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

Bobby Jeffers, Robert Broderick, Kat Jones, Mercy DeMenno
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

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

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?

SAG Updates
- Working group progress
- New investments or funding avenues
- Benefits of bringing in unique stakeholders
- Progress working with PUC’s, SEO’s, legislatures
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
- Attribute-based:
  - Number of efficient gens
  - Efficient water heaters deployed
- Performance-based:
  - Energy affordability
  - Total cost of service

### Sustainability
- Attribute-based:
  - Renewable capacity
  - PV / battery recycling capacity
- Performance-based:
  - Greenhouse gas emissions
  - Average global temperature

### Resilience
- Attribute-based:
  - kW on microgrids
- Performance-based:
  - kWh not served to critical customers
  - Social burden due to lack of services
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

Threat characterization
Impact analysis
Infrastructure performance analysis
Consequence analysis

Entergy Louisiana and New Orleans Restoration of Customer Outages vs. Time for Major Hurricanes

- Katrina (LA, 2005)
- Rita (LA, 2005)
- Gustav (LA, 2008)
- Ike (LA, 2008)
## Data and tools for performance-based process

<table>
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<tr>
<th>Threat</th>
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</table>
| **Flood:**      | **Grid components:**  
• FEMA FIRMs  
• Hydrological Modeling | **Grid system:**  
• Static and dynamic power flow models  
• Discrete event models (e.g. MDT)  
• Statistical models  
• Simplified/surrogate models | **Economy:**  
• Input-output modeling  
• Computable general equilibrium models  
• Econometrics |
| **Earthquake:** | • USGS PGA estimates                        |                                                 | **Society:**  
• Needs-based travel cost modeling  
• Quality-adjusted life years |
| **Landslide:**  | • USGS susceptibility                       |                                                 | **Security:**  
• Mission dependency modeling |
| **Wildfire:**   | • Data                                      |                                                 |                                                  |
| **Cyber Attack:** | • Event-based characterization  
• Data | |                                                  |
| **Physical Attack:** | • Criticality and vulnerability estimates | | | 
| **EMP/GMD:** | • Atmospheric modeling  
• Electromagnetic coupling modeling | | |
Connecting stakeholders to the process

1) Resilience Drivers Determination
- Define Consequence
- Define Threats
- Define interdependent infrastructures
- Set goals

2) Baseline Resilience Analysis
- Map system performance to consequence
- Threat to system performance
- Balance technical rigor with analysis burden

3) Resilience Alternatives Specification
- Connect initiatives
- Open new opportunities
- Design for triple-bottom-line
- Ensure designs address goals

4) Resilience Alternatives Evaluation
- Re-evaluate consequence given alternatives
- Evaluate system performance under alternatives
- Ensure final portfolios meet goals, are feasible, and equitable

Cities
- Define Consequence
- Define Threats

Utilities
- Define interdependent infrastructures

Regulators
- Set goals
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

Bobby Jeffers, Efrain O’Neill Carrillo, Holly Eagleston
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

References:
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”).

DRC Partner: The Caño Martín Peña Communities
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

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

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)

<table>
<thead>
<tr>
<th>Year</th>
<th>Residential</th>
<th>Commercial</th>
<th>Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>17.93</td>
<td>19.57</td>
<td>15.83</td>
</tr>
<tr>
<td>2017 (María)</td>
<td>22.26</td>
<td>22.72</td>
<td>19.70</td>
</tr>
<tr>
<td>2018</td>
<td>20.73</td>
<td>23.08</td>
<td>19.04</td>
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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)
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 |

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
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)
- Results from UPRM Solar Colloquia (2017), DOE GEARED project GridEd
Backup Content
Connecting processes and stakeholders

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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)

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

**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

**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

**Tools and Resources**

**Metrics improvement analysis**
- Methods (tools): economic value of service interruption (e.g., ICE Calculator, REAct), 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
- Multi-stakeholder definition of:
  - System
  - Threat
  - Goal
  - Metrics
- Baseline Resilience Analysis
- Policy, Market, and Technology Screening
- Resilience Mitigation Identification
- Baseline Resilience Metrics
- Resilience Alternatives Specification
- Iterative Application

Phase 2: Regulatory Frameworks
- Multi-stakeholder definition of:
  - System
  - Threat
  - Goal
  - Metrics
- Baseline Resilience Analysis
- Policy, Market, and Technology Screening
- Resilience Mitigation Identification
- Baseline Resilience Metrics
- Resilience Alternatives Specification
- Iterative Application

Phase 3: Utility Business Models
- Multi-stakeholder definition of:
  - System
  - Threat
  - Goal
  - Metrics
- Baseline Resilience Analysis
- Policy, Market, and Technology Screening
- Resilience Mitigation Identification
- Baseline Resilience Metrics
- Resilience Alternatives Specification
- Iterative Application

Technology, Policy, and Market Evolution