Resilient Community Design: From Framework to Process GMLC DRC SAG Meeting 4

PRESENTED BY

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Goals and objectives recap

Overarching Goal:

- Demonstrate an actionable path toward more resilient communities through consequence-based approaches to grid planning and investment

Objectives:

- Solidify – through demonstration, outreach, verification, and gap analysis – a framework for community resilience planning focused on grid modernization and investment involving the key stakeholders in the community including electric utilities
- Set a clear, actionable path toward widespread adoption of community-focused resilience planning within the grid community

Why the SAG?

- Inform the technical and regulatory solution space for the project, and advise an actionable path forward to implement community-focused resilience planning for utilities nationwide
- Project partners will educate stakeholders emerging technologies that can provide grid resilience, and address how these technologies can provide community resilience
- Stakeholders will provide feedback on unique aspects of their regions that enable or discourage alignment of community-focused resilience planning with electric utility investment

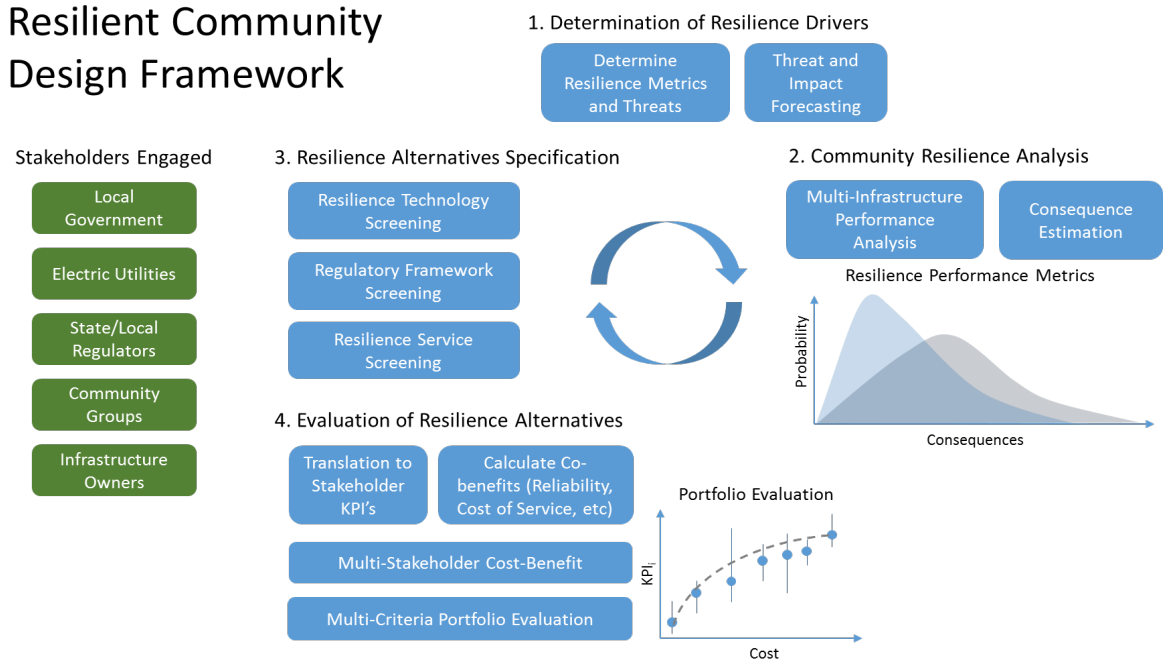
Our 4th SAG Meeting

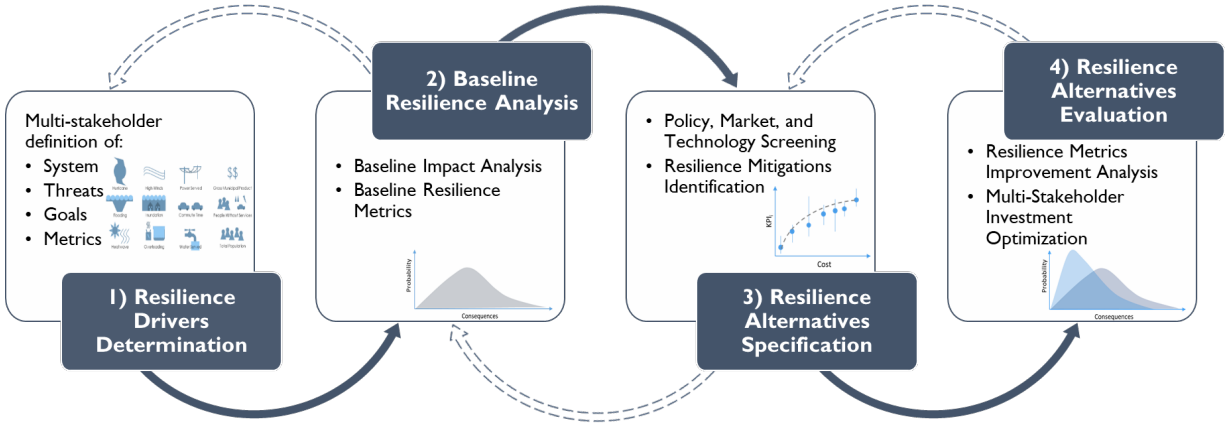
July 2018 (Washington D.C.)
- Learning about each others' challenges
- Speaking the "same language"

Jan 2019 (Los Angeles, CA)
- Focus on metrics
- Acknowledging limitations
- Putting resilience into perspective

July 2019 (New York, NY)
- Updated, more detailed framework description
- Progress on demonstrations
- Connecting stakeholders to the framework

Jan 2020 (New York, NY)
- From framework to implementation





Goals and objectives for this meeting

From Framework to Implementation

- What do you need that you don't have today?
  - Better science, data, tools, processes
  - Partners, stakeholder connections
  - More funding for resilience projects
  - Resilience-focused policy

Project Partners

- SUNY Buffalo
  - What do people lose when they lose power?
- Synapse Energy Economics
  - How do we organize our thinking toward aligning cities and utilities?
- Clemson University and NMSU
  - What is feasible today that recently wasn't?
- NARUC and DOE
  - What are the regulatory challenges and opportunities?

Demonstration Partners

- San Antonio
  - Clearest City-Utility connection
- El Cano Martin Pena Communities in San Juan, PR
  - Highly autonomous partner with strong resilience drivers
- National Grid
  - Several grid modernization and resilience investments
  - Resilience-inclusive cost-benefit framework

SAG Updates

- Working group progress
- New investments or funding avenues
- Benefits of bringing in unique stakeholders
- Progress working with PUC's, SEO's, legislatures

Perspectives on metrics

What is the difference between an attribute-based and performance-based metric?

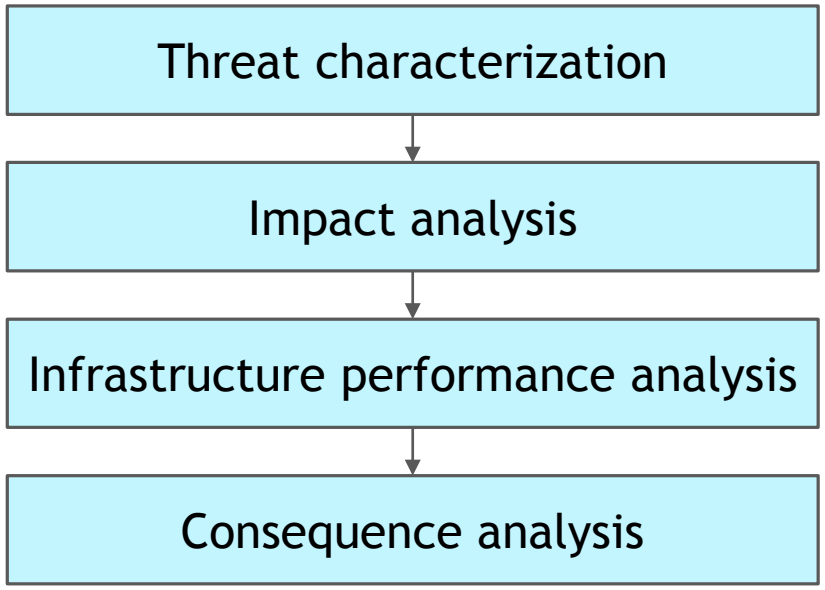
- Attribute based:
  - Things you can count today
  - Features or characteristics that we think will improve performance
    - What makes my system more resilient?
- Performance-based:
  - Things you can only measure following disruptions (or model)
  - Measures what you care about
    - How resilient is my system?

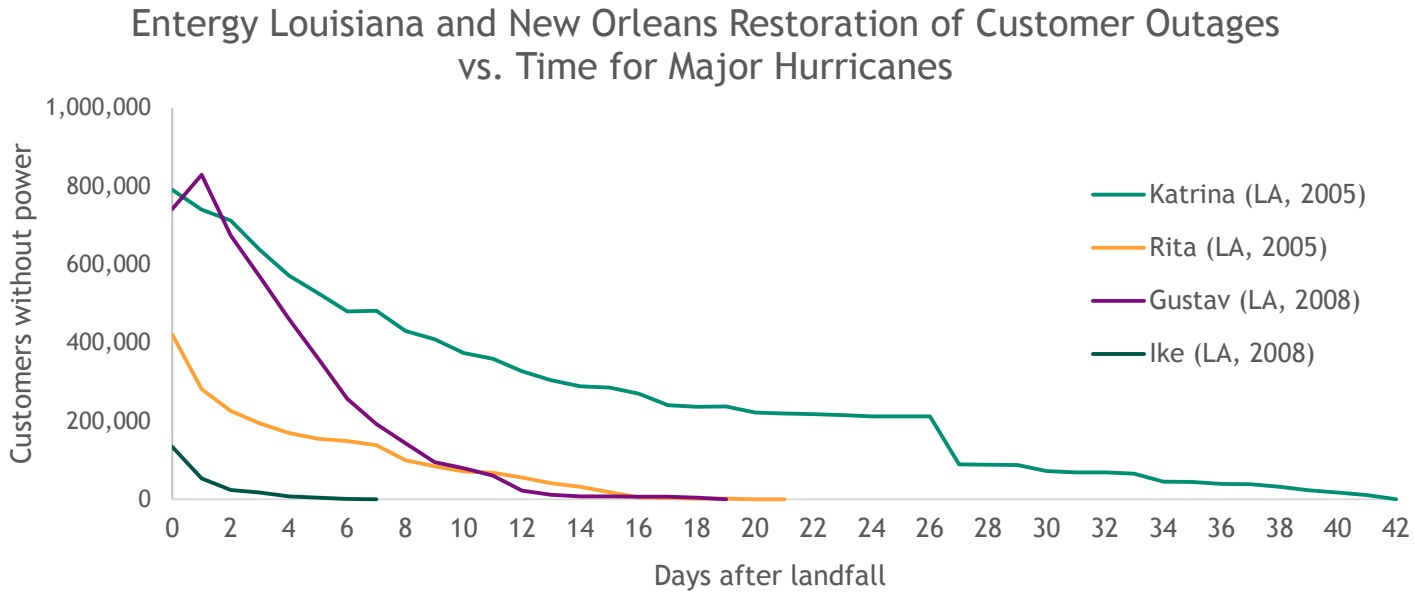
	Efficiency	Sustainability	Resilience
Attribute-based	Number of efficient gens	Renewable capacity	kW on microgrids
	Efficient water heaters deployed	PV / battery recycling capacity	miles of hardened conductor
Performance-based	Energy affordability	Greenhouse gas emissions	kWh not served to critical customers
	Total cost of service	Average global temperature	Social burden due to lack of services

Performance-based process

If I want a performance-based resilience metric, can I calculate it today?

- Pure grid-performance:
  - kWh not served to critical customers
- Consequence-focused:
  - Social burden
  - Gross production losses
  - Performance of missions ensuring national security





Data and tools for performance-based process

Threat

Flood:
- FEMA FIRMs
- Hydrological Modeling

Earthquake:
- USGS PGA estimates

Landslide:
- USGS susceptibility

Wildfire:
- Data

Cyber Attack:
- Event-based characterization

Physical Attack:
- Criticality and vulnerability estimates

EMP/GMD:
- Atmospheric modeling
- Electromagnetic coupling modeling

Impact

Grid components:
- Fragility models
- Physics-based models

Performance

Grid system:
- Static and dynamic power flow models
- Discrete event models (e.g. MDT)
- Statistical models
- Simplified/surrogate models

Additional Infrastructures:
- Natural gas
- Water
- Communications
- Wastewater
- Transportation
- Fuel delivery
- Food system

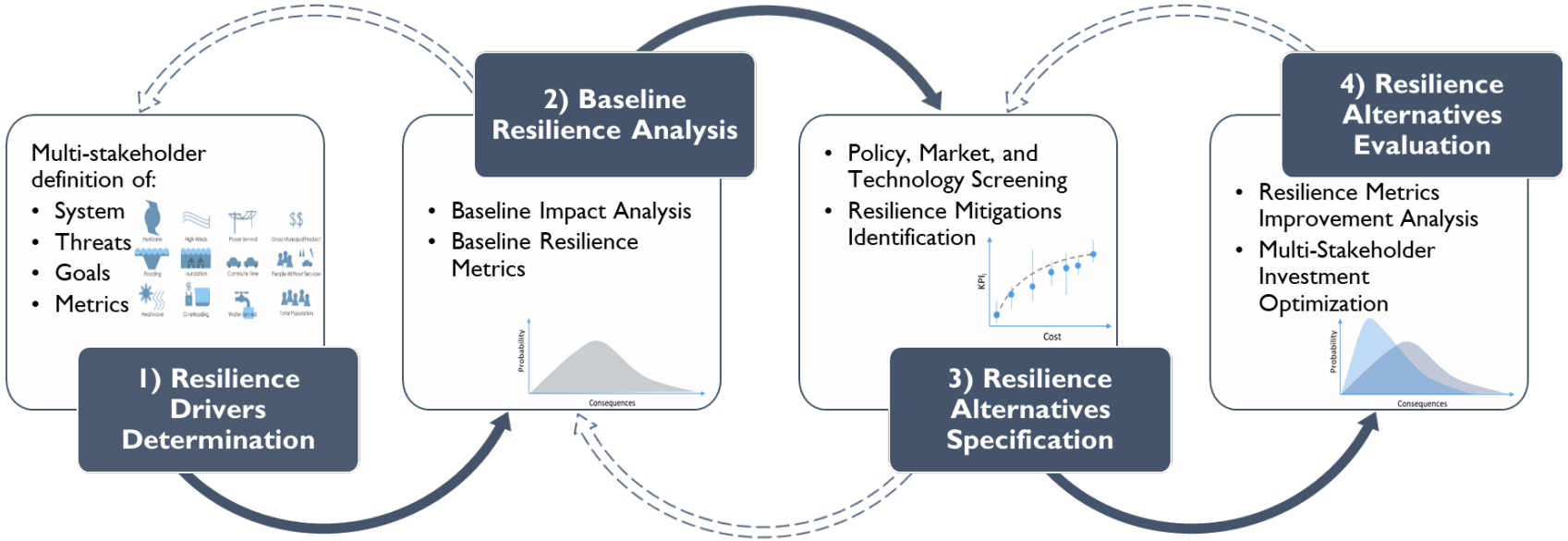
Consequence

Economy:
- Input-output modeling
- Computable general equilibrium models
- Econometrics

Society:
- Needs-based travel cost modeling
- Quality-adjusted life years

Security:
- Mission dependency modeling

Connecting stakeholders to the process



Cities	• Define Consequence • Define Threats	• Map system performance to consequence	• Connect initiatives • Open new opportunities	• Re-evaluate consequence given alternatives
Utilities	• Define interdependent infrastructures	• Threat to system performance	• Design for triple-bottom-line	• Evaluate system performance under alternatives
Regulators	• Set goals	• Balance technical rigor with analysis burden	• Ensure designs address goals	• Ensure final portfolios meet goals, are feasible, and equitable

Next steps

We are seeing value from integrating cities in the resilience discussion. How can we better integrate this viewpoint?

- Many loosely connected offices within city gov't
- Cities can be one financing opportunity
- Smaller communities also have a role (See: Puerto Rico and NY examples)

What are the strengths and challenges of the resilience node concept?

- Does it necessitate inverter-dominated or DC microgrids?
- Protection remains a challenge – what are some other challenges?

We are seeing aggressive fossil-free goals. How can we achieve these goals and maintain resilience?

- Great can be enemy of the good: cities "skipping" district thermal systems
- Better balance between sustainability, efficiency, and resilience?

How far should we go "beyond grid?"

- Transportation systems
- Emergency response
- Buildings
- Communications
- Other...

Caño Martín Peña Communities, San Juan, PR
GMLC DRC SAG Meeting 4

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Bobby Jeffers, Efrain O'Neill Carrillo, Holly Eagleston

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Applying the DRC Framework in Puerto Rico

Institutions in crisis:

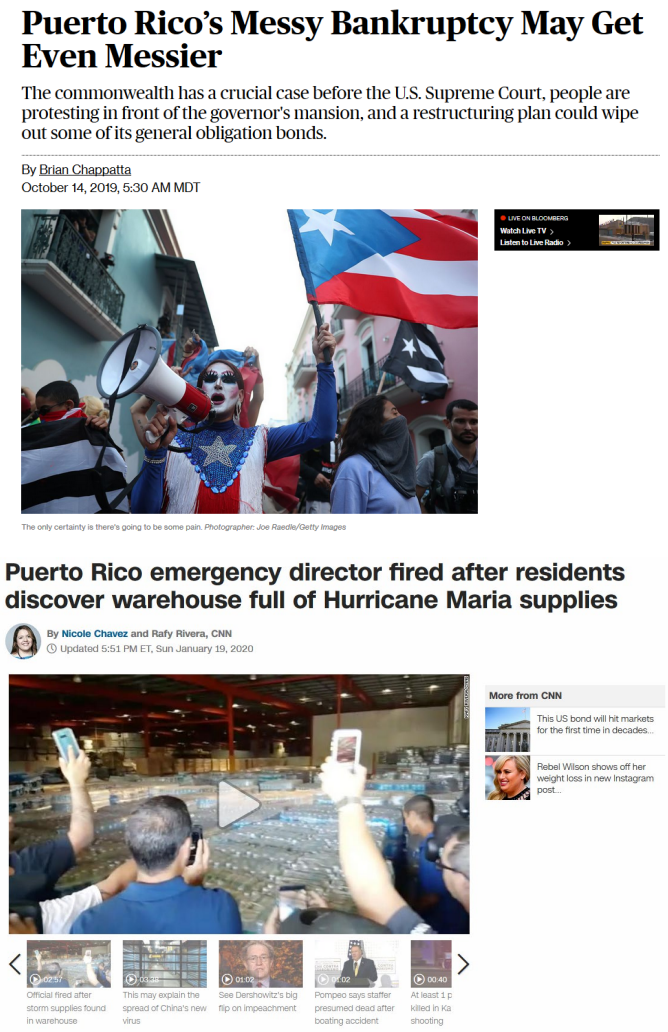
- Government and government-owned utility (PREPA) in bankruptcy
- Perceived lack of transparency and accountability
- Mistrust among key energy stakeholders
- Lack of clear leadership on energy matters

Frustrated citizens:

- Bad experiences and perceptions regarding public-private-partnerships
- Communities are getting tired of interviews, visits, questions about their experiences during and after Maria. Must provide a value-proposition.

Proposed path forward:

- Apply the DRC framework, but customize the stakeholders and processes involved for the constraints of the communities
- Ensure energy initiatives endure government changes, can be sustained, and are inclusive
- In general, there is broad support for community-based and community-led initiatives



Puerto Rico's Messy Bankruptcy May Get Even Messier

The commonwealth has a crucial case before the U.S. Supreme Court, people are protesting in front of the governor's mansion, and a restructuring plan could wipe out some of its general obligation bonds.

By Brian Chappatta
October 14, 2019, 5:30 AM MDT

The only certainty is there's going to be some pain. *Photographer: Joe Raedle/Getty Images*

Puerto Rico emergency director fired after residents discover warehouse full of Hurricane Maria supplies

By Nicole Chavez and Rafy Rivera, CNN
Updated 5:51 PM ET, Sun January 19, 2020

More from CNN

This US bond will hit markets for the first time in decades...

Rebel Wilson shows off her weight loss in new Instagram post...

Official fired after storm supplies found in warehouse

This may explain the spread of China's new virus

See Dershowitz's big flip on impeachment

Pompeo says staffer presumed dead after boating accident

At least 1 p killed in Ka shooting

References: E. O'Neill-Carrillo, E. Mercado, O. Luhring, I. Jordan and A. Irizarry-Rivera, "Community Energy Projects in the Caribbean: Advancing Socio-Economic Development and Energy Transitions," IEEE Technology and Society Magazine, vol. 38, no. 3, pp. 44-55, Sept. 2019.

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E. O'Neill-Carrillo, I. Jordán, A. Irizarry-Rivera, R. A. Cintrón. Invited paper: "The Long Road to Community Microgrids," IEEE Electrification Magazine, vol. 6, no. 4, December 2018, pp. 6 – 17.

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E. O'Neill-Carrillo, A.A. Irizarry-Rivera, Cecilio Ortiz, Marla Pérez-Lugo. "The Role of Engineers as Policy Entrepreneurs toward Energy Transformations," Proceedings of the ASEE 123rd Annual Conference, June 2016, New Orleans, LA.

DRC Partner: The Caño Martín Peña Communities

- Caño Martín Peña (CMP) is a ***3.75 mile long tidal channel*** is in the San Juan Bay Estuary (part of EPA's National Estuary Program).
- The CMP is now an obstructed, contaminated body of water creating a constant flood danger.
- Eight economically-challenged communities remain today in the vicinity of CMP (around 25,000 people).
- The ENLACE Project Corporation was created by Law 489 in 2004 to help seven of the eight communities improve their quality of life (the other community, Cantera, got a separate law).
- The seven communities occupy an area of around 1.82 km2 (High population density area).
- The law made the seven CMP communities a special planning district with autonomy with regards to planning decisions (it has been described as similar to a "county").

Source: Lyvia N. Rodriguez Del Valle. "ENLACE Caño Martín Peña: A Restoration and Resiliency Project," Written testimony during a Subcommittee on Environment hearing on Response and Recovery to Environmental Concerns from the 2017 Hurricane Season, U.S. Congress, November 14, 2017.

Image Credit: **labgov.city**

Image Credit: Wikimedia commons user **Moebiusuibeom-en**

Image Credit: US EPA

DRC Partner: The Caño Martín Peña Communities

Image Credit: US EPA

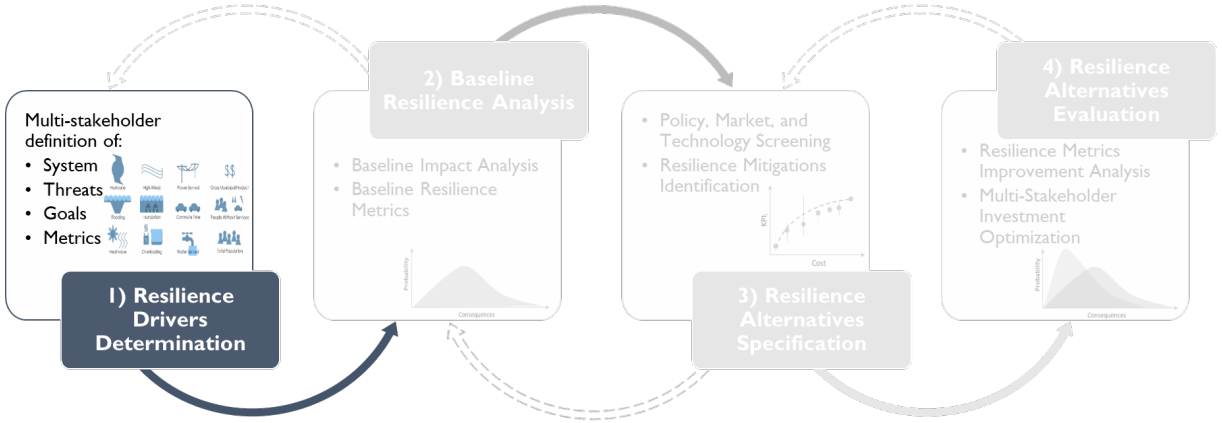
Step 1: Determining Resilience Drivers

Goals:

- Constant community engagement: Planning-Action-Reflection
- Implement Comprehensive Development and Land Use Plan
- Implement sewage system (currently, 33% of households have none)
- Environmental restoration
- Design stormwater management facilities
- Housing and redevelopment
- Prevent displacement

Example strategies/actions:

- Relocate homes in high risk flood zones
- Green infrastructure (including microgrids)
- Environmental restoration projects
- Equitable development
- Participatory democracy



Source: J. Bernagros, W. Michaels, S. Mossop, C. Muñiz Pérez. "Developing Green Infrastructure Typologies," Water Environment Federation Technical Exhibition & Conference, Oct. 2, 2018

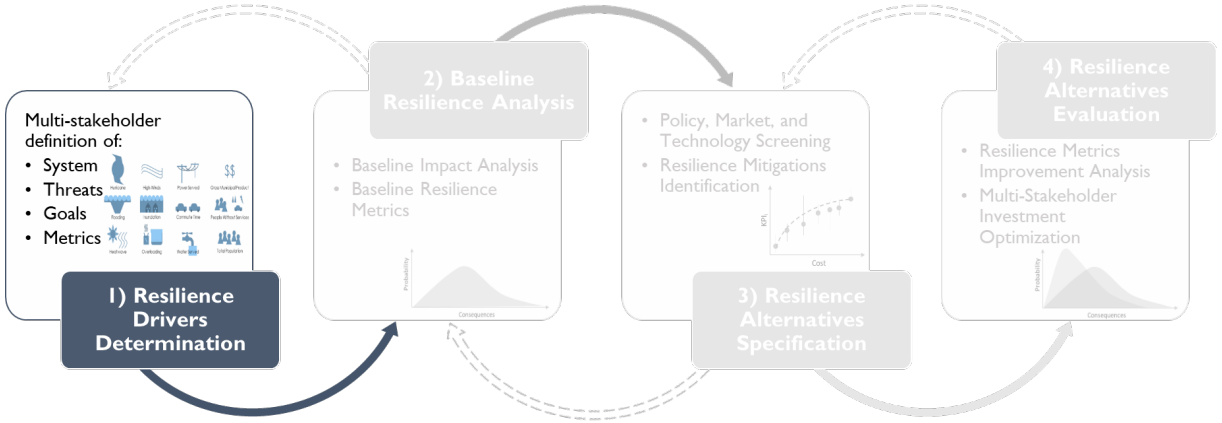
Step 1: Determining Resilience Drivers

Known threats:

- Flooding
  - Obstructed, contaminated channel
  - High water table
  - Poor soil conditions
  - Collapsed stormwater system
- Hurricanes
  - Cause flooding + high wind (local damages)
- Earthquakes
- Remotely-driven power outages

Other resilience challenges/opportunities:

- Access to funding
- History of environmental and social injustices
- High electric energy costs
- PREPA's IRP process



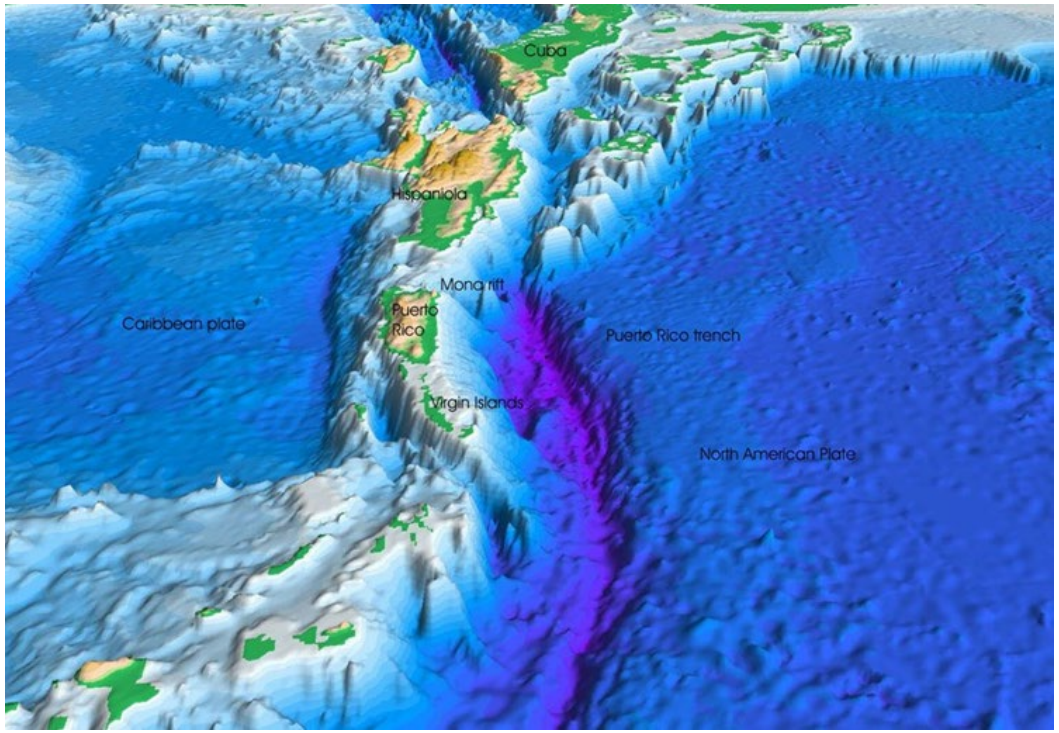


Image Credit: USGS

Sources: J. Bernagros, W. Michaels, S. Mossop, C. Muñiz Pérez. "Developing Green Infrastructure Typologies," Water Environment Federation Technical Exhibition & Conference, Oct. 2, 2018.
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Flooding in CMP

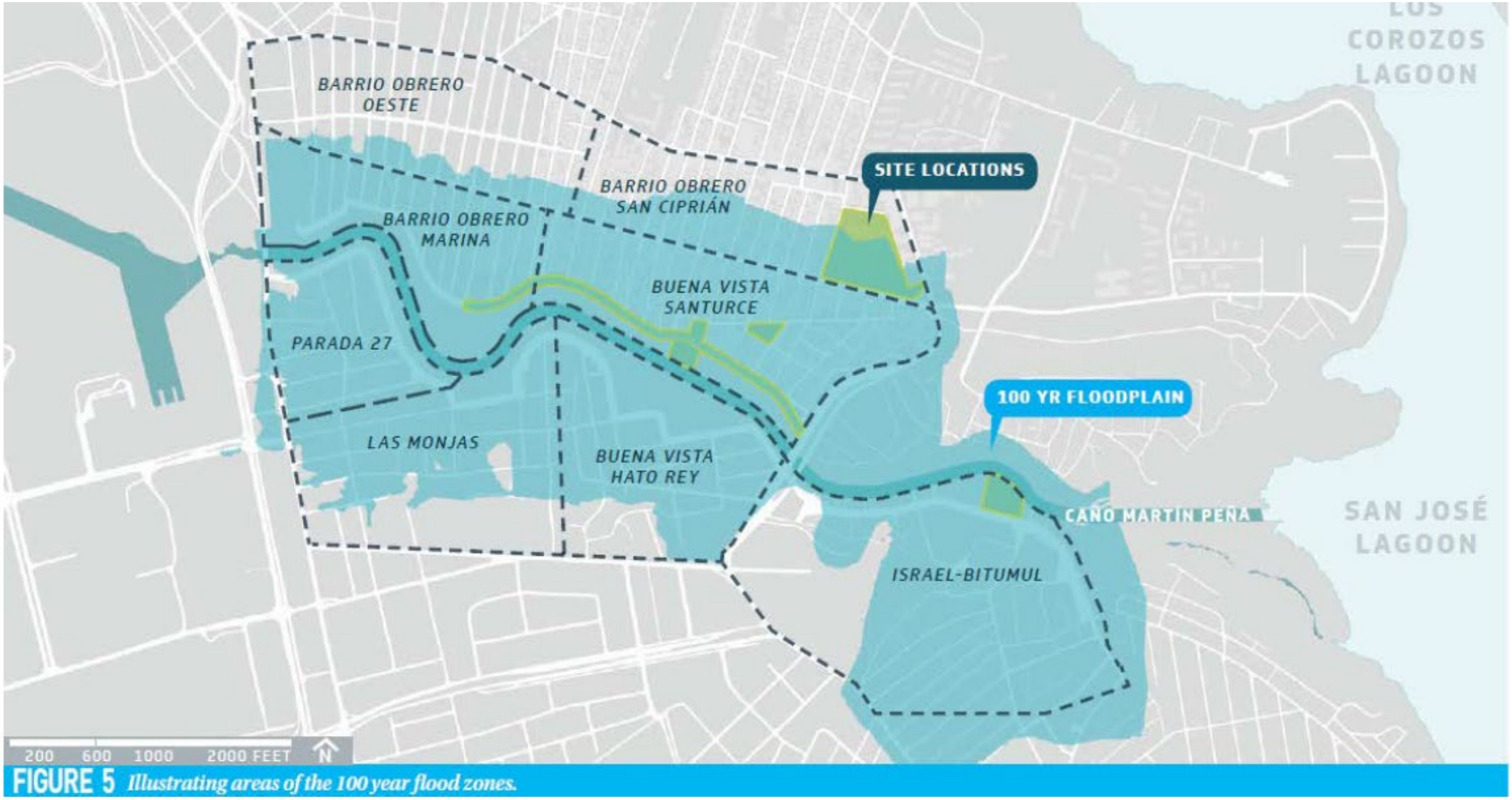


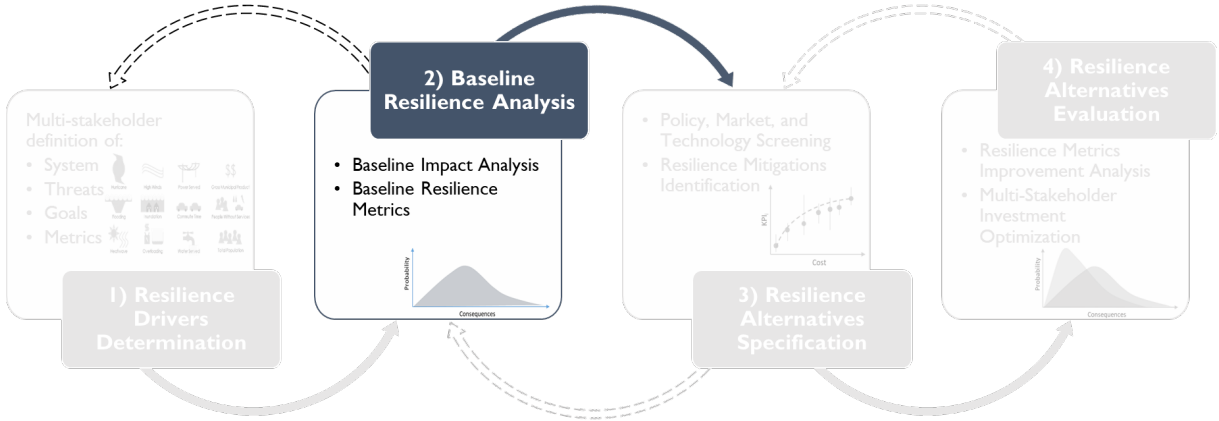
FIGURE 5 *Illustrating areas of the 100 year flood zones.*

Image Credit: US EPA and Spackman Mossop Michaels

Step 2: Baseline Resilience Analysis (we are here today)

Baseline metrics:

- Efficiency/Affordability
  - **Average bills for residential and commercial customers**
    - No tiered rates
    - Yes to net metering
    - Flat rate for public housing
- Sustainability
  - **GHG Emissions**
    - Estimated average 1.25 lbs CO2e per kWh for 2018
  - **Fraction of power from renewable sources**
    - Estimate amount of local PV installed + capacity factor
  - **Lifecycle impacts**
    - End of life challenges – no current plan for PV/battery recycling
- Resilience
  - **Social Burden to acquire services**
    - Sandia modeling methodology + U-Buffalo validation



Average in cents/kWh for the three main class rates (source: EIA, Electric Power Monthly, December 2019)

Year	Residential	Commercial	Industrial
2016	17.93	19.57	15.83
2017 (María)	22.26	22.72	19.70
2018	20.73	23.08	19.04

Infrastructure in CMP

Some infrastructure available:

- Three gas stations
- One electric power distribution substation (38kV/4.16kV, 11MVA)
- One hospital
- Two pharmacies
- One ice plant in the community
- Eleven grocery stores (most of them are small convenient stores)
- Five community centers
- Bus stops around the perimeter of the seven communities
- Train station nearby (not usable in a power outage)

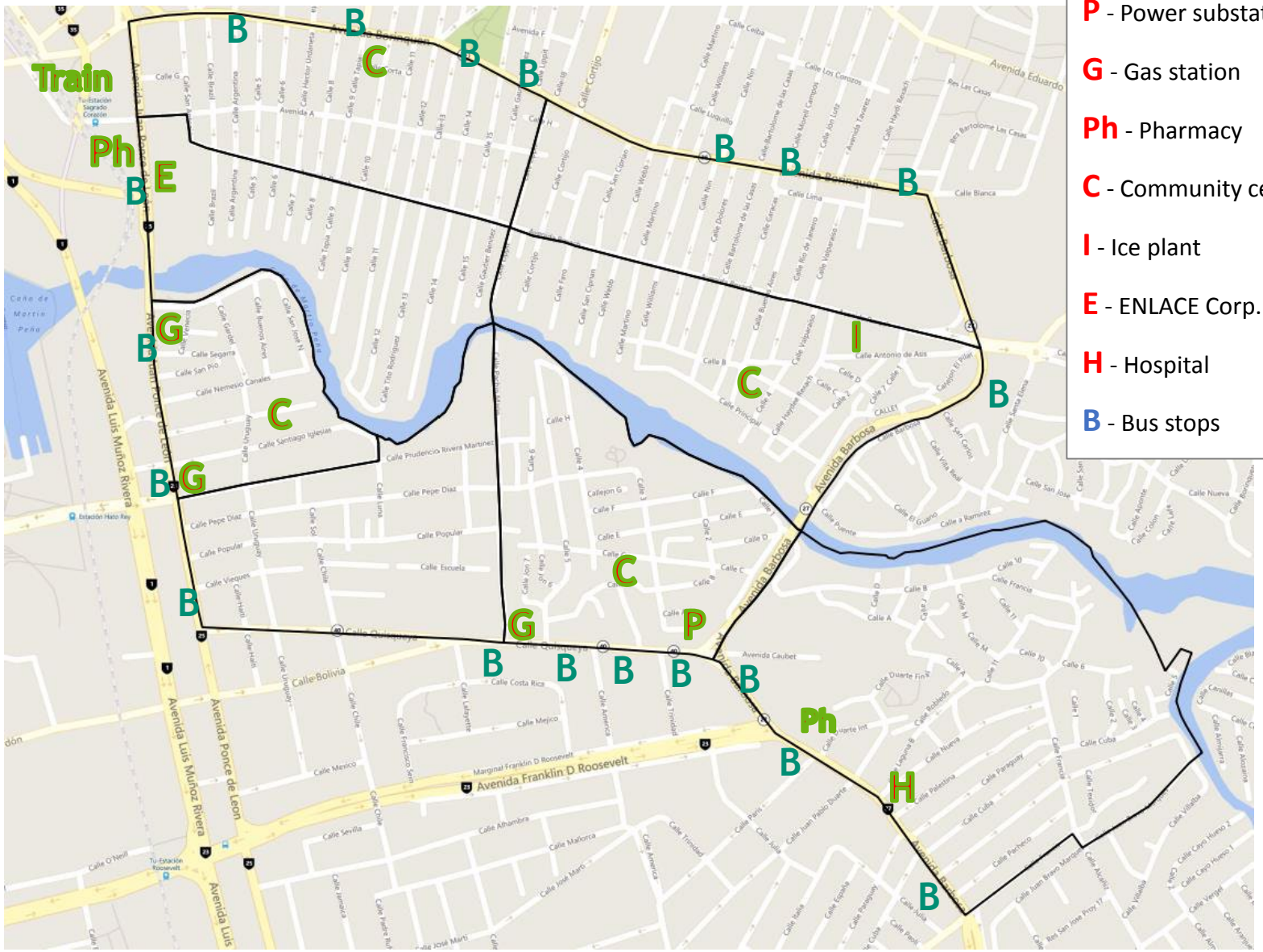
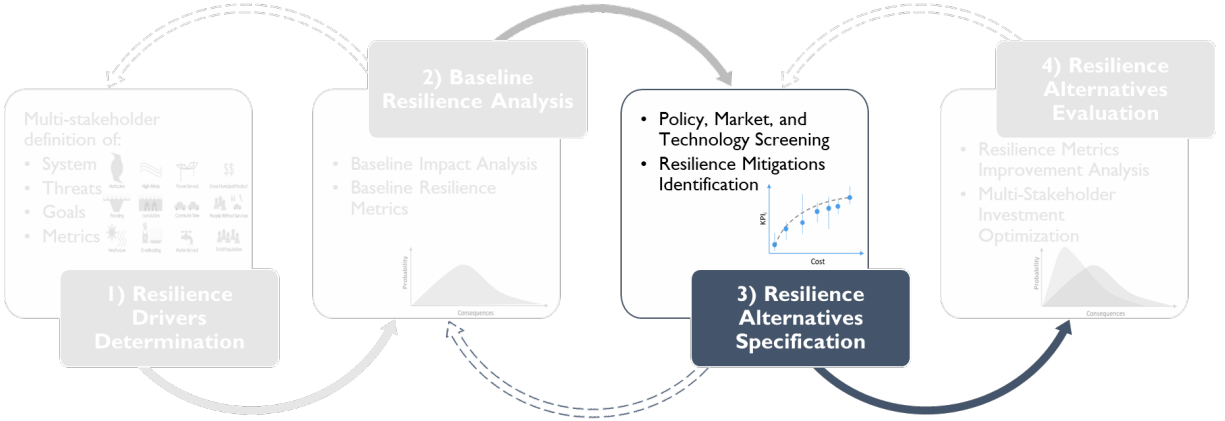


Image Credit: ENLACE project corporation

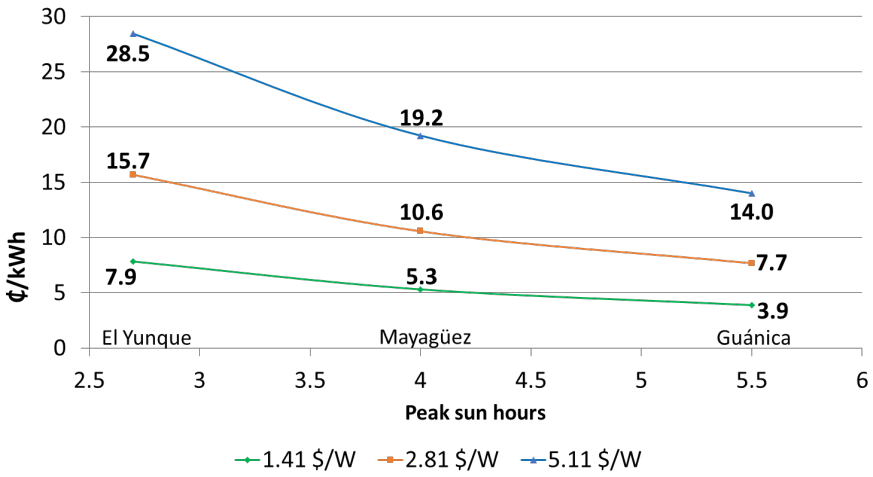
Step 3: Alternatives Specification

Two-step specification:

- 10 to 20 alternative "resilience node" locations across CMP, with:
  - Microgrid/resilient power service territory
  - Services that can be provided to citizens
- Within each resilience node, several alternative technologies:
  - Technology type, size, capacity, etc.
  - Description of how technologies will improve metrics (hypothesis)



Component/Task	Cost ($/W)
PV panels	0.71
Inverter	0.18
Charge controller	0.07
Balance of system	0.45
Sub-total (do-it-yourself)	$1.41
Installation (estimate)	0.40 to 1.50
Design, permitting (estimate)	1.00 to 2.20
Total	$2.81 to $5.11

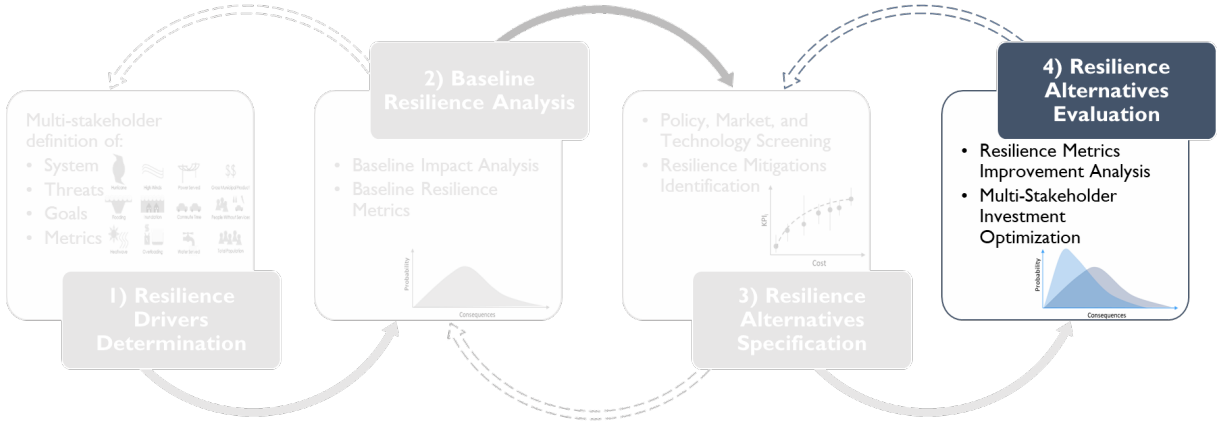


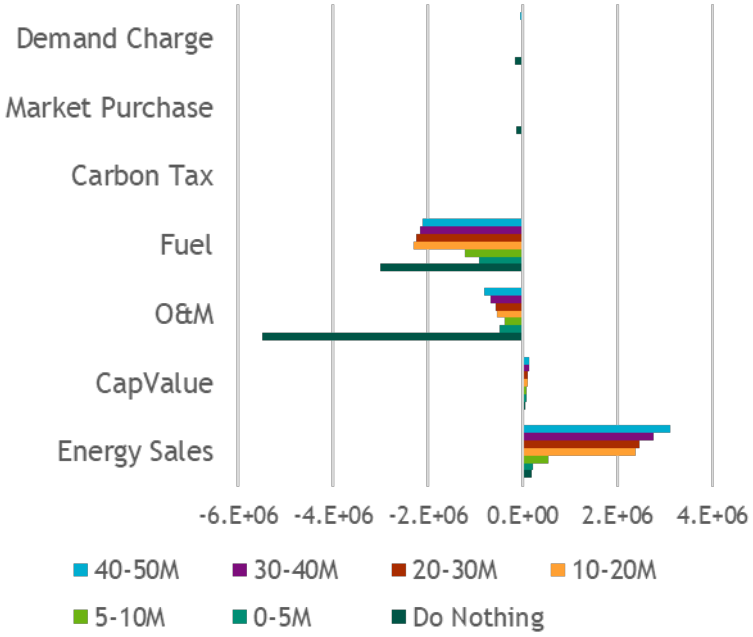
Solar cost figures from: E. O'Neill-Carrillo, I. Jordán, A. Irizarry-Rivera, R. A. Cintrón. "The Long Road to Community Microgrids," *IEEE Electrification Magazine*, vol. 6, no. 4, December 2018, pp. 6 – 17.

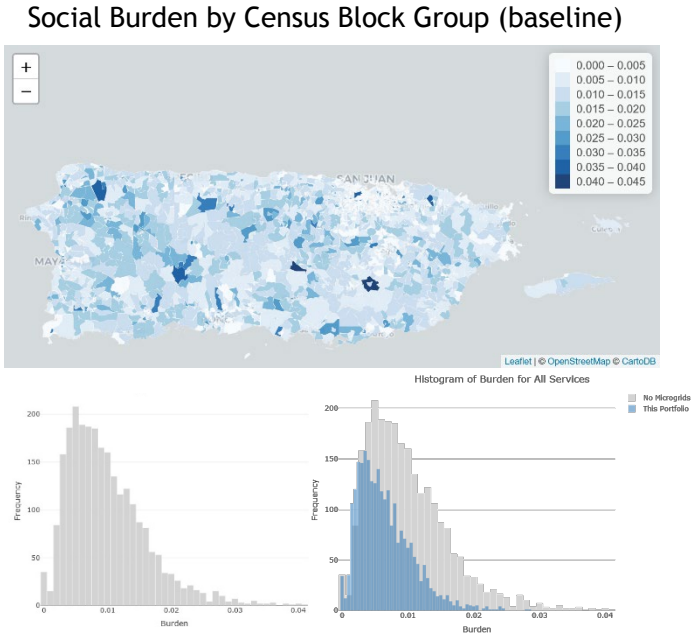
Step 4: Alternatives Evaluation

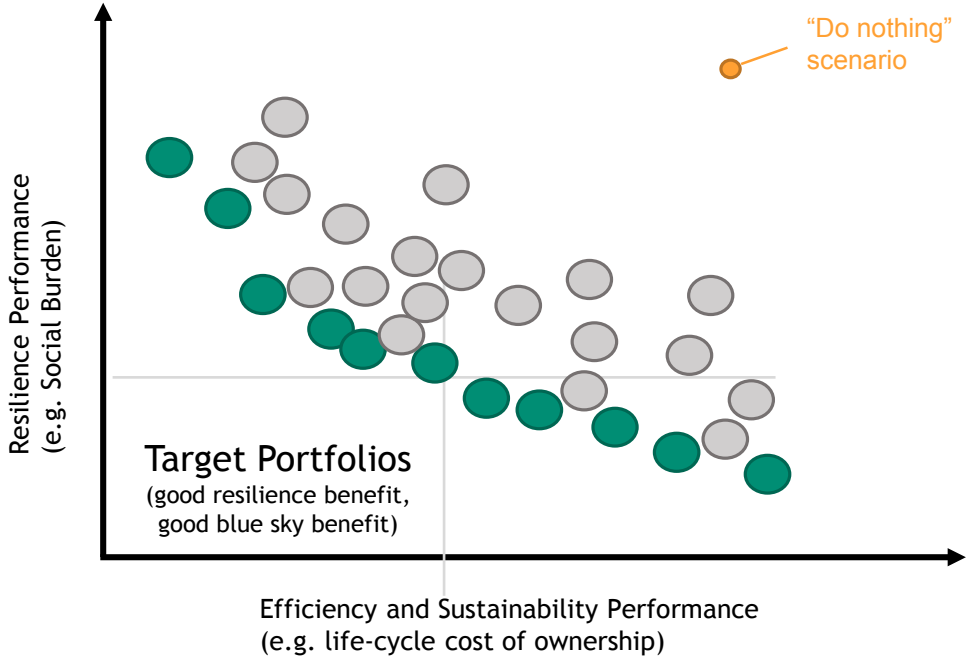
Final analysis process:

- Evaluate improvement in metrics
- Determine a small set of near-optimal portfolios
- Use multi-criteria decision analysis to incorporate one or more portfolios into community plan









Additional Considerations and Resources

Considerations:

- Mature PV Market in Puerto Rico (many local installers, trade organization – ACONER)
- Aggressive local, renewable energy goals (100% by 2050)
- Comprehensive Development Plan for the Special Planning District (ENLACE)
- PREB's microgrid regulation

Resources:

- CMP communities' support resources
- ENLACE's Feasibility Report & Environmental Impact Statement for Local Ecosystem Restoration Project (submitted to U.S. Army Corps of Engineers)
- SNL (2018), "Analysis of Microgrid Locations Benefitting Community Resilience for Puerto Rico"
- Results from UPRM Solar Colloquia (2017), DOE GEARED project GridEd
- UPRM Sunshot project report (2013), "Rooftop Solar Challenge to Induce Market Transformation in Puerto Rico"

Backup Content

Connecting processes and stakeholders

Threat	Impact	Performance	Consequence

Resilient Community Design Framework Step 1: Resilience Drivers Determination

Step 1 Description

Multi-stakeholder definition of:

1.1. System

- System can be scoped by geographic/jurisdictional boundaries, sectors/infrastructures, and/or temporal scale
- Identify the specific planning process for the system (e.g., city sustainability plan, utility integrated resource plan) and role of resilience therein

1.2 Threats

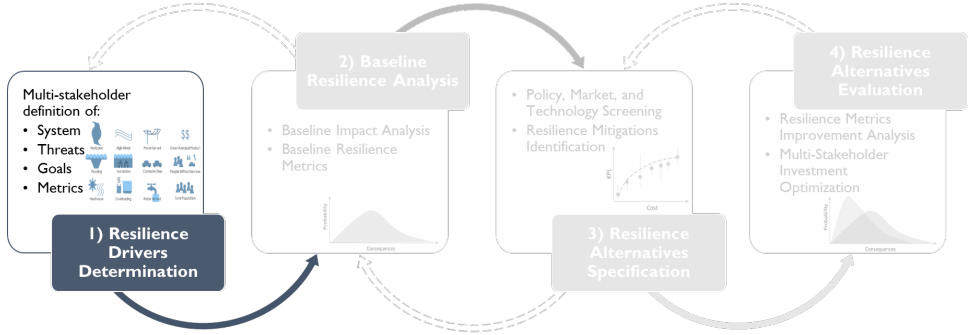
- Select threats to resilience (e.g., natural, intentional/accidental, structural) or select threat-agnostic approach
- Focus on acute threats that create high consequence disruptions, with chronic threats as constraints/drivers of acute

1.3 Goals

- Resilience goals should be as detailed as possible, and attentive to the system's ability to prepare, withstand, respond, and/or recover
- Other complementary or competing goals relevant to a given planning process should be defined and prioritized

1.4 Metrics

- Identify consequence categories (e.g., economic, social, national security, critical service/performance) and associated metrics (e.g., recovery costs, access to community lifeline services, mission assurance, critical load not served)
- Select consequence-focused performance metrics for individual infrastructures and multi-infrastructure analysis



Stakeholders

Primary
- Municipal governments
- Electric utilities
- Community/customer groups

Secondary
- State/local regulators*
- Interdependent and enabling infrastructure owners/operators
- Industry associations
- Insurance and supporting industry

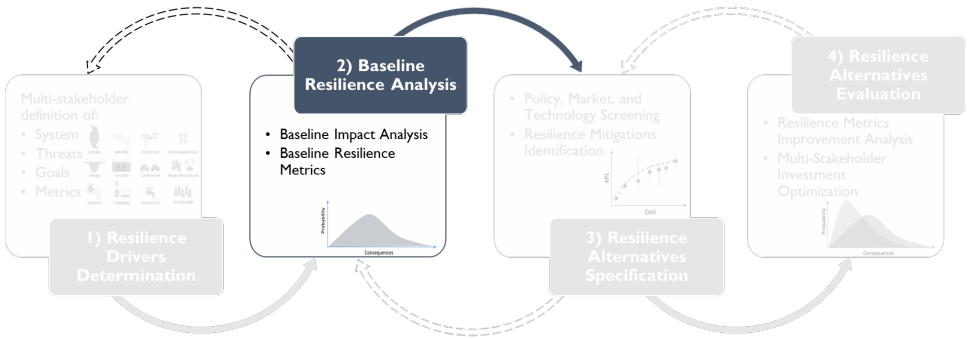
Tools and Resources

- System definition tools: FASTMap, ArcGIS
- Stakeholder elicitation methods (tools) for threats and goals: analytic hierarchy process (e.g., PARADE), Delphi technique, multi-attribute utility theory, nominal group technique, risk assessment matrix (e.g. RIMES), notice and comment process (e.g., IdeaScale)
- Metrics surveys: SNL (2014, 2019), RAND (2015), GMLC (2018, 2019), LBNL (2019)

Challenges and Opportunities

- Stakeholder disagreement on prioritization of goals and/or key metrics
- Selection of metrics for which data is or will be available

Resilient Community Design Framework Step 2: Baseline Resilience Analysis



Step 2 Description

2.1 Baseline Impact Analysis

- Using historical/observational data and/or simulation, probabilistically forecast (over the planning horizon):
  - Threats/disruptions
  - Component impacts and aggregation to infrastructure system impacts
  - Multi-infrastructure impacts

2.2 Baseline Resilience Metrics

- Calculate consequence-focused performance metrics (*without* mitigations under consideration)

Stakeholders

Primary
- Municipal governments
- Electric utilities
- Interdependent and enabling infrastructure owners/operators

Secondary
- State/local regulators
- Community/customer groups
- Industry associations
- Insurance and supporting industry

Tools and Resources

Threats/disruptions:
- Tools: FEMA Hazus, ArcGIS
- Data: FEMA Flood, NREL Wind Exceedance, FEMA/USFS Fire, USGS Seismic and Landslide, NOAA National Surge Hazard

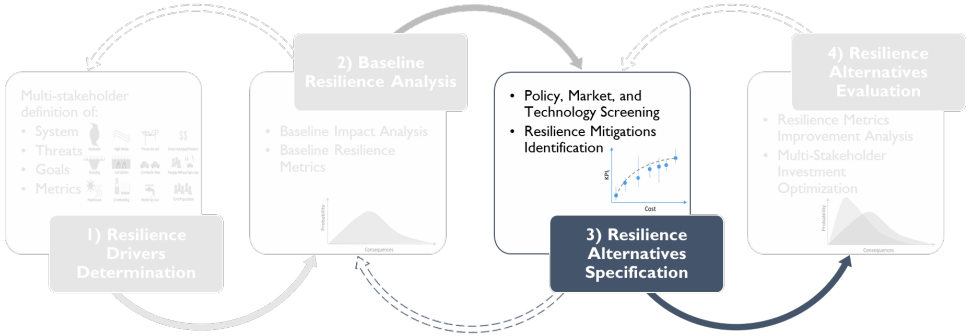
Component, infrastructure, multi-infrastructure impacts:
- Tools: GIS Fragility Models, LANL Outage and Restoration tool, WNTR
- Data: Eagle-I, utility OMS

Baseline resilience metrics:
- Methods (tools): economic value of service interruption (e.g., ICE Calculator, REAcct), production cost models (e.g., Prescient), travel cost methods, energy assurance for critical mission functions (e.g., TMO, WSTAT)

Challenges and Opportunities

- For some threats, component impact is hard to predict
- Performance-based metrics add difficulty to the process – a new paradigm, which may increase friction
- Relatively few models available for cross-infrastructure impact analysis
- Human behavior element is not internalized in most tools

Resilient Community Design Framework Step 3: Resilience Alternatives Specification



Step 3 Description

3.1 Technology, Policy, and Market Screening

- Begin with screening of alternative technologies to meet goals (e.g., resilience, sustainability, reliability) of planning process identified in step 1.1 (e.g., city sustainability plan, utility integrated resource plan)
- Consider system constraints (e.g., regulatory frameworks, utility business models) and potential evolution of constraints
    - These may be alternatives in subsequent phases

3.2 Resilience Mitigations Identification

- Specify technology investment portfolios (i.e., potential planning, operational, and policy actions/designs that enhance the system's ability to prepare, withstand, respond, and/or recover)

Stakeholders

Primary

- Municipal governments
- Electric utilities
- Community/customer groups
- Interdependent and enabling infrastructure owners/operators

Secondary

- State/local regulators*
- Industry associations
- Insurance and supporting industry

Tools and Resources

Technology Screening

- Capacity expansion modeling tools
    - Distribution: ReNCAT, LPNORM (OD&O)
    - Transmission: REEDS

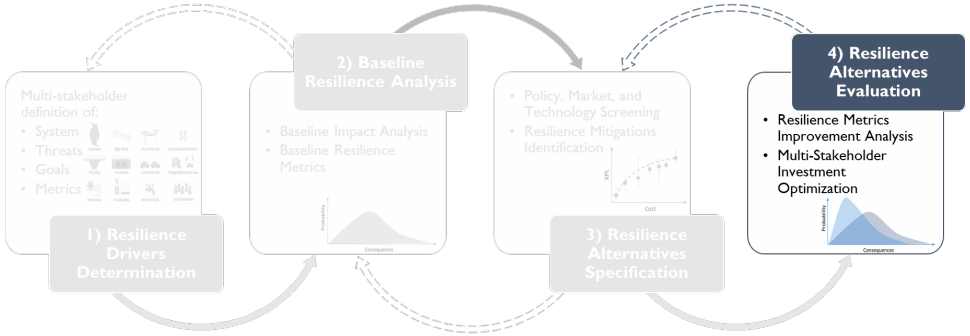
Resilience Mitigations Identification

- High level initial design tools: MDT, QSTS, DER-CAM, REOpt, HOMER, QUEST
- Down-select for feasibility tools
    - Component: Matlab/Simulink/SimPowerSystems, LabView, Xyce, Grid PV
    - Distribution: CYME, OpenDSS, GridLab-D
    - Transmission: PSS/E, PSLF, PowerWorld, Matlab Power System Toolbox

Challenges and Opportunities

- Tendency to oversimplify w.r.t. regulatory approaches
- Imprecise alignment between policy design and technology investment planning

Resilient Community Design Framework Step 4: Resilience Alternatives Evaluation



Stakeholders

Primary
- Municipal governments
- Electric utilities
- State/local regulators
- Community/customer groups
- Interdependent and enabling infrastructure owners/operators

Secondary
- Industry associations
- Insurance and supporting industry

Step 4 Description

4.1 Resilience Metrics Improvement Analysis

- Evaluate resilience mitigations by calculating consequence-focused performance metrics (repeating steps 2.1 and 2.2 *with* mitigations identified in step 3.2)

4.2 Multi-Stakeholder Investment Optimization

- Engage relevant stakeholders to negotiate weights for multiple resilience metrics
- Prioritize investment portfolio through multi-metric optimization

Tools and Resources

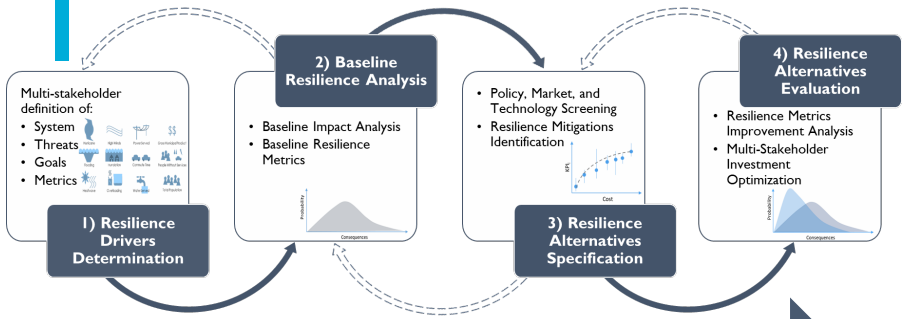
Metrics improvement analysis
- Methods (tools): economic value of service interruption (e.g., ICE Calculator, REAcct), production cost models (e.g., Prescient), travel cost methods, energy assurance for critical mission functions (e.g., TMO, WSTAT)

Multi-metric optimization
- Tools: PARADE, Prescient, ReNCAT, LPNORM (OD&O)

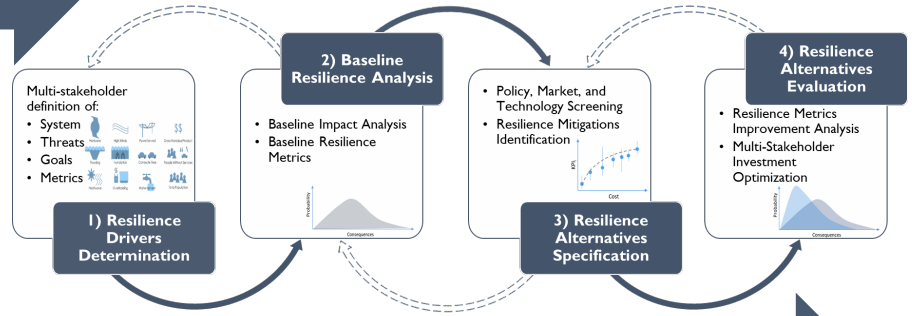
Challenges and Opportunities

- Resilience benefit streams not often internalized in current policy
- Process of final investment selection can appear opaque to communities
- Currently technically difficult to incorporate consequence-based resilience metrics within investment optimization

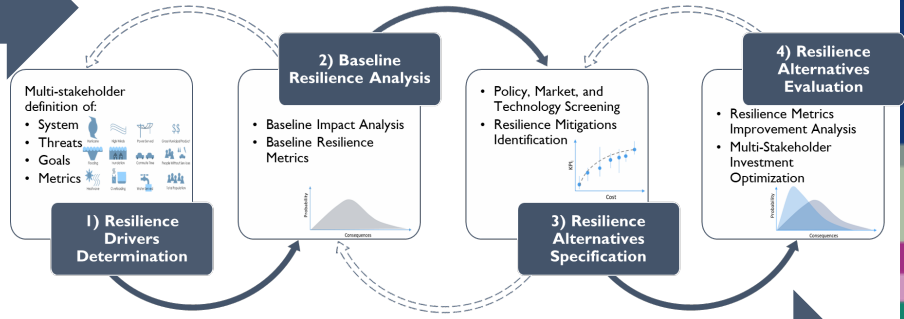
Resilient Community Design Framework Iterative Application



Phase 1: Technology Investments



Phase 2: Regulatory Frameworks



Phase 3: Utility Business Models

Technology, Policy, and Market Evolution