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Optimal investment decisions for electric power resilience in a multi-stakeholder environment

PRESENTED BY

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Motivation: Designing Resilient Communities: A Consequence Based Approach for Grid Investment

Presidential Policy Directive – Critical Infrastructure Security and Resilience (PPD-21) defines resilience as "the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions."

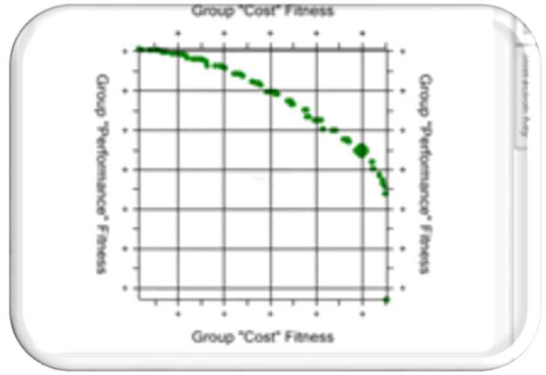
Determine Resilience Drivers

Community Resilience Analysis

Goals:

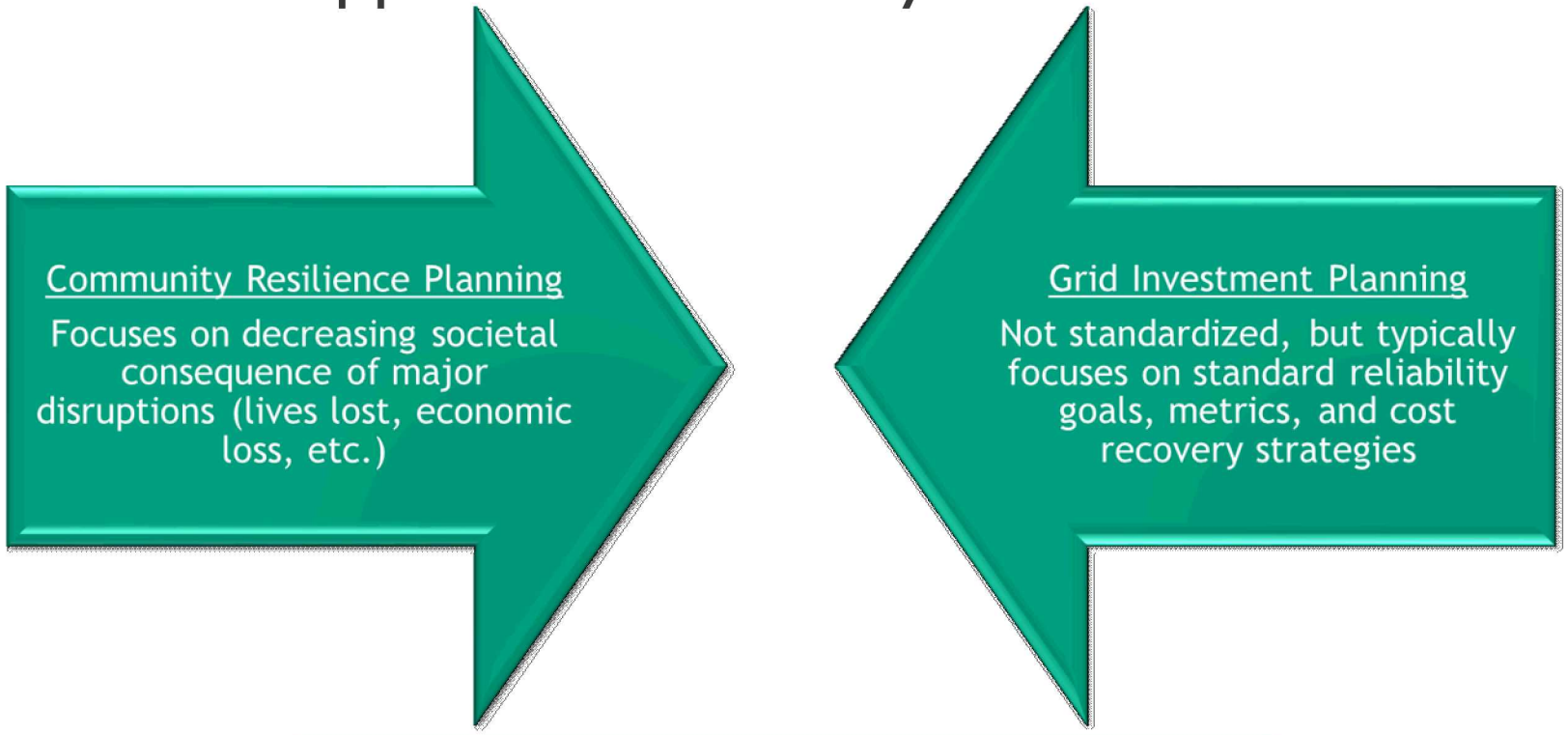
- Demonstrate a practical consequence-based approach to grid infrastructure planning and investment
- Resilient Community Resilience Design Framework
- Stakeholder engagement
- Technology demonstration

Resilience alternatives specification



Evaluation of resilience alternatives

Energy Resilience Supports Community Resilience…



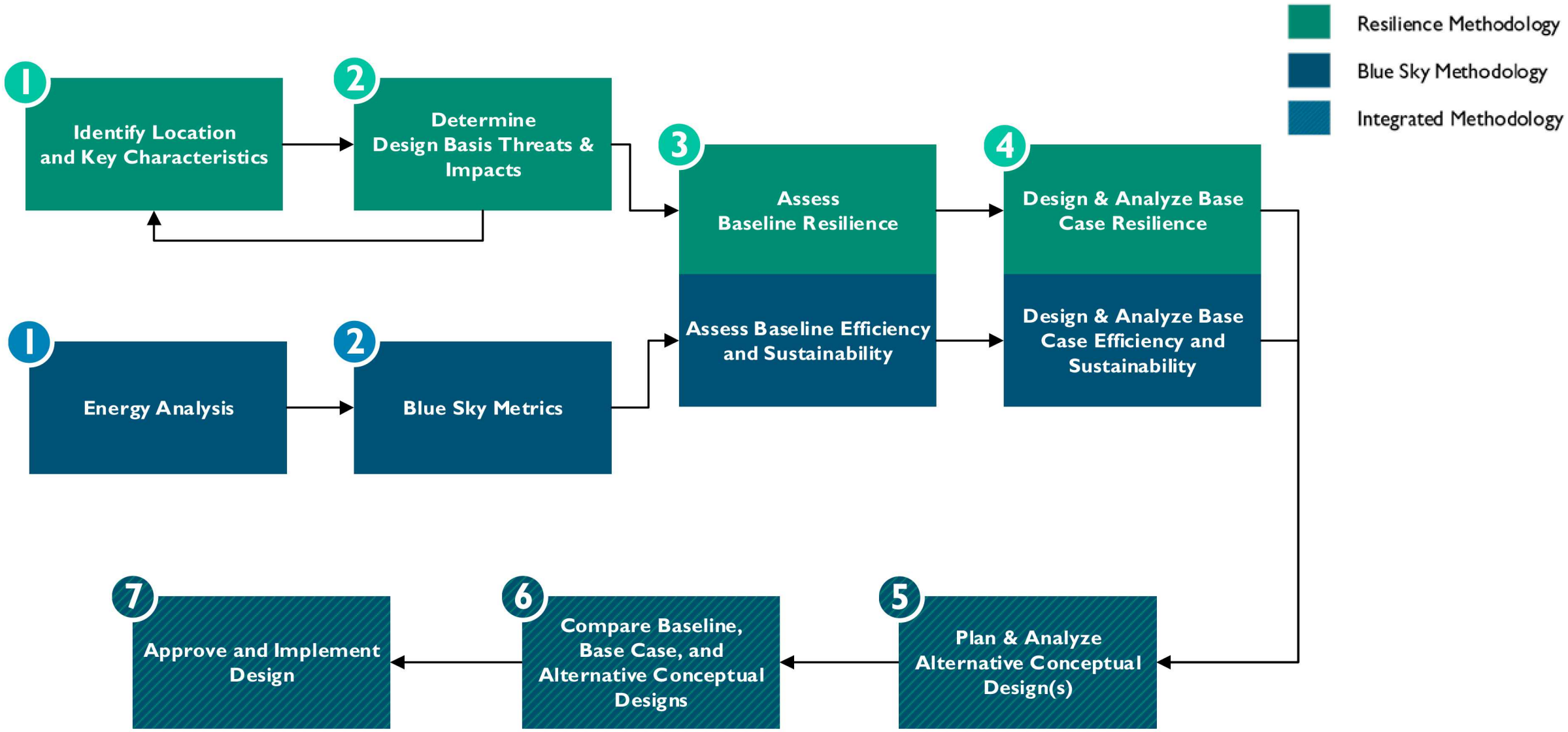
But different structures, challenges, and stressors require a flexible approach

Resilience shocks and stresses (regional differences in hazards, economic, political)

Electric utility configuration (municipal, investor-owned, cooperative) and horizontal/vertical integration

Example community with unique needs: military installation

Resilience-Inclusive Energy Master Planning Process (R-IEMP)



Military installation example (notional, realistic data)

- To ensure the continued function and resilience of key capabilities and assets, assessments are performed to identify vulnerabilities and potential mitigation strategies
- Investment decisions must then be made to select the appropriate "portfolio" of mitigation alternatives to reduce risk and provide mission assurance
- Electric utilities serving military installations have different opportunities and constraints utilities serving non-military communities
- Military base and electric power utility have different priorities and funding sources

Military-funded options

- Microgrid for use in islanded mode to support one key mission
  - 3 possible microgrid designs identified using the Microgrid Design Toolkit
  - Design attributes include diesel fuel used (gal. per 30 days), energy availability, and installation cost

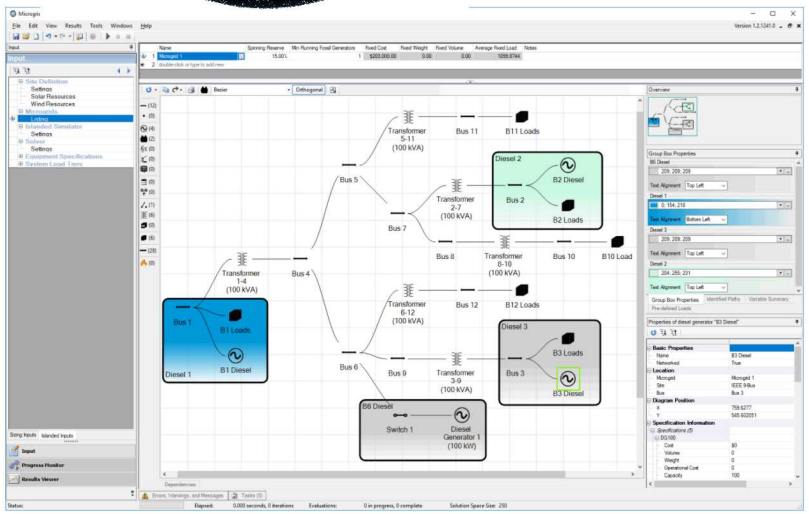
Utility-funded options

- Bury lines to protect against high winds
- Flood hardening at substation serving two of three feeders

Microgrid Design Toolkit

MDT is a decision support tool for use in the early stages of microgrid design, and includes two main capabilities:

- Microgrid Sizing Capability (MSC), focused on optimizing the net present value of blue sky cash flows for a behind-the-meter energy system investment
- Second capability, using Technology Management Optimization (TMO) model and Performance Reliability Model (PRM), focused on designing a microgrid for operation in islanded mode
  - TMO performs multi-objective optimization using a genetic algorithm to identify a collection of microgrid designs
  - Some metrics used by TMO rely on PRM, a discrete-event simulation, for calculation (such as fuel efficiency, fuel usage, or renewable spillage)



MDT is available for download from https://www.energy.gov/oe/services/technology-development/smart-grid/role-microgrids-helping-advance-nation-s-energy-syst-0

Prioritization and Resource Allocation Decision Environment (PARADE)

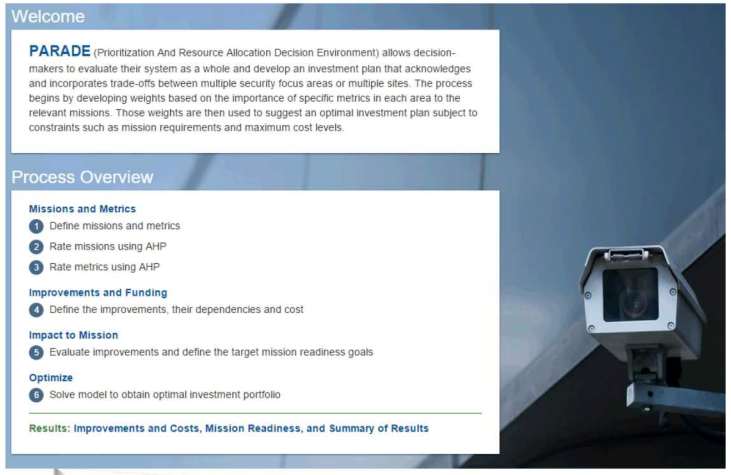
Investment optimization over time – determining the "best bang for the buck" to achieve long term goals

Analytic Hierarchy Process (AHP) turns qualitative SME input into quantitative "weights" reflecting priority

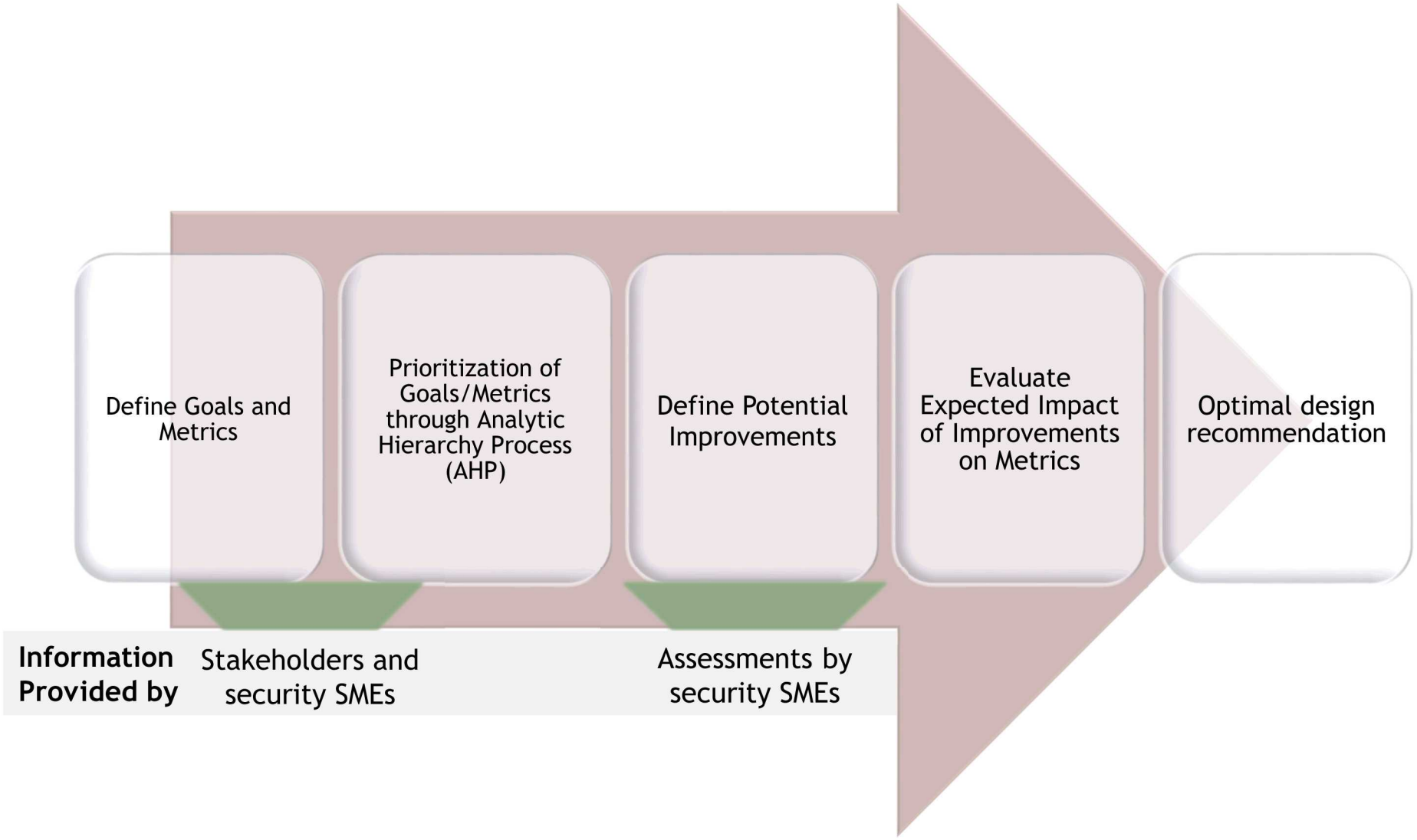
Optimization model maximizes performance for highest priority operations subject to constraints and considers

- Funding/cost levels (including recurring costs)
- Investments that preclude other investments or are dependent on other investments
- Diminishing returns
- Uncertainty

Results provide a recommended investment schedule over time that best meets stakeholder goals



PARADE Process Flow



PARADE Optimization Approach

Stochastic Mixed-Integer Nonlinear Program

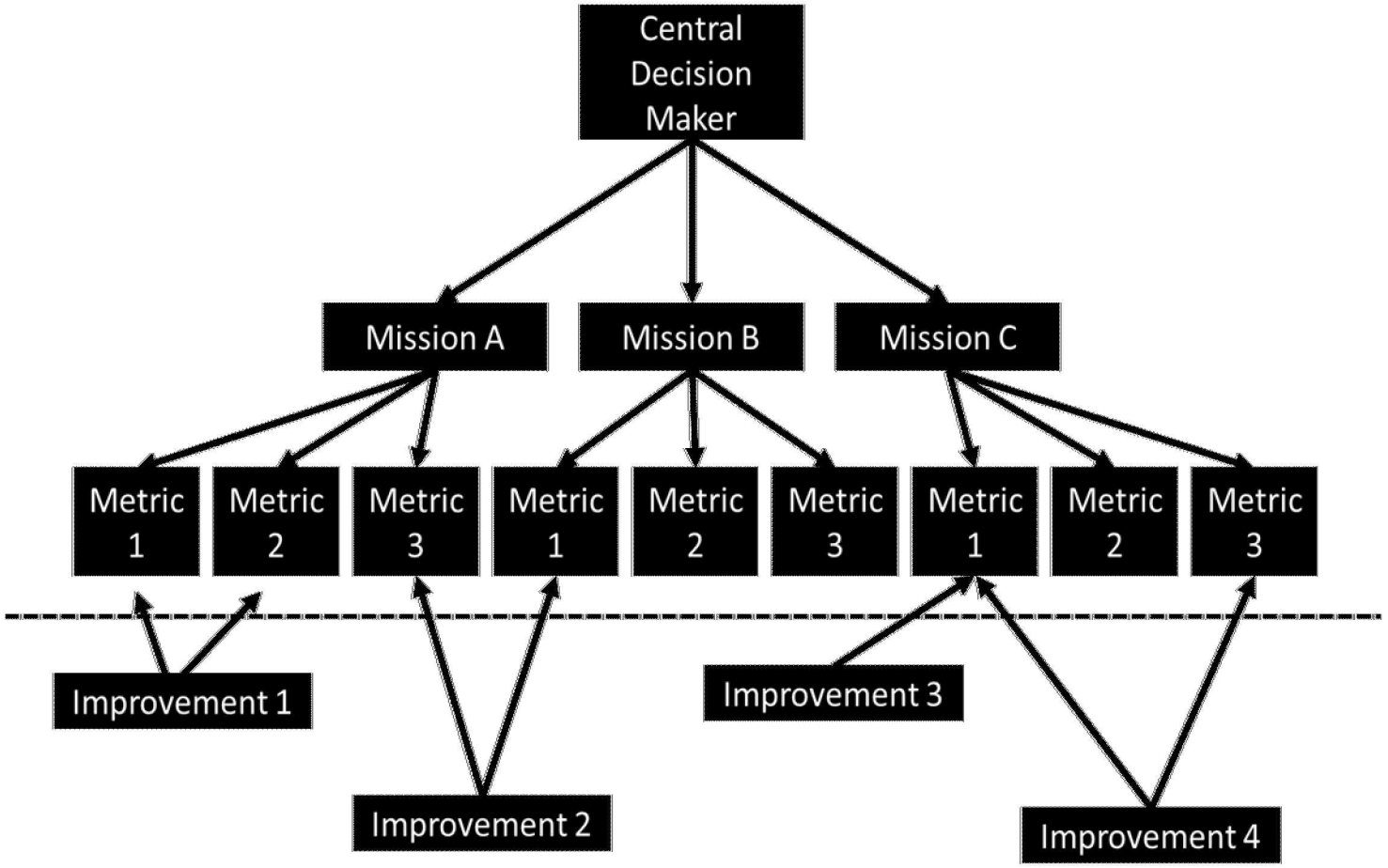
Extended version of the classic knapsack problem

Incorporates diminishing returns through piecewise linear functions

Solved using a Genetic Algorithm (or optionally using CPLEX)

Allows the use of multiple resource pools (for example, two separate sources of funding)

PARADE problem structure



For this simplified example, improvement impacts to metrics are additive. When not the case, “packages” of investments with exclusion rules can be used.

Missions AHP

WEIGHTS

Mission Name	Weight	Consistency Index (Target: 0.0-0.1) 0.07
Security and Force Protection	0.74	
Data Management and Storage	0.19	
Housing	0.06	

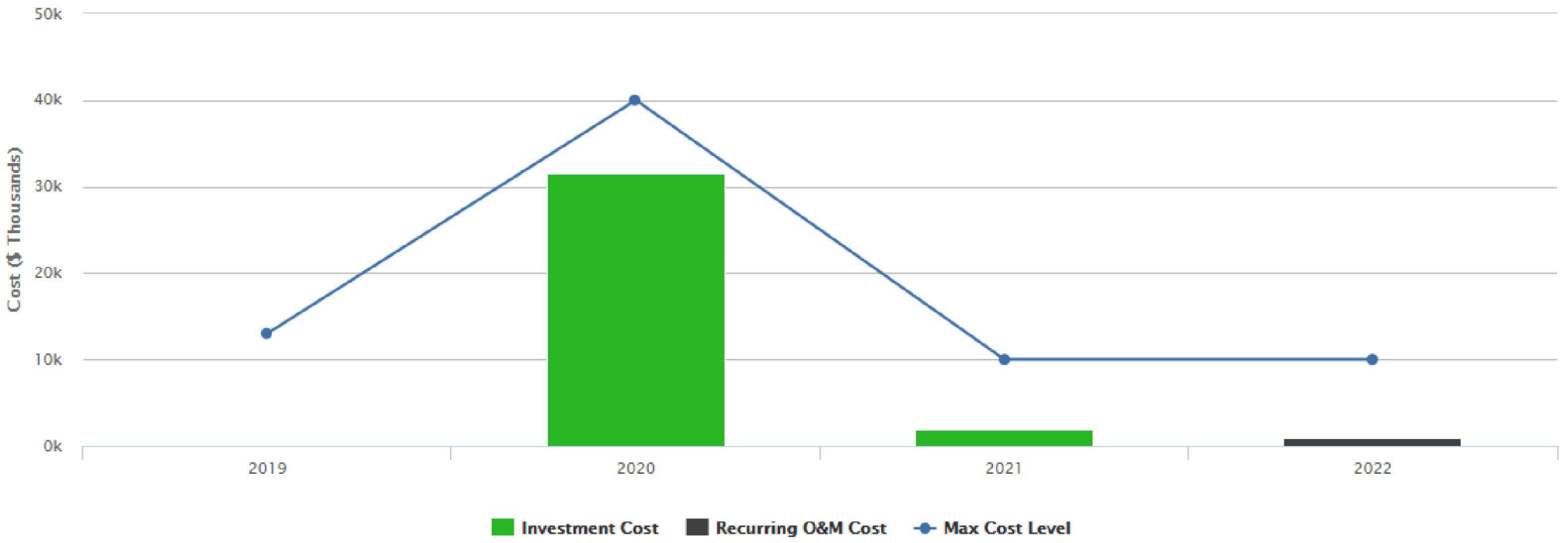
COMPARISONS

First Mission	Current Comparison Rating	Second Mission
Security and Force Protection	5 - much more important than ▾	Data Management and Storage
Security and Force Protection	9 - absolutely more important than ▾	Housing
Data Management and Storage	4 - between somewhat and much more important than ▾	Housing

Metrics include % load served under DBT, diesel fuel saved under DBT, and LCOE (blue sky)

DoD-only planning

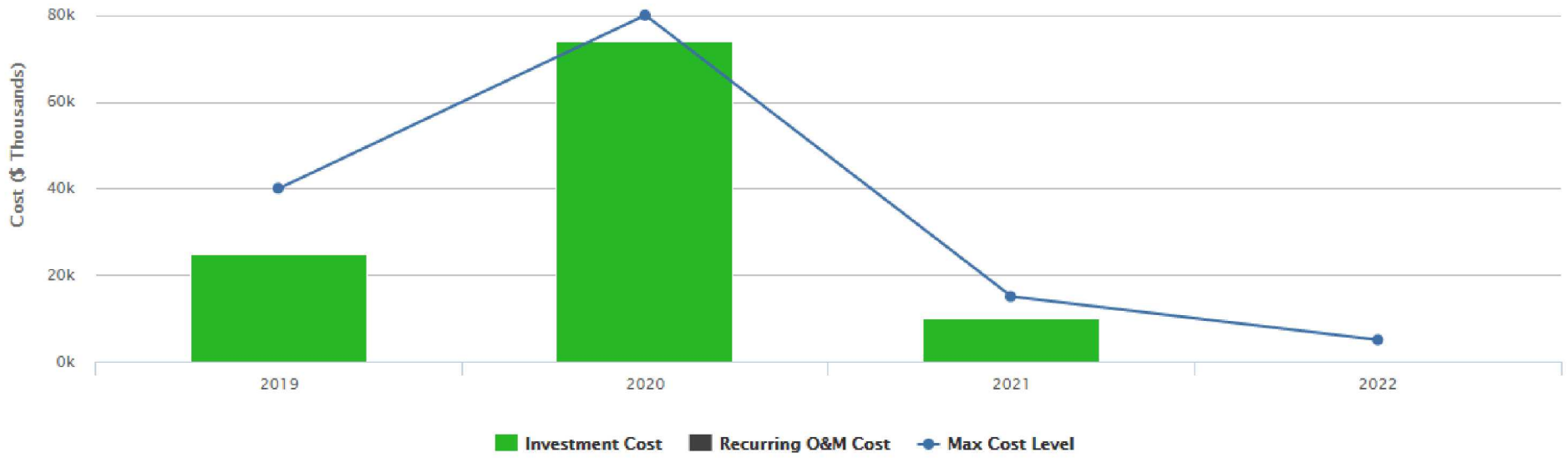
IMPROVEMENT COSTS BY FISCAL YEAR



SELECTED IMPROVEMENTS BY FISCAL YEAR

Improvement	Investment Cost ($ Thousands)	Recurring O&M Cost ($ Thousands)	2019	2020	2021	2022
Microgrid A	33500	1000		Acquired	Acquired	O&M
Microgrid B	2400	1000				
Microgrid C	20000	1000				

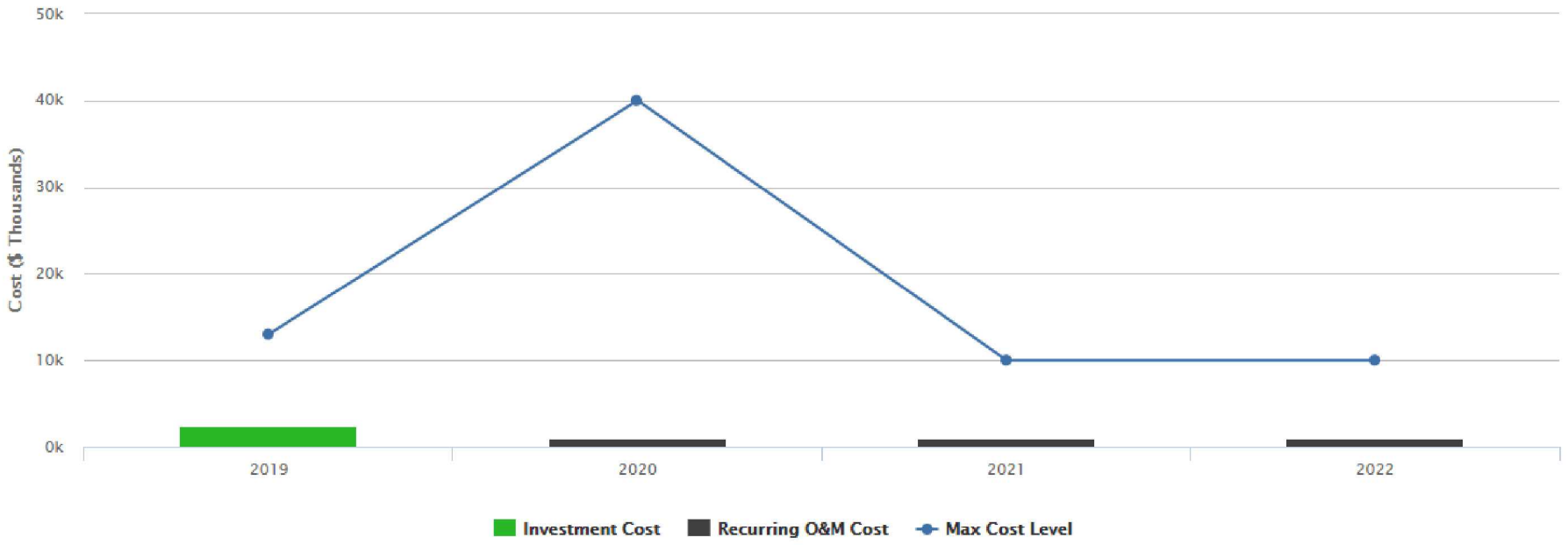
Cooperative planning – Utility Cost and Selection



SELECTED IMPROVEMENTS BY FISCAL YEAR

Improvement	Investment Cost ($ Thousands)	Recurring O&M Cost ($ Thousands)	2019	2020	2021	2022
Microgrid B	0	0				
Flood hardening	25000	0	Acquired			
Buried lines	84000	0		Acquired	Acquired	
Microgrid A	0	0				
Microgrid C	0	0				

Cooperative planning – DoD Cost and Selection



SELECTED IMPROVEMENTS BY FISCAL YEAR

Improvement	Investment Cost ($ Thousands)	Recurring O&M Cost ($ Thousands)	2019	2020	2021	2022
Microgrid B	2400	1000	Acquired	O&M	O&M	O&M
Flood hardening	0	0				
Buried lines	0	0				
Microgrid A	33500	1000				
Microgrid C	20000	1000				

Cooperative planning allows for a lower expenditure by DoD for the same performance

Summary

Sandia is developing a framework to help close the gap between utility and community planning processes for resilience investments

Illustrated an optimization tool that can be used to support multistakeholder analysis, considering mission priorities and different funding sources. It can take results from other decision support or assessment models as input (demonstrated with MDT outputs here).

Flexibility is key for modeling and analysis of these multistakeholder environments with differing goals and structural and geographic differences. This is addressed here with user-defined metrics, the ability to include quantitative and qualitative metrics, and a variety of options for describing constraints on investments.

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Backup

Resilient Community Design Framework

1. Determination of Resilience Drivers

- Determine Resilience Metrics and Threats
- Threat and Impact Forecasting

Stakeholders Engaged

- Local Government
- Electric Utilities
- State/Local Regulators
- Community Groups
- Infrastructure Owners

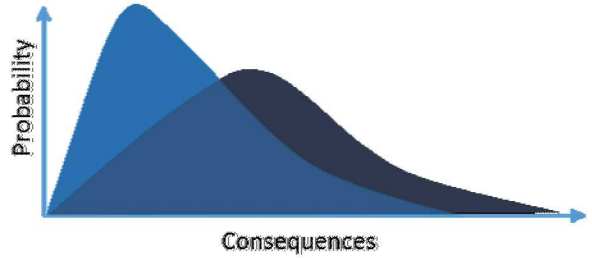
3. Resilience Alternatives Specification

- Resilience Technology Screening
- Regulatory Framework Screening
- Resilience Service Screening

2. Community Resilience Analysis

- Multi-Infrastructure Performance Analysis
- Consequence Estimation

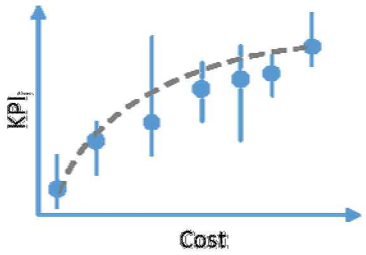
Resilience Performance Metrics



4. Evaluation of Resilience Alternatives

- Translation to Stakeholder KPI's
- Calculate Co-benefits (Reliability, Cost of Service, etc)
- Multi-Stakeholder Cost-Benefit
- Multi-Criteria Portfolio Evaluation

Portfolio Evaluation



Microgrid Design Toolkit (MDT)

Mission Requirements and Baseline Models

- Equipment deployed creates demand
- Or demand (load) models
- Or custom load models

Equipment Data Base

- Energy demand/production
- Usage specification
- Reliability information

Technology Options and User Inputs

- Identify energy producers and technology options
- Select location & season (solar and/or wind profile)
- Reliability and maintenance cost data
- Select user mode
  - Performance analysis
  - Parametric study
  - Optimization

ITERATIONS to Refine Results

MDT Results

- Energy performance
  - Energy availability, cost, fuel used, volume, silent watch, gen utilization
- Parametric sweep results
- Optimal & feasible solutions
  - Generator types/counts
  - PV type/amount
  - Battery type/quantity

PARADE Mission Readiness Level