Green Resilience Hubs

An Energy and Financial Model

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Yale Center for Business and the Environment

CONNECTICUT GREEN BANK

Yale SCHOOL OF THE ENVIRONMENT

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FOREWORD

As the President and CEO of the Connecticut Green Bank, I am honored to present this report on green resilience hubs, brought to fruition through the dedication of a team of students from the Yale School of the Environment. Their research explores an innovative strategy of technology deployment and creative project financing for climate resilience for several buildings located at our headquarters in Hartford, CT.

As we begin to witness the impacts of climate change here in Connecticut – from forest fire smoke from Canada creating local smog to rain bombs causing stormwater flooding and swollen rivers – we need new solutions to address the risks to both natural ecosystems and human settlements. Green resilience hubs offer a path forward by bringing together technology, sustainable practices, and community collaboration to safeguard our future.

Through the collaboration of the Connecticut Green Bank and the Yale student team, this report showcases the use of incentives, including federal tax credits, to achieve state policy targets while providing local resilience. By harnessing the power of financial mechanisms to drive sustainable practices, we open up new avenues for creating climate-resilient communities. The heart of this report lies in the adaptation of the new tax credits introduced in the Inflation Reduction Act to support the economics of green resilience hubs. It is a testament to the potential of collaboration between academia and government, sparking ideas that have a real and positive impact on the world.

As you read this report, I invite you to consider how this transformative technology can support climate resilience in your own communities. The insights and ideas presented are not confined to a specific location; they outline a model that could work in most communities around the world. The students have even included the model they built for you to test out for your own buildings.

This report will invite you to envision the possibilities that green resilience hubs hold for your community. This technology, along with the right partnerships and determination, can lead to a safer, more sustainable world for generations to come.

We encourage you to read this report with an open mind and an optimistic heart. Together, we can forge a path of resilience and sustainability—one that empowers communities and safeguards the environment we all call home.

Sincerely,
Bryan Garcia
President and CEO
Connecticut Green Bank

About the Connecticut Green Bank

As the nation's first green bank, the Connecticut Green Bank leverages the limited public resources it receives to attract multiples of private investment to scale up clean energy deployment. Since its inception, the Green Bank has mobilized nearly $2.5 billion of investment into Connecticut's clean energy economy at a 7 to 1 leverage ratio of private to public funds, supported the creation of 26,720 direct, indirect and induced jobs, reduced the energy burden on over 66,500 families and businesses, deployed over 509 MW of clean renewable energy, helped avoid 10.4 million tons of CO2 emissions over the life of the projects, and generated $113.6 million in individual income, corporate, and sales tax revenues to the State of Connecticut.

EXECUTIVE SUMMARY

This report provides a comprehensive analysis of the feasibility of designing and financing a Green Resilience Hub (GRH). GRHs are physical facilities equipped with clean energy technologies and strategically located to offer vital services to local communities before, during, and after emergencies such as natural disasters.

The primary goal of this report is to offer insights to developers and investors interested in constructing resilient infrastructure that can provide essential community services—even during disruptions to the electrical grid. As a group of master's students at the Yale School of the Environment, we have identified significant potential for GRHs to support communities in emergencies while also providing sustainable revenue streams during non-emergency periods.

In this report, we define the essential steps involved in designing a GRH. These steps include involving the community, determining what electrical loads will be backed up, sizing a battery, choosing a technology mix, and creating operational strategies. Furthermore, we offer potential operating and business models for GRHs. We then examine financing options, including an outline of relevant costs and revenues and an analysis of federal tax incentives. Finally, we present the key inputs and takeaways from the energy and financial model we developed using Microsoft Excel.

Our energy and financial model, published with this report, is built using the Connecticut Green Bank campus as a case study. It is designed to be easily adapted to analyze other projects. The model uses hourly energy demand and generation data as well as battery dispatch logic to calculate bill savings, revenues, and level of disaster-resilience for the project. We included incentives provided by both the Inflation Reduction Act ("IRA") and the state of Connecticut. Our case-study results demonstrate that GRHs become highly bankable in communities that qualify for the IRA "bonus" credits and thus offer an enormous economic opportunity for both communities and developers.

The provisions in the IRA boost tax credits for low-income areas, tribal land, brownfield redevelopment sites, and communities located near energy-extractive-industries. These bonuses significantly expand the opportunity for financially-viable energy resilience projects in these traditionally under-resourced communities. The case study and analysis presented herein aim to be a valuable resource for developers, investors, and interested communities striving to enhance collective resilience in the face of natural disasters. We hope this report will foster the development of these vital projects across the United States.

INTRODUCTION

Green Resilience Hubs (GRHs), or Community Resilience Hubs, are centers that provide year-round benefits to community members. “Resilience means the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from…naturally occurring threats or incidents, including… the impacts of climate change,” as defined in CT Public Act No. 20-5.[1] GRH benefits include safe living and working environments, affordable access to power, and accessible community space. In the event of a natural disaster, these hubs serve as central locations for emergency shelter, communication coordination, and backup power for refrigeration, charging stations, medical equipment, and more.

The need for GRHs is underscored by the fact that low-income and minority populations often bear the brunt of challenges and vulnerabilities during disruptions to critical infrastructure, such as the electrical grid. GRHs are vital for fostering resilience in these vulnerable communities, as they face difficulties in accessing essential resources during crises and have fewer resources to recover from disaster impacts.[2] Establishing GRHs in such communities becomes paramount in our collective effort to build resilience and energy justice in the face of climate change.

While many people associate resilience hubs as cooling or heating centers during natural disasters, GRHs also play a critical role in building community resilience in day-to-day settings. According to the Urban Sustainability Directors Network’s guide, resilience hubs "support residents, coordinate communication, distribute resources, and reduce carbon pollution while enhancing quality of life."[3] GRHs typically host programs to enhance community resilience, such as distributing food, providing information on assistance programs, and preparing resources and protocols for natural disasters. The clean energy technologies of a GRH also generate value streams during normal operation through energy bill savings, excess energy sales, and incentive programs. In turn, the clean energy technologies of a GRH generate value streams during normal operation through energy bill savings, excess energy sales, and incentive programs. These revenues can be harnessed using various business models such as a Power Purchase Agreement (PPA), the Energy Service Company (ESCO) model, the utility model, or direct ownership.

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1 State of Connecticut, "September Special Session, Public Act No. 20-5 ," September 2020, accessed August 9, 2023, https://www.cga.ct.gov/2020/act/Pa/pdf/2020PA-00005-R00HB-07006SS3-PA.PDF.

2 SAMSA Disaster Technical Assistance Center Supplemental Research Bulletin, "Greater Impact: How Disasters Affect People of Low Socioeconomic Status," July 2017, accessed July 24, 2023, http://resilience-hub.org/wp-content/uploads/2019/10/USDN_ResilienceHubsGuidance-1.pdf.

3 Urban Sustainability Directors Network, "Resilience Hubs Guidance," October 2019, accessed May 9, 2023, http://resilience-hub.org/wp-content/uploads/2019/10/USDN_ResilienceHubsGuidance-1.pdf.

To develop a GRH, it is essential to understand possible business and financial models that can get the project off the ground. We create a compelling case for GRH implementation by outlining the operating models and quantifying the costs, revenues, and incentives for resilience hubs. Our vision is for communities worldwide to have access to clean and resilient energy systems, and GRHs play an important role in advancing this goal.

DESIGNING THE GREEN RESILIENCE HUB

To envision the hub, decision-makers must create a plan for involving the community, choosing backup loads, oversizing for resiliency, making technology choices, and devising an operational strategy. Designers will also decide whether to include a microgrid or electric vehicle charging in the project.

Involving the Community

To ensure optimal functionality, GRHs are best located in accessible, central community spaces that regularly host community-building events and programming. In addition, involving the local community throughout the design is crucial for the successful establishment of a GRH. Involving local stakeholders in determining the ideal location, backup power capacity needs, technology choices, and operational protocols fosters a sense of ownership, making the GRH a true reflection of the community's resilience needs and aspirations.

Designating Backup Loads

A critical function of a GRH is the provision of electrical power to community members during a main grid outage. The GRH will maintain backup power capacity to ensure that critical services will have reliable access to power in the event of an emergency. In the process of identifying appropriate backup capacity, decision-makers will have to identify which spaces or buildings to prioritize, and which services will be considered critical enough to require backup power coverage. In addition, decision-makers will need to establish the number of days the hub will be able to operate without power.

For example, a hub can be designed to back up specific loads, such as heating, cooling, and refrigeration, for an entire building. Alternatively, it can be designed to fully power a central gathering space while shutting off other areas of the building. Some projects will seek to maximize backup power for large medical devices over many days, while others will prioritize cooling and phone charging services over just a few days.

Oversizing for Resiliency

GRH designers must balance the need for resiliency with the economic efficiency of the system. Designing a solar and storage system for resiliency in the worst-case scenario (week-long outages and little to no renewable production) would be prohibitively expensive. FIGURE 1 illustrates the tradeoff between resiliency and cost. Today, a resilience hub with only solar and storage that can back up 50% of campus load for four to seven days would require a very expensive battery. However, as will be shown later in this report, the federal Investment Tax Credit ("ITC") can help offset some of these additional costs.

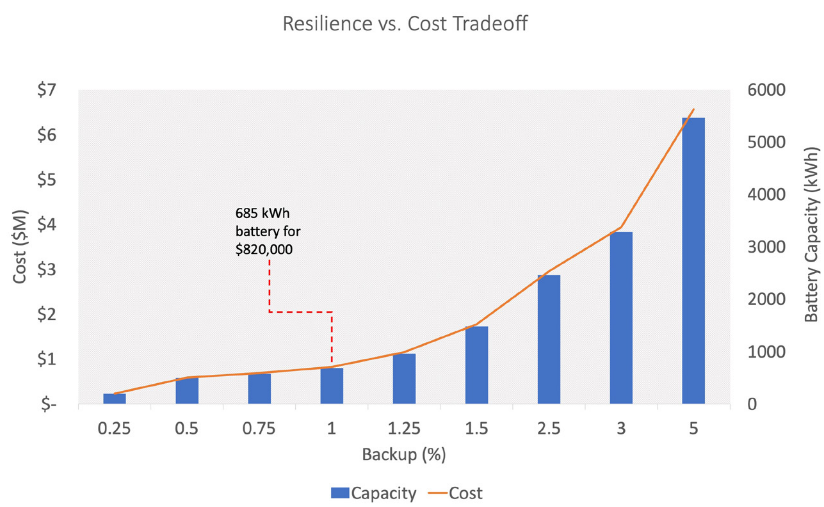

FIGURE 1. Tradeoff between resilience and cost for a theoretical mixed-use building campus. Percent backup can be utilized in different ways: 100% backup could mean 100% of loads backed up for one day or 50% of loads backed up for two days.

Choosing Technologies

Selecting the appropriate technologies for a GRH hinges on various priorities, including enhanced resilience, cost, environmental impact, and available space. Resilience hubs have the flexibility to employ different combinations of generation and storage technologies, such as solar photovoltaics, lithium-ion batteries, generators, or fuel cells. While backup generators run on fossil fuels and may not be as environmentally friendly as solar photovoltaics, they can serve as supplementary energy sources during prolonged emergencies or periods of limited renewable energy production. Fuel cells offer a promising solution because they have the potential to function on both natural gas and hydrogen, providing short-term resilience similar to generators and offering the adaptability to cleaner fuel options in the future.

Operating Strategy

In general, GRHs operate in one of two modes (**FIGURE 2**). Under normal conditions, access to grid power is consistent and weather patterns are normal. In this case, the hub can operate normally. The battery participates in peak shaving and revenue-generating incentive programs, energy is self-consumed on-site, and excess energy is sold to the utility. However, when grid outages are expected, the hub must switch into resiliency mode. The battery is then only used for backup to critical loads and all solar energy produced is either self-consumed or used to charge the battery. Operators establish protocols to determine how the switch to resiliency mode occurs.

NORMAL OPERATION	RESILIENCY MODE
• Normal weather • Battery dispatches to the grid to earn revenue • Net solar exports to the grid to gain net-metering credits • Actively import and export power to/from the grid	• Grid outage and/or natural disaster • Battery only used for backup • Operations shift to critical loads • Solar only used for self-consumption and charging battery • Microgrid 'islands'

FIGURE 2. Resilience hubs switch from normal operation to resiliency mode when grid outage or natural disaster hits.

Including Electric Vehicles

Our report and model do not encompass electric vehicle (EV) infrastructure within the framework of a GRH. Our analysis revealed that within the scope of our case study, EV charging would not yield substantial revenues to sustain the project. Typically, for residential and corporate environments, EV charging is offered as a complimentary or nominally priced amenity to attract occupants or encourage wider EV adoption.

Nonetheless, there exist scenarios wherein EV infrastructure could play a pivotal role within a GRH, including some in which EV charging may financially support the project. Revenue generation would materialize if the infrastructure includes level-three fast chargers positioned near major highway corridors or if integrated with retail spaces to prolong customer stays and expenditures.

Beyond financial considerations, project owners might integrate EV infrastructure into their GRH for various motivations. These could encompass prioritizing the reduction of greenhouse gas emissions and pollution linked to conventional vehicles or enhancing emergency transportation capabilities during power outages. Finally, there is growing interest in incorporating fleet EVs into GRHs through bidirectional charging. We found EV batteries to be significantly less expensive than standalone batteries, so using EV fleets as emergency storage may be a cost-effective option. As bidirectional charging technology evolves, the incorporation of EV infrastructure introduces a layer of flexibility and potential to a GRH.

To Microgrid or Not to Microgrid?

A microgrid is a localized energy system that can operate independently or in coordination with the main grid. The decision of whether to develop a GRH with a microgrid depends on site-specific factors such as the number of buildings, scale and complexity, budget, and other considerations. For single buildings, an energy storage system with islanding capabilities may suffice to provide backup power during grid outages. However, a microgrid's flexibility in managing diverse loads can be advantageous for multi-building facilities. Factors like crossing a right-of-way could pose challenges in installing a microgrid, while a more isolated campus may streamline the permitting and interconnection process. While microgrids come with additional costs for controllers and infrastructure, they offer substantial savings through increased system efficiency.

In **FIGURE 3**, we present an illustrative example showcasing the enhanced efficiency achieved through the microgrid approach. For this comparison, we sized a battery system independently for two different buildings and also considered the microgrid scenario. Remarkably, the microgrid scenario allows the campus to maintain the same resiliency as multifamily + office building scenario while utilizing a 500 kWh smaller energy storage system. The smaller system under the microgrid resulted in substantial savings of approximately $600,000 compared to the multifamily + office building scenario, where each building is backed up separately. This resilience remains consistently reliable under the microgrid approach, as the buildings efficiently share energy produced from the solar PV system, optimizing the overall energy distribution within the hub.

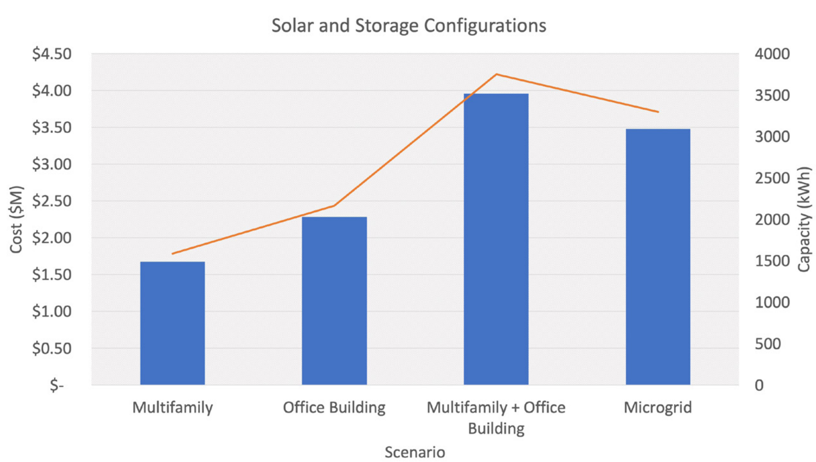

FIGURE 3. Battery capacity and costs required to provide a constant level of resilience to a multifamily building and office building separately (multifamily + office building scenario) or under a microgrid (combined scenario). Resilience is defined as 40% of loads backed up for 4 days, assuming solar is available for 2 days at 80%, based on 6/15 and 12/15 loads.

OPERATING MODEL

In this section, we outline operating model options for resilience hubs, including direct ownership, Energy Service Company (“ESCO), Power Purchase Agreement (“PPA”), and utility ownership models.

Direct Ownership

In a direct ownership model, the building owner purchases or commissions the GRH from the developer and operates it. This model offers the customer complete control over the operation and maintenance of the GRH but requires significant upfront investment. The customer receives any revenues generated by the system performance, including net metering, participation in utility incentive programs, and energy bill savings.

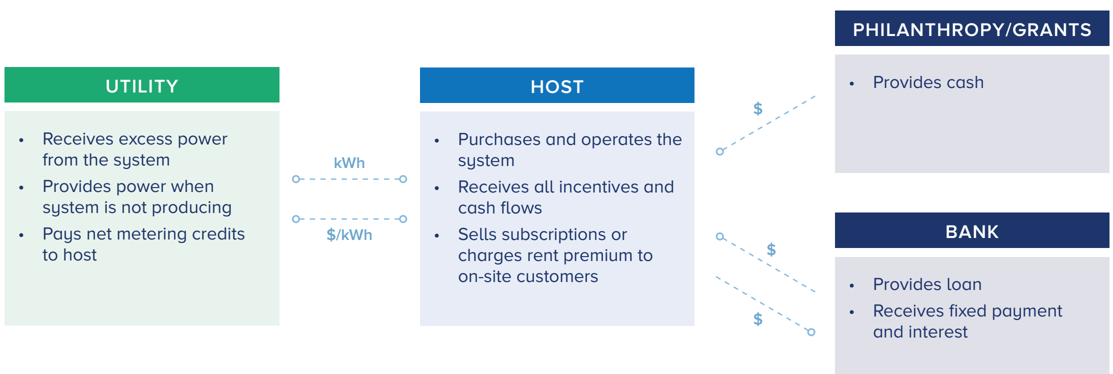

FIGURE 4. The ownership model schematic where the customer owns and operates the resilience hub.

Energy Service Company (ESCO)

As an alternative to the ownership model, an ESCO provides a turnkey energy solution. They design, finance, operate, and maintain the GRH. The customer pays for the energy generated based on obtained bill savings through a long-term contract. Some would call this an energy-as-a-service (EaaS) model.

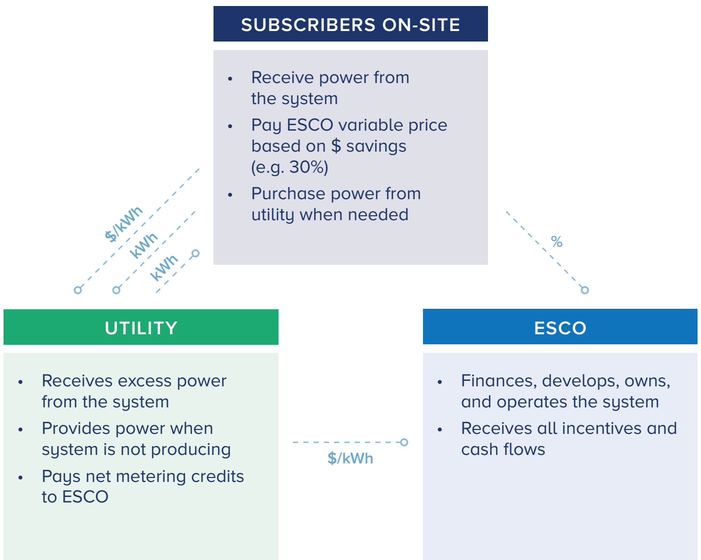

FIGURE 5. The ESCO model where the customer pays a variable price based on a share of hub revenues.

Power Purchase Agreement (PPA)

Under this model, a third-party developer installs, operates, and maintains the GRH and sells the generated electricity to the customer at a predetermined rate. The customer benefits from lower energy costs without having to bear the upfront costs or operational responsibilities. PPAs are a well-defined model for commercial solar projects, but there are fewer examples of microgrid or storage PPAs due to modeling and contract complexity.

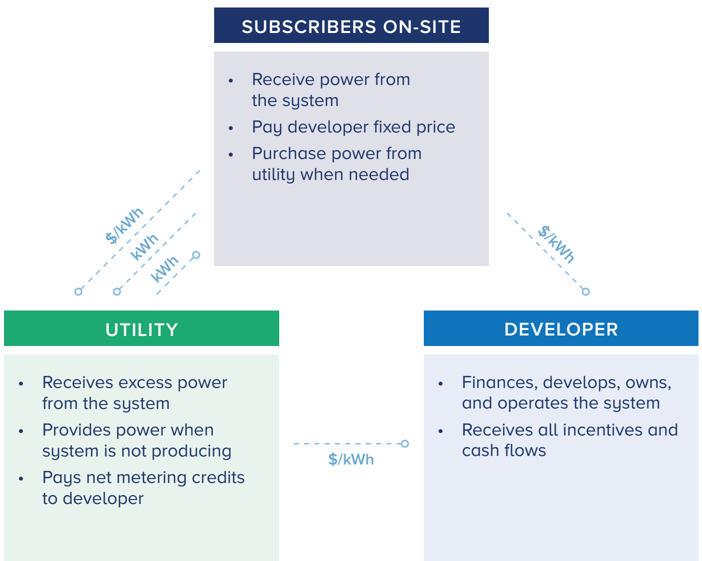

FIGURE 6. The PPA model where customers pay a fixed price to the developer, who owns and operates the hub.

Utility Ownership

Utilities are uniquely positioned to own the GRH because they can value the avoided costs of restoring power during an outage or any avoided fees incurred from failing to meet performance-based requirements. Under this model, the utility hires a developer and owns and operates the system. It then sells electricity or subscriptions to customers at a predetermined rate. This rate could include a premium for the added resilience that customers enjoy. Otherwise, the utility could rate-base the cost of developing the system, even though the project would only benefit the customers in question.

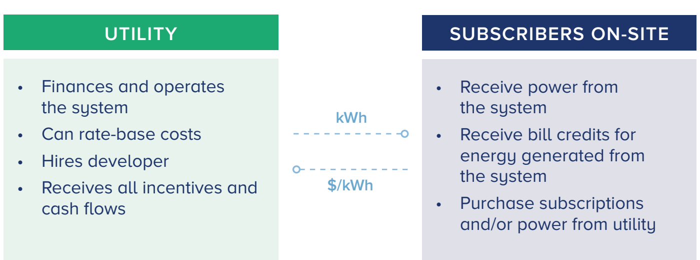

FIGURE 7. The utility-owned model where the utility sells power to the customer as normal.

FINANCIAL INPUTS

The financial inputs for a resilience hub are an essential aspect of the project. To successfully establish and operate a resilience hub, it is crucial that we have a clear understanding of the costs involved in the project, the revenues generated, and subsidies available.

Costs

Capital Costs are generally upfront costs related to procurement, installation, and integration of the GRH, while the Operations and Maintenance ("O&M") Costs account for routine upkeep, monitoring, insurance, and repairs.

We base the cost structure in our financial model on the assumptions outlined in **TABLE 1**. These estimates were sourced from both the USDN's "Resilience Hubs Guidance" document[4] and prior experience, and thus may be subject to variations due to market fluctuations, technological advancements, and unforeseen factors.

	Capital Costs	O&M Costs
Solar (Carport)	$3.00/W	$25/kW/year
Solar (Rooftop)	$2.00/W	$25/kW/year
Storage	$1,200/kWh	$35/kW/year
Microgrid	$228/kW	7% of capital costs

TABLE 1. Capital and Operations and Maintenance Costs for resilience hub technologies included in this analysis.

[4] Urban Sustainability Directors Network, "Resilience Hubs Guidance," October 2019, accessed May 9, 2023, http://resilience-hub.org/wp-content/uploads/2019/10/USDN_ResilienceHubsGuidance-1.pdf.

Revenues

Each technology in a GRH will bring a variety of revenue streams. Below, we explore how solar, storage, and microgrid technologies bring revenue into the project during normal operation.

	Self-Consumption	Peak Shaving	State Incentives	Net Metering	(Resiliency)	(System Efficiencies)
Solar	Value of avoided energy purchases	Value of avoided demand charges		Predetermined rate netting monthly		Avoided storage costs
Storage	Value of avoided energy purchases	Value of avoided demand charges	CT Energy Storage Solutions		Value of avoided costs	
Microgrid					Value of avoided costs	Avoided storage costs

TABLE 2. Schematic describing the revenue streams generated by each technology included in the hub. Column titles in parentheses indicate value streams that are not quantified in the financial model.

Self-Consumption

Both solar and storage offer the value of self-consumption because they generate or dispatch power that is directly consumed. Therefore, the value of self-consumption can be calculated as avoided energy costs, or what the customer avoided paying for energy consumption. The customer's specific rate schedule will determine the value for each kWh that is self-consumed instead of imported from the grid.

Peak Shaving

Peak shaving refers to the process of reducing the amount of power drawn from the grid during periods of high electricity demand, typically during peak hours. If the solar system generates electricity during peak demand, it contributes to peak shaving. The battery is also available for peak shaving. By reducing peak demand, commercial entities can also avoid costly peak demand charges from their utility company.

State Incentives

When developing hubs outside of Connecticut, it is important to research and understand any state- or utility-level incentive programs that may be available to support clean energy technologies such as solar, storage, and microgrid systems.[5]

We modeled a system based in Connecticut, which has a state-wide battery storage incentive program. The CT Energy Storage Solutions program offers both up-front and performance-based incentives, described below. The up-front incentive compensates for passive discharge of the battery, where the battery discharges regularly during pre-determined hours. The performance incentive compensates for participation in active discharge, where the battery discharges in response to notification.

	Effective Upfront Incentive ($/kWh)		
	Small Commercial	Medium Commercial	Large Commercial
Peak Demand	<200 kW	200 kW – 500 kW	>500kW
Incentive for first 50 MW of Commercial Storage Projects	$200	$175	$100

	Annual Performance Incentive ($/kW)			
	Years 1 - 5		Years 6 - 10	
	Summer	Winter	Summer	Winter
Maximum Season Incentive ($/kW)	$200	$25	$115	$15
Maximum Annual Incentive ($/kW)	$225		$130	

TABLE 3 AND 4. Outline of Connecticut Energy Storage Solutions upfront and performance incentives.[6]

Excess Energy Sales

Net-metering is an incentive offered to solar power producers where any excess energy that is generated but not consumed on-site is sent back to the grid, allowing the producer to receive compensation for the surplus energy at a rate determined by the utility's interconnection agreement. This process effectively credits the solar power producer for the excess energy generated and can provide additional revenue. Net-metering policy varies from jurisdiction to jurisdiction in terms of the compensation rates, how customers are compensated, true-up periods, and more.

System Efficiencies

Microgrids offer system operation efficiencies by enabling the sharing of power among multiple buildings or facilities. By connecting multiple buildings to a single microgrid, excess energy produced by one building can be used to offset the energy demand of another building within the microgrid. This sharing of power reduces the need for energy to be imported from the grid and allows the microgrid to operate more efficiently, with less wasted energy.

5 The following database can help identify potentially applicable state-based incentives across the U.S.: "DSIRE - The Database of State Incentives for Renewables & Efficiency®," North Carolina Clean Energy Technology Center, accessed May 9, 2023, https://www.dsireusa.org/.

6 "Introducing Energy Storage Solutions." Energy Storage Solutions. Accessed March 13, 2023. https://energystoragect.com/.

Solar PV panels similarly offer system efficiencies because designers can assume that solar panels will charge the battery during a power outage. Thus, the GRH can be designed with a smaller battery system while holding the level of resilience constant.

Resiliency

Both batteries and microgrids offer resiliency benefits by providing backup power during a power outage. However, putting a dollar figure to the value generated from resiliency can prove difficult. When the utility owns the resource, they might value it for resiliency by calculating avoided power recovery costs in the event of a natural disaster or avoided penalties for failure to deliver reliable power. When the developer owns the resource, they might consider the willingness-to-pay for resilience when setting the price to charge the customer. One study found that respondents were willing to pay between US $1.7 and $2.3 per kWh to sustain private demands and between US $19 and $29 per day to support their communities.[7]

Financing Sources

GRHs require significant upfront investment, and financing can significantly lower the program cost to make these technologies accessible to those who might not be able to afford the initial expense. Various financing sources offer opportunities to secure the necessary funds, making these vital projects feasible and accessible to communities seeking to enhance their resilience.

Property Assessed Clean Energy (PACE)

PACE financing allows property owners to finance upfront costs for qualified energy efficiency and renewable energy improvements, which are then paid back over time through property tax bills.[8] This financing is available for commercial properties through C-PACE financing and for residential properties through R-PACE.

Loans

When it comes to loans for resilience hubs, banks and financial institutions may offer a variety of options, including secured or unsecured loans, short or long-term loans, lines of credit, and fixed or variable interest rates. Loans may come with the requirement of collateral or a personal guarantee, and repayment periods can vary widely depending on the lender and loan terms. Green banks across the country will likely be at the forefront of financing resilience hubs.

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[7] Baik, S., Davis, A.L., Park, J.W. et al. Estimating what US residential customers are willing to pay for resilience to large electricity outages of long duration. Nat Energy 5, 250–258 (2020). https://doi.org/10.1038/s41560-020-0581-1

[8] U.S. Department of Energy, "Property-Assessed Clean Energy Programs," State and Local Solution Center, accessed April 6, 2023, https://www.energy.gov/scep/slsc/property-assessed-clean-energy-programs.

Grants and Donations

Grants, both from government and private organizations, can provide resources for support, such as the U.S. Federal Emergency Management Agency's ("FEMA'") Hazard Mitigation Assistance program or the U.S. Department of Housing and Urban Development's ("HUD") Community Development Block Grant program.[9] FEMA's Building Resilient Infrastructure and Communities program includes an annual application for projects that proactively invest in community resilience.[10] Donations from philanthropic organizations such as the Rockefeller Foundation, the Bill and Melinda Gates Foundation, and the American Red Cross can also be a potential source of capital depending on the project.

Creative Sources

Partnerships, crowdfunding, and crowd investing present innovative avenues for securing capital for a GRH. Collaborating with companies through partnerships or sponsorships can offer essential financial backing and valuable resources, and leveraging crowdfunding platforms such as GoFundMe and Kickstarter allows for community-driven fundraising. Raise Green exemplifies a platform for crowd investing for project finance that facilitates direct investment in local clean energy and sustainability initiatives.

Federal Tax Incentives

Tax Incentives Overview

The Federal Government primarily provides clean energy investment incentives through tax policy.[11] This report discusses those available federal tax credits and direct payments applicable to resilience hubs. Credits allow taxpayers to reduce their taxes owed, while direct payments are paid in cash and are available to tax-exempt entities like non-profits, tribal governments, and municipally owned utilities.

Resilience hubs, which use a variety of clean energy technologies, can benefit from either the ITC or the Production Tax Credit ("PTC"). The ITC covers a percentage of installation costs, effectively reducing the cost of the qualifying equipment, while the PTC is a per kilowatt-hour (kWh) tax credit for electricity generated, effectively providing an added value to the electricity itself.

The ITC and PTC are available for several clean energy technologies that might be included in a GRH. Microgrids, fuel cells, and energy storage qualify for the ITC, whereas solar photovoltaics qualify for either the PTC or ITC. The IRA offers additional tax bonus categories for projects sited in low-income communities or on brownfield sites. **TABLE 5** summarizes these benefits. Each technology can claim either the ITC or the PTC, but not both. However, a single system with multiple technologies, such as co-located solar and storage, can claim different credits for different technologies.

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9 U.S. Department of Housing and Urban Development. "Community Development Block Grant Program." HUD. Last modified March 31, 2021. https://www.hud.gov/program_offices/comm_planning/cdbg.

10 U.S. Federal Emergency Management Agency. "Building Resilient Infrastructure and Communities: About the Program." FEMA. Last modified February 2, 2022. https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities/about.

11 "Inflation Reduction Act Guidebook," The White House, accessed May 9, 2023, https://www.whitehouse.gov/wp-content/uploads/2022/12/Inflation-Reduction-Act-Guidebook.pdf.

Summary of Investment Tax Credit (ITC) and Production Tax Credit (PTC) Values Over Time

			Start of Construction						
			2006 to 2019	2020 to 2021	2022	2023 to 2033	The later of 2034 (or two years after applicable year[a])	The later of 2035 (or three years after applicable year[a])	The later of 2036 (or four years after applicable year[a])
ITC	Full rate (if project meets labor requirements[b])	Base Credit	30%	26%	30%	30%	22.5%	15%	0%
		Domestic Content Bonus				10%	7.5%	5%	0%
		Energy Community Bonus				10%	7.5%	5%	0%
	Base rate (if project does not meet labor requirements[b])	Base Credit	30%	26%	6%	6%	4.5%	3%	0%
		Domestic Content Bonus				2%	1.5%	1%	0%
		Energy Community Bonus				2%	1.5%	1%	0%
	Low-income bonus (1.8 GW/yr cap)	<5 MW projects in LMI communities or Indian land				10%	10%	10%	10%
		Qualified low-income residential building project / Qualified low-income economic benefit project				20%	20%	20%	20%
PTC for 10 years ($2022)	Full rate (if project meets labor requirements[b])	Base Credit			2.6 ¢	2.6 ¢	2.0 ¢	1.3 ¢	0.0 ¢
		Domestic Content Bonus				0.3 ¢	0.2 ¢	0.1 ¢	0.0 ¢
		Energy Community Bonus				0.3 ¢	0.2 ¢	0.1 ¢	0.0 ¢
	Base rate (if project does not meet labor requirements[b])	Base Credit			0.5 ¢	0.5 ¢	0.4 ¢	0.3 ¢	0.0 ¢
		Domestic Content Bonus				0.1 ¢	0.0 ¢	0.0 ¢	0.0 ¢
		Energy Community Bonus				0.1 ¢	0.0 ¢	0.1 ¢	0.0 ¢

a "Applicable year" is defined as the later of (i) 2032 or (ii) the year the Treasury Secretary determines that there has been a 25% or more reduction in annual greenhouse gas emissions from the production of electricity in the United States as compared to the calendar year 2022.
b "Labor requirements" entail certain prevailing wage and apprenticeship conditions being met.

TABLE 5. Overview of the Investment Tax Credit (ITC) and Production Tax Credit (PTC) incentive bonuses and structure enacted by the Inflation Reduction Act. Image sourced from the Department of Energy website.[12]

Tax Incentive Monetization

GRHs can take advantage of financing structures common to the renewable energy industry used to monetize tax credits. Tax-exempt entities can take advantage of the direct pay option, but non-tax-exempt entities must investigate self-sheltering, tax equity, or transferring tax credits. This section will outline these common structures.

Tax Equity

Tax equity is a financing structure common in the renewable energy industry where investors provide cash to project developers to finance the development of renewable energy projects in exchange for tax benefits.[13] The developer of the renewable energy project secures funding from an investor, known as the tax equity investor. The tax equity investor receives an ownership interest in the project in exchange for the investment and is entitled to a share of the project's tax benefits, such as tax credits or accelerated depreciation, generated by the project. These tax benefits are then used to offset the tax equity investor's federal income tax.

12 U.S. Department of Energy, "Federal Solar Tax Credits for Businesses - Tax Credit Incentives," accessed May 9, 2023, https://www.energy.gov/sites/prod/files/2021/02/f82/Business_Investment_Tax_Credit_2021.pdf

13 Megan Anhalt, "How Does Tax Equity Work for Renewable Electricity?" Schneider Electric, September 25, 2019, accessed May 9, 2023, https://perspectives.se.com/blog-stream/how-does-tax-equity-work-for-renewable-electricity.

The tax equity investor receives a return on their investment via the tax credit itself, as well as a negotiated portion of cash flows directly from the project. The developer of the renewable energy project can use the capital from the tax equity investor to finance the construction and operation of the project. Once the tax benefits have been exhausted, the tax equity investor sometimes exits the investment, in which case the project is refinanced using traditional debt financing.

Direct Pay

Organizations that have federal tax-exempt status, such as 501(c)(3) organizations, can receive tax credits through the Direct Pay Provision in the IRA. Entities such as state, local, and tribal governments, rural electric cooperatives, and others can directly monetize certain renewable energy tax credits for equipment placed in service on or after January 1, 2023, and through December 31, 2032.[14]

Transferability

Transferability is a new monetization structure introduced in the IRA which allows tax credits generated by renewable energy projects to be sold for cash. This option is attractive to developers who might not have the relationships with tax equity investors or the resources to cover the transaction costs implicit in complicated tax equity finance structures. With transferability, the credits cannot be resold after transfer. So, the credits must be purchased once for cash. The cash received from the transfer is not taxable income, and the cash paid for the credits is not deductible.[15]

The transferability mechanism lowers the cost of capital and improves the ease of financing projects. Project owners can raise project-level capital in the form of loans against the value of future tax credits. Alternatively, project owners can simply transfer the credits to other entities in exchange for cash. Since transferability is a market-based mechanism, project owners are likely to sell their credits at a discount, meaning they will not benefit from the tax incentives offered on a dollar-for-dollar basis.[16] Further, as with Direct Pay, the financial value of depreciation is foregone in transferability transactions.

Self-Sheltering

Self-sheltering is an option available to non-tax-exempt project owners who do not have the resources to transfer tax credits or work with a tax equity investor. It involves saving any unused tax credits in the current period to offset liability in a later period. This option can help reduce the overall cost of capital and improve project financing by providing a source of revenue that can be used to offset a future tax liability.

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14 U.S. Environmental Protection Agency, "Inflation Reduction Act," EPA Green Power Markets, accessed April 6, 2023, https://www.epa.gov/green-power-markets/inflation-reduction-act.

15 "Inflation Reduction Act: Tax Credit Transfer," Experian, accessed May 9, 2023, https://www.experian.com/blogs/employer-services/inflation-reduction-act-tax-credit-transfer/.

16 "Transferability Ain't All It's Cracked Up to Be," Project Finance NewsWire, August 2022, https://www.projectfinance.law/tax-equity-news/2022/august/transferability-ain-t-all-it-s-cracked-up-to-be/.

However, self-sheltering may not be the most efficient way to monetize tax credits because it requires the project owner to have taxable income in future periods to take advantage of the credits. This means that if the project owner has no future taxable income or if the value of the tax credit decreases over time, the self-sheltering strategy may not be as effective. As such, it is important for project owners to tactically evaluate their financial position before opting for self-sheltering as a monetization strategy.

State and Local Incentives

States or local entities offer a variety of incentives for clean energy technologies. More information on individual opportunities is listed in The Database of State Incentives for Renewables & Efficiency (DSIRE)'s list of all U.S. renewable energy incentives and programs, and DSIRE's database of federal incentives.[17]

[17] DSIRE. "Database of State Incentives for Renewables & Efficiency." Accessed May 11, 2023. https://www.dsireusa.org/.

THE ENERGY AND FINANCIAL MODEL

Once we understand the background, tax incentive monetization structures, financing sources, costs, and revenues, we can demonstrate the financial viability of hubs with modeling. We created an energy and financial model by utilizing inputs such as hourly data from NREL's Comstock database, generation data from PV watts, and logic created in Microsoft Excel to calculate revenue streams.[18,19]

We performed a sensitivity analysis to determine the impact of varying system design, financial inputs, and ITC level on financial returns. Our results included various types of Internal Rates of Return (IRR). Pre-tax and post-tax IRRs demonstrate the impact of federal tax incentives, and unlevered and levered IRRs demonstrate the impact of adding debt to the project. Our results uncovered various takeaways.

Financial Input Sensitivity

We conducted a base, upside, and downside scenario analysis to determine the sensitivity of our results to the cost structure assumptions (**TABLE 6**). Other financial assumptions are listed in **TABLE 7**. The results showed that the project's cash flows alone in the pre-tax unlevered IRR were barely positive in the base case scenario, except for a negative IRR with the Solar + Storage Large configuration (**FIGURE 8**). Since these IRRs are lower than the cost of debt, the pre-tax levered IRRs are all lower than pre-tax unlevered IRRs. However, under a 30% ITC, the base and upside scenarios offered much better returns in the after-tax levered IRR section. We also modeled the Direct Pay monetization structure for tax-exempt entities, which showed that the returns were slightly lower since tax-exempt entities cannot take advantage of tax depreciation. It is notable that under the downside scenario, all IRRs remain negative. These results demonstrate that the ITC remains an important incentive to make GRHs bankable.

[18] Comstock Solar I," National Renewable Energy Laboratory, accessed May 9, 2023, https://comstock.nrel.gov/.

[19] "PVWatts® Calculator," National Renewable Energy Laboratory, accessed May 9, 2023, https://pvwatts.nrel.gov/.

Base (Upside | Downside)

	Capital Costs	O&M Costs
Solar (Carport)	$3.00 ($2.75 | $3.25) /W	$25 ($22 | $28) /kW/year
Solar (Rooftop)	$2.00 ($1.50 | $2.50) /W	$25 ($22 | $28) /kW/year
Storage	$1,200 ($1,000 | $1,500) /kWh	$35 ($30 | $40) /kW/year
Microgrid	$228 ($156 | $309) /kW	7% (5% | 9%) of capital costs

TABLE 6. Base, upside, and downside cost structure scenario sensitivity inputs.

Tenor (years)	18
Target DSCR	1.25
Interest Rate	6%
Max Tax Income Offset	80%
Federal Tax Rate	21%

TABLE 7. Other Financial Assumptions.

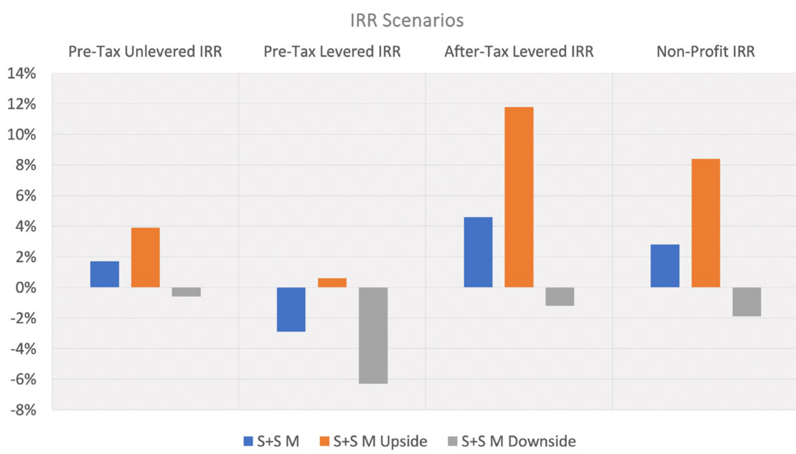

FIGURE 8. Pre-tax, after-tax, levered and unlevered IRRs for the solar + storage medium (500 kWh battery) scenario under the base case, upside and downside scenario cost structures.

System Design Sensitivity

We analyzed the financial returns for five different system design cases. The size of the solar system was held constant because we assumed that the available space would be maximized in every scenario for photovoltaics. The size of the battery varied across the small, medium, and large scenarios to test greater resiliency against financial returns.

Case	Solar Size (kW)	Battery Size (kWh)
Storage Only	0	500
Solar + Storage Small	515	250
Solar + Storage Medium	515	500
Solar + Storage Large	515	1000
Solar Only	515	0

TABLE 8. System Design Sensitivity scenarios with respective solar and battery sizes (kW and kWh, respectively)

The results show that solar alone produced the highest returns in the model. When including batteries, solar + storage small produced the highest returns, with IRR diminishing as battery size increases; installing a battery alone returned the lowest IRR. The larger batteries offered diminishing returns. This suggests that solar is 'subsidizing' the battery systems.

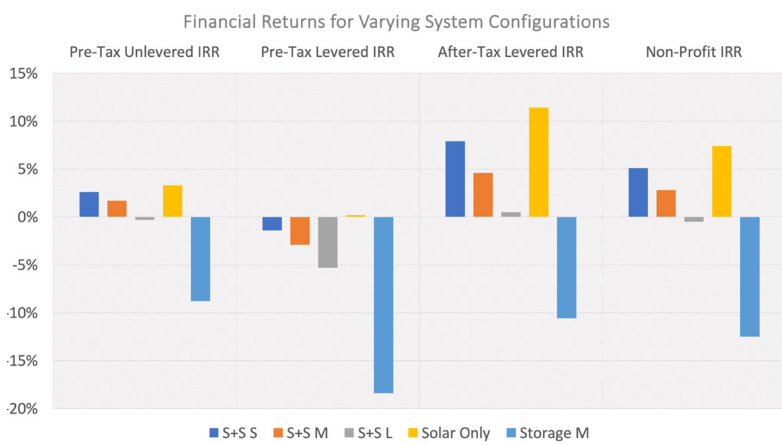

FIGURE 9. Pre-tax, after-tax, unlevered and levered IRRs for varying system and financial designs: Solar + Storage Small (250 kWh battery), Solar + Storage Medium (500 kWh battery), Solar + Storage Large (1000 kWh battery), Solar Only, and Storage Only (500 kWh battery). All scenarios are modeled with a 30% ITC. Pre-tax unlevered, pre-tax levered, and after-tax levered IRRs are modeled as an efficient taxpayer, whereas the Direct Pay IRR is under a Direct Pay structure.

ITC Sensitivity

We determined the financial returns for a GRH as a function of the level of ITC available. We ran the solar + storage medium system scenario for the ITC sensitivity, despite the other scenarios being more cost-effective, because we wanted to maintain enhanced resiliency with a larger battery. The model was therefore run for the solar + storage medium system at 20%, 30%, 40%, and 50% ITC.

As expected, the results showed that the levered after-tax IRR increased with increasing ITC (**FIGURE 10**). One of the 20% bonuses requires half of the benefits from the electricity produced to be shared with qualified households (**TABLE 9**), so we modeled pre-tax profit sharing with the 50% ITC and found a slight decrease in IRR compared to other 50% ITC scenarios. Other ITC bonuses may come with increased costs that were not modeled in this exercise. Additional analysis could help to reveal how the cost-structure assumptions change with each ITC bonus.

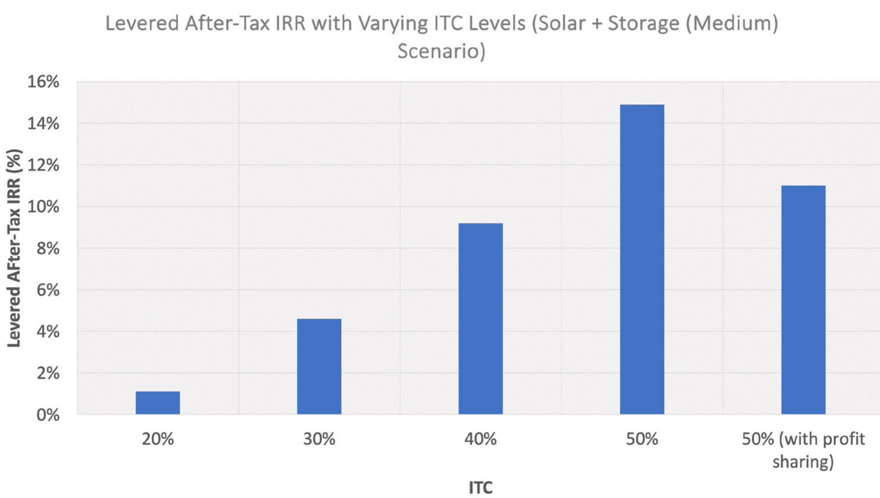

FIGURE 10. Levered after-tax IRR for 20%, 30%, 40%, and 50% ITC. The last case demonstrates the IRR under a 50% ITC while sharing 50% of the benefits from the electricity produced with qualified households (pre-tax profit sharing).

Bonus	Definition	%
1. Domestic Content	100% of the steel or iron + 40% of the component manufactured products made in the United States.	10%
2. Energy Community	Brownfield site OR statistical area that has had >0.17% direct employment or >25% tax revenues from fossil fuels OR a census tract adjoining where a coal mine has closed or retired OR unemployment > national average.	10%
3. Tribal Land	Land designated as a Tribal reservation or set apart for tribal use by the federal government.	10%
4. Low-Income Residential Building Project	Residential building project that participates in affordable housing or other listed programs.	20%
5. Low-Income Economic Benefit Project	At least 50% of the financial benefits from the produced electricity are provided to households with income <200% of the poverty line or <80% of area median income.	20%

TABLE 9. ITC bonus definitions and levels under the Inflation Reduction Act.[20, 21]

[20] "Maximizing Inflation Reduction Act of 2022 Bonus Tax Credits," Enel North America, accessed May 1, 2023, https://www.enelnorthamerica.com/insights/blogs/maximizing-inflation-reduction-act-of-2022-bonus-tax-credits.

[21] Benson, Gregg. "IRA Update," Mintz, accessed May 1, 2023, https://www.mintz.com/insights-center/viewpoints/2906/2023-02-16-ira-update-irs-releases-limited-guidance-low-income

DISCUSSION

In this report, we have explored the feasibility of designing and financing GRHs. Our analysis highlights that, without federal tax incentives, such projects may yield low financial returns, with negative pre-tax unlevered IRR for all battery systems. However, with the consideration of federal tax incentives and the non-market value of resilience, GRHs emerge as highly bankable projects. We explored how ITC incentives contribute to the profitability of GRHs, revealing that with a 30% ITC, a solar + storage small system scenario achieves an after-tax levered IRR of 7.9%, while a solar + storage medium system scenario with a 50% ITC attains an after-tax levered IRR of 14.9%. At a 50% ITC, installing a large battery returns an IRR of 8.6% demonstrating that batteries can be sized for resiliency in those communities targeted for ITC bonus incentives.

Despite the availability of tax incentives, several significant challenges continue to hinder the widespread deployment of GRHs. One prominent obstacle is the pricing of energy storage technologies, which remains a major hurdle for achieving enhanced resilience. Although there have been notable cost reductions in battery technology, further progress is essential to ensure the affordability of energy storage solutions as ITC bonuses decrease in future years.

Additionally, the complexity and novelty of GRH business models introduce contractual uncertainties which impact investor and stakeholder confidence. Implementing a microgrid for a GRH adds further complexity concerning the permitting, interconnection, and installation processes. Addressing these challenges requires the development of transparent and well-defined business models to manage perceived risk.

Continued guidance from the federal government regarding ITC and PTC bonus qualification processes is vital to improve the financial viability of GRHs. Clear and consistent guidelines will support developers and investors in maximizing the benefits of these incentives. Additionally, addressing tax credit monetization is crucial to attract investors to GRH projects. Streamlining the process for tax credit monetization and ensuring accessible mechanisms for tax equity, direct pay, or transferability can enhance funding flow into GRH initiatives.

The financial viability of GRHs is significantly bolstered by IRA tax incentives, yet there are additional revenue opportunities from value streams not currently monetized. For example, both FEMA and insurance agencies could pay for the disaster and risk mitigation offered by GRHs. FEMA traditionally focuses on disaster response and recovery, but the increasing frequency of natural disasters demonstrates that it is vital to invest in resilience before disaster strikes. Insurance agencies, in turn, could offer discounts for individuals that have access to a resilience hub. The people who benefit from a GRH would be less likely to require costly repairs and medical attention in the event of a disaster. By expanding the sources of revenue for green resilience hubs, we can further aid their development.

GRH projects represent a valuable solution for communities aiming to improve their collective resilience against natural disasters. Beyond providing emergency services, GRHs generate year-round revenue for communities and avoided emissions for the benefit of society. Notably, our calculations indicate that the net present value of avoided emissions from the modeled system amounts to approximately $312,000, assuming a social cost of carbon of $190, a social discount rate of 5%, and an expectation that the electrical grid in CT reaches net-zero carbon emissions by 2040. It is important to note that while avoided emissions are not currently monetized, they represent significant additional value that GRHs bring to society.

Each GRH is unique and tailored to address the specific resilience needs of its community. Across various iterations, it is evident that IRA resources and state tax incentives significantly improve project revenues. By addressing the challenges and leveraging untapped revenue streams, GRHs can play a crucial role in building resilient communities prepared to face future challenges.

APPENDIX A: METHODOLOGY

In this paper, we presented a model for assessing the financial viability of a resilience hub that utilizes a combination of solar photovoltaic (PV) panels and battery storage under a microgrid. The model utilizes data from multiple sources to calculate revenue streams.

Data Collection

We collected hourly load data from the National Renewable Energy Laboratory's (NREL) Comstock database.[22] We used the PVWatts tool to estimate the hourly solar generation for the location of the resilience hub.[23] We also collected hourly electricity pricing data from the local utility provider.[24]

Model Development

We developed a model in Microsoft Excel that takes into account the solar generation, electricity pricing, and battery storage capacity to calculate revenue streams. The model uses a logic-based approach to determine when the battery should charge and discharge based on incentive program rules and solar generation.

[22] "Comstock Solar I," National Renewable Energy Laboratory, accessed May 9, 2023, https://comstock.nrel.gov/.

[23] "PVWatts® Calculator," National Renewable Energy Laboratory, accessed May 9, 2023, https://pvwatts.nrel.gov/.

[24] "Electric Supply Rates," Eversource Energy, accessed May 9, 2023, https://www.eversource.com/content/business/account-billing/manage-bill/about-your-bill/rates-tariffs/electric-supply-rates.

APPENDIX B: LIMITATIONS AND FURTHER STUDY

While this report presents a comprehensive analysis of designing and financing a Community Resilience Hub, there are several limitations to our study that must be acknowledged.

First, our analysis is constrained by the limitations of the Excel model, particularly when it comes to battery dispatch. While our model provides a useful tool for financial analysis, creating a more accurate dispatch model would require using a more advanced optimization tool. Therefore, we recommend future studies consider using more advanced tools to optimize system design, battery size, battery dispatch, and other factors that may impact the financial viability of a GRH.

Second, our analysis is limited by the quality of cost information available. We were unable to accurately quantify the additional costs associated with each ITC bonus, which could have a significant impact on the overall financial viability of a GRH project. Additionally, we assumed a static price for batteries, whereas battery costs may decrease as the size of the system increases. Therefore, future studies should consider incorporating more detailed and up-to-date cost information to improve the accuracy of financial analyses.

Third, our analysis was limited to solar and storage technologies under a microgrid. Additional work could be done to explore the incorporation of a fuel cell or backup generator to provide additional resilience at a cost lower than the cost of batteries today.

Finally, while we explored potential business models for financing hubs, we did not fully incorporate them into the financial model. Specifically, we did not create a Power Purchase Agreement (PPA) or Energy Service Company (ESCO) structure within the model. Incorporating these models into the analysis could provide a more detailed understanding of the financial returns and potential risks associated with different financing strategies. Therefore, we recommend future studies consider incorporating these business models into the analysis to further improve the accuracy and usefulness of financial models for GRHs.

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