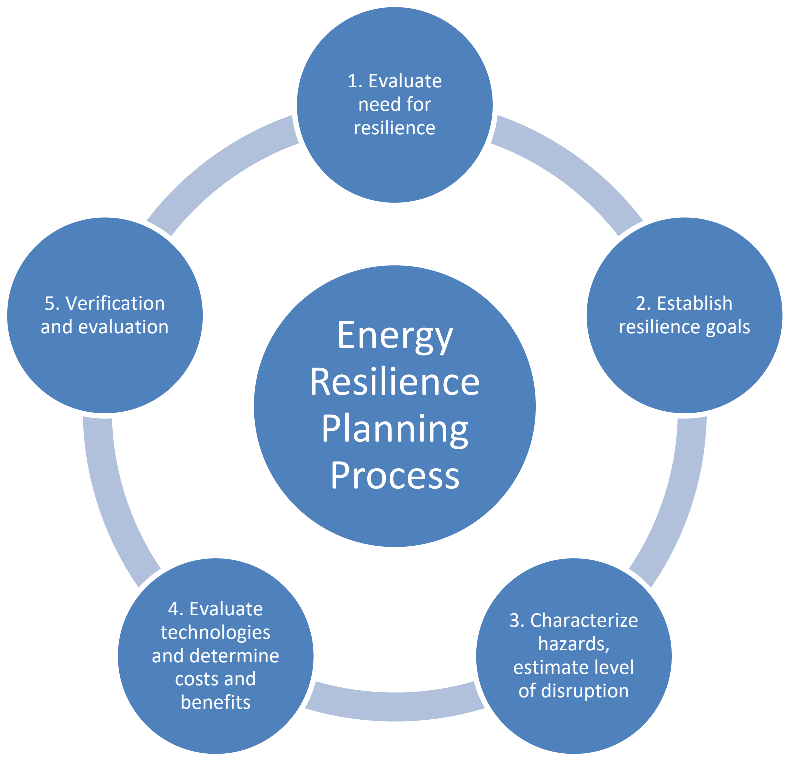

Figure 1. Energy Resilience Planning Process, based on a plan from Sandia National Laboratories and created in partnership with Steven Fitzhugh, P.E., Northfield Electric, Northfield Vermont.

The owner should first determine if planning for energy resilience is necessary. Energy resilience protects the owner from risks to life, property, or financial health. Threats come from natural weather events, accidents, or physical or cyber vandalism. The Federal Emergency Management Agency (FEMA) has created seven Community Lifelines critical to emergency preparedness, as shown in Figure 2. These categories can guide the evaluation of sources of business risks, to reach decisions about the need for energy resilience and the level of resilience. Some operations might be able to shift their functions to another site, rather than invest in assets to maintain one location. If owners determine that energy resilience is necessary to protect life and property in the event of a catastrophic event, they should proceed with making determinations about their critical loads, capital budget, and financial requirements from the system.

Figure 2. FEMA's seven Community Lifelines. https://www.fema.gov/emergency-managers/practitioners/lifelines.

Costs and Savings

Costs and financial benefits for the energy resilience infrastructure will depend on each use case. Owners have unique energy resilience goals that serve the needs and activities for the specific site, and these are not easily transferrable to another business or application. Every energy resilience investment plan must go through the resilience planning process to define what value each of the variables represents. Planners should involve relevant stakeholders in the organization to bring insight into what functions are contributing to defining the variables' values. Figure 3 shows the formulas; the variables in each equation are described below the figure.

Resilience planners should review the energy resilience plan and the infrastructure system plan with their partners to establish the values for each of the proposed infrastructure investment packages. If there is an existing energy resilience system, such as a diesel generator, it is advisable to establish values for the existing system to provide a baseline monetary value. Owners must decide what type of technologies they are willing to host and whether the site is suitable for desired technologies, before including them as an option for bidding.

1. $C_a + E_1 - R_1 + \sum_n NPV\ (B_a) < C_b + E_2 - R_2 + \sum_n NPV\ (B_b)$
2. $\text{Costs} = C + E + NPV(N)_n + NPV(M)_n$
3. $\text{Income over life of infrastructure} = U + Z + Y + VLL$
4. $U = NPV(D + T + B)_n$
5. $Z = \sum_x NPV(A)$
6. $Y = \sum_x \Delta B$
7. $(8760\text{-}h)/8760 = \%\ \text{availability}$
8. $VLL = \sum_x NPV(P + L + S)$

Figure 3. Equations used to evaluate the economic impact of energy resilience investment decisions, where:

A = Utility program yearly value
B = Yearly net metering credit
B_a = Annual utility bill with energy efficiency incorporated into energy resilience plan
B_b = Annual utility bills with no efficiency upgrades or alternate efficiency upgrade package
C = Capital cost for implementing infrastructure build
C_a = Capital costs for infrastructure configuration with energy efficiency incorporated before the resilience design stage
C_b = Capital costs for infrastructure configuration with no energy efficiency upgrades or

alternate energy efficiency upgrade package

D = Yearly demand charge reduction
E = Energy efficiency upgrade package costs
h = hours
L = Yearly cost of material losses
M = Maintenance costs
N = Operations costs
n = Infrastructure lifetime
P = Yearly cost of staff hours lost to regular job tasks
R = Utility energy efficiency rebates and incentives
S = Yearly value of lost sales
T = Year energy charge reduction
U = Utility bill savings over life of infrastructure
VLL = Value of lost load
x = Each instance of variable
Y = Ancillary cost savings
Z = Utility program value over life of infrastructure
ΔB = Ancillary item yearly incremental cost (currently yearly cost, minus estimated cost with resilience)

Energy that is not needed cannot be disrupted, so owners should evaluate the extent of energy efficiency improvement opportunities before they design for resilience. Efficiency measures cost-effectively reduce energy and demand requirements. The more efficiency is built into a design, the greater the chances of optimizing the resilience design and its costs. In that step, owners should evaluate capital costs for energy efficiency upgrades that will minimize energy and power requirements in the system, while also limiting costs for any necessary improvements to existing equipment. This helps to ensure that the resiliency infrastructure is compatible. Costs should consider energy audits and product and labor costs to implement the recommended upgrades from the audits.

Since overall reduction in energy or demand requirements can result in smaller or simpler resilience systems, owners should evaluate energy efficiency upgrade costs against resilience infrastructure costs. This step will establish an energy efficiency plan to reduce overall energy and demand requirements. As part of this exercise, the analysis should also investigate any changes to utility rate structures, whether those might relate to pending utility rate cases, or to changes that might occur from lower energy use from efficiency and other post-project energy use.

Each equation offers a path to a certain type of decision making. For example, an owner can use Equation 1 in Figure 3 to compare energy efficiency investment options and select the package of options that satisfy the equation. Each succeeding equation evaluates variables that contribute to the costs of owning and operating the assets and the financial benefits that the assets can bring. The result gives the net present value of the investment for comparison to other asset configurations to inform the best investment decision.

Expenditures in the monetization calculations consist primarily of capital costs, operations costs, maintenance costs, and costs associated with losses due to power failure. Capital cost data can come from estimates from contractor partners or from industry data on average costs for system components. Capital costs will be unique to each project because they will encompass a unique system that is specific to the owner's needs and goals. Costs from bids for infrastructure designs provide the most accurate estimate of initial outlays, but projects that have not reached the design stage and whose owners are evaluating whether to pursue a resilience project can use industry-specific capital cost data for system components.

Operating costs for a potentially unfamiliar system should be carefully evaluated to ensure the system operates as intended. It might be necessary to hire new staff with specific skill sets, train existing staff, or execute a contract with a third party to ensure efficient operations that maximize the system's capabilities to benefit the owner. Where relevant, owners should include additional salary costs, training and certification costs, and contract costs. They should also include costs for additional equipment to operate the system. Those costs might involve required testing equipment, tools, and system-external hardware or software that will communicate or be affected by it. Owners should establish the NPV of operations contracts or an increase in personnel costs to operate the infrastructure, as designed, over the life of the system.

Another cost consideration is system maintenance. This involves component replacements at appropriate intervals, and routine system tuning to ensure continued optimal operation. The analysis should evaluate ancillary equipment for operating the system in terms of the equipment lifetime, with replacement costs at appropriate intervals, and calibration requirements for any equipment. The analysis should determine costs and frequency of required maintenance on system components. Manufacturers typically specify maintenance requirements, or they can come from industry data. In either case, the analysis should also include consumable supplies for system maintenance. This calculation will need to establish the NPV of maintenance costs for the life of the system.

Resilience infrastructure can create monetary benefits through increased energy management control, utility incentive programs, and avoided costs during outages. They come from energy and operational cost savings and revenue streams from the grid services the assets can provide. Options for each will depend on utility partner offerings, individual resilience needs, and facility functions. These are summarized as *income* in the equation.

Utility bills can be optimized by designing a system to maximize economic operations. The system should continue to provide benefits, even when it is not providing resilience support. Owners can evaluate the utility rate structures and determine how utilities charge for demand, time-of-use, and demand response rates. They can then estimate potential demand savings when assets are able to shave peak loads or support base loads. Owners should evaluate net metering options through the utility, if renewable energy options are in a bid package, to estimate utility bill offsets. Owners can estimate reductions in demand charges and changes in energy billing due to energy arbitrage. Utility programs may inform system size or configuration. In some cases, it may make economic sense to invest in a more expensive system to secure the ability to take advantage of a program that provides a return for participation.

Utility programs offer payment in exchange for services an owner is willing to provide to the grid, via the resilience infrastructure. Owners should determine the utility programs that are available for the infrastructure configuration. Resilience infrastructure can shift either to island mode or to a grid-integrated asset, as necessary, to participate in a demand response program. Independent System Operators (ISOs; also known as Regional Transmission Operators or RTOs) might also have programs such as frequency regulation, capacity markets, voltage support, and upgrade deferral. Each of these provides an income stream in exchange for services the resilience infrastructure can provide to the grid. Owners should consider partnering with the utilities and ISO / RTO to determine whether the program is a fit for the resilience design and what the resulting value stream will be.

Ancillary cost savings come from cost reductions on a site, in expense categories that are not directly related to energy but are affected by energy use. For example, a site might carry insurance to protect against financial implications of lost power. Owners should therefore evaluate any insurance policies and determine what premium reductions might be available when they protect critical loads. Owners should also investigate where other tangential savings might occur. These could involve workers' compensation insurance, storage and maintenance for spare equipment parts, procuring and maintaining supply reserves or emergency equipment, labor to restart equipment, or repurposing space that can add to business value or additional services.

The VLL estimates the costs owners incur to respond to and recover from a loss of power. Costs will be either tangible (such as destroyed products or assets) or intangible (such as redirecting staff time to respond to an outage, or lost sales). Laboratories could lose critical experiments that can result in research setbacks, irreplaceable funding sources lost, and potential workplace safety concerns. Food service establishments can lose products in mid-process, resulting in sales losses and costs to replace products. Operations that are new and have no historical data can consult the IEEE Gold Book[4] or other industry data for associated cost estimates. Established entities should evaluate building automation system (BAS) or historical data on frequency and duration of power outages to estimate a timeframe for drawing out the loss.

Availability is the percent of the year the system is operational by weighted average of critical equipment importance. Using hours of outage for both planned and unplanned events, owners can calculate percentage of availability of power. The following equation provides an example of a hypothetical pump that is not operational when it is planned to be "on" for 175 hours per year:

$$(8760-175) / 8760=98\% \text{ availability}$$ [5]

Lost load costs encompass a broad range of possible consequences to downtime. Owners should evaluate how the facility responds to an outage and the resources dedicated to bringing a system back online. Owners should also estimate the value of staff production lost when those employees are not performing their typical tasks. This might involve time spent idling and time spent responding to the outage.

The next step is to apply the "percent availability" metric to estimate lost time across staff who would be idle during an outage. Staff time should be associated with restarting equipment or performing manual tasks to prevent a critical loss—for example, life support systems for patients, or guarding a restricted area normally protected with an alarm. Owners can base such costs on hourly pay rate and indirect costs for each staff member.

Owners should estimate income losses from a pause in normal function. Sales that might normally occur but are hindered by a lack of power can be estimated by each industry function. Owners who have data to show what sales tasks were canceled by outages can use the value of the sales that were to take place. Owners with less predictable sales values can apply the "percent availability" metric to approximate average sales data. Lost load costs are those associated with material losses, such as a product that is destroyed in the production process when power is cut, or a refrigerated product that must be disposed of. In some cases, there could be additional costs if destroyed material is considered hazardous or needs special handling for disposal. These costs also involve materials that must be re-consumed when processes re-start after power returns. For

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[4] IEEE Standards Association, 2007. *493-2007 – IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems.* Known as the *Gold Book.* Piscataway, NJ: IEEE. https://standards.ieee.org/standard/493-2007.html

[5] Example from Vilchuck and Chvala 2019.

example, a bakery might have to reproduce baked goods after a power loss.

Conclusion

Increasing adverse weather events, the expanding IoT environment, and aging infrastructure have broadened interest in energy resilience—across all customer classes dependent on an energy system, whether subject to a regional grid or self-contained within a single building or campus. From residential buildings to commercial enterprises, to military facilities, all building owners can consider their infrastructure at risk from severe climate events and other forms of catastrophic disruption. A security framework that makes energy resilience central to decision making is the essential step to ensuring energy security with resilient assets.

New advancements have also opened opportunities for those assets to provide energy management and cost benefits during normal operations. The wide range of asset configurations and the unique energy resilience needs and goals in each application mean that it is difficult to effectively compare the costs and benefits of investment options.

The literature offers a few proposed methods to compare the relative economics of some asset configurations, but most leave out some of the variables considered here. Energy resilience systems are complicated. They have varying components, so they are equally as complicated to evaluate from an economics standpoint. Owners must work with their stakeholders to clearly define energy goals, resilience needs, and budgets to provide the benchmarks for determining whether a system will meet those needs and how many further benefits a system can provide. Failing to first define the metrics will result in capital spent on a system that is not optimized for the need, nor will it be possible to determine whether the investment makes economic sense.

Using the metrics established in the energy resilience planning process, differing systems with unrelated energy management and incentive opportunities can be effectively compared to determine which investment will offer the best payback over the life of the equipment. It can be possible to compare the costs and benefits of systems as simple as a traditional diesel generator to those of a complex microgrid, or to compare microgrid sizes and component types. The calculations are technology agnostic, so as the industry innovates and more new technologies come to market, they will still be a viable tool for making investment decisions.

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