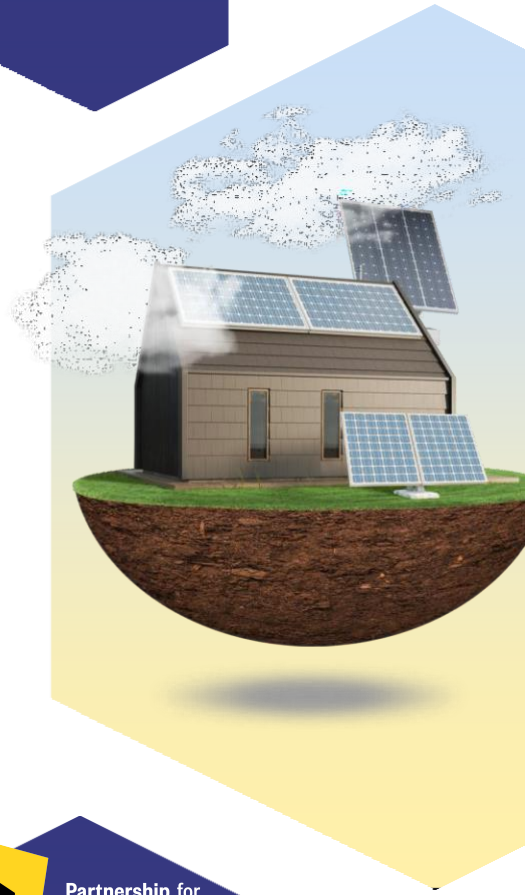
Solar Microgrid Retrofit Analysis

Greenbelt, Prince George's County Maryland



Project Proposal

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Prince George's County
DEPARTMENT OF THE ENVIRONMENT

PALS Partnership for Action Learning in Sustainability

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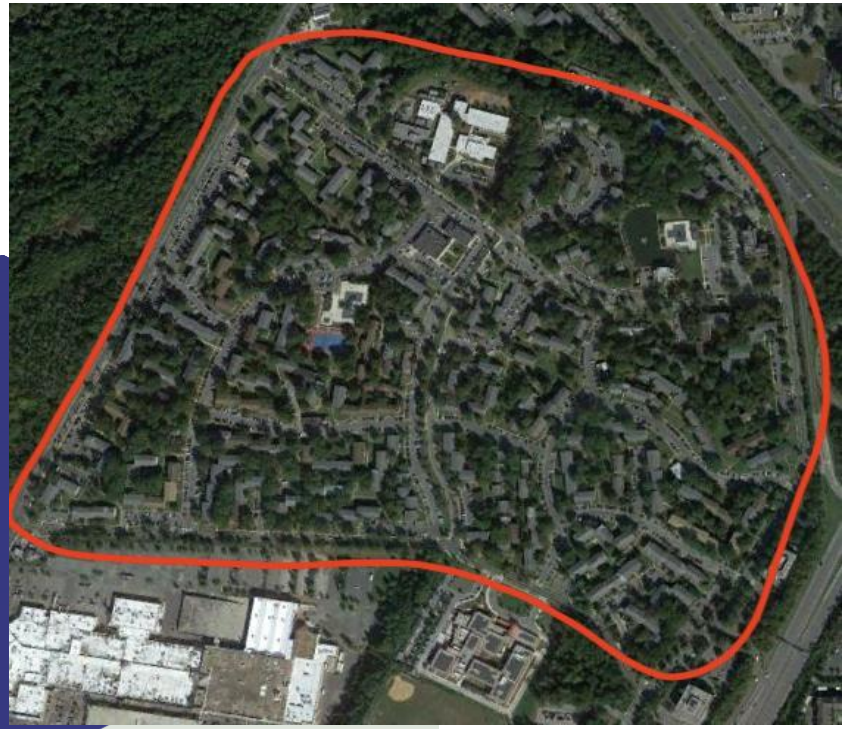
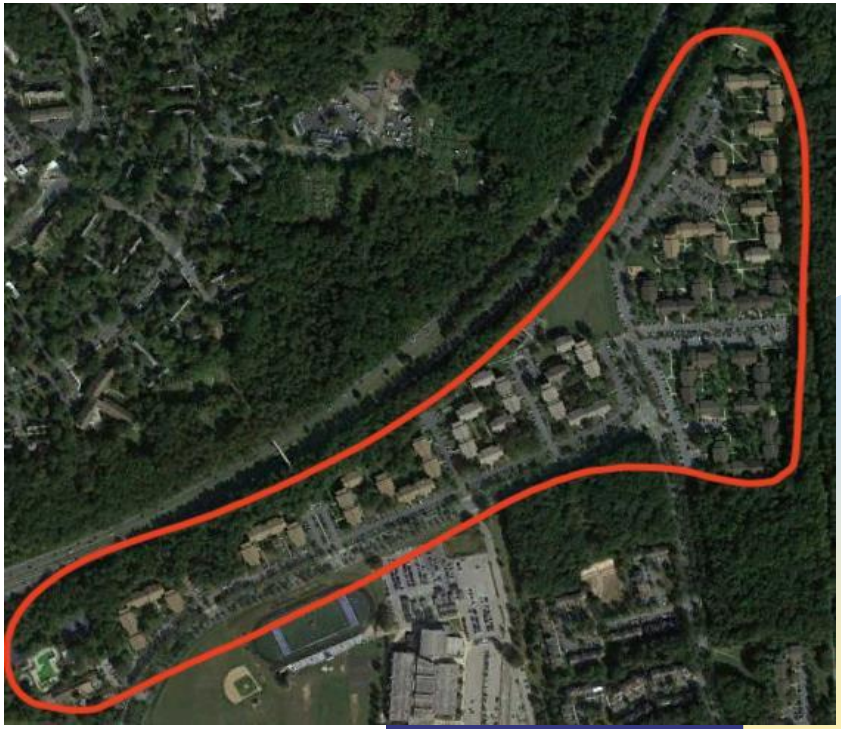




Location History

- Greenbelt is a suburb of Washington, D.C., located in Prince George's County
- Modeled after 19th century English garden cities, Greenbelt took its name from the belt of green forestland at its perimeter
- Designed to provide work for the unemployed, and affordable housing for low-income workers.

Location History

- Franklin Park Apartments have a total of 2,900 units and were built in 1970
- Hanover Park Apartments have a total of 342 units and were built in 1962

PALS and DOE

PALS, UMD's Partnership for Action Learning in Sustainability program, has relationships with local governments and nonprofit clients to bring real-world projects to its students.

This project of UMD PALS and Prince George's County's Department of Environment applied environmental justice concepts and solar energy technology to two large apartment complex communities in Greenbelt, Maryland.

The Brooklyn Microgrid

Overview

The Brooklyn Microgrid (BMG) is a local solar energy market between NYC residents and businesses. It connects those with abundant solar panel energy (prosumers) and community members who want to purchase that energy (consumers).

- Established April 2016
- LO3 Energy is the parent company
- Connects three distribution grids: Borough Hall, Park Slope, and Bay Ridge
- Uses the BMG app to facilitate solar auction—buying and selling

(BMG, 2019) (Mengelkamp et al., 2017)

BROOKLYN MICROGRID

LO3 ENERGY

The Brooklyn Microgrid

Microgrid Methodology

- TransActive Grid Smart Meter (TAGSM) in the existing utility meter and fuse box runs energy to the traditional grid, operated by Con Edison, Inc., “to supply the physical energy flow and only decouples the physical microgrid in emergency situations”
- Information from the TAGSM is transferred to **blockchain accounts**, which uploads to the TransActive blockchain architecture to update the energy market information to buy and sell electricity
- Consumers virtually pay their producing neighbors feeding the distribution grid with renewable energy only through blockchain

(Mengelkamp et al., 2017)

The Brooklyn Microgrid

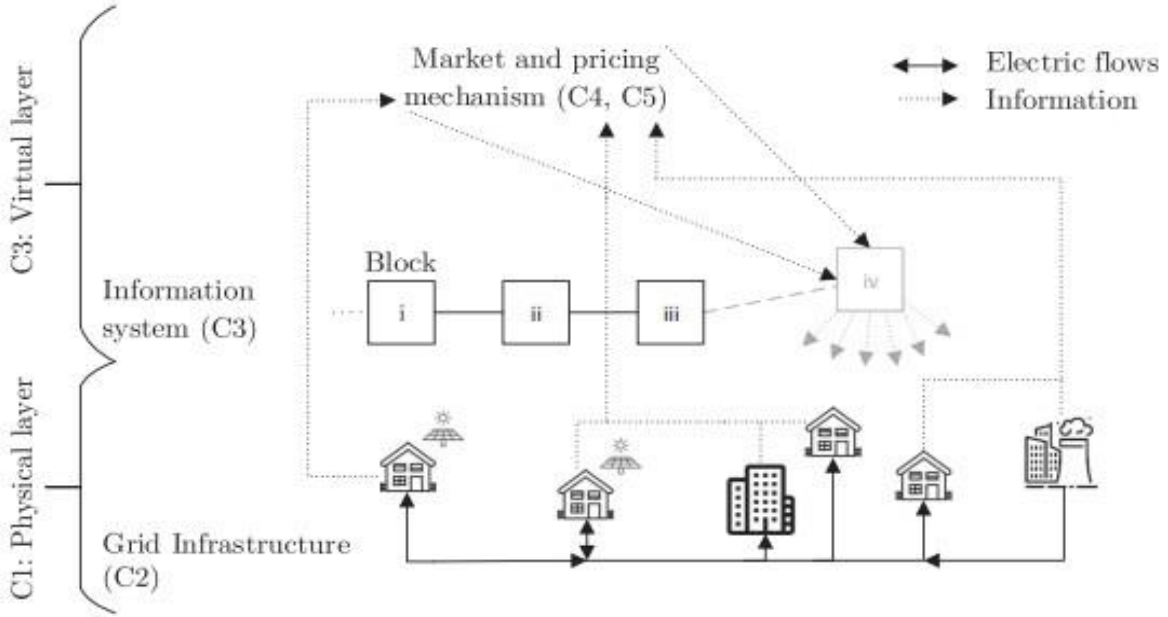
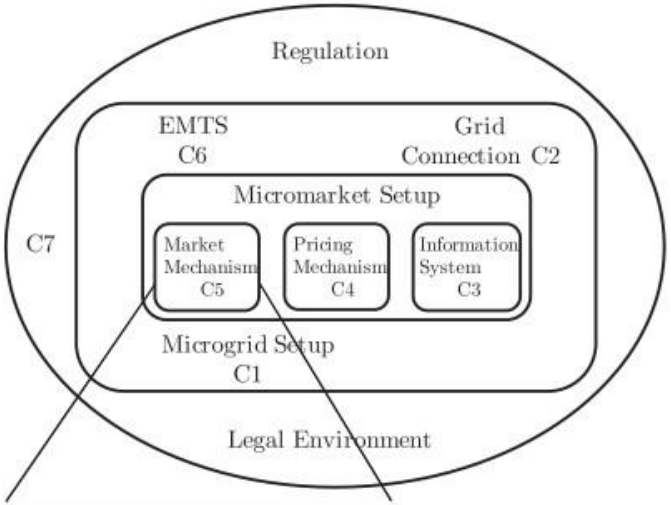


Fig. 5. High-level topology of the BMG.

(Mengelkamp et al., 2017)

The Brooklyn Microgrid



Sell Orders		Buy Order	
Price (MU/kWh)	Quantity (kWh)	Price (MU/kWh)	Quantity (kWh)
26.00	1	28.23	1
26.98	1	27.71	1
27.05	1	26.00	1
27.75	1	25.95	1
28.00	1	25.50	1

Fig. 3. A schematic overview of the seven market components. The upper two orders in the order book would be matched. The transaction price will be determined by the pricing mechanism and paid in monetary units (MU).

(Mengelkamp et al., 2017)

The EcoBlock

Overview

The EcoBlock project is developing a prototype block in Oakland, CA that expands community resilience by retrofitting various aspects of the infrastructure.

The data from this project will be available for replication in urban areas around the world.

(Barr et al., 2019)

ecoblock™

The EcoBlock

Microgrid Methodology

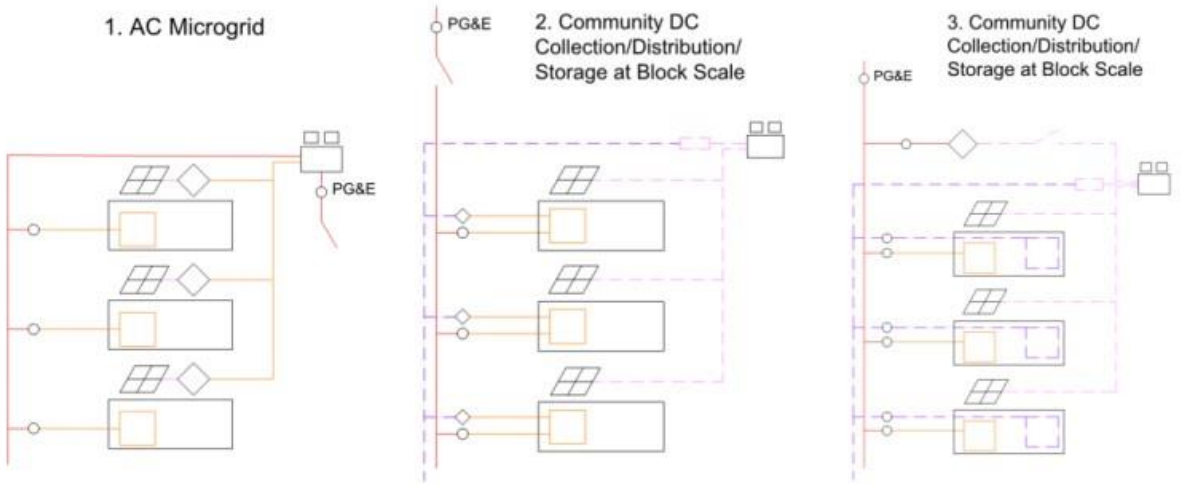
- Existing PG&E assets for distribution of AC power—telephone poles, transformers, meters, and other equipment—will be retained
- Three scenarios for the provision of AC and DC power in the EcoBlock
  - Scenario 1: PV systems are tied to a block-scale AC microgrid with a shared storing FESS providing AC power to houses and charging the flywheel; the flywheel will provide power during an outage
  - Scenario 2: PV systems are tied to a block-scale DC microgrid and shared FESS; using existing AC circuits and equipment in homes to provide power in an outage; possible net energy metering
  - Scenario 3: PV systems and DC appliances are tied to a block-scale DC microgrid which is connected to the FESS and EV chargers; exports power to utility grid; provides DC power during outages with a bidirectional converter (drawing and sending to grid)

(Barr et al., 2019)

★ Storage system
- Use Amber Kinetics
- Arranged in a row underground 30 x 8 ft.
- Connected in parallel electric circuit to increase output

The EcoBlock

Figure 3-9: Final Microgrid Scenario Topologies



Red/orange indicate AC power, purple/blue indicate DC power

(Barr et al., 2019)

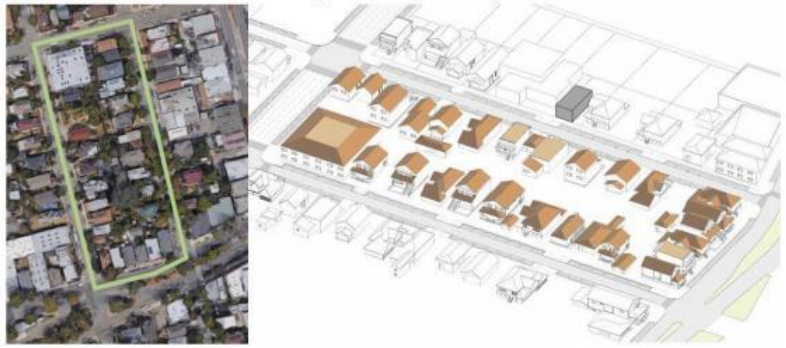
The EcoBlock

Table 3-8: Annual DER Energy Cost Performance Metrics

Economic Performance	
Grid Import: Energy Charges	$21,873
Grid Import: Demand Charges	$7,194
Grid Import Bill Savings	$39,286
Percent Grid Import Bill Reduction	57%
Grid Export Revenue	$5,564
Avoided Gasoline Costs	$27,827

Source: UC Berkeley

Figure 4-4: Site Coverage



Source: Google Maps (left); UC Berkeley (right)

(Barr et al., 2019)

Things to Consider

Safety

In these conditions, Prince George's County requires 36" fire pathways

Design

consider roof obstructions and aesthetics

Efficiency

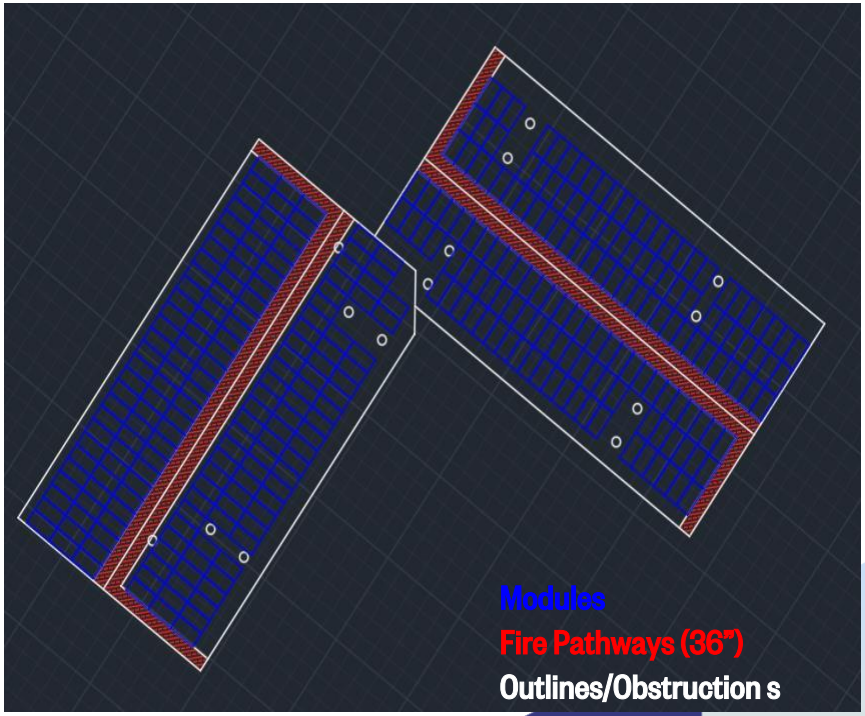
tree shading is an important factor

Constraints and Standards

Commercial Panel Dimensions	Commercial Panel Wattage	Module Spacing	Google Earth Pro	Panel Energy Efficiency
78” x 39” (6.6’ x 3.25’)	350W	1”	Date of satellite is 10/2021 and eye altitude ~350-550’	20%

(css.umich.edu)

AutoCAD Rendering Example



Project Outcomes

Number of Panels

49,937 commercial solar panels

Roof Area (Ac)

28.16 acres

Roof Area (SqFt)

1,226,730 square feet

Energy Output (W)

17,477,950 Watts

Energy Output (MW)

17.48 Mega Watts

Panel Area

1,054,919.12 SqFt, 24.22 acres

86%

Potential Solar Installation Companies

SUNPOWER®

- High-efficiency commercial and residential solar panels
- Located in the DMV
- Global solar panel manufacturer
- www.us.sunpower.com

SOLSYSTEMS

- Solar energy development firm
- Have experience working on large-scale solar projects in the DMV
- www.solsystems.com

Direct Energy Solar™

- Residential and commercial solar panel installer
- Strong presence in the DMV area
- Offer a range of solar panels and other renewable energy solutions
- www.directenergy.com

Estimated Annual Energy Production

9,025,613.38 kWh

9,025.61 MWh

Estimated Total Cost

$18,769,011.21

power of commercial unit (kW)	0.35
number of units	49,937
peak sunlight hours (365)	2,582
total kW output	17,477.95
kWh rating of system	45,128,066.9
cost of system	$28,489,058.50
state tax credit	2.6 cents per kWh
federal tax credit	30%
cost reduction from state credit	$1,173,329.74
cost reduction from federal credit	$8,546,717.55
final cost	$18,769,011.21

Equivalent to CO2 emissions from:

719,736

Gallons of gasoline

7,164,831

Pounds of coal

84.7

Tanker trucks of gasoline

1,245

Homes' electricity use for one year

1,423

Gasoline powered passenger vehicles driven for one year

778,062,135

smartphones charged

Equivalent to greenhouse gas emissions avoided by:

2,213

Tons of waste recycled instead of landfilled

242,868

Incandescent lamps switched to LEDs

1.8

Wind turbines running for a year

Equivalent to carbon sequestered by:

105,763

Tree seedlings grown for 10 years

7,628

Acres of US forests in one year

42.4

Acres of US forests preserved from conversion to cropland in one year

Importance of Community Solar

What is Community Solar?

"The U.S. Department of Energy defines community solar as any solar project or purchasing program, within a geographic area, in which the benefits of a solar project flow to multiple customers such as individuals, businesses, nonprofits, and other groups" (Solar, n.d.)

Benefits of Community Solar

- Buy/lease a portion of solar panels to receive electric credit on bill
  - Save money with renewable energy
  - Maryland passed specific legislature in 2017 to promote this accreditation (Maryland, 2021)
- Interconnectedness within the community as they work together to supply power to one another
- Improve the utility and customer relationship

Residential Clean Energy Grant

Maryland's Residential Clean Energy Grant Program—

provides a rebate as an incentive for Maryland homeowners to purchase and install eligible renewable energy generating systems at their residences.

An anticipated total of $3,600,000 is available from the Strategic Energy Investment Fund to fund this program.

Clean Energy Technology	Eligible System Capacity Range	Rebate Amount
Solar Photovoltaic	Minimum 1kW-DC	1,000$

Residential Community Solar Grant

Residential Community Solar Grant–

allows Maryland residents to purchase energy subscriptions from community solar arrays. The grant is a monetary incentive for residents who wish to purchase the energy benefits of the array.

Low- and moderate-income residents who subscribe to a community solar array under an ownership model are incentivized at a higher rate than other subscribers.

Non-Low/Moderate Income Category	$100/kW	Maximum incentive size is equal to 100% of the annual energy use divided by 20 kW
Low/Moderate Income Category	$300/kW	Maximum incentive size is equal to 100% of the annual energy use divided by 20 kW

Regulations

Rooftop solar array projects require two permits–

- A building permit to attachment solar panels to the rooftop
- An electrical permit to connect to the building's electrical service

Permit Application and Filing Fee Payment

The permits may be issued by lot or interconnection point, not individual addresses of all units underneath the roof

Regulations

- After building permit fees are paid and the project plans are approved, a licensed master electrician can obtain the electrical trade permit.

- PV solar array system plans must be designed, stamped, and sealed by a Maryland Professional Engineer.

- Architectural plans can be stamped by the structural engineer of record if no proposed changes are being made to the building's architecture and included schematics are of a structural nature (i.e., array plan, connection details, roof framing plan, and other structural members).

Solar System Installation Code Requirements

Building Code

- 2018 NFPA1 provides a comprehensive, integrated approach to fire code regulation and hazard management. Relevant to solar panels, e.g., all new electrical wiring, fixtures, appliances and equipment shall be installed according to NFPA70.

- Prince George's County Subtitle 4, Subtitle 9, and Subtitle 11:
  - Subtitle 4: Building,
  - Subtitle 9: Electrical
  - Subtitle 11: Fire

Solar Energy System Installation Code Requirements

Electrical Code

- National Electrical Code (NFPA 70, National Electric Code, Article 690): Emergency system(s) overcurrent protective devices (OCPDs) shall be selectively coordinated with load-side OCPDs.
    - Coordination is selected by a licensed professional engineer engaged primarily in the design, installation, or maintenance of electrical systems.

Health Considerations

- Hazardous Materials
- Electromagnetic Fields (EMF)
- Electric Shock and Arc Flash

Health Considerations

Hazardous Materials

- PV panels consist of glass, polymer, aluminum, copper, and semiconductor materials that can be recovered and recycled at the end of their useful life.

- Some solar panels contain tiny amounts of lead.
  - So the electrodes can make effective electrical contact with the PV cell, other materials (glass frit) are mixed with silver alloy and heated to etch the metals into the cell. This glass frit contains a small amount of lead oxide.

- General consensus is that solar panels are not a threat to public health

Health Considerations

Electromagnetic Fields

- PV systems don't emit any material during their operation but do generate electromagnetic fields (EMF).

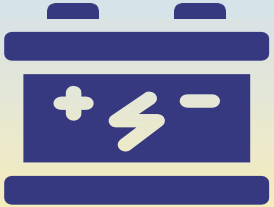
- EMF produced by electricity is non-ionizing radiation, i.e., the radiation has enough energy to move atoms in a molecule (experienced as heat), but not enough to remove electrons from an atom or to damage DNA.

- Most people are exposed to EMF in our daily lives without negative health impact.

- Negative health impacts have been found from the EMF produced in a solar array.

Energy Storage Considerations

Storing and Moving the Energy



General Solar Energy Storage

- The best way to store solar energy is in a **BESS– Battery Energy Storage System** (Stein, 2023)
  - One or more batteries that reserve the system produced energy (renewables, grid connection, etc.) until needed
  - Includes components such as inverters, control components, sensors, and modules

https://www.microgridknowledge.com/sponsored/article/33002666/pxise-energy-solu tions-finding-that-battery-size-and-roi-sweet-spot

- Battery options
  - Lithium-Ion
  - Flow
  - Flywheels (FESS)

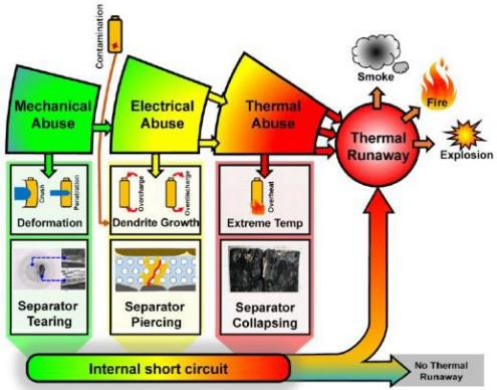
https://ambe rkinetics.com/installation/utility-of-the-future/

Solar Energy Storage Safety

Current Hazards

Thermal Runaway

- Rapid uncontrolled heat energy released from a battery cell unable to dissipate
- Leads to battery fire/explosion; produces toxic fumes and gases
- Stored energy can't discharge, may reignite fires or shock first responders



https://www.wattalps.com/thermal-runaway-propagation-and-mitigation/

Battery Failure

- Facilitates thermal runaway
- Thermal and electrical abuse such as excessive external heating or overcharging
- Mechanical abuse such as dropping, crushing, or destruction to integrity of the battery (rodents, etc.) facilitate thermal runaway

Solar Energy Storage Safety

Current Safety Measures

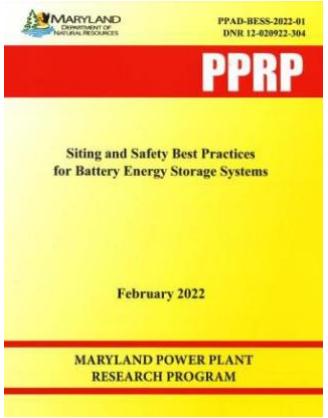
Regulations

- Must follow FERC regulations (Federal Energy Regulatory Commission), the DOE, and other state regulations (Petrova, 2021)

Maryland DNR Best Practices

- 10-foot buffer around BESS from combustible vegetation
- Utility lines should be placed underground
- Need a 7-foot tall, self-locking fence around the BESS
- Design must have specialized HVAC, interpreting devices, high-heat tolerant enclosed containers, etc.

(MDDNR, 2022)



Solar Energy Storage Safety

Current Safety Measures

Design Mechanisms

- PCS: Power Conversion System
- BMS: Battery Management System
- S.D.: Smoke Detector

(Rosewater et al., 2020)

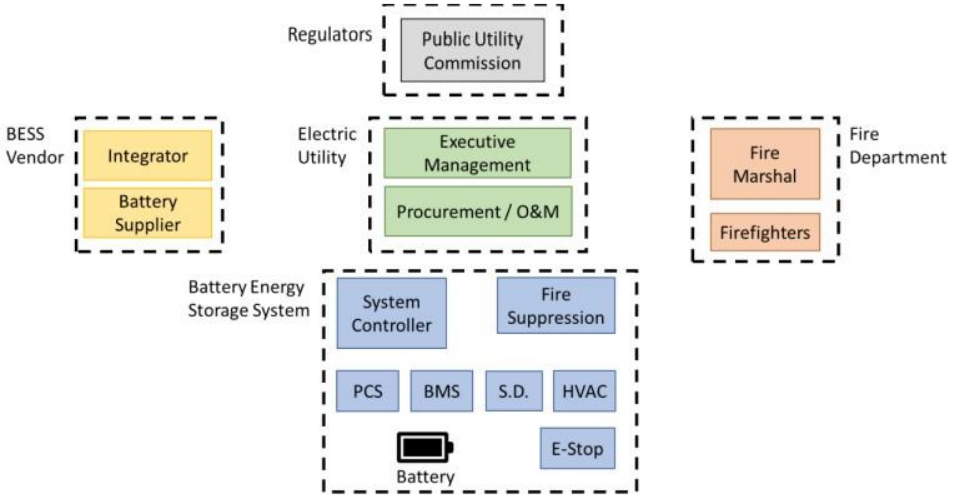


Figure 3 High-level sociotechnical safety control structure of a battery energy storage system

Goals for Energy Storage

Provide reliable local electricity

- reduce resident electric bills
- supply energy in times of crisis/emergencies

Create a more self-sustaining community

- introduce a resiliency hub
- enable economic and environmental benefits
- work with macrogrid/municipal electric utilities

Facilitate community approval and involvement

- community centered; community consulted decisions
- visually appealing and not obstructing
- responsive to changing loads

Potential BESS Companies

- US-based Global Utility Company
- Experienced and interested in developing
  - microgids; single-source capable
- More than 180 MW BESS in operation the US
- https://www.nexteraenergy.com/company/work/battery-storage.html

- GE Renewable Energy Department
- Provide reservoir solutions for commercial,
  - residential, industrial; mention microgrids
- https://www.ge.com/renewableenergy/hybrid/bat tery-energy-storage

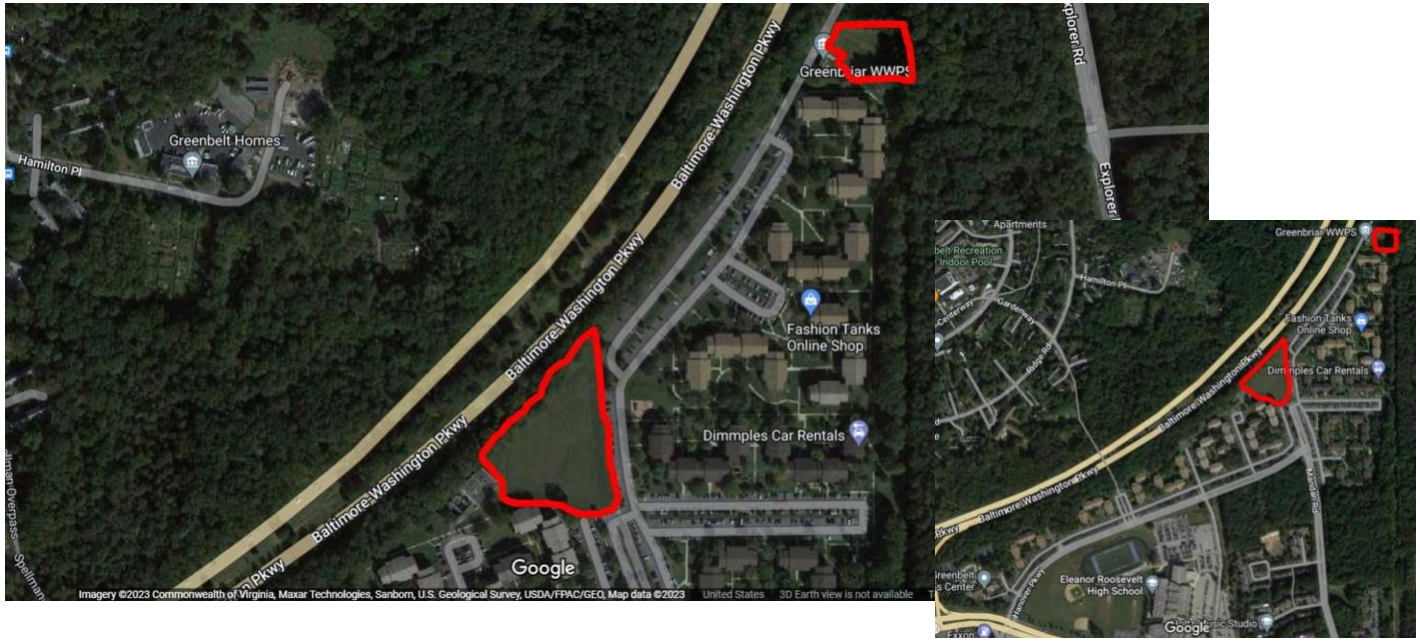
- BESS Manufacturer
- Specialize in energy storage with pre engineered products
- Offer a 500 kW BESS storage unit
- https://agreate.com/microgrid-battery-energy-storage-systems/

Potential FESS Companies

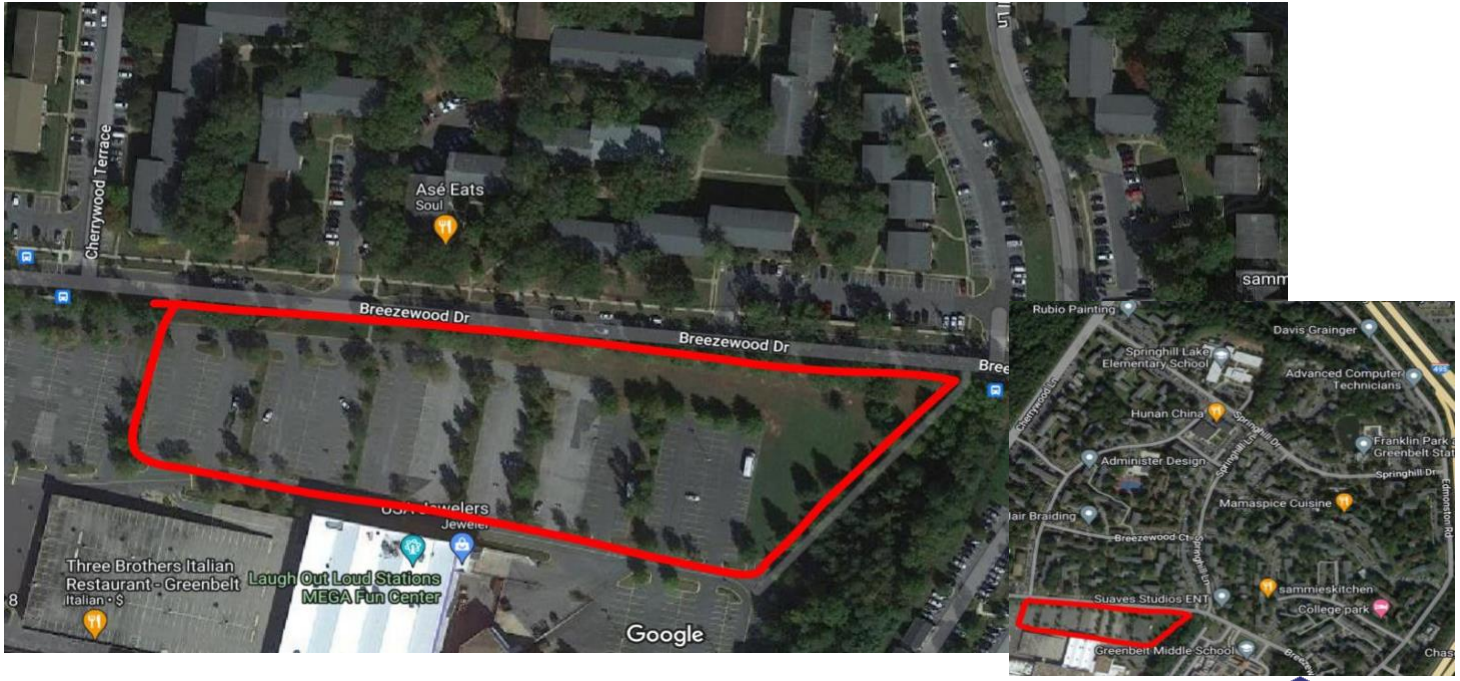
- Long-duration Flywheel Energy
  - Storage System Manufacturers
  - Numerous installations in the US and different countries
  - Located in California
  - Installed in the ground
  - https://amberkinetics.com/

- Carbon Fiber Flywheel Manufacturers
- 400 flywheels installed
- Located in Massachusetts
- Ability to move 5,000 MWh through the machine in a lifetime
- https://beaconpower.com/carbon- fiber-flywheels/

Centralized Installation (East Microgrid)



Centralized Installation (West Microgrid)

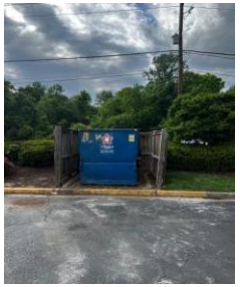


Decentralized Placement Considerations

Potential space for a decentralized design

- Each complex or local complex divisions could have a battery storage system
- Similar to dumpster fencing, the BESS or FESS is in a fenced zone

Pros	Cons
Prevent complete system destruction, unlike centralized systems	More ground space to cover maintenance-wise
Uses available space and prevent further habitat destruction	Complications with connecting the grid together
Ease of maintenance	Could cost more to install



Resilience Hubs

Background and Potential Hub Locations

What is a Resilience Hub?

A central point for a community to gather, every day or during disaster when help is needed the most.

Everyday

Planning for the future and collaborating for the betterment of the community

Disruption

A hub for internal and external communication, leading the way for response

Recovery

A safe house for a community, host volunteers and emergency aid

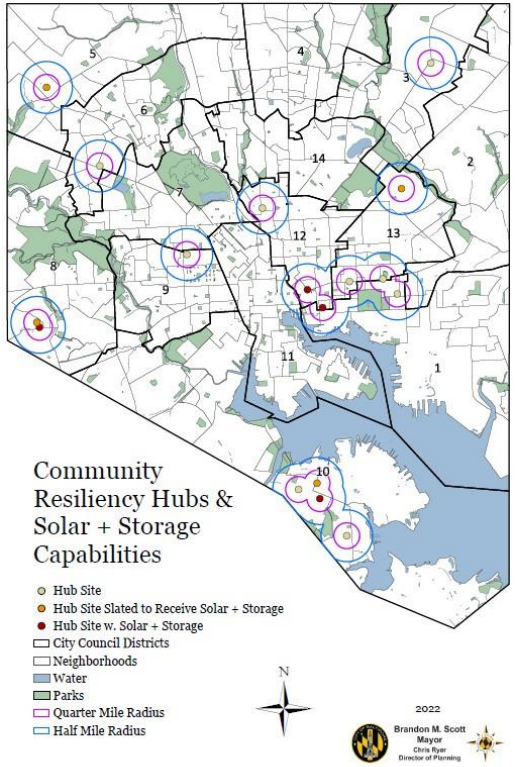
Baltimore as an Example

Baltimore's Disaster Preparedness Plan

Partnered with Baltimore's

- Office of Sustainability (BoS)
- Office of Emergency Management (OEM)
- Department of Health (BCHD)

Provide districts with solar power and battery back-up charging stations



Importance of Recovery Hub

When disaster strikes, a safe place for the community

Provide

- reliable energy, to charge essentials
- general supplies
- food
- water
- dry, temperature-controlled space to store perishable medicines
- car charging

Host

- emergency and recovery personnel
- supplies distribution
- collaborative community events

Ideal Locations for Resilience Hubs

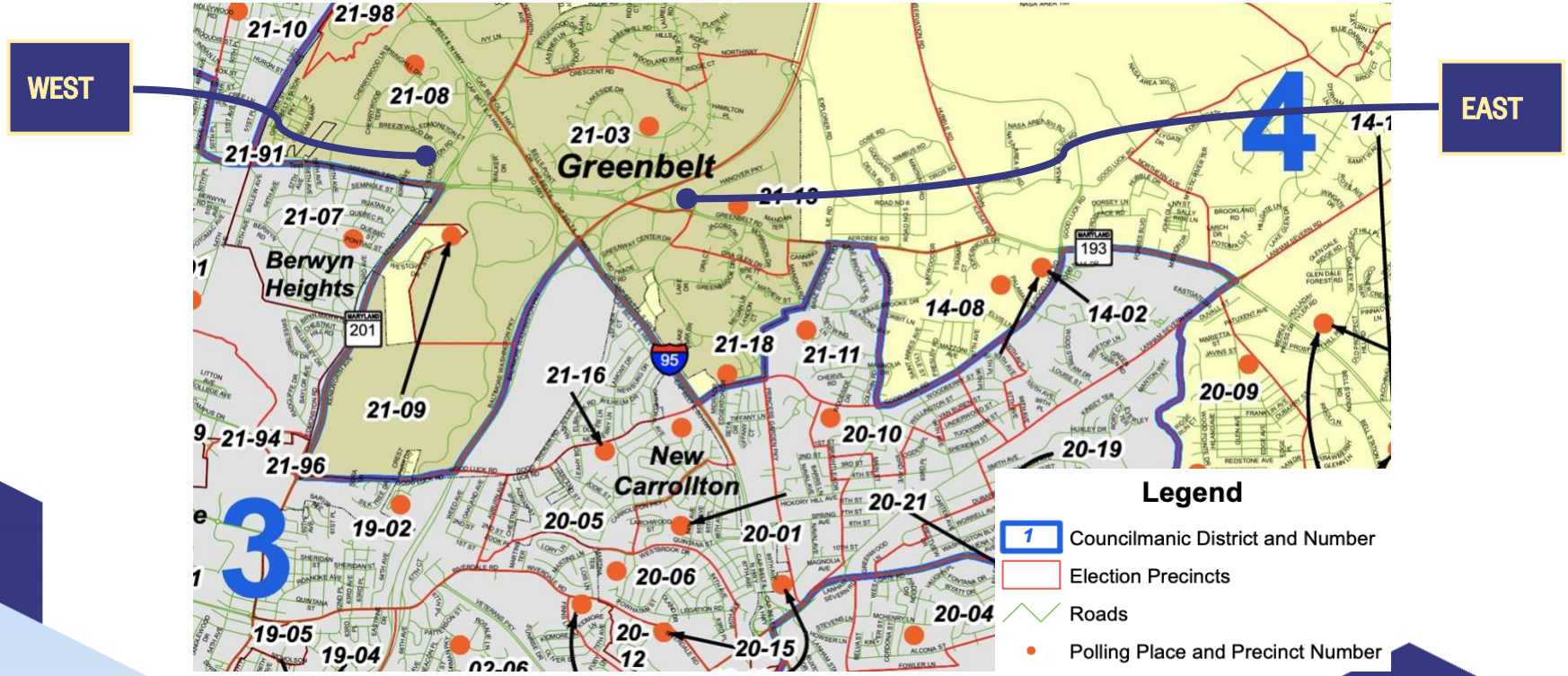
West Microgrid

Greenbelt Middle School

East Microgrid

Eleanor Roosevelt High School

Council Districts



pgcountymd.gov

Benefits of the Ideal Locations

Proximity to Grids

Minimal distance from grids keeps efficiency high

Transport

Both locations are schools, which have access to bus routes

Real Estate

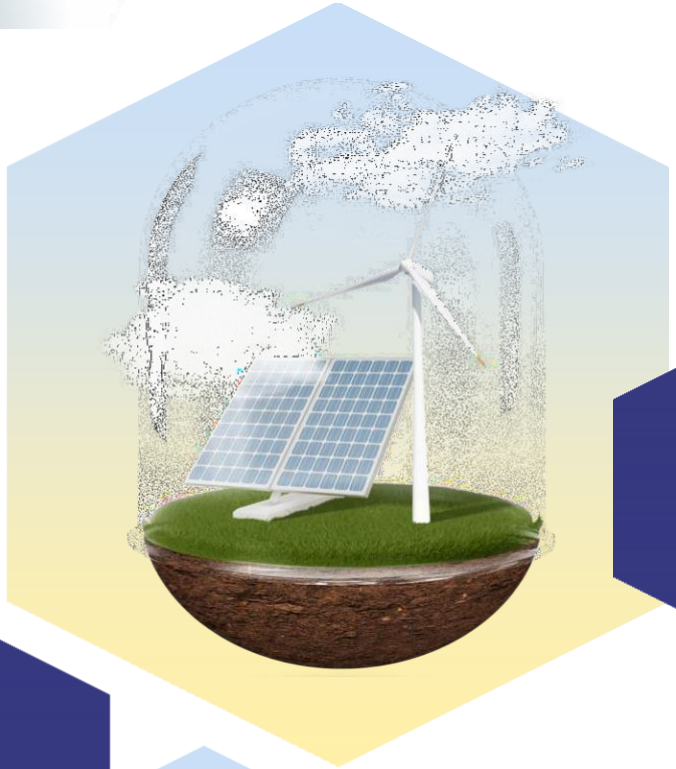
Schools have space for community meetings or emergency shelter

Emergency Care

Both locations within a mile of a hospital

Future Considerations

- Tap into macro grid utility or island microgrid
- Common area powering; won't pay for those costs (benefit owners) and tax credits (public good)
- To prevent gentrification, enforce rules to keep rent at the same rate
- BESS/FESS pricing is based on actual implementation
- Split Resilience Hubs, share east and west locations between Districts 3 and 4



Thanks!

Any questions?

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