# Understanding how investments in electricity resilience impacts adaptation of electricity systems over time

Dan Thompson
PhD Candidate in Disaster Risk Reduction

Supervisors:
Dr. Gianluca Pescaroli
Dr. Rozana Himaz
Dr. Jun Rentschler (World Bank)

Institute for Risk and Disaster Reduction (IRDR)

## A case study of electricity systems at the community level in California, USA

UCL

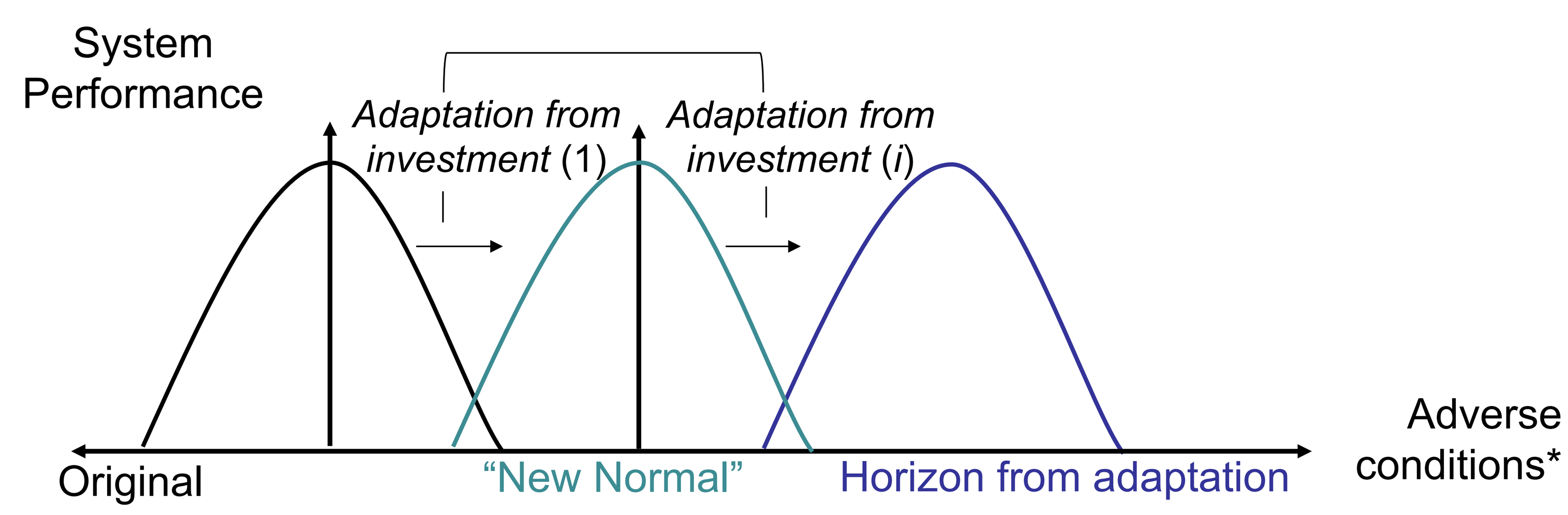
## Research Motivation

The concept of "electricity resilience" has gained traction as a way to strengthen electricity systems against the cascading impacts of electricity disruptions. Some of this research has focused on investing in the technical components of smaller-scale electricity systems for communities to improve their resilience. Existing research on investing in electricity resilience for communities has focused on investments as a singular action, rather than an action within a series of actions over time. In the U.S., electricity utilities have played a major role in investing in and across communities over time. More work is needed to understand how process of investing in resilience allows utilities to adapt and finance subsequent resilience projects.

## Aims

**Aim:** Utilities in the U.S that adapt during the process of investing in electricity resilience by changing aspects of their willingness and ability can improve their ability to invest in subsequent projects, enhancing resilience at both community and grid levels.

**Project research focus**




Adapted from Roege et al. 2014 [1]

** focus on natural hazard impacts*

### Research questions:

- What is a potential method to evaluate the relationship between investment in electricity resilience and adaptation of these systems over time, given the widespread recognition that external factors (e.g., government funding, regulation, etc.) shape these investment projects?
- Can adaptation from financing transfer to other types of resilience investments and across communities, and what factors limit this transfer?
- Can adaptation accelerate the financing process, and which factors can account for this acceleration?
- How can knowledge gained from this project calibrate understandings of how to estimate the costs and benefits of investments in electricity resilience?

## Methodology

| Components | Description | Reference |
|---|---|---|
| Model & Approach | Consumer demand model<br>Counterfactual analysis | Katona 1960 [2] |
| Data Collection & Processing | Mixed methods (Explanatory sequential design) | Creswell and Plano Clark 2017 [3] |
| Case study application | San Diego Gas and Electric (SDG&E) | Rowely 2002 [4] |

## Model: Willingness to Pay

**Investing in electricity resilience**

*Sub-components based on literature review**

**Willingness**
- Community
  - Citizen groups
  - Community entities
  - Individual electricity consumers
- Utility
  - Utility
  - NGO
  - Technology company
  - Other

**Ability**
- Financial
  - Baseline resources
  - Ability to raise capital
- Built Environment
  - Access
  - Modularity
  - Other
- Knowledge
  - Technical
  - Financial
  - Other

**Outcomes on the electricity system**

*Roege et al. 2014*

**Prevention & Mitigation**
- Load shedding buffering
- System management
- Physical hardening

**Response (disruption)**
- Restoration speed
- Buffering

**Adaptation**
- Changes in willingness
- Changes in ability

**[1]** Roege, P. E., Collier, Z. A., Mancillas, J., McDonagh, J. A., & Linkov, I. (2014). Metrics for energy resilience. *Energy Policy*, 72, 249-256. **[2].** Katona, G. (1960). The powerful consumer. *The powerful consumer.* **[3]** Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research.* Sage publications. **[4]** Rowley, J. (2002). Using case studies in research. *Management research news*, *25*(1), 16-27. *All other works referenced can be provided upon request.*

## Counterfactual analysis

**Investment cycle**

Adaptation
- **Willingness**
  - Community A
  - Partner A
- **Ability**
  - Built Environment A
  - Knowledge A

→ Financial C →

**Electricity resilience**
- Response C
- Prevention & Mitigation C
- *Other factors (e.g., legal)* C

**A** = Antecedent  **C** = Consequent

## Data collection & processing

**Data collection design**

| Phase 1 | | Phase 2 | | Phase 3 |
|---|---|---|---|---|
| Document and website analysis | Analysis | Semi-structured interviews | Analysis | Organize and embed research from phase 1 in phase 2 |
| *Secondary sources* | | *Primary sources* | | |

## Case study: SDG&E

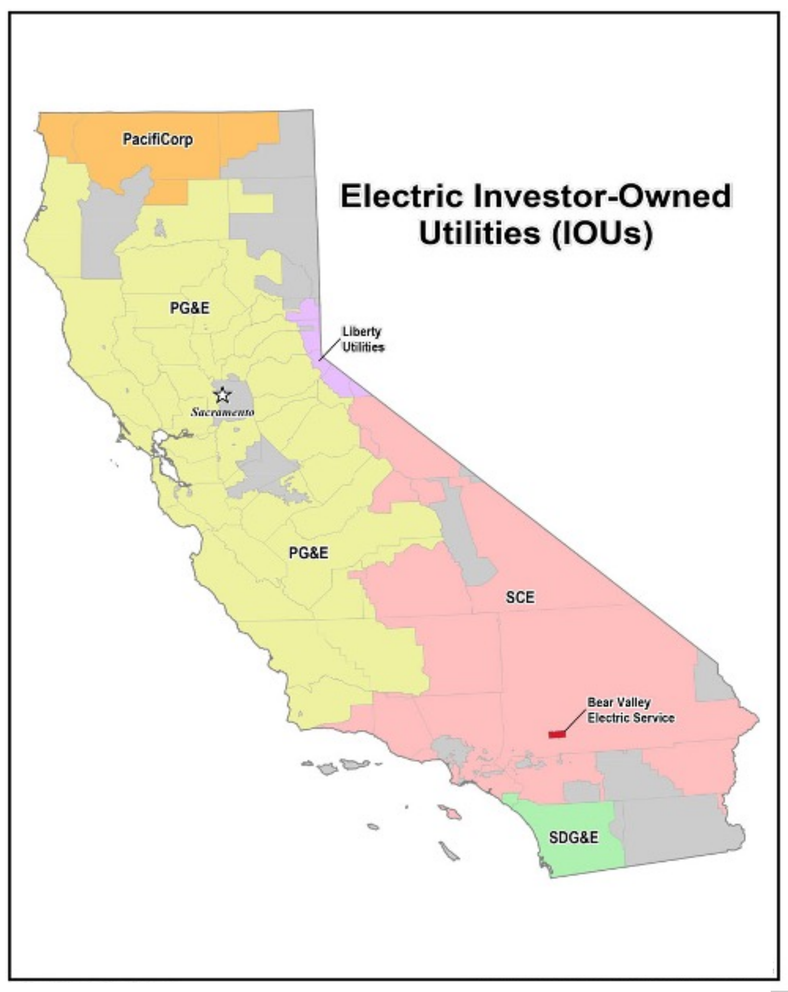



*Image from Ecology Center*

**Type:** Investor-owned utility (IOU)
**Area**: San Diego and Orange counties in California
- 4,100 sq/mi
- 3.7m customers

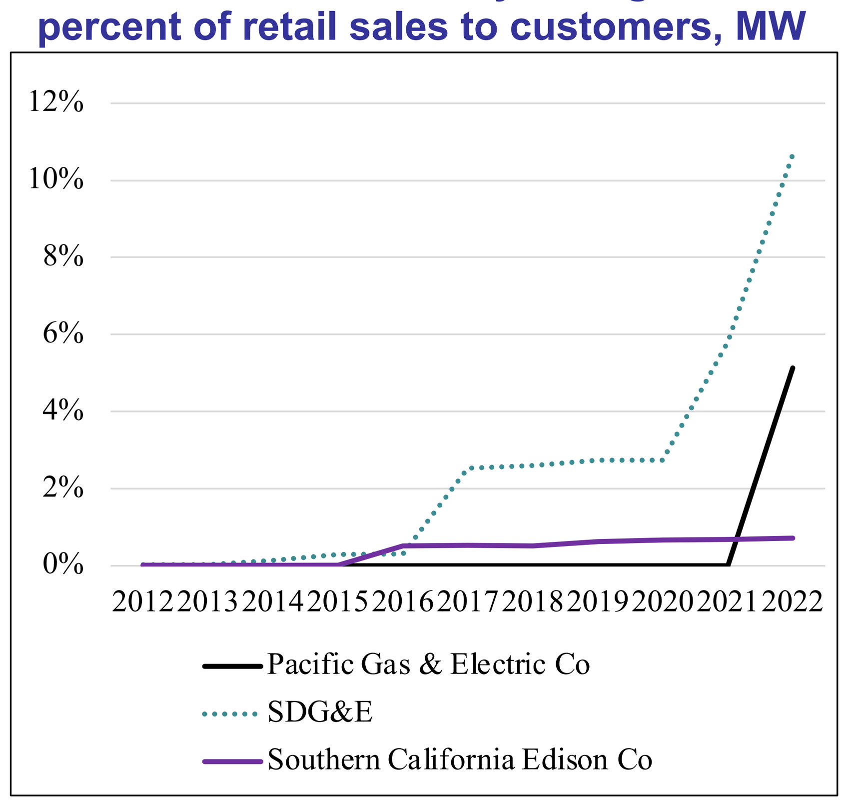
**Chief hazard risks:**
- Extreme heat
- Fire

**Investments at the community level:**
- Batteries (load shedding)
- Microgrids
  - Borrego Springs
- System management technologies

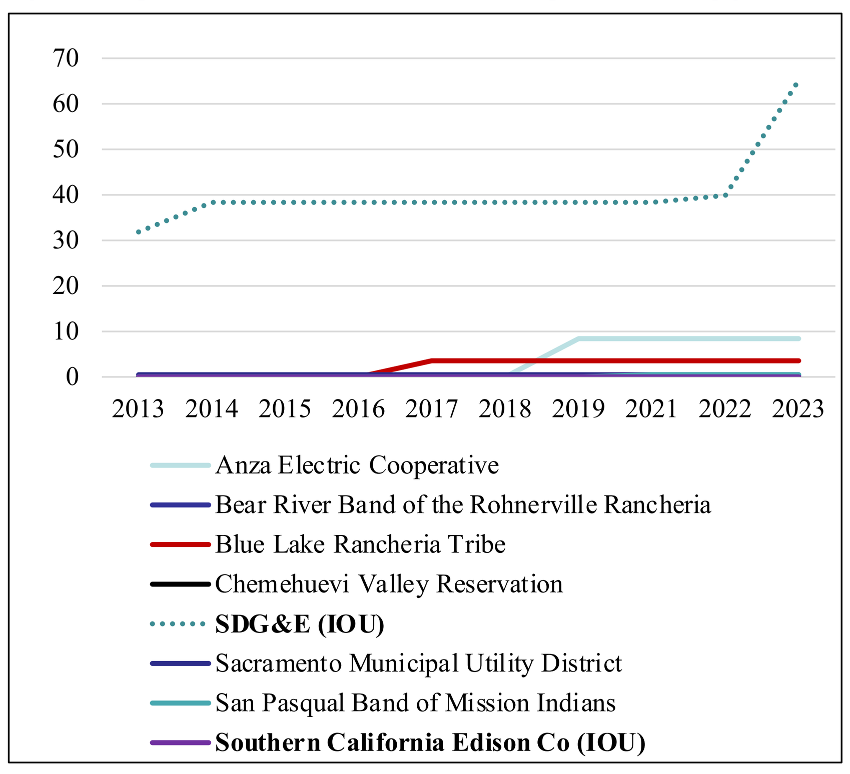
**Key external drivers:**
- Hazard risks
- Policy/regulatory directives
- High capital costs of projects
- Existing renewable energy at the distribution level

**Selected for pilot**
- California's regulatory environment
- Can compare to IOUs in the state

**California IOUs battery storage as a percent of retail sales to customers, MW**




**Microgrids for communities in California (bulk grid-connected microgrids only), MW**




## Early findings

**Willingness**

**Partner**
- Public declarations from SDG&E
- Track record of financing electricity resilience at the community level compared to other IOUs

**Communities**
- Minimal publicly available statements from communities (excepting Borrego Springs)

**Ability**

**Technical Knowledge**
- Technical knowledge of battery storage and microgrid configuration
- Leveraged earlier projects for mobile battery and virtual power plant (ongoing)

**Financing Knowledge**
- Strengthened relationship with state regulators (for funding sources)
- Use of third parties for optimizing control and flow of electricity

**Built environment**
Modularity of generation sources to prioritize or expand microgrid projects over time