Solar and Energy Storage for Resiliency

City and County of San Francisco, Department of the Environment

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SF Environment
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A Department of the City and County of San Francisco

SOLAR ENERGY TECHNOLOGIES OFFICE
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ARUP

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This Cost Benefit Analysis was co-authored by Arup and the City and County of San Francisco's Department of the Environment ("Project Team"). Lead authors include:

Arup: Abigail Rolon, Alexandra Calven, Nazik Aytjanova

San Francisco Department of the Environment:

- Jessie Denver, Distributed Energy Resources Program Manager
- Jessica Tse, Distributed Energy Resources Coordinator

Additionally, this project has benefited from the input of internal and external subject matter expert stakeholders including:

City and County of San Francisco		
Office of the City Administrator		
Brian Strong	Chief Resilience Officer and Director	Office of Resilience and Capital Planning
Heather Green	Capital Planning Director and Deputy Resilience Officer	Office of Resilience and Capital Planning
Matt Hansen	Director	Risk Management Division
Peter Goldstein	Deputy Director	Risk Management Division
Jaci Fong	Purchaser and Director	Office of Contract Administration
Office of the Controller		
Ted Egan	Chief Economist	Office of Economic Analysis
Department of Emergency Management		
Michael Dayton	Deputy Director	Division of Emergency Services
Lauren Stiger	Disaster Volunteer Coordinator	San Francisco Fire Department Neighborhood Emergency Response Team
Department of Public Health		
Naveena Bobba	Deputy Director of Health	
Matt Wolff	Health Systems and Geospatial Analyst	
Human Services Agency		
Benjamin Amyes	Emergency Services Coordinator	
Bay Area Air Quality Management District		

Ranyee Chan	Technology Officer	
Federal Emergency Management Agency		
Eric Letvin	Deputy Assistant Administrator	Mitigation Directorate
OxFam Mexico		
Alejandra D'Hyver Breña	Humanitarian Coordinator	
American Red Cross		
Trevor Riggen	Sr. Director of Disaster Operations	
Allison Bidinger	Program manager	Bay Area Disaster Services
SunSmart E-Shelters Program		
William Young	Florida Solar Energy Center	Consultant
Sherri Shields	Florida Solar Energy Center	Communications Director
Susan Schleith	Florida Solar Energy Center	Energy Education Coordinator
The Salvation Army		
John McKnight	Director of Emergency and Disaster Services	Golden State Division

Disclaimer

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1 Executive Summary

Facilitated by a grant from the U.S. Department of Energy, the San Francisco Department of the Environment (SF Environment) is working to overcome regulatory, financial and technical barriers and create a roadmap to build resilience through the implementation of solar with energy storage.

One key element of resilience is ensuring the continued operation of shelters and critical emergency management facilities in the immediate aftermath of an earthquake, flood, or other disaster, such as a nearby wildfire. To mitigate interruptions to emergency power at these facilities, the City and County of San Francisco (the "City") has established "on call" contracts with national diesel generator suppliers. However, relying solely on these suppliers poses significant risks to the City, because the supply of diesel generators in San Francisco may be limited when they are most needed, especially during hurricane season when coastal states face an increased risk of power outages. Furthermore, although diesel generators can provide a few days of power when the electric grid is down, they rely on fuel to do so, and fuel supplies can be interrupted by disasters.

To help the City address these challenges, a Resilient Solar and Storage Roadmap study was completed in 2017 that investigated the use of microgrids and stand-alone solar electric generation with battery storage at emergency shelters. The study identified 67 facilities across the City where solar and battery storage systems could be installed. Out of the 67 facilities, 42 are classified as community shelters, where people can live temporarily and receive medical attention for non-serious injuries, and 25 are libraries where people can gather and have free access to communication/information channels (internet access for communication, news, etc.). At present, none of the emergency shelter facilities have back-up power or generators on site.

The Solar and Energy Storage for Resilience project (the "Project) is intended to provide electricity to 67 emergency shelters within the City in the wake of a disaster, by implementing stand-alone solar power generation with battery storage.

This report aims to provide an assessment of the economic value and resilience benefits derived from the implementation of a solar and energy storage system at emergency shelters. This assessment is based on quantifiable metrics and grounded in a proven economic benefit-cost analysis (BCA) methodology, which help decision makers assess whether the benefits of a project or policy exceed its total costs from a societal perspective.

This is a first-of -its-kind study and it is not meant to be comprehensive. The Project Team hopes that other organizations/municipalities will use this report as a reference and refine it for use in future economic assessments on resiliency at emergency shelters. While the report focuses on a study for the City and County of San Francisco, the methods are applicable to any city or town.

The analysis is intended to help the City better prepare for the next large-scale grid outage by weighing the benefits and costs of implementing a solar energy system.

The findings of the economic BCA suggest that regardless of when a disaster happens, the execution of the Project is economically viable for the shelters only, as well as for both shelters and libraries together. The results indicate that for every $1 invested in the installation of solar and energy storage systems at shelters, more than $1.6 are generated in benefits. However, in the case of libraries only, the present value of the costs exceeds the benefits. The reason that shelter and libraries together are economically viable is because the value provided by the shelters is substantial and compensates for the libraries.

For shelters more than half of the total benefits (79%) come from reduction in morbidity and mortality, while 15% come from excess power generation revenue and incident stabilization represents 6%.

Finally, the study concludes that, in the case of both a near future and a distant future disaster, installing solar and battery storage systems to provide resilient power in shelters is a valuable investment for the City because it improves the welfare of the population.

2 Introduction

Facilitated by a grant from the U.S. Department of Energy: Solar Energy Technologies Office's, Solar Market Pathways Program, the City's Department of the Environment (SF Environment) is working to overcome regulatory, financial and technical barriers and create a roadmap to build resilience through the implementation of solar with energy storage. The deployment of resilient solar and energy storage systems at key municipal facilities is now under consideration as part of the City's emergency management plans.

One key element of resilience is ensuring the continued operation of shelters and critical emergency management facilities in the immediate aftermath of an earthquake, flood, or other disaster, such as a nearby wildfire. To mitigate interruptions to emergency power at these facilities, the City has established "on call" contracts with national diesel generator suppliers. However, relying solely on these suppliers poses significant risks to the City, because the supply of diesel generators in San Francisco may be limited when they are most needed, especially during hurricane season when coastal states, like Florida, Louisiana, Texas, and New York face an increased risk of power outages. Furthermore, although diesel generators can provide a few days of power when the electric grid is down, they rely on fuel to do so, and fuel supplies can be interrupted by disasters.

To help the City address these challenges, a Resilient Solar and Storage Roadmap study was completed in 2017 that investigated the use of microgrids and stand-alone solar electric generation with battery storage to provide power to critical facilities following a disaster.[1] The study assessed 1, 263 potential sites within the City; 67 of these sites were classified as adequate emergency shelters where solar photovoltaic (PV) and battery storage systems can be installed. Solar Market Pathways financial analysis report concluded that 12.5 megawatts (MW) of PV panels and 12.5 MW of battery storage is the optimal capacity to supply the City's municipal facilities with resilient backup power.[2] In addition to supplying resilient power post-disaster, this approach would allow the critical facilities to use renewable energy on a daily basis, thereby partially offsetting the use of grid power and the associated costs.

This report aims to provide an assessment of the economic value and resilience benefits derived from the implementation of a solar and energy storage system. This assessment is based on quantifiable metrics and grounded in a proven benefit-cost methodology. This is a first-of -its-kind study and it is not meant to be comprehensive. As research advances in resilience in emergency response

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[1] Resilient Solar and Storage Roadmap Study https://sfenvironment.org/sites/default/files/fliers/files/sfe_ee_solar_storage_roadmap.pdf

[2] Solar Market Pathways report https://sfenvironment.org/sites/default/files/fliers/files/sfe_ee_financial_analysis_report_dec2017.pdf

operations, there is room for improvement to the metrics used to quantify and monetize benefits.

The analysis is intended to help the City better prepare for the next large-scale grid outage by weighing the benefits and costs of implementing a solar energy system.

3 Methodology

3.1 Overview of Economic Benefit Cost Analysis

The purpose of the economic BCA is to help decision makers assess whether the benefits of a project or policy exceed its total costs, both from a monetary and a societal perspective. This approach is typically used by federal government agencies (e.g. Environmental Protection Agency, Federal Transit Administration, etc.) and multilateral agencies (e.g. World Bank) to prioritize projects that promote overall efficiency in government spending.

An economic BCA is not a financial exercise. A financial exercise is aimed at assessing the out-of-pocket expenses the government will incur in undertaking a project. An economic BCA goes beyond that to assess the impacts of a project from the perspective of the community's welfare.

Standard economic BCA methodology utilizes the following steps:

- **Definition of the baseline conditions**. The base case describes a scenario in which the Project is not implemented. In this case, the Project Team assessed the consequences of not implementing a solar and energy storage system at the emergency shelters. The base case is critical to the analysis because it is the reference point against which the incremental benefits and costs of the investment alternative (solar and energy storage) are measured.

- **Definition of the project situation**. The project situation assesses the consequences of the Project implementation.

- **Benefits and costs.** This step involves the identification and quantification of benefits and costs under the baseline conditions and the project situation.

- **Benefit-cost analysis of comparing the project situation with the baseline conditions.** The outcome of the comparison is summarized using a benefit-cost ratio (B/C ratio) or other metrics (ex. net present value, internal rate of return). In this case, the Project Team used the B/C ratio metric, because it offers a direct relationship between the benefits and costs of a project.

The B/C ratio compares the benefits of the Project, relative to its costs, expressed in monetary terms, over the time of the analysis. A B/C ratio greater than one (1) suggests that the benefits exceed the costs.

Typically, a project's benefits and costs occur at different points in time. Thus, to compare them properly, their values are discounted using a "discount rate." The discount rate reflects the opportunity cost of capital, or the return on investment that a society foregoes when it elects to use funds for one project versus another.

Generally, there is lack of consensus on what the most appropriate discount rate is. However, through this analysis, the Project Team found that the federal government recommends a real discount rate of 7%, based on the Office of Management and Budget (OMB) Circulars A–4 and A–94 guidelines for projects that request federal funding, and suggests undertaking a sensitivity analysis using a real discount rate of 3%.[3]

All benefits and costs in this report are expressed in discounted present values.

The formula to convert future values (benefits and costs) into present values is as follows:

$$PV = FV / (1+ i)^t$$

Where,

PV= Present discounted value of a future payment from year t
FV = Future Value of payment in year t
i = Discount rate applied
t = Years in the future for payment (where base year of analysis is t = 0)

For this analysis, the Project Team ran the BCA using two real discount rates: 7% as recommended by the federal government, and 3.5%, the City's long term real rate of borrowing.

- **Sensitivity analysis of the key variables.** An analysis of how key variables can impact the economic metrics or outcomes of the economic BCA.
- **Timeline of the analysis**. The timeline comprises 22 years, of which years 1 and 2 are dedicated to the construction of the Project and years 2-22 comprise the operating phase. Note that operations start in year 2 of the construction phase, as 50% of the Project is executed, and the Project is operational at the start of the second year

[3] Tiger Benefit Cost Analysis (BCA) Resource Guide https://www.transportation.gov/sites/dot.gov/files/docs/Tiger_Benefit-Cost_Analysis_%28BCA%29_Resource_Guide_1.pdf

- **Monetary values.** Monetary values are expressed in 2018 dollars.

4 Definition of Baseline and Project Situation

4.1 Baseline Conditions

The Resilient Solar and Storage Roadmap study identified 67 facilities across the City as adequate emergency shelters where solar and battery storage systems could be installed. Out of the 67 facilities, 42 are classified as community shelters, where people can live temporarily and receive medical attention for non-serious injuries, and 25 are libraries where people can gather and have free access to communication/information channels (internet access for communication, news, etc.) [4]

At present, none of the emergency shelter facilities have back-up power or generators on site. The City has national suppliers under contract to provide diesel generators to emergency shelters, in the event of an emergency. However, relying solely on these suppliers carries risks, as mentioned in the introduction of this report. First, generators may be in short supply when disaster strikes, particularly during the hurricane season when the coastal US faces a higher risk of power outages. Second, diesel generators can only provide backup if there is a sufficient supply of available fuel, which is not guaranteed in the aftermath of a disaster.

The baseline conditions correspond to the existing back-up power conditions at the facilities identified as emergency shelters and summarized in the table below.

Table 1: Number of Facilities and back-up power conditions

Facility	Number of facilities	Back-up power
Shelters	42	None. Potentially available upon request based on the City's contract with suppliers.
Libraries	25	None. Potentially available upon request based on the City's contract with suppliers.
Total (Shelters & Libraries)	67	

[4] Resilient Solar and Storage Roadmap Study https://sfenvironment.org/sites/default/files/fliers/files/sfe_ee_solar_storage_roadmap.pdf

4.2 Project Situation

The Project Situation assumes the implementation of solar and battery storage systems at the 67 municipal buildings identified as emergency shelters. The table below summarizes solar PV capacity and annual energy generation for all the critical facilities.

Table 2: Solar PV Capacity and Generation

Facility	PV Capacity (MW)	PV Generation (MWh)
42 Shelters	8.8	13,300
25 Libraries	3.7	5,600
Total (Shelters & Libraries)	**12.5**	**18,900**

The table below summarizes battery energy storage power capacity, storage energy capacity, and annual stored energy for all critical facilities.

Table 3: Battery Storage Capacity and Stored Energy

Facility	Storage Capacity (MW)	Storage Energy Capacity (MWh)	Stored Energy (MWh)
42 Shelters	10.00	40.0	14,000
25 Libraries	2.5	10.0	3,500
Total (Shelters & Libraries)	**12.5**	**50.0**	**17,500**

4.3 Disaster Event Scenarios: Near Future vs. Distant Future

The challenge when assessing the consequences of a potential disaster under an economic BCA is that it is impossible to predict when the event will occur. However, the moment when a disaster does occur impacts the results of the economic BCA because the Project's investment costs are incurred in the "present," while the benefits tend to occur in the future. Given that both the benefits and the costs are discounted to bring them to present value in monetary terms, the longer it takes for an event to occur, the less immediate benefit the initial investment provides.

To account for the inability to predict when a disaster will occur, the Project Team arbitrarily developed two disaster scenarios that happen at different points in time (near term versus distant future) as follows:

- Scenario 1 assumes that a disaster occurs within 5 years of Project (installation of solar and energy storage) completion.
- Scenario 2 assumes that a natural disaster occurs within 10 years of Project (installation of solar and storage) completion.

To assess the potential consequences of a major disaster capable of compromising energy supplies throughout the City, the Project Team relied on a 2014 Lifelines Interdependency Study Report, prepared by the City's Lifelines Council.[5] The study used a hypothetical scenario that repeats "the 1906 San Francisco Earthquake" or a magnitude 7.9 earthquake on the San Andreas Fault. Among the potential impacts related to the disruption of electric power are the following:

- Electric substation failure, or other significant disruption of electric power within the City, could have direct impacts on telecommunications.
- Power disruptions lasting more than 72 hours. Particularly disruptions affecting systems with a heavy power dependency and limited back-up power supplies, such as wastewater, municipal transit and telecommunication systems.

5 Stakeholders Engagement

The Project Team performed a literature review on the economic value of power resilience at emergency municipal facilities aimed at identifying metrics for benefits quantifications. Though there is abundant literature on the economic value of resiliency, no precedents for solar power resiliency at emergency facilities were found. Most of the publications address the benefits qualitatively

[5] 2014 Lifelines Interdependency Study Report https://sfgov.org/orr/sites/default/files/documents/Lifelines%20Council%20Interdependency%20Study.pdf

and acknowledge the challenges of assigning a monetary value to resilience investments, since each user (business or individual) could place widely varying values on resilience. For example, both a hospital and an office building rely on electricity for their operations, however, the consequences of a power outage for the former could prove fatal.

As a result, this is the first effort ever undertaken to develop metrics to measure the co-benefits associated with the installation of solar and energy storage systems at critical facilities.

The Project Team interviewed key internal and external stakeholders and subject matter experts, including those with first-hand experience responding to disasters. The findings of this stakeholder engagement process are summarized in the section below.

5.1 External Stakeholders

The Project Team reached out to humanitarian organizations that provide emergency assistance and disaster relief to get their perspectives on how a project like this one could benefit operations during an emergency. The disaster relief organizations interviewed, include:

- The American Red Cross is a humanitarian organization that provides emergency assistance, disaster relief, and disaster preparedness education in the United States and around the world. In 2017, the California Wildfires, Hurricanes Harvey, Irma, and Maria were among the American Red Cross's largest relief efforts.
- The Federal Emergency Agency's (FEMA) is an agency of the United States Department of Homeland Security, which primary purpose is to coordinate the federal response to a disaster occurring within the United States that overwhelms the resources of local and state authorities. In 2017, FEMA assisted 34 states with disaster relief and covered a wide range of emergencies, from floods to fires.
- The Salvation Army is an international charity with a presence in 128 countries. It provides a wide range of community services, from child care support to disaster relief. During 2017, the Salvation Army participated in 56 rapid response projects, spanning 25 countries, with more than 88,000 beneficiaries.[6]
- Oxfam (Mexico branch) is a charitable international organization that focuses on the alleviation of global poverty and the provision of disaster relief during emergencies. The Project Team was particularly interested in

[6] Salvation Army 2017 Report https://www.salvationarmy.org/ihq/annualreport

learning about Oxfam Mexico's disaster recovery experience following the 2017 earthquake.

Additionally, the Project Team interviewed representatives of Florida's SunSmart E-shelter. Coordinated by the University of Central Florida's Florida Solar Energy Center, SunSmart's E-Shelter program has installed more than 115, 10-kW photovoltaic systems at emergency shelter schools throughout Florida. We were interested in collecting pre- and post-project data on the economic value provided by solar powered emergency shelters.

Through the interviews, the Project Team tried to capture metrics including potential reduction in mortality (avoided loss of lives), morbidity, loss of perishables, insurance costs, and the value of enabling communication. It is worth noting that FEMA recognizes the challenges associated with quantifying and monetizing avoided losses, given the limits of existing data. The agency is seeking to assess the economic value of pre-disaster mitigation by developing a framework based on disaster recovery costs available under the FEMA program.

Interviewees provided positive feedback on the Project, and each acknowledged how invaluable energy resilient municipal facilities could be in helping communities deal with the aftermath of a major disaster that compromised the power grid. From a qualitative perspective, each organizational representative interviewed highlighted the following potential benefits:

- **Facilitate or expedite response.** To mitigate chaos, strong coordination among multiple agencies is required in the first 24 hours following a disaster. If shelters were designed to be fully operational following an event it would enable emergency responders to immediately focus on serving the needs of the sheltered population, rather than first focusing on locating diesel generators.

- **Benefits to high risk groups - save lives**. Both FEMA and the SunSmart E-shelter highlighted the direct benefits the Project could provide to high risk groups, especially community members who are power dependent. Following a disaster, power dependent populations (special needs population) could immediately be moved to shelters powered by solar and energy storage systems where they could receive the care they need. Special needs shelter can be set up to serve special needs population, these shelters are like general shelters, with the added resources needed to support their medical equipment. The loads

- **Improve morale among affected populations.** Being housed in a fully operational facility would improve morale among those requiring shelter in the wake of an emergency. The temporary or permanent loss of a house undermines the earning capacity, health, and well-being of a household, and thus the better the City can cover their basic living needs (access to power, potable water, sanitation, etc.) the easier to support their post-disaster recovery.

- **Facilitates communication:** Interviewees cited 'saving lives' and 'providing communication' as their top two priorities. While it is not straightforward to quantify the value of communication, each of the engaged stakeholders agreed that enabling impacted populations to reach out to family and friends, and access status updates, was critical to incident stabilization.

5.2 Internal City Stakeholders

The Project Team hosted two workshops with various City departments. Attendees included: Brian Strong, Chief Resilience Officer and Director; Heather Green, Capital Planning Director and Deputy Resilience Officer; Matt Hansen, Director of the Risk Management Division; Peter Goldstein, Deputy Director of the Risk Management Division; Ted Egan, Chief Economist of the Office of Economic Analysis; Michael Dayton, Deputy Director of the Emergency Services; Laurel Stiger, Disaster Volunteer Coordinator; Naveena Bobba, Deputy Director of Health; Matt Wolff, Health Systems and Geospatial Analyst; Benjamin Amyes, Emergency Services Coordinator.

The purpose of the workshops was to develop metrics of potential benefits, assuming a hypothetical disaster scenario where power supply was compromised. Engaged stakeholders agreed that the timeframe for the disaster event should be a week—a figure in line with the Lifeline Council Interdependence Study, which assumes a post-disaster, city-scale power outage and a return to near 100 percent power within one week.

Consensus on analysis inputs was achieved during the workshops, including but not limited to:

- The amount of significantly injured people the City could expect after a disaster
- The number of in-Home Supportive Services community members who would need to be served
- Details on the City's electrically assisted population
- The number of disaster service workers staff required per shelter facility to support the community

Additionally, the Project Team sought feedback from Ted Egan, Chief economist, on the economic methodological framework used for this study.

The Project Benefits section below provides a detailed description of the assumptions agreed upon by stakeholders during the workshops.

6 Project Benefits

6.1 Quantifiable Benefits Assumptions

The benefits of undertaking the Project can be categorized as quantifiable and non-quantifiable. A monetary value can be assigned to quantifiable benefits. However, it is more difficult to define and measure non-quantifiable benefits. As such, the non-quantifiable benefits were not included in the economic BCA.

Given that shelters and libraries would serve different purposes during an emergency, the quantification of their respective benefits was done independently. Shelters, for example, would provide temporary housing to the affected population, and services like meal preparation and medical attention for non-serious injuries. These services are very different than those of a library, which would provide no-cost access to communication channels, like internet and television, to the affected population.

6.1.1 Quantification of Benefits: Shelters

Table 4 lists the quantifiable benefits of shelters during a major grid outage resulting from a disaster.

Table 4: Shelters Benefits

Benefits	Metrics
Reduced Morbidity	Savings in hospital care resulting from shelter's ability to provide medical attention for non-emergency injuries
Reduced Mortality	Saved lives of electricity-dependent population and in-home support services (IHSS) population. IHSS population is defined as low income people who are blind, disabled, or 65 years old or older and who need personal assistance and in-home services so they can safely stay in their homes or continue working.
Incident Stabilization	Savings resulting from a reduction in the number of disaster service workers (DSW) required due to shelter's access to reliable power
Power Generation	Revenue from any excess power generation and net metering at shelters (beyond normal non-emergency operations)

- **Reduced morbidity:** During a disaster, it is more cost efficient for the City to treat non-emergency injuries at shelters than to send people to local hospitals. This translates into significant medical care savings.

  According to the statistics provided by the City, the current population of permanent residents in San Francisco is 850,000 people. Additionally, on any given day the City receives approximately 350,000 visitors, including tourists, students, and day workers. Thus, the total daily population of San Francisco is approximately 1.2 million people.

  During the internal City stakeholder workshops, participants agreed to assume that 2% of the daily population, or 25,000 people, would receive significant injuries. Out of the 25,000 people, it was also assumed that 5%, or 1,250 people, would require electricity-dependent medical care. The Project Team then assumed that 50% of the shelters would have the necessary medical supplies and equipment available after a major disaster to assist with injuries. As a result, it was assumed in this analysis that 625 people with injuries would be cared for at the shelters.

  The savings (or benefit) resulting from shelters providing medical care rather than hospitals was determined to be $900 per person per day ($1,000 cost per person at a hospital versus $100 at a shelter). Thus, the total monetary value of reduced morbidity is $562,500 ($900 x 625 people) over the course of a seven-day post-disaster period.

- **Reduced mortality:** A power outage can be a life-threatening situation for the IHSS population. The reliable power supply delivered by solar and energy storage systems at shelters would mean that IHSS populations displaced after a disaster could be safely housed and served at shelters. Internal City stakeholders agreed during the workshops that approximately 6,500 IHSS community members will likely need support. The most vulnerable residents, who are insulin and oxygen dependent, are assumed to make up 0.1% of the IHSS population. Therefore, approximately 7 lives could be saved because of solar and energy storage systems.

  U.S. federal agencies have no agreement regarding the "appropriate value" of a statistical life. In 2018, FEMA estimated a value of $7m.[7] The EPA[8] also suggested, this year, using a $10m estimate, while the U.S. Department of Transportation[9] recommends using a range of $5.2 -$13m. The Project Team reviewed these values and assumed a mid-point of $8m

[7] https://securitynotes.asdwa.org/2014/04/16/fema-updates-its-benefit-cost-analysis-toolkit/

[8] https://www.epa.gov/environmental-economics/mortality-risk-valuation

[9] https://www.faa.gov/regulations_policies/policy_guidance/benefit_cost/media/Revised%20Value%20Of%20Life%20Guidance%20Feburary%202008.pdf

for this analysis. Therefore, **the total monetary value of reduced mortality for IHSS population is $52 million**.

Additionally, individuals who are dependent on assistive electric medical technologies would also benefit from continuous power at municipal shelters in the event of a grid outage. The internal stakeholders agreed that there is an overlap between the electricity dependent population and IHSS population. However, it is challenging to determine the exact percentage. Based on the information agreed upon during the workshops, there are approximately 100 people that are power dependent and need access to electricity to survive. These residents may require care at medical facilities. However, due to likely demand at hospitals and potential chaos resulting from the disaster, the Project Team assumed that 5% of this population, or 5 people, will have access to hospitals. The Project Team also assumed that 10% of the electrically assisted population, or **10 people,** would live temporarily at the shelters. Thus, the shelters powered by solar and energy storage systems would save the lives of 10 individuals who would not survive without power.

The total monetary value of reduced mortality for the electric dependent population is $80 million.

- **Incident Stabilization:** Shelters with no power would require on average of 15 more disaster service workers (DSW) per shift to serve the impacted population, due to reductions in setup time and guidance from City leadership. The uninterrupted power supply provided to shelters by solar and energy storage systems would preclude the time and labor involved in procuring and setting up diesel generators, ensuring that flashlights are readily available, etc.

  DSWs are City employees who, in the event of a disaster, are called to support the community outside of their regular roles and responsibilities. Internal City stakeholders shared that DSWs may need to be on duty for up to one week before outside response and relief organizations arrive to take over community assistance.

  Internal City stakeholders also agreed on the following assumptions during the workshops. Approximately 65 DSWs per facility per shift would be required at $100 per hour if shelters had no reliable electricity supply, with each shift lasting 12 hours. However, with continuous electricity supply from solar and energy storage systems at the shelters this number would reduce to 50 DSWs. In total, **the City would save approximately $4 million by reducing the number of DSWs required to serve the community at shelters**.

- **Power generation:** Solar and battery energy storage systems would provide continuous power generation throughout their twenty-year operational lifetime, reducing reliance on the grid and offering additional power and storage capacity that could be sold back to the grid**. Annual revenue from power generation and storage were estimated at $665,000 and near $960,000, respectively.**

6.1.2 Quantification of Benefits: Libraries

Table 5 lists the quantifiable benefits of libraries during a major grid outage resulting from a disaster.

Table 5: Library Benefits

Benefits	Metrics
Incident Stabilization	Savings in DSW staff. Visitors unfamiliar with the City would have easier access to communication and information (internet, news, etc.), thus reducing the number of DSWs required to assist
Power Generation	Revenue generated from selling any power generated over and above that required to facilitate normal (non-emergency) operations

- **Incident Stabilization:** In an attempt to quantify the value of communication**,** the Project Team assumed that people unfamiliar with the City, like tourists and commuters stuck in the City, would demand access to informational updates on the disaster and the ability to communicate with their families. If grid electrical power is compromised, and libraries do not have power, more DSW staff would be needed to assist this population. In other words, if this population can connect to the internet, charge their cell phones, and watch the news at libraries powered by solar and energy storage systems, they will have greater "peace of mind" post-disaster and require less support from City employees deployed as DSWs.

  The Project Team assumed that daily, non-resident population is around 350,000 people and out of those 20%, or 70,0000 people, would need significant assistance and 5%, or 17,500 people, would need minor assistance. Significant assistance was assumed to demand one hour of DSW support, while minor assistance only 15 minutes. Under the project situation it was assumed that the rate at which the population could be supported would be accelerated and the affected population would require less assistance from DSWs. **The results suggest that DSW hours would be reduced by nearly 37,000 hours, representing a savings of $3.7 million.**

- **Power generation**: Solar and battery energy storage systems would provide continuous electricity generation throughout their twenty-year operational lifetime, thus reducing reliance on the grid and offering additional power and storage capacity that could bring value to the City and utility grid. **Annual revenue from power generation and storage were estimated at $240,000 and approximately $280,000, respectively.**

Please refer to Appendix B for the breakdown of the economic benefits associated with undertaking the Project.

6.2 Non-Quantifiable Benefits

The non-quantifiable benefits of supplying reliable power to critical facilitates are mainly psychological. Being able to charge phones and communicate with the external world and loved ones will provide those affected with "peace of mind" post-disaster. Additionally, having TVs will help to provide distraction and facilitate the delivery news and connection with the rest of the world.

7 Project Costs

The project costs include capital expenses and operations and maintenance (O&M) expenses. Capital expenses include purchase of solar PV modules, battery energy storage equipment, and installation labor costs. Battery energy storage systems are assumed to have a 10-year life. Therefore, the Project Team assumed this equipment would be replaced in year 10 of operation.

Installation of solar and energy storage systems is assumed to take place over a two-year period. The total capital cost listed below will be split evenly between the first year of construction (construction phase 1) and second year of construction (construction phase 2). Table 6 summarizes the capital costs for the shelters.

Table 6: Capital Costs for Shelters

	Total Cost (million USD)
PV	$20
Storage	$22
Total	**$42**

Operational costs include fixed O&M costs of battery energy storage, solar PV arrays, and the daily cost of electricity that is used to charge batteries when solar power is not available. It must be noted that the O&M cost of the Project during the first year of operations is less than the annual operational cost because only half of the solar and energy storage system would be installed during that time.

Table 7 lists the operational costs of the shelters.

Table 7: Operational Costs for Shelters

	Total Cost (million USD)
Year 1 Operational Cost	$2.2
Annual Operational Cost	$4.4
Storage system replacement Cost	$10.8

Table 8 summarizes the capital expenses for the libraries

Table 8: Capital Cost for Libraries

	Total Cost (million USD)
PV	$8
Storage	$6
Total	**$14**

Table 9 lists the operational expenses for the libraries.

Table 9: Operational Costs for the Libraries

	Total Cost (million USD)
Year 1 - Operational Cost	$0.6
Annual Operational Cost	$1.1
Storage system replacement Cost	$2.7

Please refer to Appendix A for a full breakdown of the Project costs.

8 Results and Sensitivities

8.1 Results

The purpose of the report is to assess the economic value that solar and energy storage could provide during an emergency in terms of resiliency, as measured by avoided disruptions and associated costs. Benefit to cost ratio (B/C) was calculated for shelters only, libraries only, and both shelters and libraries together. Two scenarios (e.g., within 5 or 10 years after project completion) were evaluated to analyze the effect of the time of the disaster occurrence on the B/C ratio.

The findings of the economic BCA suggest that regardless of when a disaster happens, the execution of the Project is economically viable for the shelters only, as well as for both shelters and libraries together**.** In both cases, during the timeline of the analysis, the present value of the benefits outweighs the Project costs, as figures 1 and 2 demonstrate. However, in the case of libraries only, the present value of the costs exceeds the benefits. The reason that shelter and libraries together are economically viable is because the value provided by the shelters is substantial and compensates for the libraries.

Figure 1 presents the monetary value of benefits and costs for Scenario 1 (5 years).

Figure 1: Value of Benefits and Costs – Scenario 1

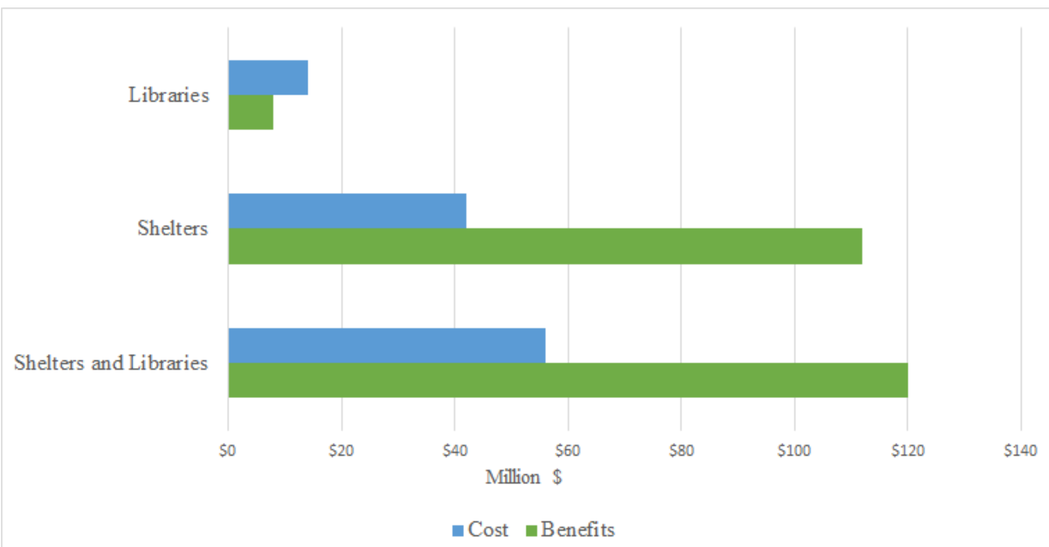
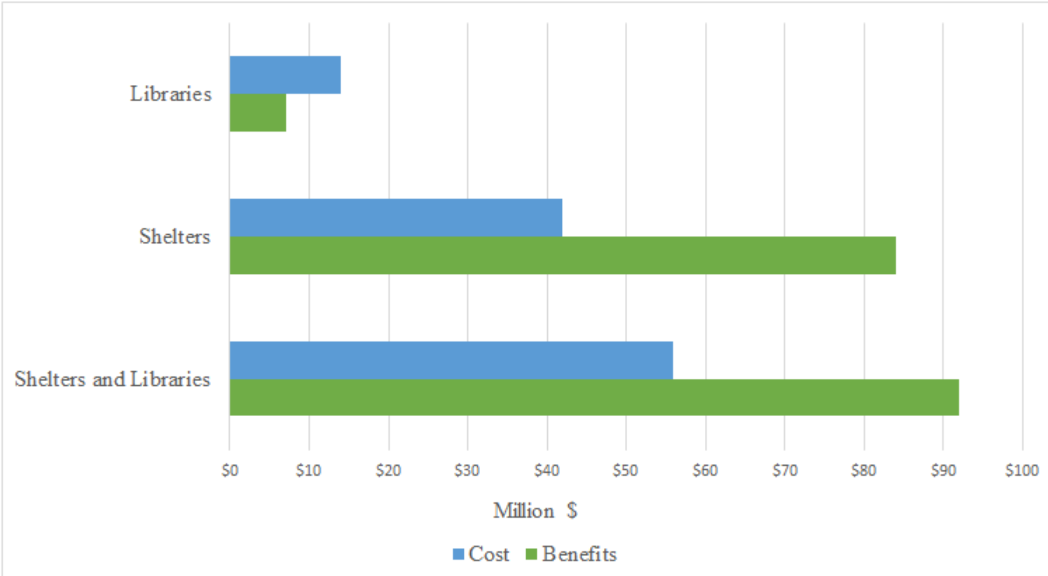


Figure 2 presents the monetary value of benefits and costs for Scenario 2 (10 years).

Figure 2: Value of Benefits and Costs - Scenario 2



The figures below break down benefits by category for shelters, libraries, and both shelters and libraries for Scenario 1.

Figure 3: Benefits by Category – Shelters

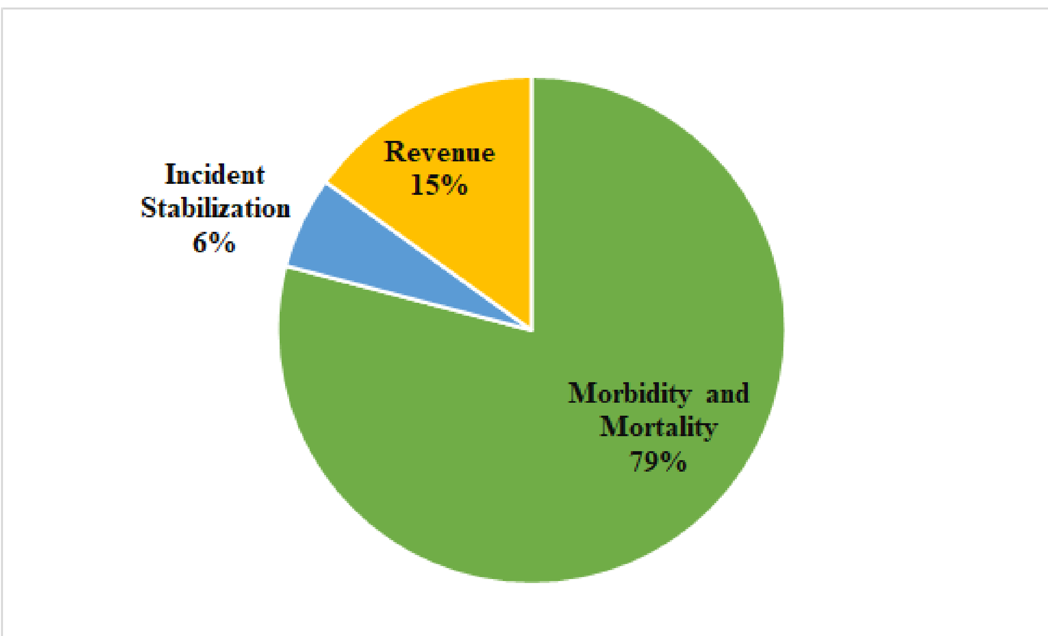
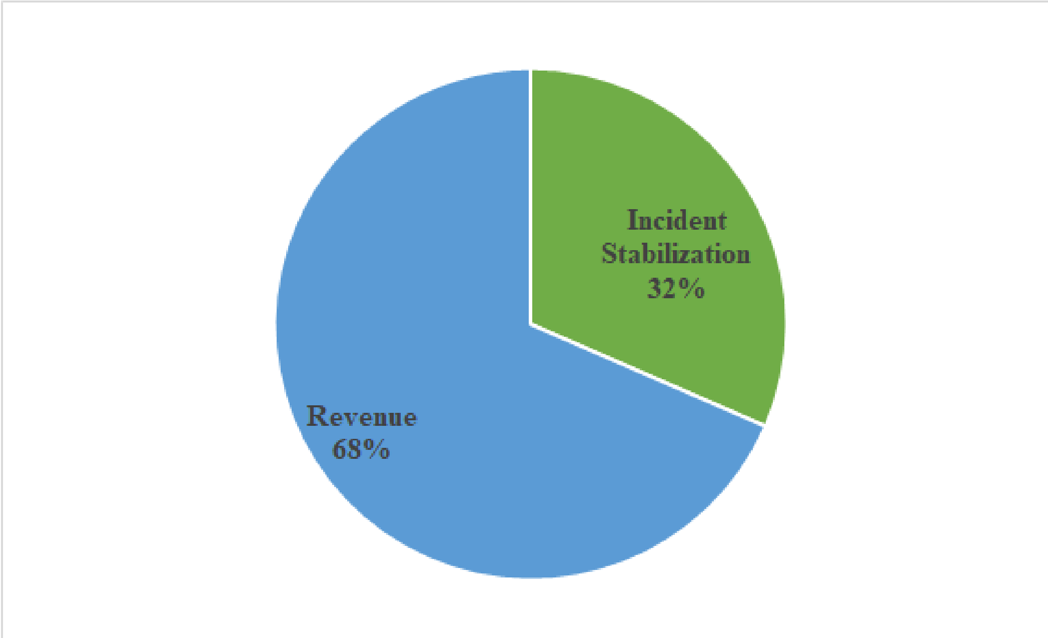


Figure 3 illustrates that for shelters more than half of the total benefits (79%) come from reduction in morbidity and mortality, while 15% come from excess power generation revenue and incident stabilization represents 6%.

Figure 4: Benefits by Category – Libraries



For libraries, more than half of the total benefits (68%) come from the excess power generation revenue, while the other 32% come from incident stabilization.

Figure 5: Benefits by Category – Shelters and Libraries

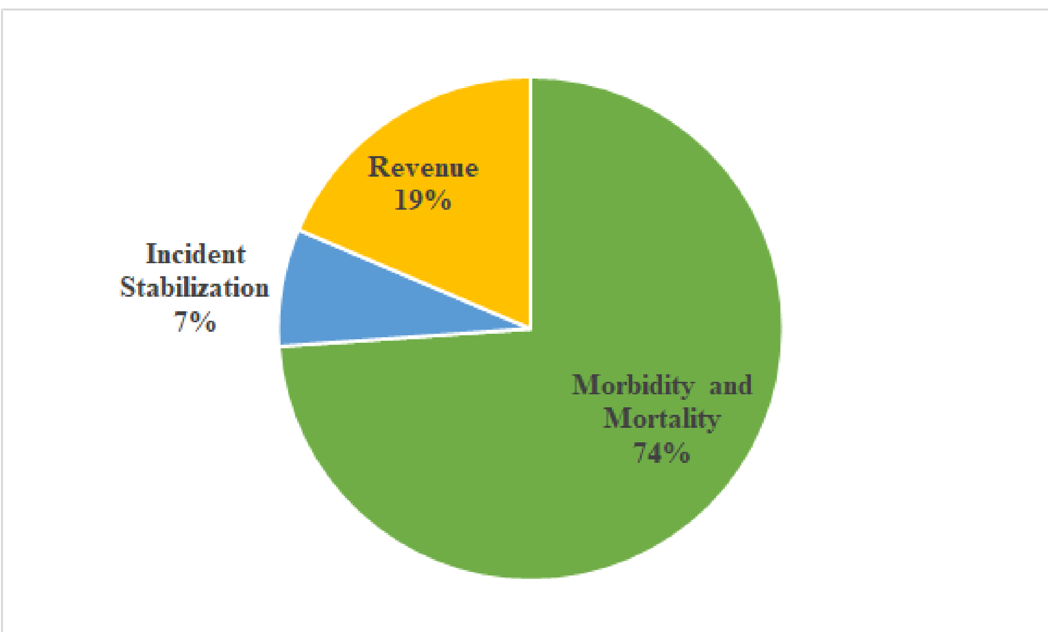


Figure 5 illustrates that for shelters and libraries more than half of the total benefits (74%) come from reduction in morbidity and mortality, while 19% come from excess power generation revenue and incident stabilization represents 7%.

Shelters and the combination of both shelters and libraries have a B/C ratio higher than 1, which suggests that the benefits exceed the costs.

Regardless of the scenario, the results indicate that for every $1 invested in the installation of solar and energy storage systems at shelters, more than $1.6 are generated in benefits.

Table 10 summarizes B/C ratio for each facility group for both Scenario 1 and Scenario 2.

Table 10: Summary of B/C Ratios

Facilities	Scenario 1 B/C Ratio	Scenario 2 B/C Ratio
Shelters only	2.6	2.0
Libraries only	0.6	0.5
Total (Shelters & Libraries)	**2.1**	**1.6**

8.2 Sensitivities

A series of sensitivity analyses were conducted to ascertain how changes to key input parameters impacted the B/C ratio: percentage of electrically assisted population accessing the shelter (mortality percentage), discount rate, and value of life. These three key parameters were determined to have the most impact on the B/C ratio.

The table below summarizes the initial and the alternative input parameters used for sensitivity analysis.

Table 11: Sensitivity Parameters

Parameters	Base case	Alternative
Power dependent population sheltered %	10%	30%
Real discount rate	7%	3.5% [10]
Value of life	$8M	$10M [11]

The figures below illustrate how the benefit-cost ratio varies as input values vary.

[10] The City's long term real rate of borrowing.
[11] https://www.epa.gov/environmental-economics/mortality-risk-valuation

Figure 6: Sensitivity Analysis – Scenario 1

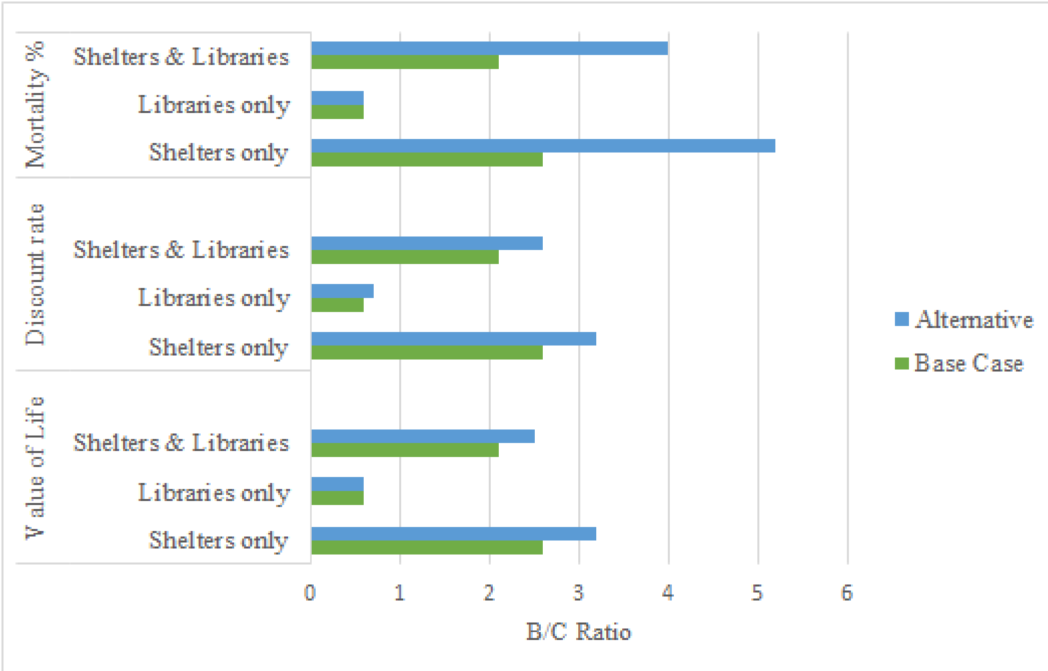
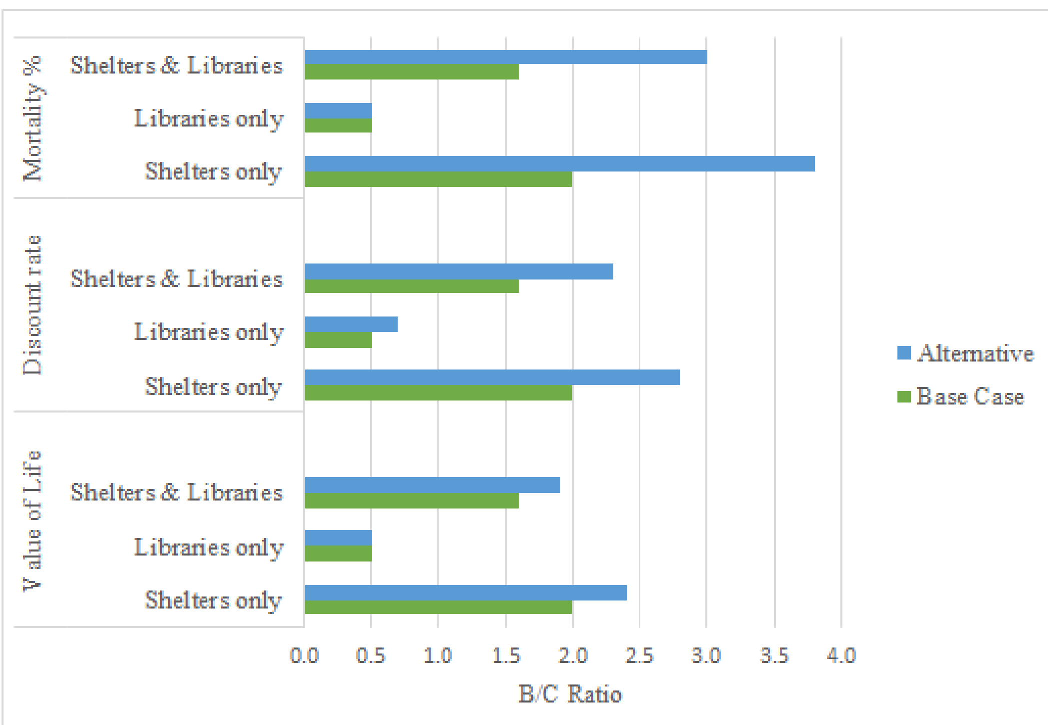


Figure 7: Sensitivity Analysis – Scenario 2



As expected, shelters and both shelters and libraries are highly sensitive to changes in mortality rate, as shown by the B/C Ratio.

The analysis is also relatively sensitive to variance in the discount rate. All B/C ratios increased when a lower discount rate of 3.5% was used, especially under Scenario 1. However, the B/C ratio for libraries is still below 1.

Finally, the study concludes that, in the case of both a near future and a distant future disaster, installing solar and battery storage systems to provide resilient power in shelters is a valuable investment for the City because it improves the welfare of the population.

9 Appendices

Appendix A

Cost Assumptions

Cost Assumptions

Color key: Inputs / Calculated values

Category	Facility Type	Subcategory	Variable	Cost per Unit	Unit	Total	Construction phase 1	Construction phase 2	Years of full operation 1-20	Year of equip. replacment 10	
PV+Storage System											
	Construction Phasing						50%	50%			
	Shelters	Capital	PV	$2,226	/kW	$19.6	$9.8	$9.8			million
			Storage	$1,113	/kW	$22.3	$11.1	$11.1			million
				$278	/kWh						
		Operation	Operating cost	$10	/kW storage capacity			$0.05	$0.10		million
			Electricity wholesale rate	$0.03	/kWh			$0.21	$0.42		million
			PV maintenance/ lifecycle cost	$0.14	million			$0.07	$0.14		million
			Storage system replacement cost	$10.8	million					$10.80	million
		Revenue	PV	$0.05	/kWh generated			$0.33	$0.67		million
			Storage	$0.96	million			$0.48	$0.96		million
	Libraries	Capital	PV	$2,226	/kW	$8.2	$4.1	$4.1			million
			Storage	$1,113	/kW	$5.6	$2.8	$2.8			million
				$278	/kWh						
		Operation	Operating cost	$10	/kW storage capacity			$0.01	$0.03		million
			Electricity wholesale rate	$0.03	/kWh			$0.05	$0.11		million
			PV maintenance/ lifecycle cost	$0.06	million			$0.03	$0.06		million
			Storage system replacement cost	$2.7	million					$2.70	million
		Revenue	PV	$0.05	/kWh generated			$0.14	$0.28		million
			Storage	$0.24	million			$0.12	$0.24		million

Footnotes:

1) Cost data (capital, operation, and revenue) are based on same input as the Solar Market Pathways Financial Analysis.

2) Note that the capital costs do not include the financing of the project.

Appendix B

Economic Assumptions

Economic Assumptions

Color key: Inputs / Calculated values

Category	Subcategory	Variable	Assumption	Unit	Notes
Population					
		Residents	850,000	people	Permanent residents
		Visitors	350,000	people	Commuters to SF/Students/tourists approx. 70K based on city's stats.
		Total population	1,200,000	people	Daily population
Reduce Morbidity					
	Significant injuries				
		Significant injuries	25,000	people	2-3% of total daily population. Depends on what time of day the earthquake strikes (more people in the city during daytime).
		Electricity dependent care	5%	of people with significant injuries	Percentage of significantly injured people that will require electricity dependent care.
		People needing electricity dependent care	1,250		
		Equipment availability	50%	of shelters	Percentage of shelters that will have required equipment available shortly after earthquake event (e.g. oxygen generators).
		Significant injuries cared for in powered shelters	625		Number of people that can be cared for in shelter if power is provided.
	Medical care				
		Cost for care at shelter	$100	per person/day	
		Cost for care at hospital	$1,000	per person/day	
Reduce Mortality					
	IHSS population				
		IHSS population	22,000	people	IHSS = In Home Support Service. Out of these people, many with access and functional needs.
		Displaced	50,000	permanent residents	50,000 out of 850,000 permanent residents are assumed to be displaced.
		Vulnerability factor	5		People that require IHSS are 5 times more likely to be displaced.
		IHSS population sheltered	6,500	people	
		Mortality rate	0.1%	of IHSS population	E.g. Insulin dependent and oxygen dependent
		Lost lives w/o powered shelters	7	people	Lives lost if no power provided at shelters.
		Saved lives w powered shelters	7	people	Saved lives if power provided in shelters.
	Electrically assisted population				
		Electrically assisted	100	people	Most vulnerable (can not shelter at home).
		Hospital access	5%	of electrically assisted people	How many of electrically assisted people will make it to the hospital
		Lost lives w/o powered shelters	95		Lives lost if hospital is only place with power.
		Shelter access	10%	of electrically assisted people	How many of electrically assisted people will make it to the shelter (easier access)
		Lost lives w powered shelters	85		Lives lost if power provided at shelters.
		Saved lives w powered shelters	10	people	Saved lives if power provided in shelters.
	Cost of life				
		Cost of life	$8,000,000	per person	$6-10M, check source
Incident Stabilization - Reduce DSW Staff Time in Shelters					
	DSW staff time				
		Staff required (no power)	65	per facility per shift	DSW staff per shelter facility with no power (serving 1000 people).
		Staff required (power)	50	per facility per shift	If power in shelter, less DSW staff required due to less setup time and guidance (less flashlights, lighting, generators to set up)
		People served	1,000	per facility	Average people capacity per shelter.

	Shift length	12	hrs/shift	DSW work shifts.
	DSW reduction	50%	when Red Cross comes in	Once Red Cross arrives, less DSW needed.
	Days before Red Cross	7	days	Set up time before Red Cross comes in.
Cost of DSW				
	DSW cost	$100	per worker per hour	Hourly rate for DSW.

Incident Stabilization - Increase Cell/Internet Communication by Providing Power at Libraries

Get visitors out of the city				
	Fraction needing significant assistance	20%	of visitors	People that don't know the city well.
	Fraction needing minor assistance	5%	of visitors	People that are fairly familiar with the city.
	Fraction needing no assistance	75%	of visitors	People that are familiar with the city (daily commuters).
	Number of people needing significant assistance	70,000	people	
	Number of people needing minor assistance	17,500	people	
	DSW hours - significant assistance	1.0	hours per visitor per day	DSW = Disaster Service Worker
	DSW hours - minor assistance	0.25	hours per visitor per day	DSW = Disaster Service Worker
	Reduction in visitors (w/o powered libraries)	33%	per day	Powered libraries increase cell/internet connection which help people to get out of the city. More savings the faster the visitors get out.
	Reduction in visitors (w powered libraries)	50%	per day	
Cost of DSW				
	DSW cost	$100	per worker per hour	Hourly rate for DSW.

Appendix C

Economic Benefits

Economic Benefits

Color key:	
	Inputs
	Calculated values

Category	Facility Type	Savings			Total	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Morbidity and Mortality												
	Shelters	Reduce Morbidity	Medical Costs	*delta*	$562,500	$562,500	$0	$0	$0	$0	$0	$0
				w/o power	$1,250,000	$1,250,000	$0	$0	$0	$0	$0	$0
				w/ power	$687,500	$687,500	$0	$0	$0	$0	$0	$0
	Shelters	Reduce Mortality - IHSS Population	Lives Saved	*delta*	$52,000,000	$52,000,000	$0	$0	$0	$0	$0	$0
				w/o power	$52,000,000	$52,000,000	$0	$0	$0	$0	$0	$0
				w/ power	$0	$0	$0	$0	$0	$0	$0	$0
	Shelters	Reduce Mortality - Electrically Assisted Population	Lives Saved	*delta*	$80,000,000	$80,000,000	$0	$0	$0	$0	$0	$0
				w/o power	$760,000,000	$760,000,000	$0	$0	$0	$0	$0	$0
				w/ power	$680,000,000	$680,000,000	$0	$0	$0	$0	$0	$0
Incident Stabilization												
	Libraries	Increase Cell/Internet Communication	DSW Costs	*delta*	$3,718,750	$0	$1,239,583	$2,479,167	$0	$0	$0	$0
				w/o power	$14,875,000	$7,437,500	$4,958,333	$2,479,167	$0	$0	$0	$0
				w/ power	$11,156,250	$7,437,500	$3,718,750	$0	$0	$0	$0	$0
	Shelters	Powered Shelter Operation	DSW Costs	*delta*	$9,828,000	$1,512,000	$1,512,000	$1,512,000	$1,512,000	$1,512,000	$1,512,000	$756,000
				w/o power	$42,588,000	$6,552,000	$6,552,000	$6,552,000	$6,552,000	$6,552,000	$6,552,000	$3,276,000
				w/ power	$32,760,000	$5,040,000	$5,040,000	$5,040,000	$5,040,000	$5,040,000	$5,040,000	$2,520,000

Appendix D

Cost Benefit Analysis Scenario 1

Cost Benefit Analysis Scenario 1

Scenario 1: Earthquake happens 2025

Color key: Inputs | Calculated values

Facility Type	Category	Costs/Savings		Construction phase 1	Construction phase 2	First year of operation	Disaster event	Replacement of storage	
			Year of construction	1	2				
			Year of operation	0	0	1	5	10	20
Benefits									
Shelters									
	Morbidity and Mortality								
		Reduce Morbidity	Medical Costs	$0	$0	$0	$562,500	$0	$0
		Reduce Mortality - IHSS population	Lives Saved	$0	$0	$0	$52,000,000	$0	$0
		Reduce Mortality - electrically assisted population	Lives Saved	$0	$0	$0	$80,000,000	$0	$0
	Incident Stabilization								
		Powered Shelter Operation	DSW Costs	$0	$0	$0	$9,828,000	$0	$0
	Revenue								
		Revenue	PV	$0	$333,000	$665,000	$665,000	$665,000	$665,000
			Storage	$0	$479,000	$957,000	$957,000	$957,000	$957,000
Libraries									
	Incident Stabilization								
		Increase Cell/Internet Communication	DSW Costs	$0	$0	$0	$3,718,750	$0	$0
	Revenue								
		Revenue	PV	$0	$140,000	$280,000	$280,000	$280,000	$280,000
			Storage	$0	$120,000	$239,000	$239,000	$239,000	$239,000
Costs									
Shelters									
	Expenses								
		Capital	PV	-$9,819,000	-$9,819,000	$0	$0	$0	$0
			Storage	-$11,128,000	-$11,128,000	$0	$0	$0	$0
		Operation	Operating	$0	-$50,000	-$100,000	-$100,000	-$100,000	-$100,000
			Electricity	$0	-$210,000	-$420,000	-$420,000	-$420,000	-$420,000
			PV maintenance/ lifecycle	$0	-$71,000	-$141,000	-$141,000	-$141,000	-$141,000
			Storage system replacement		$0	$0	$0	$10,800,000	$0
Libraries									
	Expenses								
		Capital	PV	-$4,091,000	-$4,091,000	$0	$0	$0	$0
			Storage	-$2,782,000	-$2,782,000	$0	$0	$0	$0

Operation	Operating	$0	-$13,000	-$25,000	-$25,000	-$25,000	-$25,000
	Electricity	$0	-$53,000	-$105,000	-$105,000	-$105,000	-$105,000
	PV maintenance/ lifecycle	$0	-$29,000	-$59,000	-$59,000	-$59,000	-$59,000
	Storage system replacement	$0	$0	$0	$0	$2,700,000	$0

Summary

Shelters

Summary							
Benefits	Morbidity and Mortality	$0	$0	$0	###########	$0	$0
	Incident Stabilization	$0	$0	$0	$9,828,000	$0	$0
	Revenue	$0	$812,000	$1,622,000	$1,622,000	$1,622,000	$1,622,000
Costs	Total Costs	-$20,947,000	-$21,278,000	-$661,000	-$661,000	$10,139,000	-$661,000
Net Benefit	Net Benefit	-$20,947,000	-$20,466,000	$961,000	###########	$11,761,000	$961,000

Libraries

Summary							
Benefits	Incident Stabilization	$0	$0	$0	$3,718,750	$0	$0
	Revenue	$0	$260,000	$519,000	$519,000	$519,000	$519,000
Costs	Total Costs	-$6,873,000	-$6,968,000	-$189,000	-$189,000	$2,511,000	-$189,000
Net Benefit	Net Benefit	-$6,873,000	-$6,708,000	$330,000	$4,048,750	$3,030,000	$330,000

Discount Factor

Discount Factor						
7%	1.00	0.93	0.87	0.67	0.48	0.24

Present Value

Shelters

Present Value Estimation with 7% Discount Rate						
Present Value of Benefits	$0	$758,879	$1,416,718	$95,961,610	$770,601	$391,734
Present Value of Costs	-$20,947,000	-$19,885,981	-$577,343	-$440,452	$4,816,966	-$159,640
NPV Benefit @ 7%	-$20,947,000	-$19,127,103	$839,375	$95,521,157	$5,587,566	$232,094

BC Results using 7% Discount Rate	
Total Present Value of Benefits	$111,699,018
Total Present Value of Costs	-$42,246,506
Net Present Value	$69,452,513
B/C Ratio	2.6

Libraries

Present Value Estimation with 7% Discount Rate						
Present Value of Benefits	$0	$242,991	$453,315	$2,823,792	$246,573	$125,345
Present Value of Costs	-$6,873,000	-$6,512,150	-$165,080	-$125,939	$1,192,958	-$45,646
NPV Benefit @ 7%	-$6,873,000	-$6,269,159	$288,235	$2,697,853	$1,439,531	$79,699

BC Results using 7% Discount Rate	
Total Present Value of Benefits	$7,859,543
Total Present Value of Costs	-$13,973,678
Net Present Value	-$6,114,135
B/C Ratio	0.6

Total (sum of Shelters and Libraries)

Present Value Estimation with 7% Discount Rate						
Present Value of Benefits	$0	$1,001,869	$1,870,032	$98,785,401	$1,017,174	$517,080
Present Value of Costs	-$27,820,000	-$26,398,131	-$742,423	-$566,391	$6,009,924	-$205,286
NPV Benefit @ 7%	-$27,820,000	-$25,396,262	$1,127,609	$98,219,010	$7,027,098	$311,793

BC Results using 7% Discount Rate	
Total Present Value of Benefits	$119,558,561
Total Present Value of Costs	-$56,220,184
Net Present Value	$63,338,377
B/C Ratio	2.1

Appendix E

Cost Benefit Analysis Scenario 2

Cost Benefit Analysis Scenario 2

Scenario 1: Earthquake happens 2025

Color key: Inputs / **Calculated values**

	Facility Type	Category	Costs/Savings		Construction phase 1	Construction phase 2	First year of operation	Disaster event	Replacement of storage	
				Year of construction	1	2				
				Year of operation	0	0	1	5	10	20
Benefits										
	Shelters									
		Morbidity and Mortality								
			Reduce Morbidity	Medical Costs	$0	$0	$0	$0	$562,500	$0
			Reduce Mortality - IHSS population	Lives Saved	$0	$0	$0	$0	$52,000,000	$0
			Reduce Mortality - electrically assisted population	Lives Saved	$0	$0	$0	$0	$80,000,000	$0
		Incident Stabilization								
			Powered Shelter Operation	DSW Costs	$0	$0	$0	$0	$9,828,000	$0
		Revenue								
			Revenue	PV	$0	$333,000	$665,000	$665,000	$665,000	$665,000
				Storage	$0	$479,000	$957,000	$957,000	$957,000	$957,000
	Libraries									
		Incident Stabilization								
			Increase Cell/Internet Communication	DSW Costs	$0	$0	$0	$0	$3,718,750	$0
		Revenue								
			Revenue	PV	$0	$140,000	$280,000	$280,000	$280,000	$280,000
				Storage	$0	$120,000	$239,000	$239,000	$239,000	$239,000
Costs										
	Shelters									
		Expenses								
			Capital	PV	-$9,819,000	-$9,819,000	$0	$0	$0	$0
				Storage	-$11,128,000	-$11,128,000	$0	$0	$0	$0
			Operation	Operating	$0	-$50,000	-$100,000	-$100,000	-$100,000	-$100,000
				Electricity	$0	-$210,000	-$420,000	-$420,000	-$420,000	-$420,000
				PV maintenance/ lifecycle	$0	-$71,000	-$141,000	-$141,000	-$141,000	-$141,000
				Storage system replacement		$0	$0	$0	$10,800,000	$0
	Libraries									
		Expenses								
			Capital	PV	-$4,091,000	-$4,091,000	$0	$0	$0	$0
				Storage	-$2,782,000	-$2,782,000	$0	$0	$0	$0

Operation	Operating	$0	-$13,000	-$25,000	-$25,000	-$25,000	-$25,000
	Electricity	$0	-$53,000	-$105,000	-$105,000	-$105,000	-$105,000
	PV maintenance/ lifecycle	$0	-$29,000	-$59,000	-$59,000	-$59,000	-$59,000
	Storage system replacement	$0	$0	$0	$0	$2,700,000	$0

Summary

Shelters

Summary							
Benefits	Morbidity and Mortality	$0	$0	$0	$0	$132,562,500	$0
	Incident Stabilization	$0	$0	$0	$0	$9,828,000	$0
	Revenue	$0	$812,000	$1,622,000	$1,622,000	$1,622,000	$1,622,000
Costs	Total Costs	-$20,947,000	-$21,278,000	-$661,000	-$661,000	$10,139,000	-$661,000
Net Benefit	Net Benefit	-$20,947,000	-$20,466,000	$961,000	$961,000	$154,151,500	$961,000

Libraries

Summary							
Benefits	Incident Stabilization	$0	$0	$0	$0	$3,718,750	$0
	Revenue	$0	$260,000	$519,000	$519,000	$519,000	$519,000
Costs	Total Costs	-$6,873,000	-$6,968,000	-$189,000	-$189,000	$2,511,000	-$189,000
Net Benefit	Net Benefit	-$6,873,000	-$6,708,000	$330,000	$330,000	$6,748,750	$330,000

Discount Factor

Discount Factor						
7%	1.00	0.93	0.87	0.67	0.48	0.24

Present Value

Shelters

Present Value Estimation with 7% Discount Rate						
Present Value of Benefits	$0	$758,879	$1,416,718	$1,080,807	$68,419,301	$391,734
Present Value of Costs	-$20,947,000	-$19,885,981	-$577,343	-$440,452	$4,816,966	-$159,640
NPV Benefit @ 7%	-$20,947,000	-$19,127,103	$839,375	$640,355	$73,236,267	$232,094

BC Results using 7% Discount Rate	
Total Present Value of Benefits	$84,466,917
Total Present Value of Costs	-$42,246,506
Net Present Value	$42,220,411
B/C Ratio	2.0

Libraries

Present Value Estimation with 7% Discount Rate						
Present Value of Benefits	$0	$242,991	$453,315	$345,832	$2,013,324	$125,345
Present Value of Costs	-$6,873,000	-$6,512,150	-$165,080	-$125,939	$1,192,958	-$45,646
NPV Benefit @ 7%	-$6,873,000	-$6,269,159	$288,235	$219,893	$3,206,283	$79,699

BC Results using 7% Discount Rate	
Total Present Value of Benefits	$7,148,334
Total Present Value of Costs	-$13,973,678
Net Present Value	-$6,825,344
B/C Ratio	0.5

Total (sum of Shelters and Libraries)

Present Value Estimation with 7% Discount Rate						
Present Value of Benefits	$0	$1,001,869	$1,870,032	$1,426,639	$70,432,626	$517,080
Present Value of Costs	-$27,820,000	-$26,398,131	-$742,423	-$566,391	$6,009,924	-$205,286
NPV Benefit @ 7%	-$27,820,000	-$25,396,262	$1,127,609	$860,248	$76,442,550	$311,793

BC Results using 7% Discount Rate	
Total Present Value of Benefits	$91,615,251
Total Present Value of Costs	-$56,220,184
Net Present Value	$35,395,067
B/C Ratio	1.6

Appendix F

Sensitivity Analysis

Sensitivity Analysis

Impact on BC Ratio

Variable	Base Case	Alternative
Scenario 1		
Value of life	**$8M**	**$10M**
Shelters only	2.6	3.2
Libraries only	0.6	0.6
Shelters & Libraries	2.1	2.5
Discount rate	**7%**	**3.5%**
Shelters only	2.6	3.2
Libraries only	0.6	0.7
Shelters & Libraries	2.1	2.6
Mortality percentage - Electrically assisted population	**10%**	**30%**
Shelters only	2.6	5.2
Libraries only	0.6	0.6
Shelters & Libraries	2.1	4.0
Scenario 2		
Value of life	**$8M**	**$10M**
Shelters only	2.0	2.4
Libraries only	0.5	0.5
Shelters & Libraries	1.6	1.9

Discount rate	7%	3.5%
Shelters only	2.0	2.8
Libraries only	0.5	0.7
Shelters & Libraries	1.6	2.3

Mortality percentage - Electrically assisted population	10%	30%
Shelters only	2.0	3.8
Libraries only	0.5	0.5
Shelters & Libraries	1.6	3.00