SPRING 2024

GEORGIA INSTITUTE OF TECHNOLOGY

FINAL REPORT

ADVISED BY
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PUERTO RICO PLANNING STUDIO

ACKNOWLEDGEMENTS

We would like to acknowledge and thank the many participants of this planning studio that made this research and this studio project come together. I will start by acknowledging the clients, Deepak Lamba-Nieves (Policy Link, formerly Center for the New Economy), Raúl Santiago-Bartolomei (Center for the New Economy), and Amaury Rivera (Condado community leader), for their participation and support of this research studio. Only with their collaboration, influence, and expertise could we effectively proceed with our research.

Next, we would like to thank our teaching assistant, Joshua Ayers, for his invaluable contributions to this studio and consistent impact on the students and their work.

We would also like to acknowledge and thank the many people that served as direct mentors to our team through formal interviews. We would like to acknowledge and thank the interviewees for Group 1: Raphael Osuna (Habitat for Humanity), Jairo Garcia (Georgia Tech), and Modesta Irizarry (Taller Sallud). For Group 2, we would like to thank Newton Tang (FEMA), Kevin Edwards (FEMA), Amaris Torres-Rivera (Fundacion Fondo de Acceso a la Justicia), Rosaura Rodríguez (Artist and Educator), Elga Novoa (Departamento de la Vivienda), Laury Rivera (Departamento de la Vivienda), Wanda García Sánchez (Departamento de la Vivienda), Johann Sasso (US Army Corps of Engineers). Also the interviewees of Group 3: Eileen Rodriguez Velez (Oficina Municipal de Permisos, Caguas), Emilio Venegas (Venegas Construction, Georgia Tech Alum), Herminio Pagan Calderin (Gestores de Puerto Rico, LLC), Giselle Villafane Santiago (Oficina Municipal de Permisos, San Juan), Ashley M. Rivera Figueroa (OGPe), and Nory Rivera (Asociación de Constructores de Puerto Rico). And finally, we would like to thank the interviewees of Group 4: Brian Stone (Georgia Tech), Valentina Garramuño (Fundación Borincana), Frankie Alemany, Gabriel Sepulveda, Dardo Gimenez, Manuel Baez Jr., and Miguel Angel De Jesus Soto. Thank you all for your instrumental contributions to this research process.

Now, we would like to acknowledge the organizations and individuals that hosted us to provide a more grounded understanding of work being done on the island. We would like to start by thanking Ariel Félix for her inspiring work and warm reception of our research on the island. We would like to the thank the individuals of the HORNE Puerto Rico Team that hosted us: Samir El-Hague, Laura Martí, Aptemis Rodriguez, Javier Perez, Daniel Díaz, Nelssida Martinez, Ann Marie Lugo, Emily Tulier. We would also like to thank the ENLACE team for hosting us and providing crucial insight into their work: William McCormick and Moisés Abdel-Rahman López. Finally, we would like to acknowledge the Autoridad del Transporte Integrado (ATI) team: Luisa M. Rivera Pérez, Sonia Soto, Jeannette Laureano, Carlos Yamil Martínez Marrero, Carlos Del Valle, Escuela Graduada de Planificación, Universidad de Puerto Rico (UPR), Criseida Navarro, and Angeliz Encarnación Burgos. Thank you all for your hospitality and for hosting us to further the depth and accuracy of our work.

Penultimately, we would like to acknowledge and thank the hosts of our presentations, allowing for a facilitated flow of information and spreading awareness of the hard work we put in. Thank you to Brook Byers Institute for Sustainability Initiatives (BBIS), “Sustainability Showcase” at Georgia Tech, Vanderbilt Hotel in Condado, San Juan, Escuela Graduada de Planificación, Universidad de Puerto Rico (UPR), and Dr. Jairo Garcia’s “Sustainable Urban Development” course at Georgia Tech. Your willingness to host our academic work helps to lower the barrier to communicating our results and allowing people insight to our studio.

Finally, we would like to acknowledge our funders: College of Design (CoD), Georgia Tech, School of City and Regional Planning (SCaRP), Georgia Tech, and Steven A. Denning Foundation. Without this financial support, none of this would have been possible. Thank you for your contributions.

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PREFACE

I am pleased to present the results of Georgia Tech School of City and Regional Planning's (SCaRP) 2024 Puerto Rico Planning Studio, which took place during the Spring semester. This is the fifth iteration of a Puerto Rico Planning Studio series which I originally co-created and co-directed with Dr. Catherine Ross in 2019. During these past 5 years, the Puerto Rico Planning Studio has collaborated with a number of different public, private and non-governmental organizations on topics centered on Puerto Rico's post-disaster recovery, reconstruction and resilience.

Central to this Planning Studio series are three fundamental principles. First, students engage in real-world, client-based projects that demand ongoing student-client interaction, fieldwork, and application of the theoretical and analytical skills prioritized by SCaRP's programs. Second, as they work on these projects, students acquire a detailed and nuanced understanding of the Puerto Rican context through both a lecture- and discussion-based course in Atlanta, as well as travel to Puerto Rico during Spring Break. And third, collaboration between the Puerto Rico Planning Studio program and clients is long-term, involving multi-year engagement and projects.

At the same time, the 2024 Puerto Rico Planning incorporated two noteworthy innovations with respect to prior studios in the series. For one, students worked with not one, but two clients in Puerto Rico on different projects. The first, the Center for the New Economy (CNE), had also served as a client in 2023. The 2024 project, addressing post-disaster vulnerability, damage and disbursement of public and private reconstruction funds, built on that prior initiative. The second client was Amaury Rivera, a community leader in Condado, San Juan for whom students prepared an assessment and intervention guide for improved electric service.

If the doubling of the clients and projects was the first innovation of the 2024 Studio, the second was the participation of undergraduate students from Georgia Tech's Sustainable Cities Minor. In contrast to prior iterations of the Studio, which were tailored solely for Master's students, the 2024 version incorporated mixed teams of graduate and undergraduate students working together. As you will see in the following pages, the results of these innovations speak for themselves.

In closing, I would like to thank all those who supported this 2024 Puerto Rico Planning Studio, foremost among them our clients Raúl Santiago-Bartolomei and Deepak Lamba-Nieves from CNE, as well as the aforementioned Amaury Rivera. I would also like to thank our teaching assistant, Joshua Ayers, for his indispensable work, as well as those who so graciously agreed to interviews with students, hosted us during our Spring Break visits and presentations, and provided funding.

Lastly, I would like to thank the thirteen students who participated in the 2024 Puerto Rico Planning Studio. You have made me and Georgia Tech proud!

Alberto Fuentes

INTRODUCTION

Objectives and Conceptions

Key Framing Context

Objectives and Conception: Key Framing Concepts

The 2024 Planning Studio's goal was to understand the lifecycle of a natural disaster– from preparedness, to impact, to response and recovery. The project was divided in two, with the work distributed among four groups. These groups investigated how post-disaster emergency response and recovery is influenced by resilience and sustainability, disaster colonialism, and critical infrastructure. In Puerto Rico, all these themes interact, and it is impossible to talk about one without addressing the others. To understand the impact of natural disasters in Puerto Rico, we must recognize the "perfect storm" of structural challenges facing the island. Using the key concepts of sustainability alongside an understanding of Puerto Rico's political economy, history, and disaster impact, we designed our theoretical framework and conducted research that fit the cultural context.

Resilience and sustainability emerged as the first key concepts in our work. Resilience is the ability to "withstand shocks and disturbances and resume to a prior form or state of being" (Benson and Craig 2014). For example, if a natural disaster strikes a resilient community, it will be able to adapt and overcome. However, if a natural disaster strikes a vulnerable community, the outcome will be very different. Some assumptions about resilience assume the prior state of being as the standard, even though the original state of being was extremely fragile. Reconstruction is only sustainable if it is resilience. When we look at federal initiatives in Puerto Rico – such as FEMA disaster relief for housing assistance and assistance for PREPA electrical grid restoration – we see that they address reconstruction without addressing the underlying weaknesses that caused the vulnerabilities in the first place. By understanding resilience, we can understand what makes communities vulnerable and how these vulnerabilities are exacerbated by natural disasters.

The second concept is disaster colonialism. Disaster colonialism is "real structural oppression operating through institutional inaction or poor response to post-disaster reconstruction" (Rivera 2020). The theory of disaster colonialism can be used to understand Puerto Rico's history, its vulnerabilities, and the motives behind federal relief aid. In this project, we will see how colonialism operates in Puerto Rico through repeated disasters. Due to Puerto Rico's status as a U.S. unincorporated territory, it is denied full autonomy exercised by states, rendering it insufficiently capable of managing its own disaster preparation and response. Puerto Ricans argue that the mainland can manage these affairs but neglects to do so. This neglect – either passive or active, intentional or unintentional, by design or by default – reinforces colonial control by exacerbating dependency.

The third concept is critical infrastructure. As defined by the Cybersecurity and Infrastructure Security Agency (CISA), critical infrastructure are "infrastructure systems and assets that are so vital that their incapacitation or destruction would have a debilitating effect on security, the economy, public health, public safety, or any combination thereof." The infrastructure systems are interconnected and inter-dependent, therefore damage to one system often has cascading effects on others. Natural disasters are one example of disruption to critical infrastructure that produces major interruptions that threaten survival. Restoring critical infrastructure is one of the first and most complex steps taken towards recovery. Puerto Rico's fiscal challenges and geographic isolation from the mainland contributed to poor infrastructure maintenance and created vulnerabilities, particularly with the electrical grid, telecommunications networks, and food supply chains. When major natural disasters, such as Hurricane Maria, struck, they exploited those preexisting vulnerabilities, further complicating the recovery efforts.

Puerto Rico Since 2017

Since 2017, Puerto Rico has confronted a convergence of economic, political, and natural disasters, each posing significant challenges to the island's stability and development. Economically, Puerto Rico has grappled with a severe debt crisis, prompting the implementation of austerity measures, and contributing to financial instability (Garriga-López 2020). High unemployment rates have persisted, exceeding those of the mainland United States, exacerbating the island's economic woes. Moreover, the territory has experienced a notable population decline, as many Puerto Ricans have migrated to the mainland in search of better economic opportunities (Hinojosa 2018). Decades of underinvestment have left Puerto Rico with an aging infrastructure, further hindering its economic development (Aros-Vera 2021). Politically, governance issues and corruption have plagued the island, eroding public trust in government institutions. The ongoing debate over Puerto Rico's political status—whether it should become a state, independent nation, or remain a territory—continues to shape political discourse and policy decisions. Moreover, the relationship between Puerto Rico and the federal government has come under scrutiny, particularly regarding the adequacy of federal aid and support, especially in the aftermath of natural disasters (Willison 2019).

Puerto Rico has faced unprecedented challenges due to natural disasters in recent years. Hurricane Maria, one of the deadliest hurricanes in United States history, struck in 2017, causing widespread devastation, thousands of deaths, and leaving the island's infrastructure severely damaged. In addition to hurricanes, the island was rocked by earthquakes in 2019-2020, causing significant damage to homes, infrastructure, and public buildings. Furthermore, Hurricane Fiona, which struck in 2022, added to the island's woes, causing additional damage and further straining resources. Puerto Rico's susceptibility to tropical storms and floods further compounds its vulnerability to natural disasters, disrupting economic activity and exacerbating infrastructure deficits.

Despite efforts at recovery, the response to Puerto Rico's challenges has been marred by criticism, with many arguing that the assistance provided has been insufficient and slow. In the wake of the earthquakes and Hurricane Fiona, there was widespread condemnation of the federal government's response, with accusations of neglect and inadequate support (Bonilla 2019). The slow disbursement of aid and the lack of a coordinated response exacerbated the suffering of Puerto Ricans and hindered the island's ability to recover effectively. Furthermore, the long-term recovery and rebuilding process has been hindered by ongoing political disputes and bureaucratic inefficiencies, which slow the implementation of much-needed infrastructure improvements and economic revitalization initiatives. The persistent shortcomings in the response to Puerto Rico's crises highlight the need for greater accountability, transparency, and proactive measures to address the island's vulnerabilities and ensure a more robust and equitable recovery process in the future.

Project Descriptions

To address Puerto Rico's challenges, the 2024 Planning Studio worked with two clients on parallel projects. Groups 1, 2, and 3 worked with the Center for a New Economy to explore post-disaster vulnerability, damage and reconstruction. Group 4 worked with community leader Amaury Rivera to explore the impacts of improving energy resilience.

The first client was the Center for a New Community (CNE). CNE is recognized as Puerto Rico's first autonomous, nonpartisan research institution, dedicated to addressing the territory's most urgent economic development challenges, including reconstruction and recovery, energy, housing, and fiscal matters. Relying solely on philanthropic, private, and individual funding, CNE has enhanced productivity and stability in Puerto Rico for 25 years through empirical research and analysis of hard data. The organization maintains offices in San Juan, Puerto Rico, Madrid, Spain, and Washington, D.C. For more information about CNE, visit the website grupocne.org.

The second client was community leader Amaury Rivera. Rivera is an influential Puerto Rican community leader in Condado, a neighborhood in the capital San Juan. Before being an investment banker at Bear Stearns, Rivera pursued his education at Boston University and New York University. Rivera has held several board positions, such as the Chairman of the Puerto Rico Telecommunications Board's Universal Service Committee, President of the Board of the Puerto Rico Productions Association, and the White House Conferences of Small Businesses.

The Students

This year's studio blended graduate and undergraduate students from diverse academic backgrounds, which was a novel approach to the team organization. Out of the 13 participants, six were graduate students from a range of programs including City and Regional Planning, Global Development, and International Affairs.

The seven undergraduate students came from various disciplines, including Public Policy, Architecture, and Computer Science.

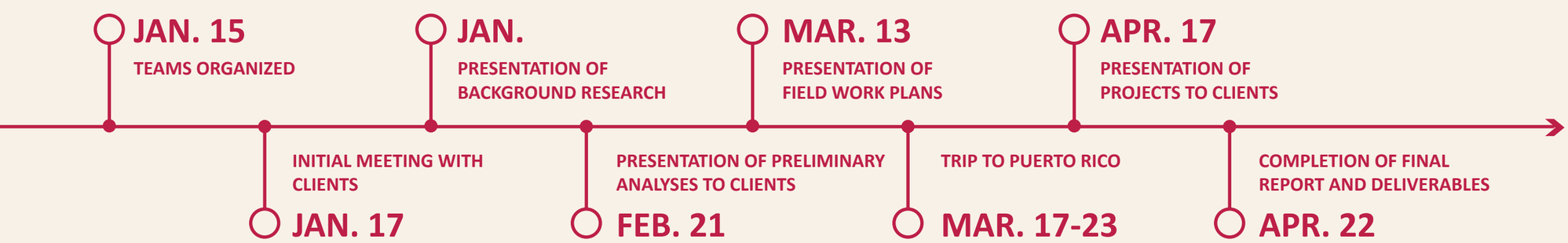
Students were divided into four groups based on their academic background, skills, and interests. Each group had at least one graduate student and one student with working knowledge of Spanish. Within each group, tasks were designated as follows: one member managed social media, another handled quantitative analysis, and a third led qualitative research. Collaboration across groups was encouraged to foster a collective effort to fulfill the studio objectives.

Team Structure		
Student	Program	Group
Mary Jane McCain	City and Regional Planning	1
Geyu Lyu	City and Regional Planning	
Diego Shipmon	Biology	
Samantha Bolton	Business Administration	
Ana Santos	Global Development	2
Ornela Gjoni	City and Regional Planning	
Noemi Carrilo	Public Policy	
Alison Hopkins	City and Regional Planning	3
Dimitri Castiblanco	Civil Engineering	
Jack Keller	Computer Science	
Kylie Regina Hossom	Architecture	4
Violeta Escandon Correa	Chemical & Biomolecular Engineering	
Michael Luke Nicholson	International Affairs	

Studio Structure and Timeline

The Planning Studio course was organized into two distinct parts. The first part was the lecture component, in which students studied the socio-economic, political, and disaster conditions in Puerto Rico. The second part was the studio time to work on client-based projects. The four teams of students devoted time to group work outside the normal lecture hours every week, often meeting with the professor and teaching assistant during these hours.

To complete this work, the course followed a strict timeline to complete all the objectives in one semester. After the students were organized into their groups, the teams met with the clients and began conducting background research on their respective projects. At the end of January, the teams presented their background research to the class. In the following few weeks, the teams conducted initial research of their projects and presented their preliminary findings to the clients and the class. In the weeks leading up to spring break, the students prepared for their fieldwork in Puerto Rico. During spring break, the class conducted site visits, field research, and interviews in Puerto Rico. At the end of the week, each group presented their findings and project updates to their clients. After returning to Georgia Tech, the teams finalized and submitted their deliverables, presented their final projects to the clients and the Georgia Tech community, and



CHAPTER 1

VULNERABILITY AND DAMAGE

Mary Jane McCain
Samantha Bolton
Diego Shipmon
Geyu Lyu

Introduction

Puerto Rico has faced a series of devastating disasters in recent years, including hurricanes, earthquakes, and other natural events, significantly impacting the daily lives of its residents across various sectors such as housing, infrastructure, and healthcare. The response to these disasters has often fallen short, with a notable disparity between the urgent needs of affected communities and the actual aid provided by the government. This gap has led to widespread criticism and highlighted the necessity of a more effective and targeted approach to disaster preparedness and response.

To better prepare for future disasters, it is imperative to identify the communities and areas within Puerto Rico that are most vulnerable. By pinpointing these vulnerable regions, resources and efforts can be strategically allocated to implement pre-disaster mitigation measures, such as infrastructure improvements and community resilience programs. Having a clear understanding of vulnerability hotspots enables authorities to streamline post-disaster response efforts, ensuring that aid reaches those in need more efficiently and effectively.

While there exist various vulnerability indices developed by different government and research agencies, they often lack specificity and may not fully capture the unique challenges faced by Puerto Rico. In this study, we aim to develop a localized vulnerability index tailored to the island's specific socio-economic and environmental context. This index will be informed by existing research and data, supplemented by fieldwork and stakeholder interviews conducted across the island.

The proposed localized vulnerability index will offer a more comprehensive and nuanced understanding of the factors contributing to vulnerability in Puerto Rico. By incorporating insights from local communities and experts, we can ensure that the index reflects the complex interplay of socio-economic, environmental, and infrastructural factors that influence vulnerability to disasters in the region. Ultimately, this index will serve as a valuable tool for policymakers, emergency responders, and community leaders, empowering them to make informed decisions and allocate resources more effectively in both pre-disaster planning and post-disaster recovery efforts.

In addition to constructing a vulnerability index, our research also places emphasis on analyzing the impacts of Hurricane Fiona and the 2020 earthquake to visualize the housing damage caused by these disasters and the extent of hazard exposure. By comparing the regions with the highest housing damages and hazard exposure to the special communities defined by the Puerto Rican government, we aim to identify communities that have been overlooked by governmental assistance and require future support. This approach serves as a valuable complement to the vulnerability index, as it provides insight into the specific impacts of disasters on communities. By incorporating disaster-specific impacts into our assessment, we can better understand the unique challenges faced by communities in Puerto Rico. This holistic approach enables us to develop comprehensive strategies for disaster resilience and preparedness, ensuring that vulnerable communities receive the support and resources they require to withstand future disasters.

Historical Context of Puerto Rico

Before we address vulnerability and hazard impact, we must introduce the sociopolitical and socioeconomic context in which the island exists. Puerto Rico is a territory of the United States shaped by a longstanding legacy of exploitation and colonialism. Puerto Rico's long-lasting attachment to a colonial power has left much of the island's infrastructure brittle, and its population largely disenfranchised. This lack of strong Puerto Rican autonomy and self-determination, combined with the growing impacts of climate change, make each natural disaster increasingly devastating.

The suppression of the Puerto Rican people has historically been two-fold; there is the cultural suppression of the Puerto Rican identity, and the subjugation of the Puerto Rican economy and government. Puerto Rico was a Spanish colony from the 17th century to the late 19th century. Spanish rule created strong cultural ingroups consisting of the children of any surviving indigenous Taíno, and slaves brought in from Africa to work on the sugar and coffee plantations. These marginalized people resented the Spanish regime and gave birth to cultural resistance movements like the Grito de Lares uprising in 1868 and the Intentona de Yauco in 1896. While powerful Puerto Rican heroes and symbols emerged from each of these rebellions, neither attempt was successful. After the Intentona de Yauco, Puerto Rico briefly managed to attain an independent charter status. Though the island was on a path towards autonomy, after the end of the Spanish-American war and the Treaty of Paris in 1898, Puerto Rico became an American territory. Puerto Rico possessed its self-governing status for less than a year.

While Puerto Rico's official status as an American colony was short lived compared to the island's time under the Spanish empire, the economic and cultural damage done to the island only deepened. Through a series of laws, the United States defined Puerto Rico as an unincorporated territory–, which gave Puerto Ricans U.S. citizenship but denied them the right to vote in federal elections, –and established a position of "Resident Commissioner" which was appointed by the president.

The Puerto Rican populace was thus cut out of the process of governance for their own island, and its lack of political autonomy would only deepen as the 20th century progressed.

So would the means of control. For instance, Law 116 in 1937 initiated a concerted eugenics effort on the island. By the 1950s, one in three Puerto Rican women had been forcefully sterilized. An already vulnerable population became endangered, and Puerto Rican culture was only further villainized by the mainland. The history of cultural and economic exploitation in Puerto Rico has led to a distinct lack of autonomy, weakening Puerto Rican communities and making them far more vulnerable to the impact of natural disasters. Any attempt to encapsulate, summarize, or infer Puerto Rican vulnerability must consider that the region has been repeatedly abused, disenfranchised, and suppressed by its colonial owners.

Vulnerability

To investigate vulnerability and resilience in Puerto Rico, we first developed a comprehensive understanding of the concepts of vulnerability and resilience. As we have seen, Puerto Rico has a very unique social, political, and economic context, which makes breaching the question of community vulnerability difficult. Many past studies have focused on single hazard-based variables like flood risk, or one category of indicators like housing damage. Considering the complexity of the Puerto Rican landscape, we believed it was most exigent to create a holistic and comprehensive measure of vulnerability. This way, community development programs and disaster mitigation funds could be disbursed to the communities with this highest need.

In this report, we take a three-pronged approach to the matter of community vulnerability in Puerto Rico (Appendix A). We evaluated vulnerability based on infrastructural, socioeconomic, and environmental indicators. Infrastructural variables refer to critical infrastructure such as telecommunications, electricity, access to food, water, and shelter. Socioeconomic variables consist of the demographic information of a region, including but not limited to the racial makeup of the region and median income. Environmental factors are those which are largely out of control of a given community but have a strong relationship with human development. Many of these factors are compiled in the Junta de Planificacion's (Planning Board of Puerto Rico) "Special Communities" framework, and we began our research by taking a deep dive into this methodology. While we found that the Junta de Planificacion was very thorough, many variables that contribute to vulnerability were missing. Therefore, we complemented this work by collecting community testimony from non-profit groups and NGOs on the island.

The culmination of this work is the Puerto Rican Community Vulnerability Index. This proposed vulnerability index would include all of the information used by ODSEC and the Junta de Planificacion to generate the special communities maps, but adds themes that arose from our fieldwork on the island. The additional variables we identified were as follows:

Infrastructural indicators

- Concentration of residents that hold their property titles
- Number of wood-built houses
- Remaining damaged houses (post most recent major disaster declaration)

Socioeconomic indicators

- Literacy rate
- Disability status
- Concentration of English Speakers

Environmental indicators

- Soil type
- Tree cover
- Flood plain status

We also selected three municipalities to highlight, based on those with the highest amount of damage from both the 2019-2020 earthquakes and hurricane Fiona. Loiza we chose through our fieldwork and conversation with Modesta from Taller Salud, while Jayuya is emblematic of the central, mountainous and rural communities affected by high rainfall, and Ponce is emblematic of those municipalities most impacted by the earthquakes.

Loiza

- Municipality with the highest density of Afro-Caribbeans on the island
- Almost half the population is at a vulnerable age, with 39.3% being under the age of 19 and 8.2% above the age of 65
- 67% of the population of Loiza is under the poverty line. More than half of all people in Loiza under the age of 19 or above the age of 65 live in poverty per the 2020 census
- Represents many communities of color which live in highly socioeconomically vulnerable states

Jayuya

- 56% of the population lives below the poverty line
- Municipality with strong ties to indigenous Taino roots
- Historically very culturally significant, but remote.
- Difficulty with informal construction and construction built on slopes
- Represents the difficulty in accessing and preparing remote mountainous communities.

Ponce

- According to the 2020 census, Ponce is the 4th most populous municipality, with similar economic and demographic composition to San Juan, Bayamon, Carolina & Caguas.
- Ponce is much less vulnerable than communities like Loíza and Jayuya, but we chose to highlight it to show that the municipalities interact with each other in a way that simply isn't captured by the Junta de Planificacion's special communities framework.
- The southwest corridor of Puerto Rico is home to a lot of the island's critical infrastructure, and damages to these areas have an intense impact on

Methodology

Qualitative

We gathered qualitative data to better understand the issues faced by local communities. This research involved two separate parts. We started with formal, virtual interviews from our location at Georgia Tech. The second portion was the fieldwork conducted on the island between March 17and March 27, 2024.

Our formal interviews began with Raphael Osuna. Raphael Osuna is an architecture alum from the University of Pennsylvania who served as an architect for the municipality of San Juan as well as for Habitat for Humanity, helping with the post-disaster reconstruction of recent hurricanes. We interviewed Raphael virtually on March 8th, focusing on how NGO's designate vulnerability and decide who is "more" or "less" in need. From this interview, we learned that a top-down approach is most effective for addressing communities in need. He explained that it is best to start by looking at the whole of Puerto Rico, and then narrowing down to a neighborhood, and then doing individual interviews.

Our second formal interview was with Dr. Jairo Garcia, a professor at Georgia Tech. Dr. Garcia is an expert in sustainable urban development, carbon mitigation, and climate resiliency He has held research and academic positions with the Earth Institute at Columbia University, UCLA, and presently teaches classes at Georgia Tech in Sustainable Urban Development, the Sustainable Cities Studio, and Introduction to Land Use Planning. In this interview, Dr. Garcia explained to us the value of community testimony.

During our fieldwork, we met with a small number of community, government, and NGO representatives. These interactions allowed us to understand how funding and resources are being distributed. This also helped us determine what factors of vulnerability needed to be considered in developing our index. For example, after our meeting with Modesta, a community leader of Loiza and member of Taller Salud, we understood that it was not funding that was missing, but human resource and volunteers to help with reconstruction, and that this lack of effective resource allocation also played into the community vulnerability status. Our meeting with ENLACE, showed the efficiency of partnership between community and government. Overall, gathering qualitative data from people and organizations on the island of Puerto Rico helped us create a comprehensive understanding of vulnerability and disaster impact on local communities.

Quantitative

I. Housing Damage Analysis

The Dataset

The dataset used for the analysis is from FEMA (OpenFEMA Dataset: Individuals and Households Program - Valid Registrations – v1). This dataset contains FEMA applicant-level data for the Individuals and Households Program (IHP). The original dataset only includes county, city, and zip code information for each applicant which was not granular enough for our study. We initiated a FOIA request and get data with census tract, block group, and block information included.

Data Cleaning, Manipulation and Mapping

We cleaned the data following the steps as follows:

a) Filter data based on disaster number: 4671 for Hurricane Fiona and 4473 for earthquake
b) Remove duplicate rows: no duplicates found
c) Remove rows with poor address (only for the FOIA request data): not all rows have full information of census tract/block group/block which is usually tied to poor address information being supplied at registration (i.e. incomplete street address, P.O. boxes, etc.). The dataset uses 'noint' to represent poor address which means the Applicant's Damaged Dwelling Address when geocoded did not intersect the Census geometry. These rows were removed.

Due to the FEMA Aggregate Policy, if a block contained 10 or fewer applicants, the block was identified as requiring the GEOID data to be filtered. In those cases, the attribute was changed from the GEOID to the attribute 'FILTERED'. These rows were removed. The filtering results show that block-level data include only a small portion of the original data which may not be representative enough so we decided to use block group-level data for the following analysis.

d) Aggregation: We aggregated the housing damage to the zip code/census block group. Although block level data is more granular, from Appendix B Table 1, we can see that only very small percentage of the records are kept due to the FEMA Aggregation Policy. We chose block group as the unit for our further analysis.

To calculate the housing damage value, we only included homes inspected by FEMA and having FEMA damage value, which means that not all records (valid registration) are included in the calculation, as shown in Appendix B Table 2 and 3.

The total damage is the sum of two attributes "rpfvl" and "ppfvl" in the dataset, which include real property components and personal property components.

- **rpfvl:** FEMA-determined value of disaster-caused damage to real property components, including floors, walls, access roads and bridges, electrical, plumbing, HVAC, etc.

- **ppfvl:** FEMA-determined value of disaster-caused damage to personal property components, including appliances, furniture, etc.

e) Mapping: We downloaded the 2020 census block group boundary shapefile and joined the aggregated housing damage value for each census block group we got from the last step to the shapefile based on the block group GEOID using ArcGIS Pro.

II. Hazard Exposure

Data and Mapping

There are four major datasets used for the hazard exposure maps which are listed below:

a) Earthquake Intensity
The earthquake intensity data is from USGS which shows the contours in the Mercalli Intensity Scale.

b) Liquefaction
The liquefaction data is from USGS and there are 32 liquefactions included in the dataset.

c) Flood Hazard
Flood Hazard data is from the FEMA National Flood Hazard Layer. We only visualize the area with a 0.2% annual chance flood hazard, the area with 1% annual chance flood hazard, and the regulatory floodway.

d) Precipitation
The precipitation data are quality-controlled, multi-sensor (radar and rain gauge) precipitation estimates obtained from National Weather Service (NWS) River Forecast Centers (RFCs) and mosaicked by National Centers for Environmental Prediction (NCEP). We downloaded the daily precipitation data from 2022/9/16 to 2022/9/20 and summed the value to get the accumulated rainfall during this period.

By overlaying the above data with the census block group boundaries, we generate maps to illustrate how the two disasters affected Puerto Rico. We also incorporated the municipal boundaries of Puerto Rico to emphasize the municipalities severely affected by the disasters.

III. Special Communities

The Data

To develop our vulnerability index, it was important that we explore the Special Communities initiative that was instituted by the Oficina Para El Desarrollo Socioeconómico y Comunitario de Puerto Rico in 2001. This initiative is designed to address the challenges faced by communities on the island that exhibit a significant level of social and economic vulnerability. The maps pertaining to these regions were generated in the years 2006 (Appendix C Figure 1) and 2018 (Appendix C Figure 2). However, obtaining data from the original special communities was challenging for our project due to the fact that the map was based on 76,000 household data collected by ODSEC through travel to various areas, to interview households involving the condition of their homes, economic status and education. The second map was also created by the Puerto Rico Planning Board but contained indicators mostly related to transportation. Finally, we used the Census Community Resilience Estimates that determine what areas have a high risk of natural disasters and their ability to withstand them.

Deliverables

Special Communities

Oficina Para El Desarrollo Socioeconomico y Comunitario de Puerto Rico (ODSEC), a government agency, established the Special Communities in Puerto Rico in 2001 with the aim of enhancing the infrastructure and economic prospects of marginalized communities on the island. The primary objective of this office is to eliminate poverty in Puerto Rico, employing the establishment of Comunidades Especiales de Puerto Rico, also known as "Special Communities," to determine the specific regions on the island that require the most significant socioeconomic transformations within their respective communities. This deliverable entails a comprehensive examination of the special communities and the maps created by the ODSEC. Our analysis aims to provide valuable insights into how the island can efficiently utilize hard data and other resources to compare the state of the communities before and after natural disasters, the COVID-19 pandemic, and other economic factors that have exacerbated the emergence of additional marginalized communities.

Vulnerability Index

Vulnerability indices were developed to quantify the extent of exposures within a given population. The indices consist of several qualitative indicators that assess the level of risk associated with each indicator. We considered all adverse impacts that can lead to external human health pressures, like the CDC/ATSDR Social Vulnerability. Developing such an index can assist individuals in Puerto Rico's communities in their efforts to anticipate and recuperate from calamities. We construced an index that encompasses economic, social, and environmental vulnerabilities. Emergency planners, public health officials, and local governments can utilize this index to provide guidance for meeting community-based needs. Our index distinguishes itself from the conventional index by targeting vulnerable communities or "Special Communities" already identified by the ODSEC qualitative research through interviews with residents and community leaders to gather their perspectives on the factors that render their community vulnerable, and the ongoing community needs they perceive.

Housing Damage Map

The Housing Damage Map we developed illustrates the aftermath of earthquakes and hurricanes, specifically assessing their effects on housing and housing damages. The data utilized in this study was obtained from the OpenFEMA Dataset, specifically from the Individuals and Household Program and the Valid Registrations of the respective organizations. This dataset provides information on the individual housing aid received by each housing unit and the FEMA-identified Homes with Damages. However, it is important to note that housing damage encompasses a broader range of impacts, including power outages, which further exacerbate vulnerabilities outside of physical housing damage. When constructing this map, our intention was to provide a more comprehensive analysis of the effects of the natural disaster, as they undermined the infrastructure and intersected with the island's recovery efforts and the communities residing within it.

Hazard Exposure Map

The island's housing damage is mainly attributed to environmental disasters, particularly Hurricanes such as Fiona and the series of earthquakes that occurred in 2020. Consequently, it is crucial for us to acknowledge the enduring consequences of past disasters, such as Hurricane Maria, on the hazard exposures of specific communities. To assess the magnitude of these natural disasters, it is necessary to analyze the primary indicators that arise from the elevated frequency of hazard exposures. Hurricanes are evaluated using key indicators, such as the distribution of rainfall measured in inches, to analyze flood risk, which contributes to landslides. The seismic events that also occurred in 2020 serve

as evidence of the vulnerability to hazards, despite their localized occurrence in a specific region near the island's southwestern part. However, the earthquakes and hurricanes have a significant damaging impact on social centers, churches, and mostly homes, leading many residents on the island to seek shelter and evacuate, further creating Special Communities.

Findings

Housing Damage

Appendix B compares the results of Hurricane Maria, Hurricane Fiona, and the earthquake. The table shows how many homes are inspected by FEMA and how many of them have further identified damage value. We noticed that only 12% of homes are inspected by FEMA and only 7% have damage value which is much lower than the other 2 disasters. We also calculated the total damage value and average value. Different types of damage to homes are identified by FEMA and we show the total number for each housing damage type.

Figures 1 and 2 display the housing damage at the zip code level caused by Hurricane Fiona and the earthquake, respectively. Nearly all zip codes were affected by Fiona, with most damage concentrated in the southeastern region and along the hurricane's path. The earthquake's damage is centered around the epicenter of the earthquake in the southwestern region, and there is a noticeable pattern: the closer a zip code is to the epicenter, the more damage it has suffered.

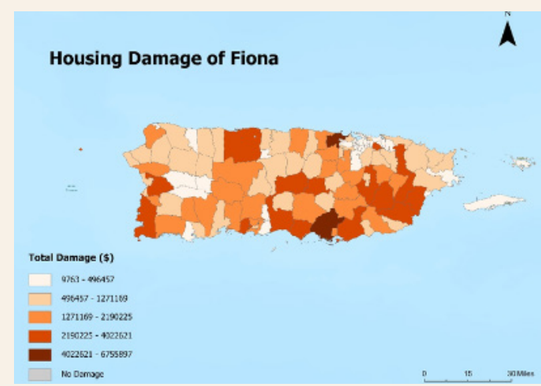


Figure 1. Zip Code Level Housing Damage of Fiona

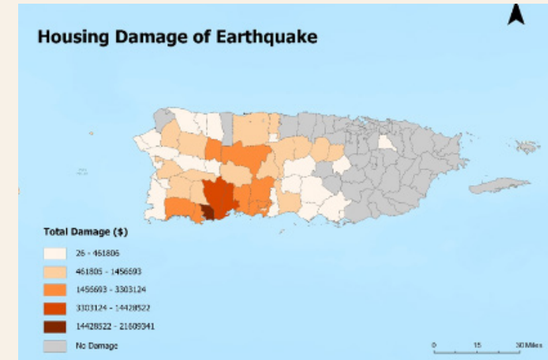


Figure 2. Zip Code Level Housing Damage of Earthquake

Figures 3 and 4 depict the housing damage at the block group level caused by Hurricane Fiona and the earthquake, respectively. Out of 2531 block groups, 1946 were affected by Fiona, while 524 were affected by the earthquake. Unlike the map at the zip code level, the distribution of damage does not exhibit a clear pattern. This discrepancy arises from numerous block groups lacking damage values, which may reflect the actual situation or result from data filtering due to insufficient address information for geocoding to the census boundary.

By utilizing a more detailed dataset, we aim to identify communities significantly impacted by these disasters, allowing for comparison with the special communities designated by the Puerto Rico government. This comparison could inform updates to the special communities dataset. However, the quality and accuracy of the FEMA dataset currently hinder further analysis. We anticipate that FEMA will enhance data quality, particularly by improving efforts during the data collection stage—for example, by recording applicant addresses more precisely. Such improvements would provide researchers and policymakers with a better dataset to support future studies.

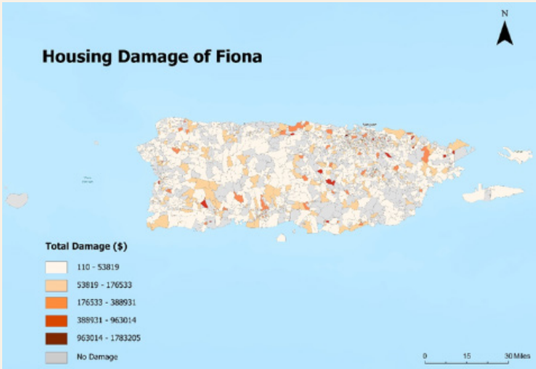


Figure 3. Block Group Level Housing Damage of Fiona

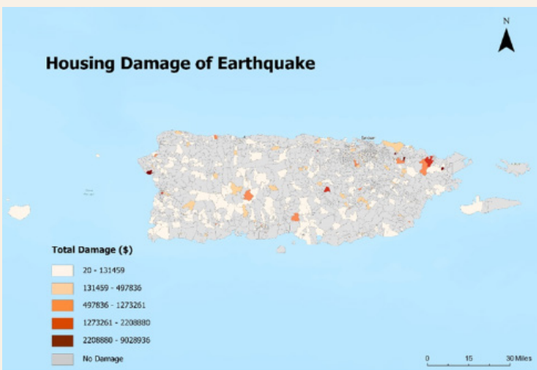


Figure 4. Block Group Level Housing Damage of Earthquake

Hazard Exposure

Figure 5 shows that most rainfall occurred in the central and southeastern regions. When comparing this data with FEMA's identified flood risk zones, most regions are not recognized, indicating a lack of preparation for flooding. This absence of preparation and experience in handling floods renders these areas more vulnerable compared to regions that have undergone specific flood risk mitigation measures. Figure 6 demonstrates the varying intensities of the earthquake across different regions. We have identified seven municipalities severely impacted by the earthquake."

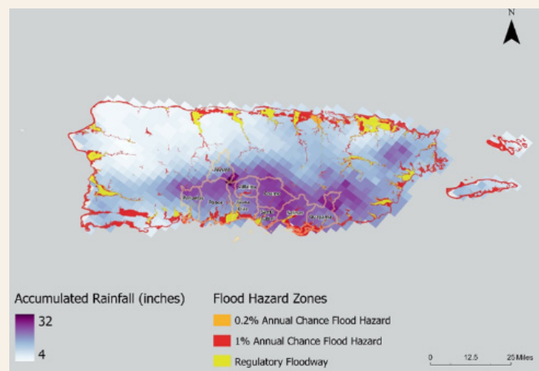


Figure 5. Hazard Exposure of Fiona

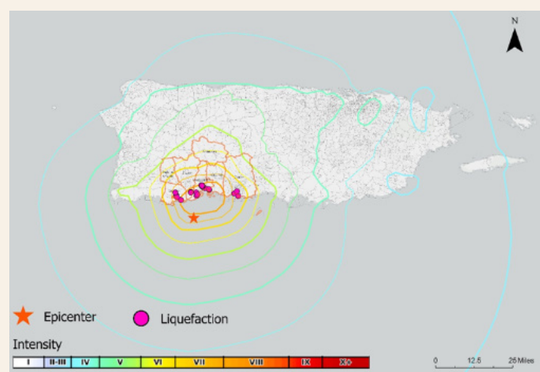


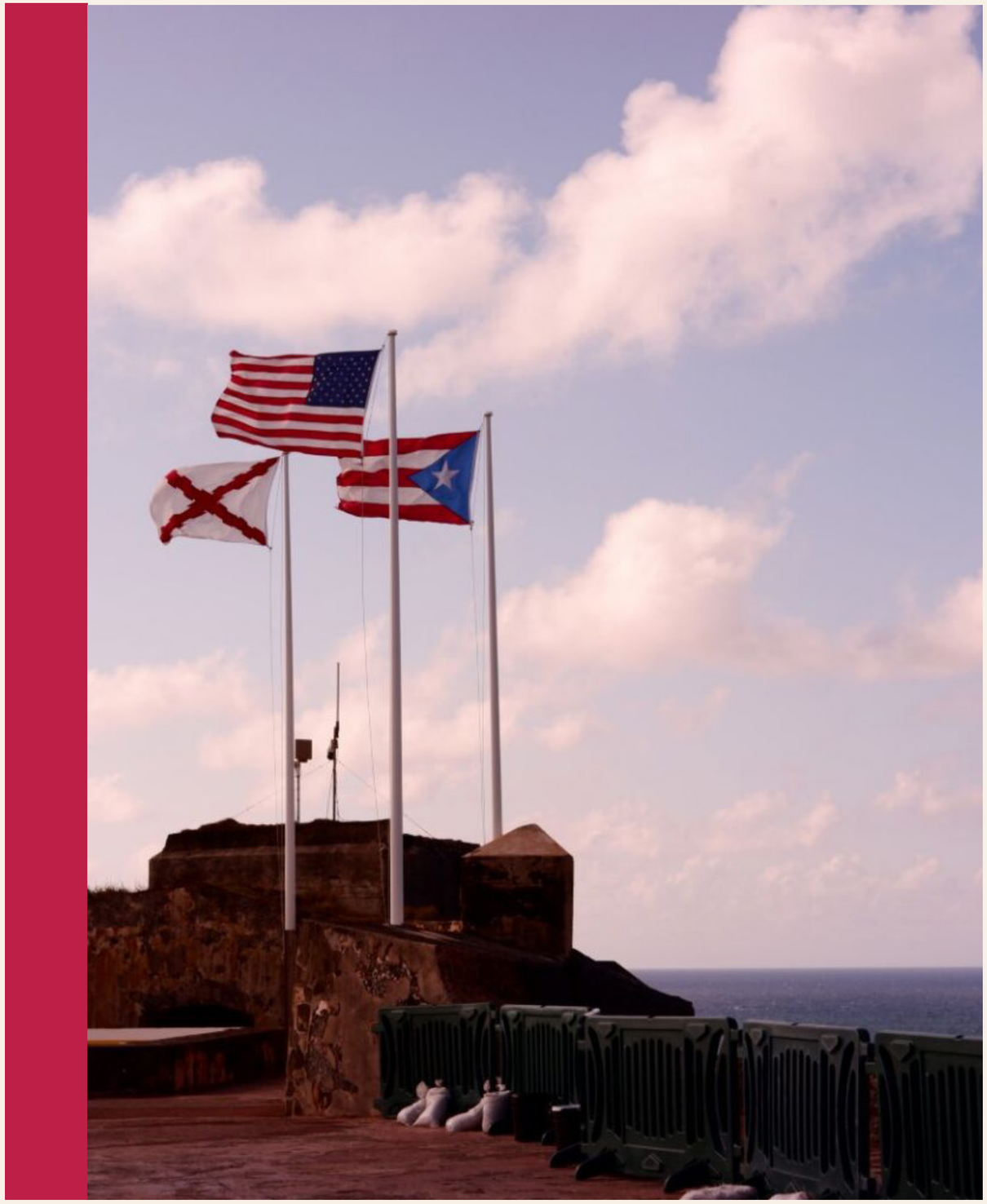
Figure 6. Hazard Exposure of Earthquake

CHAPTER 2

PUBLIC RECOVERY AND RECONSTRUCTION

Analysis of FEMA Housing Relief Aid Post-Earthquake and Hurricane Fiona

Ana Santos
Noemi Carrilo
Ornela Gjoni



Introduction

How was the allocation of Federal Emergency Management Agency (FEMA) relief aid stratified among certain factors–such as residential tenure status–after Hurricane Fiona and the 2020 earthquakes in Puerto Rico? Our group's objective was to analyze and map Puerto Rico's public recovery and reconstruction for the immediate periods following those major natural disasters. For the public recovery effort, we focused on housing relief, specifically FEMA's Individual Assistance (IA) program and distribution of Individuals and Households Program (IHP) funds.

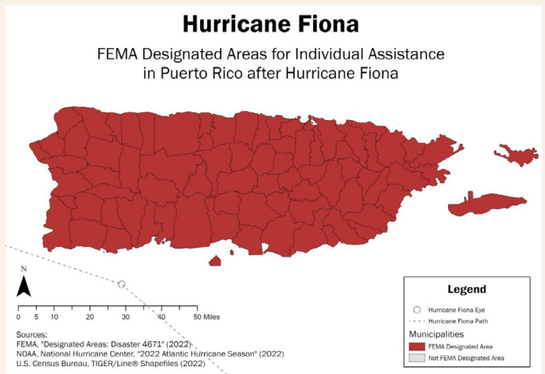


Figure 7. FEMA designated areas for Individual Assistance in Puerto Rico after Hurricane Fiona

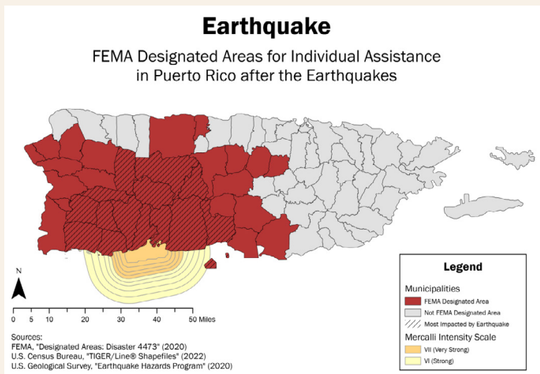


Figure 8. FEMA designated areas for Individual Assistance in Puerto Rico after the earthquakes

On September 18, 2022, Hurricane Fiona struck Puerto Rico as a Category 1 storm. The eye of the hurricane made landfall on the southwestern side of the island, but the hurricane's wind and rainfall affected the entire island (Ramos Scharrón et al., 2023). Hurricane Fiona was characterized by high amounts of rainfall, upwards of 32.4 inches in some areas. This excessive rainfall led to mudslides and flooding throughout the island. Due to the island-wide impacts of Hurricane Fiona, FEMA classified all the island's 78 municipalities as Designated Areas for Individual Assistance for disaster declaration DR-4671-PR.

How was the allocation of Federal Emergency Management Agency (FEMA) relief aid stratified among certain factors–such as residential tenure status–after Hurricane Fiona and the 2020 earthquakes in Puerto Rico? Our group's objective was to analyze and map Puerto Rico's public recovery and reconstruction for the immediate periods following those major natural disasters. For the public recovery effort, we focused on housing relief, specifically FEMA's Individual Assistance (IA) program and distribution of Individuals and Households Program (IHP) funds.

FEMA

The federal government's Puerto Rico's post-disaster reconstruction efforts rely on multiple federal funding sources. However, our analysis focused on one of FEMA's Individual Assistance (IA) programs: the Individuals and Households Program (IHP). FEMA's IA Program is a major source of housing aid and assistance in Puerto Rico's post-disaster reconstruction. The IA program offers essential assistance in the initial months after a disaster, addressing basic needs and the most pressing reconstruction problems. The IA program is a crucial resource due to its ability to deliver swift and impactful assistance following an extreme weather event, as opposed to other major housing reconstruction initiatives which unfold over prolonged periods of time.

The goal for the allocated funds is to improve the habitability standards to a reasonable level. Eligible individuals can receive rental, repair, or replacement assistance. Inspections are an important component in the IA program, as they allow FEMA to verify losses and damages. Through the inspections, FEMA collects the needed information to decide whether an applicant is eligible for assistance or not.

There are several types of housing damage the program acknowledges: roof damage, flood damage, foundation damage, and destroyed households. However, these categories may not encompass all potential damages identified during onsite inspections. For instance, there might be documentation of issues such as broken windows, damaged doors, or fallen fences, but these would not fall under the specified damage categories (Lamba-Nieves, Santiago-Bartolomei, 2022).

Literature Review

Factors

Hurricane Maria

Hurricane Maria, which struck Puerto Rico in September 2017, brought to light many issues the disaster recovery and relief mechanisms employed by the federal government. Hurricane Maria was one of the costliest natural disasters in the U.S. history. Official federal government reports estimated up to $90 billion in damages and nearly 3,000 official deaths due to Hurricane Maria (García, 2021). Hurricanes Harvey and Irma hit the mainland in Texas and Florida respectively and Maria arrived in the same timeframe. Through analyzing the disaster responses to Hurricanes Harvey, Irma, and Maria, Researchers were able to see a great difference between the mainland and Puerto Rican responses (Willison et al., 2019). While all three hurricanes were strong, the response to each varied, with Maria receiving less than a third the aid that Harvey and Irma saw in similar time frames. The legacy of Hurricane Maria continues to affect federal disaster response and recovery in Puerto Rico.

Issues with Application and Inspection Process

FEMA has standards in place to mitigate issues with aid approval and distribution, such as secondary or vacation homes not qualifying for IHP assistance (FEMA, 2024). However, there are still concerns about the effectiveness of FEMA's application and inspection process. There have been several occasions where assessments were incomplete and inaccurate. This can be attributed to several problems encountered during the inspectors' training process (Lamba-Nieves and Santiago-Bartolomei, 2022). Additionally, there were stark differences in response between the concurrent natural disasters on the mainland and Hurricane María in Puerto Rico. This difference in response has been studied by various individuals seeking to identify what caused such a poor response from the federal government. García found that, in the FEMA inspection process for IA, recurring problems included: the inability to schedule an inspection, language barriers, funds received insufficient to cover damages, home titling verification issues, and inspectors' inability to navigate the island (2021).

Residential Tenure Status

"Tenure security" remains a significant issue in Puerto Rico, as high levels of informality in both construction and titling have placed a significant portion of households in a vulnerable position, according to research by Lamba-Nieves and Santiago-Bartolomei (2022). FEMA administrative procedures disproportionally favor certain aid applicants over others. For example, homeowners and other "finally secure households" are more likely to receive aid, while areas with high concentration of rental housing tend to have "less access to federal disaster assistance" (2022). Households without formal property titles were less likely to be eligible for aid. Additionally, after Hurricane María, residents with "unknown tenure status" were unlikely to receive any type of assistance (2022). Therefore, it is crucial to analyze whether the same observation can be made for Hurricane Fiona and the 2020 earthquakes.

Methodology

Quantitative Data

Our data methodology uses individual registrant information to assess housing damages after natural disasters, disbursement of FEMA housing aid, and social characteristics of aid recipients. Our project's methodology is modeled after Lamba-Nieves and Santiago-Bartolomei's "Who Gets Emergency Housing Relief? An Analysis of FEMA Individual Assistance Data After Hurricane María" in which they examined how federal post disaster aid was disbursed post-Hurricane Maria. The researchers looked at how FEMA's Individual Assistance (IA) operates, which applicants were aided, what sociodemographic factors determined probability of assistance, and if housing needs were equitably addressed. The determining factors examined were poverty, residential tenure status, and geographic vulnerability. Their data set included applicant-level information for the Individuals and Households Program (IHP) from FEMA. The researchers also used U.S. Census Bureau's Puerto Rico Community Survey (PRCS) to analyze sociodemographic characteristics down to the census block geographic level. For our project, we applied this data methodology to evaluate the impact of the 2020 earthquake and Hurricane Fiona and how aid was disbursed based on residential tenure status. Data about IA registrants came from the "OpenFEMA Dataset: Individuals and Households Program - Valid Registrations – v1" and a Freedom of Information Act (FOIA) request (Case Number 2024-FEFO-00499). These datasets contained FEMA IHP applicant-level data for declared disasters, including DR-4473-PR (Earthquakes) and DR-4671-PR (Hurricane Fiona). FEMA removed all Personal Identifiable Information (PII) information. In our FOIA request, we asked FEMA to include more granular geographic information such as census tract and census block. We also used U.S. Census Bureau data from the 2020 and 2022 American Community Survey.

Qualitative Data

To gain a fuller perspective of the distribution of FEMA relief we identified a need to speak to impacted individuals, inspectors, and the government agencies which distribute the funds. Through our literature review, we identified areas of interest which may benefit from qualitative insight, such as the inspection and application process. We then created a list of questions for each group we wanted to contact, which are listed in Appendix D: Table 1. We identified which specific organizations and people to contact through our client. We contacted these individuals by emailing the general departments or organization's email on their websites and being redirected to the appropriate point of contact. In the case that emailing did not work well, as was the situation for some smaller organizations in Puerto Rico, we called the number provided and were able to set up meetings. If no response was given otherwise, our method of contact was to go to the organization or agency's offices during business hours and request a meeting which allowed us to interview three individuals. All interviews were semi-structured, enabling the natural flow of conversation and unplanned follow-up questions which could clarify information we did not have.

The interviewees also changed as our research progressed and our scope for what additional information we may benefit from changed. This widened our government agencies we sought to interview from FEMA and its directly related agencies in Puerto Rico to also include those relevant to the disbursement of Community Development Block Grant Disaster Recovery (CDBG-DR) program funding such as the Puerto Rico Department of Housing (Departamento de la Vivienda). From our new list of groups of interest, we interviewed nine individuals, listed in Appendix D: Table 2.

Findings

Interviews

For our project, we interviewed government agencies, local organizations, and community leaders to understand the effects of disaster response in Puerto Rico. The interview topics were the impact of natural disasters and how public aid disbursement may have been stratified among certain factors, such as poverty or geographic vulnerability. Even though our focus was on the 2020 earthquakes and Hurricane Fiona in 2022, it is impossible to talk about natural disasters in Puerto Rico as singular events. As we found in our interviews, all discussions about disaster response in Puerto Rico start with Hurricane Maria, which devastated the island in 2017. In our discussions with local and federal government representatives, legal aid funds, and community leaders, we learned about how FEMA assistance was distributed throughout the island for these disasters and the impact it has left.

People in Puerto Rico faced many obstacles when it came to accessing government assistance. The disbursement of aid may not have reached all who were qualified or eligible due to lack of access, issues of titles and ownership, and language barriers. Interview subjects who worked with low-income and disadvantaged communities said government aid was difficult to access. FEMA addressed these concerns and explained how the agency was responsive to concerns and issues of accessibility.

A common theme among the interviews was lack of access to resources. First, the FEMA assistance application process was difficult for many. Amaris Torres-Rivera, Executive Director of Fundación Fondo de Acceso a la Justicia, emphasized the collapse of the electrical grid and telecommunications services in the aftermath of Hurricane Maria compounded on an already existing "technology gap" (2024). She highlighted her Puerto Rico-based civil legal aid organization's work to address this gap by bringing mobile hotspots, portable printers, and technical and legal assistance to affected communities. According to Rosaura Rodríguez, a Puerto Rican artist and educator based in Jayuya, FEMA's highly bureaucratic nature makes aid inaccessible for many people, especially those who do not speak English, who are unfamiliar with "government lingo," and who have low levels of literacy (2024).

FEMA addressed some issues of accessibility for disasters due to the COVID-19 pandemic. One major difference between Hurricane Maria and Hurricane Fiona is that applicants could submit their own photos in assistance applications, rather than only permitting inspector's photos. This helped reduce the caseload for inspectors since the submissions were enough evidence for some applications, with a smaller portion having follow-ups with inspectors. Kevin Edwards, Incident Management Assistance Team (IMAT) Operations Section Chief of FEMA's Region 2, also addressed issues of internet access and telecommunications (2024). Edwards said that during FEMA's response to Hurricane Fiona, remote areas had temporary communications technology brought in to facilitate relief efforts.

Another issue was how FEMA's procedures did not fit Puerto Rico's context. One example is how Puerto Rico's way of proving property titles and ownership is different than FEMA's. The issue of ownership and land titles proved to be a systemic barrier for many people seeking assistance. Torres-Rivera said that up to 85,000 households after Hurricane Maria and 20,000 households after Hurricane Fiona were

denied assistance "based on ownership." FEMA needs to understand the "long Spanish, Hispanic tradition," the "influences of civil code," and the "culture of land tenure and ownership" on the island. Another example is how Puerto Rico is an isolated island distant from the mainland. Johann Sasso, an Emergency Manager for the U.S. Army Corps of Engineers (USACE) in Puerto Rico and the U.S. Virgin Islands, said that the federal response plans for the contiguous 48 states, such as timelines and guidelines, do not "fit" the constraints of the Caribbean island.

A final issue was language barriers. FEMA personnel who responded to Hurricane Maria in Puerto Rico, a majority Spanish-speaking island, "all spoke English," said Torres-Rivera, which is a "violation of civil rights." Prospective applicants who were not able to use the internet and tried to apply for assistance via phone faced up to six hours of waiting time to speak to a representative in Spanish, according to Torres-Rivera. Sasso said that during Hurricane Maria, local USACE staff were being overutilized for translation services, which is beyond the scope of their mission. Sasso says that FEMA has since addressed that issue by adding a "line item" to pay for translation services in disaster response budgets.

FEMA acknowledged concerns about Spanish-speaking inspectors. In an interview, Edwards said the quantity of available housing inspectors during Hurricane Fiona in Puerto Rico was affected by a concurrent disaster relief effort in Florida, which also has a need for Spanish-speaking inspectors. This increased demand for Spanish-speaking inspectors exacerbated communication and translation issues between inspectors and those in need of an inspection in Puerto Rico. Newton Tang, the Operational Planning Branch Chief for Region 2 at FEMA, said that FEMA prefers temporary local hires from the impacted areas to reduce lodging costs for imported inspectors, injects money into the local economy, and acts as an initial push to help remedy post-disaster recovery efforts.

Aid disbursement was criticized for not reaching low-income and disadvantaged people. Modesta Irizarry, a community leader in a coastal town near San Juan called Loíza, said FEMA assistance "never arrived" and that the most productive recovery efforts were from nonprofits, not governments. It was difficult for low-income, disadvantaged people to benefit from the government's housing voucher program. The housing voucher process was too slow, and the vouchers were too small, according to Irizarry. Not only did the vouchers take up to one year to arrive, but by the time they arrived, they did not cover the costs of the home. In the meantime, many potential buyers from the mainland were coming to her town and offering bids on homes, said Irizarry. Many residents were forced to choose between selling their home for immediate cash or waiting for an insufficient voucher. Rodríguez, who lives in the central mountainous region of Puerto Rico, also found the FEMA aid to be insufficient. After Hurricane Maria, Rodríguez's household tried to apply to some available assistance funding, but said FEMA offered them loans instead, "which wasn't what we were needing."

One issue FEMA raised was the issue of communication and information dissemination. For example, after Hurricane Fiona, FEMA designated all municipalities as designated areas eligible for Individual Assistance. Edwards said around 600,000 applicants registered for assistance within the first 72 hours of the disaster declaration, with 1.2 million registered for assistance within the allotted period. Edwards said the volume of registrations was unexpectedly high and that he suspected this to be due to possible misinformation spread at the time of the declaration. According to our analysis of FEMA data, approximately 300,000 houses, or 25 percent of the total applicants, were reported as damaged. Sasso from the USACE also cited communication as an issue for disaster response, saying that different agencies and organizations often push different, sometimes conflicting messages before, during, and after a natural disaster. This negatively impacts the ability of individuals and groups to prepare for and respond to a storm.

In conclusion, people affected by the natural disasters said that FEMA assistance was inaccessible and not distributed equitably. Issues such as lack of access to the FEMA application, issues of titles and ownership, and language barriers were barriers to assistance. FEMA appeared aware of the criticisms directed at their agency in the aftermath of Hurricane Maria. FEMA gave specific examples of how administrative changes have been implemented to address these issues. However, affected people in Puerto Rico still await to see if these changes "on paper" translate into changes in on-the-ground response.

Data

First, we looked at relevant figures from the U.S. Census Bureau. We used American Community Survey 5-year estimates for the two years in which our specific disasters struck. These Census figures were used in later analysis of FEMA data.

According to the data, the total population increased by 0.51 percent, whereas the mean household size saw a decrease by 0.63 percent. As Table 1 shows, there was an increase of 13.98 percent in the median household income over two years. Furthermore, the percentage of residents living under the poverty line decreased by 2.83 percent. Most notably, the category of Mobile Home or Other saw a substantial decrease of 30.76 percent.

Damages

Our objectives for the quantitative analysis of our project included analyzing the data to build three categories of tables for each of the disasters in focus. The first table category provides detailed information about the housing damage following the disasters. The second category targets the housing assistance distribution through the IA Program. Finally, the third table category aims to summarize information on how the post-disaster aid was distributed when broken down by tenure status.

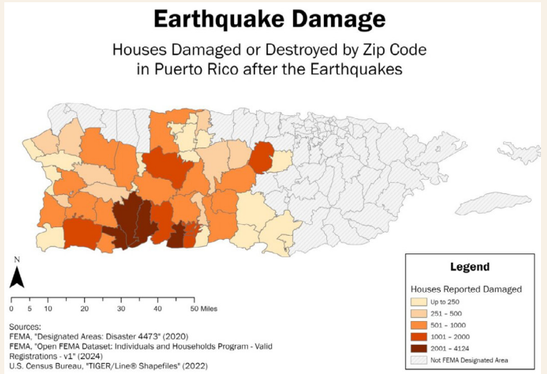
Table 1: Comparison of Census Figures in Puerto Rico

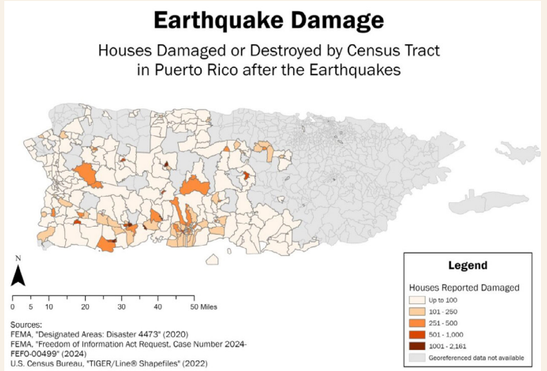
Puerto Rico	2020	2022	Percent Change
Population	3,255,642	3,272,382	+0.51%
Housing Units	1,205,749	1,219,658	+1.15%
Mean Household Size	2.7	2.68	-0.63%
Median Household Income	$21,058	$24,002	+13.98%
Percent Under Poverty Line	43%	41.8%	-2.83%
Percent Owner Occupied	67.6%	68%	+0.38%
Percent Renter Occupied	32.2%	31.9%	-0.79%
Percent Mobile Home or Other	.4%	.2%	-30.76%

The process of estimating housing damages by FEMA precedes aid distribution. Onsite inspections and other alternate methods are employed by FEMA to record and classify those damages. However, an inspection does not always follow the submission of an IA application. As mentioned earlier, there are four main categories for housing damage: roof damage, flood damage, foundation damage, and destroyed housing units. However, it is worth noting that this list of housing damages is not exhaustive (Lamba-Nieves, Santiago-Bartolomei, 2022).

Table 2 gives detailed figures regarding the number of applications inspected and determined to have suffered housing damage following the 2020 earthquakes. As the data indicates, over 37,000 households were determined by FEMA to have suffered some type of residential or personal property damage. Additionally, 3.1 percent of the houses experienced some kind of damage. Table 2 shows that the average home damage amounts to $2,226.71 with 294 homes destroyed. Foundation damage was the most prevalent kind of structural harm, followed by roof damage with 2,346 housing units reporting this type of damage. Finally, two housing units experienced flood damage.

Table 2: Housing Damages in Puerto Rico after the Earthquakes	
Occupied Housing Units in Puerto Rico	1,205,749
Homes with Damages	37,501
Percent of Damaged Homes	3.1%
Aggregate Damage	$83,503,662
Average Home Damage	$2,226.71
Total Homes Destroyed	294
Total Homes with Flood Damage	2
Total Homes with Roof Damage	2,346
Total Homes with Foundation Damage	20,121



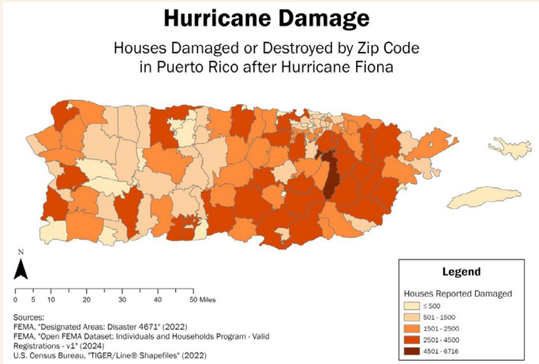


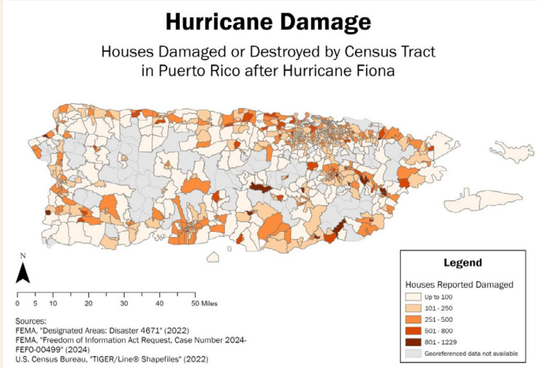
The two maps above show the number of housing units reported as damaged in the aftermath of the earthquakes, according to FEMA IHP data. The first map aggregates total houses damaged by ZIP Code Tabulation Areas (ZCTA) and the second map aggregates total houses damaged by census tracts.

We conducted the same analysis for Hurricane Fiona as well. The number of households with damage was much higher for Fiona – over 307,000 households were reported to have experienced some type of damage.

Table 3 summarizes the number of applications inspected and determined to have suffered housing damage after Hurricane Fiona. As shown in the table, 25.2 percent of the houses experienced some kind of damage. Additionally, the average home damage amounts to $2,106.70, which is slightly less than that of the earthquakes. Only 36 homes were destroyed, less than the number of destroyed houses following the earthquakes. As expected, the data indicates flood damage as the most prevalent kind of structural harm that affected residential units in Puerto Rico, with 7,561 housing units experiencing this type of damage. Furthermore, among the applications that were inspected, none reported roof damage or foundation damage.

Table 3: Housing Damages in Puerto Rico after Hurricane Fiona	
Occupied Housing Units in Puerto Rico	1,219,658
Homes with Damages	307,225
Percent of Damaged Homes	25.2%
Aggregate Damage	$647,229,925
Average Home Damage	$2,106.70
Total Homes Destroyed	36
Total Homes with Flood Damage	7,561
Total Homes with Roof Damage	0
Total Homes with Foundation Damage	0





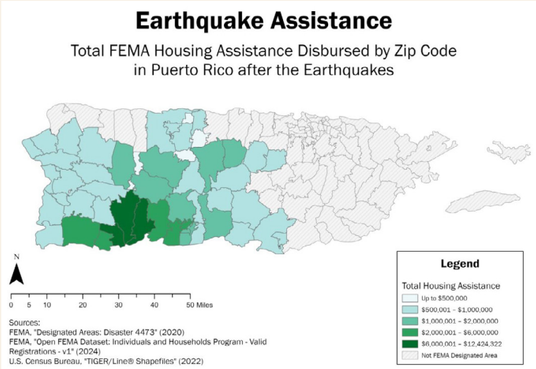
The two maps above show the number of housing units reported as damaged in the aftermath of Hurricane Fiona, according to FEMA IHP data. The first map aggregates total houses damaged by ZIP Code Tabulation Areas (ZCTA) and the second map aggregates total houses damaged by census tracts.

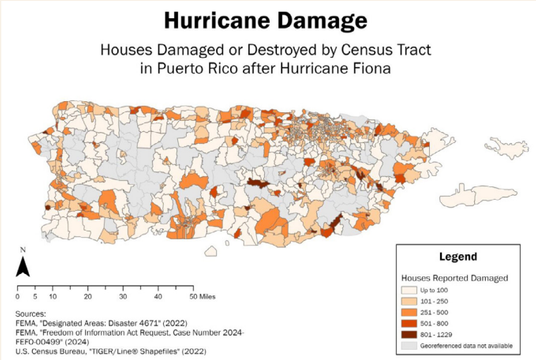
Disbursement

Under the IA program, affected households can receive several types of assistance. Our analysis is focused on the Housing Assistance subprogram which covers damage to residential and personal property, including furniture and essential equipment to meet household needs (Lamba-Nieves, Santiago-Bartolomei, 2022). Table 4 summarizes how assistance was disbursed following the 2020 earthquakes.

Table 4: Housing Assistance through the IA Program for the Earthquakes	
Total Homes that Received Monetary Housing Assistance	12,538
Percent of Damaged Homes that Received Assistance	33.4%
Aggregate Housing Monetary Assistance	$74,569,701
Total Homes that Received Rental Assistance	9,980
Average Rental Assistance Amount	$1,094
Total Homes that Received Repair Assistance	9,226
Average Repair Assistance Amount	$5,920
Total Homes that Received Home Replacement Assistance	292
Average Home Replacement Assistance	$30,933
Percent of Destroyed Homes Replaced	99.3%

Although over 37,501 inspected homes suffered some form of damage, only 33.4 percent were eligible for and received some form of housing assistance for home rental, repair, or replacement. Like in Hurricane Fiona, the two most common forms of housing assistance were rental and repair assistance. Over 18,000 applicant households received these benefits. The average repair amount provided by the FEMA IA program was $5,920 which is about $3,000 more than the average damage per applicant household determined by FEMA. The average rental amount provided by the FEMA IA program was $1,094, which is about $1,000 less than the average damage per applicant household determined by FEMA. 292 applications received home replacement assistance. In addition, the average home replacement assistance was $30,933. Finally, 99.3 percent of the destroyed homes were replaced.





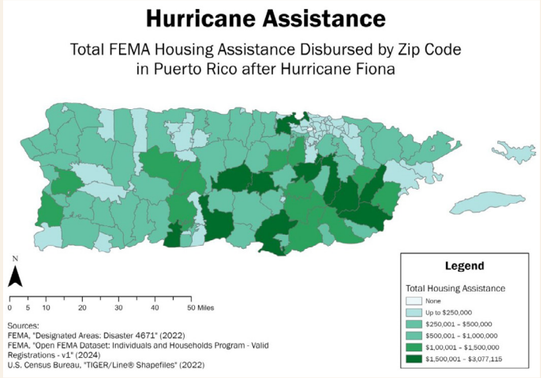
The two maps above show the amount of housing aid disbursed in the aftermath of the earthquakes, according to FEMA IHP data. Housing aid is the sum of rental assistance, repair assistance, and replacement assistance. The first map aggregates the total monetary assistance disbursed by ZIP Code Tabulation Areas (ZCTA) and the second map by census tracts.

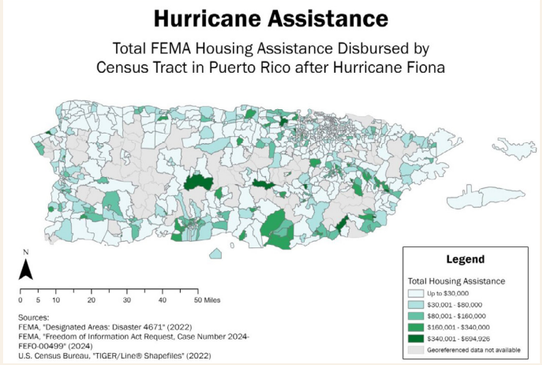
Using the same methodology, we were able to analyze Hurricane Fiona's aid distribution. Table 5 provides a summary of those findings. The data unearths some trends which seem to persist across the disasters.

Table 5: Housing Assistance through the IA Program for the Hurricane Fiona	
Total Homes that Received Monetary Housing Assistance	19,819
Percent of Damaged Homes that Received Assistance	6.5%
Aggregate Housing Monetary Assistance	$72,987,263
Total Homes that Received Rental Assistance	10,773
Average Rental Assistance Amount	$1,045
Total Homes that Received Repair Assistance	14,564
Average Repair Assistance Amount	$4,189
Total Homes that Received Home Replacement Assistance	19
Average Home Replacement Assistance	$37,900
Percent of Destroyed Homes Replaced	52.8%

Although over 307,225 inspected homes had some form of damage according to FEMA standards, only 6.5 percent were eligible for and received some form of housing assistance for home rental, repair, or replacement. However, it is worth noting that this percentage is due to the substantial number of applications, with Hurricane Fiona receiving over 1.2 million. Similarly to earthquakes, the two most common forms of housing assistance were rental and repair assistance. Over 25,000 applicant households received these benefits. The average repair amount provided by the FEMA IA program was $4,189 is about $2,000 more than the average damage per applicant household determined by FEMA.

The average rental amount provided by the FEMA IA program was $1,045, which is about $1,000 less than the average damage per applicant household determined by FEMA. Only 19 applications received home replacement assistance. In addition, the average home replacement assistance was $37,900.





The two maps above show the amount of housing aid disbursed in the aftermath of Hurricane Fiona, according to FEMA IHP data. Housing aid is the sum of rental assistance, repair assistance, and replacement assistance. The first map aggregates the total monetary assistance disbursed by ZIP Code Tabulation Areas (ZCTA) and the second map by census tracts.

Distribution by Tenure Status

Our research question seeks to address how relief aid was stratified among certain factors such as residential tenure status for both disasters. As a result, for the following tables, we focus on tenure status alone and try to understand how this factor influenced post-disaster aid distribution.

Table 6: IHP assistance distribution by tenure status – 2020 Earthquakes

Tenure Status	Any Assistance		Rental Assistance		Repair Assistance		Replace Assistance		Total # of Applicants
	App. that received assistance	% Total	App. that received assistance	% Total	App. that received assistance	% Total	App. that received assistance	% Total	
Homeowner	10,390	0.6	37,832	23.1	9,224	27.2	292	0.9	33,994
Renter	2,147	6.3	32,147	36.3	1	0.02	0	0	5,909
Unknown	1	0.3	1	0.3	1	0.3	0	0	331
Total	12,538	7.2	69,980	59.7	9,226	27.52	292	0.9	40,164

When broken down by tenure statues, the 2020 earthquakes' distribution of assistance varied greatly by assistance and program type (Table 6). Repair assistance was overwhelmingly allocated to homeowners, but only 27.2 percent of these households were recipients, a larger share compared to Hurricane Fiona. Similarly to Fiona, renters benefited more from renter assistance when compared to repair assistance, with 36.3 percent of renters receiving aid from the renter assistance program. The percentage of homeowners who received rental assistance was 23.1 percent. Finally, replacement assistance was completely allocated for homeowners. Similarly to Hurricane Maria, households deemed to have unknown tenure status were almost completely excluded from these programs. Finally, by comparing Hurricane Maria, Hurricane Fiona, and the 2020 earthquakes, we concluded there are consistent patterns across these disasters. Furthermore, they align with what we gathered from our fieldwork and with what existing literature suggests.

Employing the same variables, we constructed Table 7, which provides a summary of how IHP assistance was distributed by tenure status after Hurricane Fiona hit the island.

The data indicates that, similarly to the 2020 earthquakes, there is great variance in how aid was distributed. In this case too, repair assistance was overwhelmingly allocated for homeowners, but only 1.9 percent of these households were recipients. For rental assistance, renters benefited much more when compared to repair assistance, but only 0.5 percent of them received aid from this program. The percentage of homeowners that received rental assistance was 1.2 percent. Finally, replacement assistance was completely allocated for homeowners. The trend of "exclusion of the unknown status" persists –- households that were deemed to have this tenure status were almost completely excluded from every type of aid.

Table 7: IHP assistance distribution by tenure status – Hurricane Fiona

Tenure Status	Any Assistance		Rental Assistance		Repair Assistance		Replace Assistance		Total Number of Applicants
	App. that received assistance	% Total	App. that received assistance	% Total	App. that received assistance	% Total	App. that received assistance	% Total	
Homeowner	17,534	2.3	8,489	1.2	14,561	1.9	19	0	776,516
Renter	2,282	0.5	2,281	0.5	2	0	0	0	458,517
Unknown	3	0.42	3	0.42	1	0	0	0	709
Total	19,819	3.2	10,773	2.12	14,563	1.9	19	0	1,235,742

CHAPTER 3

POST-DISASTER PRIVATE CONSTRUCTION AND PERMIT DISTRIBUTION

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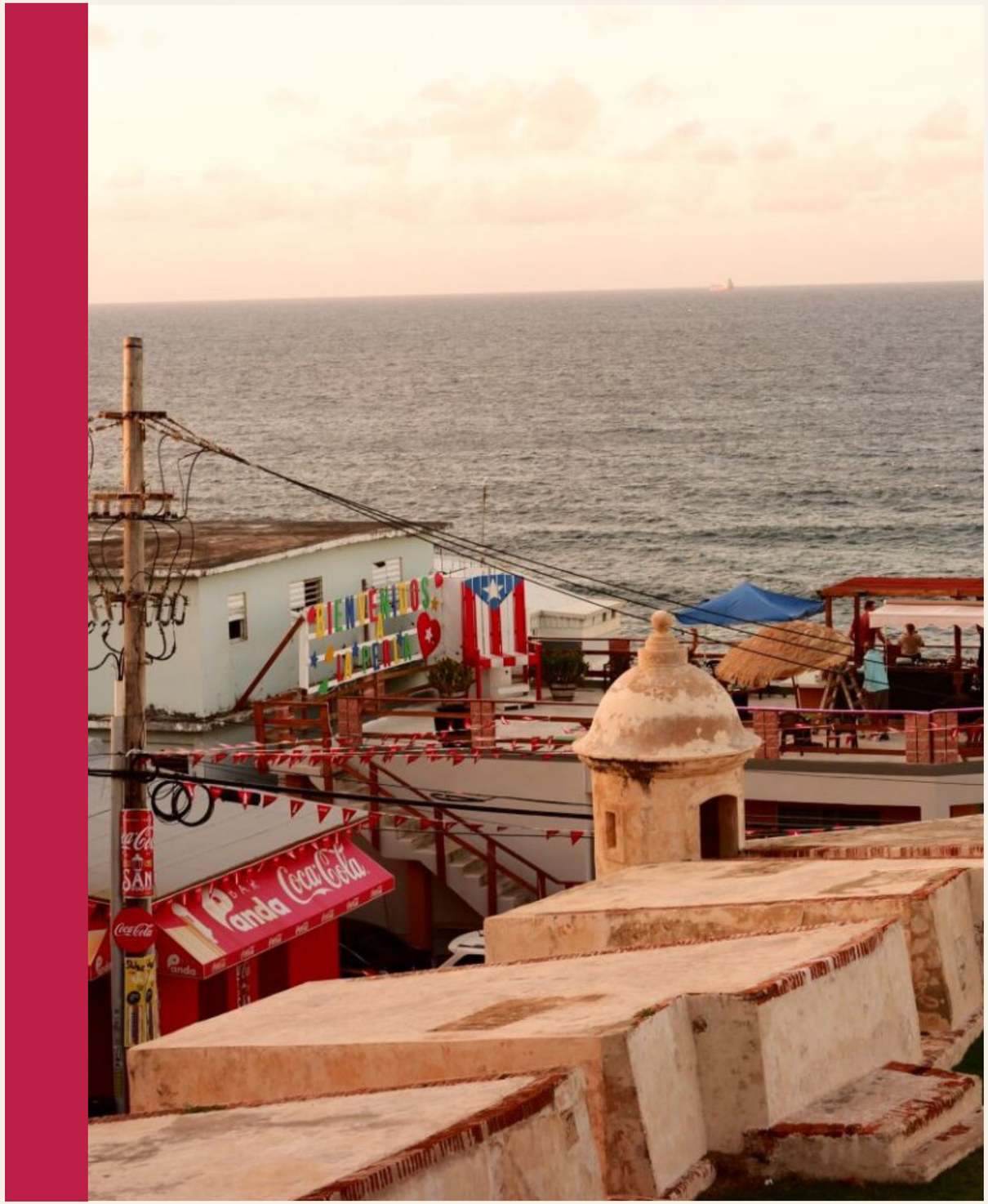

Introduction

Our group was tasked with understanding the role of the private construction industry in Puerto Rico's post-disaster recovery process. We aimed to build upon preexisting scholarship and the work of the 2023 Studio by updating the construction permits dataset they gathered, analyzing trends in the data, and crafting a narrative describing patterns and challenges faced by the island's construction industry. We analyzed the spatial distribution of construction permits and chronological trends in permit issuance following Hurricanes Irma, Maria, and Fiona, as well as the 2020 earthquakes. The repeated shocks left Puerto Rico's housing stock and infrastructure seriously damaged. Our findings indicate that despite flaws in the permitting process, uneven permit distribution, and serious challenges to reconstruction, the amount of formal construction occurring in Puerto Rico has been growing.

Regulatory Context and Construction in Puerto Rico

The practice of issuing construction permits is intended to ensure that changes to the built environment comply with land use and structural regulations. Land use regulations are one of the key mechanisms that planning entities use to guide and control development and construction. The laws establishing land use patterns in Puerto Rico are called the Reglamento Conjunto. This "joint regulation" was established in 2010 by the Junta de Planificación–the Planning Board of Puerto Rico.

There have been a series of unsuccessful attempts to modify this code. During the development of the 2019-2020 Reglamento Conjunto, the required public involvement actions were modified or conducted improperly, and the Supreme Court of Puerto Rico annulled it (Microjuris). The permit offices have been enforcing an outdated code while keeping track of changes to code with uncertain legal standing. In June of 2023, the government issued an emergency order to implement the 2023 Reglamento Conjunto. The outdated legislation and uncertainty mean that the changes the Planning Board has made intending to increase sustainable development are not being implemented. The Reglamento Conjunto exists alongside special area zoning codes administered by some municipalities.

In addition to ensuring land use compliance, permits ensure that construction projects are structurally sound and meet safety and design standards. The current building code on the island was enacted in 2018 and was developed with input from FEMA so that new construction would be less likely to flood, more resistant to wind in the event of a hurricane and have more structural features that respond to liquefaction in the event of an earthquake.

Construction permitting in Puerto Rico is done by two offices. At the commonwealth level, there is the Oficina de Gerencia de Permisos (OGPe) or the Permit Management Office responsible for permits in municipalities that do not have the means to support their own offices. Then, there are municipal-level offices. These offices work in tandem to review and approve permits submitted through the Single Business Portal (SBP), which handles construction and usage permits. The Single Business Portal is the online portal that OGPe and the municipal offices use to review and approve permits. Usage permits include fire occupancy certifications, electrical permits, or plumbing permits that are an extension of the building code. All construction projects must submit blueprints signed by a licensed architect or engineer. Projects that comply with the Reglamento Conjunto are issued ministerial permits. Projects that do not align with the existing zoning are classified as discretionary permits. These permit applications are required to undergo an environmental impact assessment and are subject to public input and judicial review. Ministerial permits are often exempted from environmental review and are generally approved quicker. The 2023 studio report concluded that the permitting process in Puerto Rico was "inefficient, piecemeal, and expensive" (Batool et. al 2023).

Before the natural disasters, Puerto Rico experienced la crisis Boricua, a period marked by labor market deterioration. "The number of public-sector employees at the 'state' level in Puerto Rico fell by about 33 percent [...] between 2006 and 2014, and those employed by local

and municipal governments declined by 12 percent" (Mora, 2017). In 2016, the passage of PROMESA and the creation of the Junta de Supervisión Fiscal financial oversight board added additional austerity measures that limited the island government's ability to carry out basic functions (Mora, 2017). The firms on the island that are involved in the formal construction sector are at a disadvantage, competing with mainland contractors, with "the bulk of federal expenditures for both relief and recovery efforts [...] not flowing into Puerto Rico-based businesses, and [...] has not been very effective in stimulating the local economy" (Marxuach, 2022).

To understand the role of the private construction industry in Puerto Rico's post-disaster recovery process, we sought to answer key questions. How have permit issuances changed between 2017 and 2023? How are permitted construction projects distributed geographically? What kinds of issues are causing the problems in permitting identified by the 2023 studio? What patterns have people involved in construction and construction permitting noticed following natural disasters? What issues have people in the private sector identified as barriers in reconstruction efforts?

Methodology

Quanitative

Data Overview and Preprocessing

Two primary datasets were utilized in the quantitative portion of our research. The first is a construction permit dataset, which contains records of construction permits filed with the Oficina de Gerencia de Permisos (OGPe), or Permitting Office of Puerto Rico, from December 2014 through November 2023. The 2023 Puerto Rico Studio used previous version of the same dataset with data through September 2022.
The second dataset, "Selected Statistics of the Construction Industry," was compiled by the Junta de Planificación, or Planning Board of Puerto Rico. While this dataset includes many categories of statistics, we focused on the total value of private construction activity in Puerto Rico. According to the Junta de Planificación, this is estimated by summing investments in the construction of housing, commercial and industrial buildings, and privately funded infrastructure. Property insurance is another factor in the valuation (Ruiz et al., 2023). The data is broken down by fiscal semester, ranging from 2012 to 2022.

We took steps to clean both datasets (See Appendix F: "OGPe Construction Permits Dataset - Cleaning & Analysis" and "Construction Industry in Puerto Rico – Data Summaries") using the R programming language. The raw OGPe construction permits dataset contained 33,505 rows and 20 variables. First, we translated the dataset from Spanish into English. Next, we removed duplicate rows. A small subset of rows were missing cost (2.95 percent), and we denoted these missing costs with the value 0. Next, Federal Information Processing Standards (FIPS) codes were generated for each row based on the "x" and "y" variables, which define cartesian coordinates. Notably, 0.53 percent of rows were missing latitude and longitude coordinates; thus, we relied on cartesian coordinates when mapping instead, which were provided for every permit. Additionally, we created a duration variable that represents each permit's approval time. Lastly, we parsed the description variable to estimate the categories each permit may belong to, such as residential, construction, or corporate owner. We created 28 categories, each represented by a binary-encoded variable.

The Junta de Planificación dataset was cleaned similarly by formatting the Excel dataset to be workable, removing missing values, renaming variables, and converting columns to numeric data types. We filtered the data to include private construction statistics only.

Spatial Mapping of Permits

We used ArcGIS software to map the permits geographically. The data was first preprocessed and filtered using RStudio, as described earlier. We filtered the data to include permits that were filed within a given reconstruction period. We also removed all publicly funded permits. Private, public-private alliance, and public with private contracting permit types were included while mapping. It is important to note that all the permits in the dataset were either approved or pre-approved, so there was no need to filter for approval status. All the permits included in the maps represent real, on-the-ground construction projects.

We analyzed four distinct reconstruction periods. The first spans one year after Hurricane Irma struck. Since Hurricane Maria struck shortly after Hurricane Irma, we included it in the same reconstruction period. The next period spans one year after the 2020 Earthquakes. We chose the day after the most powerful earthquake in the series hit, January 8th, as the beginning of this reconstruction period. Next, we analyzed the one-year period following Hurricane Fiona. Finally, we analyzed an overall reconstruction period which spans from Hurricane Irma's landfall to November of 2023.

Once the data for each reconstruction period was gathered, the spatial coordinates corresponding to each permit were converted to point data using the "Add XY Point Data" function in ArcGIS. It is important to note that while the Census data is formatted according to spatial code EPSG:4269, the permit coordinates are in EPSG:4437 format. TIGER/Line shapefiles provided by the United States Census Bureau were used to gather 2020 census data at the Census Block and Census Tract level. For all maps, populations corresponding to the Census Block level were summed to the Census Tract level using the "Summarize Within'' function. We chose to map permits at the Census Tract level because they are digestible yet granular. Next, the following steps were repeated for each distinct reconstruction period. First, the construction permits were binned into their respective Census Tracts using the "Aggregate Points" function. Then, the raw permit counts were normalized by dividing them by each respective Census Tract's population. This ratio was multiplied by 100,000 to obtain the permit count per 100 thousand capita for each Census Tract. Finally, the permit counts were divided into equal-frequency categories using the "Quantile" distribution. In each case, one more category was added to capture outliers which included counts greater than a threshold, such as 1,000 permits.

Qualitative

We conducted a series of semi-structured interviews with individuals in the public sector and the private sector. In the public sector, we interviewed employees at OGPe, the San Juan Municipal Permitting Office, and the Caguas Municipal Permitting Office. In the private sector, we interviewed engineers with Venegas Construction, employees at the Puerto Rico Builders Association, and a gestor (a person who can be hired by people trying to go through the permit process). These interviews were conducted over the phone, through Zoom, online video conferencing, and in person. Interviews were conducted in English or Spanish, based on the interviewee's preference. The interview questions covered the permitting process, the impacts of the hurricanes, earthquakes, the COVID-19 pandemic, informal construction, changes to the building code and the Reglamento Conjunto, and economic development strategies (See Appendix E: Group 3 Interview Question List.).

Overview of Deliverables

Our final deliverables included both quantitative and qualitative components. On the quantitative side, raw and clean data and the code used to clean the data were provided. A data dictionary that describes the OGPe dataset and its variables and records of the correspondence with organization staff to obtain the dataset was prepared as well. For mapping, the ArcGIS project itself and a description of the mapping procedure were included. Lastly, the generated figures, tables, and maps were provided.

On the qualitative side, a comprehensive narrative of the permitting process in Puerto Rico, including regulatory context, the permitting process itself, and obstacles to permitting was created. Information gained from interviews with construction companies and organizations was also discussed within this narrative. Copies of our interview questionnaires, fieldwork agenda, and pictures of site visits were also provided in the deliverables.W

Findings

Overall, our findings seek to understand the role that the private construction industry has played in Puerto Rico's post-disaster recovery process. To answer this, we have relied heavily on both quantitative and qualitative methods, including various interviews. On the quantitative side, the geographic mapping and analysis of construction permit data over time have proved crucial to our research. However, before this process began, we sought to better understand the data by calculating descriptive statistics and visualizations. The results of this preliminary analysis are highlighted below.

Variable	Statistic/Category	Value/Count
Approval Time (days)	Mean	108.951
	Standard Deviation	162.307
	Range	0 - 2480
Estimated Cost (US$)	Mean	275,299.203
	Standard Deviation	1,689,750.323
	Range	0.210 - 179,675,453
Project Type	Private	29,423 (90.5%)
	Public	879 (2.7%)
	Public with Private Contracting	2155 (6.6%)
	Public-Private Alliance	53 (0.2%)
Rural/Urban	Rural	14,494 (44.6%)
	Urban	18,016 (55.4%)
Filed by Permitting Assistant (PA)	Yes	6,076 (18.7%)
	No	26,434 (81.3%)
Corperate Owner	Yes	4,506 (13.9%)
	No	28,004 (86.1%)
Total Rows		33,441

Table 1 gives an overview of the construction permits dataset with descriptive statistics such as mean, standard deviation, and range, along with the distributions of different permit types.

Table 1: Construction Permits Summary highlights the mean, standard deviation, and range for continuous variables in the dataset such as approval time and estimated cost. It also includes counts and percentages of the total dataset for categorical variables like project type and corporate owner. Note that the filed by PA variable denotes whether a permit was filed by an authorized permitting assistant or not. Table 1 reveals that the mean approval time for a permit filed in Puerto Rico is roughly 109 days. Also, the standard deviation of estimated cost is extremely high, which means the dataset is representative of construction projects of vastly different scales. Lastly, while the dataset contains a fairly even split of rural and urban permits, most are private.

Figure 1: Approval Time Vs. Estimated Cost of Construction Permits by Project Type

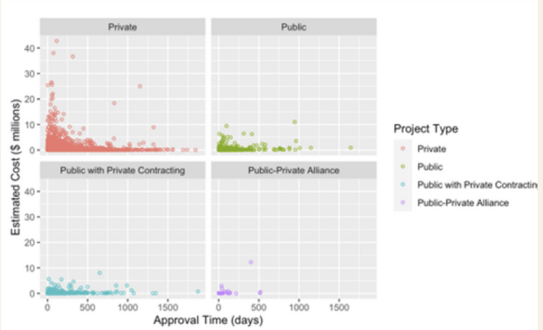

Figure 1 contains four scatterplots for private, public, public with private contracting, and public-private alliance permit types which show the relationship between approval time and estimated cost in US dollars.

Figure 2: Approval Time Vs. Estimated Cost of Construction Permits by Rural/Urban Classification

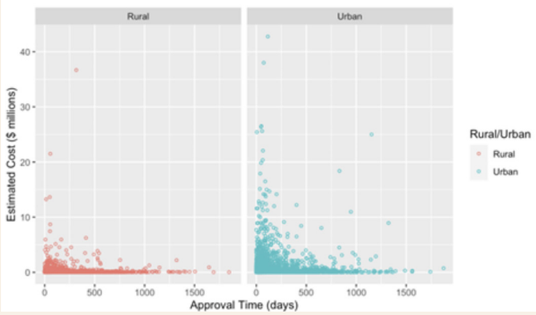

Figure 2 contains two scatterplots for rural and urban permit types which show the relationship between approval time and estimated cost in US dollars.

Figures 1 and 2 (see above) plot the permits based on two variables: approval time and estimated cost. Additionally, the data points are color-coded to represent different categories or types, which differ across the plots. In general, the plots highlight that approval time and estimated cost are inversely related (this is especially true in the rural and private categories). Therefore, the more expensive a construction project is, the quicker its permit will be approved, on average.

To illustrate how private reconstruction trends in Puerto Rico have changed over time, the following figures in this section are organized chronologically from Hurricanes Irma and Maria until the present day.

Figure 3: Total Value of Private Construction Activity in Puerto Rico

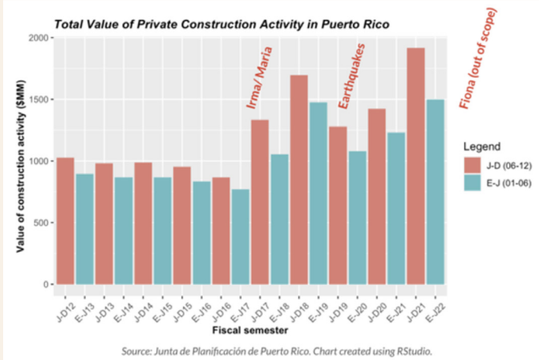

Figure 3 is a bar chart showing the total value of private construction activity in Puerto Rico broken down by fiscal semester from 2012 to 2022.

Figure 3 (see above) was generated from the "Selected Statistics of the Construction Industry" dataset provided by the Junta de Planificación (Ruiz et al., 2023). To understand trends and patterns in reconstruction following recent natural disasters, we analyzed construction patterns during the individual time periods following each disaster and comprehensively analyzed them from Hurricane Irma to the present day.

As shown in Figure 3, private construction activity dipped in the six months immediately following recent disasters but rose one year later. We chose to map permits filed at the year mark following each of the natural disasters to reflect real-life reconstruction patterns.

Our qualitative research indicates that construction picked up more at the annual mark than the 6-month mark because of the delayed permitting process. In interviews, OGPe and certain municipal permit offices reported staffing problems and technological issues with the SBP since its

in 2018. During the SBP's introduction, OGPe had to send people to individual permit management offices to teach them how to operate the SBP. Our interviews also found that the SBP may not appropriately filter permits to the correct office based on the cadastre or location information. Additionally, information available in the GIS data provided by the planning board can slow down the permitting process if it ever goes down. These issues with the SBP learning curves, technological problems, and the COVID-19 pandemic could explain the "dip" in construction activity from 2018 to 2020 in Figure.

In interviews with the private sector, we learned that COVID-19 significantly impacted the construction industry, with restrictions limiting the amount of work they could take on and the health risks to the workforce. There has been a steady increase in construction and permitting since Hurricanes Irma and Maria. There are several contributing factors to this including increased

Figure 4: Distribution of Private Construction Permits in Puerto Rico 1-Year Following Hurricanes Irma/Maria by Census Tract

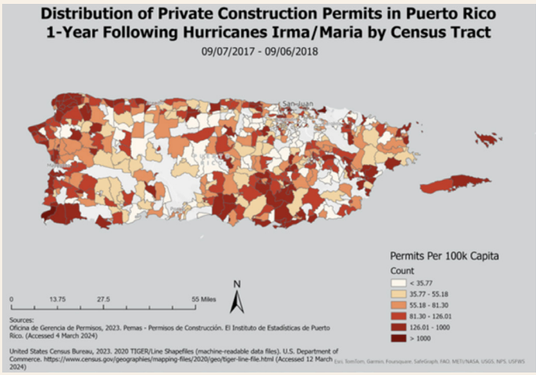

Figure 4 is an aggregate map showing the distribution of private construction permits in Puerto Rico during the one-year period following Hurricanes Irma and Maria, broken down by Census

Figure 4 (see above) shows the distribution of private construction permits per capita in the one-year interval following Hurricane Irma. Since Maria struck only two weeks later, causing even more damage, we combined these two disasters into one reconstruction period in our analysis. The darker areas on the map correspond to denser concentrations of permits. The gray areas indicate places where zero permits were recorded or where data was unavailable. The permit counts are adjusted by population so permit distribution can be compared in a standardized way.

Large regions of the island show a complete lack of formal construction. Puerto Rico's cultural acceptance of informal construction was emphasized during several of our interviews. This idea showed up, particularly in our interview with employees from the Caguas Municipal Permitting Office. They said many families in Puerto Rico build new homes as their family grows, leading to many homes on one parcel of land. For this very reason, many households in Puerto Rico lack official land titles for their property. However, proof of ownership is an integral part of the permitting process. A lack of a title precludes permit issuance, so those without paperwork to prove their land ownership choose to build without the permit instead. As people choose to build informally without a permit, they also inevitably end up without a title or proof of ownership, which leads to a self-perpetuating cycle of informal construction and lack of land titles.

Figure 5: Distribution of Private Construction Permits in Puerto Rico 1-Year Following Earthquakes by Census Tract

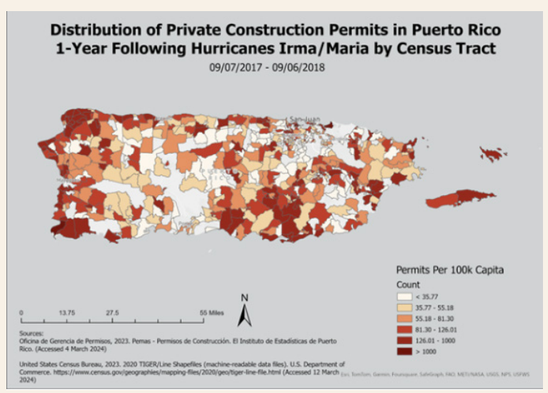

Figure 5 is an aggregate map showing the

bution of private construction permits in Puerto Rico during the one-year period following the 2020 Earthquakes, broken down by Census Tract.

Figure 6: Distribution of Private Construction Permits in Puerto Rico 1-Year Following Earthquakes by Census Tract in Ponce

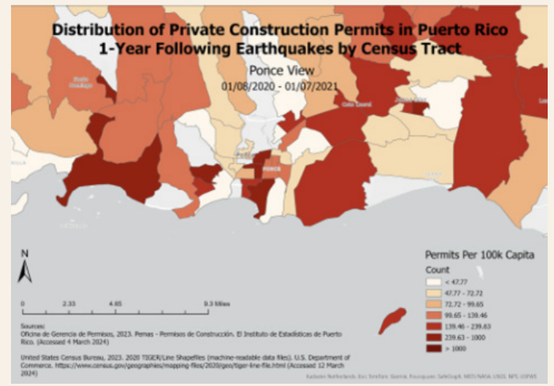

Figure 6 is an aggregate map showing the distribution of private construction permits in the city of Ponce during the one-year period following the 2020 Earthquakes, broken down by Census Tract.

Figures 5 and 6 (see above) highlight permit distribution in the one-year interval following the earthquakes. Since the impact of the earthquakes was fairly concentrated around the city of Ponce, we have provided a municipality-level map as well (see Figure 6). Here, we see fewer areas of the island that lacked any formal construction in the year following the earthquakes than after Hurricanes Irma and Maria. Interviewees from the Caguas Municipal Permitting Office indicated people realized after Hurricanes Irma and Maria that without proper land titles and permits, they would be denied essential FEMA aid. They also mentioned that many homes destroyed by Hurricane Maria were informally constructed, and the challenges people experienced heightened the population's awareness of bureaucratic processes and the value of building safety codes. Increased population awareness does not change that the permitting process takes a long time. Even in a concentrated region like Ponce, there are still areas without

Figure 7: Distribution of Private Construction Permits in Puerto Rico 1-Year Following Hurricane Fiona by Census Tract

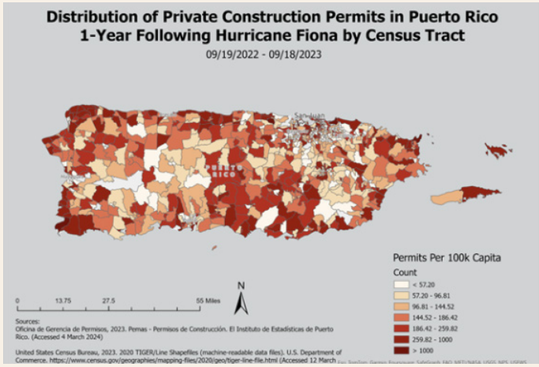

Figure 7 is an aggregate map showing the distribution of private construction permits in Puerto Rico during the one-year period following Hurricane Fiona, broken down by Census Tract.

Figure 7 (see above) shows the distribution of private construction permits one year after Hurricane Fiona's landfall. This map is clearly darker and more populated than the map showing permit distribution after Hurricanes Irma and Maria (see Figure 4) five years earlier. The maps we created show an increase in formal construction over time, consistent with the construction activity shown in Figure 1.

Figure 8: Distribution of Private Construction Permits in Puerto Rico Since Hurricanes Irma/Maria by Census Tract

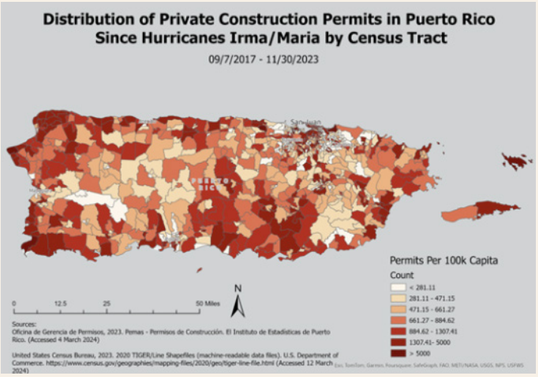

Figure 8 is an aggregate map showing the distribution of private construction permits in Puerto

Figure 8 (see above) shows the overall distribution of construction permits filed per capita from September 2017 through November 2023. This map indicates that formal construction is distributed unevenly but generally concentrated along the coast. The island's central-southern region has experienced high permit counts relative to other rural or mountainous areas. This area also experienced high levels of housing damage relative to others, as shown by the housing damages maps created by Group 1 and Group 2.

Figure 9: Administrative Regions of OGPe

Figure 9 is a photo of a map of the regional, administrative OGPe offices which was taken at the OGPe office in the municipality of San Juan.

Figure 9 (see above) is a map of the regional OGPe offices that reveals an additional explanatory factor as to why there are more permits in the central-southern region. These offices provide permitting assistance, and the darker region described earlier loosely corresponds to the Consorcio CCVS, a group of four municipalities that share a well-organized and autonomous permitting office. The distinction may be due to more accessible, higher quality permitting assistance available in the Consorcio CCVS than in other regions.

Figure 10: Distribution of Private Construction Permits in Puerto Rico Since Hurricanes Irma/Maria by Census Tract in San Juan

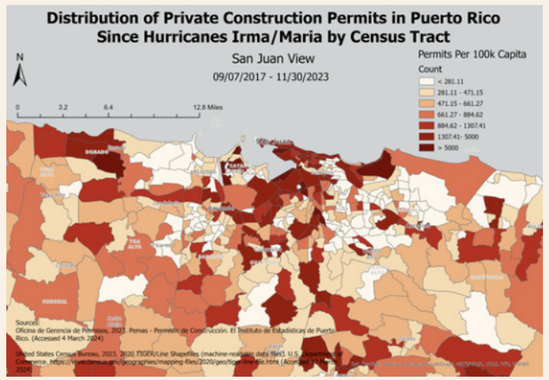

Figure 10 is an aggregate map showing the distribution of private construction permits in San Juan from Hurricane Irma's landfall in September 2017 to November of 2023, broken down by Census

Figure 10 (see above) provides a closer look at the overall construction distribution in San Juan since Hurricane Irma's landfall. The lack of gray areas indicates that every census tract in this area has experienced at least some level of recorded permitting and construction since 2017. It also makes it clear that even in the capital city, permit issuance is unevenly distributed. Generally, the city's coastal areas, which are typically wealthier and touristy, experience disproportionately higher amounts of permitting. This trend is mirrored throughout the island.

Figure 11: Frequency of Permit Categories

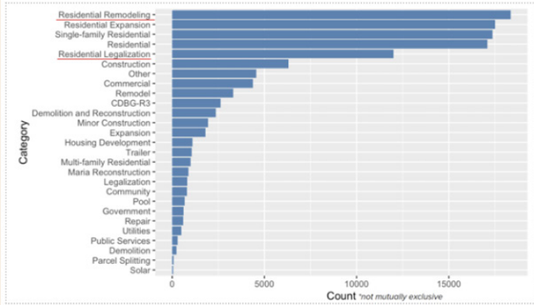

Figure 11 is a bar chart displaying the counts of different categories that permits in the construction permits dataset belong to, ranked in descending order from the top.

Figure 11 (see above) highlights the frequencies of the different permit categories captured in the dataset. Note that permits may belong to more than one category. This chart reveals that residential permits or residential-related permits are the most commonly filed permits. The largest category of permits was residential remodeling projects. This was corroborated by our interviewees in the private sector, who said that.... The other category we have highlighted is residential legalization, which refers to permits filed to help bring informal construction into compliance with the law. Our interviews suggest that this increase in legalization might represent a shift in awareness of the vulnerability that results from unclear property titles and informal construction practices. Our qualitative research also revealed that Puerto Rican companies are disadvantaged in the competition for bids against mainland firms looking to capitalize on Community Block Grant investments. Industry professionals expressed skepticism about the government's economic development strategies, partly because the organizations we spoke with have not seen increased profits as real estate prices rise. The main concern for public and private sector actors is the lack of skilled and unskilled labor. Our Puerto Rico Builder's Association interviewees posed H-2B work visas as a potential strategy to bolster the workforce. A professional organization of developers told us that they were working to convince the government to change social security benefits benchmarks to draw people into the labor force.

Conclusion

Reconstruction in Puerto Rico is a complex task. There are barriers in the public sector impeding the ability of the employees tasked with enforcing the laws governing construction and preventing them from operating effectively. Attempts to update those laws have been stifled on a constitutional level. There is a serious weakness in the labor force, in both public and private sectors as they compete with the mainland for both skilled and unskilled labor. Puerto Rican-based firms are at a disadvantage in competition with large mainland companies due to reconstruction financing requirements. High costs, cultural norms, and a lack of clear land titles drive informal construction. Additionally, technological issues within the SBP increase the time it takes to receive a construction permit. Despite this, our findings indicate some growth in formal construction projects between September 2017 and November 2023. The next steps in this research would be to compare our maps with the vulnerability, damage, and public funding distribution maps produced in the other parts of this report. We also hope that the clearer picture we offer of formal construction on the island provides a foundation for additional research into the informal construction that our data does not capture.

CHAPTER 4

ENCHANCING ENERGY RESILIENCE

Proposals for Sustainable Power in Condado

Kylie Regina Hossom
Micheal Luke Nicholson
Violeta Escandon Correa

Introduction

In the wake of Hurricane Maria and Fiona, Puerto Rico's already weak energy infrastructure has not been able to recover effectively. Delivering reliable, sustainable energy to the residents and visitors of Puerto Rico at an affordable price seems almost unattainable. Frequent power outages and soaring energy prices, combined with an over-reliance on imported fossil fuels, has had devastating impacts on the daily lives of Puerto Ricans. Some communities have organized to improve the deteriorated state of public service access and delivery. One influential Puerto Rican, Amaury Rivera, community leader in San Juan aims to improve energy conditions in his neighborhood Condado. Our partnership with Amaury aims to find and analyze the state of electricity services in Condado, and discover actionable, equitable, and sustainable solutions for improving these services. With Amaury and with the help of several other community members, our team designed four proposals to address the unreliable, unsustainable, and unaffordable electrical systems. We opted for a small-scale, localized approach, that plays into the strengths of our client, such as his vast influence in the community, as well as his embeddedness and receptiveness to the voice and spirit of Condado.

Our group provided an initial analysis of the socio-economic impact of and nature of vulnerability to the state of electricity service in Condado. Then, our team developed four proposals for addressing inequality and vulnerability. These plans were developed with expert consultation. The first three aim to reduce energy demand while the fourth aims to increase Condado's energy supply. The first proposal is a behavioral intervention campaign aimed at ensuring that residents, businesses, and tourists reduce electricity consumption, costs, emissions, and reliance on an unstable grid. The second proposal is a tree planting guide to reduce the "heat island effect," improve air quality, and reduce cooling costs. The third proposal is a cooling materials plan that provides retrofittable building implementations to reduce cooling costs. The third proposal is a cooling materials plan that provides retrofittable building implementations to reduce cooling costs in homes and businesses. Our fourth proposal is a solar power plan for targeted areas with logical steps, and implementation strategies. While these proposals might require a considerable amount of work, resources, and organizing, our team expects to see improved resilience, affordability, equity, and sustainability. The following section of the paper reveals the methodology behind our proposals, as well as discussion, description, and helpful supplements to the proposals themselves.

Context

Puerto Rico's energy model is a private-public partnership between the Puerto Rico Electric Power Authority (PREPA) and Luma. PREPA is a government-owned utility service that manages the generation of power. The transmission and distribution of power have been carried out by he private company Luma since 2017. There are two major problems associated with Puerto Rico's electricity infrastructure island-wide, but also in the neighborhood of Condado. Firstly, there is the outrageously high and volatile cost of electricity. Puerto Ricans spend nearly 8% percent of percent annual income on electricity compared to 2.4 percent spent on the mainland (Walton, 2022). The cost of electricity has peaked in the last five years at $.35KwH in July 2022 and was at $.23KwH in October 2023, compared to a mainland US average of around $ .16 KwH (EIA). Secondly, along with the high cost of electricity on the island, there are extremely frequent and long-lasting outages. These issues have common causes. Firstly, the rising costs are associated with over-reliance on imported fossil fuels. 97 percent of Puerto Rico's energy generation is from imported fossil fuels (EIA), leaving the island subject to commodity price volatility (Grabow, 2022). High costs are also associated with the growing debt faced by PREPA ($10 billion (about

$31 per person in the US) USD before privatization), which austerity measures under the PROMESA scheme are aimed at tackling (Morales, 2020). The outages are largely reported to be due to tropical vegetation, and poor maintenance of the grid, along with a relatively centralized grid, all coupled with the fact that almost 80 percent of its grid was destroyed in hurricanes (Blunt, 2023).

. Condado is a small sub-barrio of Santurce in San Juan, Puerto Rico. With a population of 4,800, the community is a relatively dense neighborhood with many high-rise condominiums and lively streets that are frequented by tourists (US Census Bureau). Heavily commercialized, Condado is home to many high-rise buildings, and successful businesses. As an effect, the neighborhood has a higher average income than the rest of the island. However, Condado is not immune to these problems faced in other parts of the island.

Methodology

Developing the Report

Our project proposals were informed by academic readings on resilience (Rodin, 2014), and urban heat island effects, renewable energy solutions, and energy efficiency programs. We also reference prior Planning Studio's energy project report (PR Studio, 2022). This foundation was complemented by comprehensive background research, encompassing an analysis of the region's multifaceted challenges through community engagement via platforms such as Facebook, newsletters, and local journalism. We hosted an "Ideation Event" with the client soliciting input. From this collaborative process, we identified the primary issues of increasing energy costs and frequent outages, leading to the segmentation of our project into demand and supply-side proposals, augmented by a diagnostic and analytical component.

We developed baseline proposals based on our client's objectives and armed with a thorough understanding of political, geographical, economic, technological, and environmental factors. We conducted fieldwork in Puerto Rico, including site visits for tree planting, cooling materials assessment, and solar implementation planning. We also conducted in-person interviews with relevant experts and participated in sustainability energy networking events in Puerto Rico. We also prioritized community input to ensure that our solutions are tailored to the specific needs of our region.

Context for Proposals

Diagnosis and Analysis

For the diagnosis and analysis components of the deliverable and report, we sourced demographic data including age, population, and consumption statistics for Condado from the U.S. Census Bureau's QuickFacts tool, which offers granularity down to the block group level. Other information was directly cited. Estimations on per month cost came from interviews with residents and calculating it as a portion of average income. We constructed maps of building use with a publicly available dataset of the footprint of buildings, and visual analysis of the size and use of the buildings. The categorization of building usage is available on the map legend. After we calculated building size (area floor levels = approximate total square footage), we applied an Energy Use Intensity function based on U.S. averages from EnergyStar. Information on the yearly consumption of Condado, consumption by building, consumption by building type, and residences and population were all derived from this database. While there might be a large margin of error in this information, due to geographical differences, and building-specific information, this project aims to use this information for relative purposes, and the relative consumption data appears to be consistent with other research on the subject. Maps on age were developed using the U.S. Census Bureau's feature layer on age and sex information (ESRI).

We created income maps using U.S. Housing and Urban Development's (HUD) data (ESRI). We combined the two maps to form a narrow vulnerability index. Information on the impact on small businesses was developed by a case study of a medium-sized hotel room, by multiplying the average room rate by the total number of rooms by the average occupancy rate of hotels worldwide, to arrive at a conservative estimate of nightly revenue.

Informational Campaign

The informational campaign was crafted using research and interviews with community stakeholders. We used U.S. Department of Energy data on energy consumption trends and the benefits of adopting efficient practices. We also referenced after an initiative at Georgia Tech which utilized stickers near light switches to prompt students turning off lights when not in use to conserve energy.

Tree Planting Plan

The tree planting project emerged from our client's interest in replicating recent initiatives in El Condado focused on tree planting. We interviewed Brian Stone; a Georgia Tech professor researches the urban heat island effect and its adverse public health ramifications. Stone demonstrated the efficacy of metro-wide vegetation coverage to mitigating heat, with findings indicating a temperature reduction of 2 to 10°F in vegetated zones (Stone, 2012). Additionally, research indicates that street canopies, grass, and agriculture contribute significantly to nighttime cooling effects (Bowler et al., 2010; Coutts et al., 2013; Gover et al., 2010; Jernertee et al., 2007; Phelan et al., 2015; Shasusha-Bar, Pearmutter, and Erell, 2009; Stone et al., 2014).

To test the viability of a tree planting proposal, we modeled potential temperature reductions resulting from increased tree coverage in Condado. Key parameters including air surface temperature and humidity were identified as pivotal factors to analyze influencing heat exposure and temperature levels (Stone, 2012). We compared relative humidity and absolute humidity values, we derived a theoretical framework to estimate the temperature reduction attributable to each additional tree, factoring in both heat absorption and water vapor release. This approach serves as a starting point for the future to develop expected temperature reduction values per tree, relative to its species, and assess the potential impact of implementing the tree planting initiative in Condado.

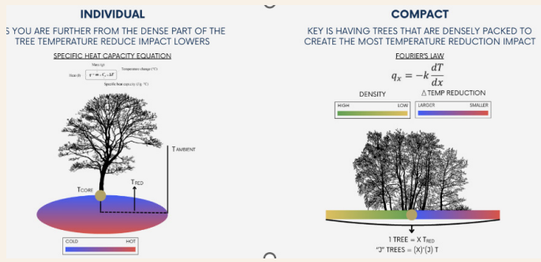

Figure 1. Visual explaining the theoretical analysis that drove reasoning and pursue for continuation of this demand focused proposal.

We conducted interviews with a tree specialist and a city planning professor and solicited feedback from community members to create the guide. We also conducted on-site observations to assess current tree canopy conditions in Condado. We used Adobe Photoshop and Google Maps aerial view to create a map of an existing tree canopy. The final map was then developed by adding tree coverage in the areas highlighted in our scenarios, providing a clear visualization of the potential impact of the tree planting initiative. To quantize the predicted impact of our solution based on the applied scenarios we derived the estimated current tree coverage and the projected coverage. To do this, the maps were analyzed in Python. The total pixels of the image were identified, and the number of green pixels were divided by the total pixels to output a ratio of the green coverage. The code details are included in the appendix.


```
Current tree coverage ratio: 0.11755029
---
Proposed tree coverage ratio: 0.06763810
---
Total tree coverage ratio (current + proposed): 0.18518839
```

Figure 2. Code results showing the ratio of the current and proposed solution tree coverage.

Cooling Materials

Our research came from interviews with community members and the U.S. Environmental Protection Agency's Heat Island Effect program.

Harvesting Sunshine: Solar Energy Integration

Adopting this solution stemmed from client feedback based on previous initiatives in other parts of Puerto Rico, coupled with research highlighting the impact of energy infrastructure during hurricanes (Kwasinski, 2018).

To identify suitable locations for solar installation, we embarked on a process that involved compiling a table detailing the square footage of individual buildings and conducting research to ascertain regions with the highest solar capacity per area. Utilizing data from the National Renewable Energy Laboratory (NREL), which indicates an average daily solar radiation annual range of 6 to 8 kWh/m^2 for the east-southern parts of the US, we applied a conversion factor of 0.007 kW/sq ft. While this figure was not utilized for further analysis, it provided a general correlation between area and potential solar capacity. Subsequently, we identified five solar candidate sites, which we planned to visit during fieldwork to assess their size and roof conditions.

Following reflections based on observations and discussions with experts, we narrowed the focus of the solar plan to a critical infrastructure building meeting specific criterion, namely high foot traffic, large size, essential for living necessities, and lacking solar energy implementation. This culminated in Proposal #1 targeting Ashford Hospital. Solar sizing, focusing solely on Building A (referenced in Figure X), was determined through data collection from various sources.

Utilizing the NREL PVWatts tool, Google's Project Sunroof, and collaboration with SolarIT from Fundacion Boricana, we obtained system size estimates ranging from 94.34 kW to 97 kW, with a standard deviation of 1.37. The SolarIT software was selected for its alignment with other trusted sources and used to design the system, incorporating JA Solar's 445 Watt panels (model CS3W-450 Ms., Mono-Crystalline Silicon, 20.37% efficiency), Solar Ark's 15 kW inverters (model 15K-2P-N, hybrid type, 96.5% efficiency), and UNIRAC's fixed (roof-mount) racking system with envoy-enlighten monitoring. Critical specifications guiding the design included an azimuth value of 186.42 (adjusted for Puerto Rico), portrait orientation of panels at 2 degrees inclination, and assumption of a flat roof (0 degrees inclination).Our second proposal involves donating a full solar system for a single-family home, a decision reached after extensive discussions with representatives from SunSol and Dyness during the energy week networking event conducted during our fieldwork visit.

Figure 3. Showing that our solar design was assuming that only building A is under the hospital as there was no clear ownership of the other parts.

Diagnosis & Analysis

** For graphical and other information on the diagnosis and analysis section, please visit the diagnosis and analysis page: https://arcg.is/1PrTWW2

PHASE	OBJECTID	Latitude	Longitude	Physical Address	Name	Area	Solar Capacity (kW)	Recent Renovation/Built
I	351	18.46100288	-66.08102529	999 Ashford Ave, San Juan, 00907, Puerto Rico	The Condado Plaza Hotel	69046	486.7743	No
I	7	18.45603911	-66.06545985	1451 Ave Dr Ashford, San Juan, 00907, Puerto Rico	Ashford Presbyterian Community Hospital	64723.15351	456.2982322	No
I	318	18.45393086	-66.06534139	5 C. Nairn, San Juan, 00907, Puerto Rico	Robinson School	62943.51579	443.7517863	No
I	330	18.45454117	-66.06503755	1454 Ashford Ave, San Juan, 00907, Puerto Rico	Saint John's School	31927.1908	225.0866951	No
I	139	18.45528813	-66.06742168	1369 Ashford Ave, San Juan, 00907, Puerto Rico	AC Hotel by Marriott San Juan Condado	31446.40592	221.6971617	No
I	368	18.45873982	-66.07686945	1020 Ashford Ave, San Juan, 00907, Puerto Rico	Apartments for you - La Roda	21482.80442	151.4537712	No
I	441	18.45501852	-66.06461129	1477 Ashford Ave, San Juan, 00907, Puerto Rico	Torre del Mar (Multi-unit residential building)	17602.29116	124.0961527	No
I	383	18.45700211	-66.07606008	#6 Calle Mariano Ramírez Bages, San Juan, 00907, Puerto Rico	Laguna Terrace (Lodging)	17167.95075	121.0340528	No
I	442	18.455605	-66.06426582	1479 Ashford Ave, San Juan, 00907, Puerto Rico	Condado Del Mar Rentals	16551.22825	116.6861592	No
I	374	18.45938859	-66.07727999	1045 Ashford Ave, San Juan, 00907, Puerto Rico	Condado Ocean Club Hotel	15978.4672	112.6481938	No
I	30	18.45389828	-66.0734794	76 Condado Ave, San Juan, 00907, Puerto Rico	The Wave Hotel	15454.87431	108.9568639	No
I	21	18.45579741	-66.07542876	20 Clf Deleasse, San Juan, 00907, Puerto Rico	Condominio del Mar (Condominium Complex	15082.20498	106.3295451	No
I	336	18.45459047	-66.06589995	1450-1452 Magdalena Ave, San Juan, 00907, Puerto Rico	Ligia (Condominium Complex + Doctors Off	14316.56325	100.9317709	No
II	462	18.45621601	-66.07081208	1307 Ashford Ave, San Juan, 00907, Puerto Rico | 1309 Ashford Ave, San Juan, 00907, Puerto Rico	CVS | Casino	105562.141	744.2130941	No
II	393	18.45734563	-66.07324422	1077 Ashford Ave, San Juan, 00907, Puerto Rico	Mar | Squarly Bomb N Cafe | The Loft Beach I	79792.95037	562.5403001	No
II	506	18.45533133	-66.06325802	St. Mary's Plaza Norte, 1485 Av. Ashford, San Juan, 00907, Puerto Rico	End of Small Would have to ADd 405 and 50	18430.8149	129.937245	No
II	92	18.45602989	-66.07196385	1130 Ashford Ave, San Juan, 00907, Puerto Rico	Walmart	15990.90921	112.7359099	No
II	106	18.45523081	-66.06983549	1302 Ashford Ave, San Juan, 00907, Puerto Rico	Estate Agency + Small Business All Around,	14243.15113	100.4142155	No

Figure 3. Preliminary solar capacity calculations and buildings selected that fueled the field work itinerary for the solar implementation plan.

Below are some basic statistics on Condado that have helped inform solutions strategies. There are approximately 4,800 residents in the Condado sub-barrio, although the actual number of individuals in Condado at any given time is much greater due to tourism and surrounding industry. The median household income of Condado is $75,000 a year (U.S. Census Bureau, Income). The median age of Condado residents is around 51 years old (U.S. Census Bureau, Age). We estimate that Condado consumes approximately 330 million kWh a year in electricity, while the average individual resident of Puerto Rico consumes 24,177 kWh a year (EIA). The average outage in Puerto Rico in 2017 lasted around 850 minutes (Li,2022), and at the time of writing (April 5, 2024) there were five unplanned outages with 11-12 thousand customers affected across Puerto Rico (Luma). The average Puerto Rican household will spend 8 percent of their income on electricity, while the average on the mainland is 2.4 percent (Rosado, 2023). We estimate that the average household spends $250 to $300 per month on electricity.

Analysis

Most of the infrastructure in Condado is residential, such as high-rise condominiums, apartment blocks, or single-family homes. Condado also has several hotels dotted around the neighborhood. Retail and commercial activity is largely concentrated around Avenida Dr. Ashford. Many of the residential buildings serve as rental units for tourists, that a significant portion of the residential consumption is driven by tourism and fluctuates during on/off seasons. We estimate that nearly half of all energy consumption in Condado is from residential activity, while hotels consume close to a third, with retail and food making up one-fifth. The map on consumption shows us that consumption is higher on the coast, and lower in more inland areas.

Impact

According to U.S. Census Bureau data, elderly populations are more concentrated on the coastal and center regions of Condado. The more southern, inland parts of Condado have a higher portion of lower-income households. Coupling both variables gives us an index that can drive the prioritization of proposed solution targets, likely in the more inland portions of Condado. While the outages and high energy costs disproportionately affect elderly and lower-income populations, it also adversely affects businesses in the area. A medium-sized hotel without a generator could lose up to $6,000 in revenue if an overnight outage limits its ability to book rooms (The Wave).

These are only a few of the ways in which the poor state of electrical services in Puerto Rico affects. The health, comfort, daily lives, and economic well-being of Condado's residents rely on a reliable and affordable electrical system, which is why the implementation of certain strategies to improve the service is imperative.

Solutions

Condado can take measures to reduce demand for power and reduce reliance on the electrical grid. A commonly proposed solution is to separate Condado from the centralized grid. Firstly, while the below measures might save a considerable amount of money for residents and businesses alike, and increase local resilience, this means that the central service providers lose a considerably large customer base, one that has been helping to contribute to the servicing of public debt. Losing this customer base, to whatever degree, almost inevitably means an increase in prices for the rest of the island, due to the decrease in scale and subsequent increase in the per unit cost of energy production, as well as shifting the debt servicing to other customers. Considering that Condado is a wealthier than average neighborhood, this might perpetuate and exacerbate already existing inequalities.

This team still advocates for the proposed solutions despite this for two major reasons. Firstly, through our socio-economic analysis and considerations within Condado, we have tailored our recommendations to target those most vulnerable to price shocks and outages, the desired effect being reducing inequality within Condado. Secondly, while these solutions will benefit community members in the near future, upfront costs can be very high for some proposed measures, such as solar energy solutions. We view the work in Condado as a testing ground for a broad, multi-pronged approach to improving resilience, and if successful in its intended goals, could serve as a guide for other districts in Puerto Rico. This means broader benefits for the island, while many of the less wealthy neighborhoods in Puerto Rico shoulder less of the burden of experimentation, and high upfront costs.

Proposals from Demand

Informational Campaign

Condado, Puerto Rico, faces the challenge of balancing the needs of its thriving tourist industry

Condado, Puerto Rico, faces the challenge of balancing the needs of its thriving tourist industry with the island's energy resilience. However, many residents and tourists may not fully understand the importance of energy resilience. To address this challenge, we have created a two-part informational campaign to bridge this knowledge gap and help both residents and tourists make better choices about energy use.

Solutions

Part 1: A Comprehensive Brochure for Residents

The informative brochure is focused on empowering residents to take control of their energy usage and reduce their energy bills. Consisting of clear explanations and actionable tips on energy-saving measures, our goal is to educate and empower the residents on the overall concept of energy resilience and why they should save energy.

Part 2: A Reminder Postcard for Tourists

Condado is a popular tourist destination. While tourism can bring in a much-needed boost to the economy, tourism can also have a negative impact on the area's energy consumption. Using clear, concise messaging and eye-catching visuals, the campaign educates tourists about the importance of energy conservation. Simple actions, like turning off lights and air conditioning when not in use can reduce energy consumption. The postcard subtly introduces the concept of energy resilience, encouraging tourists to become active participants in sustainability efforts.

Drawbacks and Benefits

Residential:

Residents who understand their energy usage can make informed decisions about their consumption habits. By providing information on minor changes, such as switching to LED light bulbs or unplugging unused electronics, the brochure can guide residents towards lowering their energy bills.

Lower energy consumption across households can ease the strain on the local power grid. Being informed also helps residents prepare for potential power outages due to weather events or infrastructure issues. Furthermore, by reducing overall energy consumption, residents contribute to lowering greenhouse gas emissions. The campaign can create a sense of shared purpose among residents, fostering community cohesion and empowering collective action.

However, not everyone in Condado may receive a physical brochure, which could limit the campaign's reach. Encouraging people to change their daily habits requires time and consistent messaging. Additionally, there are upfront costs associated with creating, printing, and distributing the brochures. A language barrier may also exist, so ensuring the brochure is available in both English and Spanish is essential. Accessibility could be an issue, as not everyone may have access to a physical brochure. Finally, some individuals may not take the time to read a brochure due to their busy schedules.

Tourists:

Targeting tourists directly can provide immediate and relevant information, quickly raising awareness about energy issues in a concise and captivating way. The campaign offers clear and simple tips for tourists to conserve energy during their stay, such as turning off lights and air conditioning when leaving the room. This positive reinforcement encourages tourists to contribute positively to the island's environment and community, promoting tourist education and awareness. Postcards are an inexpensive means of reaching many tourists, and tourists may keep them as mementos, extending the campaign's reach and educational value.

On the downside, not all tourists may receive or pay attention to the postcard. Language barriers could be a challenge when reaching a diverse tourist population. The campaign's success is also reliant on hotels' willingness to distribute postcards to guests or post them in popular visible areas. Additionally, there will be upfront costs associated with creating, printing, and distributing the postcards.

Residents Information Brochure

Figure 5. Front and back of the brochure part of the informational campaign; outlines low and free tactics as well as an introduction to our supply/demand side solutions, and a funding guide.

Tourist Information Postcard

Figure 5. Back and forth of the post card serving as the infographic for tourists' mindset change.

Next Steps for Implementing the Campaign

The next steps for implementing the campaign begin with resource allocation. This involves setting aside funds for printing and distributing campaign materials. Once resources are in place, the campaign can be launched using a targeted communication strategy that includes social media announcements and community events to raise awareness and build momentum.

Distribution and outreach efforts are the next focus. Campaign materials should be distributed to locations frequented by both residents and tourists, such as hotels, airports, and tourist attractions. For residents, materials should be distributed at gathering centers, local businesses, and residential areas through door-to-door delivery or local events. This approach will help ensure that the campaign reaches a broad audience and effectively promotes the initiative.

Energy conservation requires ongoing efforts and a collaborative approach. This campaign serves as a starting point for promoting responsible energy use in Condado. By utilizing the information provided in the resident brochure and following the simple tips on the tourist postcard, everyone can become an active participant in building a more sustainable community. As awareness and participation grow, Condado can become a leading example of a community committed to responsible tourism practices and energy security.

Tree Planting Plan

** For the full tree planting plan:Tree Planting Guide

Condado is grappling with the Urban Heat Island (UHI) effect, which not only affects residents' comfort but also significantly increases energy consumption, especially for cooling. To address this issue, we propose a tree-planting strategy.

Several factors exacerbate the problem: the lack of a comprehensive long-term plan, the frequent planting of inappropriate tree species causing damage to sidewalks and power lines, and limited knowledge about the benefits and maintenance of trees. By prioritizing tree planting in areas most affected by the UHI effect, particularly those housing vulnerable communities, we can provide natural cooling benefits. This targeted approach not only reduces reliance on energy-intensive cooling systems but also helps mitigate the UHI effect itself by reintroducing greenery and enhancing evaporative cooling. Involving the community in the planning and implementation process, and ensuring ongoing maintenance, will maximize this initiative's effectiveness. Through this plan, our goal is to combat the effects of urban heat islands and create a more sustainable and comfortable urban environment in Condado.

Benefits and Drawbacks

Tree planting offers numerous benefits, including shade and cooling, which reduces the need for air conditioning and lowers energy consumption. Trees can also mitigate floods by absorbing excess rainfall and decreasing runoff, providing natural protection against strong winds and flying debris, and enhancing safety and resilience during storms. Tropical trees contribute to soil stability with their deep root systems, preventing erosion and promoting surrounding landscape health. They also support biodiversity by providing habitats for various species and sequestering carbon dioxide, crucial for climate change mitigation and air quality improvement. Community involvement is promoted through tree planting and care initiatives, fostering social cohesion. Being in green spaces and around trees can improve mental well-being, reduce stress, and promote relaxation. They enhance neighborhood aesthetics, potentially increasing property values, and contribute to air purification by trapping pollutants and releasing oxygen. Trees also mitigate the Urban Heat Island effect by providing shade and cooling, improving urban comfort.

However, tree planting comes with some drawbacks. Regular maintenance tasks such as pruning, and debris cleanup are necessary to ensure the health and safety of trees. Some tree species require ample space to grow properly, limiting their suitability for urban environments with limited space. In extreme weather conditions, there is a risk of trees falling, potentially causing property damage, and posing a danger to pedestrians and structures. Careful species selection is crucial to mitigate risks such as susceptibility to wind damage, diseases, and sidewalk cracking. Trees may interfere with infrastructure, requiring careful planning and maintenance. Despite benefits, there are associated costs.

Current Conditions

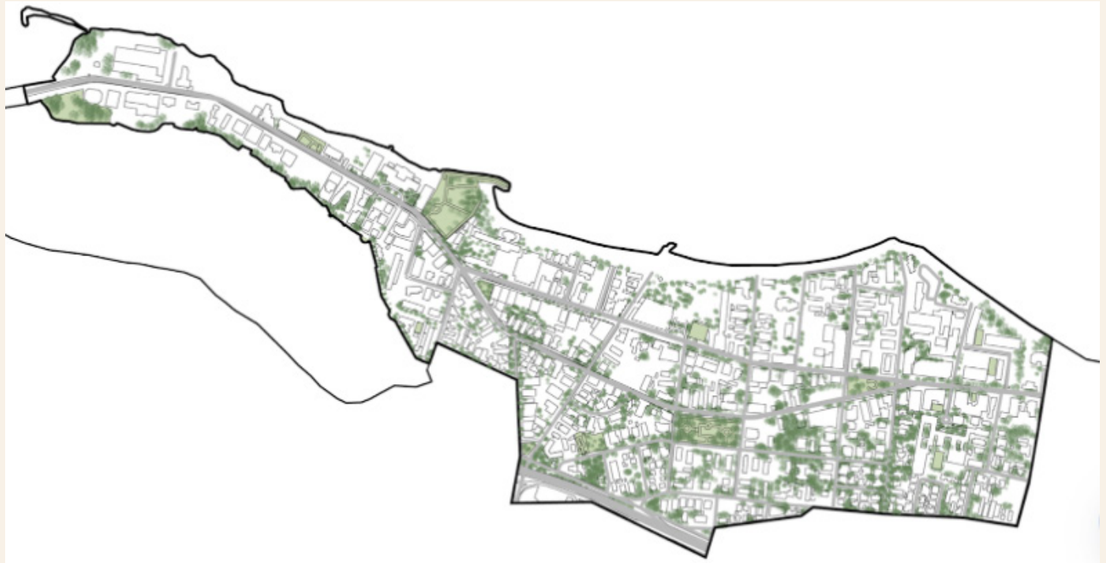

Figure 7. After measuring the current tree coverage, it was found to be approximately 11.76%, significantly lower than Atlanta's tree coverage of around 40%.

Priorities

The tree planting initiative mainly prioritizes vulnerable areas, including neighborhoods with higher percentages of aging populations and low-income residents. Planting trees in these areas offers benefits such as improved air quality, shade, and cooling, making outdoor spaces more comfortable and accessible. Additionally, available planting spots in existing holes along sidewalks where trees once stood and public open spaces such as parks and plazas will be used to restore the tree canopy and enhance community aesthetics and well-being.

Considerations

Before undertaking tree planting in Condado, it is essential to evaluate key factors influencing the suitability and long-term health of trees in urban settings. Considerations include the mature size and root growth of tree species, as some trees possess extensive root systems capable of damaging sidewalks and nearby infrastructure. Additionally, tree height should be assessed to prevent interference with overhead wires and power lines, necessitating regular pruning for safe clearance. Maintenance requirements vary among tree species, with some needing frequent pruning to control growth and ensure health, while others require heightened care during the initial six months post-planting. Legal considerations are also crucial, as certain regulations in Puerto Rico mandate permits for tree removal. Property owners may prune trees over their property within specified limits, typically up to 35% of the tree's canopy. Understanding these factors ensures trees are planted in suitable locations and managed effectively for community benefit.

Tree Types and Their Attributes

The tree planting plan in Condado features four tree species chosen for their specific attributes and benefits to the community.

TREE TYPE	DESCRIPTION	COMMUNITY BENEFITS
Retama San Jose Poitea florida	Height: 15-20 feet Moderate Growth Crown: Round Space Required: Small	Visual appeal: flowers Provides shade Attracts pollinators Native
Retama Prieta Senna polyphylla	Height: 15 feet Moderate Growth Crown: Irregular Space Required: Small	Visual appeal: flowers Provides shade Attracts pollinators Native
Santa Maria Calophyllum antillanum	Height: 45 feet Moderate Growth Crown: Round Space Required: Ample	Provides shade Wildlife habitat Native
Hedionda Senna occidentalis	Height: 15 feet Fast Growth Crown: Round Space Required: Medium	Visual appeal: flowers Aromatic Wildlife habitat Native

Source: Para la Naturaleza

Scenario 1: Vulnerable Areas

In vulnerable areas of Condado, narrow roads and sidewalks present challenges for planting trees alongside the street. However, open grassy spots within these neighborhoods offer ideal opportunities for tree planting to cool nearby homes and reduce energy consumption.

The trees Retama San Jose, Retama Prieta, and Hedionda are suitable for these locations. These species are not large and fit well within available spaces. They also provide visual appeal with their flowers and foliage, enhancing the neighborhood's aesthetic. Planting these trees in grassy areas can significantly improve residents' comfort and lower energy costs.

Figure 8. Observations recorded from in-person walkthroughs of the vulnerable community showing the small side walks

Scenario 2: Available Spots Along Roads

Condado features numerous areas where trees were previously planted, leaving behind dirt or grassy holes in the sidewalks. These vacant spots provide easy opportunities for tree planting, helping to restore the tree canopy and improve the streetscape.

Figure 9. Observations recorded from in-person walkthroughs of the covered tree spaces.

The ideal trees for these locations are Retama San Jose and Retama Prieta. These species are small and manageable, ensuring they will not reach power lines or disturb the sidewalks. Planting trees in these existing holes can efficiently enhance the environment by providing shade, improving air quality, and adding visual appeal to the area.

Scenario 3: Public Open Spots Such as Parks

Public open spaces like parks provide many opportunities for tree planting without the constraints of size restrictions. All the tree types selected for Condado—Retama San Jose, Retama Prieta, Santa Maria, and Hedionda—are suitable for these areas.

Figure 10. Observations recorded from in-person walkthroughs of nearby parks/open areas.

Implementation

The implementation guide for the tree planting initiative in Condado emphasizes a community-driven approach, encompassing planning, sourcing, and executing the planting event. This involves collaborating with local leaders to organize a multi-day event for volunteers to plant trees sourced from Vivero Árboles Más Árboles de Río Piedra, a local nursery, selecting species suited to the climate and soil. During the planting event, volunteers receive necessary tools and instructions for planting, along with guidance on ongoing tree care practices such as watering, mulching, and pruning. Specific planting directions are provided to ensure proper techniques, supplemented by QR codes linking to maintenance guidelines. The guide underscores the importance of celebrating the community's achievement in enhancing the local environment and promoting environmental sustainability

Goals and Intended Impact

The tree planting initiative in Condado aims to combat urban heat islands and enhance community well-being. By prioritizing vulnerable areas and involving the community, the initiative seeks to reduce energy consumption, improve air quality, and foster social cohesion. Through strategic tree planting and ongoing maintenance, Condado can create cooler, more resilient spaces while serving as a model for other communities.

After adding new trees according to the previously discussed scenarios using Google Maps aerial view, the estimated tree coverage increased to around 18.52 percent, which is an improvement of nearly 7 percent from the initial level.

Cooling Materials Plan

** For helpful graphical and other information, please visit the cooling materials page: https://arcg.is/1y1C8K

Following the analysis from before, it is imperative to implement interventions to improve both independence from the broader electrical grid, and efficiency of homes in Condado. One proposed solution explored here is the implementation of cooling materials. In addition to other measures of reducing demand, cooling materials are broad building implementations that can help to reduce cooling costs by reducing the heat gain effect. Some examples include liquid roof coatings and installing awnings.

Heat Gain is the phenomenon where heat builds up in a building either through windows, or directly onto building surfaces like walls or roofs, making comfortable temperatures harder to reach in warm and sunny places like Condado. Elderly individuals, especially those with health risks, such as cardiovascular issues or others, are particularly vulnerable to these high temperatures. As a result, heat gain can have detrimental effects on the health of individuals. In many cases, especially in Condado, individuals have access to air conditioning. This is not an entirely reliable solution. Firstly, the frequency of power outages in Puerto Rico means that residents often go days or weeks without power. Secondly, the high cost of energy on the island means that cooling one's home, even when/if power is reliable, places a significant economic burden on residents and business owners. Heat island effect is when densely packed urban areas like Condado and San Juan more broadly have limited green space and structural factors absorb and reemit heat, bringing daytime temperatures up to 7 degrees warmer (Velazquez-Lozada, 2006).

Figure 11. Tree coverage after added scenarios (new trees shown in bright green).

Benefits of Cooling Materials

Cooling materials, or heat island reduction techniques in general could cut temperatures by up to 3 degrees F in warm places Southern California. Reducing heat not only reduces costs and efficiency but makes for a more reliably cool and comfortable home should the power go out, further reducing dependency on the failing grid (Pearce, 2021). Cooling materials can make it significantly easier to cool a home, significantly reducing cooling costs, by tens of USD in many cases. Some studies have found that cooling materials have been helpful in reducing non-communicable diseases due to reducing heat exposure (Vineis et al., 2021).

In the case of Condado, considering target areas with older individuals and lower income individuals as they are some of the most vulnerable to high costs and high heat, should be a priority. Based on the vulnerability map, as well as visual analysis of areas with less shade, below is linked a map highlighting areas that might be the best priority areas. While many buildings in Condado already have lightly colored roofs, it would be helpful to consider alternative cooling options for these areas.

Types of Cooling Materials and Their Properties

Here are a couple of the less invasive cooling material options that are less expensive to retrofit. Different window awnings, such as fixed or retractable, can significantly reduce heat gain in the summer and winter, by as much as 65% on south-facing windows and 77% on west-facing windows (Pearce, 2021), translating to tens of dollars in savings per month. Synthetic materials are more weather resistant, helping them last longer. Benefits of window awnings include their significant heat gain reduction, and flexibility. Some of their drawbacks are that they are more maintenance intensive in the long run than other options and could become hurricane debris. Another very useful option is reflective roof coatings. There are several roof covering options, but some of the most helpful for the low sloped roofing common to El Condado, are liquid applied roof coatings, and fluid applied membranes. Both are non-invasive and affordable. These are also some of the most effective solutions for buildings that might not get enough direct sunlight on the sides or through the windows. Cool roofs can reduce heat by up to 3 degrees Celsius (Pearce, 2021).

Similar to the heat reflective properties of the roof coatings is light-colored exterior paint. Using light colored paint on buildings is especially helpful on South facing, and West facing walls due to their orientation to the sun. They are helpful when the building might not have direct shade nearby, such as taller buildings. Some of the benefits of both roof coatings and light-colored paint are that they require less maintenance in the long run, and their significant heat gain reduction. Some of the drawbacks are that they are potentially aesthetically problematic, with high retrofitting costs, and could interrupt bird migration

While this guide primarily emphasizes less invasive options, it is essential not to disregard cost-intensive alternatives as long-term solutions. One such innovative option is green roofing, involving the placement of soil and vegetation on building roofs. This approach offers significant benefits, including improved air quality, health, and reduced energy consumption. Another option, cool pavement, entails repaving roads with reflective and sequestering materials, offering similar benefits such as improved air quality and stormwater runoff reduction.

Cooling materials offer various benefits, including heat gain reduction, cost savings, reduced reliance on the grid, improved health, and enhanced air quality. However, they can be costly to implement, especially more invasive measures, potentially pose aesthetic concerns, and often encounter coordination issues among residents. Therefore, we recommend initially targeting single-family homes, as residents typically have more autonomy in these arrangements. Implementing different cooling material interventions over time could significantly reduce temperatures in Condado, benefiting the entire community. Residents stand to save thousands of dollars in energy costs over the years while contributing to improved community health outcomes.

Proposals from Supply

Harvesting Sunshine: Solar Energy Integration

** Full proposal: Link | Technical Specification for Panels & Inverter: Link

The impact of high costs and the disturbances of frequent outages in the life of the residents in El Condado were made as evident challenges from the early background research phase and reiterated all throughout our field work. As mentioned before, the root of these frustrations is multilayered from the organizational and infrastructure failure within the energy sector in the region. The challenges combined with the political discrepancies and geographical conditions a strong push for alternative energy solutions has been made. Considering the underdeveloped solar energy sector in El Condado, the biggest challenges this community faces, and the community input for developing a solar plan this proposal was curated. The two solutions discussed below include (1) solar design for the Ashford Hospital and (2) details regarding the donation of a full solar system for a single-family home as a result of connections made during the energy week event in Puerto Rico.

Before diving into the plan, it is important to understand how the solar energy sector functions in Puerto Rico. Residents have two options to stay on the grid or be off it. The solar panel supplier and installers must be approved by LUMA for the energy output to be returned to the grid. This option is appealing for users because the additional energy that is produced by the panels would not be wasted but instead can be credited, this occurs monthly and stored in a database. At the end of the year the energy that was overproduced by user would be converted into monetary value by a standard energy retails price determined by LUMA which is about 75% of the consumers actual monthly costs and lead for reimbursement. Apart from the cash value they can gain by being connected to the grid they add a layer of resiliency in the case of a sunny day or a malfunction with their system. The second option is remaining off the grid which means that if the demand of energy is greater than the supply of the solar panels then consumers would not have the option to get additional energy front the grid as well as not qualify for energy credit reimbursements.

Benefits and Drawbacks

Solar energy in Puerto Rico offers a cost-effective alternative to traditional electricity sources, providing users with energy independence during daylight hours and reducing reliance on the grid, thus lowering carbon emissions. However, transitioning to solar energy faces challenges, including incentives provided to grid consumers. Technical specifications for solar panel suppliers include resistance to wind speeds up to 180 mph, along with considerations for installation availability and associated costs. Moreover, ownership ambiguity arises in regions like Condado, densely populated with condominiums and high-rise buildings, where infrastructure ownership remains unclear.

Additional Technical Considerations

Solar panels must be tailored to meet the energy demands of the specific space they are installed in, ensuring optimal efficiency. Factors such as geographical location, solar incidence, and shading levels must be meticulously considered to accurately predict solar energy output. Additionally, the orientation, tilt angle, and condition of the roof play crucial roles in determining the potential energy generation capacity of solar panels.

Proposal #1: Ashford Hospital

This critical infrastructure was identified as pivotal for facilitating the transition to renewable energy within the community, amplifying exposure to sustainable practices while also ensuring resilience in the face of disasters. To ascertain the solar capacity required, a comprehensive analysis was conducted, revealing a projected output of 94.34 kW for the designated building. This design necessitates the installation of 212 solar panels and 6 inverters. Following extensive research and interviews with members of Fundación Borincana, it was estimated that the total cost would amount to approximately 2.8 dollars per watt for a system without storage, resulting in a preliminary total cost of $260,000 for the proposed system.

Figure 12. Satellite perspective of the projected solar panels post-implementation.

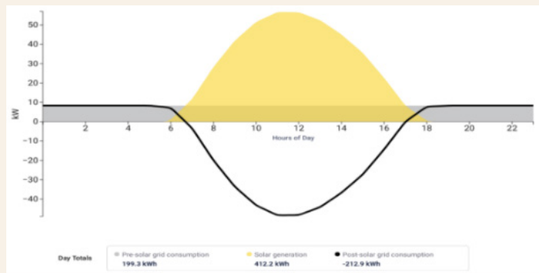

Figure 13. This is the expected solar output curve for the respective solar design.

Proposal #2: Donation from SunSol & Dyness

During the energy week networking event, Sunsol and Dyness (supplier and instillation companies), esteemed suppliers and installation companies, expressed verbal agreement to generously donate a complete solar system for installation in a single-family home. This noteworthy development signifies a significant milestone, as it not only incentivizes other community members to consider adopting solar energy solutions but also signals a promising opportunity for additional companies to enter and invest in this burgeoning market.

Next Steps

The hospital solar plan represents an initial stride towards diversifying energy options in Condado. However, to maximize its impact, it is imperative to conduct a thorough review of the hospital's electrical bill and inventory of critical loads. This will allow us to ascertain the percentage of energy usage that our solar system size can effectively support and prioritize connecting critical loads such as medicine fridges to the system. In terms of the donations, the subsequent steps entail collaborating with the community leader to identify a deserving family that would derive the greatest benefits from an expansion of their energy supply options, particularly individuals residing in vulnerable areas. Subsequently, we will liaise with the companies' contacts to arrange a site visit and commence the development of the solar system for the selected residential space.

CONCLUSION

The goal of the 2024 Puerto Rico Planning Studio was to understand the lifecycle of a natural disaster, including preparedness, impact, response, and recovery. To achieve this, Groups 1 through 3 worked under the Center for a New Economy, exploring post-disaster vulnerability, damage, and reconstruction. Meanwhile, Group 4 worked for Amaury Rivera in Condado, explored the impacts of improving energy resilience.

Group 1 designed a new Puerto Rico Vulnerability index that combines community testimony and pre-existing special communities maps to represent vulnerability on the island. The group added several new indicators into their index including infrastructural, demographic, and environmental indicators to compensate for information gaps commonly found in previous indexes. Finally, they recommended merging many different existing indexes into one centralized database.

Group 2 examined public aid disbursement and found significant differences in how government agencies reported the operations of their aid programs and what aid applicants and recipients reported experiencing. Community leaders say that federal assistance regularly fails to reach those most in need, while federal government leaders say they have been responsive and adaptive to disasters in Puerto Rico. Hurricane Maria was regularly cited by federal officials to support this position. Group 2 looked at recent earthquakes and Hurricane Fiona and found that the most common forms of FEMA housing relief aid were repair and rental assistance. Repair assistance almost entirely went to homeowners, while rental assistance went only to homeowners, and any homes with unknown tenure status were almost wholly excluded from programs.

Group 3 examined the reconstruction process following the disasters, particularly private reconstruction and the construction permitting process. They identified challenges in the construction permitting process and concerns individuals in the construction industry have about the recovery effort. They found that permit distribution on the island was uneven, but the investment in formal reconstruction efforts has been growing.

Finally, Group 4 recommended an informational campaign in the Condado neighborhood of San Juan to help decrease electricity use. Other suggestions to decrease required energy consumption included planting different trees in Condado and using new and comparable cooling materials to reduce the urban heat island effect. Lastly, they suggested installing solar panels on economically and physically feasible roofs. All these recommendations are designed to increase energy efficiency and self-sufficiency in the Condado neighborhood.

The reports of this studio highlight areas of stress and potential solutions to combat existing challenges in Puerto Rico following natural disasters. Facing the certainty of the growing number, strength, and unpredictability of natural disasters, it is imperative that Puerto Rico take measures to prepare for both future disasters and the recovery process following them.

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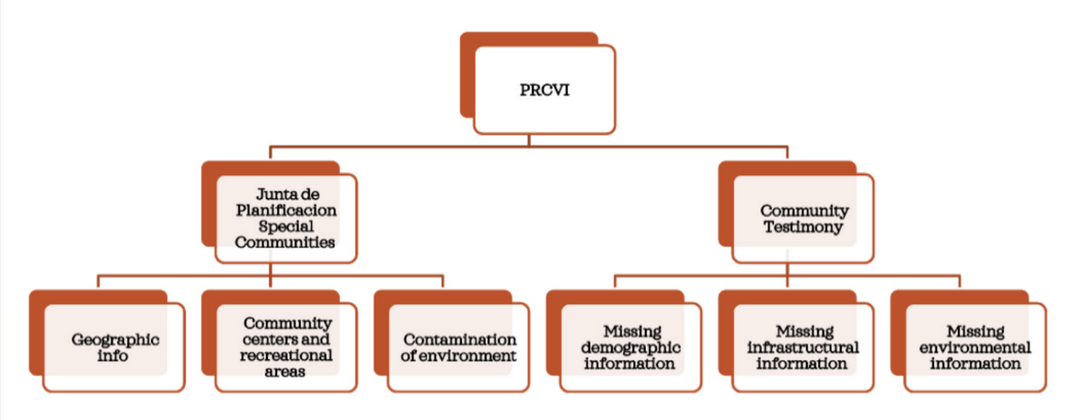
APPENDIX

Appendix A.

Structure of the Vulnerability Index Data



Appendix B.

Housing Impact Data Comparisons

Table 1. Data cleaning comparisons

	Earthquake	Fiona
Raw	40,237	1,239,102
Valid - zip code	40,223	1,237,491
Valid - track	37,750	668,914
Valid - block group	37,750	668,914
Valid - block	2,218	37,750

Table 2. Housing damage comparisons - block group level			
	Maria	Earthquake	Fiona
Valid Registrations	1,066,288	37,750	668,914
Home Inspected by FEMA	715,145	33,141	81,785
Homes with damage (FEMA identified)	423,620	27,342	45,680
Total damage	1,624,860,342	77,276,695	76,719,196
Average damage	3,836	2,826	1,679
Total homes destroyed	4502	304	25
Total homes with flood damage	21,405	2	3,749
Total homes with roof damage	126,994	2,244	0
Total homes with foundation	13,411	19,272	0

Table 3. Housing damage comparisons - block group level			
	Maria	Earthquake	Fiona
Valid Registrations	1,066,288	40,223	1,237,491
Home Inspected by FEMA	715,145	35,347	152,915
Homes with damage (FEMA identified)	423,620	29,119	86,998
Total damage	1,624,860,342	83,531,582	147,665,491
Average damage	3,836	2,869	1,697
Total homes destroyed	4502	294	36
Total homes with flood damage	21,405	2	7,575
Total homes with roof damage	126,994	20,140	0
Total homes with foundation damage	13,411	2,348	0

Appendix C.

Special Communities Maps

Figure 1. Special Communities 2006

Figure 2. Special Communities 2018

Appendix D.

Group 2 Interview Questions and Interviewees

Subject & People of Interest	Questions

Time for Residents and Homeowners
 	
Legal Aid Groups/Individuals
	• Approximately how long did the inspection/Review process take from application to decision?
	  ○ At what points did you encounter bottlenecks or was the process more difficult?
	• Are you a renter or a homeowner? What did you file for with FEMA (IA renter, IA household)?
	  ○ For people who helped in the process: Did you notice any differences in processes or patterns between homeowner assistance and renter assistance?
	• How would you describe your/the experience applying for assistance?
	• If approved, how did it help?
	• Overall, do you view the decision as fair?

Time for Inspectors/Agencies that contract out inspections	For Inspectors:
	• Do you know how long was the time from application acknowledgement to assignment of inspection?
	• How long was the average inspection?
	• Do you know if the inspections were location dependent, as in were you sent to specific areas for a day or so to do multiple inspections in the same neighborhood? If so, please describe
	• What training do you have in this area?
	• What is the average day for an inspector?
	  ○ Please describe with some detail
	• Are you from PR?
	  ○ How do you think being from outside of PR may have impacted inspection work?
	  ○ From your perspective, how did this impact recovery efforts?
	• Do you feel that you were prepared for the work in PR?
	• Which disasters have you worked on for inspection and recovery efforts?
	  ○ If multiple, what differences have you perceived between them?
	For agency:
	• How are inspections distributed at the agency?
	• Do you know if inspectors came from outside of Puerto Rico to aid in inspection efforts?
	  ○ How do you think being from outside of PR may have impacted inspection work?
	  ○ From your perspective, how did this impact recovery efforts?
	• Have there been changes in inspection distribution processes?
	  ○ If so, please describe.

Administrative Questions Federal & Territory-Level
 	
FEMA
 	
Puerto Rico Department of Housing (Vivienda)
	• To your knowledge, are you aware of any or how many inspectors came from outside of Puerto Rico to aid inspection efforts?
	• Are you aware of how long it took for inspectors to respond?
	• FEMA criticized for its response during Maria, how did you address those concerns in recent disasters?
	  ○ What lessons have you learned?
	  ○ What do you wish you had known?
	  ○ What issues came to light?
	  ○ What were the specific differences between your response in Fiona from response to Maria and Irma?
	  ○ How did response to Maria impact response to earthquakes?

Organization	Name	Interview
FEMA, Response Division	Newton Tang, Operational Planning Branch Chief	3/8/2024
FEMA, Response Division	Kevin Edwards, IMAT Operations Section Chief	3/8/2024
Fundación Fondo de Acceso a la Justicia	Amaris Torres-Rivera, Executive Director	3/20/2024
Taller Salud	Modesta Irizarry, Community Leader in Loiza	3/20/2024
	Rosaura Rodríguez, Artist and Educator	4/2/2024
Departamento de la Vivienda (Puerto Rico Department of Housing)	Wanda Garcia Sanchez, Coordinator	3/20/2024
Departamento de la Vivienda (Puerto Rico Department of Housing)	Laury Ribera, Public Housing Administration	3/20/2024
Departamento de la Vivienda (Puerto Rico Department of Housing)	Elga Novoa	3/20/2024
U.S. Army Corps of Engineers	Johann Sasso, Emergency Manager	3/22/2024

Appendix E.

Group 3 Interview Questions

Introduction:

1. What is your name? (Don't collect)
Can we record? We're anonymizing our data.
2. What municipality are you located in?
3. What is your profession?
    a. Gestores
    b. Architects/Engineers
    c. Municipios
    d. Other

Building Permit Process

1. Do you do construction permitting? What's your experience/relationship with the OGpe?
2. How do you apply for a construction permit?
3. What are the different pathways you can take to obtain a building permit?
4. What do you find to be the biggest reason that some people may not get permits?

For Municipios:

5. How often do permit applications go unfinished?
6. What kind of follow-up happens to ensure that the construction project proceeds as directed by an issued permit?
7. Have you noticed any patterns in permitting

following a natural disaster? (Do you see residential before commercial? What follows?)
8. Do you issue more residential or commercial permits?
9. Are most of the commercial permits you issue going to long-term island residents or newcomers?

Patterns in the Construction Industry

For Gestores:

1. Could you explain what you do in more detail?
2. How did you get into this line of work?

For Architects/Engineers/Gestores

3. Can you tell us about your company?
    a. What kind of projects do you usually do?
    b. Can you give us an idea of who your clients are?
4. How have the pandemic/hurricanes/earthquakes affected you/your industry?
5. What types of projects pick back up first after a disruption? What takes more time to come back after a hurricane?
6. Why do you think so many residents come to ask you for help?
7. Is there any recurring reason that you find people continue asking
for help?

Factors that Influence Reconstruction Efforts

1. Do you find there is a lot of informal construction in Puerto Rico?
2. What can you tell us about the changes to the building code since 2017?
    a. Did it have an impact on the types of permits issued or denied?
    b. Did those changes impact your business?
3. Do you think they will help [Municipality] be more prepared for natural disasters? Why or why not?
4. Are you aware of the tax breaks in Act 60?
If yes,

    a. Has that impacted the kinds of permit requests your office receives?
    b. Do you think your municipality will see any benefits?
    OR
    c. Have they had an impact on your business/clientele?
    b. Do you think they will have an impact?
5. Is there anything you were expecting us to ask that we didn't? What should we have asked?
6. What does a "recovered" Puerto Rico look like?

Appendix F.

Data Processing and Visualization Code

The code for data processing and visualization are compiled into documents listed below:

Construction Industry in Puerto Rico - Data Summaries.pdf

OGPe Construction Permits Dataset - Cleaning & Analysis.pdf

Appendix G.

Solar Plan and Design

Ashford Hospital - Solar Sizing Design (SolarIT).pdf

Harvesting Sunshine Solar Energy Integration.pdf

Inverter Technical Specifications - 15K-2P_ SpecSheet.pdf

Solar Panel Technical Specificaitons - JA Solar JAM78S10-445_MR (445W) Solar Panel.pdf

Appendix H.

Ideation Slides and Surveys

CP 4813 - Ideation & Design Sprint Presentation.pdf

CP 4813 - Survey _ Field Work.pdf

Appendix I.

Tree Planting Plan

Tree Coverage Code - Calculator Model

Tree Planting Guide

Tree Maintenance Guide

Appendix J.

Behavioral Campaign

Bahavioral Campaign Plan