Data-enriched Grid Modeling of End-user Profiles, Energy Equity, and Situational Preparedness

Panel Chair: Dr. Xiaoyuan Fan

Invited Panelists:

Prof. Liang Du (Temple Univ.)

Dr. Kendall Parker (PNNL)

Prof. Marcel J. Castro-Sitiriche (UPRM)

November 7th, 2023 @ San Juan, Puerto Rico

PNNL-SA-191900, unlimited distribution.

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How Data Can Support Grid Operations: From Distribution to Transmission, to Energy Equity

Advancing Equity through Technical Assistance Programs

Boricua Energy Equity

PNNL is one of the DOE's 17 national laboratories tackle critical scientific challenges

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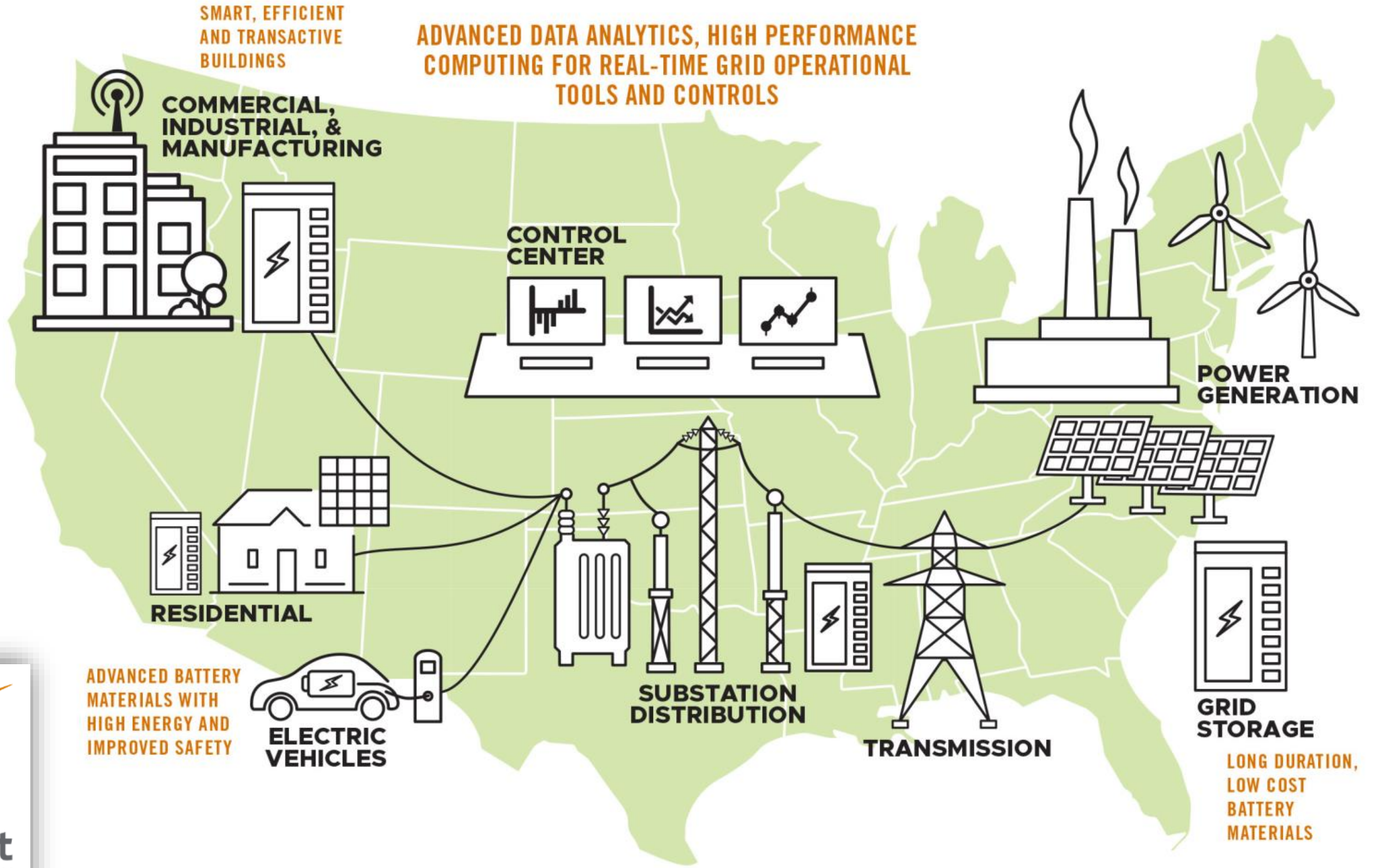
PNNL's Laboratory Objective to Support Decarbonized Digital Economy



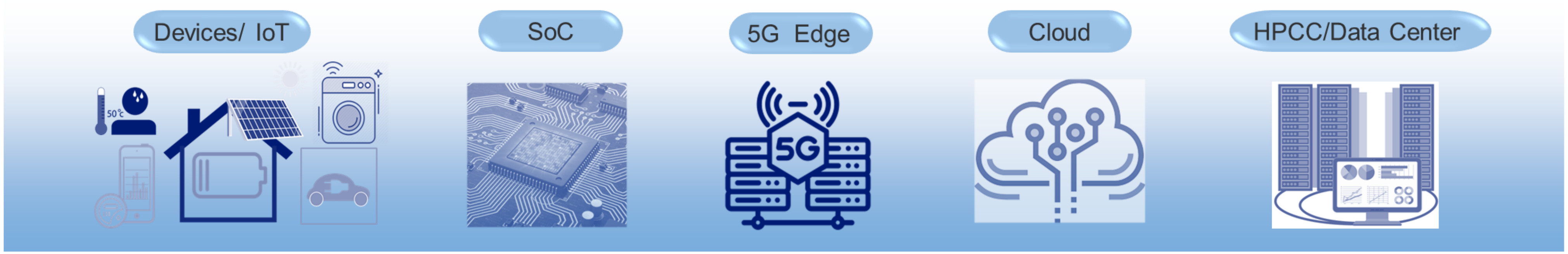
Pacific Northwest NATIONAL LABORATORY

VISION

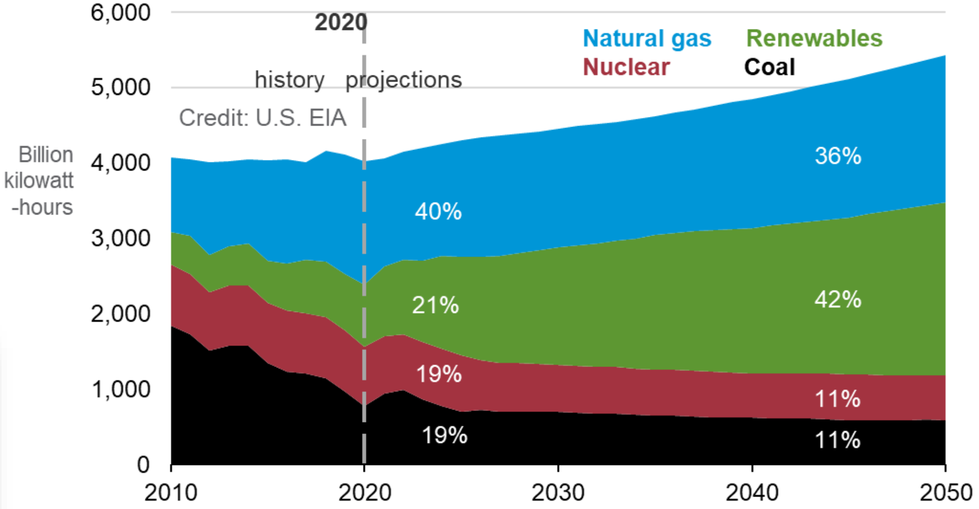
We will be the national leader in defining the inherently resilient grid of the 21st Century, delivering:

- New tools to increase system transparency and flexibility that will deliver unparalleled grid performance (reliability, security, efficiency)
- New control and architecture paradigms spanning demand and supply
- Unprecedented consumer engagement

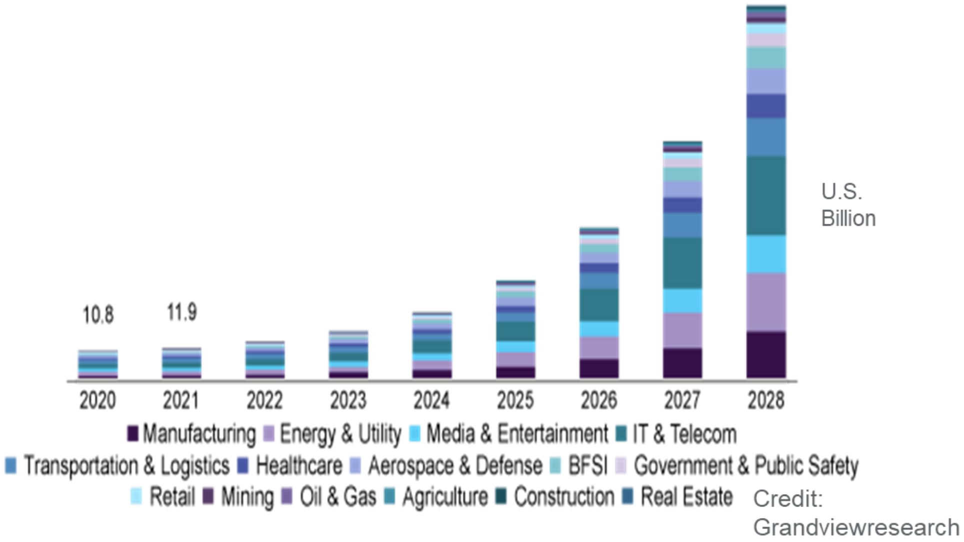
Decarbonized Digital Economy Outlook



COMPUTING



Decarbonized Energy Mix



5G Communication Market

Pacific Northwest
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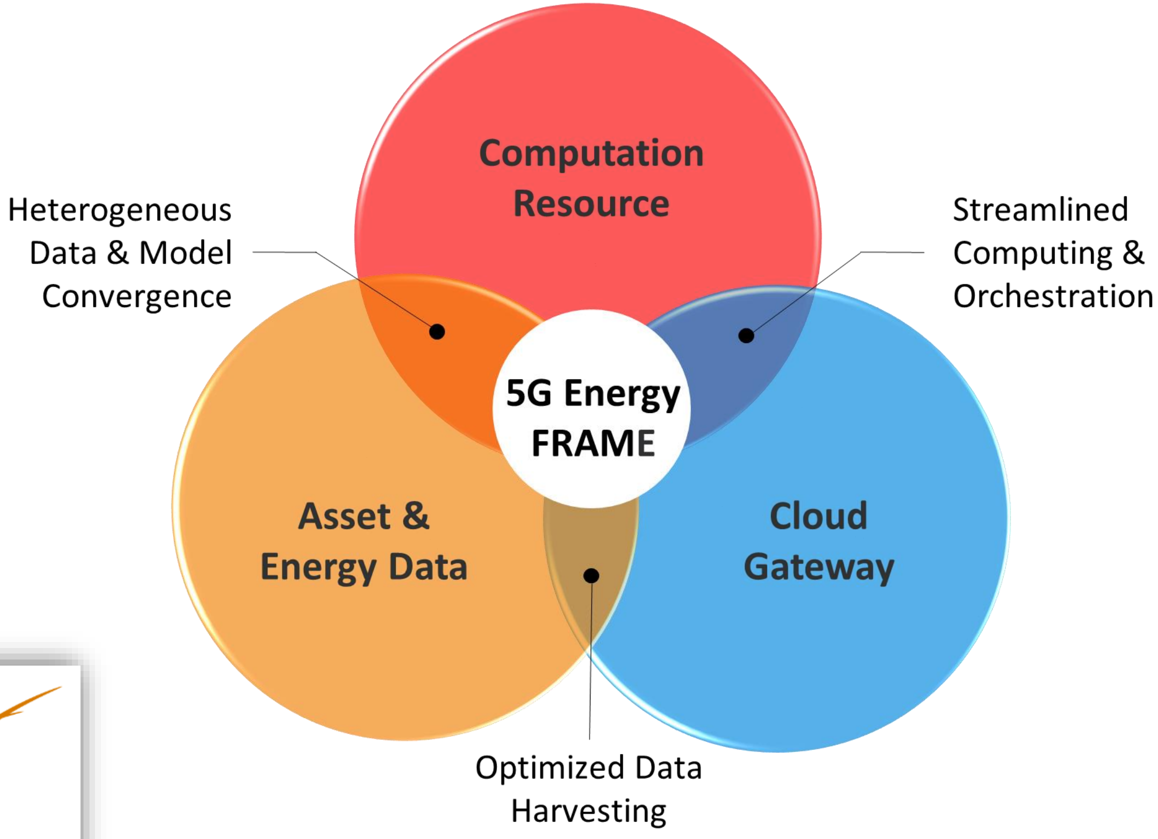
5G Merging Cyber and Physical for Value

5G @ PNNL

Alternative video link: https://www.youtube.com/watch?v=6dsgMq2bzl0

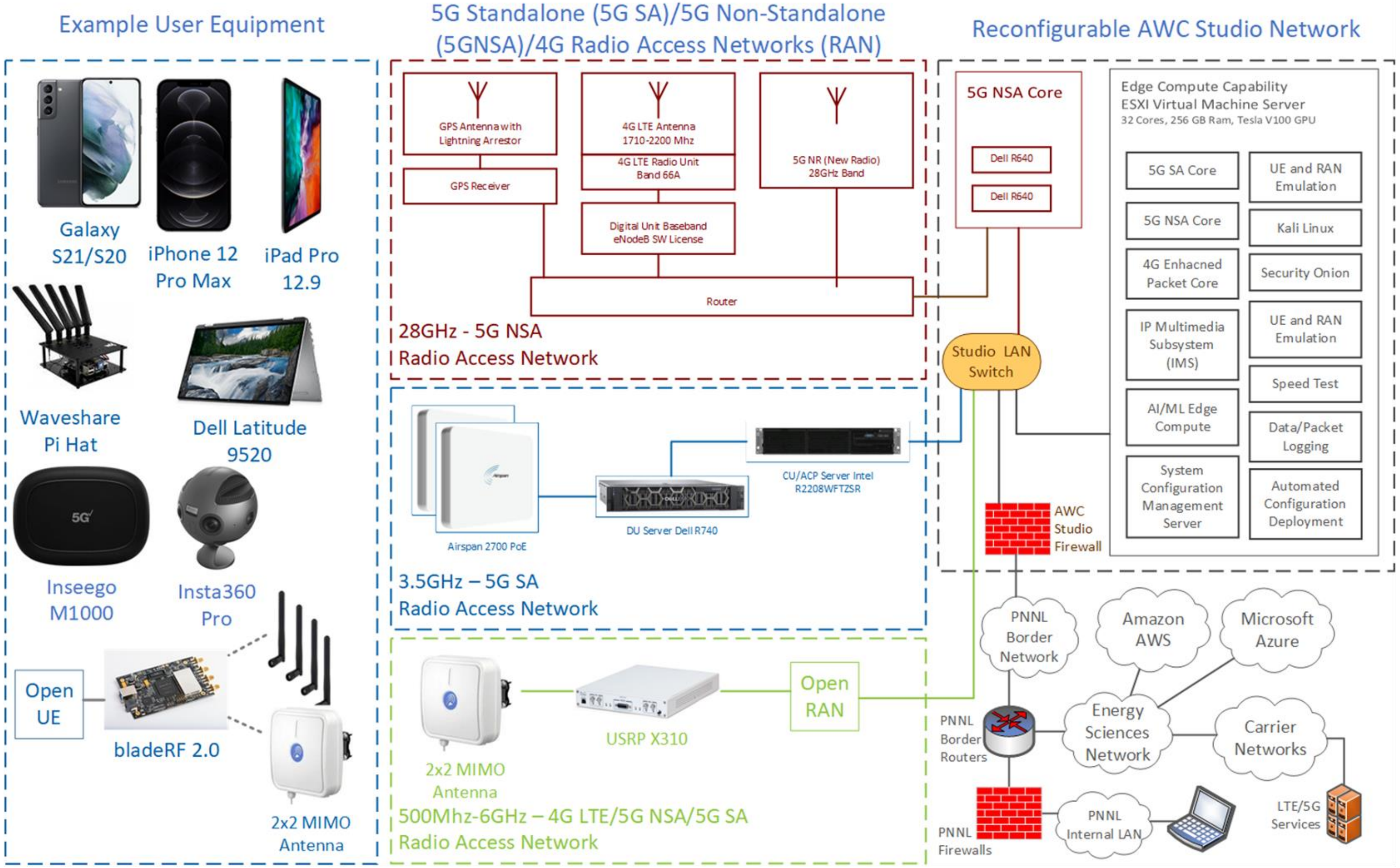
5G Fabricated Resource and Asset Management Encompassment for Energy Infrastructure



PNNL project website: https://www.pnnl.gov/projects/5g-energy-frame

- 5G Energy FRAME embraces 5G technologies to break data silos, bridge computing resources, and enhance the energy infrastructure asset management through cohesive data integration and intelligent analytics.
  - Energize the potential of data and computing with 5G-enabled digital continuum
  - Enable heterogeneous and edge computing resources & orchestration
  - Explore a co-design framework for complex distributed engineering systems

PNNL 5G Advanced Wireless Communication Lab

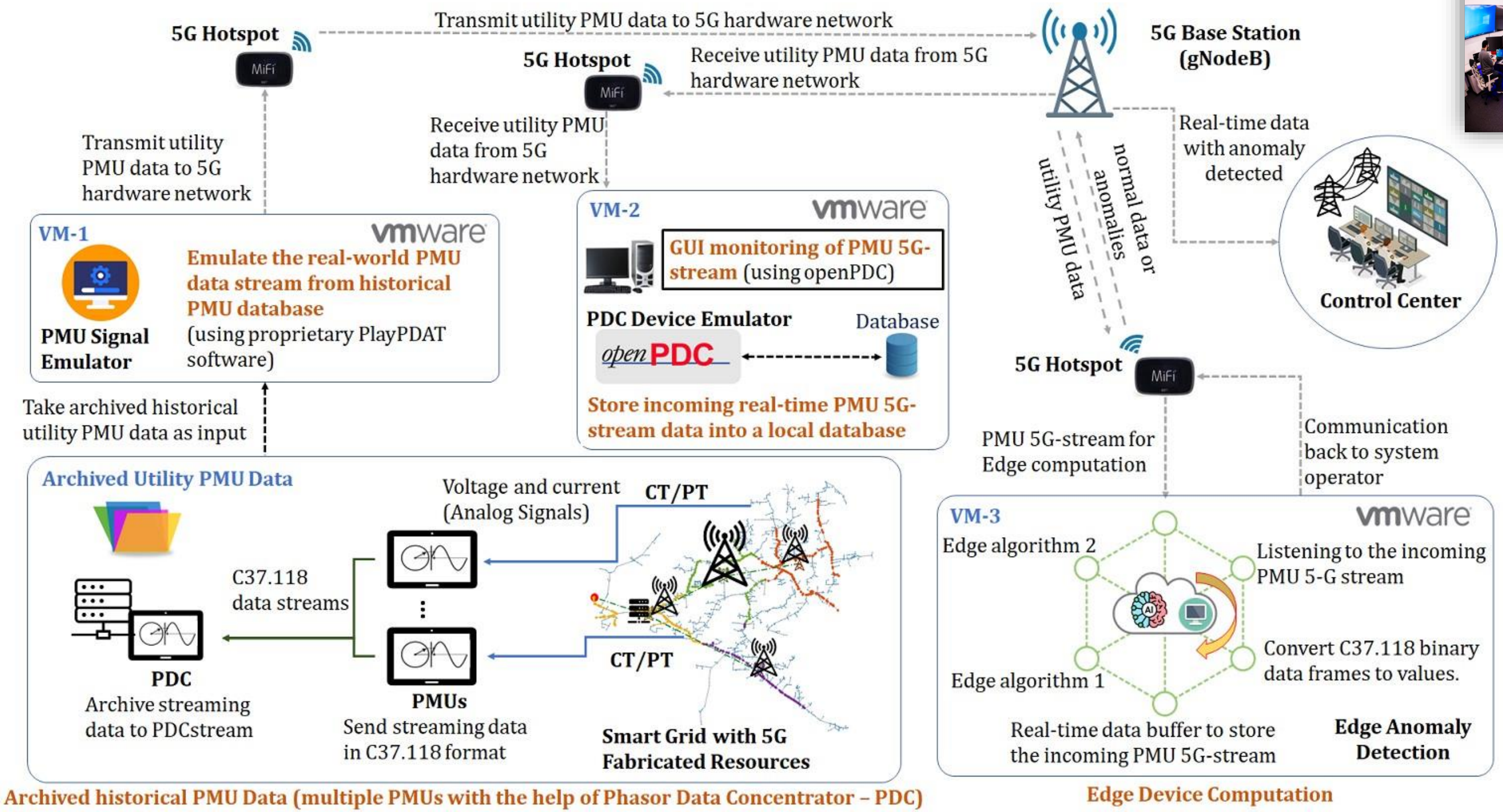


Elena Peterson

Johnathan Cree

[*] Fan X., J.P. Ogle, J.V. Cree, D. Wang, Y. Chen, E.S. Peterson, and T. Fu, et al. 2022. Technical Characterization and Benefit Evaluation of 5G-Enabled Grid Data Transport and Applications. PNNL-33221. Richland, WA: Pacific Northwest National Laboratory.

5G enabled AI/ML for Grid Integration of Renewable Energy

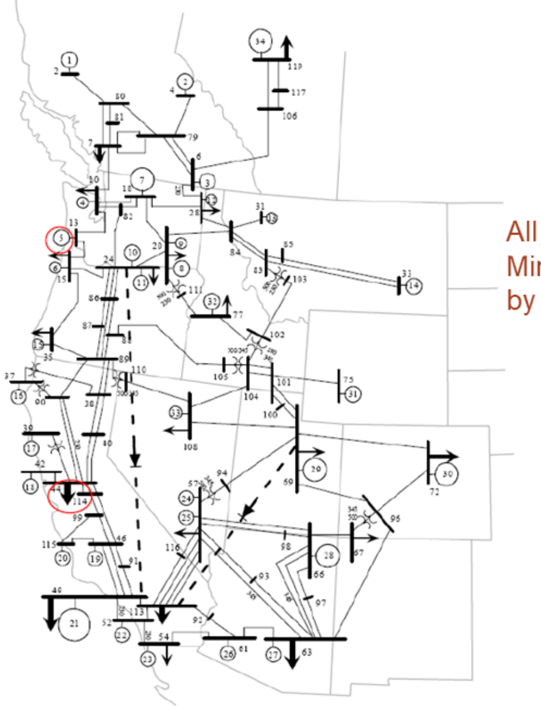


[*] Qin C., D. Wang, K. Guddanti, X. Fan, and Z. Hou. 2023. "Synchrophasor Data Anomaly Detection on Grid Edge by 5G Communication and Adjacent Compute." submitted to 2024 IEEE conference. PNNL-L-SA-189162.

PNNL's Integrated T&D Co-Simulation Platform [*]

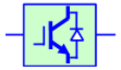
- Developed a T&D co-simulation platform leveraging DOE invested open-source tools GridPACK, HELICS, and GridLAB-D
- System size: ***10,000+ IBRs***, and ***160,000+ nodes***
- The platform can be used to investigate the impact of grid-following (GFL) and grid-forming (GFM) IBRs on the system dynamic stability at any penetration levels (up to 100%)

GridPACK™ + H + GridLAB-D

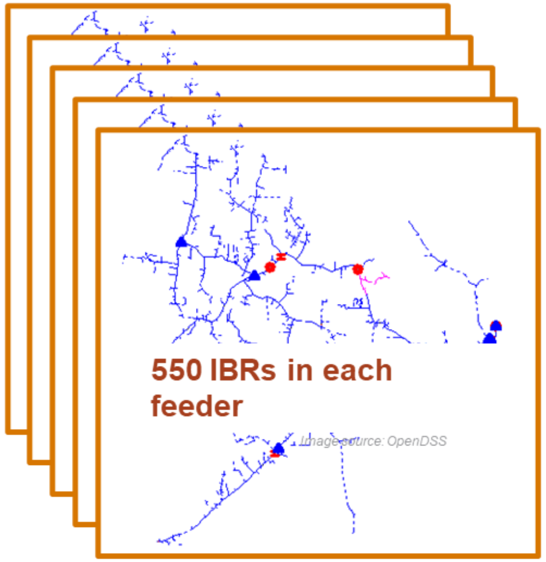


MinniWECC system

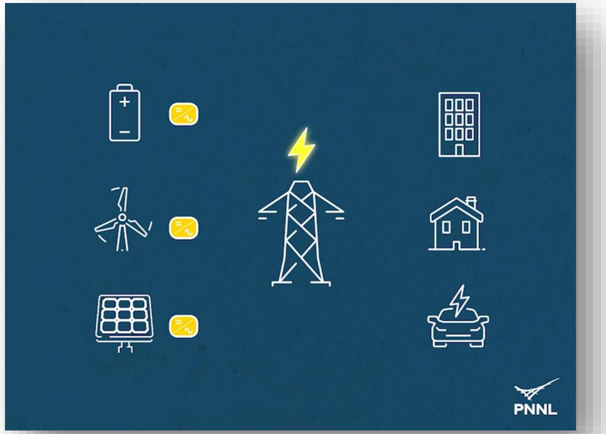
All 19 load buses of the MinniWECC system are replaced by detailed feeder models



10,000+ IBRs



Modified IEEE 8500-Node Test Feeder

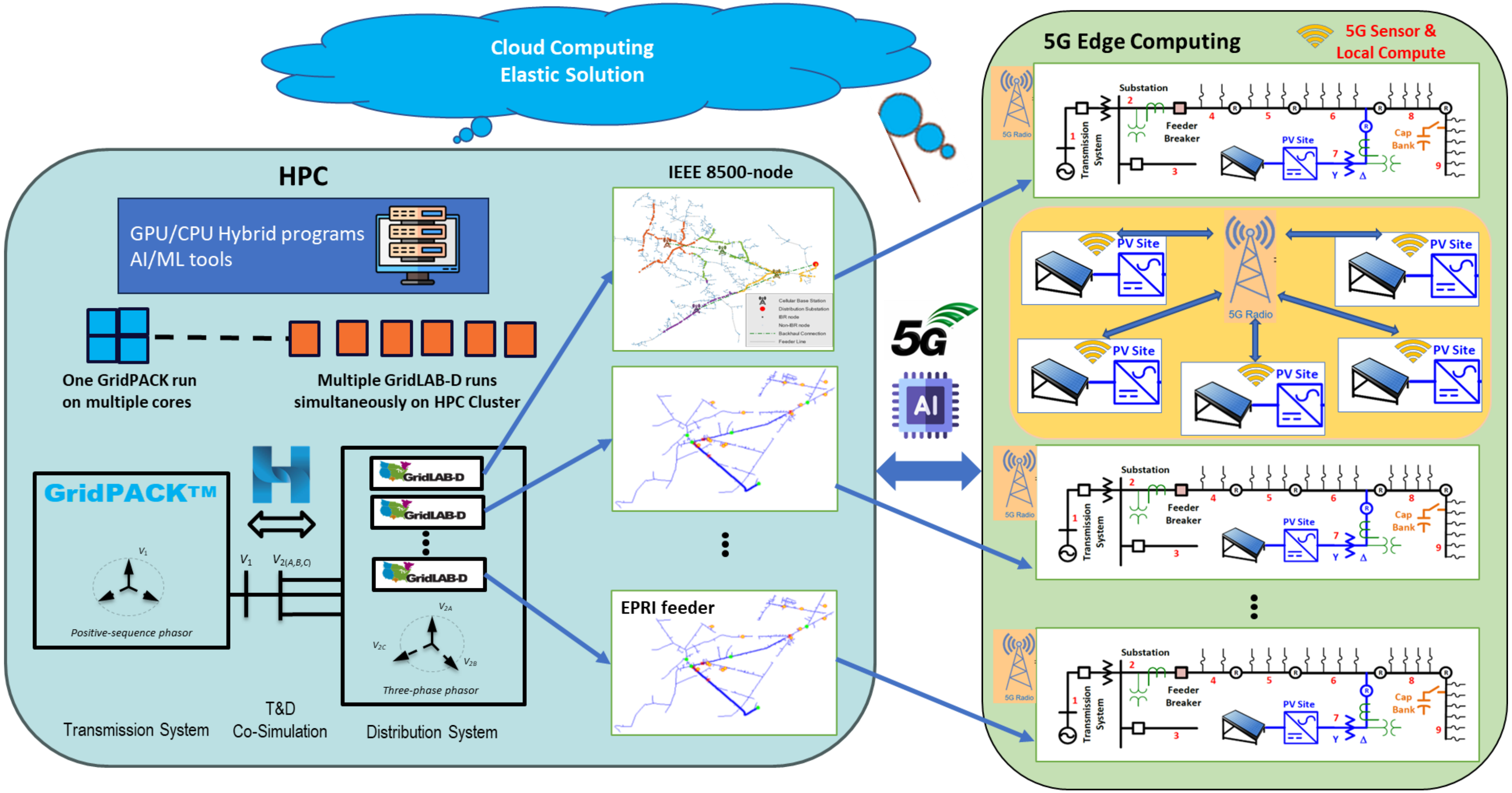


Simulating the Role of Grid-Forming Inverters in the Future Electric Grid

https://www.pnnl.gov/news-media/simulating-role-grid-forming-inverters-future-electric-grid

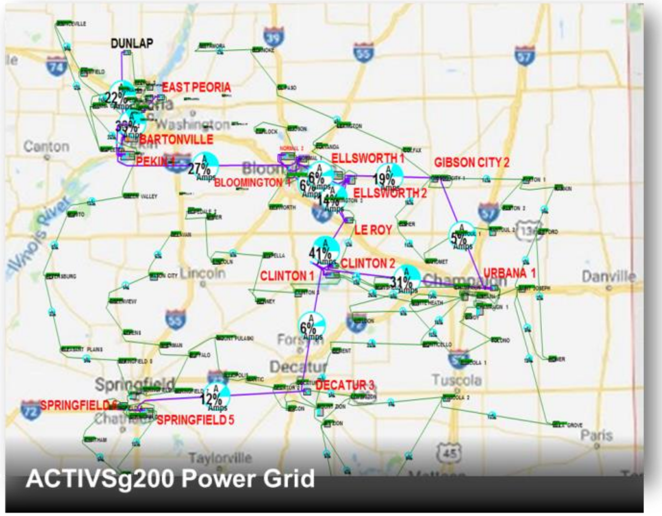
[*] Y. Liu, R. Huang, W. Du, A. Singhal and Z. Huang, "Highly-Scalable Transmission and Distribution Dynamic Co-Simulation with 10,000+ Grid-Following and Grid-Forming Inverters," in IEEE Transactions on Power Delivery, doi: 10.1109/TPWRD.2023.3302303. This work is funded by the PNNL Laboratory Directed Research and Development (LDRD) Program.

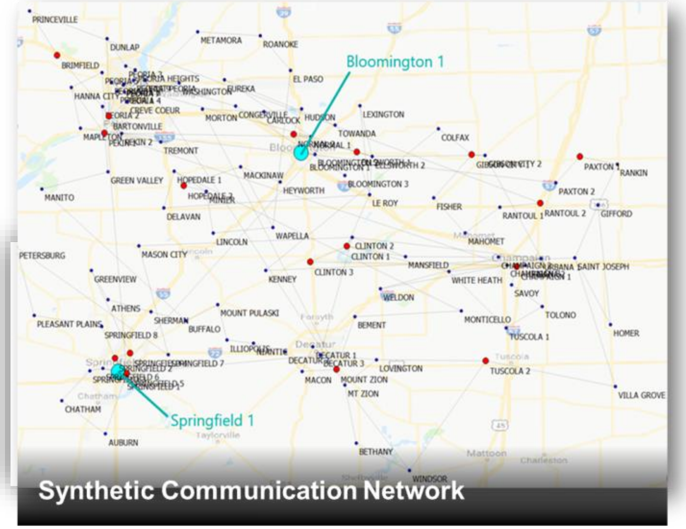
Power Electronics for Grid Decarbonization: First 5G-for-Grid Use Case (to be delivered FY24 Q2)

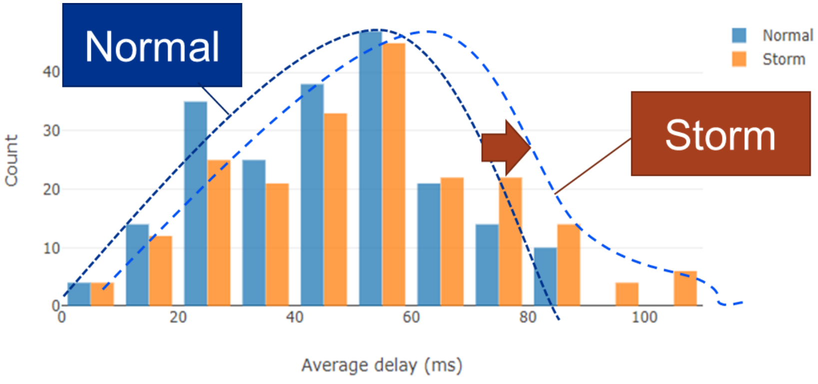


[*] Fan X., D. Wang, C. Qin, K. Guddanti, V. Tiruchirappalli Narayana Kumar, Y. Chen, and J.P. Ogle, et al. 2023. 5G Energy FRAME: The Design and Implementation of Data, Model, and Use Case - Year 2 Report, PNNL-34658, Richland, WA: Pacific Northwest National Laboratory.

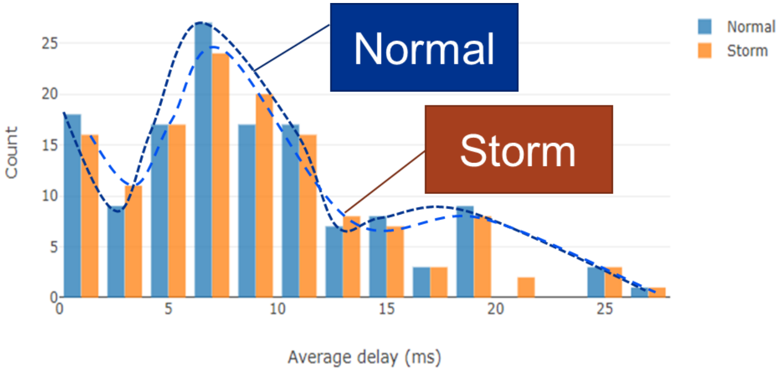
Situational Preparedness for multi-domain Infrastructure Resilience evaluation





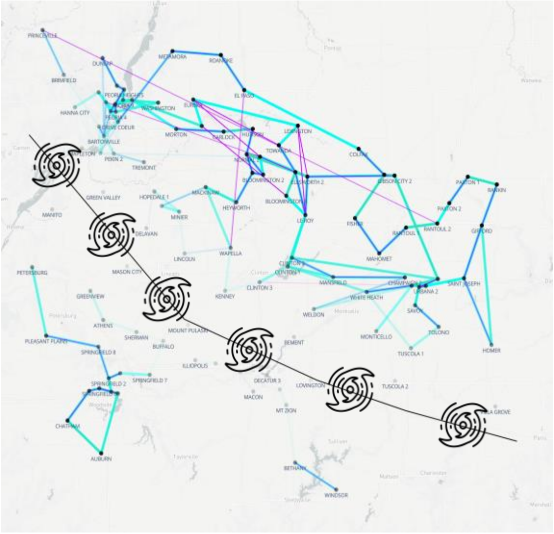


A real-world comm. network with microwave-heavy topology



A comm. network based on the Illinois 200-bus system

Microwave performance degradation due to storm passing through



Transmission Network & Communication Network Interdependency evaluation with Hurricane Disruptions

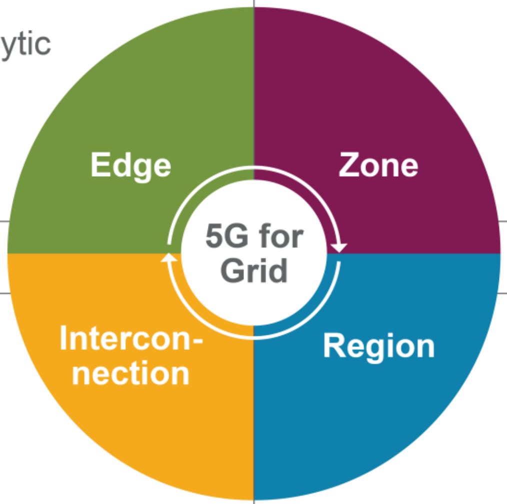
[*] X. Fan, et al. 2020. "Automated Realistic Testbed Synthesis for Power System Communication Networks based on Graph Metrics." In *IEEE ISGT 2020.*

Co-design of Energy, Communication, Computing in Decarbonized Clean Energy Economy

Compute	Compute + Networking			
Compute + Communication + Data				
Devices/IoT	Access	5G Edge	Network Core	Data Center/Cloud/HPCC

5G for Grid Edge
- Edge Streaming Analytic
- Asset Health
- Prosumer volatile computing

5G for Energy Zone
- Data reduction
- Coordinated edge computing
- Private Zone
- Extreme grid device density

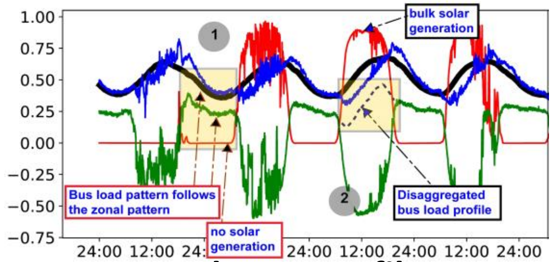


5G-eMBB & mMTC
High Throughput & Connectivity, Network Slicing

5G-uRLLC
Ultra-reliable Low-latency Communication

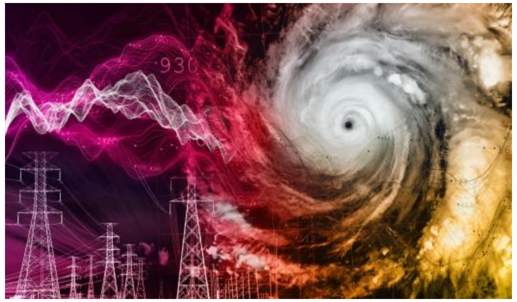
5G for Grid Interconnection
- Advanced sensing & Low-latency Control
- Extreme events emergency response

5G for Regional Utility & Industry
- Prosumer Resilience
- Trans. + Dist. + Edge Orchestration



End User Profiles

Energy Equity & Community



Situational Preparedness

[*] Fan X., J.P. Ogle, Y. Chen, D. Wang, and J.A. Ang. 2022. 5G Enabled Transformative Co-design and Co-simulation Framework for Grid Decarbonization and Modernization. PNNL-SA-173337. Richland, WA: Pacific Northwest National Laboratory. doi:10.2172/1869831.

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5G and ASCR Collaborators:

Elena Peterson, Johnathan Cree, Seth Sandland, Nathan Moore, Tyler Andersen, Venkat Kumar, Jim Ang, Kevin Barker, David Manz

Research Stakeholders:

Temple Univ., Virginia Tech., Univ. of Wyoming, New York Univ., Clemson Univ., George Washington Univ., PJM Interconnection, Verizon, Nokia

PNNL-SA-191900, unlimited distribution.

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How Data Can Support Grid Operations: From Distribution to Transmission, to Energy Equity

Advancing Equity through Technical Assistance Programs

Boricua Energy Equity

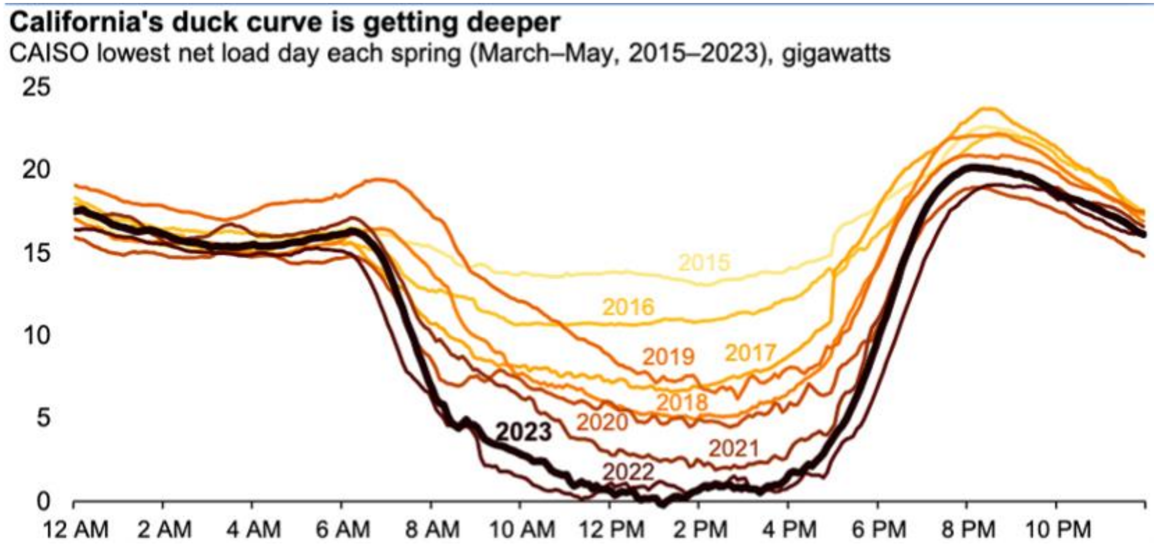
How Data Can Support Grid Operations: From Distribution to Transmission, to Energy Equity

Liang Du, Temple University, Philadelphia

Why Data is Important?

Our power grid is transforming

- BTM solar + storage
- Self-managed loads
- Increasingly frequent, severe extreme weather + outages

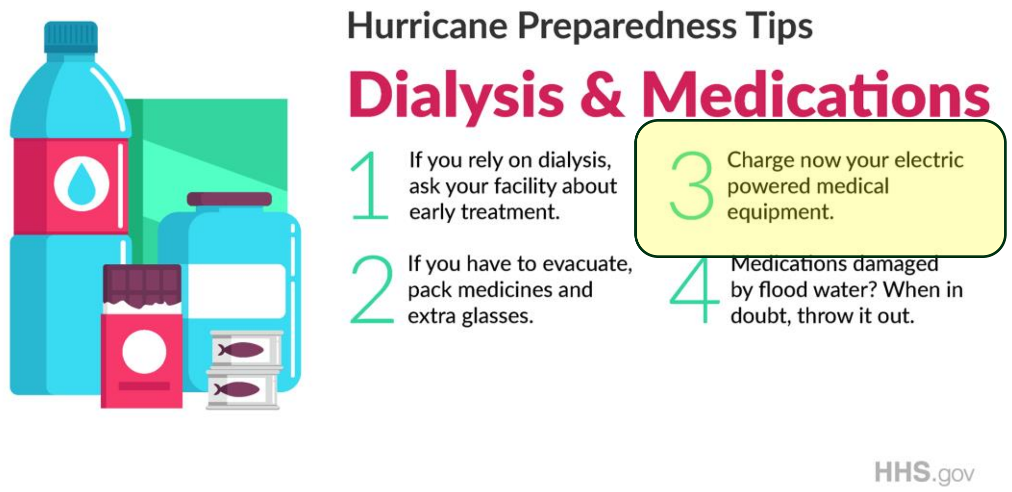


Why Data is Important?

Handling Imbalance, Even When Things Do Not Work

Need to know

- Actual capacity, demand, at least closely
- **Flexible vs Rigid** demands
- Not just today, but adaptively look-ahead



- ❑ It could be worse than we used to handle
  - CDC: Millions reside at home & depend on electrically-powered medical equipment
  - Power outages, however short, may expose to life-threatening risks
  - 95% of dialysis facilities closed during Hurricane Sandy, prolonged power outages,
  - Consequently, Hurricane Sandy was called “a Kidney Failure Disaster” by NIH

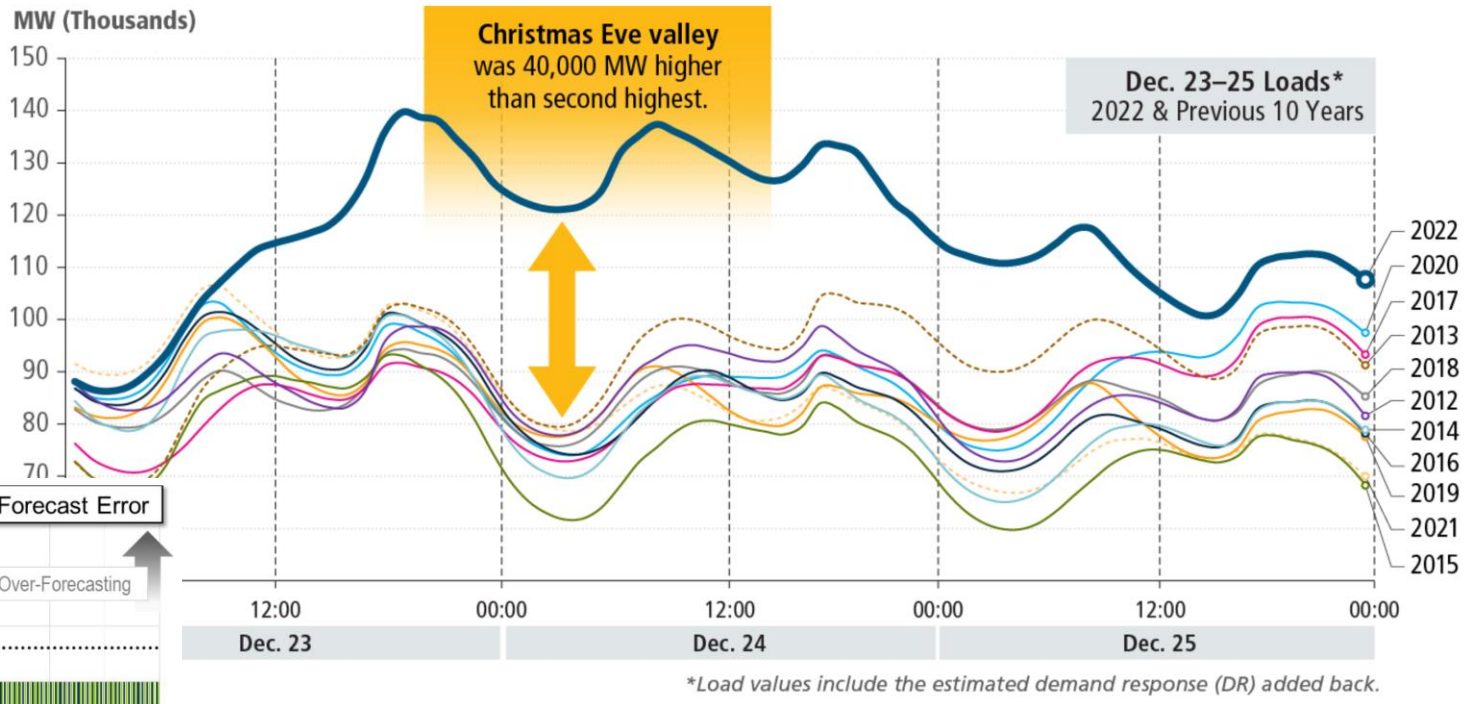
State-of-the-practice: Load Forecast

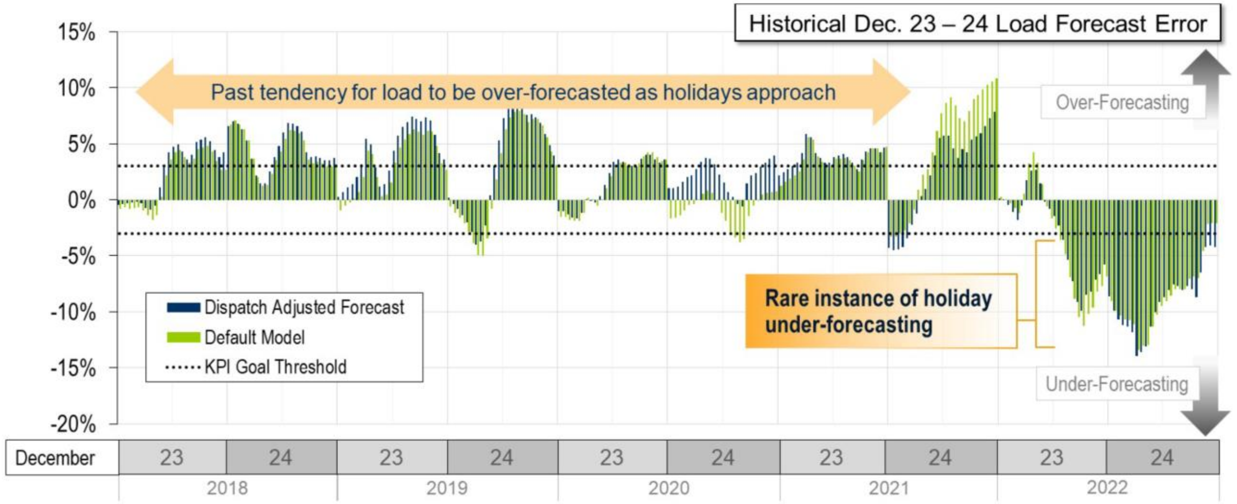
We assume load and solar forecast are accurate

PJM Market-wise Load Forecast:
40 GW Off for 2022 Christmas Eve

vs

Typically less than 1% forecast error





Why? **Winter Storm Elliott**

Handing Imbalance

Size Matters, But Sizing Up Does Not Solve the Problem

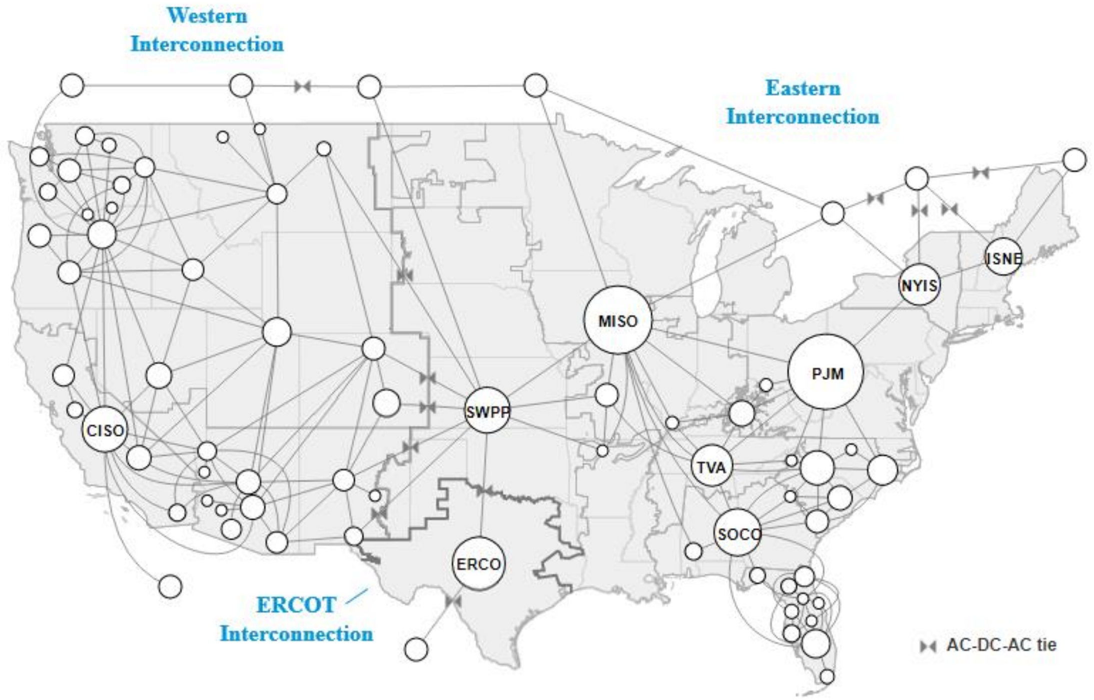
RTO/ISO: by the end of 2022, waiting in interconnection queues

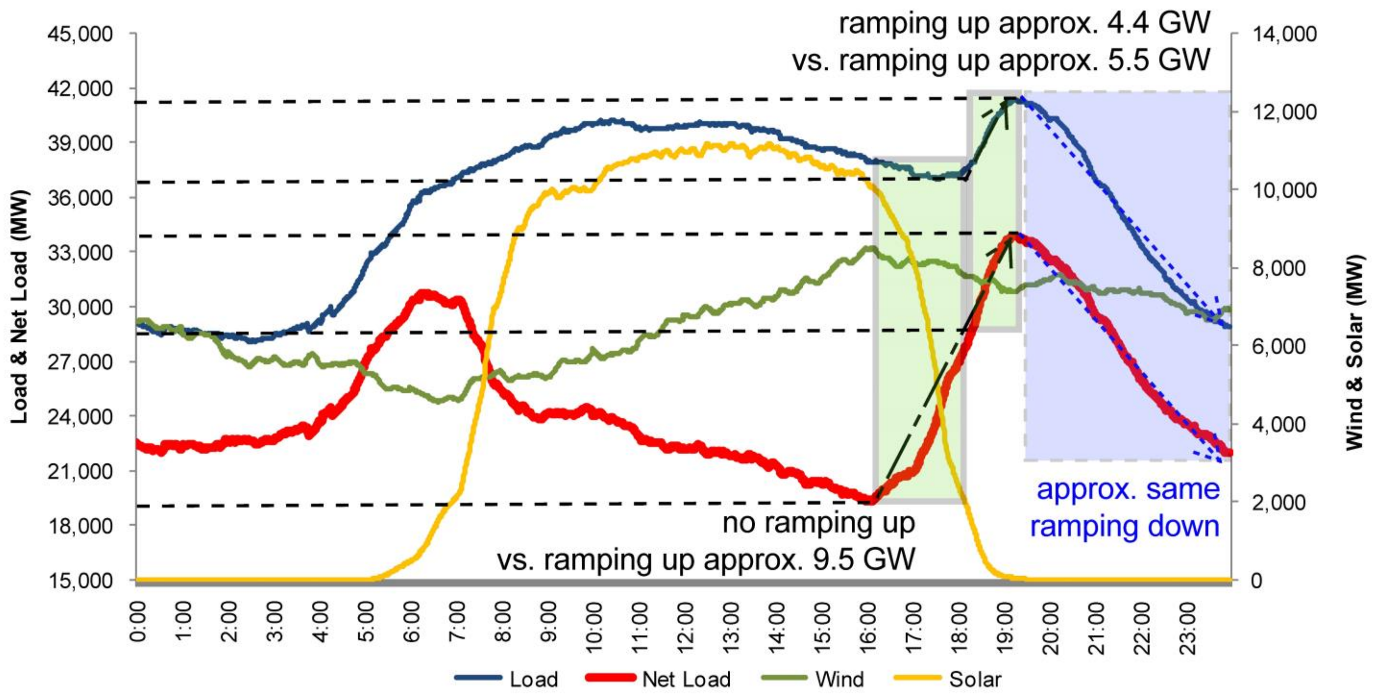
676 GW solar

247 GW wind

213 GW standalone ESS

208 GW hybrid battery capacity

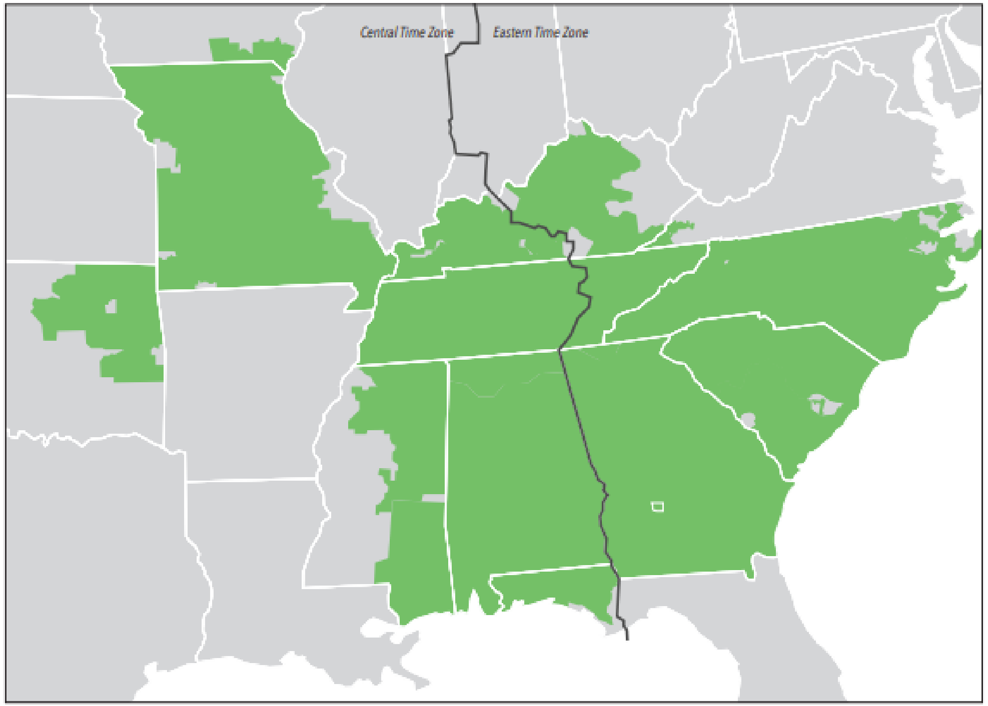




Vertically integrated utilities

It Helps to Have a Network of Individually Operator BAs

Southeastern Energy Exchange Market (SEEM)
16 entities in parts of 11 states



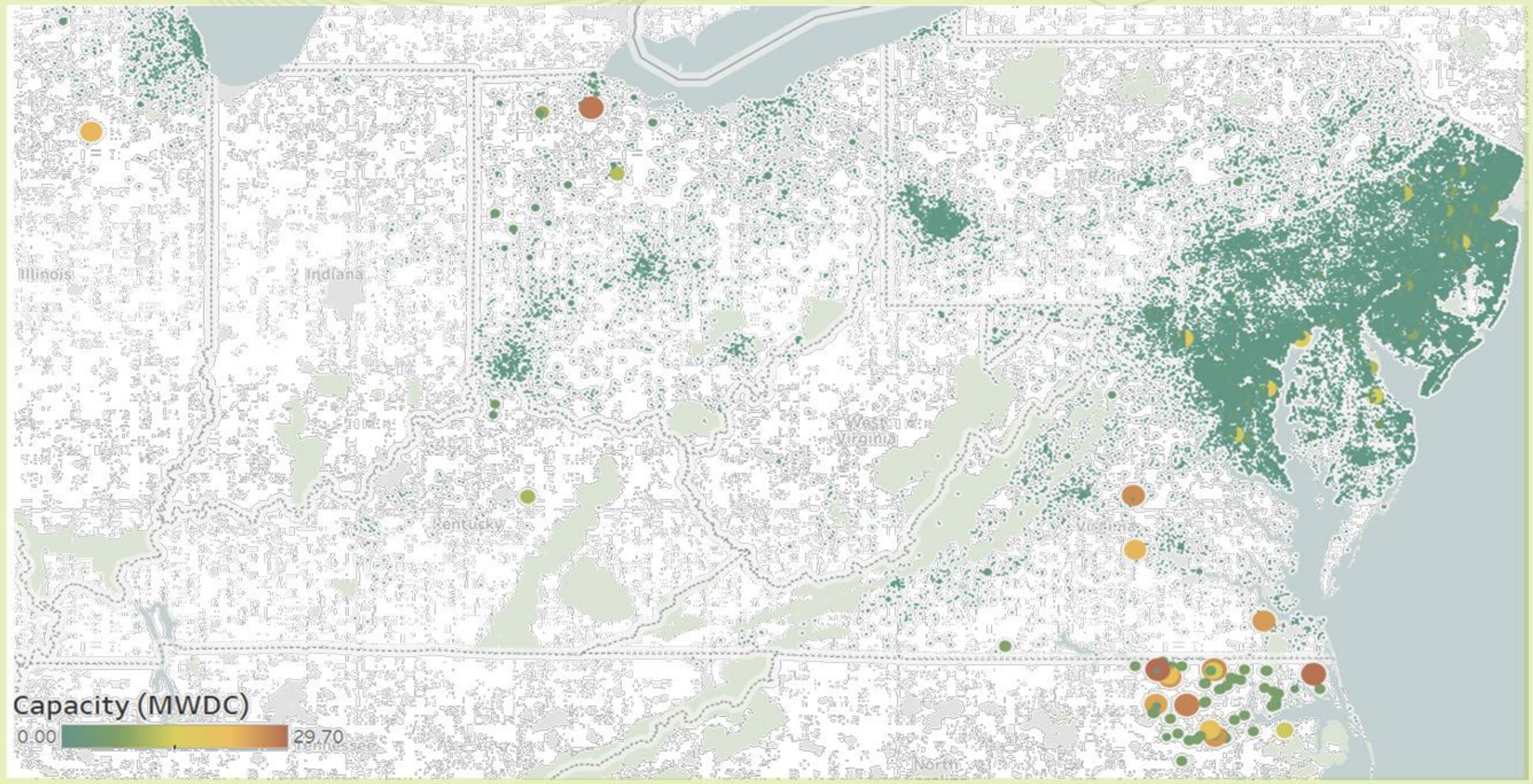
How is SEEM similar or different from the Western Energy Imbalance Market?

	Western EIM	Southeast EEM
Resource Dispatch	5-minute nodal SCED market platform sends individual resource dispatch signals to participating resources every 5 minutes	15-minute block schedule via electronic interchange tags – BA/BA interface transactions – the Market Platform tool matches bids and offers to maximize benefit savings, while adhering to transmission capability (ATC) constraints
Complexity	Moderately complex due to establishing marketing system that also assesses security constraints	Simple due to leveraging existing bilateral trading processes
Costs	Significant startup costs	Low startup and ongoing costs
Transmission Service Charge	$0/MWh	$0/MWh
Ancillary Services	Limited	Limited
Manual/Automated	Automated	Automated
Day Ahead Market	No	No
Resource Offer into Market	Voluntary	Voluntary
Manages Imbalance	Directly	Indirectly

Need BTM Data

Behind-the-Meter (BTM) Generation at PJM

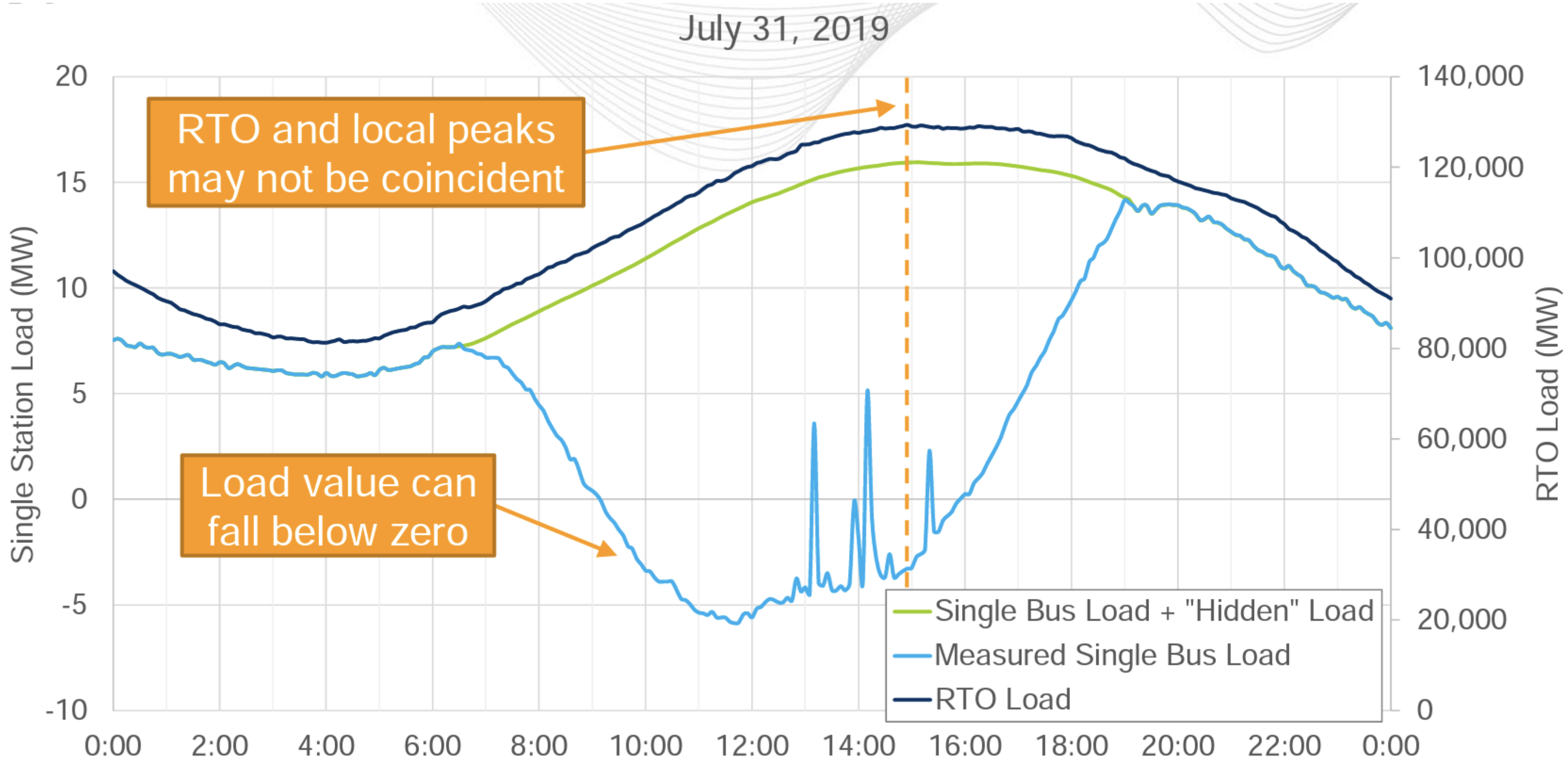
- Physically located behind a utility meter
- Does not participate in PJM wholesale markets
- Does not enter the PJM New Services queue



Need BTM Data

Need Nodal Information

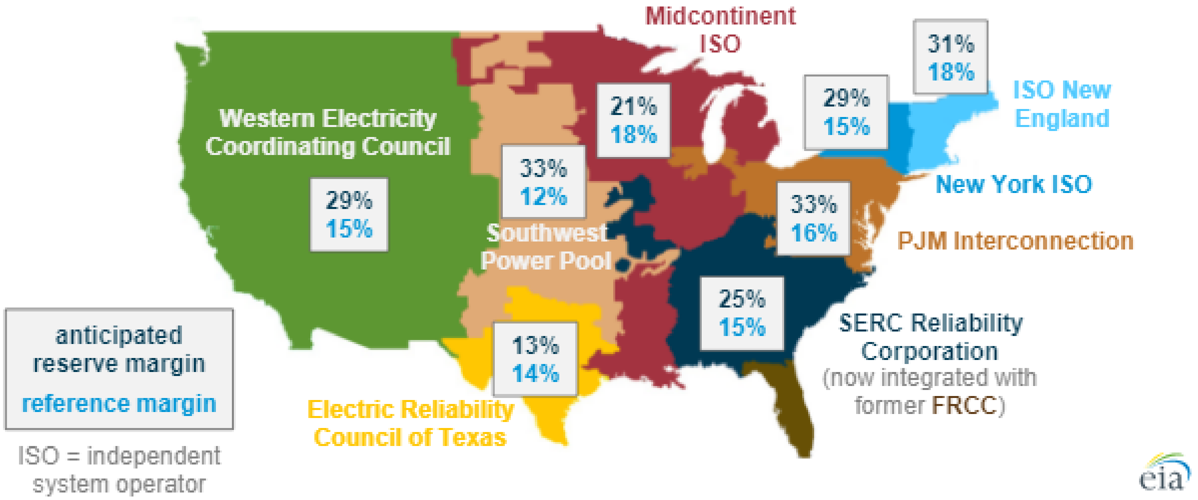
- Nodal vs Zonal
- Overgeneration
- Lack of Situational Awareness

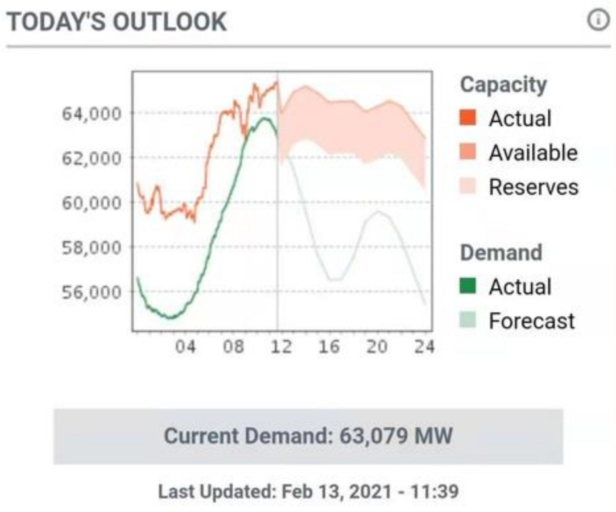


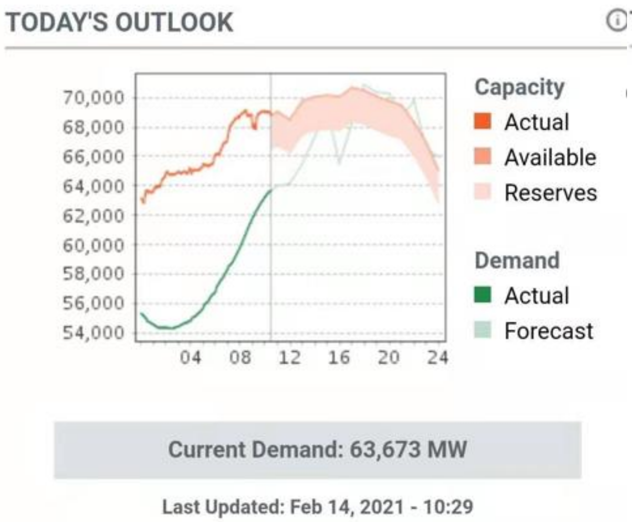
Learning from 2021 Texas Blackouts

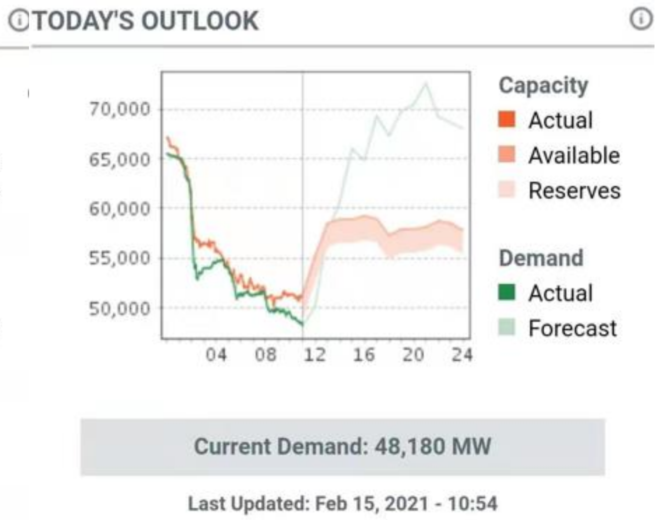
- In June, PJM issued an extreme hot weather alert, and prepared for historically high load + reserves
- Outages in Ohio for 3 days, why?

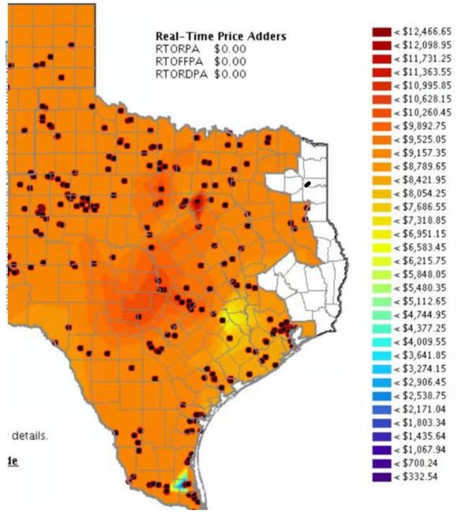
Summer 2020 reference margins and anticipated reserve margins in select NERC regions





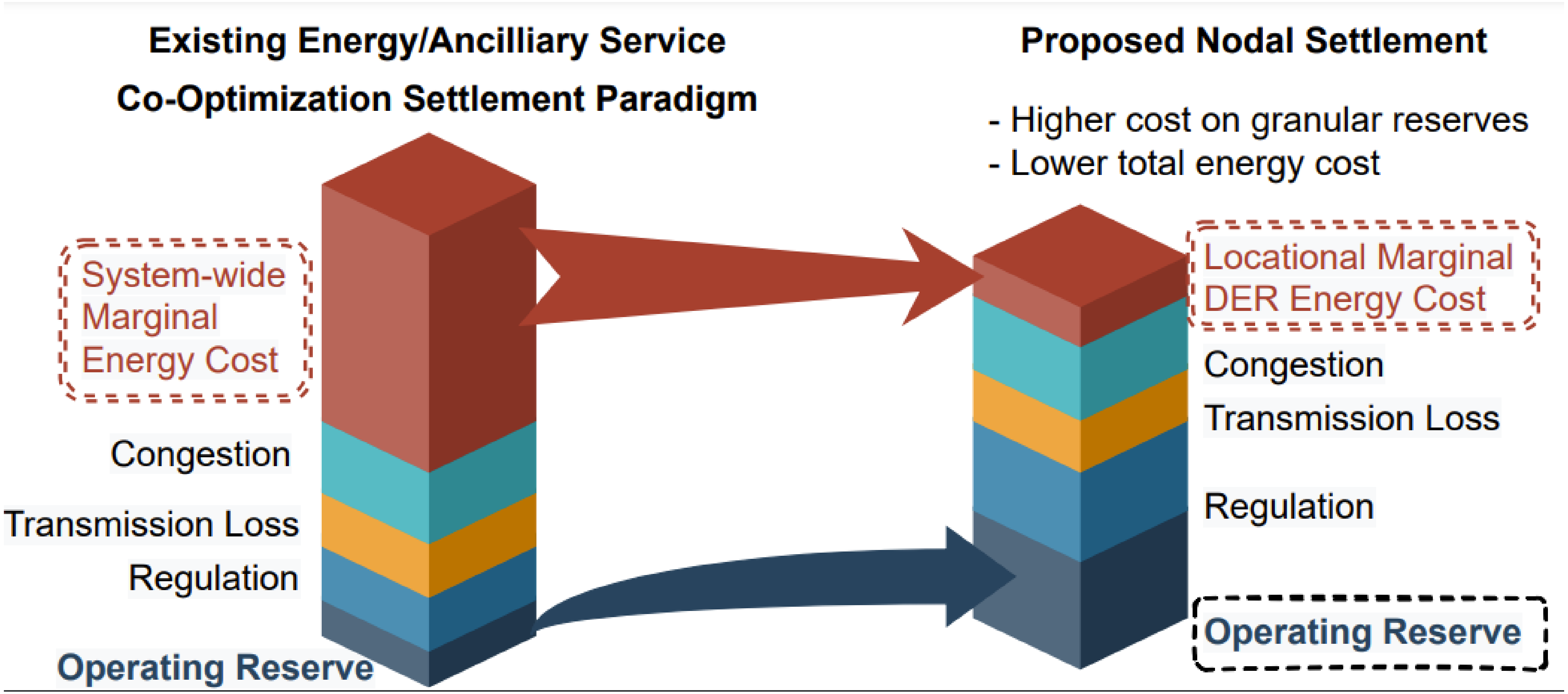




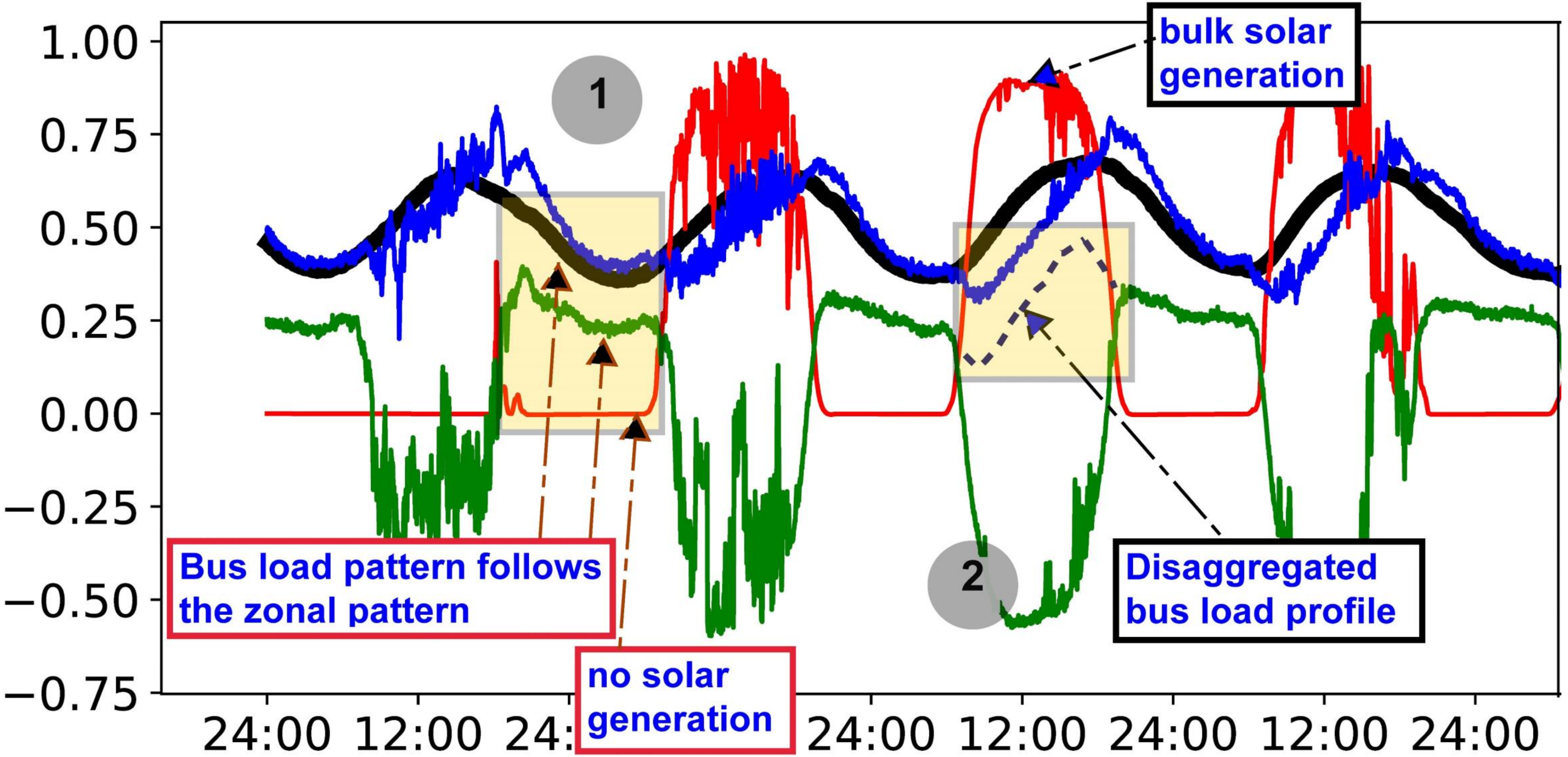


My Provision on Future Energy Cost

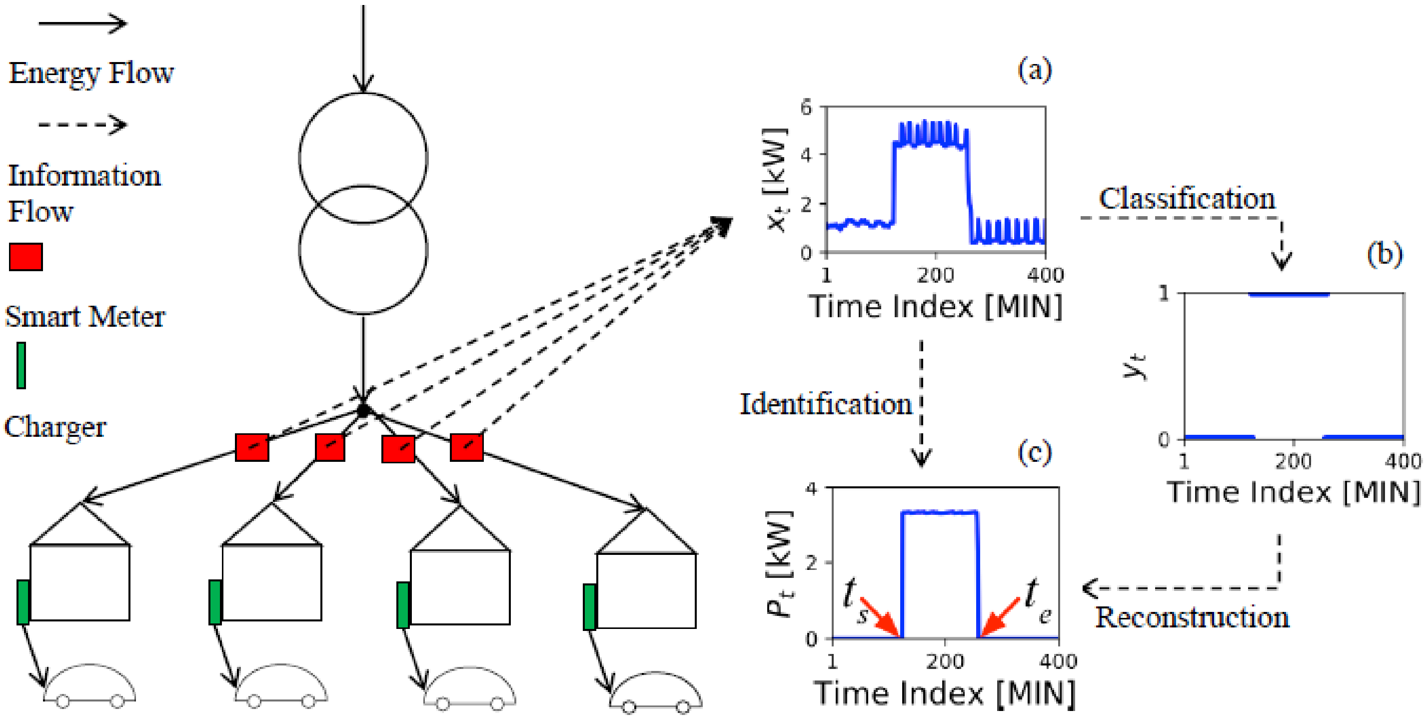
Ancillary Services Needed to be Redesigned

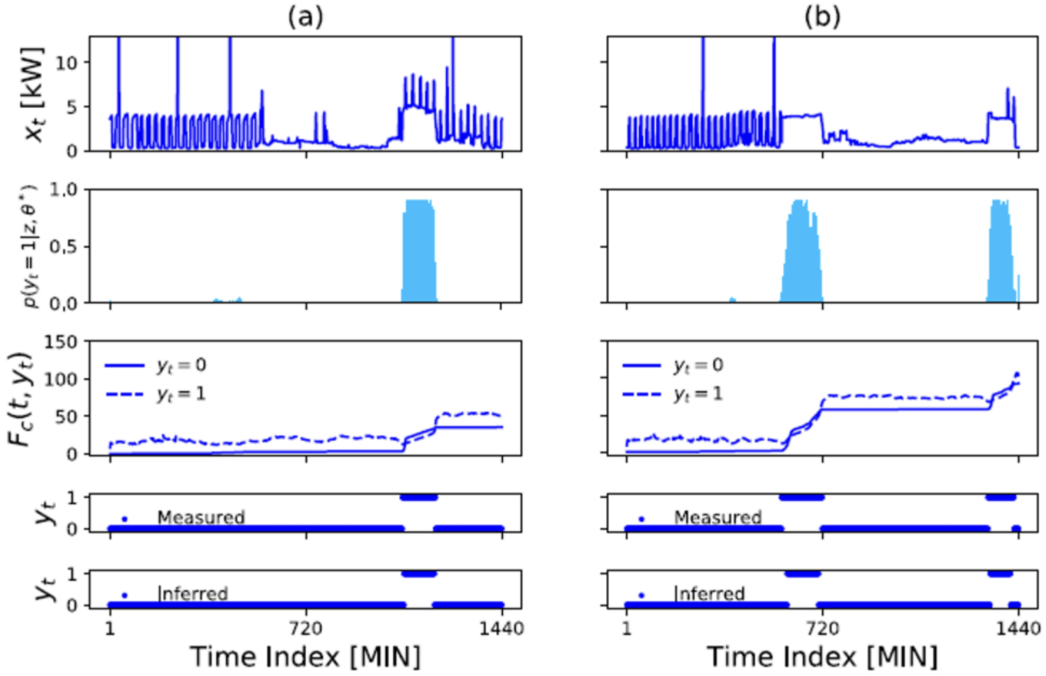


Nodal Profile Disaggregation



Load Disaggregation: Smart Meter





Bottom-up: Household Energy Profiles

Communities with electricity-dependent, at-risk individuals

- We are investing for BTM solar + storage
- How to determine which communities are of more needs?
- How to ensure energy equity in an unbiased manner?

We can try purely data-driven methods, for example:

- Existence and type of household electricity-powered medical devices
- Electric heating & cooling usage profiles during winter storms or heat waves
- For example, if an AC unit is OFF during heat waves, this household may need support

Disclaimer

Sources of Figures

- US Energy Information Administration
- PJM Interconnection website
- NERC
- Google

Thank You!

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Advancing Equity through Technical Assistance Programs

Kendall Parker, PhD
Pacific Northwest National Laboratory

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What is Technical Assistance (TA)?

TA is "non-financial assistance meant to impart information, skills, and expertise from one person or entity to others".[1]

Examples of Community Technical Assistance for Energy Projects

- Co-development of projects with communities' goals, plans, needs
- Conducting observational studies to understand community conditions and energy needs
- Identifying solutions, technologies, partners, or funding
- Assessing community energy needs to determine achievable goals
- Analyzing the feasibility and impacts of technology options

[1] Lyons, J., Dunleavy Hoag, S., Orfield, C., & Streeter, S. (2016). Designing Technical-Assistance Programs: Considerations for Funders and Lessons Learned. The Foundation Review, 8(5).

New Thinking in Technical Assistance

Emerging TA priorities focus on shifting power and promoting system change.

TA is shaped by:

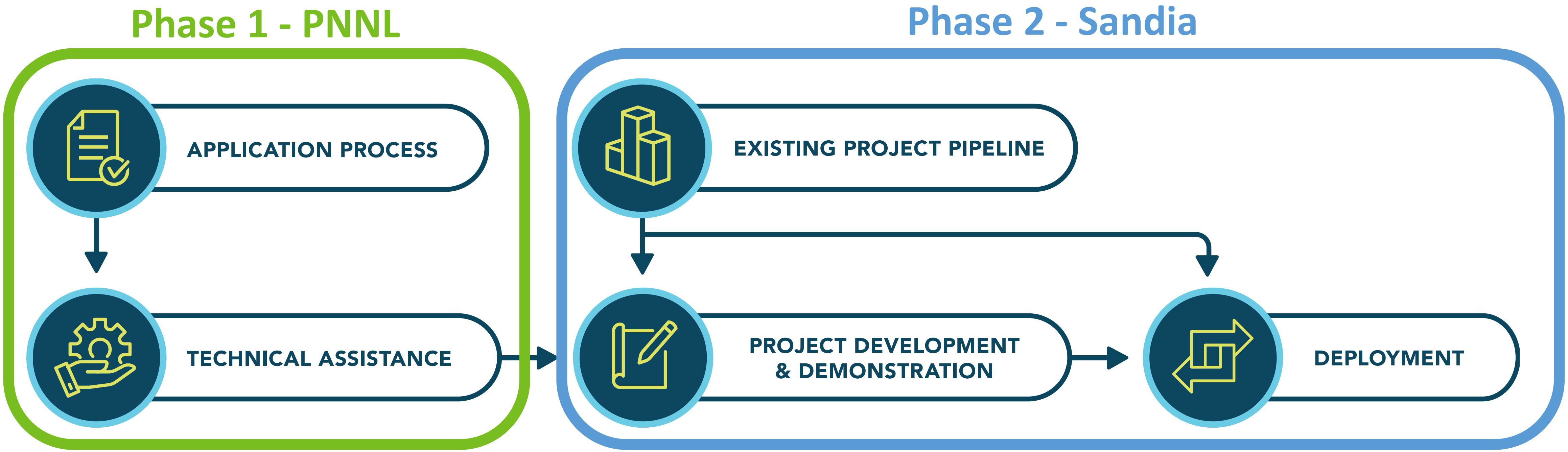
- Program Priorities
- Project Types
- Participant Preferences
- Available TA Formats
- Participant goals, plans, and needs

Emerging TA Priorities:

- Resilience to Climate Change
- Project Autonomy
- Advancing Equity
- Workforce Development
- Long-term Capacity Building

Example: Energy Storage for Social Equity (ES4SE) Initiative

ES4SE supports disadvantaged communities affected by unreliable and expensive energy systems through technical assistance.

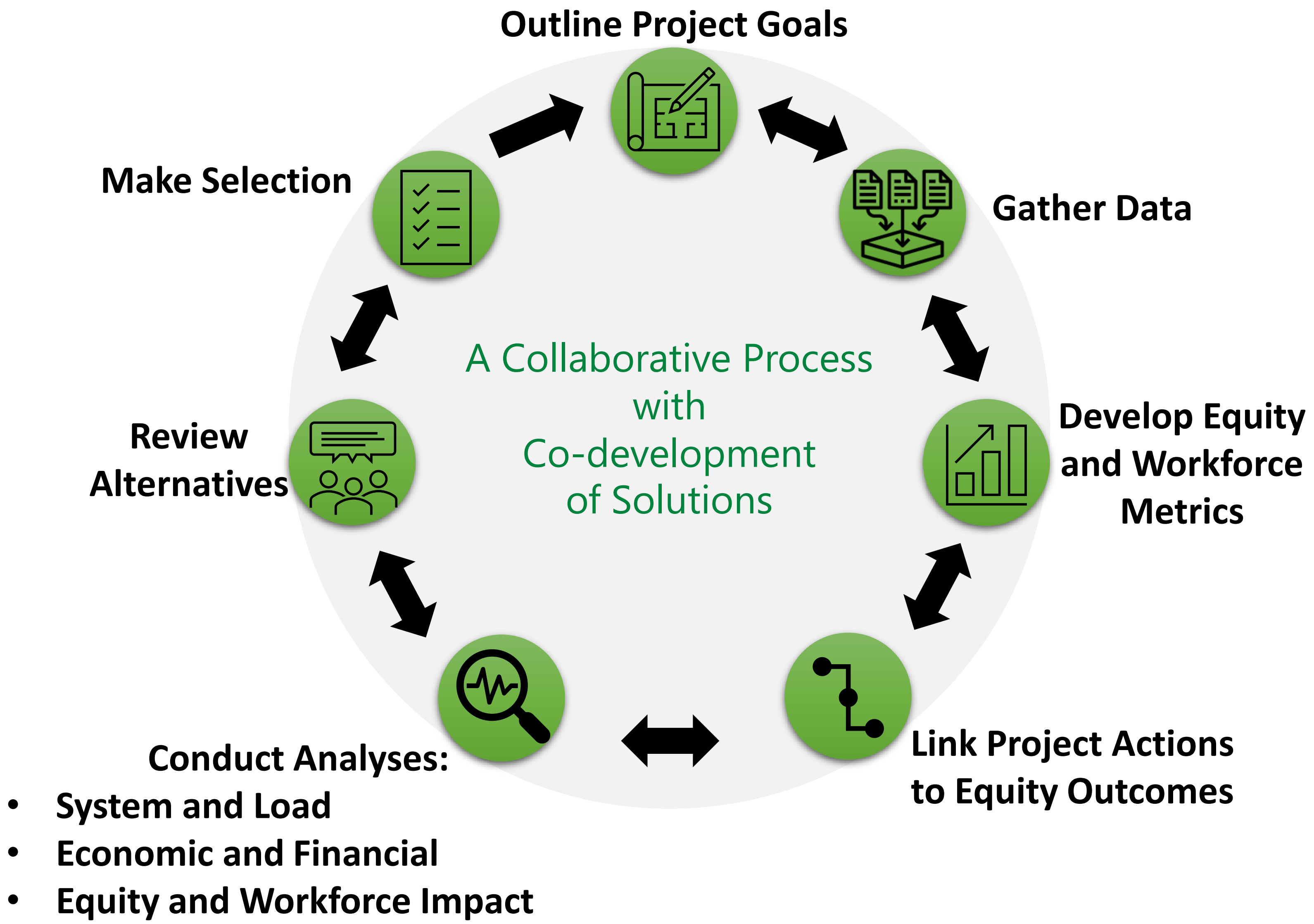


Advancing Energy Equity through ES4SE

Energy Inequities
Energy Burden Percent of income spent to cover energy cost.
Energy Insecurity The inability to meet basic household energy needs.
Energy Poverty A lack of access to basic, life-sustaining energy.
Energy Vulnerability The propensity of a household to suffer from a lack of adequate energy services in the home.

How Energy Storage Fits
Curb demand charges
Reduce affordable housing energy cost
Maintain operation in facilities critical to public health and safety
Reduce utility disconnection
Support grid reliability and resilience (backup power)
Intentional siting in underserved communities
Serve remote communities
Support energy independence
Generate community wealth

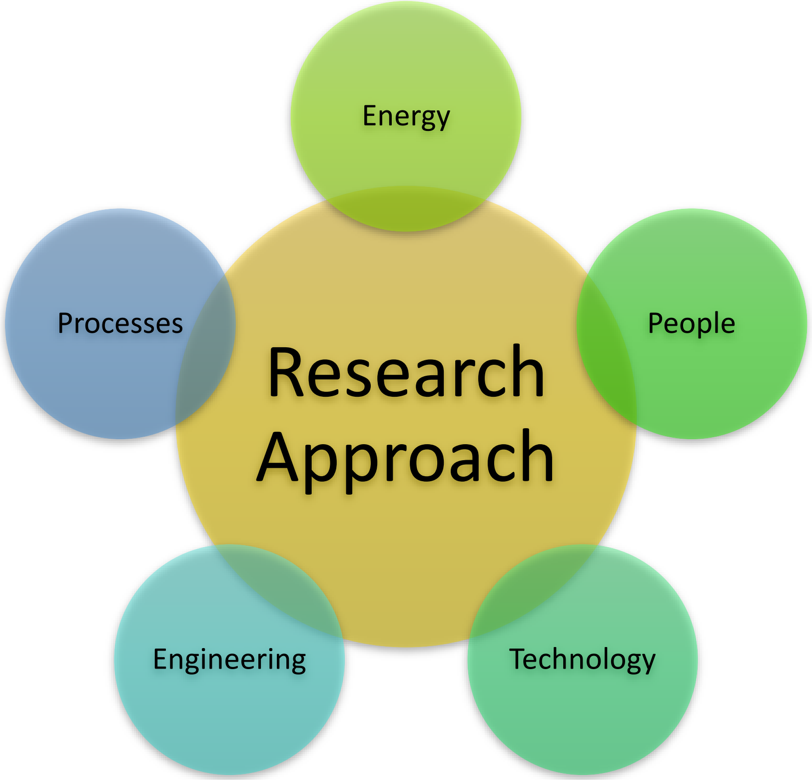
Technical Assistance for an ES4SE Community



- The TA process is iterative, with each step led by community feedback
- Workshops occur throughout TA to improve community knowledge and encourage informed decision-making

Data-Enriched Approaches for Energy Equity

Quantitative and qualitative data are informative, but meaningful relationships are key to successful project outcomes.



EQUITY emerges as a theme and objective because

1. We want people to participate in their energy decision making
2. We want energy system impacts distributed evenly

Example approach to advance energy equity:

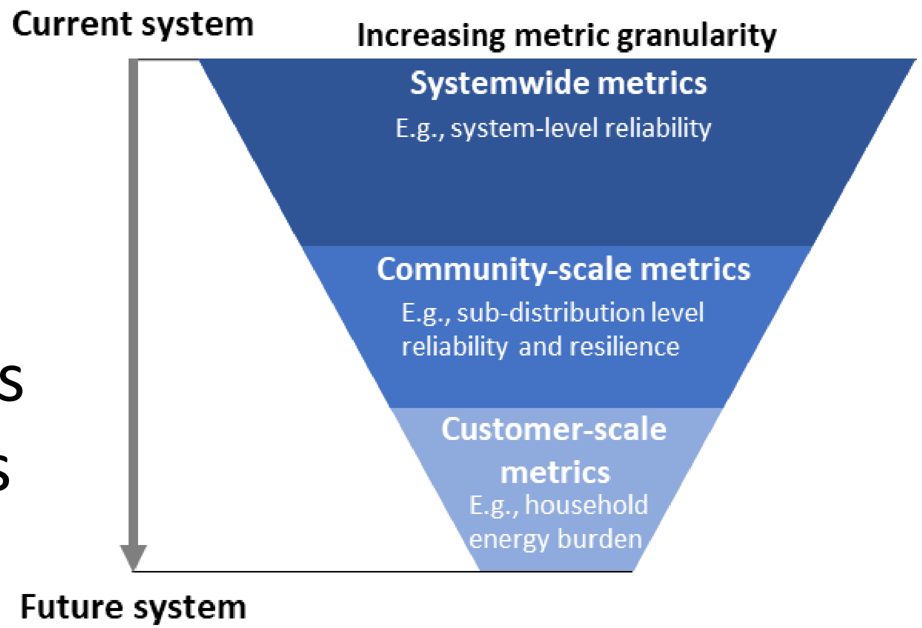
TECHNICAL ASSISTANCE

Data Needs for Energy Equity Metrics

TA is an opportunity to pursue new approaches in developing and managing energy equity metrics.

Focus of new approaches

- Increase development pathways with multi-stakeholder and community collaboration
- Compliment the usual performance metrics with lived experiences and tracking metrics
- Consider more granular data *(figure)*



Parker, K.M., Barlow, J., Eisdorfer, J. *et al.* Observations of an Evolving Grid: Resilience and Equity Performance Metrics. *Curr Sustainable Renewable Energy Rep* (2023). https://doi.org/10.1007/s40518-023-00227-0

The Impact of Technical Assistance

Data-enriched TA is at the intersection of community challenges and collaborated solutions.

Community Challenge
- Example Solution
- Example Solution

Resilience
- Create resilience hubs
- Power critical infrastructure

Energy Burden
- Reduce pass-through costs and free up cash flow
- Promote affordable housing

Energy Access
- Pilot for residential electrification
- Support uninterrupted business operations

Decarbonization & Environmental Impact
- Replace fossil fuel generators and wood stoves
- Air quality improvements and environmental values

Social Impact
- Support intergenerational engagement & education
- Inspirational aspect

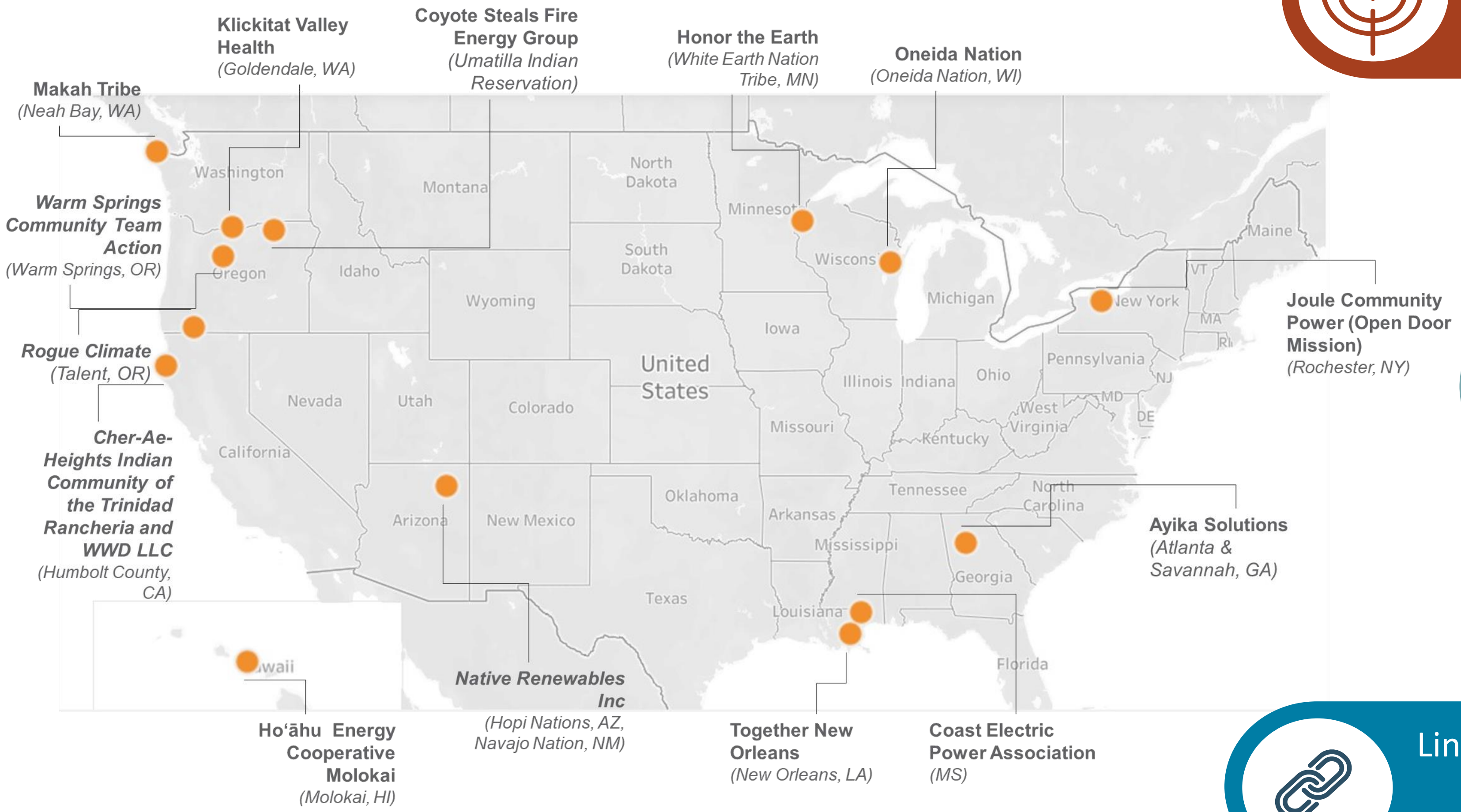
Workforce
- Build local capacity & partnerships for training programs
- Revisiting contract mechanisms for design & development

Energy Independence
- A step towards energy sovereignty
- Places decision-making authority with those affected

Thank you!

kendall.parker@pnnl.gov

Features of the Energy Storage for Social Equity Initiative



Easy Access and Targeted Outreach

Workforce and equity are part of TA

Community of Communities

Direct connection to future project funding

Linking Grid and Community Resilience

Working Definition of Energy Equity

Energy equity is defined as the ability of the energy system to:

https://www.pnnl.gov/projects/energy-equity

- **Fairly distribute the benefits and burdens** of the clean energy transition
- Guarantee that energy **decision-making procedures are fair**
- Guarantee stakeholders have **access to information and participation in energy decision-making**

This definition implies we **recognize there are communities that have been historically harmed** by disproportionately high and adverse human health or environmental effects in the energy system.

Invited Panelists

Prof. Liang Du (Temple Univ.)

Dr. Kendall Parker (PNNL)

Prof. Marcel J. Castro-Sitiriche (UPRM)

How Data Can Support Grid Operations: From Distribution to Transmission, to Energy Equity

Advancing Equity through Technical Assistance Programs

Boricua Energy Equity

IEEE PES Power & Energy Society® | IEEE

Boricua Energy Equity

Panel: Data-enriched Grid Modeling of End-user Profiles, Energy Equity, and Situational Preparedness
7 / November / 2023

Marcel Castro-Sitiriche
University of Puerto Rico Mayagüez

IEEE PES Innovative Smart Grid Technologies Latin America 2023
“Disaster recovery and network transformation in times of climate change”
ISGT-LA 2023, in San Juan, Puerto Rico

CLEAN ENERGY

Transition to Clean Energy

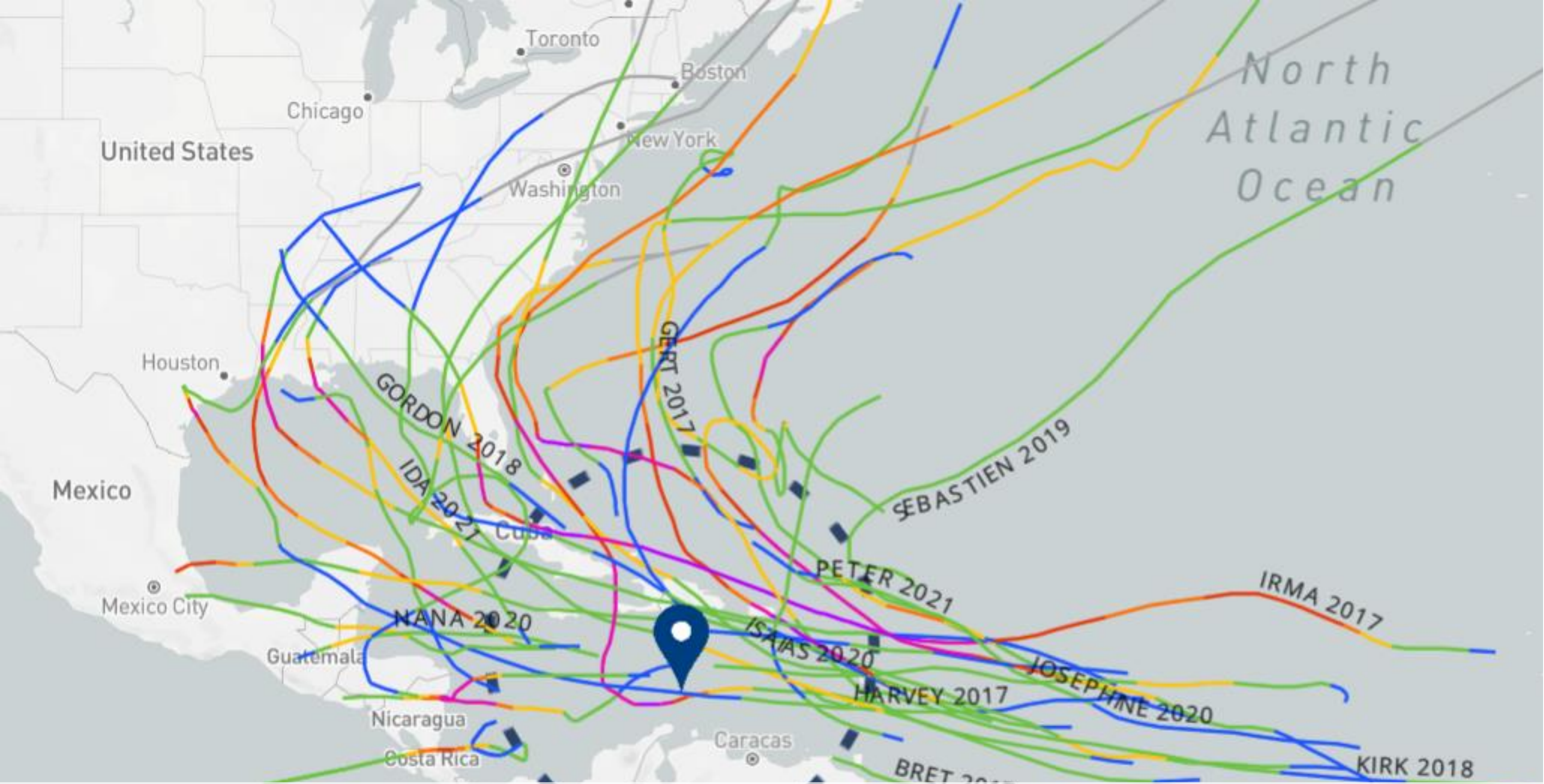
Energy clean from carbon emissions, but also

- Clean from Corruption
- Clean from Colonialism
- Clean from Oppression
- Clean from Imperialism

Marcel Castro-Sitiriche, "Resilience Energy Justice: Boricua Power and Equity", Plenary Session, *IEEE-WEA*, Cartagena, Colombia, November 2, 2023.

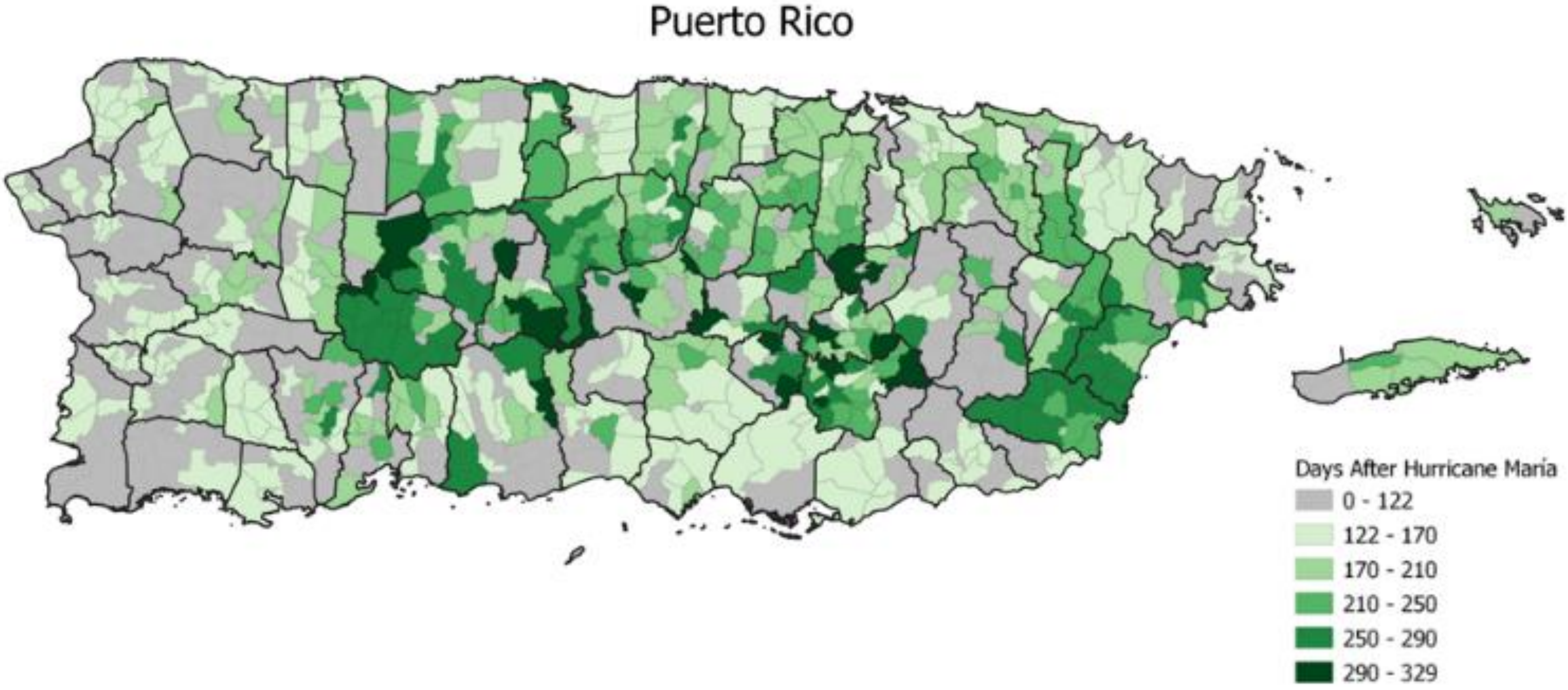
Hurricane María

Longest Power Outage in History



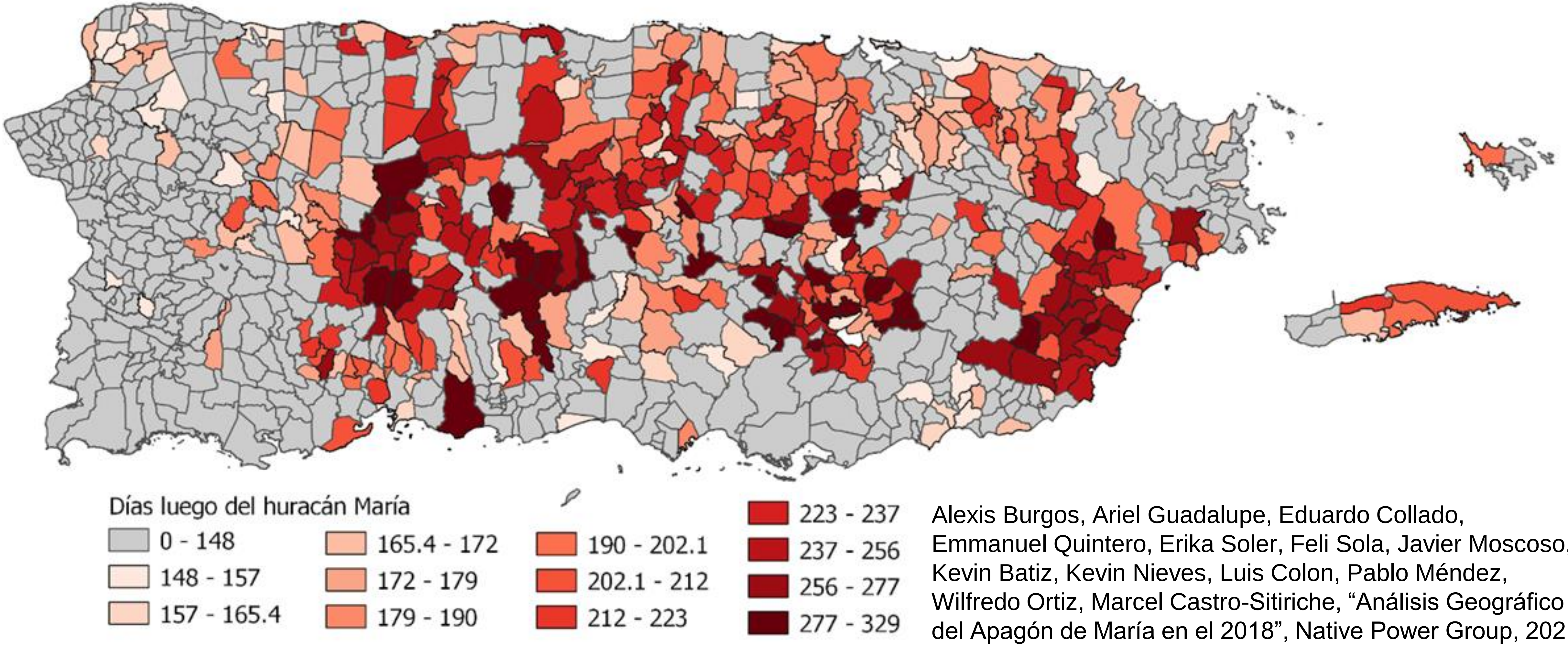
Marcel J. Castro-Sitiriche, Caribbean Region, Resilient Power and Energy Justice: The Case of Puerto Rico, Global Energy Access Innovation Workshop: IEEE Power Africa Conference, August 22, 2022, Kigali, Rwanda

Electricity Service Restoration After Hurricane María



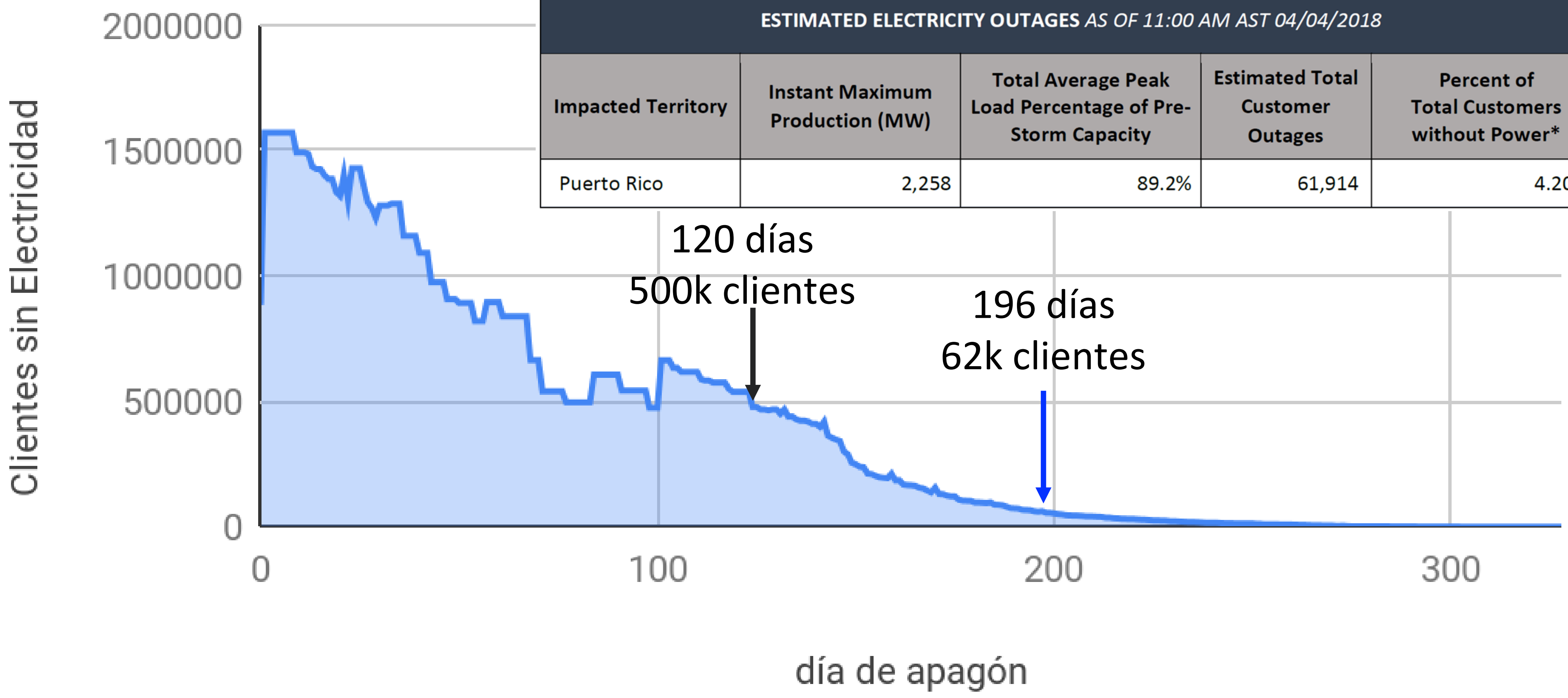
Javier Moscoso, Pablo Méndez, Willian Pacheco, Carlos Peña, Alexis Burgos, Miguel de Jesús, Marcel Castro-Sitiriche, “Boricua Energy Justice as a Humanitarian Claim”, *International Humanitarian Technologies Conference (IHTC) 2023*, Cartagena, Colombia, November 2, 2023.

Comunidades con hogares que se reconectaron a la AEE desde febrero hasta agosto 2018



Alexis Burgos, Ariel Guadalupe, Eduardo Collado, Emmanuel Quintero, Erika Soler, Feli Sola, Javier Moscoso, Kevin Batiz, Kevin Nieves, Luis Colon, Pablo Méndez, Wilfredo Ortiz, Marcel Castro-Sitiriche, “Análisis Geográfico del Apagón de María en el 2018”, Native Power Group, 2021

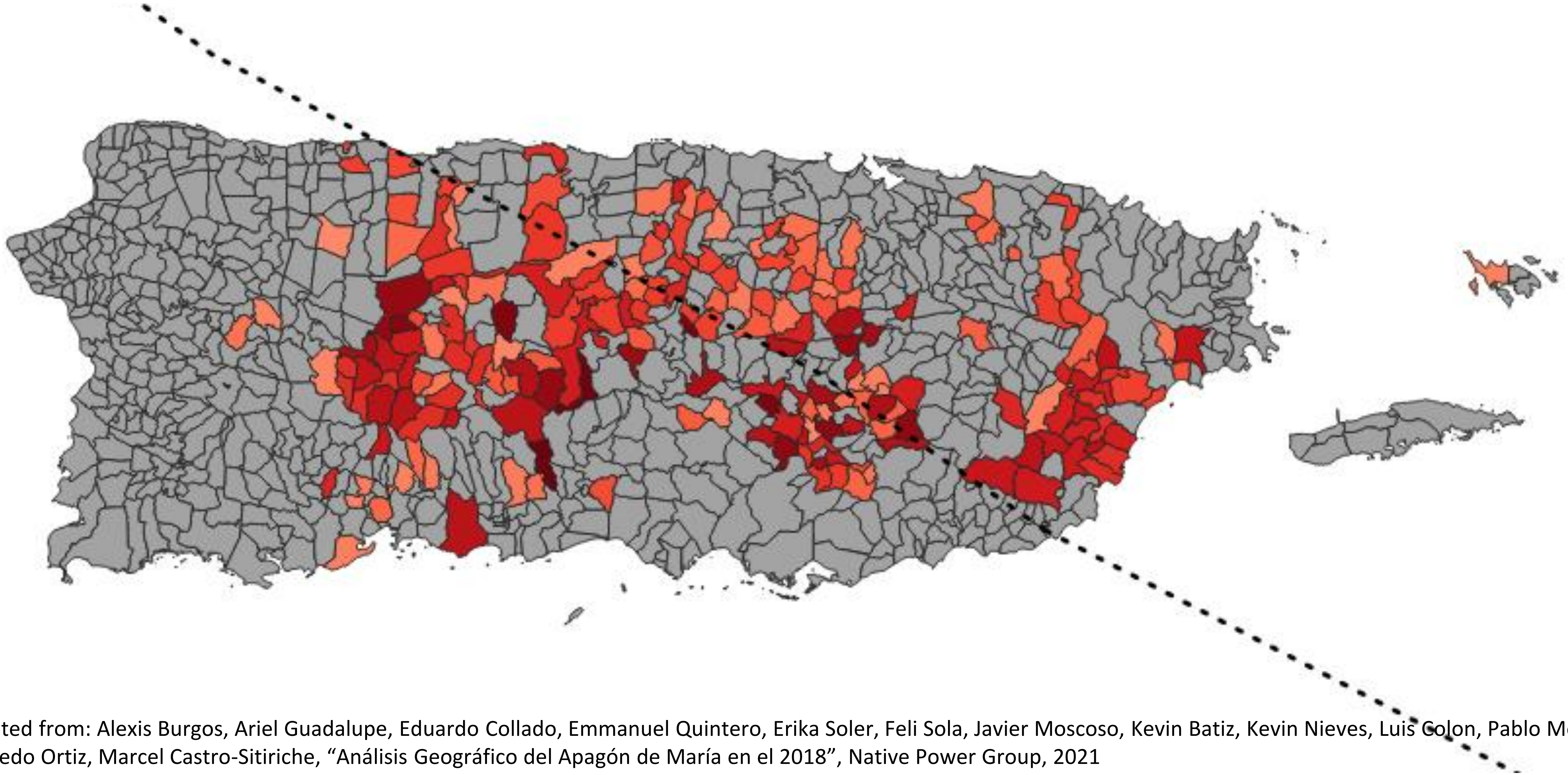
Clientes sin Electricidad: septiembre 2017 - agosto 2018



ESTIMATED ELECTRICITY OUTAGES *AS OF 11:00 AM AST 04/04/2018*				
Impacted Territory	**Instant Maximum Production (MW)**	**Total Average Peak Load Percentage of Pre-Storm Capacity**	**Estimated Total Customer Outages**	**Percent of Total Customers without Power***
Puerto Rico	2,258	89.2%	61,914	4.20%

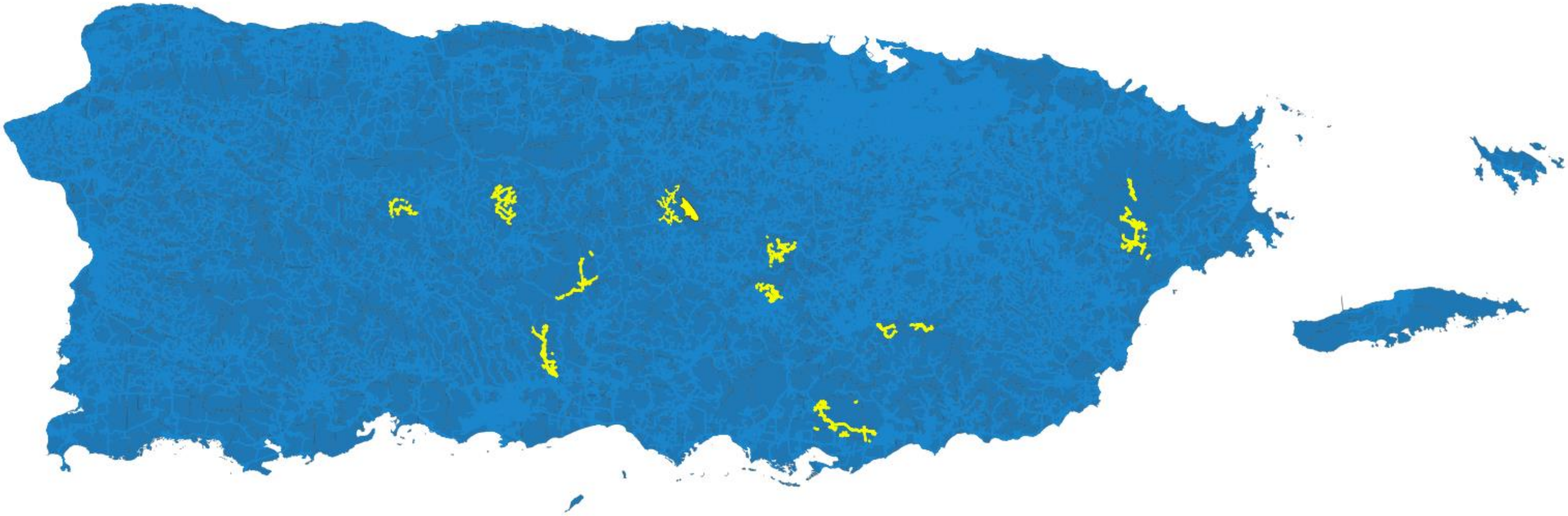
M. Castro-Sitiriche, "Boricua Energy Justice", **Infrastructure as Destiny: Resilience, Innovation and Equity**, AEG Thought Summit 2022, February 23, 2022.
Source: https://www.energy.gov/ceser/articles/hurricanes-nate-maria-irma-and-harvey-situation-reports

Comunidades con hogares que se reconectaron a la AEE desde abril hasta agosto 2018: 62,000 familias



Adapted from: Alexis Burgos, Ariel Guadalupe, Eduardo Collado, Emmanuel Quintero, Erika Soler, Feli Sola, Javier Moscoso, Kevin Batiz, Kevin Nieves, Luis Colon, Pablo Méndez, Wilfredo Ortiz, Marcel Castro-Sitiriche, “Análisis Geográfico del Apagón de María en el 2018”, Native Power Group, 2021

Alimentadores sin electricidad: 316+ días



Marcel J. Castro-Sitiriche, “Boricua Energy Equity”, Panel on Data-enriched Grid Modeling of End-user Profiles, Energy Equity, and Situational Preparedness, *IEEE-ISGT*, San Juan Puerto Rico, November 7, 2023

Oasis de Luz

Bottom-up Microgrids for Puerto Rico

Justicia Energética: Colaboración Oasis de Luz

Jayuya
noviembre, 2017

marcel.castro@upr.edu

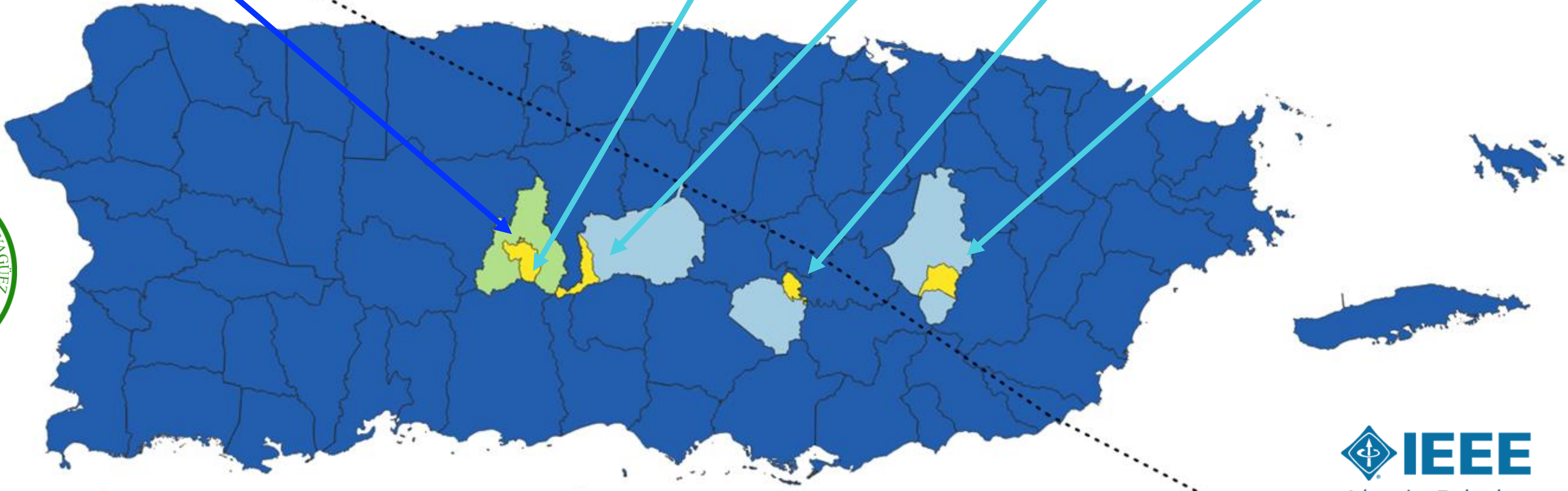

Oasis de Luz
RECINTO UNIVERSITARIO DE MAYAGÜEZ
UNIVERSIDAD DE PUERTO RICO
Jayuya
Febrero, 2018
marcel.castro@upr.edu

Oasis de Luz para La Montaña

November 2017: Jayuya Pueblo

2018:

Jayuya, Orocovis, Aibonito, Caguas



Borintek Inc. Engineering Solutions

WPS WEST POWER SOLUTIONS

Finca Alzamora

INESI INSTITUTO NACIONAL DE ENERGÍA Y SOSTENIBILIDAD ISLEÑA UNIVERSIDAD DE PUERTO RICO

IEEE Advancing Technology for Humanity

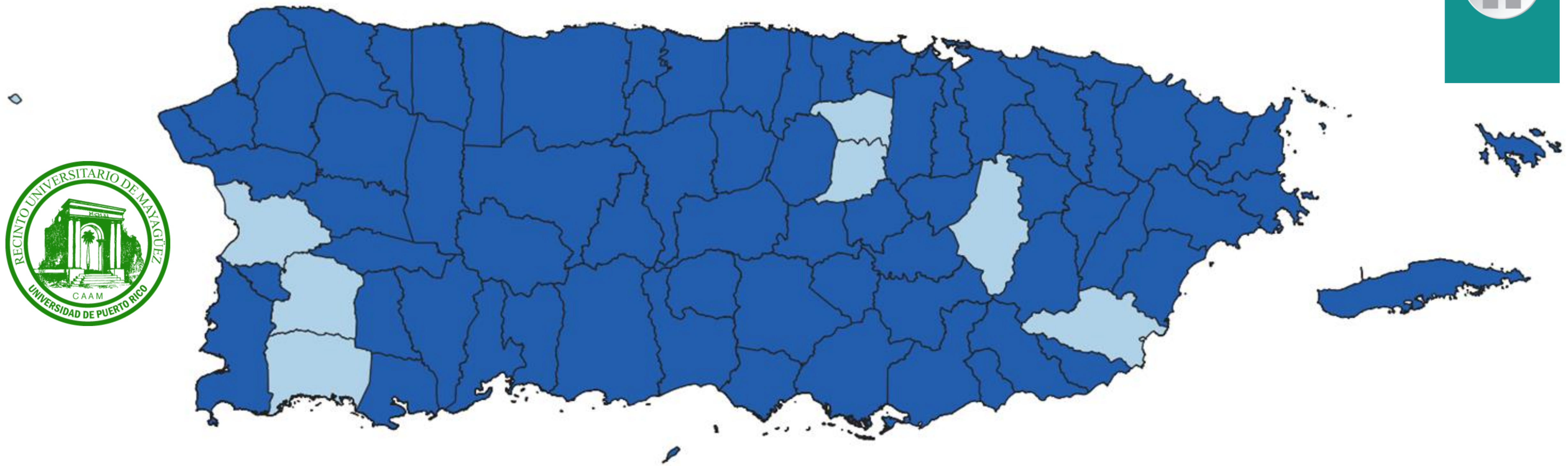
Efraín O'Neill y estudiantes de UPRM
Barrio Borinquen, Caguas
Marzo, 2018

Veguita Zamas, Jayuya
Mayo, 2018
Foto: marcel

UPRM Power Group: 2018-2022 Peer-reviewed Publications related to Hurricane María

1. **E. O'Neill-Carrillo**, Miguel A. Rivera-Quiñones. "Energy Policies in Puerto Rico and their Impact on the Likelihood of a Resilient and Sustainable Electric Power Infrastructure," *CENTRO*, Journal of the Center for Puerto Rican Studies, Hunter College, no. 3, vol. 30, 2018
2. **A. Irizarry-Rivera**, K. Montano-Martinez, S. I. Alzate-Drada and **F. Andrade,** "A case study of residential electric service resiliency through renewable energy following Hurricane Maria," *Mediterranean Conference on Power Generation, Transmission, Distribution and Energy Conversion (MEDPOWER 2018)*, Dubrovnik, Croatia, 2018, pp. 1-6.
3. R. Darbali-Zamora, J. E. Quiroz, J. Hernández-Alvidrez, J. Johnson and **E. I. Ortiz-Rivera**, "Viability Assessment of a Real-Time Simulation Model for a Residential DC Microgrid Network to Compensate Electricity Disturbances in Puerto Rico," *2018 IEEE ANDESCON*, Santiago de Cali, Colombia, 2018, pp. 1-6.
4. G. Lopez-Cardalda, M. Lugo-Alvarez, S. Mendez-Santacruz, **E. O. Rivera and E. A. Bezares**, "Learnings of the Complete Power Grid Destruction in Puerto Rico by Hurricane Maria," *2018 IEEE International Symposium on Technologies for Homeland Security (HST)*, Woburn, MA, 2018, pp. 1-6.
5. **Castro-Sitiriche, M**., J. Gomez, Y. Cintrón, "The Longest Power Blackout in History and Energy Poverty", *International Conference on Appropriate Technology 2018*, Porto-Novo, Benin, November 2018.
6. E. O'Neill-Carrillo, I. Jordán, A. Irizarry-Rivera, R. A. Cintrón. "The Long Road to Community Microgrids," *IEEE Electrification Magazine*, vol. 6, no. 4, December 2018, pp. 6 – 17.
7. A. Kwasinski, **F. Andrade, M. J. Castro-Sitiriche and E. O'Neill-Carrillo**, "Hurricane Maria Effects on Puerto Rico Electric Power Infrastructure," in *IEEE Power and Energy Technology Systems Journal*, vol. 6, no. 1, pp. 85-94, March 2019.
8. **E. O'Neill-Carrillo,** J. McCalley, A. Kimber, R. Haug. "Stakeholder Perspectives on Increasing Electric Power Infrastructure Integrity." *ASEE Annual Conference*, June 2019, Tampa.
9. C. J. Newlun, A. L. Figueroa-Acevedo, J. D. McCalley, A. Kimber and **E. O'Neill - Carrillo**, "Co-Optimized Expansion Planning to Enhance Electrical System Resilience in Puerto Rico," *2019 North American Power Symposium (NAPS)*, Wichita, KS, USA, 2019, pp. 1-6.
10. **E. O'Neill-Carrillo**, E. Mercado, O. Luhring, I. Jordan and **A. Irizarry-Rivera**, "Community Energy Projects in the Caribbean: Advancing Socio-Economic Development and Energy Transitions," *IEEE Technology and Society Magazine*, vol. 38, no. 3, pp. 44-55, Sept. 2019.
11. Chen, S.E., Tang, W., **Irizarry, A.A.**, Baez-Rivera, Y., Pando, M.A., Majrekar, M., Young, D. and Ng, Y., "Posthurricane Investigation of a Critical Component toward Improved Grid Resiliency in Puerto Rico." *Journal of Performance of Constructed Facilities* 34.4 (2020): 02520001.
12. E. Parés-Atiles, **E. O'Neill-Carrillo and F. Andrade**, "Best Practices for Microgrids Applied to a Case Study in a Community," *2020 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT)*, Washington, DC, USA, 2020, pp. 1-5.
13. M. Lugo-Alvarez, R. Broderick and **E. I. Ortiz-Rivera**, "Strategic Placement and Design of Microgrids using Nighttime Imagery," *2020 47th IEEE Photovoltaic Specialists Conference (PVSC)*, Calgary, AB, Canada, 2020, pp. 1730-1734.
14. C. J. Newlun, F. M. Currie, **E. O'Neill-Carrillo, E. A. Bezares** and R. H. Byrne, "Energy Resource Planning for Puerto Rico's Future Electrical System," *2020 IEEE/PES Transmission and Distribution Conference and Exposition (T&D)*, Chicago, IL, USA, 2020, pp. 1-5.
15. G. Lopez-Cardalda, **E. Ortiz-Rivera** and M. Lugaro-Alvarez, "Evaluation and Load Selection using Energy Storage System Priority Index (ESSPI)," *2020 IEEE International Symposium on Technology and Society (ISTAS)*, Tempe, AZ, USA, 2020, pp. 225-229.
16. F. Saker, G. Lopez, J. Pacheco, **E. Ortiz-Rivera and E. Aponte**, "Design of a Microgrid for Rural Community in Puerto Rico," *2021 IEEE 48th Photovoltaic Specialists Conference (PVSC)*, Fort Lauderdale, FL, USA, 2021, pp. 1758-1761.
17. G. Lopez-Cardalda and **E. I. Ortiz-Rivera**, "Proposed Methodology Using the Energy Storage System Prioritization Index," *2021 IEEE 48th Photovoltaic Specialists Conference (PVSC)*, Fort Lauderdale, FL, USA, 2021, pp. 2529-2533.
18. Chen, S. E., Pando, M. A., **Irizarry, A. A.**, Baez-Rivera, Y., Tang, W., & Ng, Y., "Resiliency of Power Grid Infrastructure Under Extreme Hazards-Observations and Lessons Learned from Hurricane Maria in Puerto Rico." *Advanced Geotechnical and Structural Engineering in the Design and Performance of Sustainable Civil Infrastructures: Proceedings of the 6th GeoChina International Conference on Civil & Transportation Infrastructures: From Engineering to Smart & Green Life Cycle Solutions--Nanchang, China, 2021 6*. Springer International Publishing, 2021.
19. M. Vázquez Nieves, J. A. Moscoso Cabrera, F. Lozano-I, **E. I. Ortiz-Rivera**, R. Darbali-Zamora and C. Birk Jones, "Analysis of PV Microgrids with Storage to Improve the Resiliency of the Island of Culebra, Puerto Rico," *2022 Resilience Week (RWS)*, National Harbor, MD, USA, 2022, pp. 1-8.
20. M. F. Sandoval, J. Hernández, S. Grijalva, R. J. Broderick, **E. O'Neill-Carrillo.** *Optimal Portfolio Design of Distributed Energy Resources on Puerto Rico Distribution Feeders with Long Outages after Hurricane Maria*. SAND2022-11264. Sandia National Laboratories, Albuquerque, NM, August 2022.
21. Echevarria, Angel, Rivera-Matos, Yiamar, Irshad, Nafeesa, Gregory, Christopher, **Castro-Sitiriche, Marce**l, King, Richard R., and Miller, Clark A. "Unleashing Sociotechnical Imaginaries to Advance Just and Sustainable Energy Transitions: The Case of Solar Energy in Puerto Rico," in IEEE Transactions on Technology and Society, 2022, doi: 10.1109/TTS.2022.3191542.

UPRM Power Community Engagement:
Whole Community Resilience Planning



UPRM Team: Luisa Seijo from Social Sciences, Ricardo Fuentes from Economics, Lizzette González from Agricultural Science, Reinaldo Rosado from Social Sciences, Ingrid Rodríguez from Social Sciences, Francisco Maldonado from Civil Engineering, Marcel Castro-Sitiriche from Electrical and Computer Engineering, Whole Community Resilience Planning, CDBG-DR Funds through the Puerto Rico Department of Housing, 2022-2023.

Office of Energy Justice and Equity

DOE Awards Nearly $1 Million to Strengthen Community Energy Resilience for Puerto Rico

OCTOBER 17, 2023

UPRM Team: Luisa Seijo from Social Sciences, Ricardo Fuentes from Economics, Lizzette González from Agricultural Science, Reinaldo Rosado from Social Sciences, Ingrid Rodríguez from Social Sciences, Francisco Maldonado from Civil Engineering, Marcel Castro-Sitiriche from Electrical and Computer Engineering, Whole Community Resilience Planning, CDBG-DR Funds through the Puerto Rico Department of Housing, 2022-2023.

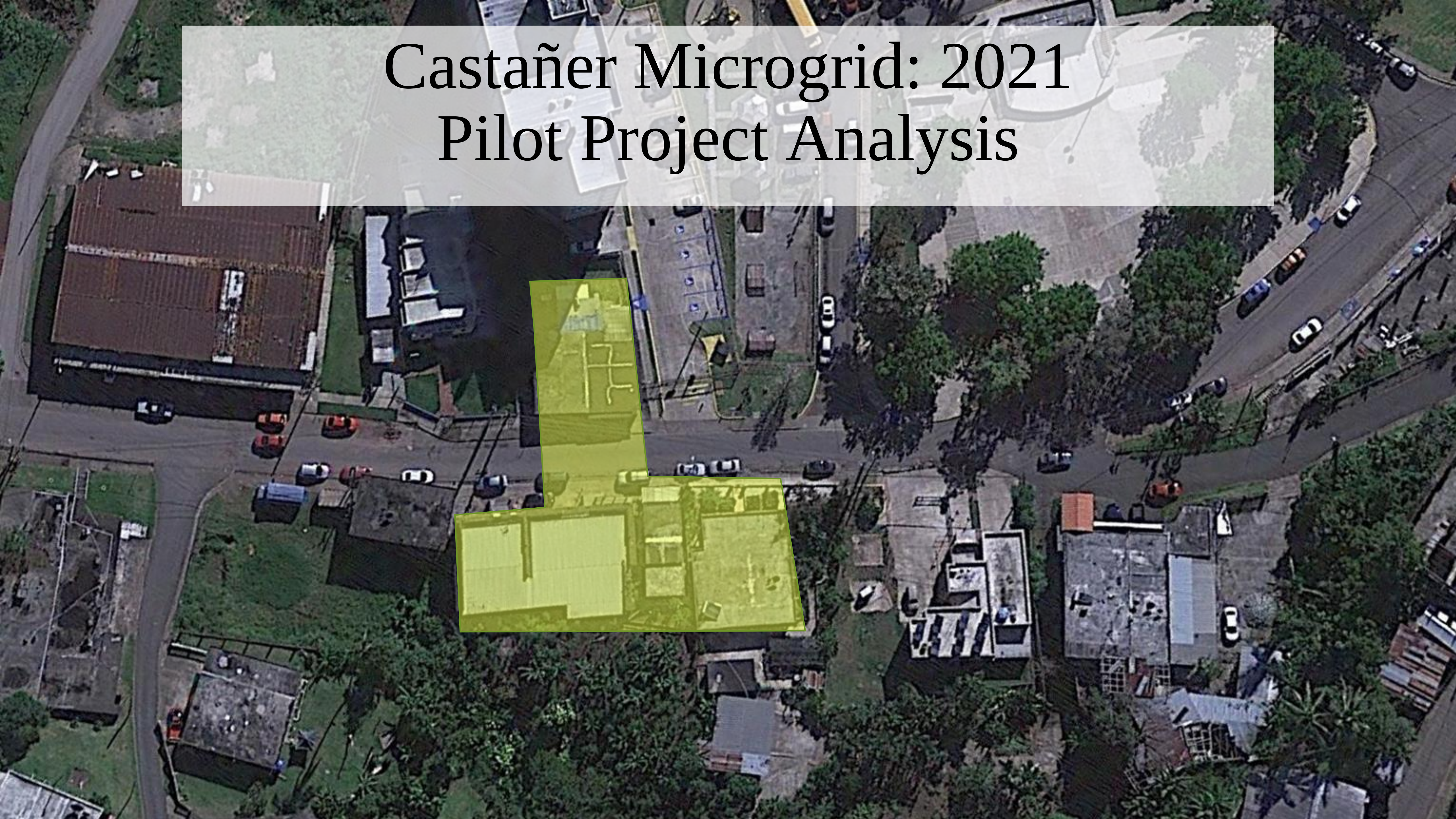
UPRM Power Community Engagement:

Community Microgrid Projects

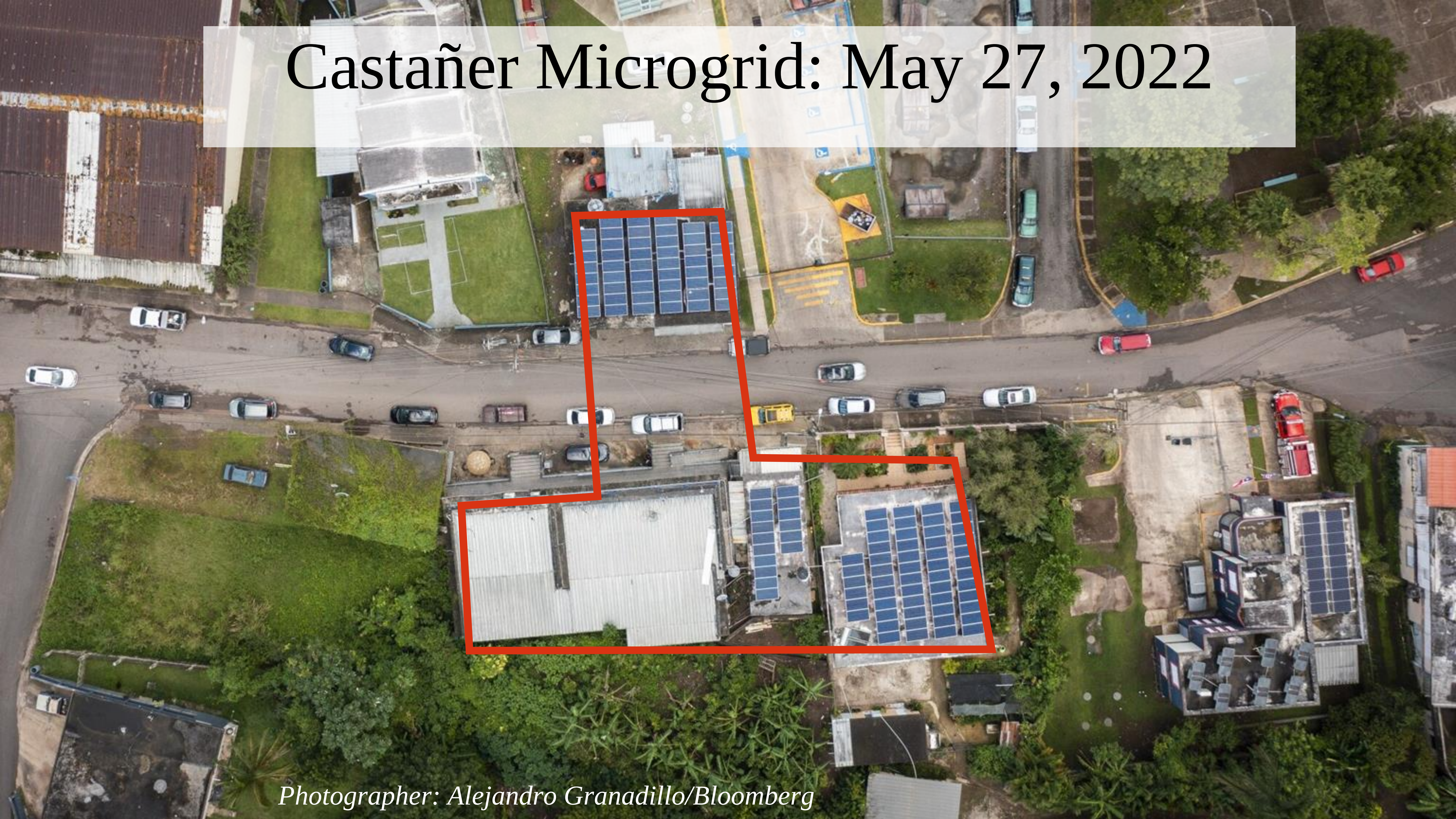
UPRM Team: Marcel Castro-Sitiriche, Agustín Irizarry, Fabio Andrade, Gerson Beauchamp from Electrical and Computer Engineering, Arturo Massol from Biology, Solar Business Accelerator Project, EDA Funds, 2019-2023 and Resilient Operation of Networked Community Microgrids with High Solar Penetration Project, DOE Funds, 2021-2024.


Castañer, Lares
Noviembre, 2020
Foto: marcel

Castañer Microgrid: 2021
Pilot Project Analysis



Castañer Microgrid: May 27, 2022

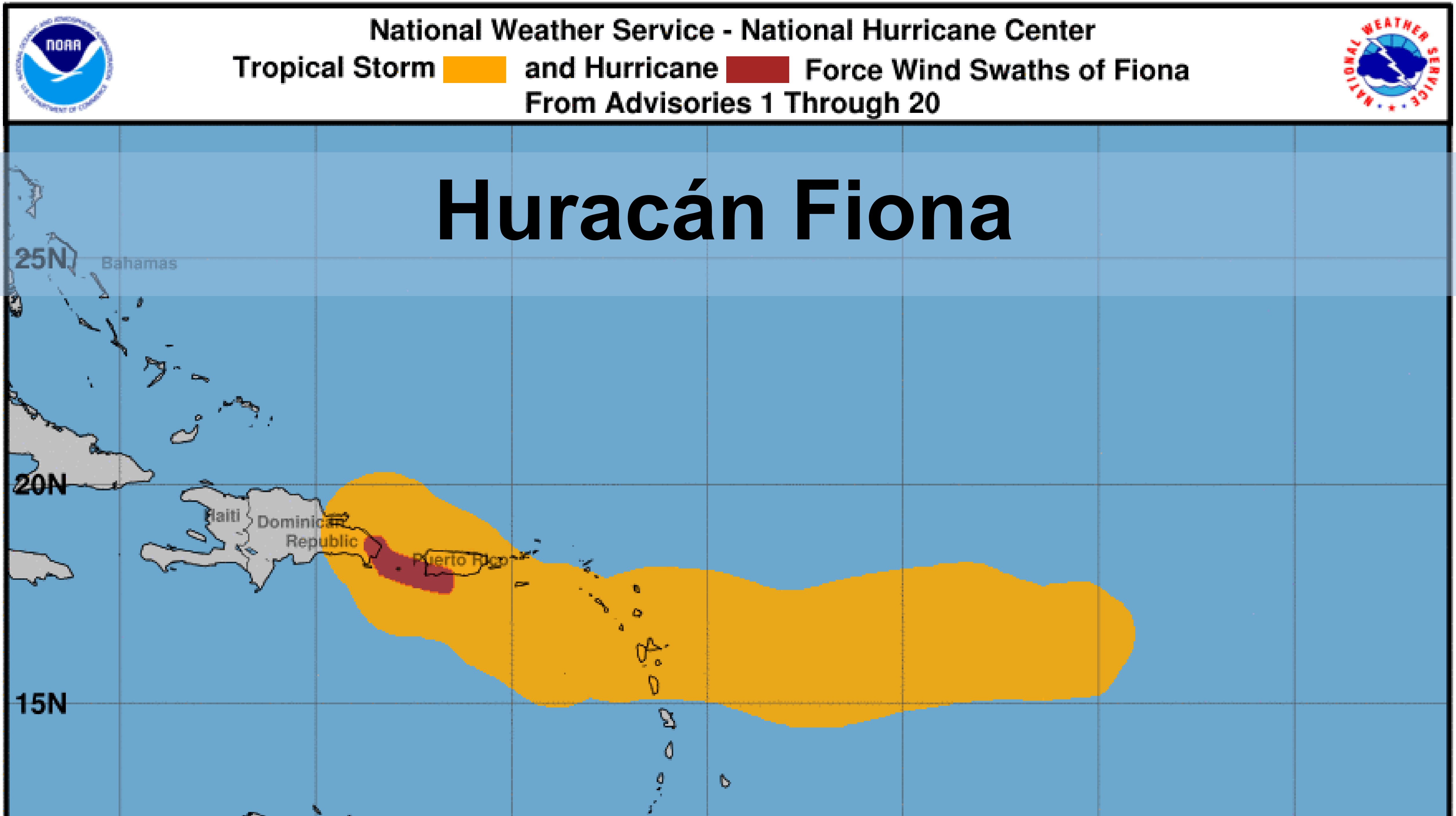


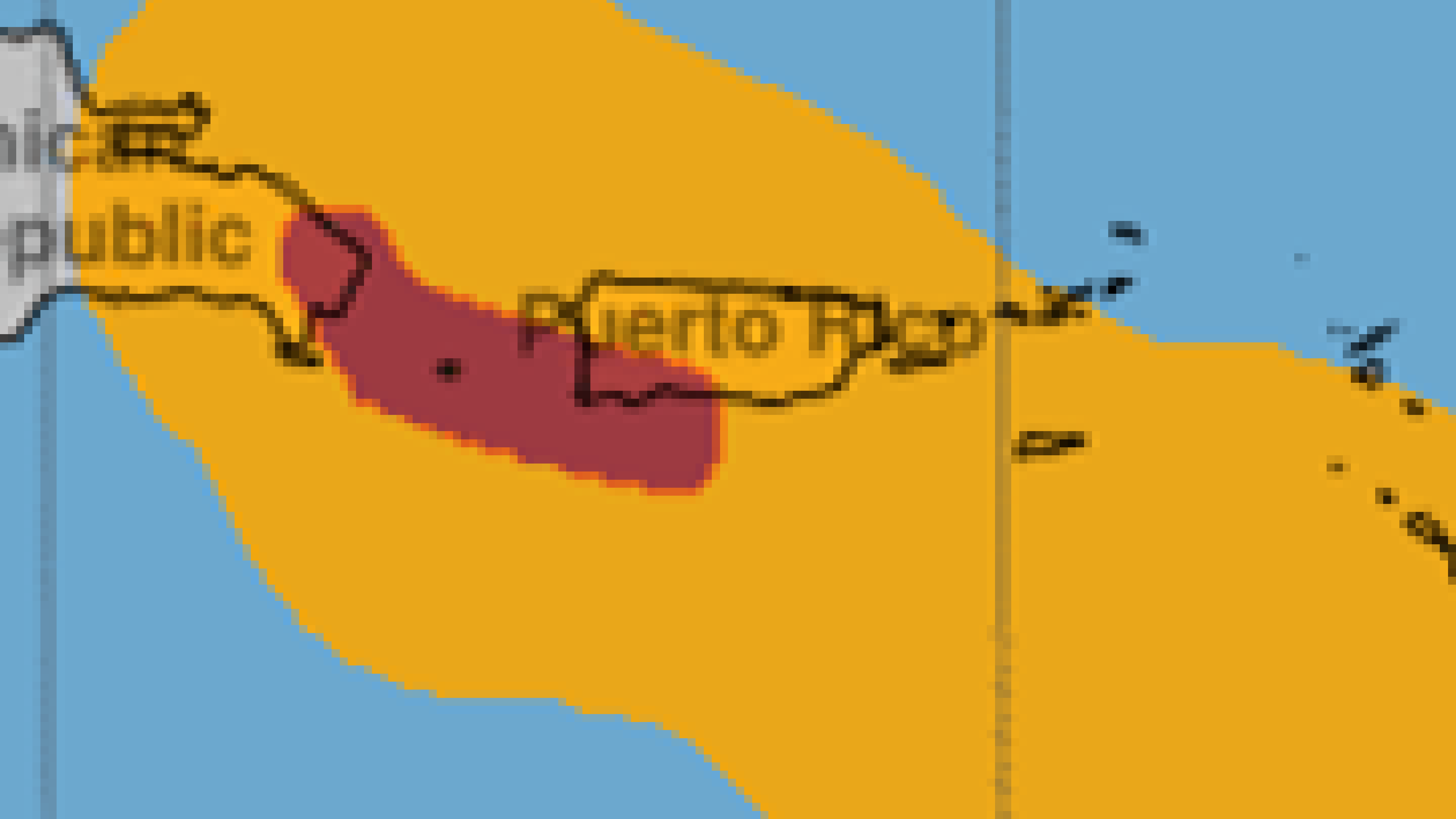
Photographer: Alejandro Granadillo/Bloomberg

Hurricane Fiona 2022

Greatest Preparedness and Response Failure

Huracán Fiona




public
Puerto Rico

VIGILANCIA
DE FATALIDADES ASOCIADAS AL HURACÁN FIONA

44 deaths:
Category 1 Hurricane Impact in Southwest.

*UNO POR ADJUDICAR.

Conteo de casos	Sexo	Edad (años)	Región de Salud	Fecha de la muerte (mm/dd/aaaa)	Clasificación	Tipo de muerte relacionada con el desastre	Causas de muerte
43	F	93	PONCE	11/22/2022	BAJO INVESTIGACION	BAJO INVESTIGACION	HYPERCAPNIC RESPIRATORY FAILURE, CARDIO RESPIRATORY ARREST, CHRONIC OBSTRUCTIVE PULMONARY DISEASE, HYPERTENSION, DIABETES MELLITUS, ASTHMA, ATRIAL FIBRILLATION
44	M	88	PONCE	12/07/2022	BAJO INVESTIGACION	BAJO INVESTIGACION	ACUTE RESPIRATORY FAILURE, UREMIC SYNDROME, ACUTE RENAL FAILURE

Nota: Esta información es preliminar; fue obtenida de los documentos compartidos por los Epidemiólogos Regionales y/o el Registro Demográfico y/o el Instituto de Ciencias Forenses. Causas de muerte según reportadas. En total se han registrado 44 casos fatales, los cuales se desglosan de la siguiente forma:

- Confirmados = 23 (2 muertes directas y 21 muertes indirectas con el desastre)
- Bajo investigación = 21.

https://www.salud.gov.pr/CMS/494

Energy Injustice: Disregard to the last 10% of customers with service restored in each region

El 24 de septiembre (una semana):
33% de hospitales sin luz
Gran mayoría de muertes NO son de municipios más afectados

Casos Fatales asociados al Huracán Fiona

En total se han registrado 16 casos fatales, los cuales se desglosan de la siguiente forma:

Confirmados = 4

- Muerte directa = 1
- Muerte indirecta= 3

Bajo investigación = 12

Edad - Género - Región - Fecha
65 - M - Ponce - 09/18/2022
50 - F - Fajardo - 09/18/2022
52 - M- Caguas - 09/17/2022
70- M - Arecibo - 09/19/2022
89 - M - Metro - 09/19/2022
58 - M - Bayamón - 09/19/022
74 - F - Caguas - 09/19/2022
64 - M - Metro - 09/18/2022
77 - M - Fajardo - 09/17/2022
50 - M - Mayagüez - 09/18/2022
56 - M - Caguas - 09/22/2022
77 - M - Arecibo - 09/20/2022
89 - F - Aguadilla - 09/20/2022
N/A - M - Bayamón - 09/212/2022

Status Hospitales

67% de Hospitales y CDTs con energía eléctrica .

Clínicas y Operaciones Electivas reanudarán en el día de mañana, miércoles, 21 de septiembre en:

- Centro Médico
- Hospital Universitario de Adultos
- Hospital Pediátrico

Centro Cardiovacular de Puerto Rico y del Caribe
Reanudaron las cirugías, procedimientos y pre-adminisiones desde el martes, 20 de septiembre.

Actualización:
9/24/2022 11:00 PM

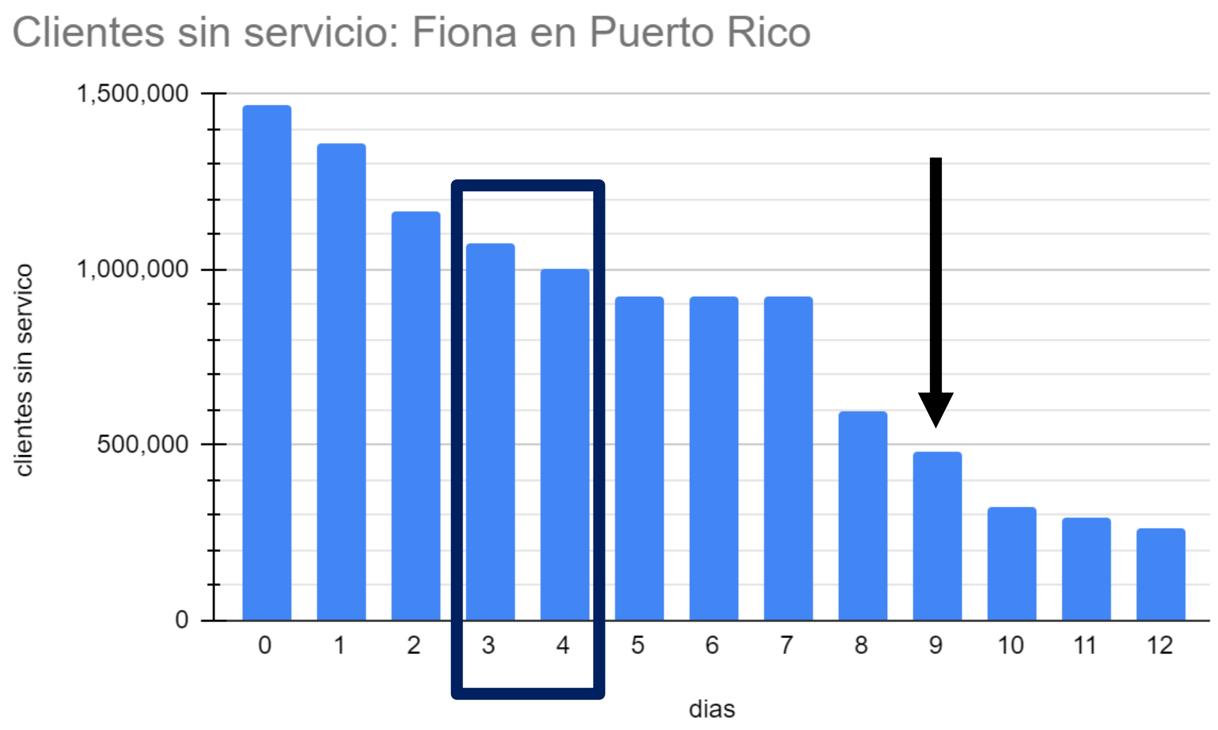
Dept. de Salud

https://twitter.com/marceljcastro/status/1574034401956012032

LUMA Energy y el gobierno prometen que "gran parte" de Puerto Rico tendrá luz entre hoy y mañana

En las zonas sur, suroeste y central, el restablecimiento demoraría "un poco más" por los daños en la red

martes, 20 de septiembre de 2022 - 7:52 a.m. | Por Gerardo E. Alvarado León



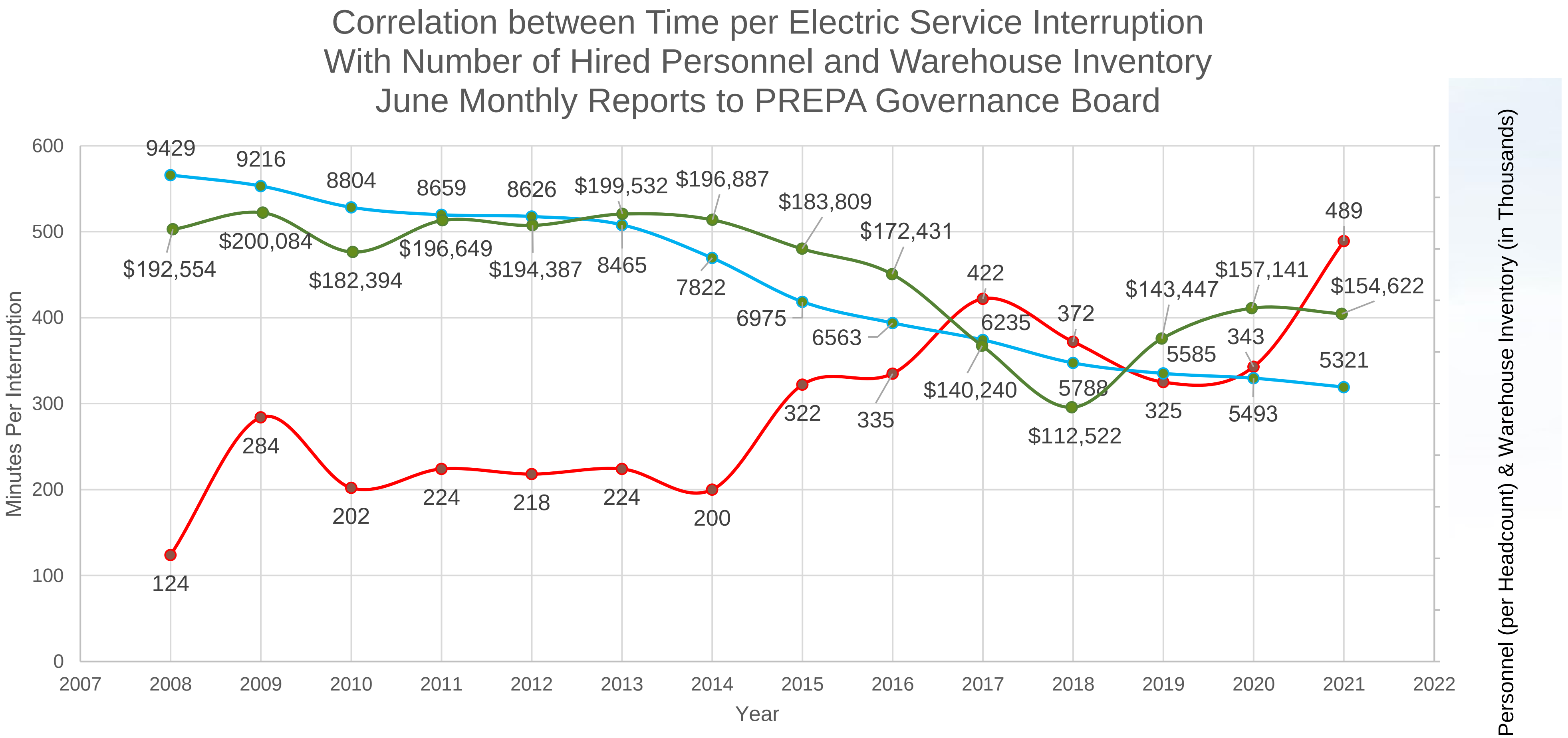
Sources: https://www.elnuevodia.com/noticias/locales/notas/luma-energy-y-el-gobierno-prometen-que-gran-parte-de-puerto-rico-tendra-luz-entre-hoy-y-manana/
Situation Reports by the Office of Cybersecurity, Energy Security, and Emergency Response: https://www.energy.gov/ceser/hurricane-fiona-situation-reports

Marcel Castro-Sitiriche, "Resilience Energy Justice: Boricua Power and Equity", Plenary Session, *IEEE-WEA*, Cartagena, Colombia, November 2, 2023.

Hurricane Fiona 2022

Austerity and Workforce Response Failure

Imposed Austerity and Grid Unreliability



Return

En Florida: 44,000 trabajadores de 33 estados + DC

Electricity Sector Summary

- There are an estimated 33,000 customer outages in Florida as of 10 AM EDT, October 10, down from a peak of 2.7 million customers without power from the storm. Outages in Florida are down 99% from the peak on September 29.
- Restoration efforts continue in the hardest hit areas. At this some, some power outages are not related to impacts from Hurricane Ian.
- At the peak, more than 44,000 workers from 33 states and the District of Columbia were supporting power restorations.

https://twitter.com/DOE_CESER/status/1578769760891723777

En Puerto Rico habían aproximadamente:

- 11,000 trabajadores en 1998 para Huracán Georges
- 5,000 trabajadores en 2017 para Huracán Maria
- 3,000 trabajadores en 2022 para Huracán Fiona

Marcel Castro-Sitiriche, “Resilience Energy Justice: Boricua Power and Equity”, Plenary Session, *IEEE-WEA*, Cartagena, Colombia, November 2, 2023.

Luma promete 5,000 trabajadores adicionales de ser necesario luego de Fiona

El presidente y principal oficial ejecutivo de Quanta, Duke Austin, aseguró en declaraciones escritas que "los recursos de la empresa están a la disposición de LUMA". El principal ejecutivo indicó además que, de ser necesario, "podrá añadir al equipo local de LUMA más de 5,000 trabajadores especializados en coordinación con la Hermandad Internacional de Trabajadores Eléctricos (IBEW, por sus siglas en inglés) para restaurar la energía tras los impactos de la tormenta tropical Fiona".

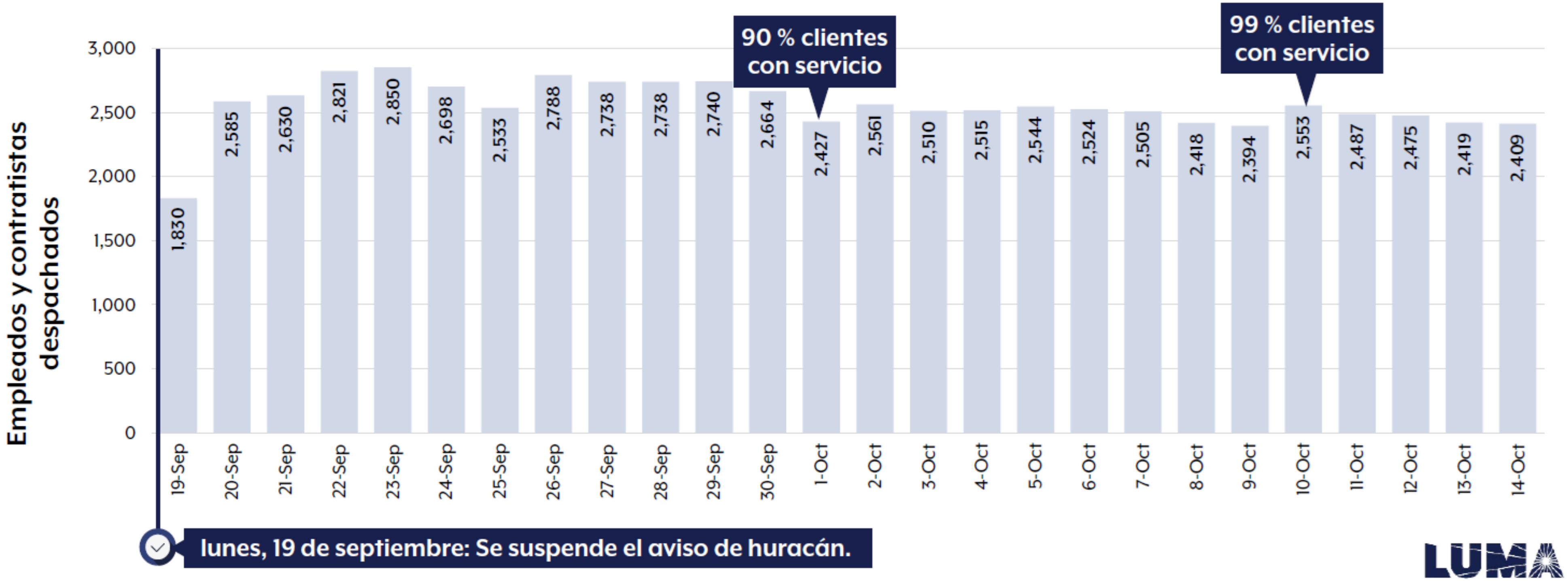
El Vocero, 18 de septeimbre de 2022, antes del paso de Fiona - https://www.elvocero.com/gobierno/agencias/sin-brindar-datos-concretos-luma-y-quanta-anuncian-que-atienden-aver-as-ante-el-paso/article_c33a9522-374c-11ed-afe3-d72dafded8f3.html

Nunca Sumaron 3,000 en total

Huracán Fiona – Empleados y contratistas

A medida que avanzamos con los esfuerzos de restauración tras el paso del huracán Fiona y obtuvimos acceso a las zonas más afectadas, LUMA despachó brigadas y contratistas para darle prioridad al restablecimiento de servicio en las regiones del sur y el oeste.

TODAS LAS REGIONES



LUMA

https://lumapr.com/resumen-de-la-respuesta-y-la-restauracion-tras-el-huracan-fiona/

Luma trae menos de 300 celadores de Quanta para trabajar en la reconstrucción luego de Fiona

Huracán Fiona

RECURSOS DESPACHADOS

- **2,500+** trabajadores de campo
- **2,500+** vehículos
- **7** helicópteros
- Centro de Operaciones de Emergencias de LUMA **24/7**, según la Estructura de Comando de Incidentes
- **6** centros de operaciones regionales
- **$130 millones** en inventario disponible para operaciones de respuesta a emergencias

8

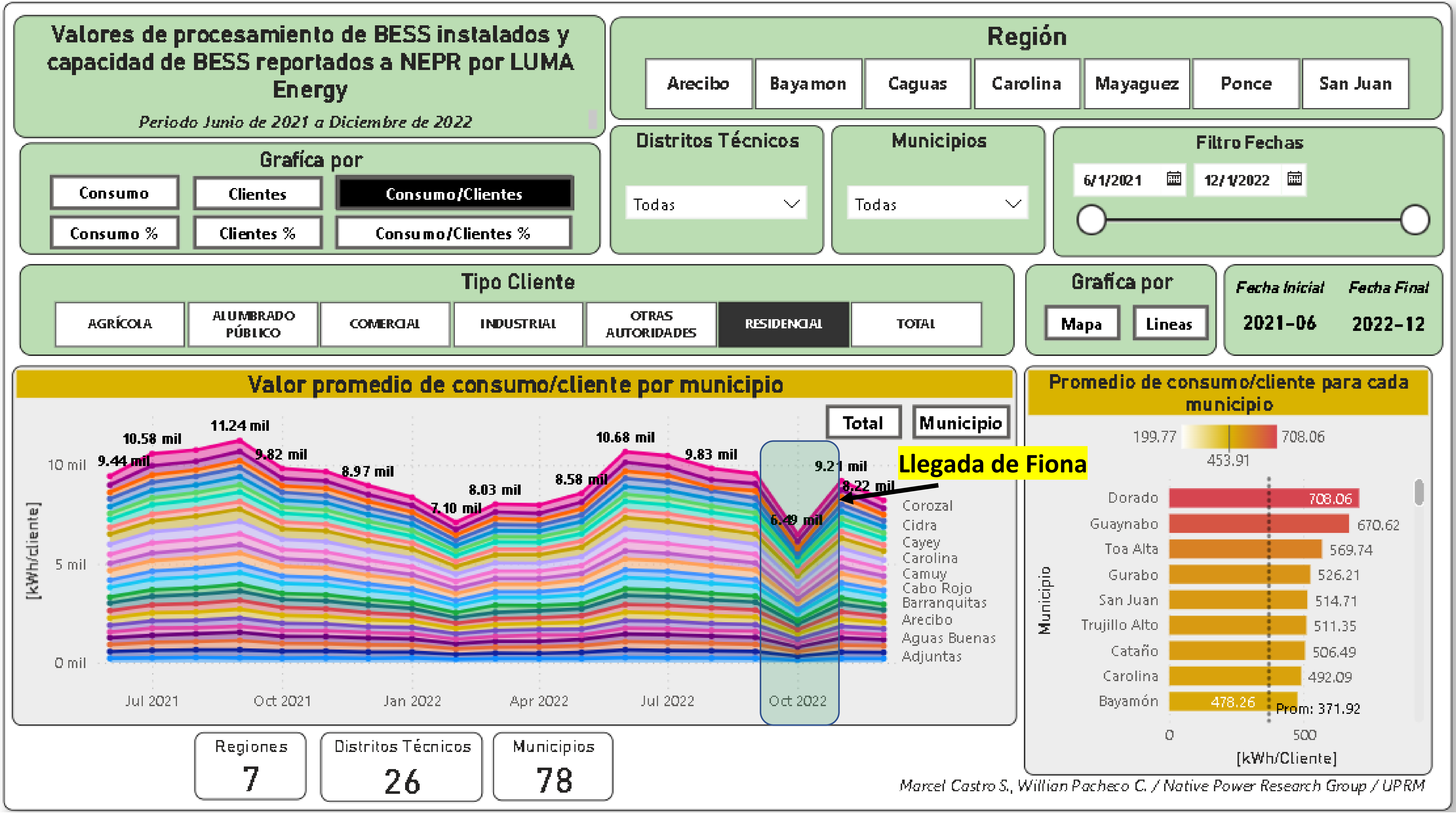
LUMA preposicionó brigadas, vehículos y equipos antes de que el huracán Fiona tocara tierra.

Movilización de Quanta Services

221	56	22
trabajadores de servicios públicos	camiones canasto	excavadoras

LUMA

https://lumapr.com/resumen-de-la-respuesta-y-la-restauracion-tras-el-huracan-fiona/



Valores de procesamiento de BESS instalados y capacidad de BESS reportados a NEPR por LUMA Energy
Periodo Junio de 2021 a Diciembre de 2022
Región
Arecibo
Bayamon
Caguas
Carolina
Mayaguez
Ponce
San Juan
Grafica por
Consumo
Clientes
Consumo/Clientes
Consumo %
Clientes %
Consumo/Clientes %
Distritos Técnicos
Todas
Municipios
Todas
Filtro Fechas
6/1/2021
12/1/2022
Tipo Cliente
AGRÍCOLA
ALUMBRADO PÚBLICO
COMERCIAL
INDUSTRIAL
OTRAS AUTORIDADES
RESIDENCIAL
TOTAL
Grafica por
Mapa
Lineas
Fecha Inicial
Fecha Final
2021-06
2022-12
Valor promedio de consumo/cliente por municipio
Total
Municipio
[kWh/cliente]
10 mil
5 mil
0 mil
9.44 mil
10.58 mil
11.24 mil
9.82 mil
8.97 mil
7.10 mil
8.03 mil
8.58 mil
10.68 mil
9.83 mil
6.49 mil
9.21 mil
8.22 mil
Llegada de Fiona
Corozal
Cidra
Cayey
Carolina
Camuy
Cabo Rojo
Barranquitas
Arecibo
Aguas Buenas
Adjuntas
Jul 2021
Oct 2021
Jan 2022
Apr 2022
Jul 2022
Oct 2022
Promedio de consumo/cliente para cada municipio
199.77
453.91
708.06
Municipio
Dorado 708.06
Guaynabo 670.62
Toa Alta 569.74
Gurabo 526.21
San Juan 514.71
Trujillo Alto 511.35
Cataño 506.49
Carolina 492.09
Bayamón 478.26
Prom: 371.92
0
500
[kWh/Cliente]
Regiones
7
Distritos Técnicos
26
Municipios
78
Marcel Castro S., Willian Pacheco C. / Native Power Research Group / UPRM

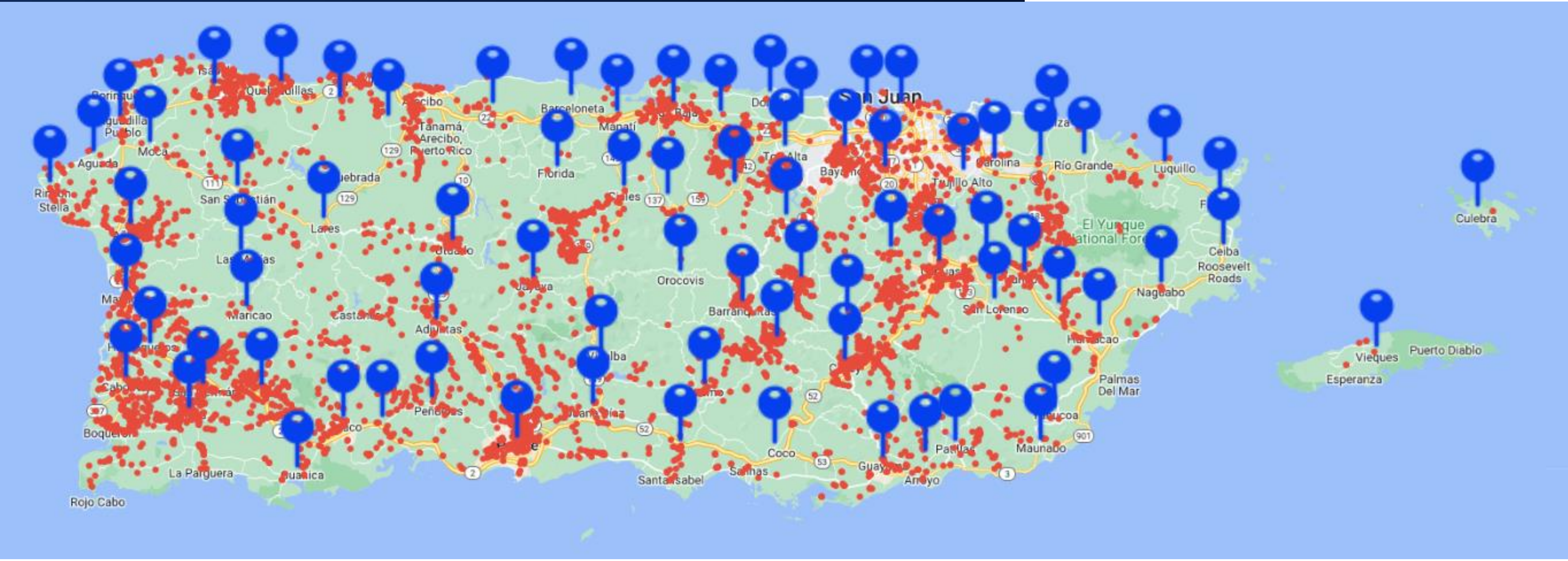
LUMA

RESIDENTIAL ▾ COMMERCIAL ▾ SUPPLIERS ▾ INDUSTRIAL OTHER GROUPS

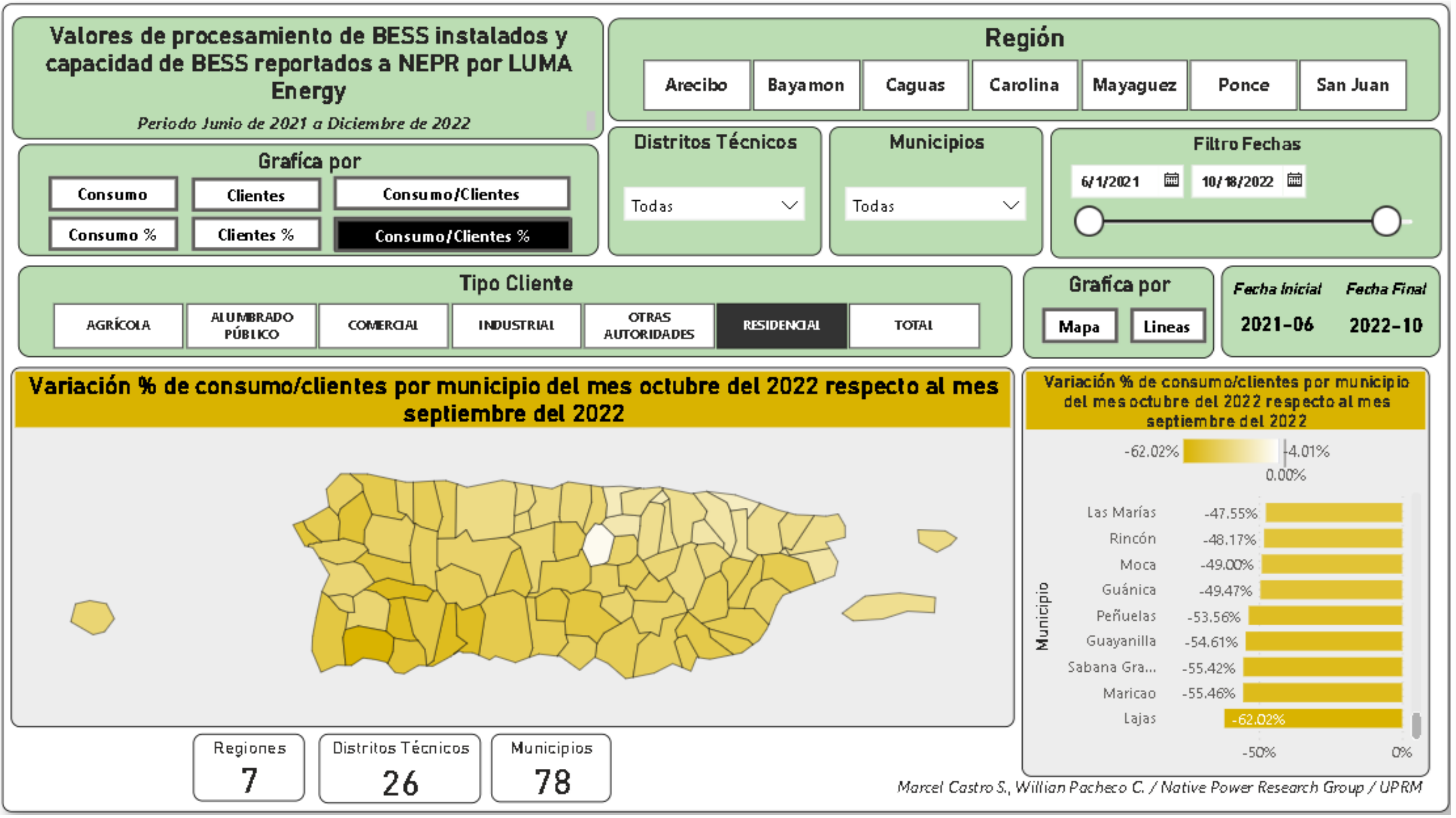
OUR OFFICES ▾ ABOUT LUMA ▾

Hurricane Fiona Damage Map

Hurricane Fiona was a serious category 1 hurricane that brought winds reaching over 100 miles per hour and over 30 inches of rain that caused severe floods, mudslides and washed-out roads and bridges across Puerto Rico – resulting in more than $4 billion in damage to critical electric infrastructure. Below find an interactive map detailing the locations and examples of the damage to the island's distribution system that LUMA and our partners are working to repair.



Source - https://lumapr.com/fiona/?lang=en

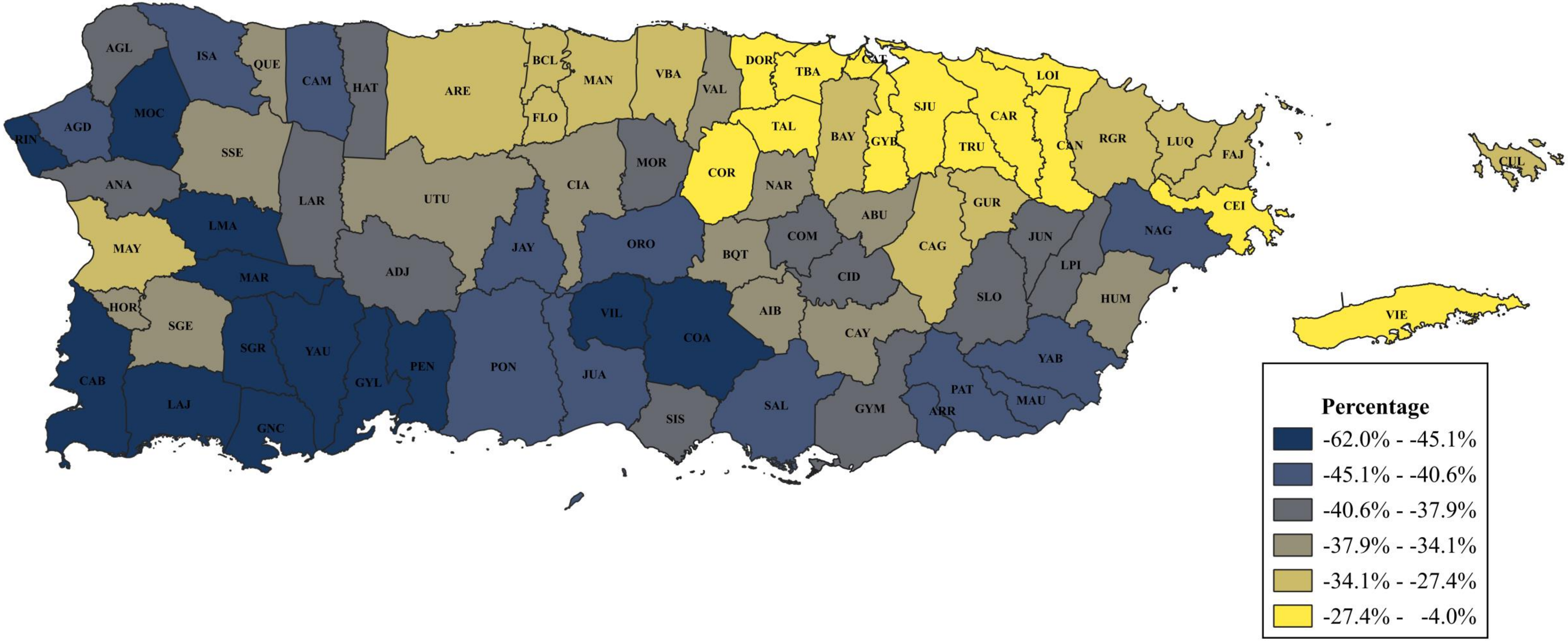


Numero	Municipio	Variacion % consumo/clientes
1	Corozal	-4.01%
2	Loíza	-15.07%
3	Dorado	-16.51%
4	Cataño	-17.15%
5	Toa Alta	-19.30%
6	Trujillo Alto	-21.06%
7	Carolina	-21.57%
8	Ceiba	-21.83%
9	Canóvanas	-23.25%
10	Toa Baja	-25.36%
11	Vieques	-26.91%
12	San Juan	-27.19%
13	Guaynabo	-27.26%
14	Bayamón	-27.44%
15	Río Grande	-27.52%
16	Fajardo	-27.77%
17	Luquillo	-29.12%
18	Culebra	-29.34%
19	Arecibo	-29.76%
20	Barceloneta	-30.12%
21	Caguas	-31.06%
22	Manatí	-31.11%
23	Florida	-31.36%
24	Gurabo	-31.69%
25	Vega Baja	-32.49%
26	Mayagüez	-34.06%
27	Aguas Buenas	-34.09%
28	San Germán	-34.26%
29	Ciales	-34.45%
30	Vega Alta	-35.02%
31	Aibonito	-35.15%
32	Hormigueros	-35.70%
33	Quebradillas	-36.01%
34	Naranjito	-36.12%
35	Utuado	-36.32%
36	Cayey	-36.76%
37	San Sebastián	-37.14%
38	Humacao	-37.23%
39	Barranquitas	-37.56%
40	Aguadilla	-38.19%
41	Añasco	-38.49%
42	Santa Isabel	-38.60%
43	Lares	-38.74%
44	Hatillo	-38.97%
45	Guayama	-39.20%
46	Adjuntas	-39.90%
47	Cidra	-39.94%
48	Comerío	-40.15%
49	Juncos	-40.32%
50	Las Piedras	-40.39%
51	San Lorenzo	-40.39%
52	Morovis	-40.50%
53	Camuy	-40.86%
54	Arroyo	-41.07%
55	Salinas	-41.16%
56	Juana Díaz	-41.56%
57	Yabucoa	-41.72%
58	Orocovis	-42.00%
59	Aguada	-42.51%
60	Naguabo	-42.68%
61	Maunabo	-42.73%
62	Ponce	-43.05%
63	Isabela	-43.26%
64	Patillas	-43.99%
65	Jayuya	-45.03%
66	Yauco	-45.42%
67	Cabo Rojo	-45.90%
68	Villalba	-45.97%
69	Coamo	-46.42%
70	Las Marías	-47.55%
71	Rincón	-48.17%
72	Moca	-49.00%
73	Guánica	-49.47%
74	Peñuelas	-53.56%
75	Guayanilla	-54.61%
76	Sabana Grande	-55.42%
77	Maricao	-55.46%
78	Lajas	-62.02%

La variación de consumo por cliente entre los meses de octubre a septiembre de 2022 se encuentra entre el -15% y -62% para el 99% de los municipios.

PERCENTAGE CHANGE IN ELECTRICITY CONSUMPTION PER RESIDENTIAL CUSTOMER – OCTOBER 2022

MUNICIPALITIES OF PUERTO RICO



Carlos Peña, Graduate Student, Native Power Research Group. Javier Moscoso, Pablo Méndez, Willian Pacheco, Carlos Peña, Alexis Burgos, Miguel de Jesús, Marcel Castro-Sitiriche, "Boricua Energy Justice as a Humanitarian Claim", *International Humanitarian Technologies Conference (IHTC) 2023*, Cartagena, Colombia, November 2, 2023.

Critical Loads

Prevent one death

Thousands of homes

Veguita Zamas, Jayuya
Mayo, 2018
Foto: marcel

1,000,000 houses by 2035

- Cost per household: \$7,000: (Solar PV: 2 kWp, Battery : 10 kWh)
- 1,000,000 residential clients with houses (100%)
  - Capital Investment Need: \$7,000 million
  - Solar PV Capacity: 2 GW
  - Energy Storage Capacity: 10 GWh
  - Annual Energy Production (4 SPH): 2,920 million of kWh
    - 45% of residential energy consumption (Sept. 2016 – Aug. 2017)
    - 17% of total energy consumption (Sept. 2016 – Aug. 2017)
    - **One third contribution for the 50% target for 2035**

Source: M. Castro-Sitiriche, J. Gomez, Y. Cintron, “The Longest Power Outage, María and Energy Poverty”, International Conference on Appropriate Technology, November, 2018.

500,000 houses by 2025

- Cost per household: $7,000: (Solar PV: 2 kWp, Battery : 10 kWh)
- 500,000 residential clients with houses (50%)
  - Capital Investment Need: $3,500 million
  - Solar PV Capacity: 1 GW
  - Energy Storage Capacity: 5 GWh
  - Annual Energy Production (4 SPH): 1,460 million of kWh
    - 22% of residential energy consumption (Sept. 2016 – Aug. 2017)
    - 8% of total energy consumption (Sept. 2016 – Aug. 2017)

Source: M. Castro-Sitiriche, J. Gomez, Y. Cintron, “The Longest Power Outage, María and Energy Poverty”, International Conference on Appropriate Technology, November, 2018.

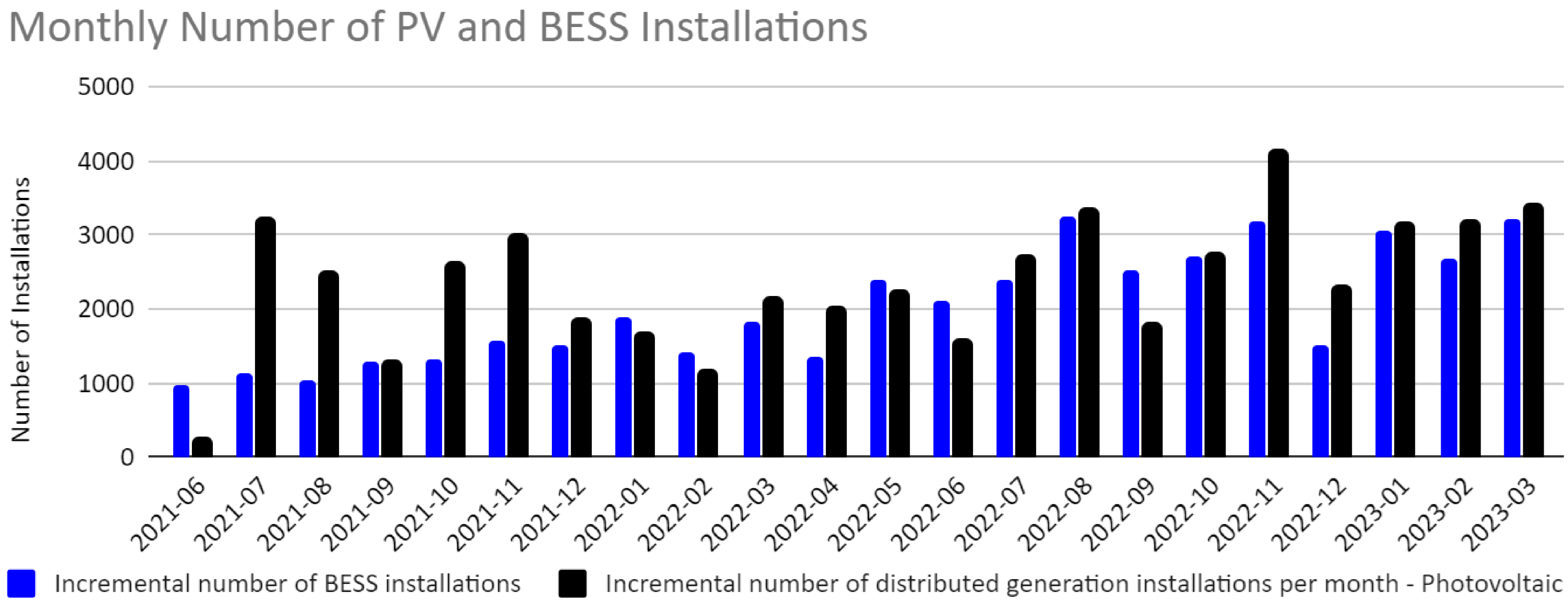
Small Solar Rooftop: 200,000 houses (by 2020)

- Cost per household: $7,000: (Solar PV: 2 kWp, Battery: 10 kWh)
- 200,000 residential clients with houses (20%)
  - Capital Investment Need: $1,400 million
  - Solar PV Capacity: 400 MW
  - Energy Storage Capacity: 2 GWh
  - Annual Energy Production (4 SPH): 584 million of kWh
    - 9% of residential energy consumption (Sept. 2016 – Aug. 2017)
    - 3% of total energy consumption (Sept. 2016 – Aug. 2017)

Source: M. Castro-Sitiriche, J. Gomez, Y. Cintron, "The Longest Power Outage, María and Energy Poverty", International Conference on Appropriate Technology, November, 2018.

> 3,000 net-metering installations per month, total monthly estimate of 4,000
50,000 total approximate installations per year

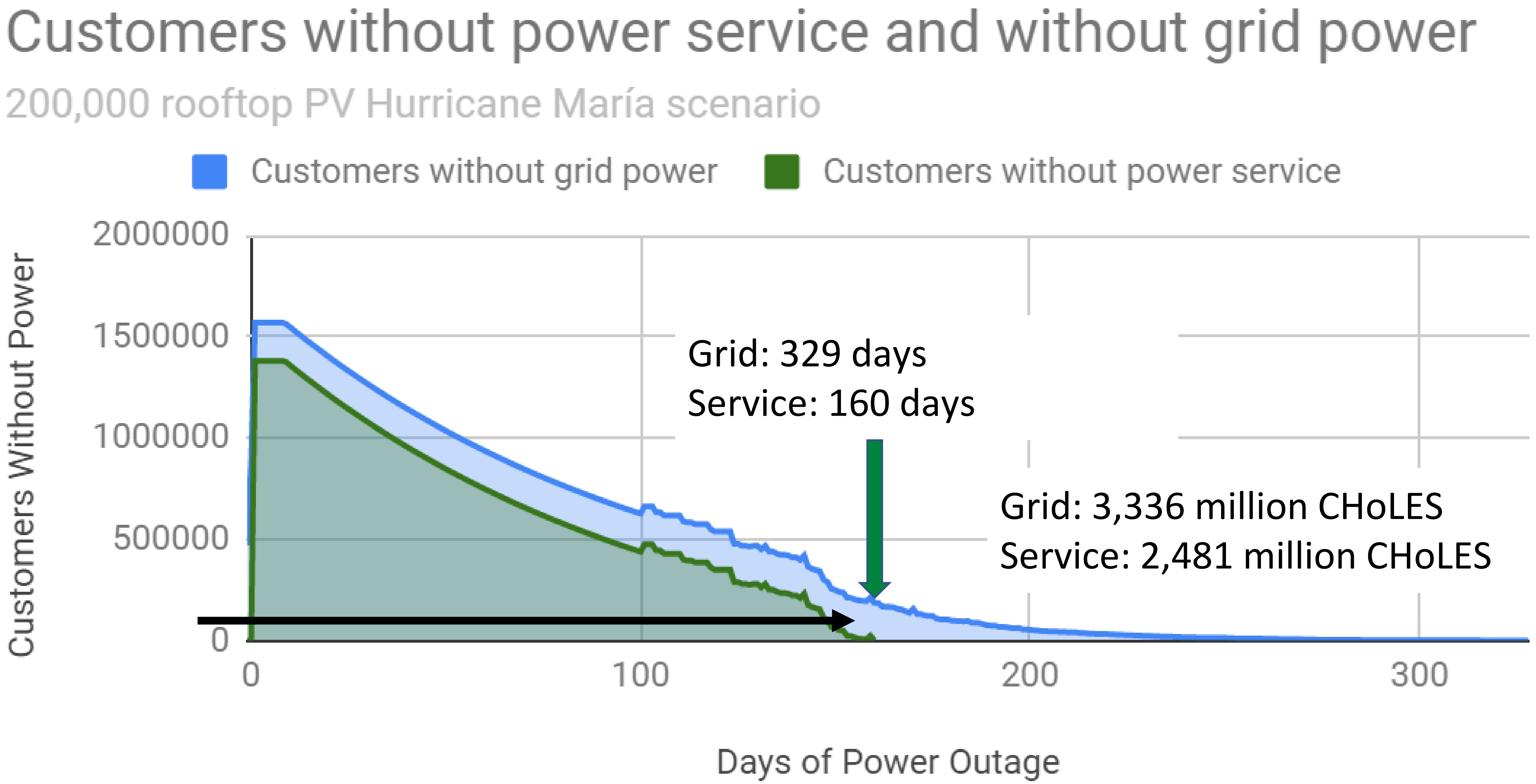
200,000 installations in four years are possible (2018-2021)



Marcel Castro-Sitiriche, NEPR Data Analysis, PR100 Update 2023. Source: Negociado de Energía de Puerto Rico (NEPR) https://energia.pr.gov/numero_orden/nepr-mi-2019-0007/

Energy Equity and Resilience

Boricua Energy Justice



Marcel Castro-Sitiriche, "Resilience Energy Justice: Boricua Power and Equity", Plenary Session, *IEEE-WEA*, Cartagena, Colombia, November 2, 2023.

Cost of Solar Rooftop Power

Economies of Small Scale

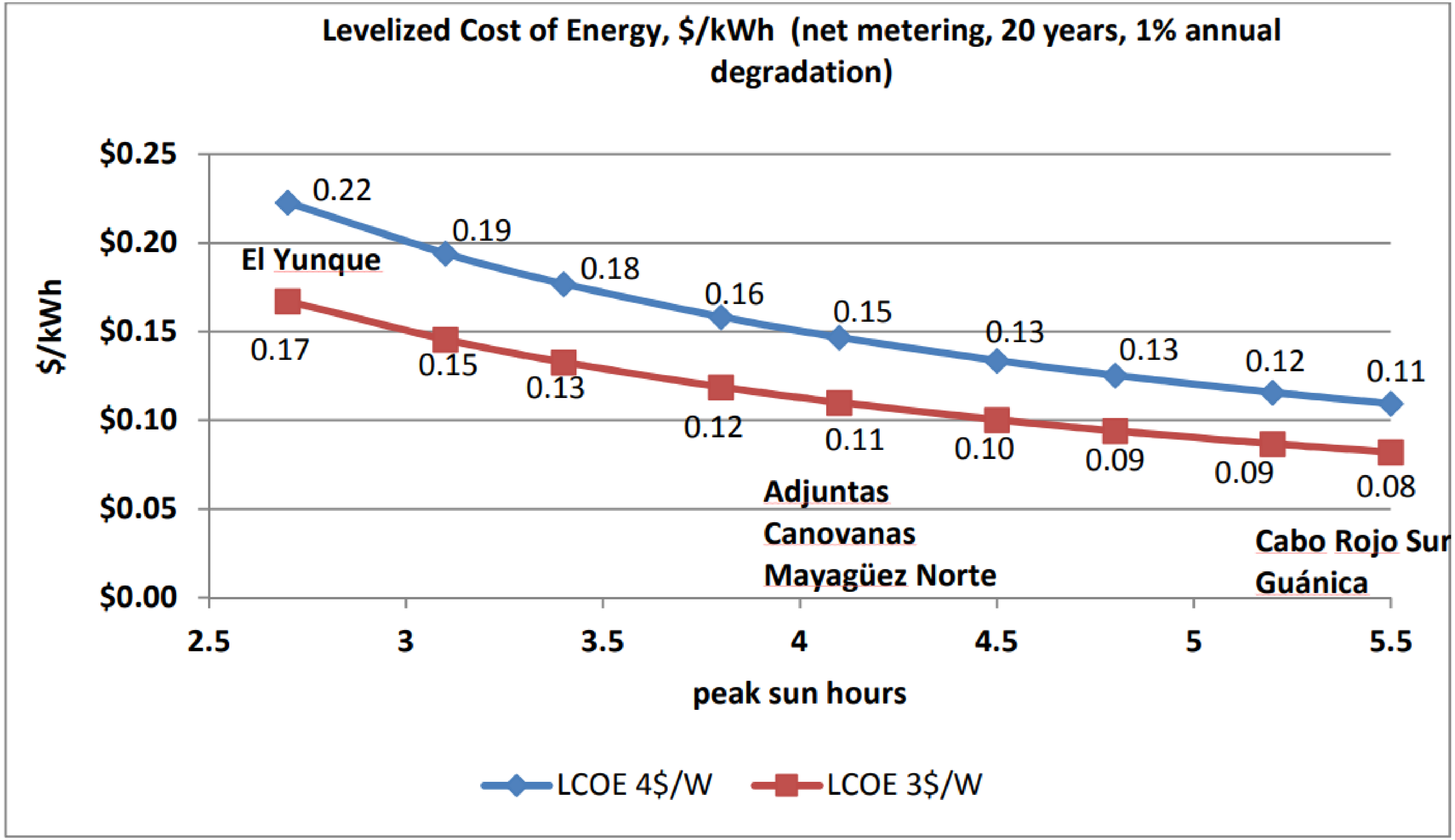
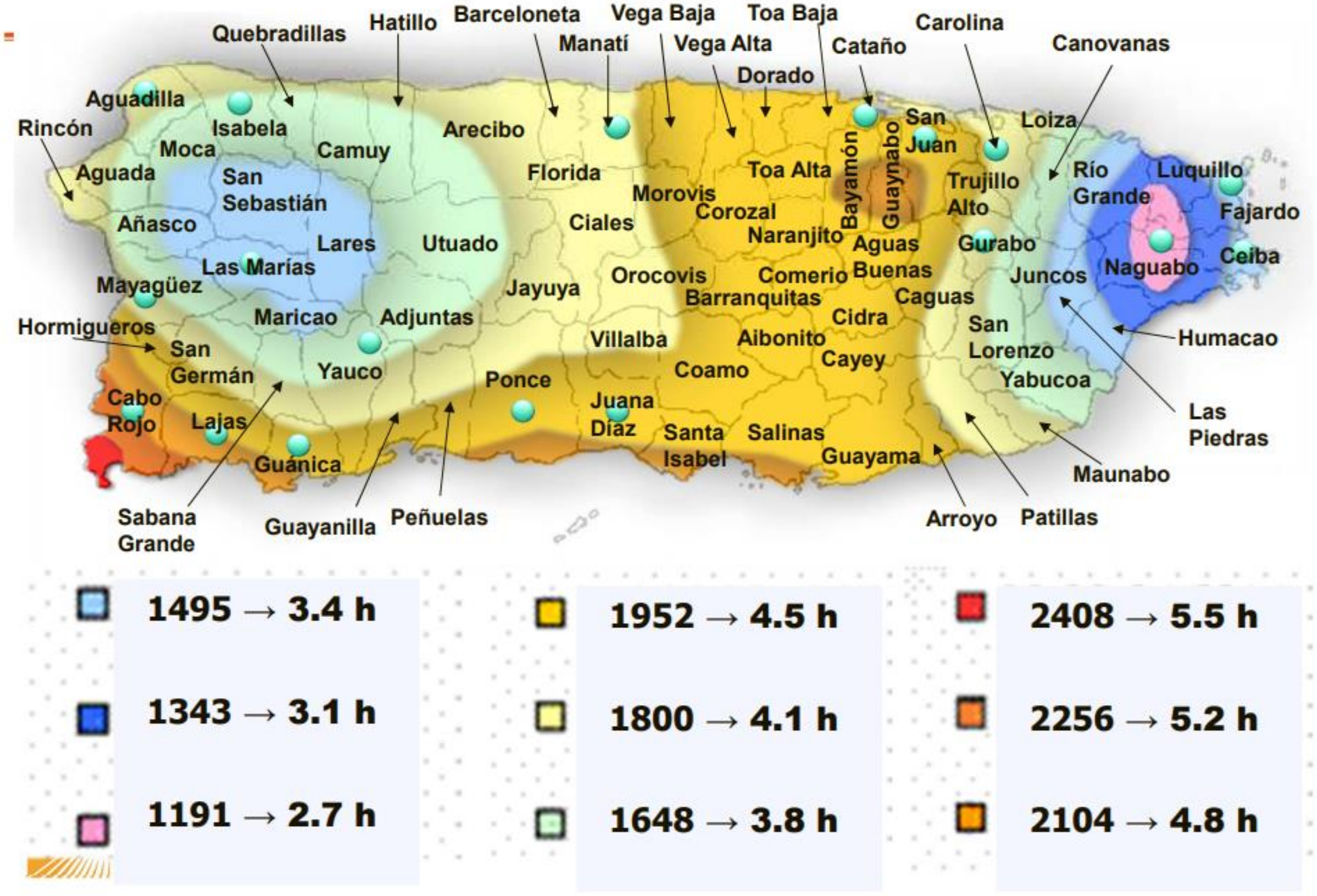


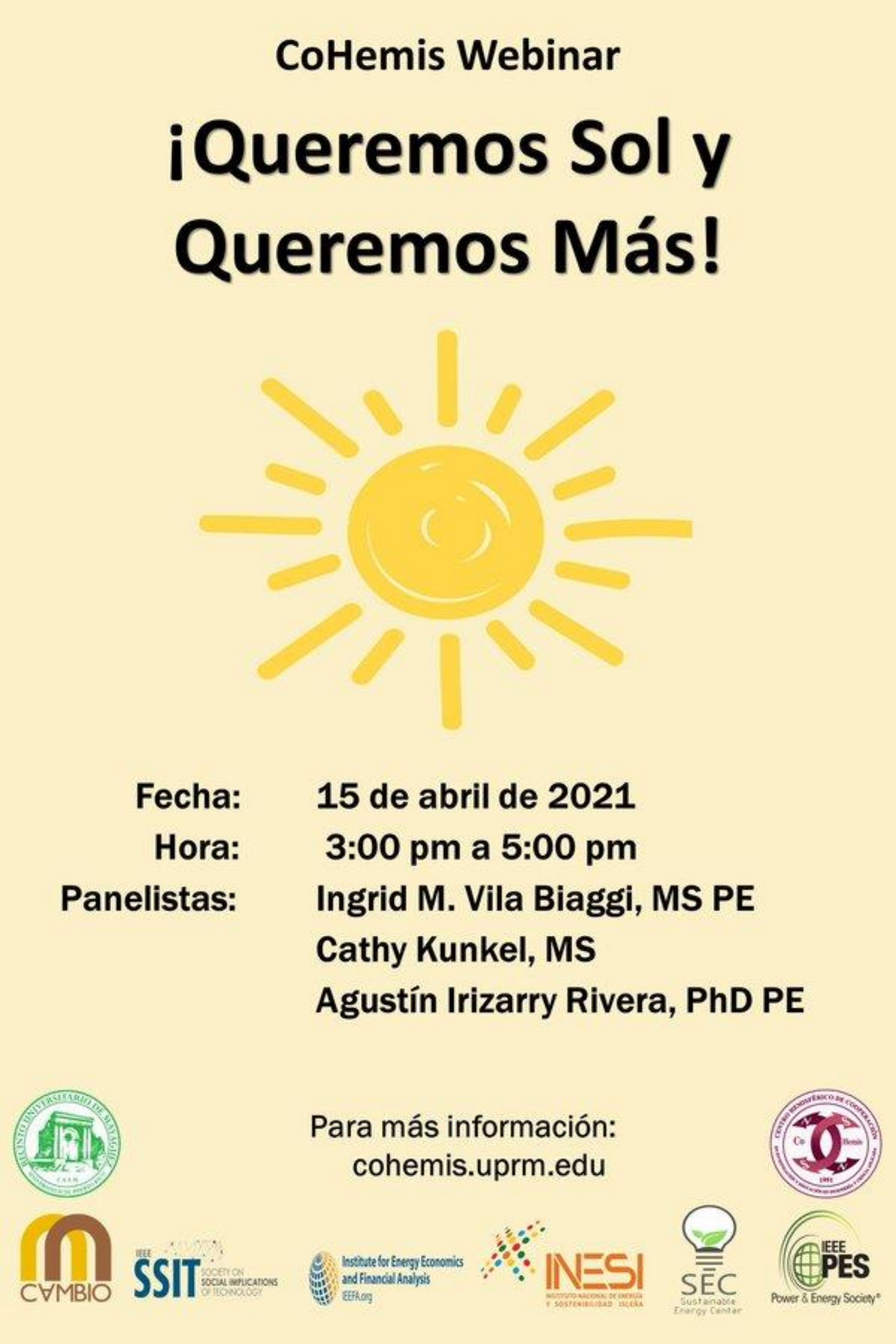
Figure 3.3: Levelized Cost of Energy (LCE), in $/kWh, at different sites in Puerto Rico as a function of peak sun hours.

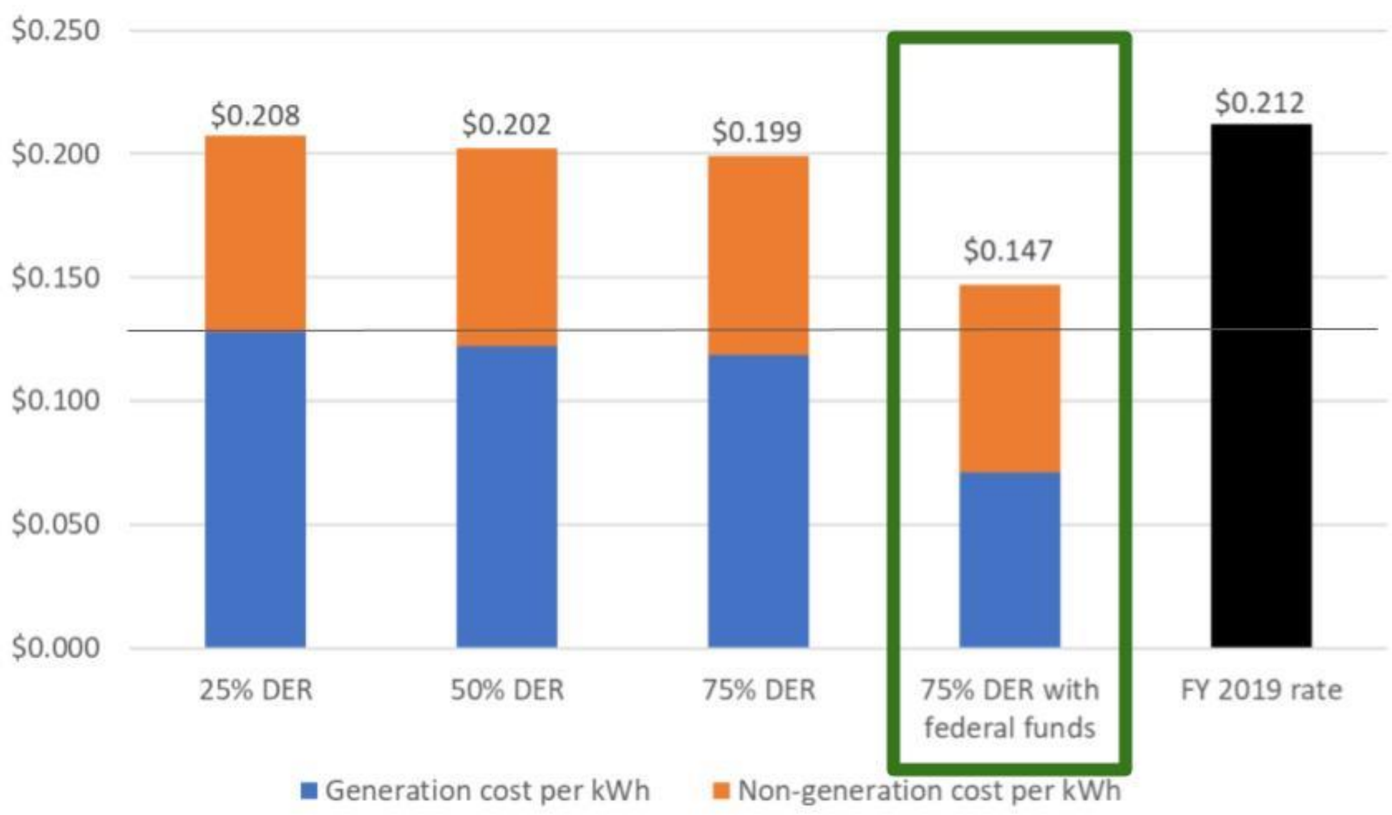
BOOK: Improved Permitting and Interconnection Processes for Rooftop PV Systems in Puerto Rico
http://prsolar.ece.uprm.edu/resources.html

Estimated average insolation in Puerto Rico, kWh/m^2 per year



Fuente - http://prsolar.ece.uprm.edu/docs/PV-Summit-October-30-2012.pdf lámina 77





http://cohemis.uprm.edu/sol2021/

https://twitter.com/marceljcastro/status/1402582449113210884

Tranche 1 Solar Farms: 11 sites in 8 municipalities

https://www.energiaestrategica.com/con-un-34-de-incremento-puerto-rico-aprueba-11-ppas-de-energias-renovables/

“Muchos arrancan en los diez centavos o hasta por debajo de los diez centavos, y según van pasando los años, aumentaría hasta 14 centavos y un poco más”, indicó.

Francisco Berríos

Secretario auxiliar de Energía y presidente de la Junta de Gobierno de AEE

https://www.elvocero.com/exclusivo/exclusivo-defiende-ubicaci-n-de-proyectos-de-energ-a-renovable/article_ee710b46-4073-11ee-b3ff-8b33d4130a7f.html

Marcel Castro-Sitiriche, “Resilience Energy Justice: Boricua Power and Equity”, Plenary Session, *IEEE-WEA*, Cartagena, Colombia, November 2, 2023.

ARET Study in 2009

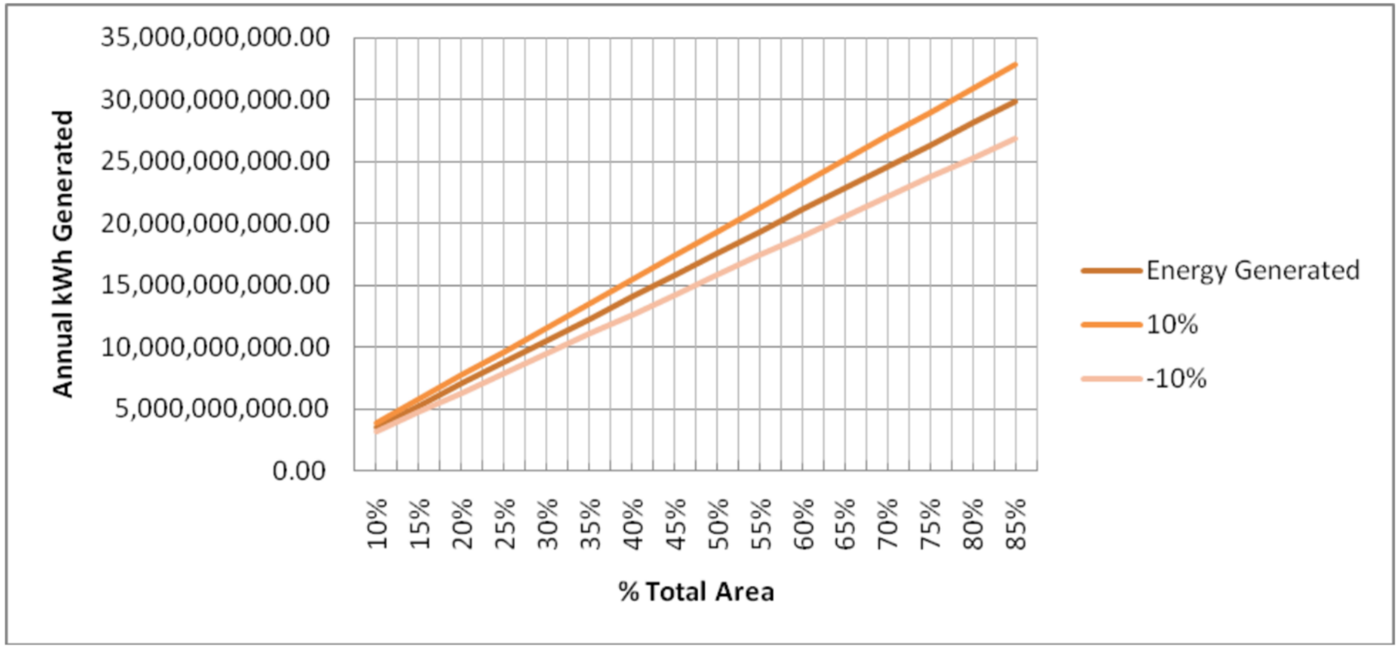


Figure 5.20 Annual Residential Generation Potential

The percentage of total rooftop space needed to displace the electric energy production (25Twh) reported for Puerto Rico on 2005 is 65%.

Irizarry, A., B. Colucci, and E. O'neil. "Achievable Renewable Energy Targets for Puerto Rico's Renewable Energy Portfolio Standard." *Puerto Rico Energy Affairs* (2009). https://www.uprm.edu/aret/

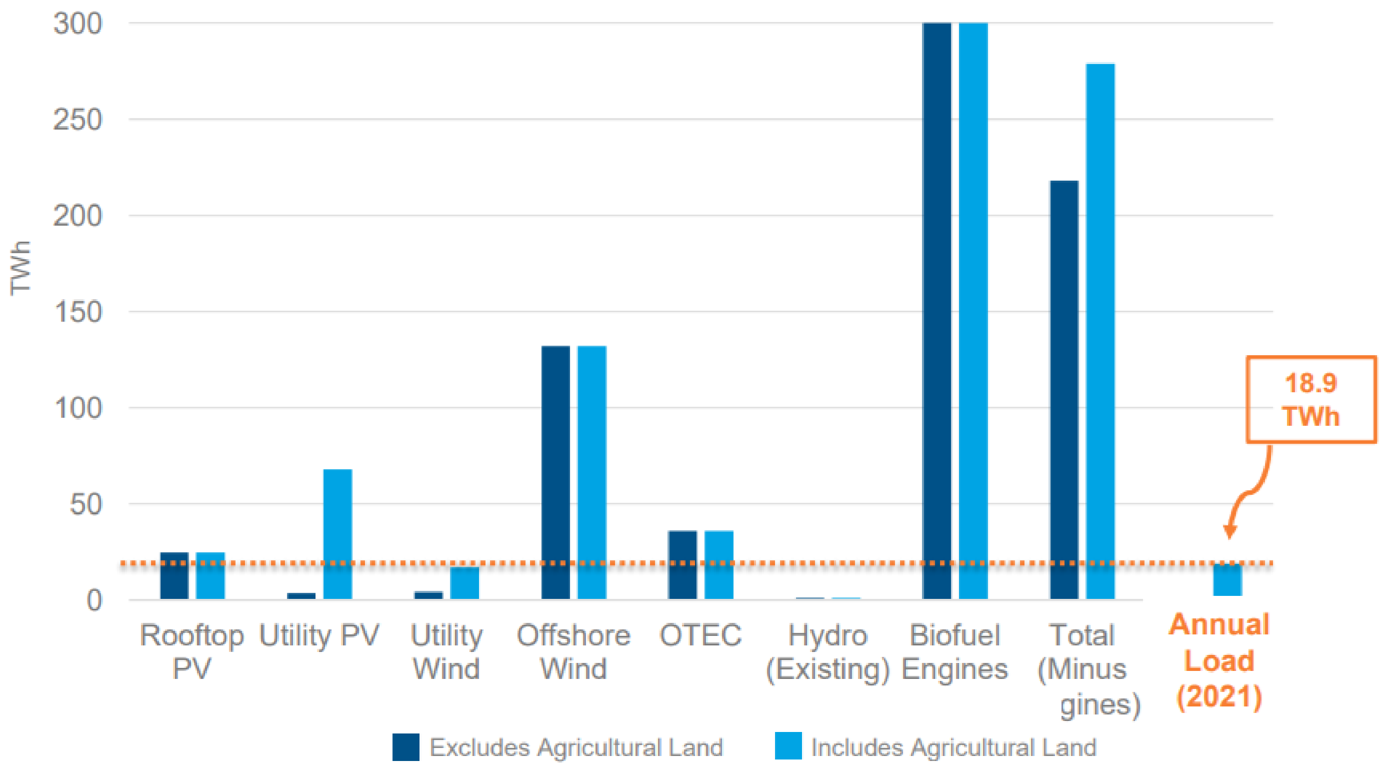
Preliminary Findings From *Renewable Energy Potential and Distributed Energy Resource Adoption*

Answer:

- Resource is more than ten times the demand.

Preliminary Findings:

- The **renewable energy technical resource in Puerto Rico significantly exceeds** the current and projected total annual loads through 2050.
- Adoption of **distributed solar and storage is projected to increase** considerably in all scenarios.



Potential annual generation in TWh of various renewable technologies compared to load (in 2021). ***Graphic by NREL.***

https://www.nrel.gov/docs/fy23osti/85126.pdf

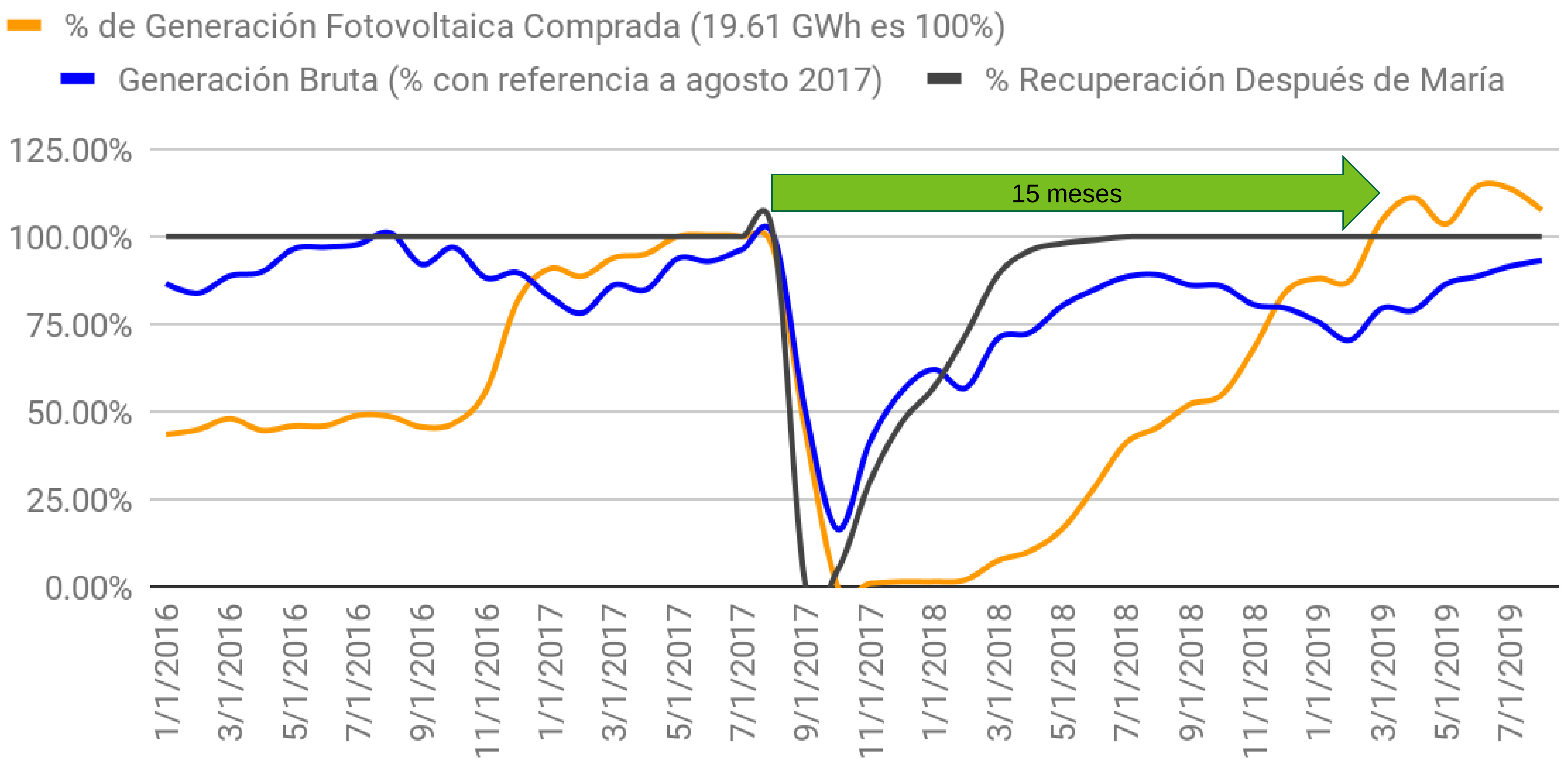
Government Disinformation: Last Week

…el gobernador destacó que la producción de energía en la finca solar es menor de 10 centavos (0.0989) el kilovatio hora, cuando el costo de la energía para el abanado está en la actualidad a 23 centavos el kilovatio hora.

"Los que piensan que aquí con sistemas solares en los techos ya sería suficiente, se olvidan que hay muchísimas estructuras en Puerto Rico que no están aptas para tener sistemas solares. … Pero, la única manera de tú sustituir las plantas, decomisar plantas, que es una de las funciones que tiene Genera en Puerto Rico, es sustituyéndolas con fincas solares como esta que tenemos aquí. Si no, nunca vamos a decomisar planta alguna"

https://www.primerahora.com/noticias/gobierno-politica/notas/pierluisi-inaugura-la-finca-solar-mas-grande-de-puerto-rico/

Recuperación después del Huracán María

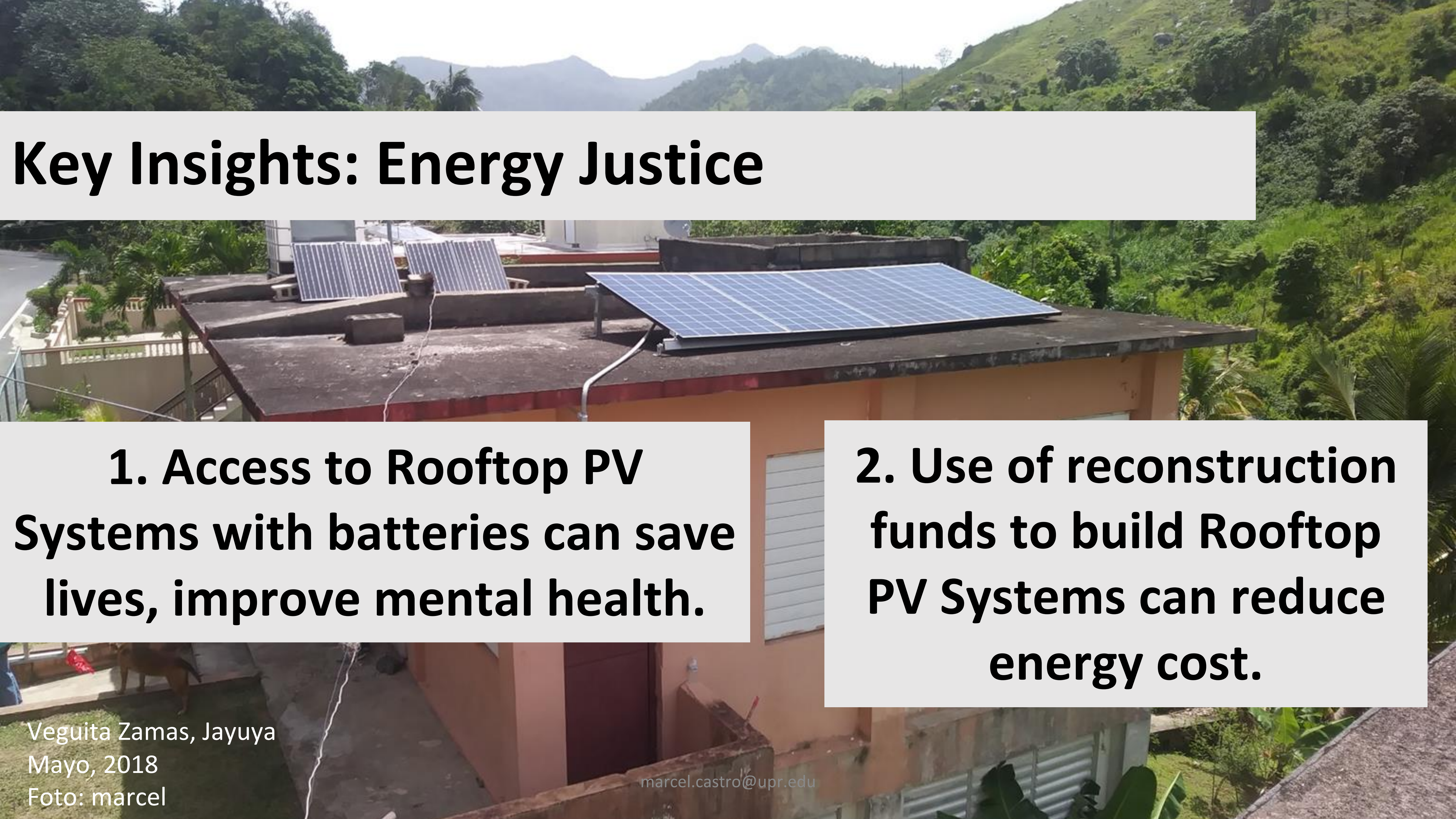


M. Castro-Sitiriche, “Clean Energy Boricua”, Webinar: Can solar rooftop help the transition to clean energy in Puerto Rico? December 17, 2020.

Key Insights: Energy Justice

1. Access to Rooftop PV Systems with batteries can save lives, improve mental health.

2. Use of reconstruction funds to build Rooftop PV Systems can reduce energy cost.



Veguita Zamas, Jayuya
Mayo, 2018
Foto: marcel

marcel.castro@upr.edu

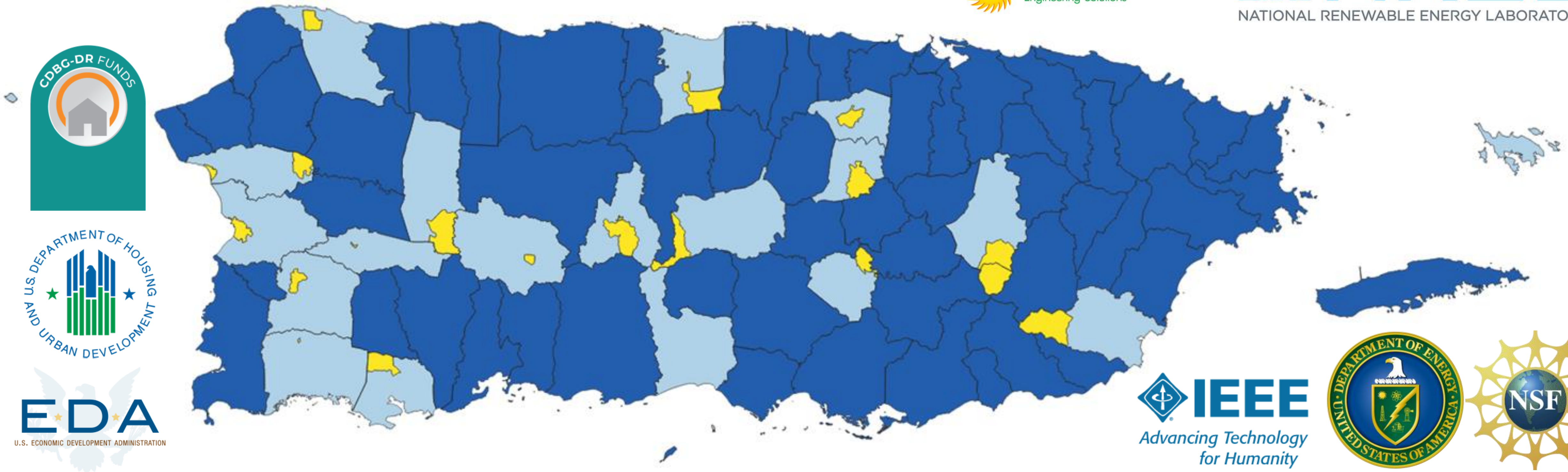
Decentralization of Power

Future Power Research ennabled by one million solar rooftops PV systems with batteries

- Bottom-up microgrids
- Microgrid Clusters
- Virtual Power Plants
- V2G and V2H
- Transactive Energy
- Democratization of Energy
- Energy Governance

Marcel J. Castro-Sitiriche, “Boricua Energy Equity”, Panel on Data-enriched Grid Modeling of End-user Profiles, Energy Equity, and Situational Preparedness, *IEEE-ISGT*, San Juan Puerto Rico, November 7, 2023.

UPRM Power Community Engagement: Communities in 19 Municipalities



UPRM Team: Luisa Seijo from Social Sciences, Ricardo Fuentes from Economics, Lizzette González from Agricultural Science, Reinaldo Rosado from Social Sciences, Ingrid Rodríguez from Social Sciences, Francisco Maldonado from Civil Engineering, Marcel Castro-Sitiriche, Agustín Irizarry, Fabio Andrade, Gerson Beauchamp from Electrical and Computer Engineering, Arturo Massol from Biology, Christopher Papadopoulos from Engineering Sciences, William Frey from Business Administration, 2019-2024.

Key Insights

Resilient Power Service

- Power Resilience Metric: Total days of power outage
- Power Grid not managed to provide energy equity
- Expensive Solar Farms that provide no resilience
- Solar Rooftop PV Systems with Batteries need to upscale
- The future of power research in Puerto Rico: decentralized

Marcel J. Castro-Sitiriche, “Boricua Energy Equity”, Panel on Data-enriched Grid Modeling of End-user Profiles, Energy Equity, and Situational Preparedness, *IEEE-ISGT*, San Juan Puerto Rico, November 7, 2023.