



MICROGRIDS: A GLOBAL VIEW

INTERNATIONAL SYMPOSIUM ON
MICROGRIDS: NEWCASTLE, AUSTRALIA

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NAVIGANT
RESEARCH

MICROGRIDS ARE PART OF AN EMERGING ENERGY CLOUD MADE UP OF A DIVERSE SUITE OF DER TECHNOLOGIES

- 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

MICROGRIDS AND VIRTUAL POWER PLANTS

Applications or groupings of distributed energy resources (DER) that operate either connected or independent from a traditional centralized grid

DIGITALIZATION OF THE GRID:

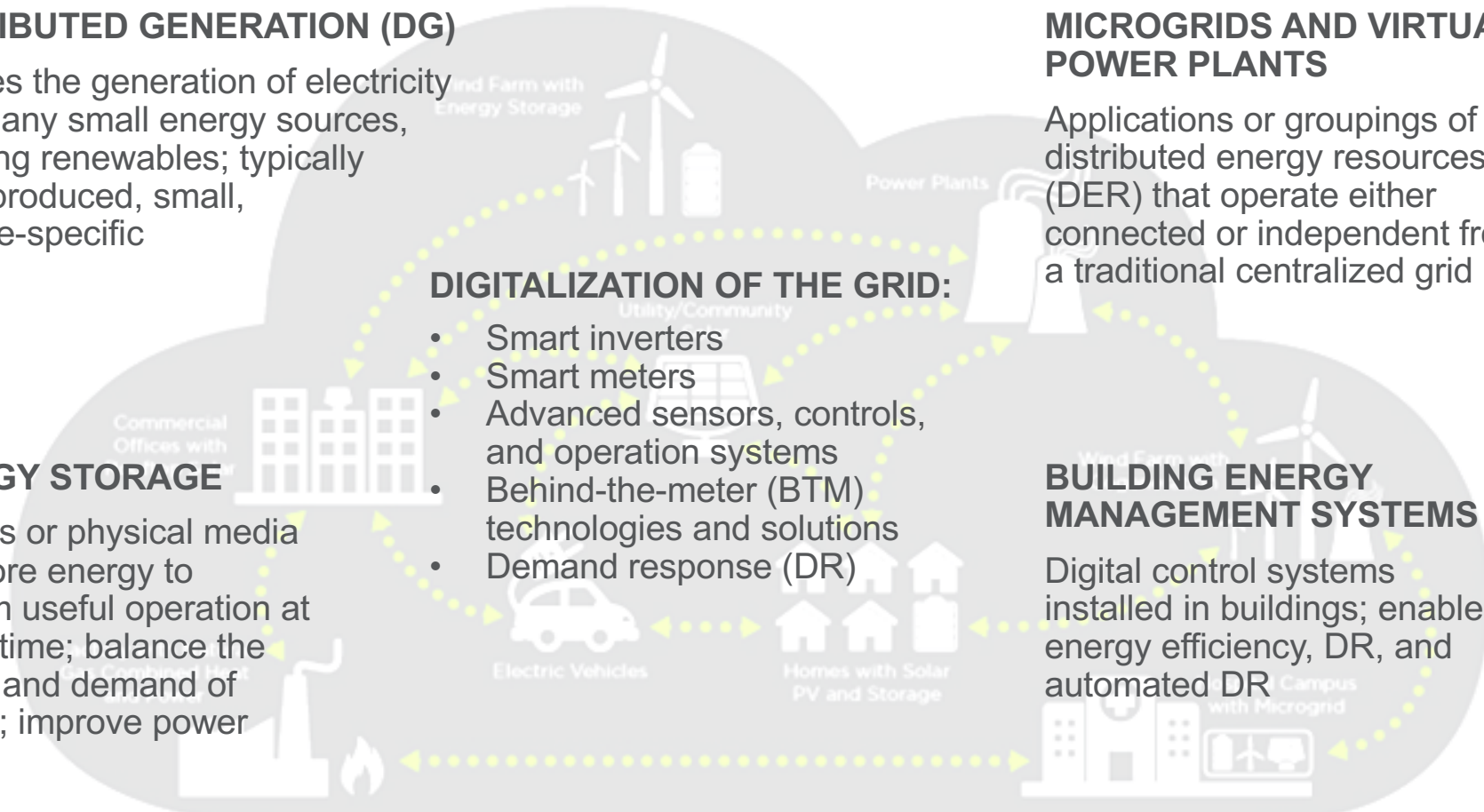
- Smart inverters
- Smart meters
- Advanced sensors, controls, and operation systems
- Behind-the-meter (BTM) technologies and solutions
- Demand response (DR)

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

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

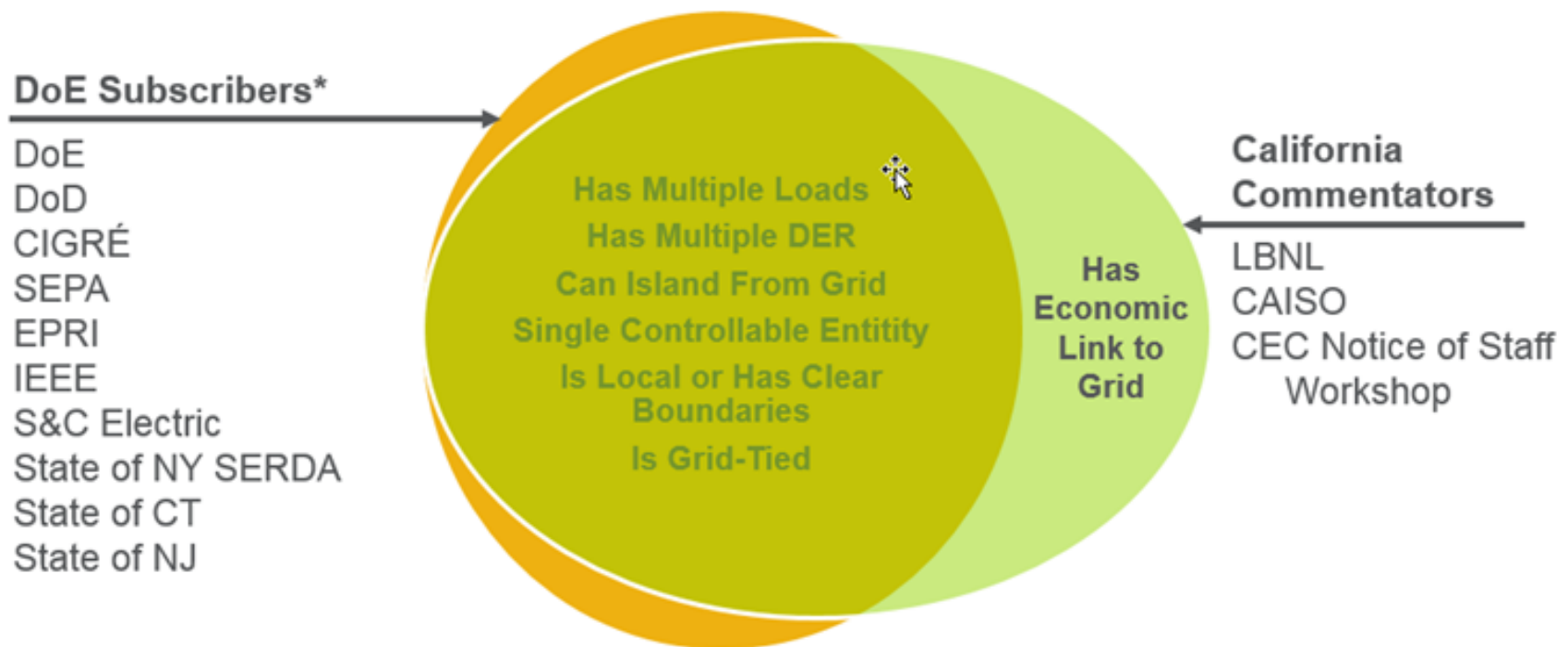
Summary: Components of 17 Microgrid Definitions

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

(Source: Navigant Research)

MICROGRIDS: OVERLAP WITH DOE DEFINITION

Microgrid Definitions and Notable Overlap

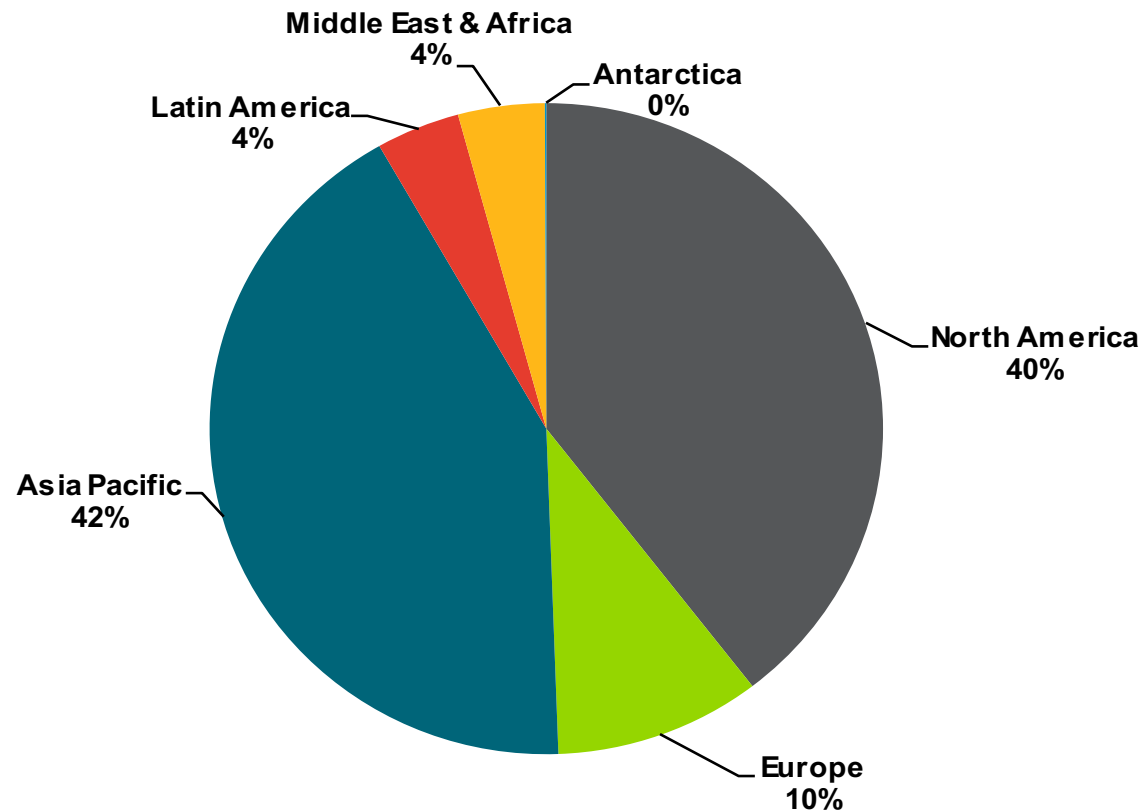


* Institutions that subscribe to the DoE definition of microgrids or have nominally similar definition.

(Source: Navigant Research)

ASIA PACIFIC & NORTH AMERICA ARE MARKET LEADERS

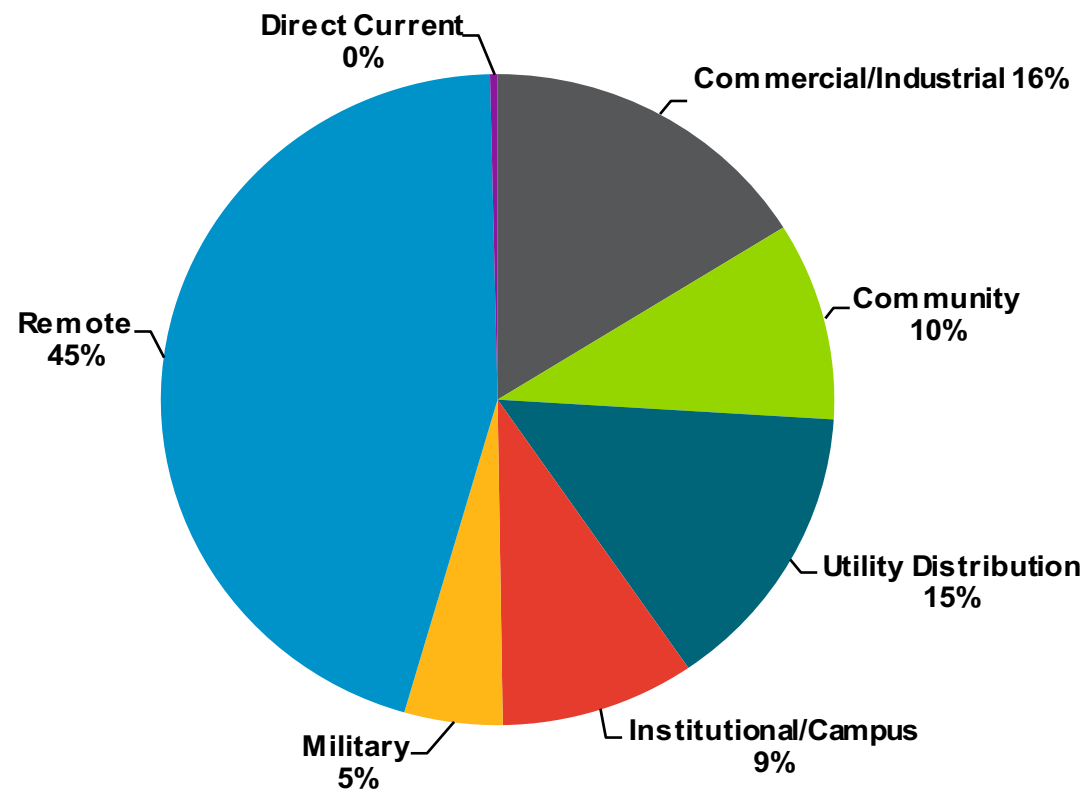
Total Microgrid Power Capacity Market Share by Region, World Markets: 2Q 2017



(Source: Navigant Research)

REMOTE MICROGRIDS CLEAR GLOBAL SEGMENT LEADER

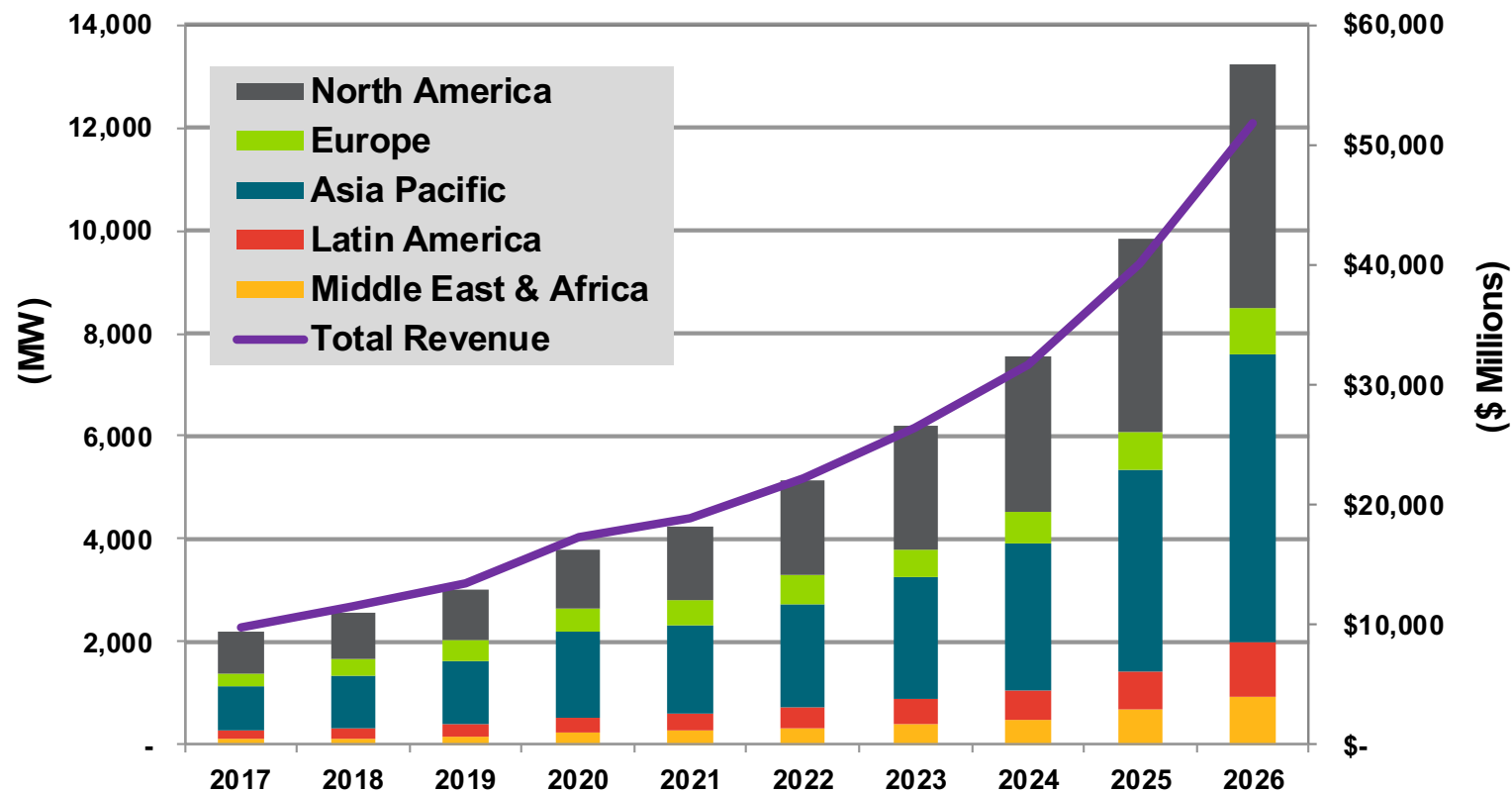
Total Microgrid Power Capacity Market Share by Segment, World Markets: 2Q 2017



(Source: Navigant Research)

MICROGRIDS: GLOBAL GROWTH TRENDS

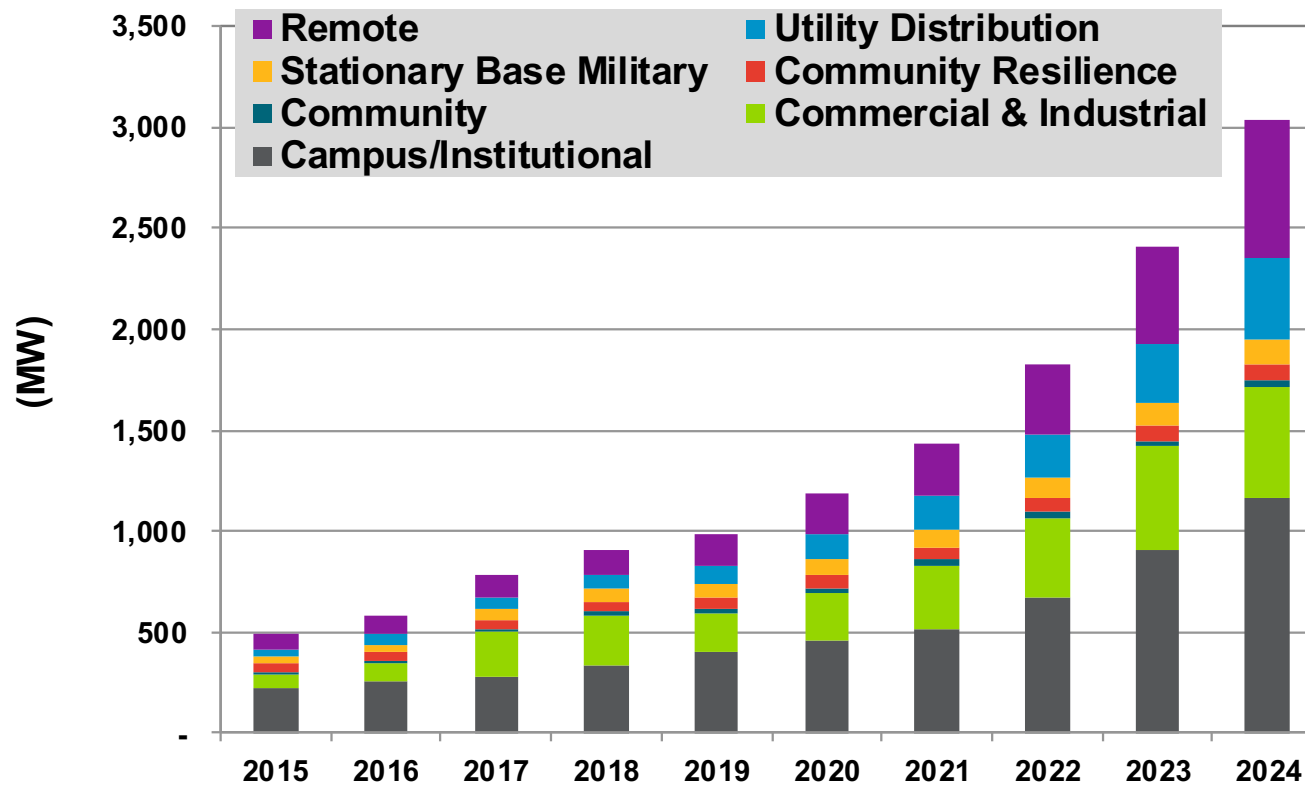
Total Microgrid Capacity and Revenue, World Markets: 2017-2026



(Source: Navigant Research)

MICROGRIDS CAPACITY FORECAST: NORTH AMERICA

Microgrid Capacity by Segment, North America: 2015-2024

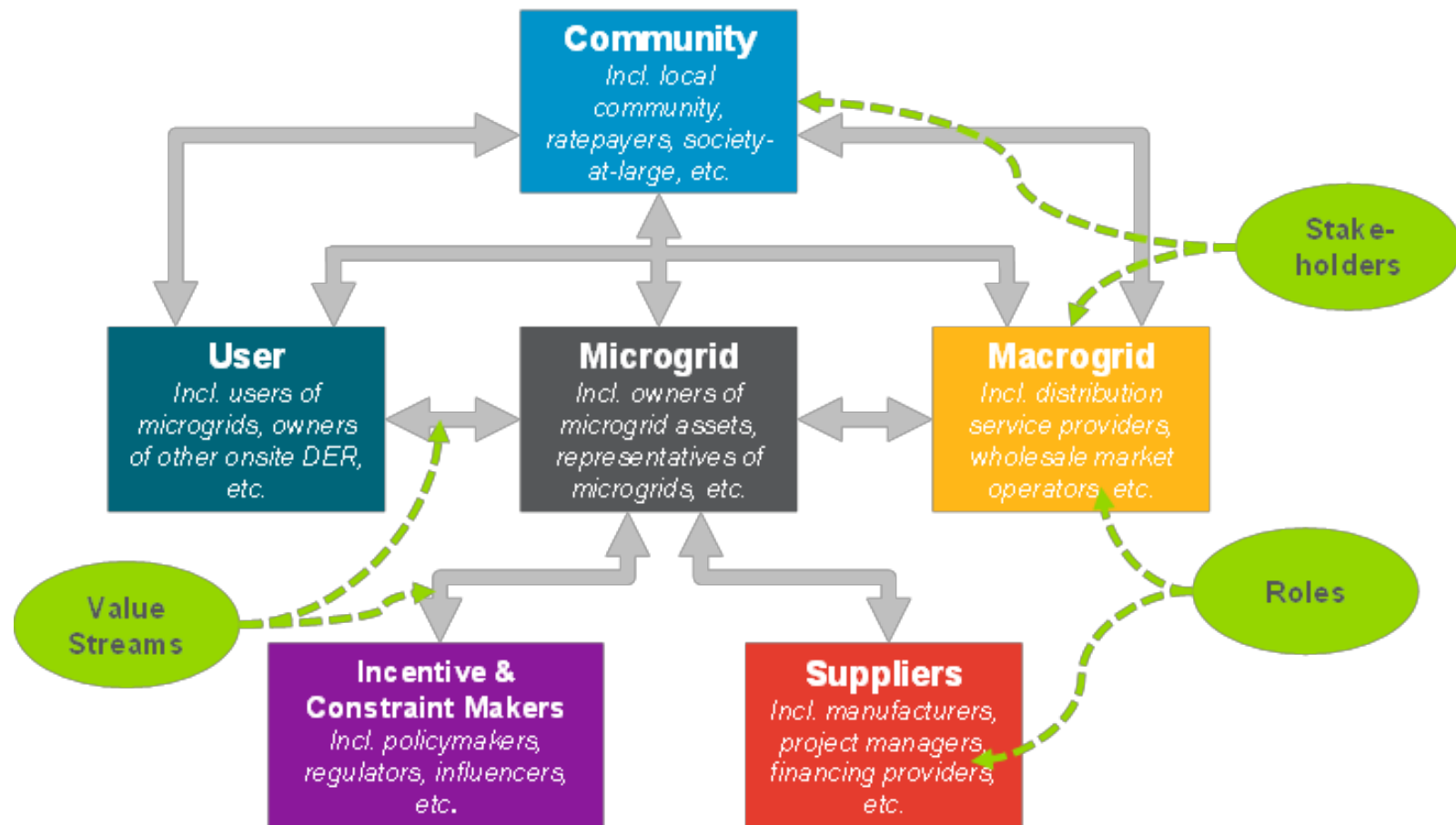


(Source: Navigant Research)



BUSINESS MODELS – AND WHAT ABOUT UTILITIES?

MICROGRID STAKEHOLDER MAPPING

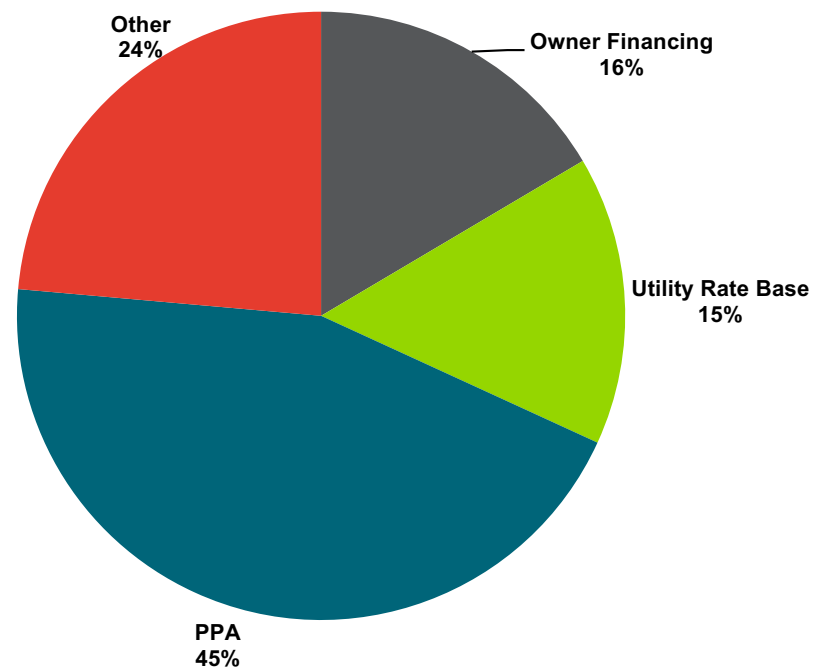


WHAT ARE THE CHALLENGES ON FINANCING?

- 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

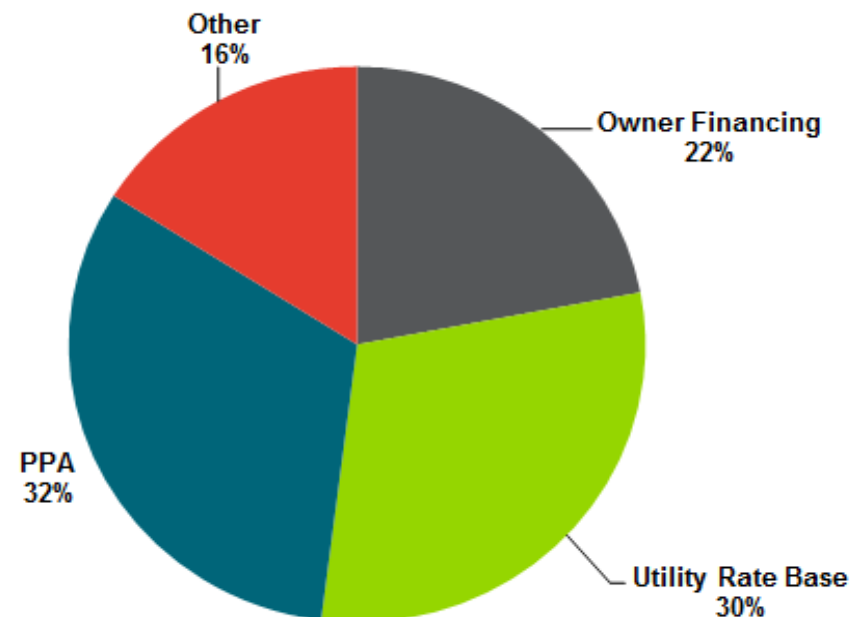
Grid-Tied, Non-Military Microgrids by Business Model Capacity, North America: 2015-2016



(Navigant Research-Hitachi)

MICROGRID BUSINESS MODELS IN N.A. BY PROJECT NUMBER

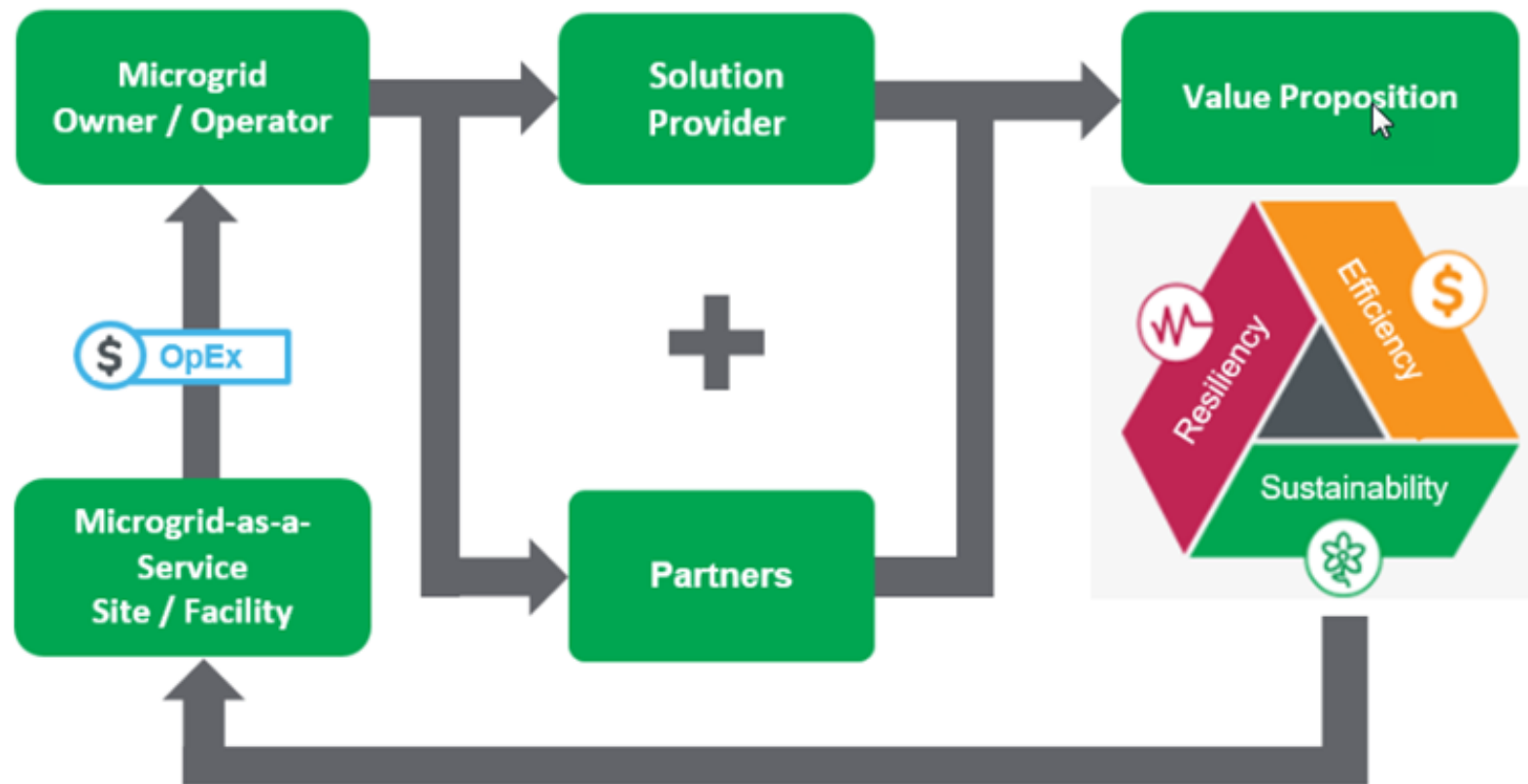
Grid-Tied, Non-Military Microgrids by Business Model Projects, North America: 2015-2016



(Navigant Research-Hitachi)

NEW EMERGING MICROGRID BUSINESS MODELS

Microgrids-as-a-Service



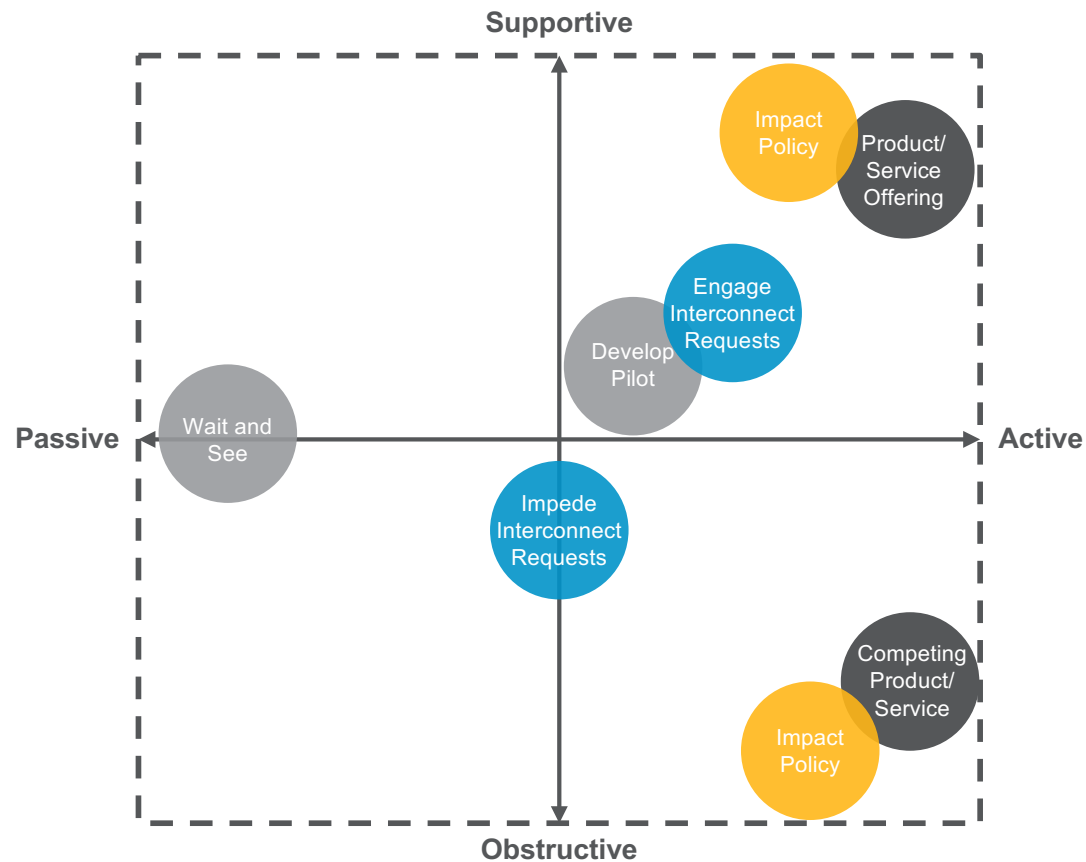
(Source: Schneider Electric)

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

ROLE OF UTILITY AS MICROGRID GATEKEEPER

Mapping Utility Microgrid Strategies



(Source: Navigant Consulting)



**WHAT IS THE
VALUE
PROPOSITION?**

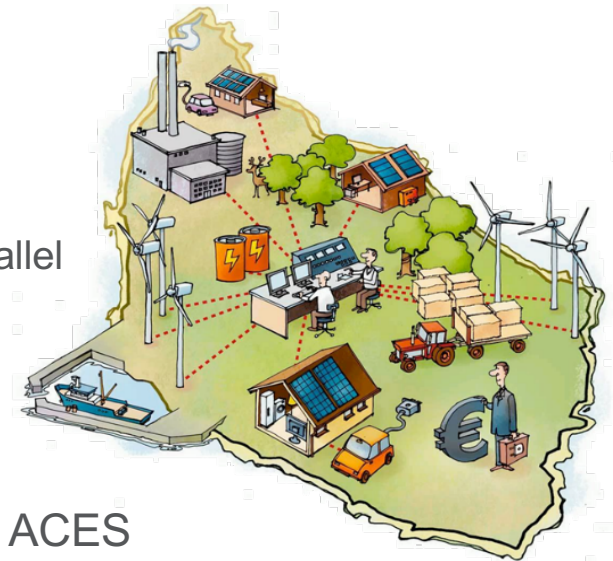
WHAT IS THE VALUE PROPOSITION FOR A MICROGRID?

- **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.

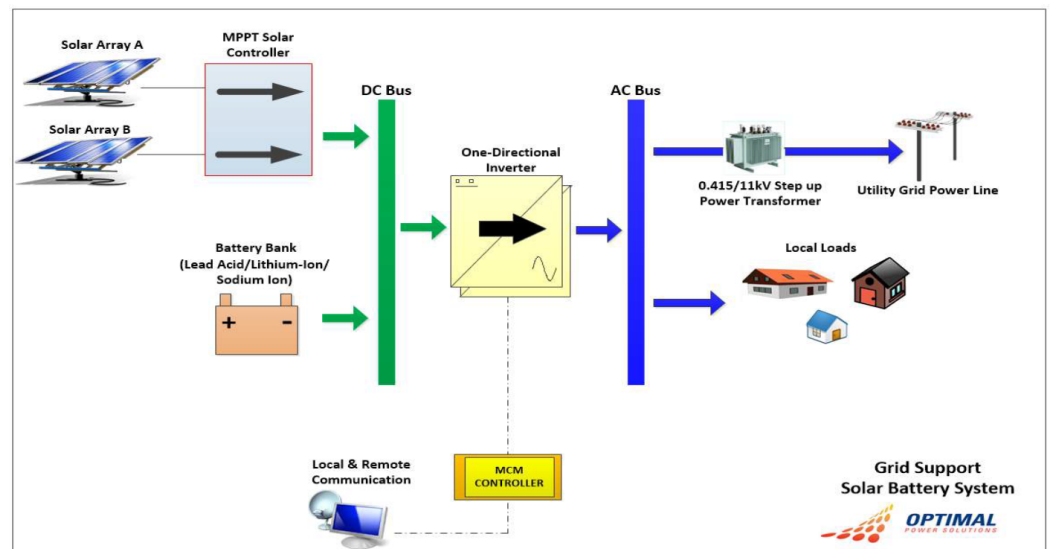
- The Bornholm Island system is larger than a typical microgrid, but is capable of islanding from the main grid (the Nordic interconnected power system).
- When grid-connected, the system has a high penetration of wind and some solar power. When islanded, it depends significantly on fossil fuel generation.
- 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).



Source: EcoGrid

GLOBAL PROJECT HIGHLIGHT #2: NAGOYA JAPAN LANDFILL

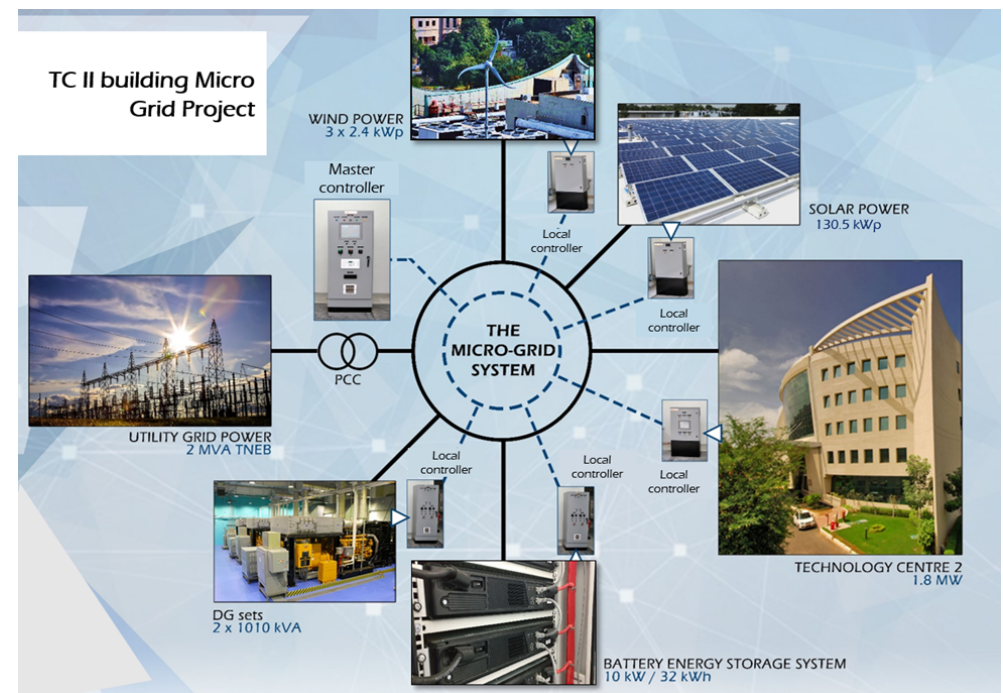
- **Extending the value proposition of a completed landfill, this microgrid uses batteries to make solar PV “dispatchable” and boosts local resiliency.**
 - Paved-over landfill unusable for most construction types, ideal for PV.
 - DERs include 0.5MW PV, 0.2MW/1.2MWh battery storage on 2 acre footprint.
- **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

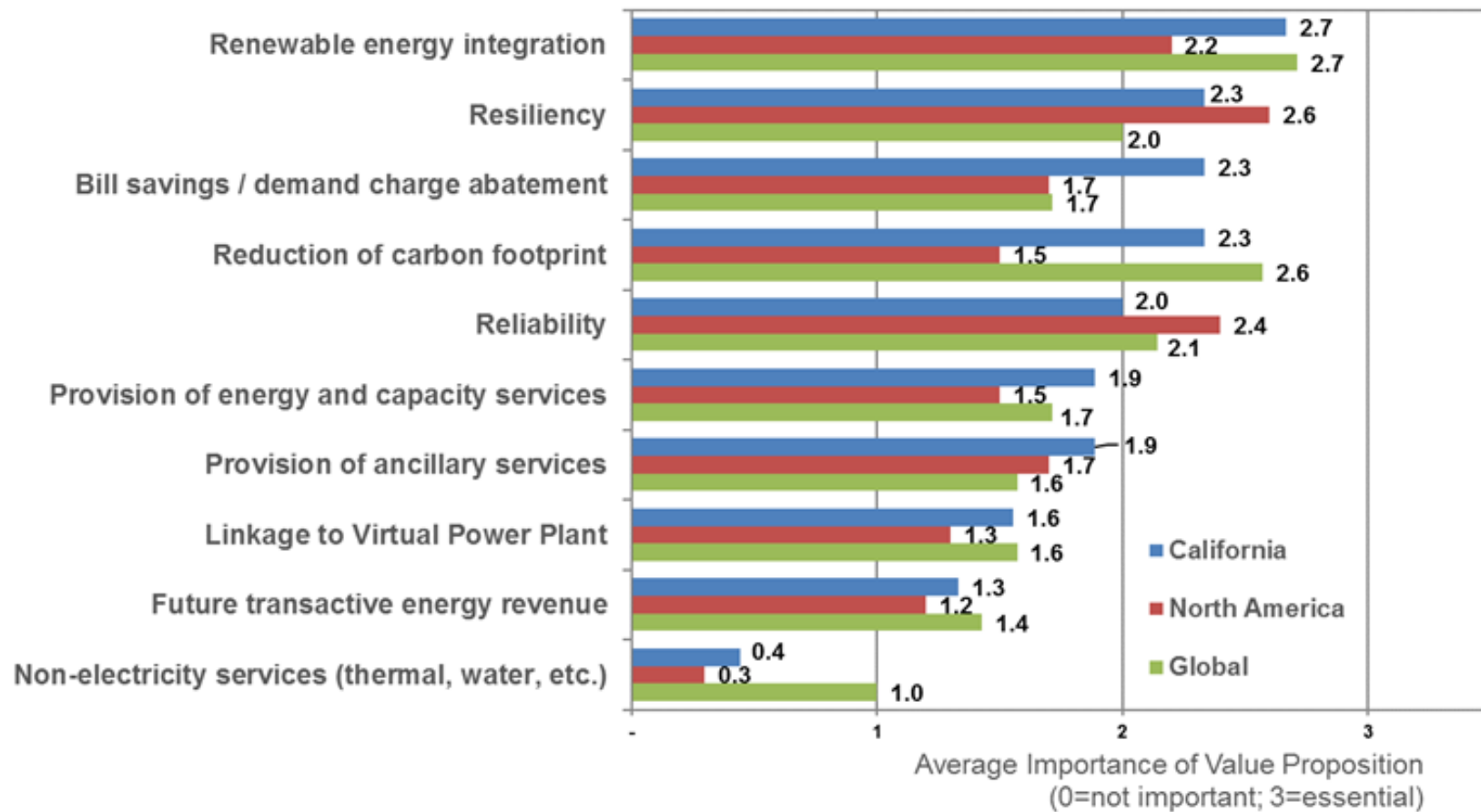
L&T's Chennai Campus Microgrid provides resilient power, enhances renewables integration, and serves as a showcase for microgrids in India

- **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



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