CHRES CONSORTIUM OF HYBRID RESILIENT ENERGY SYSTEMS

DE-NA0003982

UPRM's CHRES Summer Research Program 2022

ENERGY STORAGE SYSTEM PRIORITY INDEX FOR LOAD PRIORITIZATION

RECINTO UNIVERSITARIO DE MAYAGÜEZ
CAAM
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Education

- Master’s degree at UPRM

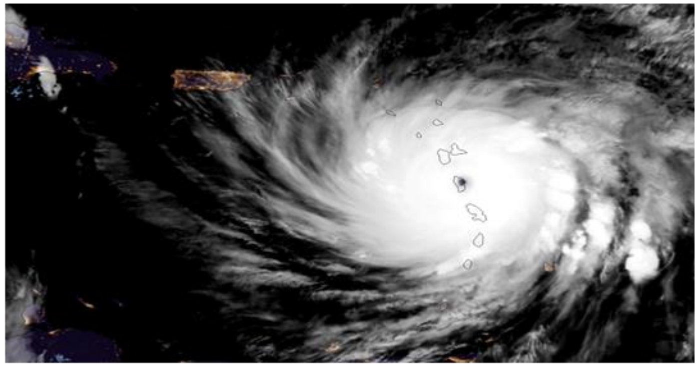
Relevant Publications

1. **Lopez-Cardalda, Guillermo**; Ortiz-Rivera, Eduardo I.; "Proposed Methodology Using the Energy Storage System Prioritization Index (ESSPI)" 48th IEEE Photovoltaic Specialists Conference (PVSC), June 20-25, 2021.
2. Saker, Farid; **Lopez-Cardalda, Guillermo**; Pacheco, Jenssen; Ortiz-Rivera, Eduardo; Aponte, Erick; "Design of a Microgrid for Rural Community in Puerto Rico"; 48th IEEE Photovoltaic Specialists Conference (PVSC) from June 20-25, 2021.
3. Lugo-Alvarez, Melvin; **Lopez-Cardalda, Guillermo;** Mendez-Santacruz, Sergio; Ortiz-Rivera, Eduardo; Aponte, Erick; "Learnings of the Complete Power Grid Destruction in Puerto Rico by Hurricane Maria" 2018 IEEE International Symposium on Technologies for Homeland Security (HST), October 23 - 24, 2018 Woburn, MA USA.

Awards

- GEM Fellowship for 2022 selected by NREL
- GMiS Scholars Class of 2022 sponsored by The Boeing Company
- Hispanic Scholarship Foundation for 2022
- NASA PR Space Grant Fellowship/Scholarship for the 2023-2024 academic year

Timeline: Natural Disaster in the last years



Geocolor image of Hurricane Maria making landfall over Dominica (Source NOAA)

Map of PR red show area of epicenter of earthquake(source NYTimes)

Visible satellite image of Hurricane Fiona (source NOAA)

2017

- Hurricane Maria landfall on September 20, 2017, at 6:15 a.m.
- Sustained winds of Maria were 155 mph making it a Category 4 hurricane.

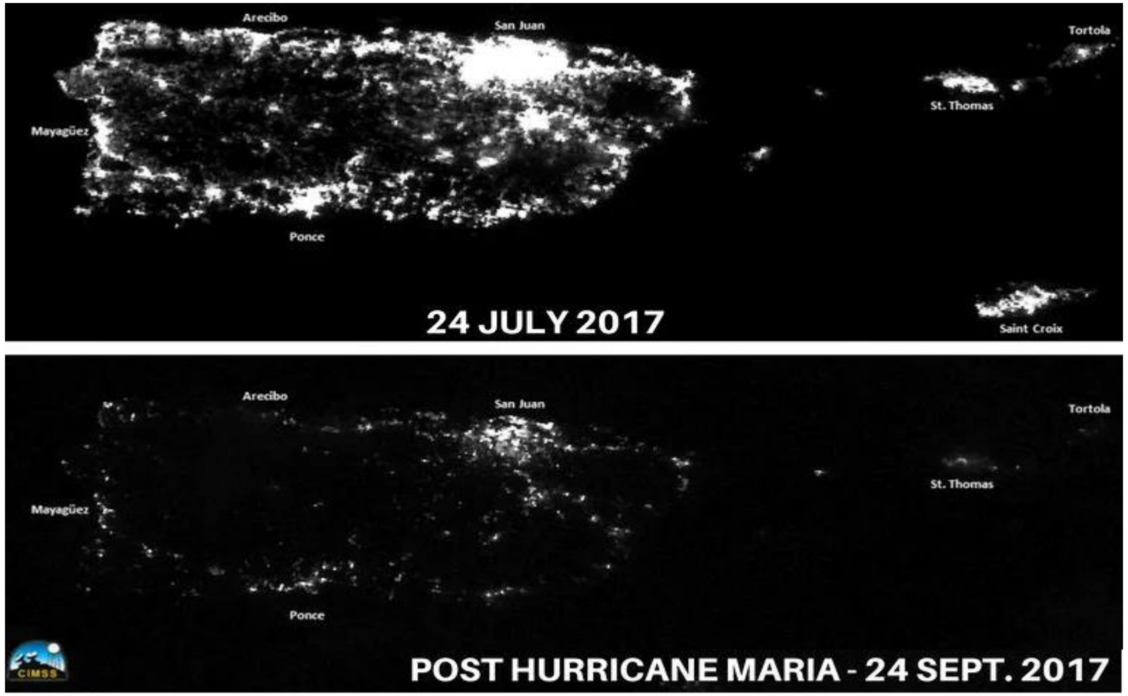
2019-2020

- A sequel of 14 earthquakes with magnitude greater or equal to 4.5.
- 5.0 magnitude on Dec. 29, 2019.
- 5.8 magnitude o Jan. 6, 2020.
- 6.4 magnitude on Jan. 7, and its main aftershock of magnitude 6.0.

2022

- Hurricane Fiona landfall on September 18 , 2022 at 3:20 p.m.
- Sustained winds of Fiona were 85 mph making it a Category 1 hurricane.

Destruction of The Electrical System



Pre and Post hurricane Maria night-time satellite view of Puerto Rico. Note the lack of lighting on most of the island. (Source The Guardian)

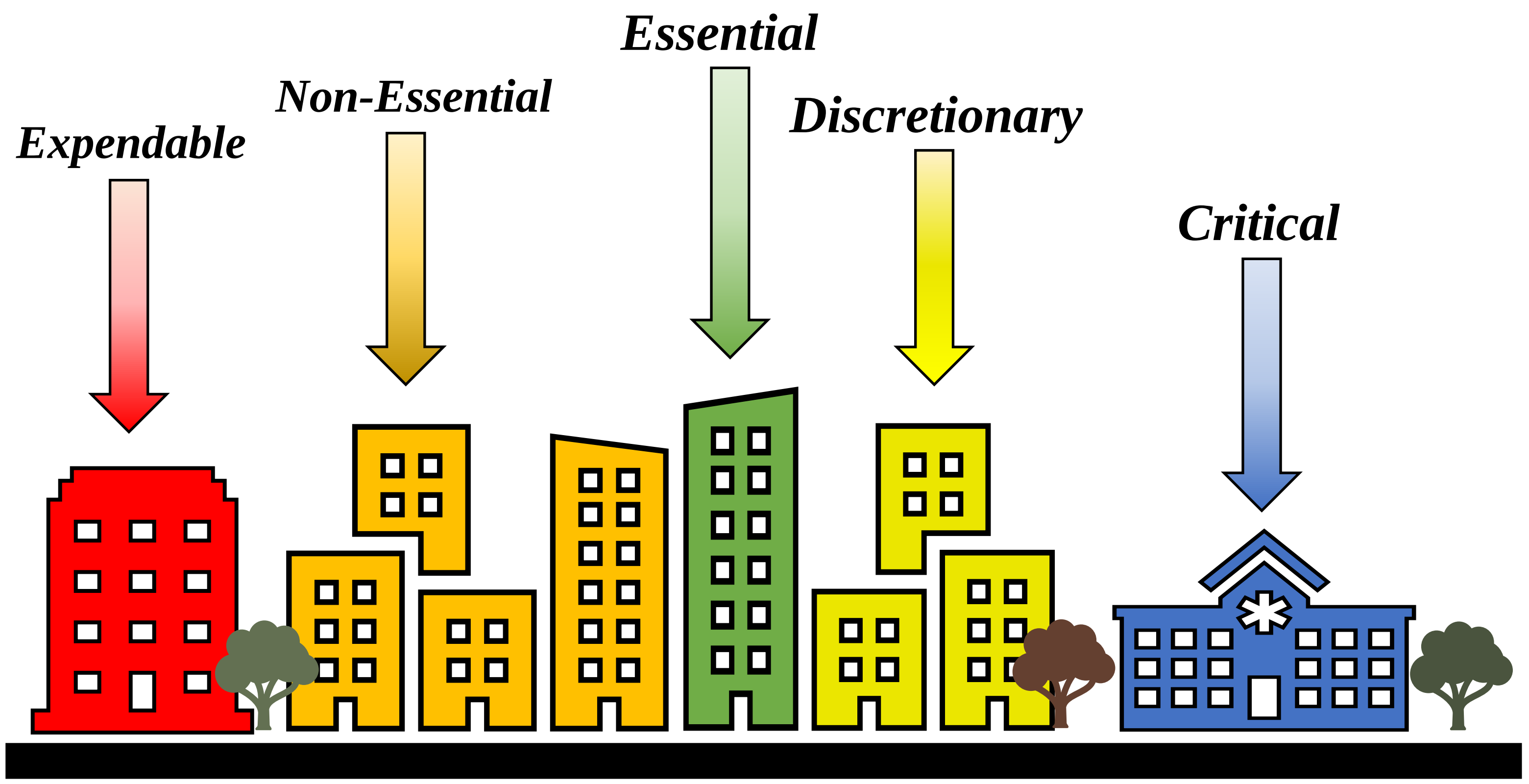
Transmission line that fell in residential area. (Image source: CNN)

Question?

- What can be done to prevent the destruction of the electrical system?

Problems?

- No energy
- Power generation is not sufficient



Criteria to classify loads

Expendable (0) – Loads with minimal impact. The majority of users do not benefit from them and do not provide life-sustaining services. For example: parking lots, floodlighting in sports complexes, advertising lighting and billboards etc.

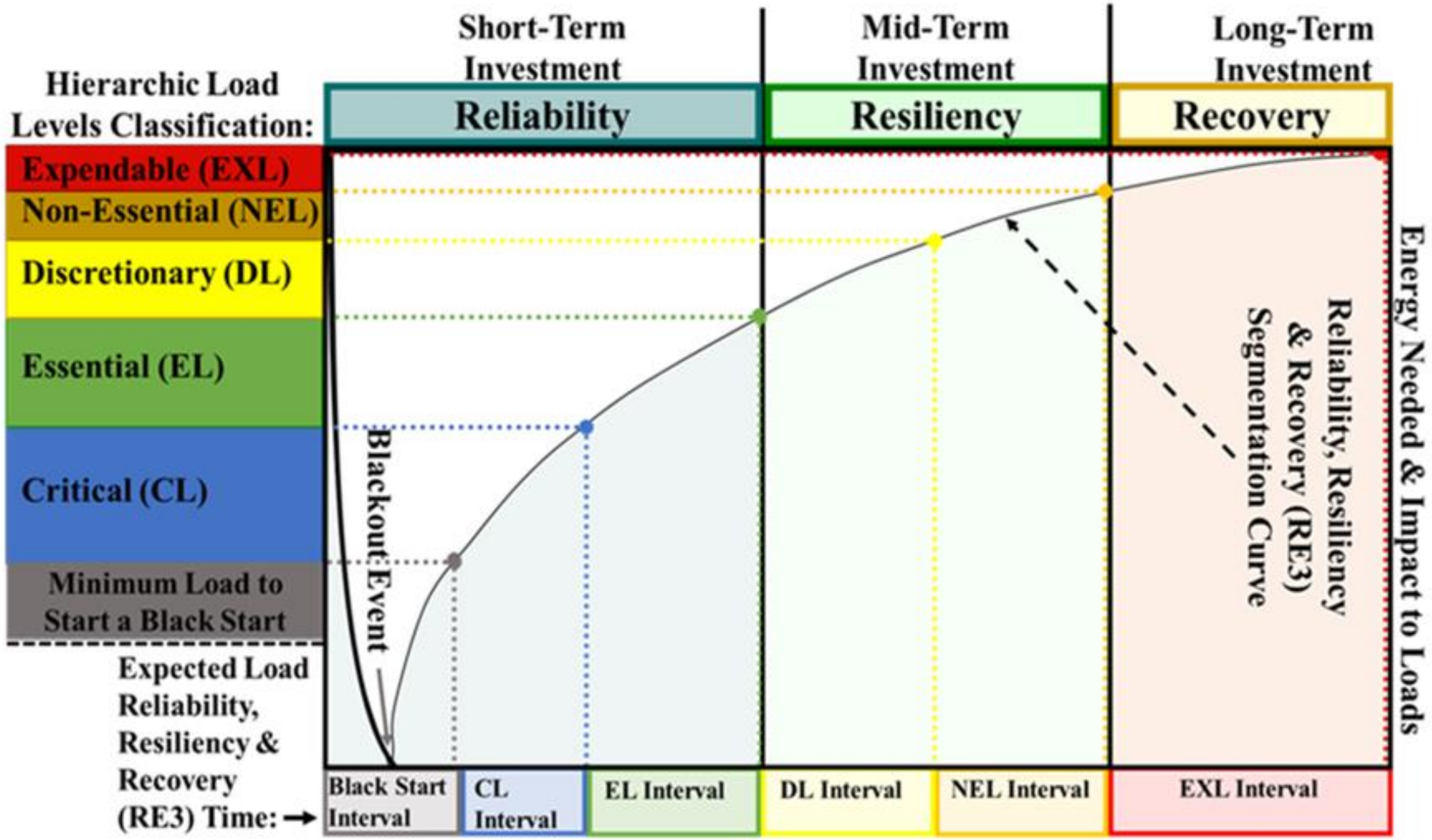
Non-Essential (1) – Do not provide life-sustaining services but may impact a non-trivial number of people. For example, cinemas, satellite government offices, coffee shops, bars/pubs, etc.

Discretionary (2) – Do not provide life-sustaining service but may impact and provide useful services or goods. For example: department stores, private offices, etc.

Essential (3) – Have a high impact on services for most people. Provide non-critical life-sustaining services or manufacturing capability that supports critical services. For example, restaurants, the pharmaceutical industry, bakeries, agriculture, food processing industry, fire department, etc.

Critical (4) – indispensable and absolutely necessary loads for life sustaining, health and security services. For example, food stores, shelters, hospitals, police departments, communications, government, etc.

Load Reliability, Resiliency & Recovery Load (RE3) Curve



Proposed Energy Storage Selection Priority Index (ESSPI)

$\boldsymbol{t}_{(\boldsymbol{n})}$ – Maximum Critical Recovery Time: The maximum down time (days) a load can experience before services are affected.

$\boldsymbol{T}_{(\boldsymbol{n})}$ – Complete Recovery Time: Number of *days* a load requires to recover from a blackout. After an event, analysis of the affected areas is required to gauge the complete energy restoration time.

$\boldsymbol{CLE}_{(\boldsymbol{n})}$– Critical Load Energy: Total energy needed from loads classified as critical.

$\boldsymbol{ELE}_{(\boldsymbol{n})}$– Essential Load Energy: Total energy needed from loads classified as essential.

$\boldsymbol{DLE}_{(\boldsymbol{n})}$– Discretionary Load Energy: Total energy needed from loads classified as discretionary.

$\boldsymbol{NELE}_{(\boldsymbol{n})}$– Non-Essential Load Energy: Total energy needed from loads classified as non-essential.

$\boldsymbol{EXLE}_{(\boldsymbol{n})}$– Expendable Load Energy: Total energy needed from loads classified as expendable.

Proposed Energy Storage Selection Priority Index (ESSPI)

VLE– Vital Load Energy: The sum of the number of *i* $CLE_{(n)}$ loads and the number of *j* $ELE_{(n)}$ loads of the system.

SLE– Supplementary Load Energy: The sum of all the number of *m* $DLE_{(n)}$ loads and the number of *k* $NELE_{(n)}$ loads of the system.

TLE– Total Load Energy: The sum of the VLE, SLE and all the *q* $EXLE_{(n)}$ loads.

$\boldsymbol{PoCLI_{(n)}}$ – Precent of Classified Load Impact: Each *type of load* (ToL) divided by *TLE*.

$\boldsymbol{STESSPI_{(n)}}$ – Short-Term Energy Storage Selection Prioritization Index: Eq. 5 and Eq. 6 are used to calculate the index that helps prioritize loads earmarked for short-term ESS investment.

$\boldsymbol{MTESSPI_{(n)}}$ – Mid-Term Energy Storage Selection Prioritization Index: Eq. 7 and Eq. 8 are used to calculate the index that helps prioritize loads earmarked for mid-term ESS investment.

$$VLE = \sum_{n=1}^{i} CLE_{(n)} + \sum_{n=1}^{j} ELE_{(n)} \quad (1)$$

$$SLE = \sum_{n=1}^{m} DLE_{(n)} + \sum_{n=1}^{k} NELE_{(n)} \quad (2)$$

$$TLE = VLE + SLE + \sum_{n=1}^{q} EXLE_{(n)} \quad (3)$$

$$PoCL_{(n)} = \frac{ToL}{TLE} \times 100 \quad (4)$$

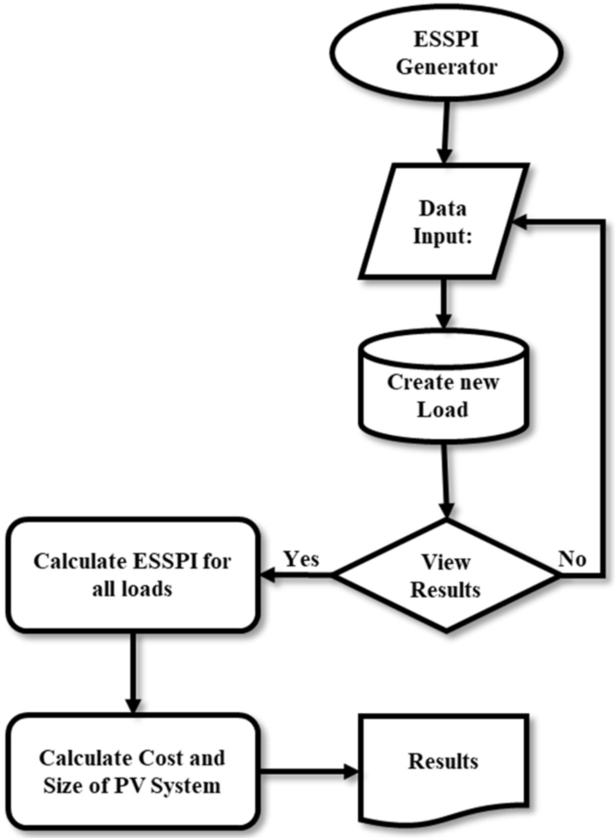
$$STESSPI_{(n)} = \frac{CLE_{(n)}}{VLE}\left(\frac{T_{(n)}}{t_{(n)}}\right) \quad (5)$$

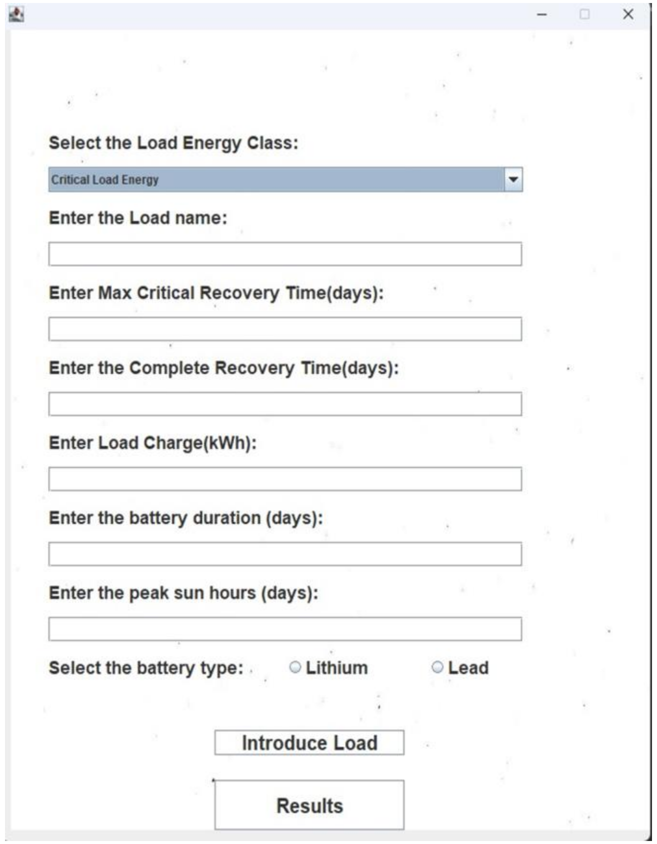
$$STESSPI_{(n)} = \frac{ELE_{(n)}}{VLE}\left(\frac{T_{(n)}}{t_{(n)}}\right) \quad (6)$$

$$MTESSPI_{(n)} = \frac{DLE_{(n)}}{VLE + SLE}\left(\frac{T_{(n)}}{t_{(n)}}\right) \quad (7)$$

$$MTESSPI_{(n)} = \frac{NELE_{(n)}}{VLE + SLE}\left(\frac{T_{(n)}}{t_{(n)}}\right) \quad (8)$$

ESSPI programming/flowchart





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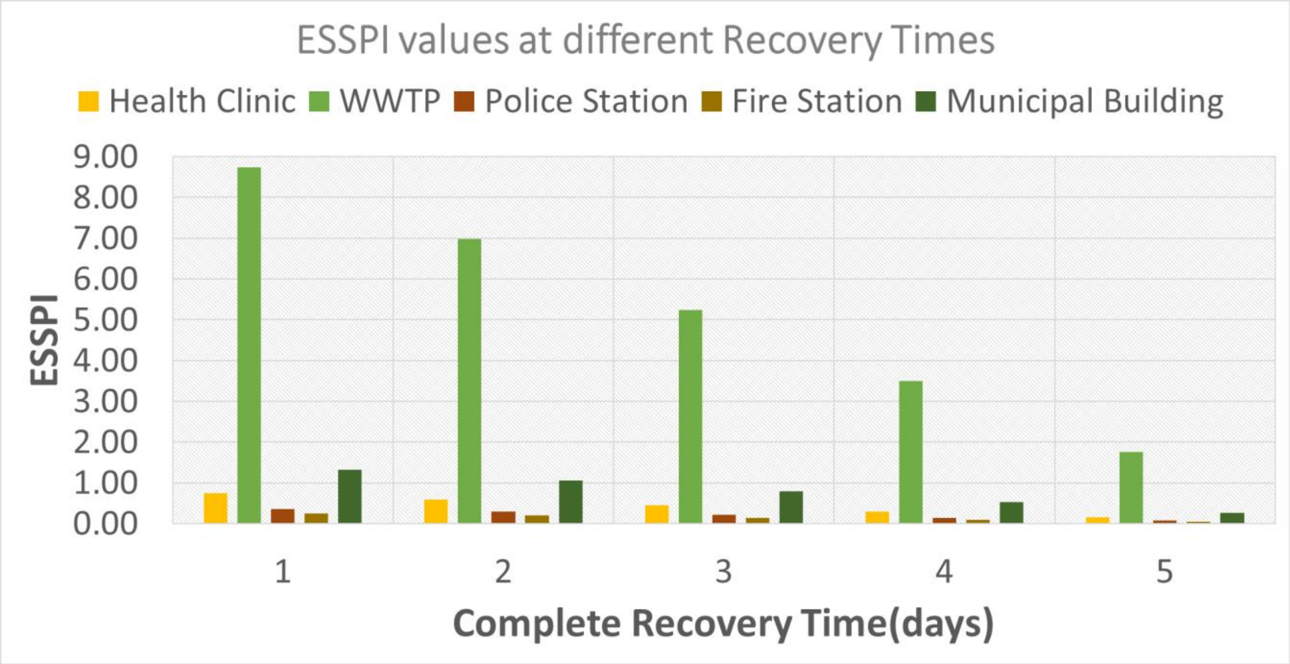
Case of Study Example

- Energy Resilience Assessment: Culebra, Puerto Rico
- Report Prepared for the Municipality of Culebra by NREL in collaboration with EPA.
- Authors:
- Jimmy Salasovich and Gail Mosey
- As part of the contributors, UPRM:
  - Dr. Eduardo Ortiz
  - Melvin Lugo Alvarez, Graduate Student
  - Francisco Matos Ortiz, Graduate Student
  - **Guillermo J. Lopez, Undergraduate Student**

Salasovich, James; Mosley, Gail; Rosado, Fernando; Wesley, Terry; Mitchell, Schenine; Luna, Zolymar; Pitruzzello, Vince; Panagakos, Jilian; Cui, Linyuan; Ortiz, Eduardo; Lugo-Alvarez, Melvin; Matos-Ortiz, Francisco; Lopez-Cardalda, Guillermo J.; "**Energy Resiliency Assessment: Culebra Puerto Rico**" NREL Report for the Municipality of Culebra, Techinical Report NREL/TP-7ª40-72562, Oct. 2018

Results

Infrastructure Type	Health Clinic	WWTP	Police Station	Fire Station	Municipal Building
Daily avg Energy Use (kWh)	689.622	680	112.564	74.838	527.493
t (days)	3	0.25	1	1	1
T (days)	2	2	1	3	2



Conclusion

The idea of the tool is to facilitate the identification and prioritization of loads for the user for a microgrid. The user can also obtain other useful information such as the size of the batteries needed to maintain the system and the estimated cost. As well as the size of the PV system and its cost. Then based on that information, the next objective of the tool is to suggest to the user, in a fast way, the size of the system needed to satisfy the energy and power requirements of those loads. Also, sizes and systems costs may vary depending on if the user wants the analysis for short-, mid-, and long-term investment.

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Thanks!

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