MICROGRIDS: A GLOBAL VIEW

INTERNATIONAL SYMPOSIUM ON MICROGRIDS: NEWCASTLE, AUSTRALIA

NOVEMBER 29, 2017
Emerging infrastructure is far more integrated, dynamic, and complex.

**DISTRIBUTED GENERATION (DG)**
Includes the generation of electricity from many small energy sources, including renewables; typically mass-produced, small, and site-specific.

**ENERGY STORAGE**
Devices or physical media that store energy to perform useful operation at a later time; balance the supply and demand of energy; improve power quality.

**DIGITALIZATION OF THE GRID:**
- Smart inverters
- Smart meters
- Advanced sensors, controls, and operation systems
- Behind-the-meter (BTM) technologies and solutions
- Demand response (DR)

**MICROGRIDS AND VIRTUAL POWER PLANTS**
Applications or groupings of distributed energy resources (DER) that operate either connected or independent from a traditional centralized grid.

**BUILDING ENERGY MANAGEMENT SYSTEMS**
Digital control systems installed in buildings; enables energy efficiency, DR, and automated DR.

(Source: Navigant Consulting)
MICROGRID DEFINITIONS: SELECTED EXAMPLES

• U.S. Department of Energy definition:
  - “An integrated energy system consisting of distributed energy resources (DER) and multiple energy loads operating as a single controllable entity in parallel to or islanded from the existing power grid”

• U.S. Department of Defense definition:
  - “A DoD installation microgrid is an integrated energy system consisting of interconnected loads and energy resources which, as an integrated system, can island from the local utility grid and function as a stand-alone system.”

• International Council on Large Electric Systems / CIGRÉ:
  - “Microgrids are electricity distribution systems containing loads and distributed energy resources (such as distributed generators, storage devices, or controllable loads) that can be operated in a controlled, coordinated way either while connected to the main power network or while islanded.”

*DOE recently updated microgrid definition to include “remote” off-grid systems.
### MICROGRIDS: INVENTORY OF KEY TERMS

#### Summary: Components of 17 Microgrid Definitions

<table>
<thead>
<tr>
<th>Explicit component of the definition: &quot;A microgrid...&quot;</th>
<th>Fraction of Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorporates Multiple Loads</td>
<td>88%</td>
</tr>
<tr>
<td>Incorporates Multiple DER</td>
<td>82%</td>
</tr>
<tr>
<td>Is Able to Island</td>
<td>76%</td>
</tr>
<tr>
<td>Acts as Single Controllable Entity</td>
<td>76%</td>
</tr>
<tr>
<td>Is &quot;Local&quot; or Has Clear Boundaries</td>
<td>71%</td>
</tr>
<tr>
<td>Is Nominally Grid Connected</td>
<td>88%</td>
</tr>
<tr>
<td>Has established economic link w/ grid</td>
<td>18%</td>
</tr>
<tr>
<td>Is &quot;Small&quot;</td>
<td>18%</td>
</tr>
<tr>
<td>Functions like smaller version of grid</td>
<td>12%</td>
</tr>
<tr>
<td>Islands Automatically</td>
<td>0%</td>
</tr>
<tr>
<td>Can include thermal/heat energy</td>
<td>12%</td>
</tr>
<tr>
<td>Can Shed Load or Control Loads</td>
<td>12%</td>
</tr>
<tr>
<td>Can Be Non-Interconnected (Virtual)</td>
<td>0%</td>
</tr>
<tr>
<td>Can Incorporate Intermittents/Renewables</td>
<td>12%</td>
</tr>
<tr>
<td>Subscribes to DOE Definition</td>
<td>41%</td>
</tr>
</tbody>
</table>

(Source: Navigant Research)
MICROGRIDS: OVERLAP WITH DOE DEFINITION

Microgrid Definitions and Notable Overlap

DoE Subscribers*
- DoE
- DoD
- CIGRÉ
- SEPA
- EPRI
- IEEE
- S&C Electric
- State of NY SERDA
- State of CT
- State of NJ

Has Multiple Loads
Has Multiple DER
Can Island From Grid
Single Controllable Entity
Is Local or Has Clear Boundaries
Is Grid-Tied

California Commentators
- LBNL
- CAISO
- CEC Notice of Staff Workshop

* Institutions that subscribe to the DoE definition of microgrids or have nominally similar definition.

(Source: Navigant Research)
ASIA PACIFIC & NORTH AMERICA ARE MARKET LEADERS

Total Microgrid Power Capacity Market Share by Region, World Markets: 2Q 2017

(Source: Navigant Research)
Remote Microgrids Clear Global Segment Leader

Total Microgrid Power Capacity Market Share by Segment, World Markets: 2Q 2017

(Source: Navigant Research)
MICROGRIDS: GLOBAL GROWTH TRENDS

Total Microgrid Capacity and Revenue, World Markets: 2017-2026

(Source: Navigant Research)
Microgrid Capacity by Segment, North America: 2015-2024

(Source: Navigant Research)
BUSINESS MODELS – AND WHAT ABOUT UTILITIES?
WHAT ARE THE CHALLENGES ON FINANCING?

• Developing a more streamlined approach to microgrid design, implementation and financing
• Reducing soft and other customized engineering costs
  - As a result, new trend toward standardization, “plug-and-play” offers, concept of “configurable” microgrids and “microgrids-as-a-service”
• Finding financing for entire projects, instead of for individual components
  - Thereby shrinking transaction costs
• Figuring out the best role for utilities in both development cycle and in ongoing operations of microgrids
  - Regulated or unregulated ventures?
  - As microgrid fleet grows, are utilities in best position to do O&M?
• Deciding which market segment offers the best near-term growth versus long-term and sustainable growth
  - Military, community, utility, institutional, remote or C&I?
• Who should I partner with on the financial front, and how should deals be structured (PPAs, owner financing, utility rate-basing?)
MICROGRID BUSINESS MODELS IN NORTH AMERICA


- PPA: 45%
- Utility Rate Base: 15%
- Owner Financing: 16%
- Other: 24%

(Navigant Research-Hitachi)
Grid-Tied, Non-Military Microgrids by Business Model
Projects, North America: 2015-2016

- Owner Financing: 22%
- Utility Rate Base: 30%
- PPA: 32%
- Other: 16%
NEW EMERGING MICROGRID BUSINESS MODELS

Microgrids-as-a-Service

(Source: Schneider Electric)
UTILITY REGULATORY ISSUES ON MICROGRIDS

• Despite significant grant funding, many projects and programs have been delayed due to regulatory issues including:
  • Power crossing public rights-of-ways
  • Who owns what/which asset?
  • Interconnection with utility grid (and resynchronization once power is restored to utility grid)
  • Islanding concerns/safety
  • Revenue loss issues for incumbent utilities

• Utilities are expanding their roles in the microgrid market, signaling commercial opportunities among market players historically opposed to microgrid concepts
  - Yet many utilities – ComEd, PECO and Baltimore Gas & Electric – have had proposals for rate-basing of microgrids rejected by state regulators
  - Several unregulated arms of utilities investing in third-party microgrids outside of own service territories
  - Duke Energy is moving forward on both unregulated and regulated side of business
Mapping Utility Microgrid Strategies

- Impede Interconnect Requests
- Engage Interconnect Requests
- Impacts Policy
- Develop Pilot
- Competing Product/Service
- Impact Policy
- Product/Service Offering
- Wait and See

(Source: Navigant Consulting)
WHAT IS THE VALUE PROPOSITION?
WHAT IS THE VALUE PROPOSITION FOR A MICROGRID?

• The CEC and Navigant seek to explore what value propositions are driving microgrids that have not been supported by government grants.
• The following value propositions were put forward to project developers and owners:
  - Reliability
  - Resiliency
  - Transactive energy
  - Bill savings/Demand charge abatement
  - Provision of capacity and energy services
  - Provision of ancillary services (DR, frequency regulation, etc.)
  - Reduction of carbon footprint
  - Non-electricity services (thermal energy, water, etc.)
  - Linkage to “virtual power plants” and other DER concepts.
• Two additional value propositions were added after interviews
  - EV charging
  - Cyber security
GLOBAL PROJECT HIGHLIGHT #1: BORNHOLM ISLAND

EcoGrid 2.0 is a demonstration project on the Danish island of Bornholm. Its predecessor, EcoGrid EU, ended in 2015.

- The Bornholm Island system is larger than a typical microgrid, 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.
- EcoGrid 2.0 is leveraging the 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).
GLOBAL PROJECT HIGHLIGHT #2: 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 unusable for most construction types, 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 ~6yrs with latest Li-ion technology.
GLOBAL PROJECT HIGHLIGHT #3: 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 kWp of solar PV power generation
  - 7 kW of micro-wind power generation
  - 10 kW/32kWh li-ion battery storage
  - 2020 kW of diesel generation
VALUE PROPOSITIONS DRIVING MICROGRIDS

CEC Case Study Rankings

(Source: Navigant Research)
MID-TERM GLOBAL MARKET OUTLOOK

• All microgrid segments will show growth over the next 5-10 years
• Remote microgrids show largest market share globally due to legacy systems and shift to greater reliance upon distributed renewables
  - North America is more focused on grid-tied systems
  - Most recent trends there point to community and utility distribution microgrids
• Segment poised for major global growth is C&I segment
  - This is because economics of both solar PV and energy storage help build the business case, as well new innovative business models focused on low-cost natural gas
  - Data centers appear to be the best long-term market bet among C&I prospects
• Business model innovation is accelerating
  - PPA apparently best path for third-party microgrids
  - Utility rate-basing still facing regulatory acceptance
• Merging of microgrids and VPPs also a recent trend
  - Focus of vendors shifting from hardware to software
  - Increased interest in “plug-and-play” and “configurable” microgrids across all market segments
CONTACT US

MAIN OFFICE
1320 Pearl Street, Suite 300
Boulder, CO 80302
+1.303.997.7609

WORLDWIDE OFFICES
United States:
Boulder, Colorado
Chicago, Illinois
San Francisco, California
Washington, D.C.

Europe:
Copenhagen, Denmark
London, United Kingdom

Asia Pacific:
Seoul, South Korea

PETER ASMUS
Principal Research Analyst
+1.415.399.2137
peter.asmus@navigant.com