CALIFORNIA ENERGY COMMISSION MICROGRID RESEARCH ROADMAP

GLOBAL CASE STUDIES & SUMMARY

OCTOBER 2, 2017
OVERVIEW OF PROJECT

• **Project objective:** Develop California, North America, and global microgrid analysis and case studies.
  - Microgrid projects funded by at least 50% private investment or non-governmental grant funding; online or will be online in the next year.
  - Develop case studies for up to 10 microgrid projects each in California, North America, and globally, answering the following key questions (among others):
    ✓ What were the key **drivers** behind the project?
    ✓ How was the **value** of investment determined by the sponsor, and with what metrics?
    ✓ What was total **cost** (and cost $/MW)?
    ✓ What was the **business model** and how was the project financed?
    ✓ Did **market participation** revenue play a role in the business case analysis?

• **Purpose of case studies:** What lessons can be learned to help shape the CEC Microgrid Research Roadmap? Is there a way to better target state R&D EPIC funding to meet state policy goals on climate change, renewable energy, distributed energy resources (DER), and grid modernization via microgrids?
SUMMARY OF CASE STUDIES COMPLETED

California Summary

9 Case Studies
25.6 MW Peak Capacity
2.84 MW Average Capacity

• Solar PV and some form of energy storage are deployed in every microgrid
• Business models range from PPAs to owner financing to the utility rate base

California Projects

1. Inland Empire Utilities Agency, San Bernardino, 13.5 MW, Advanced Microgrid Solutions
2. Mission Produce, Oxnard, 1.5 MW, UniEnergy Technologies
3. 2500 R Midtown Affordable Housing Complex, Sacramento, 153 kW, Sunverge Energy
4. San Diego Zoo, City of San Diego, 190 kW, Princeton Power Systems
5. Alpha Omega Winery, Rutherford, Napa Valley, 980 kW, Princeton Power Systems
6. Stone Edge Farm, Sonoma, 1.2 MW, Wooster Energy Engineering
7. Camp Pendleton, Oceanside, 354 kW, Cleanspark
8. Confidential Commercial Customer, Thousand Oaks, 2.4 MW, Cleanspark
9. The Thatcher School, Ojai, 1.0 MW, JLM Energy
SUMMARY OF CASE STUDIES COMPLETED

North America Summary

<table>
<thead>
<tr>
<th>10 Case Studies</th>
<th>34.1 MW Peak Capacity</th>
<th>3.41 MW Average Capacity</th>
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<tbody>
<tr>
<td>• Compared to California, the DER mix is more diverse, less reliant on solar PV</td>
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<td>• Greater focus on resiliency/reliability</td>
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North America Projects

1. Kansas Survival Condo, Kansas, 450 kW, Sustainable Power Systems
2. Montgomery County Public Safety & Correctional Facility, Maryland, 7.6 MW, Duke Energy Renewables
3. US Marine Corps Logistics Base, Georgia, 15.6 MW, Constellation
4. OATI Microgrid Technology Center, Minnesota, 2.4 MW, USA Microgrids, Inc.
5. General Motors E-Motor Plant, Maryland, 610 kW, TimberRock Energy Solutions
6. Peña Station NEXT, Colorado, 2.9 MW, Younicos
7. EaglePicher Power Pyramid™ Demonstration, Missouri, 1.0 MW, EaglePicher Technologies
8. Marcus Garvey Apartments, New York, 1.2 MW, Demand Energy
9. General Motors Milford Data Center, Michigan, 76 kW, Empower Energies
10. Ameren Microgrid, Illinois, 1.5 MW, S&C Electric Company
SUMMARY OF CASE STUDIES COMPLETED

Global Summary

| 7 Case Studies | 6.7 MW Peak Capacity¹ | 1.12 MW Average Capacity¹ | • More limited in number due to difficulty reaching contacts  
  • Systems profiled rely much more on diesel generation in addition to renewables |

Global Projects

2. Renewable Energy Integration Demonstration, Singapore, 2.78 MW, ENGIE
3. Palama Holdings, Oahu, Hawaii,² 624 kW, EnSync Energy
4. EcoGrid 2.0, Denmark, 163.5 MW, Bornholms Energi og Forsyning (prev. Østkraft)
5. Chennai Campus, India, 1.76 MW, Larsen & Toubro (L&T)
6. Nagoya Landfill, Japan, 700 kW, Optimal Power Solutions
7. Medjumbe Island, Mozambique, 675 kW, Optimal Power Solutions

¹ Does not include Bornholm Island, a large microgrid sized 112.5MW. With this project, total peak capacity is 119.2 MW and average capacity 17.0 MW.
² Not included in North America case studies because the Hawaiian islands have more similarities to global projects than those on the continental US.
GLOBAL PROJECT HIGHLIGHT #1: NAGOYA JAPAN LANDFILL

- Extending the value proposition of a completed landfill, this microgrid uses batteries to make solar PV “dispatchable” and boosts local resiliency.
  - Paved-over landfill not usable for most construction types, but is ideal for PV.
  - DERs include 0.5MW PV, 0.2MW/1.2MWh battery storage on 2 acre footprint.
- Fukushima ‘11 → Solar Feed-in Tariffs ‘12 → PV production up 250% ‘14–’16
  - This project subject to newer feed-in tariff that incentivizes dispatchable PV.
  - Dispatchability important to address the duck curves that exist in several areas.
  - Discharge during peak load, 4pm-9pm.
- Resilient power provided to smaller local loads.
- Goal is to be highly repeatable.
- Lead-acid batteries were used due to low cost, but will be replaced in ~6 yrs with latest Li-ion technology.
GLOBAL PROJECT HIGHLIGHT #2: CHENNAI CAMPUS MICROGRID

L&T’s Chennai Campus Microgrid provides resilient power, enhances renewables integration, and serves as a showcase for microgrids in India.

- Host and developer L&T is a $17BN conglomerate, the “GE of India.”
  - Most Indian microgrids are small and off-grid; this system is proof of concept for larger, grid-tied systems for utility backup and renewables integration.

- The system enhances resiliency.
  - Boosts renewable self-consumption in both grid-tied and islanded operation.
  - Historical power deficits / outages enhance the value of reliable power.

- Diverse DERs operate in concert
  - 131 kW of solar PV power generation
  - 7 kW of micro-wind power generation
  - 10 kW/32 kWh li-ion battery storage
  - 2020 kW of diesel generation
EcoGrid 2.0 is a demonstration project on the Danish island of Bornholm. Its predecessor, EcoGrid EU, ended in 2015.

- Larger than a typical microgrid (112.5 MW), but is capable of islanding from the main grid (the Nordic interconnected power system).
- When grid-connected, the system has a high penetration of wind and some solar power. When islanded, it depends significantly on fossil fuel generation.
- The system leverages previously installed equipment from EcoGrid EU, but is introducing a market for flexibility for residential heating.
  - 1,000 families on the island are participating in a flexible household heating program.
  - EcoGrid 2.0 aggregates the heating load and responds to bid requests from the system operators to increase or decrease the amount of renewable energy exported to the grid (for now, on a parallel trading platform to existing markets).
- Bornholm’s Energy & Supply is the public utility and Distribution System Operator, and funded approximately 50% of the demonstration.
- The island is also host to a new electric vehicle demonstration, ACES (EVs selling frequency regulation services to the grid).

Source: EcoGrid
Case Study Capacity by Technology – California

- Solar PV Capacity (MW); 10.0; 39%
- Combined Heat and Power Capacity (MW); 0.1; 0%
- Energy Storage Capacity (MW); 5.6; 22%
- Fuel Cell Capacity (MW); 2.8; 11%
- BioGas DG (MW); 0.4; 2%
- Diesel Capacity (MW); 5.7; 22%

<table>
<thead>
<tr>
<th>% Clean Energy</th>
<th>% Other Energy¹</th>
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<td>77%</td>
<td>23%</td>
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¹ Includes CHP and Diesel only

Source: Navigant
CASE STUDY MICROGRID TECHNOLOGIES

Case Study Capacity by Technology – North America

- **BioGas DG Capacity (MW):** 12.6; 37%
- **Fuel Cell Capacity (MW):** 0.4; 1%
- **Other Capacity (MW):** 3.0; 9%
- **Energy Storage Capacity (MW):** 3.8; 11%
- **Wind Capacity (MW):** 5.2; 15%
- **Combined Heat and Power Capacity (MW):** 1.6; 5%
- **Solar PV Capacity (MW):** 7.3; 21%
- **Other Capacity (MW):** 3.0; 9%

**% Clean Energy** | **% Other Energy**
--- | ---
65% | 35%

1 Includes CHP, Diesel, and “Other” which consists of Natural Gas Gensets

Source: Navigant
Case Study Capacity by Technology – Global

- **Energy Storage Capacity (MW): 0.9; 13%**
- **Wind Capacity (MW): 0.1; 2%**
- **Solar PV Capacity (MW): 1.7; 24%**
- **Other Capacity (MW): 0.1; 1%**
- **Diesel Capacity (MW): 4.0; 60%**

Note: chart and table on left half of slide exclude Bornholm Island due to its large size.

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<tr>
<th>% Clean Energy</th>
<th>% Other Energy¹</th>
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<tbody>
<tr>
<td>40%</td>
<td>60%</td>
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</table>

¹ Includes Diesel and one Nat Gas genset

Source: Navigant
**Case Study Capacity by Technology – All Regions**

- **BioGas DG Capacity (MW)**; 13.0; 20%
- **Diesel Capacity (MW)**; 17.0; 26%
- **Combined Heat and Power Capacity (MW)**; 1.7; 2%
- **Other Capacity (MW)**; 3.1; 5%
- **Fuel Cell Capacity (MW)**; 3.2; 5%
- **Energy Storage Capacity (MW)**; 10.3; 15%
- **Solar PV Capacity (MW)**; 16.9; 25%
- **Wind Capacity (MW)**; 1.4; 2%

**Notes:**
- Includes CHP, Diesel, and Nat Gas gensets
- Chart and table on left half of slide exclude Bornholm Island due to its large size.

**% Clean Energy | % Other Energy**

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<tbody>
<tr>
<td>67%</td>
<td>33%</td>
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</table>

**Source:** Navigant
CASE STUDY MICROGRID COSTS

Average Unit Costs by Region

Source: Navigant
Case Study Value Proposition Rankings – California

- Renewable energy integration: 2.7
- Resiliency: 2.3
- Bill savings / demand charge abatement: 2.3
- Reduction of carbon footprint: 2.3
- Reliability: 2.0
- Provision of ancillary services: 2.0
- Provision of energy and capacity services: 1.9
- Linkage to Virtual Power Plant: 1.7
- Future transactive energy revenue: 1.3
- Non-electricity services (thermal, water, etc.): 0.4

Source: Navigant
Case Study Value Proposition Rankings – California vs. North America

- Renewable energy integration: California (2.7), North America (2.9)
- Resiliency: California (2.3), North America (2.9)
- Bill savings / demand charge abatement: California (2.3), North America (2.9)
- Reduction of carbon footprint: California (1.4), North America (2.3)
- Reliability: California (2.0), North America (2.7)
- Provision of ancillary services: California (2.0), North America (2.7)
- Provision of energy and capacity services: California (1.9), North America (2.7)
- Linkage to Virtual Power Plant: California (1.7), North America (1.9)
- Future transactive energy revenue: California (1.3), North America (1.9)
- Non-electricity services (thermal, water, etc.): California (0.4), North America (1.3)

Average Importance of Value Proposition
(0 = Not Important; 3 = Essential)

Source: Navigant
VALUE PROPOSITIONS DRIVING MICROGRIDS TODAY

Case Study Value Proposition Rankings – All Regions

- Renewable energy integration
- Resiliency
- Bill savings / demand charge abatement
- Reduction of carbon footprint
- Reliability
- Provision of ancillary services
- Provision of energy and capacity services
- Linkage to Virtual Power Plant
- Future transactive energy revenue
- Non-electricity services (thermal, water, etc.)

Source: Navigant
INSIGHTS: VALUE PROPOSITIONS VARY AMONG REGIONS

• California projects put more emphasis on renewables integration, carbon footprint reduction, and demand charge abatement.
  - Drivers include state carbon reduction and renewable energy mandates.
  - California’s high electricity rates and demand charges (compared to most US states) play a key role.

• North America projects emphasize reliability and resiliency.
  - Likely due to impact of extreme weather events, especially on the US east coast.
  - California’s mild weather limits the demand for uninterruptible power; earthquakes are less frequent.

• Global projects also emphasize renewables integration and carbon footprint reduction, but have more capacity from legacy diesel generation.
  - Europe and Japan have high renewables penetration, similar to California.
  - Energy/capacity, VPP linkage, and transactive energy score similar to CA, and above North America, pointing to advanced trading markets developing in high-renewables areas.
  - Note small sample size across wide geography; further study could solidify findings.

• **Bottom line:** Microgrids in all regions show a diversity of value propositions, a diversity of DER, and a diversity of business models. Navigant believes this diversity will continue into the near-future. CA projects are more inclined to value state policy goals on renewables and grid services while also addressing project economics.
• Diverse microgrids for a variety of clients are moving forward today.
  - Majority of case studies (14) or 52% could be considered commercial hosts.
  - Four are governmental entities; Four are related to agriculture or food production.
  - Two are unique affordable housing complexes; two are built on landfills.
• Majority of projects deploy solar PV (93%) and energy storage (93%).
• Business models for recent projects shifting capital to operating expenses.
  - Energy Savings Performance Contract vehicle.
  - Shared savings between host and project developer/controls vendor.
• Most projects developed by small vendors offering energy storage or controls.
  - Large vendors like Schneider Electric, and utilities like Ameren still well represented.
• Most projects are 1 MW or above (56%); just 3 projects above 10 MW (11%).
• Much interest globally in implementing VPPs, transactive energy.
• The most common challenge across regions: difficult interconnections.
  - In global projects, lack of trained workforce a key issue.
RECOMMENDATIONS TO ENERGY COMMISSION

• Focus future R&D investment in technologies that enhance integration and control of diverse DER to limit reliance upon back-up diesel generators.

• Do not limit funding to just solar + energy storage systems deployed in microgrids.
  - Diversity in renewable generation benefits the larger grid as well as a microgrid.

• Support projects that help CA meet its Loading Order/climate regulation goals.

• Consider benefits outside of electricity when judging microgrid candidates.
  - Thermal energy, water, and waste management solutions can be wrapped into microgrids.
  - Less common today, but could be helped by funding support.

• Seek out innovative business models that shift risks of project development to market participants with a track record and financial stability.
  - Yet also support smaller, more innovative companies that actually require R&D funding to validate promising technology or financial solutions.

• Target projects that could not move forward without government support.
  - E.g. community-based projects, projects testing new controls or providing new grid services.
  - Help drive these projects toward the commercial viability already seen in other segments.
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