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# Research Report

## Microgrids

Islanded Power Grids and Distributed Generation for Community, Commercial, and Institutional Applications

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**Peter Asmus**
Industry Analyst

**Adam Cornelius**
Research Associate

**Clint Wheelock**
Managing Director

# Section 1

## EXECUTIVE SUMMARY

Microgrids have a long history. In fact, Thomas Edison's first power plant constructed in 1882 – the Manhattan Pearl Street Station – was essentially a microgrid since a centralized grid had not yet been established. By 1886, Edison's firm had installed fifty-eight direct current (DC) microgrids. However, shortly thereafter, the evolution of the electric services industry evolved to a state-regulated monopoly market, thus removing incentives for microgrid developments.

Today, though, a variety of trends are converging to create promising markets for microgrids, particularly in the United States. It has been become increasingly clear that the fundamental architecture of today's electricity grid, which is based on the idea of a top-down system predicated on unidirectional energy flows, is obsolete. The election of Barack Obama as president of the United States in 2008 and the passage of government stimulus funding packages in 2009 to respond to the economic recession have led to significant new federal funds earmarked for the "smart grid." Consequently, the United States is in position to become the global market leader in microgrids.

The fundamental concept of a "microgrid" can be summed up as follows: an ***integrated energy system*** consisting of ***distributed energy resources*** and ***multiple electrical loads*** operating as a ***single, autonomous grid*** either ***in parallel to*** or ***"islanded" from*** the existing ***utility power grid***. In the most common configuration, distributed energy resources are tied together on their own feeder, which is then linked to the grid at a single point of common coupling. Microgrids can be viewed as the building blocks of the smart grid or as an alternative path to the much hyped smart "Super Grid."

Perhaps the most compelling feature of a microgrid is the ability to separate and isolate itself – known as "islanding" – from the utility's distribution system during brownouts or blackouts. Under today's grid protocols, all distributed generation, whether renewable or fossil-fueled, must shut down during times of power outages. This fact exasperates microgrid advocates, who argue that this is precisely when these on-site sources could offer the greatest value to both generation owners and society. Such sources could provide power services when the larger grid system has failed consumers and owners of distributed energy generation systems.

The prospect of local control of one's energy services is threatening to politically powerful incumbent electricity utilities, whether privately or publicly owned. To date, these utilities have helped stall widespread growth of microgrids throughout the United States. However, new inverter technologies may be assuaging utility opposition to microgrids due to fears about unintentional islanding, a traditional safety concern.

The five primary microgrid application segments profiled in this report are the following:

- **Community/Utility Microgrids:** The word "community" implies a geographical region that includes residential customers. Most observers predict that this class of microgrids will not achieve widespread commercial acceptance until standards are in place and regulatory barriers are removed.
- **Commercial/Industrial:** The first "modern" industrial microgrid in the United States was a 64 MW facility constructed in 1955 at the Whitling Refinery in Indiana. All told, 455

megawatts (MW) of these vintage microgrids are currently online in the United States. Unlike today's conceptual state-of-the-art models, these initial designs for the petrochemical industry still feature centralized controls and fossil-fueled generation sets. Japan is a modern leader in the commercial/industrial sector, though most of its microgrids include governmental and other institutional customers.

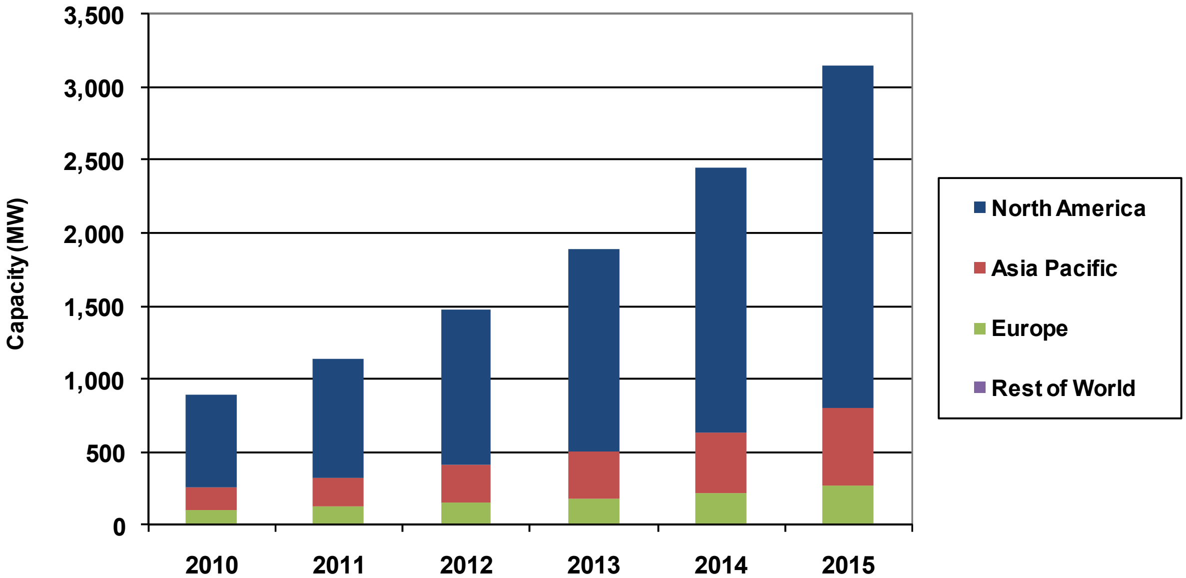
- **Institutional/Campus:** Because of the advantage of common ownership, this class of microgrids offers the best near-term development opportunity. At present, 322 MW of college campus microgrids are up and running in the United States, with more sophisticated state-of-the-art microgrids on the drawing boards. In the U.S., 40% of future microgrids will be developed in this market segment, adding 940 MW of new capacity valued at $2.76 billion by 2015.

- **Remote Off-Grid Systems:** This segment represents the greatest number of microgrids currently operating globally, but it has the smallest average capacity. While many systems have historically featured diesel distributed energy generation (DEG), the largest growth sector is solar photovoltaics (PV). Small wind is projected to play a growing role, as well.

- **Military Microgrids:** The smallest market segment, these microgrids are just now being developed. They are integrating Renewable Distributed Energy Generation (RDEG) as a way to secure power supply without being dependent on any supplied fuel. GE and Sandia are moving forward in this area and model prototypes are expected in 2010.

Just how big will the microgrid market be over the next five years? Between now and 2015, over 3.1 gigawatts (GW) of new microgrid capacity is projected to come online worldwide, representing a total market value of $7.8 billion. North America will capture $5.8 billion, or 74% of this market. The United States is the current capacity leader – with at least 626 MW operating by 2010 – and that capacity will increase to 2,352 MW by 2015.

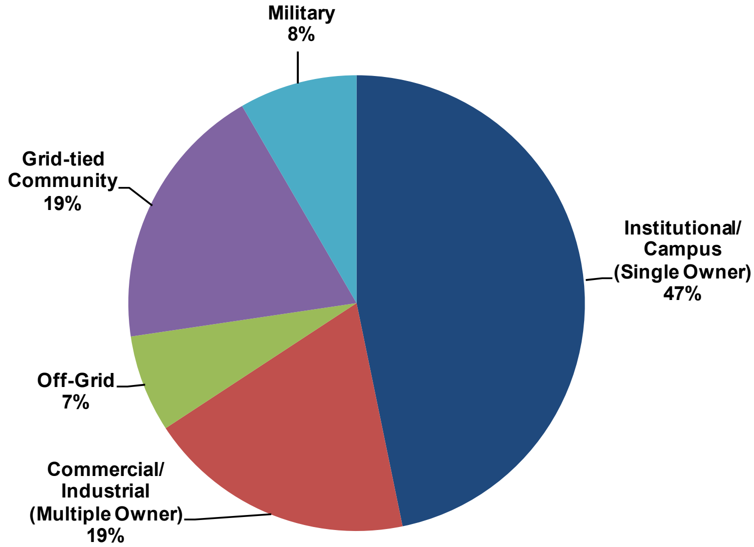
***Chart 1.1 Microgrid Capacity, World Markets: 2010-2015***




*(Source: Pike Research)*

North America will have a global market-leading position in all five segments profiled in this report by 2015, with total revenues exceeding $3.5 billion.

***Chart 1.2 Market Sector Revenue Breakdown, North America: 2015***




*(Source: Pike Research)*

Among the benefits of microgrids identified by the Lawrence Berkeley National Laboratory (LBNL) are the following:

- **Autonomy:** Microgrids allow generation, storage, and loads to seamlessly operate in an autonomous fashion, balancing out voltage and frequency issues with recent technology advances.
- **Stability:** Control approaches are based on frequency droops and voltage levels at the terminal of each device, allowing the entire network to operate in a stable manner, regardless of whether the larger grid is up or down.
- **Compatibility:** Microgrids are completely compatible with the existing centralized grid, serving as a functional unit that assists in building out the existing system, helping to maximize otherwise stranded utility assets.
- **Flexibility:** Expansion and growth rates do not have to follow any precise forecasts since lead times are short and buildout incremental. Microgrids are also technology neutral, able to tap a diverse mix of renewable and fossil fuels.
- **Scalability:** Microgrids facilitate the use of many small generation, storage, and load devices in a parallel and modular manner in order to scale up to higher power production and/or consumption levels.
- **Efficiency:** Energy management goals – including economic and environmental – can be optimized in a systematic fashion.
- **Economics:** Droop frequency control techniques allow for economic decision-making to be programmed into standard operating protocols.
- **Peer-to-Peer Model:** Microgrids represent a new paradigm – a true peer-to-peer energy delivery model that does not dictate size, scale, peer numbers, or growth rates.