U.S. Microgrids 2017: Market Drivers, Analysis and Forecast

Detailed Segmentation and Ownership Trends

Colleen Metelitsa
Analyst, GTM Research
metelitsa@gtmresearch.com

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About the Analyst

Colleen Metelitsa
Analyst, Grid Edge

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Colleen Metelitsa is an Analyst with GTM Research and covers microgrids research. Before joining GTM Research, Colleen completed a Master of Public Administration degree in Energy Finance and Policy at Columbia University, where she served as Co-Director of the Columbia University Energy Symposium. During her graduate school experience she worked with NY Green Bank, GE and Environmental Defense Fund spanning blockchain, energy storage and project finance. She has four years of experience in energy consulting, with a focus on utility program evaluation, at DNV GL and APPRISE.

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1. Executive Summary

Executive Summary

The U.S. microgrid market continues to evolve; over the past 12 months both the number of 1-10 MW projects and third-party and mixed-ownership business model structures have come to characterize a larger portion of the overall market. Microgrid developers continue to focus on finding ways to make their solutions more modular to reduce the customization required for most projects today. While remote communities constitute a significant topic in the international microgrid market, in the U.S. the primary focus remains on providing reliability and resilience to grid-connected premises, rather than renewables integration or energy access.

In 2017, two major hurricanes hit the southern U.S.; Hurricane Harvey dropped over 50 inches of rain on the Houston, Texas area and Hurricane Irma is one of the strongest recorded Atlantic hurricanes in history. As “500-year” storms occur more frequently, energy surety and grid reliability become an increasingly important political topic. The U.S. Department of Energy’s 2017 Grid Reliability study includes microgrids as a way to provide reliability and resilience. Superstorm Sandy drove favorable state-funded microgrid initiatives in the Northeast for the development of municipal and public institutional (e.g., hospitals, universities) microgrids, and it is likely that following this hurricane season, the states in the hurricane belt will continue to develop beyond the traditional basic microgrids that currently make up the majority of the market. The recent wave of state-level resilience and grid modernization programs will help fuel this growth in the community and public institutional microgrid markets.

Despite their traditional disassociation with the concept, there has also been a recent surge in regulated utility interest to deploy microgrids as a platform for “grid modernization” or as a “non-wires” alternative to traditional capital infrastructure investments. Simultaneously, major developers and Energy Service Companies (ESCOs) continue to increase investment and involvement in the development, ownership and operation of distributed energy resources (DERs) and microgrids. New projects continue to test innovative contract structures to better align potential benefits to multi-stakeholder ownership models to include consumers, utilities, municipalities and other third-party entities.

Though substantial regulatory overhauls will be necessary for this market to truly flourish, policymakers and regulators are increasingly funding and considering legislation to further promote the development of microgrids for a variety of applications. As factors including heightened customer demand, continued technological maturity, and the decreasing price of distributed generation drive project economics forward, the market will move past niche applications intended for military bases and remote communities to viable, multi-stakeholder, bundled solutions. Basic commercial microgrids will remain an important component of the market, but will face increasing competition from more advanced solutions that provide fuel diversity and more energy and demand management controls.

This microgrid report provides a comprehensive overview and analysis of the U.S. microgrid market, including conceptual explanations, stakeholder benefits and development considerations, an in-depth explanation of customer drivers and emerging ownership structures, detailed segmentation of the current market, and thorough examinations of future market forecasts and expectations.

2017 Report Marks Increased Coverage of Basic Microgrids

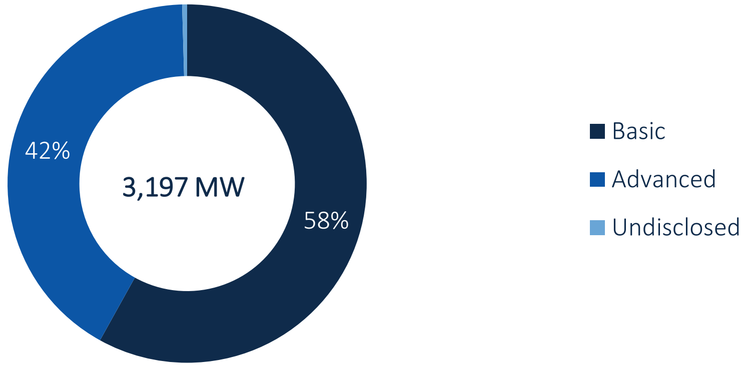
In 2017, we saw many hurricanes hit states in which very few advanced microgrids that fit GTM's previous microgrid definition were present. However, the Southeast does have a large market for basic microgrids, defined as a site with one deployed DER technology, with the ability to island for at least 24 hours, that can provide both power and energy services when in grid-connected or island mode. These generation systems must also either be oversized or have ability to automatically shed load. These do not include DERs that cannot run in parallel with the grid. (For more information on the difference between basic and advanced microgrids, see slide 14.)

GTM Research chose to incorporate these systems as they represent the vast majority of what the market has been installing to date. These systems make up 58% of capacity and 88% of all projects.

Given the recent increase in scope of the type of microgrids in this report, GTM Research does not currently cover the entire basic microgrid market. However, it does cover a significant portion of recently installed systems incorporating data from PowerSecure, Enchanted Rock and other project developers.

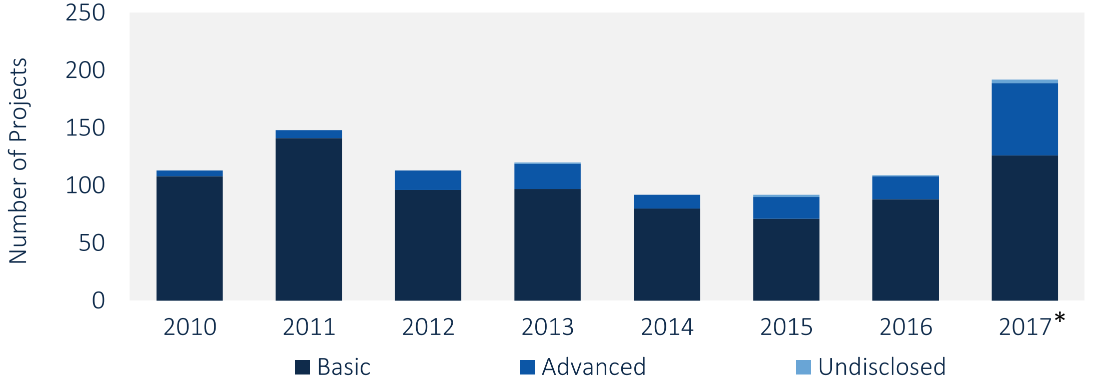
Note: The initial report incorrectly classified a group of 45 projects, which account for 50 MW of completed and planned capacity in 2017, as advanced instead of basic. This correction was made in December 2017 and has been applied here.

Operational Microgrid Capacity by Complexity, Q3 2017



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

Operational Microgrids by Complexity, 2012-2017



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

* 2017 includes projects planned for completion

2. Key Takeaways

Evolving Use Cases Give Rise to New Growth Opportunities

2017 Microgrid Market Still Largely Fossil Fuels and Targeted Within Specific Regions

1. **Cumulative operational microgrid capacity in the U.S. is currently 3,197 MW and still dominated by conventional fuel generation**
   The current microgrid capacity mix, largely fossil-fuel-driven, is expected to increasingly turn to renewable sources. Renewables contribute 12% of today's cumulative operational capacity; storage makes up an additional 3%. The known pipeline of planned microgrid generation capacity continues to favor a more diverse resource portfolio; natural gas represents the largest planned capacity resource followed by solar.
2. **74% of currently operational microgrid generation capacity is distributed among 10 states, driven by regional DG and microgrid incentives**
   Operational microgrid generation capacity is concentrated among very few states, with Florida's 478 MW representing 15% of overall capacity, largely due to 464 MW of basic, diesel-only microgrids supplied by PowerSecure.
3. **Microgrid growth has not reached its full potential due to financial and regulatory barriers**
   Larger-scale multi-customer microgrids continue to face significant regulatory hurdles, including utility franchise rights and the threat of being subject to public utility commission regulation. Franchise rights allow utilities to construct wires and facilities in public areas without fear of competition from other distribution grid providers. Designed to govern the use of public space by third parties, these rules substantially limit the ability of third-party providers to realize economically attractive project sizes. New business models, such as microgrids-as-a-service, could help reduce financial barriers by bringing in outside capital for the upfront costs.
4. **Commercial microgrids will continue to make up plurality of installations as more companies recognize their efficacy**
   The basic microgrid market has largely targeted commercial entities, with 94% of commercial microgrids being basic diesel or natural-gas-only microgrids. PowerSecure has historically been the biggest player in this space, and Enchanted Rock has increased deployments in 2016 to become a contender with regional strength centered in Texas.

Supply Diversity and Modularization Will Continue to Develop

5. **The value proposition for energy storage is growing within microgrids, especially in a few select states**
   With 74% of operational advanced microgrids (8% of all microgrids) including some form of energy storage, the U.S. market offers storage-solution providers a unique opportunity to leverage high incentives and microgrid-specific subsidies to further develop technologies and underlying business cases that stack values such as demand-charge reduction, peak shaving, backup power and renewables capacity firming.

6. **ESCOs and unregulated utility branches target microgrid development**
   Generally provided through a long-term agreement (e.g., custom-designed lease or power-purchase agreement), third-party energy service companies (including deregulated utility branches) such as Duke Energy Renewables, Enchanted Rock (through its joint venture Texas Microgrids), Ameresco and NRG are increasingly providing "microgrids-as-a-service." Such an offering can significantly reduce the end-customer liabilities including capital investments and O&M costs in exchange for the third-party investor receiving the revenue from ancillary services.

7. **Largely supported by state incentive programs, the critical infrastructure market exhibits the fastest near-term growth for non-commercial microgrids**
   Microgrids for critical infrastructure, mainly in cities and small communities, will grow most rapidly within the next five years, driven by solar PV adoption, CHP incentives, PACE financing and state resilience programs along the East Coast. In 2017 alone, five states (California, Connecticut, Massachusetts, New Jersey and New York) announced or awarded early-stage funds for microgrid feasibility studies and/or microgrid design and build.

Market Expected to Reach $2.8 Billion in Annual Spending by 2022 With 6.5 GW of Cumulative Capacity

8. **Slower 2017 capacity deployment combined with higher project growth prompts readjustment; 2022 forecast to reach 6.5 GW**

   In this Q3 2017 release – despite a slowdown in 2017 installed capacity – GTM Research continues to expect the market to expand significantly given the number of increasingly favorable market trends:

   a. A positive uptick in state incentive programs and policies
   b. Adoption of merging business models that share benefits, costs and ownership among multiple stakeholders
   c. Increased interest and activity from utilities and ESCOs
   d. An uptick in discussions on creating more streamlined, plug-and-play microgrid solutions to enable greater commercial adoption

   The U.S. cumulative market capacity is expected to reach 6.5 GW by 2022, representing a 2016-2022E compound annual growth rate (CAGR) of 14.1%. As energy storage costs continue to fall rapidly, increased deployments of storage are helping integrate more renewables as well as to provide more real-time response and as a grid-forming device. GTM Research expects storage to continue to play an increasing role, though fossil-based generation is still commonly favored for providing on-site reliability.

9. **Annual market opportunity expected to double over the next five years**

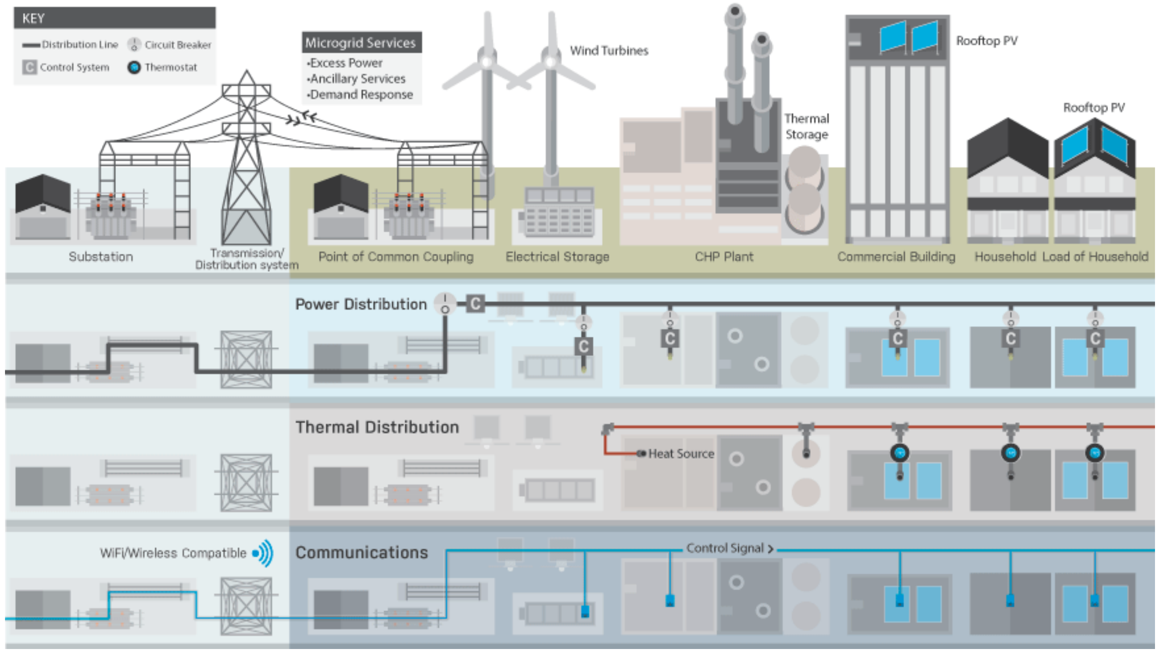
   The annual market opportunity is expected to grow from $1.4 billion in 2017 to $2.8 billion in 2022. Combined six-year investments (2017E-2022E) are expected to exceed $12.5B as generation (including storage) will continue to represent the most significant market opportunity (especially in greenfield projects), followed by distribution grid enhancements. This is an increase over 2016, due in part, to a higher average cost of microgrid; this may be an indication of more generation being installed with the microgrid, as well as more complex systems being financed, and potentially the increasing complexity of microgrid controls opening up new value streams.

3. What Is a Microgrid?

A Conceptual Explanation of Microgrids and Related Technologies

Microgrids Can Operate Independently From the Grid

Microgrids Conceptualized as a Layered Combination of Different Networks



Source: GTM Research

A microgrid in its most basic iteration can be deployed at the facility of an end customer to add reliability behind a low-voltage interconnected point of common coupling (PCC) and manage/dispatch onsite resources. In its most complex form, microgrids can be a utility-controlled medium-voltage segment of the distribution grid that provides both utility and customer benefits.

Microgrids are often deployed to address project-specific challenges on a case-by-case basis, highly dependent on ownership structures, objectives, business plans and the local regulatory landscape. Layers of different networks, such as power and heat distribution infrastructure and communication networks, enable the microgrid to transmit and receive control signals and manage internal resources as well as any macrogrid interactions. In addition to their ability to disconnect from the grid when there is a power outage (islanding), microgrids can also provide other values including integrating DERs, providing ancillary services to the grid, and helping defer other grid investment.

GTMR Microgrid Definition: A microgrid is an independently operable part of the distribution network, including distributed energy resources, loads and network assets, that is controlled within clearly defined geographical boundaries and can operate in grid-connected or islanded mode.

Defining Features:

1. Ability to provide power and energy services in both grid-connected and island mode
2. Single building (> 100 kW) or multiple buildings
3. Local electric and/or heat generation and load
4. Advanced DER and grid asset control, monitoring and dispatch

Microgrids Offer Solutions That Address an Array of Challenges

Generalized Characteristics by Microgrid Complexity

Multifunctional

- **Plug-and-Play:** Scalable and interoperable architectures, interaction of several microgrids in a clustered distribution grid
- **Market Interaction:** Internal and external control and forecasting, demand response automation, ancillary service optimization

Intermediate

- **Multioptimization:** Control of multiple DERs and loads to simultaneously meet economic, environmental and/or societal goals
- **Integration:** Managing both dispatchable and intermittent resources, internal forecasting

Basic

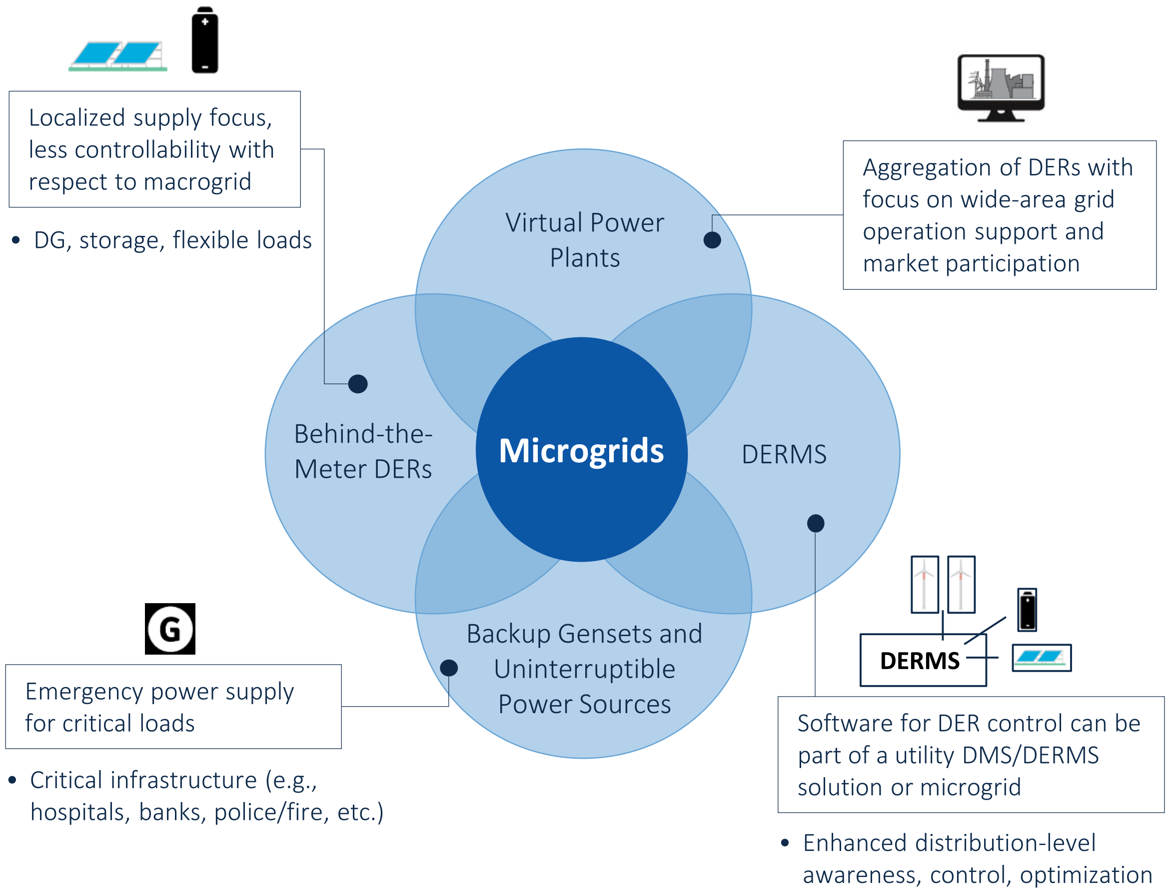
- **Reliability:** Enhanced protection, switching and control, islanding capabilities and backup generators to provide emergency power
- **Local supply:** On-site generation meeting local demand for power and/or heat; provides energy and power services

Microgrids vary in complexity from a basic microgrid – a backup generator that is capable of running in parallel with the grid and has the ability to automatically island and resynchronize to the grid after an outage – to a multifunctional microgrid with wider applications of providing flexible generation and reliability to both the local community and bulk power grid. For the purpose of this report, intermediate and multifunctional microgrids will both be referred to as advanced microgrids.

Basic power management and supply technologies for remote or island communities continue to be deployed, and wider-ranging behind-the-meter, utility and wholesale market applications have rapidly developed within recent years, allowing organizations to re-examine their applicability to broader use cases that can apply to multiple stakeholders. Notable ongoing research initiatives and technology commercialization-oriented programs indicate that microgrids may become the building blocks of an increasingly diffuse yet interconnected distribution network of the future.

Microgrids Combine Grid Edge Technologies to Provide Unique Functionalities

Microgrid Commonalities Shared With Other Grid Edge Technologies



Source: GTM Research

Microgrids are often mentioned in conjunction with other systems and technologies that are transforming the grid edge, since a microgrid bundles these DERs and software solutions into a single platform that can address a diverse set of use cases. Leveraging the full spectrum of potential benefits requires integration of systems to bridge the gap between new and distributed technology, legacy equipment, ISO telemetry requirements and utility interconnection protocol.

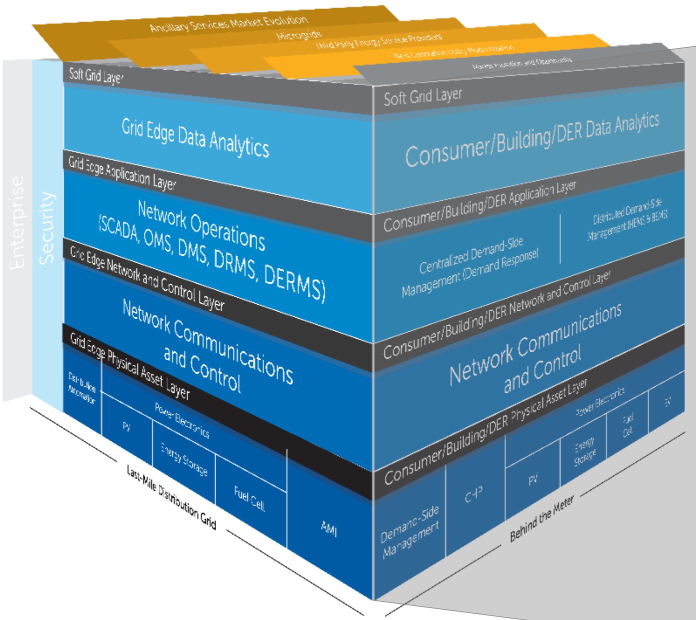
Microgrid technologies include:

- **Switching and Protection Equipment**: Circuit breakers, switchgear, over-current protection relays, static switches to transition safely from grid-connected to islanded mode
- **Microgrid Controller**: Centralized and/or distributed monitoring and decision-making on economic dispatch to balance supply and demand, frequency response, voltage management, etc. executed in grid-connected and islanded mode; controllers also provide a utility distribution management system and/or wholesale market interface
- **Advanced Power Electronics**: Smart inverters, load controllers, other power electronic distributed energy resource (DER) interfaces
- **High-Speed Communication Networks**: Control signal transmission and fast reaction to change in resource availability
- **DER Analytics, DERMS**: Software for DER control, load and power flow analysis, heat/power demand and supply forecasting
- **Energy Management Systems at the Building, Community and Microgrid Levels (µEMS)**

Microgrid Controllers Provide the Link Between DERs in Grid-Connected and Islanded Mode

Microgrid controllers are local communication and coordination solutions that optimize under various conditions; these controllers function in a manner similar to the macrogrid and therefore can be viewed as a hybrid of the grid edge cube’s distribution and behind-the-meter sides as it encompasses both distribution and local DERs.

Microgrid Control Architecture Aligns with Grid Edge Cube Structure



Level 4: Microgrid-Macrogrid Data Analytics

Distribution management system, economic dispatch (e.g., ancillary services, demand charge arbitrage); coordination of DER output to optimize microgrid stability and economics, which involves reacting to market price signals

Level 3: Microgrid Management Application Layer

Optimizing dispatch across DERs and load controls within microgrid in grid-connected and islanded mode; load sharing and shedding to enable optimal operation and supply of critical load; voltage and frequency stability in grid-connected and islanded mode

Levels 1 and 2: Device-Level and Network-Level DER Controls

Voltage and frequency stability at the individual DER level and across DERs within the microgrid; communication between device controls and other control layers; resynchronization of the microgrid with main grid

Level 0: Physical Assets in Microgrid

Generation assets (e.g., CHP, solar, wind), energy storage, load control assets, point of common coupling

Source: GTM Research

4. Microgrid Benefits and Considerations

Project Development Is Dependent on Regional Regulation and Incentives

Section Overview: General Benefits and Considerations

Microgrids are incrementally developed on a case-by-case basis, tailored to the specific needs of each site and project phase. The underlying drivers and barriers, therefore, often vary depending on the regional regulatory environment, applicable incentive programs, renewable generation penetration and grid reliability concerns.

Takeaways:

1. The different assets in microgrids enable multiple value streams across the grid above and beyond resilience; these value streams are the key to commercializing the microgrid market.
2. Regulation continues to be the primary barrier to microgrid adoption, including the infringement of utility franchise rights and the threat of being regulated as an electric corporation under the public service commission.
3. Major technical challenges include overcurrent projection and relaying, safety hazards (backfeeds and downed conductors), synchronization, voltage and power control.

While Reliability Promotes Interest, Stacked Benefits Drive Adoption

Reliability and resilience are difficult items to value accurately. While it is relatively straightforward for a business owner to calculate the value of lost perishable goods at their grocery store or the cost of lost production in a factory for one day, calculating the social value of reliability and resilience associated with the value of human life or the ability to communicate with others after a large storm is difficult. There are, however, other value streams that assets installed as part of microgrids can provide that can be calculated, which can help incentivize and drive adoption of microgrids in addition to the core reliability and resilience benefit.

Representative Value Streams for Microgrids

Customer Value Streams	Distribution Value Streams	Wholesale Value Streams
BACKUP POWER	RESILIENCE	BLACKSTART
GRID SERVICE PROGRAMS	DISTRIBUTION LOSSES	VOLTAGE SUPPORT
ENVIRONMENTAL INCENTIVE	LOCAL VOLTAGE AND REACTIVE POWER SUPPORT	FREQUENCY REGULATION
SYSTEM PEAK CHARGES	LOAD SHAPING	SPIN/NON-SPIN RESERVES
DEMAND CHARGES	T&D DEFERRAL	ENERGY
ENERGY PRICE ARBITRAGE	CAPACITY	CAPACITY

Value Drivers

- Retail electricity prices
- Retail demand charges
- Demand growth
- Wholesale capacity prices
- Wholesale energy prices
- Wholesale ancillary services prices
- Reformed markets for independent system operator (ISO) or regional transmission operator (RTO) wholesale-level value streams
- Emerging markets for utility services at distribution level

Source: GTM Research

Note: Value streams may not be readily accessible due to regulations and traditional business processes.

Despite Multiple Value Streams, Microgrid Customization and Regulations Still Pose Barriers

Key Microgrid Drivers and Barriers

Drivers:

- Reliability; outage and storm resilience (e.g., Superstorm Sandy, Hurricane Harvey)
- Improved renewables integration
- Mitigation of energy cost and fuel procurement risks
- Grid modernization and rural electrification efforts
- Transmission and distribution investment deferral (e.g., line construction, substation upgrade)
- Positive political momentum through incentives initiatives (e.g., CHP/microgrid funding, R&D grants, etc.)

Barriers:

- Utility franchise rights
- Threat of being subject to public utility regulation
- Insufficient definition and variance of interconnection policies
- Unresolved issues associated with distribution network costs
- Lack of standard microgrid ownership and financing models (e.g., umbrella PPA)
- Absence of scalable prototypes and all-in-one deployments
- High cost of customer integration and development
- Low customer and community education/awareness

As microgrids are deployed on a project-by-project basis and tailored to specific use cases, the underlying drivers and barriers often differ for each project, affected by regional regulation and incentive programs, renewable generation penetration, existing infrastructure and grid reliability (e.g., outages due to weather-related events).

* The accelerated growth and declining cost of DERs (e.g., solar, storage, CHP) are considered major supporting factors in the recent buildout of microgrid systems. Though not considered a primary driver, its effect is acknowledged.

The Top 3 Barriers to Adoption Are Regulatory, Not Technical

The top barriers to microgrid adoption are regulatory, not technical. While some regulatory momentum is supporting microgrid development, most of the current environment has prevented third-party-owned and -operated microgrids from functioning as small-scale utilities.

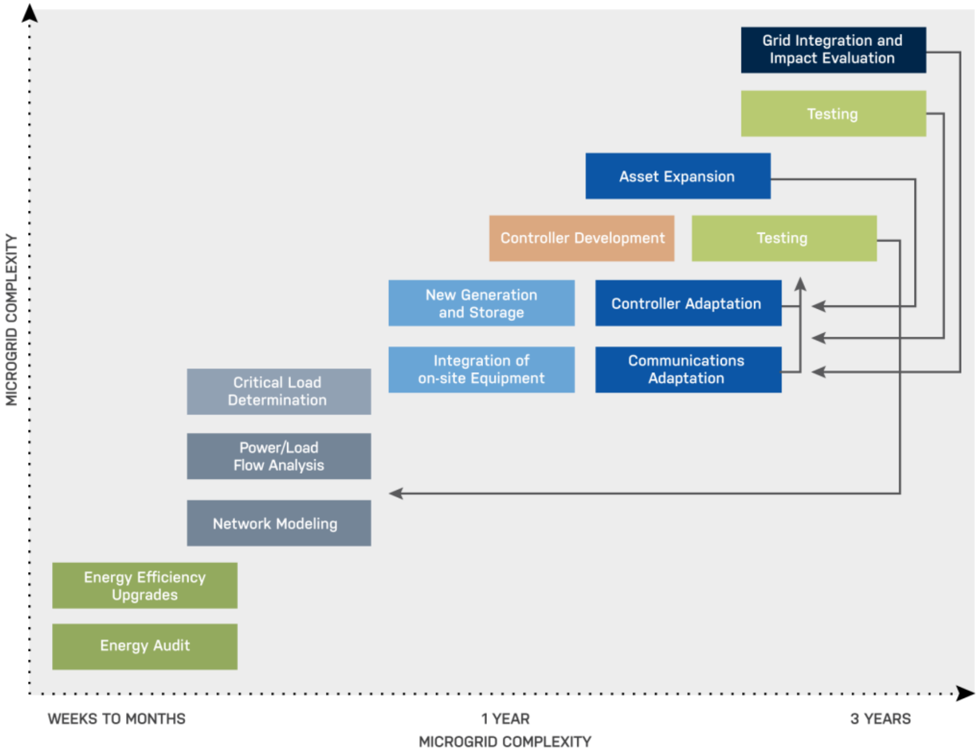
1. **Utility Franchise Rights**: Selling power to third parties via new distribution lines that cross rights of way infringes on utility franchise rights. Designed to govern the use of public space, these rules allow utilities to construct wires and facilities in public areas. In the context of microgrids, franchise rights substantially limit the ability of third-party providers to realize larger-scale projects that may potentially be more economical. Third-party providers may see significant litigation costs if forced to go to court.
2. **Threat of Being Subject to Public Utility Regulation**: Any entity that sells energy or power and whose equipment crosses a public street is defined as an electric corporation that therefore falls under the traditional utility regulation and ratemaking authority of the public utility commission, which governs billing, rates and quality of service. The prospect of being treated as a traditional utility shifts additional burdens onto third-party providers, making it more difficult to achieve economic viability.
3. **Lack of Microgrid Financing Models and Performance Metrics**:
   - High upfront costs constrain third-party interest in microgrids: Most existing projects are financed by end users, requiring complex, lengthy financing horizons that are most common among public institutions or government entities. Microgrid contracts are designed to combine long-term energy savings, vendor guarantees, and multi-vendor requirements into a single contract.
   - Lack of performance metrics: Streamlined documentation of microgrid benefits is required to build business cases and financing models, but metrics to quantify the value of reliability and investment deferral have not yet been developed and applied to a larger and more broadly representative customer base. High project-to-project customization of system configuration, generation types and financing structures makes it difficult to generalize cost metrics across installed microgrids.

Necessary Customization Across 8 Development Phases Slows Market Growth

Uncertainties surrounding the duration and outcome of microgrid deployments have slowed the growth of the market. The chief reason for lengthy microgrid implementation timelines is the iterative development style that is common in the space. The following figure outlines the many iterations that can occur during microgrid development. While many developers mentioned streamlining their products into a more modular system, all recognized that the nature of microgrids will continue to make them custom for years to come. Of the 181 advanced microgrids, 25 have had at least one expansion (defined as a change to the microgrid two or more years after commissioning). Microgrids that have changes within the first two years are not captured in this database.

8 Microgrid Development Phases

- Comprehensive energy audits facilitate energy-efficiency upgrades.
- Granular analysis and simulation of the power and load flows in the existing network help clarify contingencies.
- Decisions must be made about which loads to shed or maintain during an outage.
- New generation and storage are integrated with existing network assets to meet demand.
- Control algorithms and associated software/hardware are fully developed and integrated with the generation assets.
- Generation assets are adapted by adding storage, which necessitates the adaption of controls and communication networks.
- Grid-impact studies can trigger additional network architecture changes that in turn necessitate another round of systems adaption and testing.



Source: GTM Research

Note: The initial report incorrectly classified a group of 45 projects, which account for 50 MW of completed and planned capacity in 2017, as advanced instead of basic. This correction was made in December 2017 and has been applied here.

Microgrids Must Solve 4 Main Technical Challenges

1) Overcurrent Protection and Relaying

The microgrid must be able to coordinate with overcurrent protection systems to accommodate a fault or disturbance by: 1) Separating entirely (distribution event) or isolating a fault (internal microgrid event) through use of switching and relaying equipment and 2) Implementing a line-grounding strategy. As such, microgrids must have sufficient fault current to operate protective devices. In grid-connected mode, generators need to contribute to the distribution system's overcurrent protection plan while abiding by short-circuit limits and minimizing distribution disruption. Internal faults during islanded mode generally can be addressed with off-the-shelf generator-relaying equipment.

2) Safety Hazards (Backfeeds and Downed Conductors)

During a storm, a microgrid may introduce additional safety hazards, including backfeed currents, to the grid that may unexpectedly energize distribution lines and downed conductors. The risk of such hazards can be reduced through: closer synchronization between microgrid load and generation to minimize unintentional islanding and limit energizing additional equipment; increased utility control of the microgrid to enhance coordination with utility-owned equipment; and effective grounding capability that enables enhanced fault detection.

3) Synchronization

Matching the speed and frequency of the microgrid to that of the utility's distribution system is an imperative precursor to avoid unnecessary disturbances (i.e., harmonics, voltage and frequency misalignment, etc.) during the reconnection process. Effective synchronization can be achieved through: the active alignment of voltage and frequency prior to reconnection; imposing a synch check that only allows reconnection when systems are within a certain tolerance; and de-energizing the microgrid prior to reconnection.

4) Voltage and Power Control

Maintaining service (at utility interconnection) and utilization (at equipment) voltage is vital for effective microgrid operation. Both real and reactive power must be controlled to maintain voltage and frequency control. The most straightforward approach taken by microgrid developers to maintain voltage and reduce harmonics and flicker is to size generators to have sufficient voltage support capacity. Secondary options include load-shedding and fast inverter support. For voltage control, two strategies can be implemented: voltage droop and reactive power-sharing. For frequency control, strategies include speed droop, real power-sharing and isochronous control.

Source: GTM Research, NYSERDA

5. Insights Into End-Customer Characteristics

Section Overview: Understanding the Customer

The following section maps specific microgrid drivers to certain end consumers, then elaborates on customer types and provides insights into project sizing and average implementation cost (per kilowatt of generation) trends.

Takeaways:

1. There are a variety of potential end users that are likely to invest in microgrid solutions, each with different characteristics and associated adoption drivers; though cost reduction and reliability are the two primary drivers for most microgrids.
2. Ownership structures and utility relationships are often complicated. Utilities and municipals often have partial ownership (e.g., wires, generation, etc.) of city/community microgrids. They are also involved in many research-oriented pilot projects as well as military microgrids. However, in other cases, such as New York, utilities can only own distributed generation in select circumstances, such as when providing services to low-income households.
3. Storm and outage resilience and energy-cost reductions continue to be the major microgrid adoption drivers. Over the past five years, U.S. states have committed $86 million to microgrid-related technology innovation and early-stage project development (feasibility studies), and $189 million specifically to constructing microgrid projects.
4. Third-party energy services companies (including deregulated utility branches) are increasingly providing microgrids-as-a-service (MaaS) to help customers overcome high upfront capital costs. Duke Energy Renewables, Enchanted Rock (through the Texas Microgrids joint venture), Ameresco and NRG all offer MaaS in which the end customer signs a long-term agreement (e.g., custom-designed lease or PPA) and gets reduced capital costs in exchange for sharing some or all of the day-to-day value streams provided by the microgrid.
5. On an average per-kW-of-generation basis, costs range between roughly $1,100/kW for islands and $4,400/kW for city/community microgrids.

Cost Reduction and Reliability Remain the Dominant Drivers

Ranking of Microgrid Implementation Drivers by End-Customer Type

	Primary Driver	Secondary Driver	Tertiary Driver
University, R&D	Cost Reduction	High Reliability (Labs, Campus)	R&D, Emissions Reduction
Military Installation	High Reliability (Mission-Critical)	Less Risk (Supply, Security), R&D	Cost Reduction
City, Community	Reliability (Critical Infrastructure)	Energy Policy Targets	Defer Investment
Public Institution	Reliability (Public Safety)	Cost Reduction	Emissions Reduction
Commercial	Cost Reduction	Reliability (Critical Infrastructure)	Environmental Stewardship
Remote Community	Renewables Integration	Investment Deferral	Reduce Supply-Chain Risk
Island	Cost Reduction	Reduce Supply-Chain Risk	Renewables Integration

Specific customer priorities can be addressed by a wide variety of microgrid drivers, from military energy security and C&I cost-reduction efforts to supporting urban critical infrastructure such as hospitals or community centers.

Ownership structures vary and are highly dependent on state regulations as well as customer need. For example, distribution utilities in New York are barred from owning distributed generation, so all microgrids installed there are end-user or third-party owned. Meanwhile, in Illinois, Ameren built a microgrid to serve the community as a utility-owned operational asset controlled via its Network Operations Center.

Utilities and municipalities are increasingly investing in microgrids to improve the resilience of their systems during storms. Unsurprisingly, utility and municipal ownership are also often correlated with transmission and distribution investment deferral drivers. Rather than spending to increase line-hosting capacity or building new infrastructure, effective demand management through microgrids is increasingly seen as a viable option.

Military bases oscillate between end-user and joint utility-military ownership because the military wants complete control over its operations and is sometimes concerned about letting the utility have control. Wheeler Army Air Field in Hawaii, Tinker Air Force Base in Oklahoma and Robins AFB in Georgia, however, have utility-operated natural-gas-fired peaker plants located on base. When operating in islanded mode, these plants provide their respective bases with energy security during a grid outage.

Traditionally, Microgrids Were Owned by End Users or Utilities

End User: The majority of end-user-owned microgrids are driven by stacking value propositions, almost always inclusive of added onsite reliability. Large customers, such as the military, university campuses or data centers, are increasingly willing to pay for a higher degree of energy security. This ownership class is simply defined to be a behind-the-meter project (often interconnected to the low-voltage grid) that is entirely owned and operated by the end customer. Examples include many universities (e.g., the 26 MW Princeton University Microgrid), military bases (e.g., Fort Hood’s 30 MW deployment), and commercial properties (e.g., Stone Edge Farm Estate Vineyards’ Sonoma Microgrid).

Utility: Owned by the regulated utility, microgrids that employ this ownership structure are generally operated as 1) a “non-wires alternative” solution to defer transmission and/or distribution investment (e.g., substation or line capacity upgrades) by addressing congestion, capacity constraints and/or reliability on a feeder; 2) a “public-purpose” solution to modernize existing assets and better serve underlying customers; or 3) a customer-sited solution that is partially leased to a tenant for added reliability while also providing the utility with a source of local generation and grid support. In recently deployed and prospective customer-sited utility-owned projects, the utility has generally covered project costs including design, permitting, finance, construction and O&M, while leasing the facility to the end-customer at a significantly reduced price. Each contract agreement would further define resource-dispatch rights and obligations. In regulatory regimes that permit utility-controlled DERs, the utility often holds the right to dispatch onsite generation to target local congestion and provide grid services while the end customer benefits from guaranteed onsite backup generation.

Utility-owned microgrid examples includes Duke’s McAlpine Creek Circuit and Mount Holly microgrids, PGE’s Salem Power Center, and Oncor’s Lancaster Microgrid, as well as the military’s Fort Huachuca Direct Coupling Microgrid (owned and operated by Tucson Electric Power).

A New Set of Business Models has Expanded Ownership Types

Third Party: Traditionally provided through a long-term agreement (e.g., custom-designed lease or PPA), third-party energy service companies (including deregulated utility branches) like Duke Energy Renewables, Hitachi, Enchanted Rock (through its joint venture Texas Microgrids), Ameresco and NRG are increasingly providing "microgrids-as-a-service." Such an offering can significantly reduce end-customer liabilities including capital investments and O&M costs.

Examples include the Duke Energy- and REC-owned and -operated microgrid at Schneider Electric's Boston One Campus; Cogen Power Technologies' Burrstone Energy Center (between Faxton-St. Luke's Healthcare, St. Luke's Nursing Home, and Utica College); and Gen-X Energy Development's SkyGrid Microgrid in Hawaii. Several other microgrids employ third-party ownership models but have been categorized under "mixed," as other stakeholders also hold ownership rights to the microgrid and underlying assets.

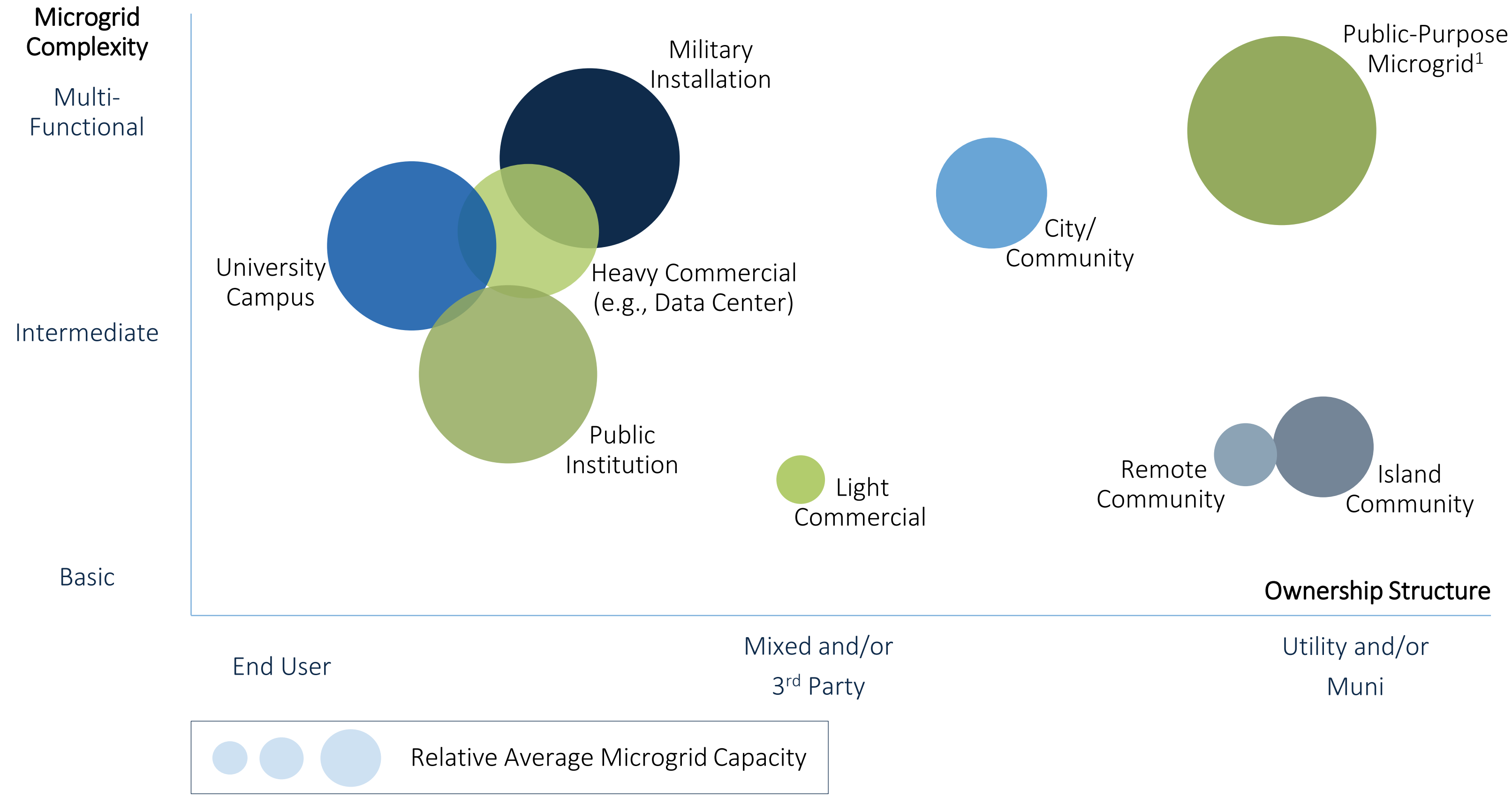
Municipality/Community: The recent wave of state-level resilience programs has spurred the development of community-type microgrids for outage and storage resilience. While projects are still competitively solicited, incentives often play a major part in the decision-making process. Municipality/community projects can range from single-site wastewater plants to multi-site critical infrastructure deployments that include several stakeholders (e.g., municipalities, regulated utilities, behind-the-meter customers, etc.). Distinguished from the "mixed" category, these projects focus on community- and/or municipality-owned critical infrastructure. Though these projects have not yet resulted in significant capacity deployment due to the relatively small size of their critical load, the next stage of state-driven programs (e.g., NYSERDA's NY Prize) are moving beyond feasibility studies toward actual project development.

Examples include many several Alaskan remote communities (e.g., Kodiak Island), municipal projects under Connecticut's DEEP program (e.g., Town of Windham), and others.

Mixed: Microgrids that host multiple owners and operators of the system and underlying assets. Mixed co-ownership examples include Bridgeport University (NRG owns fuel cell), Aligned Data Center Microgrid (with APS), MCAS-Yuma (with APS), Woodbridge (United Illuminating owns fuel cell), the proposed NJ TransitGrid microgrid, and SDG&E's Borrego Springs microgrid expansion (to include NRG's 26 MW solar generation facility and expanded to incorporate all 2,800 metered customers in Borrego Springs).

Ownership Structure and Microgrid Complexity Vary Depending on Project Needs

Generalized Ownership and Characteristics by Microgrid Complexity



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

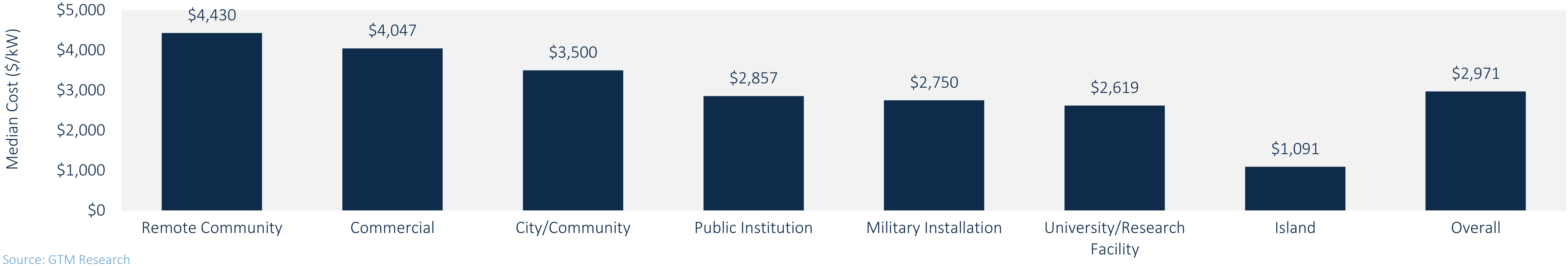
This graphic provides a high-level comparison of end-consumer trends related to deployed microgrid technology complexity and ownership structures.

- Light commercial microgrid adoption has traditionally focused on basic tech and simple ownership structures. Recent interest in providing "microgrids-as-a-service" from key players like Duke Energy Renewables and Enchanted Rock (through its joint venture Texas Microgrids) suggest third-party ownership models through umbrella PPA financing solutions are becoming increasingly attractive.
- At potential microgrid sites with large generation facilities (often fast-ramping natural gas), the military is increasingly turning to co-ownership agreements with utility partners such as HECO, Georgia Power and APS.
- City community microgrids have many ownership structures based on whether the microgrid includes multiple buildings with different owners, only city buildings, etc.

[1] Refers to utility-owned and -operated developments focused on grid modernization and infrastructure upgrades similar to those proposed by ComEd under HB3328/SB1879

Average Project Costs Vary Between $1,100/kW and $4,400/kW for Advanced Microgrids

Comparing Median Microgrid Cost ($/kW) by End User



Source: GTM Research

Microgrids differ in purpose, technology and associated costs, and therefore individual developments vary widely in terms of costs; average project costs ranged from hundreds of dollars per kW to tens of thousands.[1] GTM Research uses the median to avoid extremely large, fringe projects from skewing the average cost upward. Some other factors that may skew results that are not accounted for:

- Focusing on critical infrastructure projects that generally have high associated costs (e.g., Connecticut DEEP projects)
- Leveraging existing assets (generation, wires, communication/intelligence systems, etc.) reduces the average cost per kW
- Integration of additional DER adds system complexity and with it the average cost per kW
- Basic microgrids that have high generation capacities but require low infrastructure and control investments

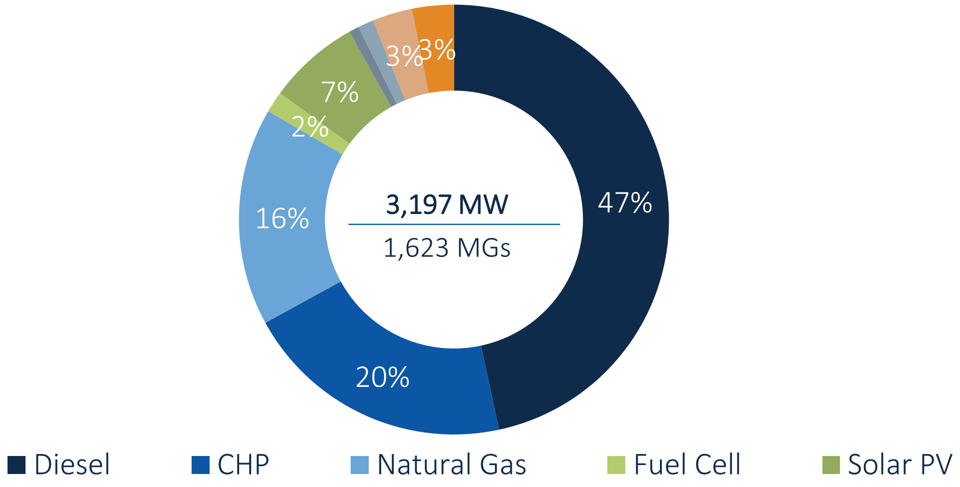
GTM Research gets costs from public data; as a result, these projects tend to be more complex and thus we expect these costs to be more consistent with advanced microgrids that are integrating multiple DER types.

[1] Comparisons include costs associated with project development, siting, permitting, engineering, and purchase of generation and distribution network assets, as well as completed and planned projects for which cost data was available.

6. Resource Mix of the U.S. Microgrid Market

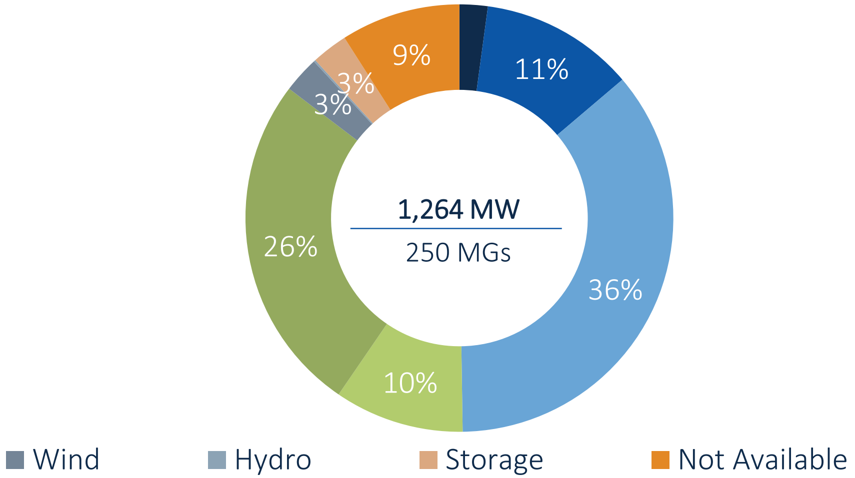
As of Q3 2017, U.S. Operational Microgrid Capacity is 3.2 GW Across 1,623 Deployments

Known U.S. Microgrid Operational Capacity by DER, Q3 2017



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

Announced U.S. Microgrid Planned Capacity by DER, Q3 2017

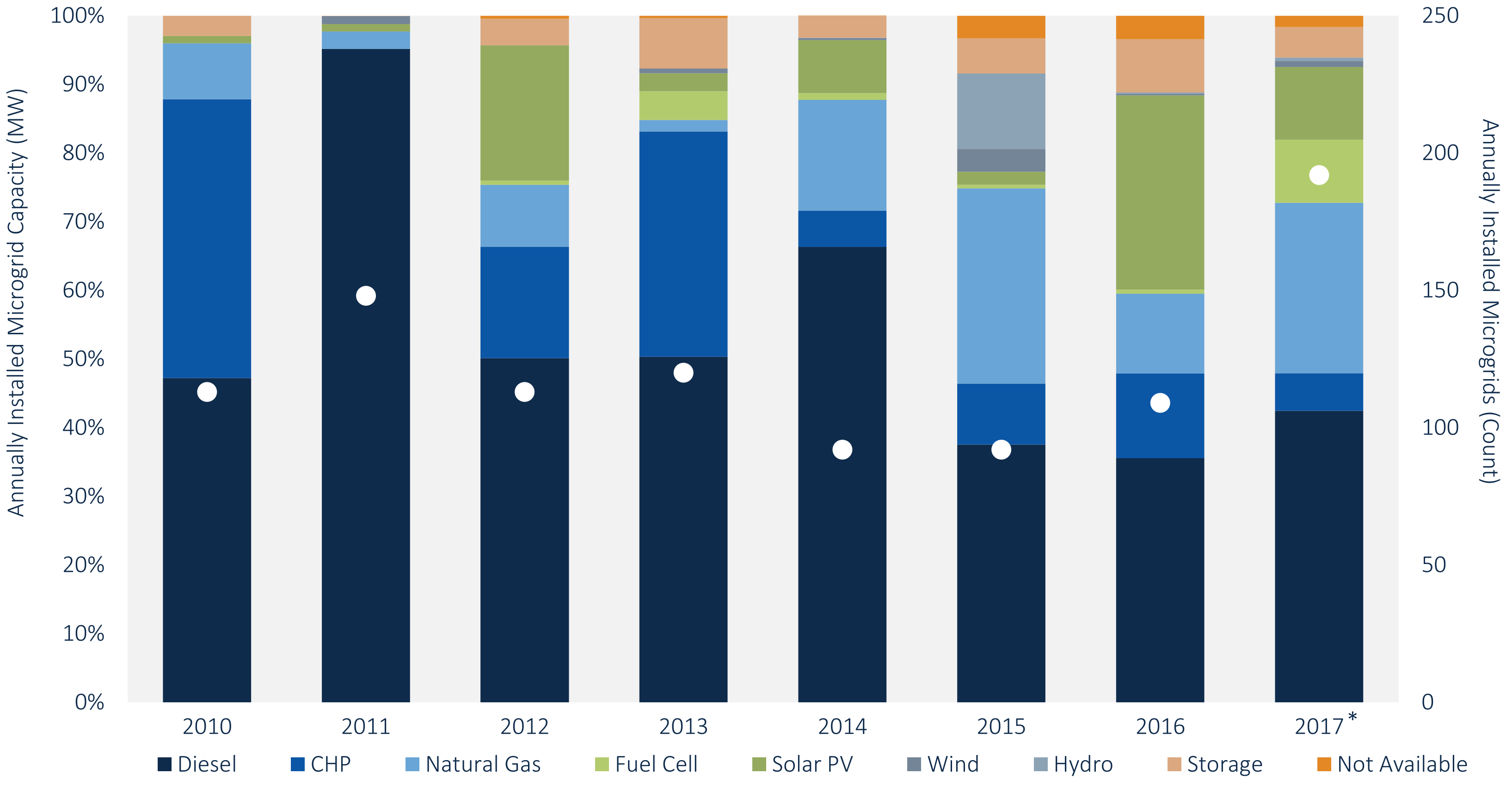


Source: GTM Research, U.S. Microgrid Tracker Q3 2017

The current microgrid capacity mix, largely driven by fuel-based generation, is expected increasingly to turn to renewable sources that do not require fuel transport. The known pipeline of planned microgrid generation capacity continues to favor a more diverse resource portfolio, though fossil fuels continue to make up over 50 percent of planned deployments. While there is little diesel in the known pipeline, GTM Research continues to expect diesel to play a large role in microgrids; often brownfield diesel systems will not be listed in initial microgrid program announcements. Additionally, the lead time for basic diesel-only microgrids is shorter, which may make advance announcements of projects less likely.

Fuel-Based Generation Continues to Dominate Installed Microgrid Capacity

Annually Commissioned Microgrid Capacity by Resource Type



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

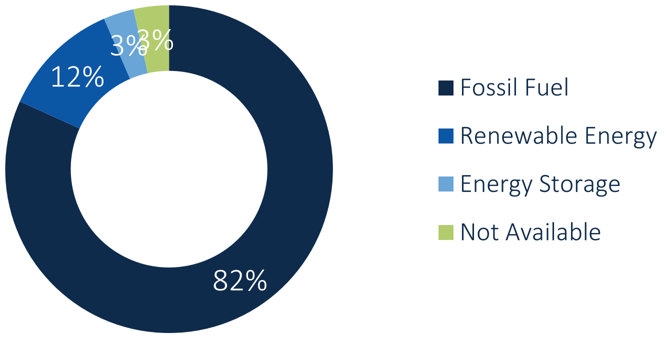
* 2017 includes projects planned for completion

Renewables (solar PV, wind, biogas and hydro) represent 12% of known capacity, but they have followed an arbitrary deployment trajectory with minimal annual growth consistency since 2012.

While 2016 saw a large increase in solar deployments in microgrids, 2017 has not followed suit, with the majority of installations being for basic diesel-only or natural-gas-only microgrids. For example, APS installed a 63 MW diesel-fueled microgrid installed at a data center in Arizona, which provides grid services to APS the majority of the time, but can island during grid outages to provide backup power to the data center.

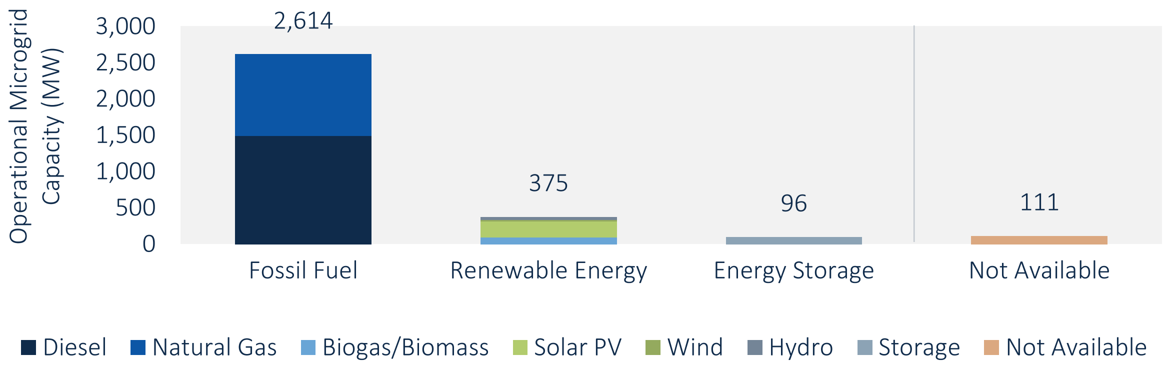
Diesel and Natural Gas Are the Fuel Sources of Choice for Microgrids

Operational Microgrid Capacity by Fuel Type



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

Operational Microgrid Capacity by Fuel and DER Type



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

Eighty-two percent of installed capacity is driven by fossil fuels; of this, about 60% is diesel and 40% natural gas. Given that many state grant microgrid programs encourage renewable deployments and that solar and storage costs continue to decline, GTM Research expects renewables to continue to rise in microgrid deployment.

Renewable energy accounts for 12% of the total energy deployed, of which a quarter is from biogas, biomass and biodiesel systems incorporated in fuel-based DERs. Energy storage accounts for 3% of overall capacity; this is forecasted to rise as energy storage becomes less expensive in coming years

GTM Research expects diesel and natural-gas generators to continue to remain the energy source of choice. However, renewables will continue to increase in complex microgrids aiming for fuel diversity; California's most recent microgrid proposal only provides funding to renewables-based microgrids. CHP is expected to continue to rise in the Northeast, where it is commonly included in community microgrid feasibility studies.

7. Regional Analysis of the U.S. Microgrid Market

Section Overview: Regional Analysis of the U.S. Microgrid Market

GTM Research has identified 1,623 currently operational U.S. microgrids, with a total generation capacity of 3,197 MW, concentrated in state hotspots such as Florida, Texas, New York and California. This section presents market insights by segmenting the regional markets by end-consumer type, generation resources and energy storage technology.

Takeaways:

1. The Southeast has the largest installed capacity (1,074 MW) and number of projects (1,226 microgrids); the majority of Southeast microgrids are basic, diesel or natural-gas-only microgrids. When examining advanced microgrids only, the Northeast has the most capacity and projects; the region is driven by state incentives targeting enhanced community reliability at critical infrastructure.
2. Excluding Alaska and the West Coast, regional microgrid generation capacity is dominated by conventional-fuel-driven generation, with diesel generators being the biggest in the Southeast and Southwest and CHP leading in the Northeast.
3. Due to the West Coast's favorable incentive programs, supportive regulatory environment and progressive utilities, almost half the region's capacity is renewables and energy storage.
4. Alaska has historically deployed wind-diesel microgrids to meet the growing electricity demand of remote communities. As state policy increasingly favors non-conventional generation and as energy storage price points decline, fast-reacting storage technologies such as flywheels have become attractive. In September 2017, the Department of Energy released $6.2 million to enhance Alaskan distribution grid resilience and will likely include increased renewable integration with diesel-fueled grids.
5. The top five states – Florida, Texas, New York, California, Georgia – account for 49% of the total microgrid capacity; the top 10 states account for 74% of microgrid capacity. The state mix is different from the 2016 report in large part due to the addition of basic microgrids in the database. For example, over 95% of Florida's microgrid capacity is in diesel-only microgrids, so with the inclusion of basic microgrids, Florida became the state with the most capacity.

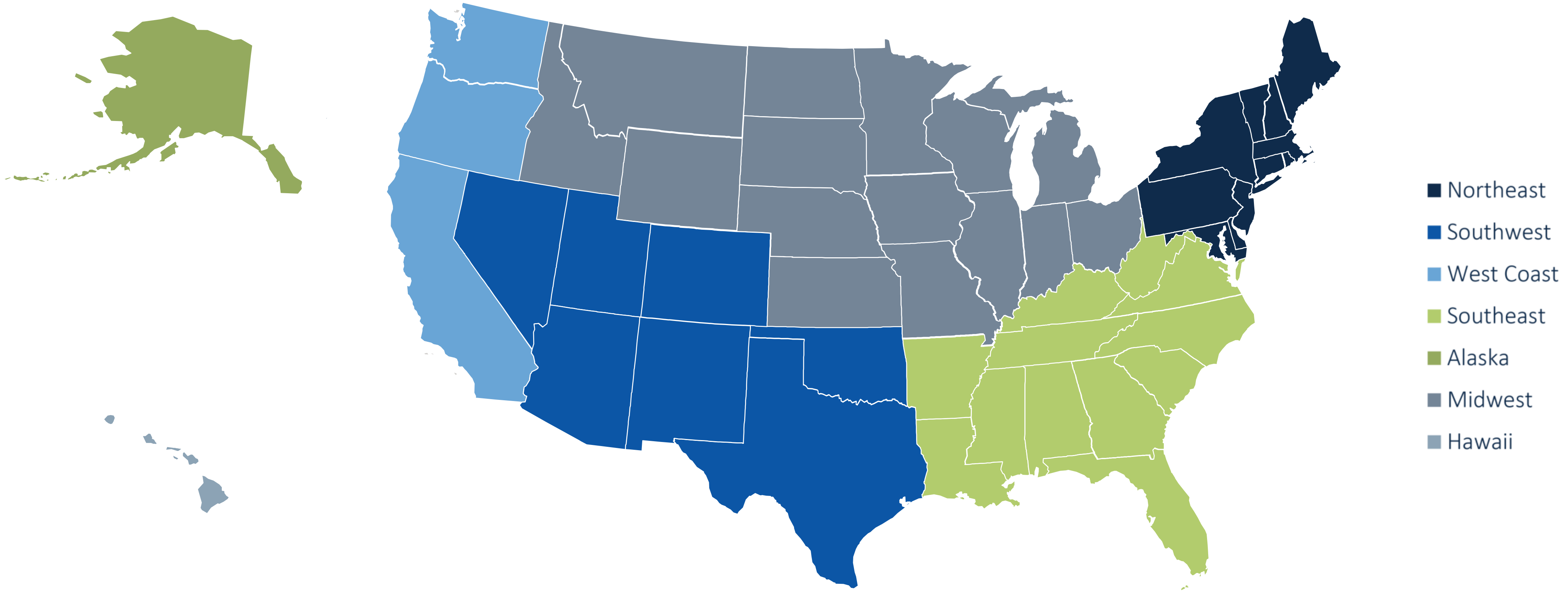
State Microgrid Ranking by Total Installed Capacity, 2016-Q3, 2017

Rank	2016	Q3, 2017	2016-2017 Δ
1	Florida	Florida	-
2	New York	Texas	+1
3	Texas	New York	-1
4	California	California	-
5	Georgia	Georgia	-
6	Oklahoma	North Carolina	+3
7	Maryland	Oklahoma	-1
8	Alaska	Arizona	+3
9	North Carolina	Maryland	-2
10	Virginia	Alaska	-2

Source: GTM Research

GTM Research Breaks the U.S. Into 7 Distinct Regions

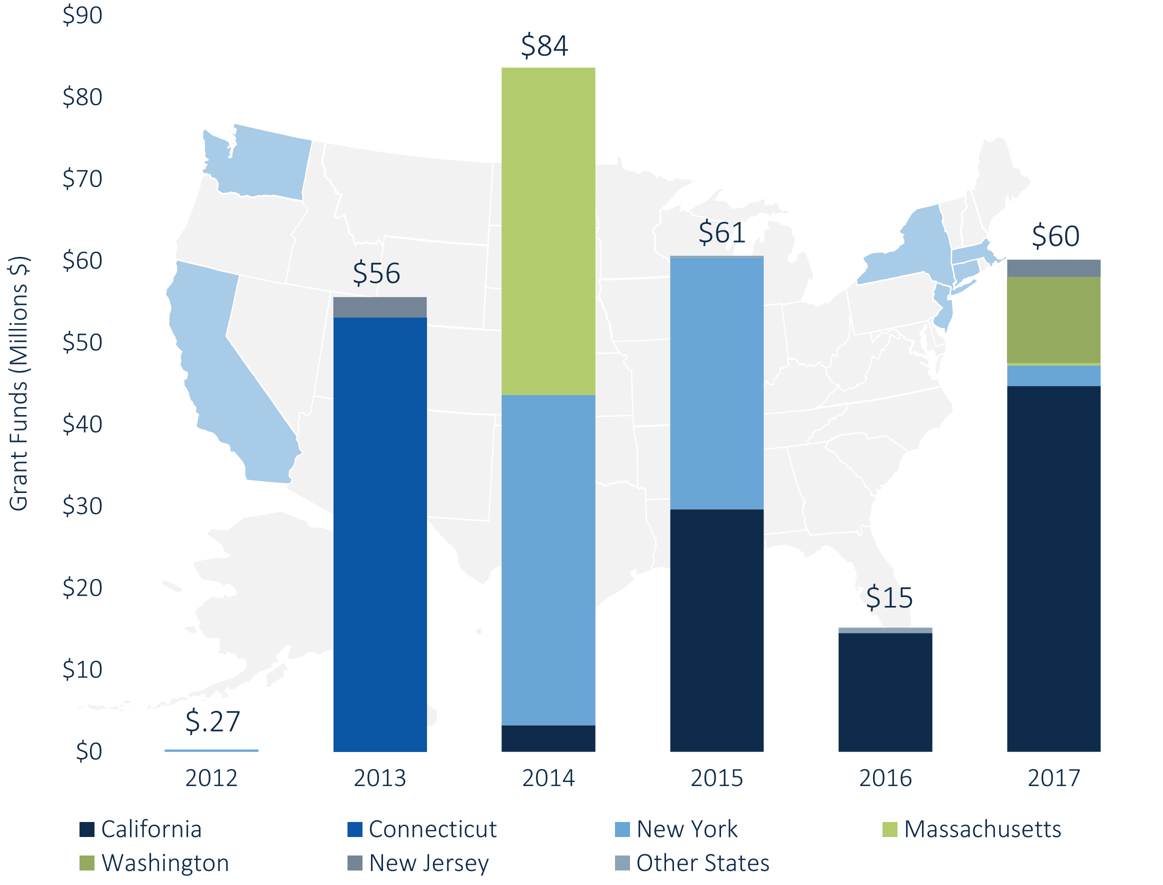
Map of U.S. Regions



Source: GTM Research

6 States Dominate Public R&D and Project Development Funding

State Funding for Microgrids, 2012-2017



Source: GTM Research

Connecticut was the first state to announce a large microgrid initiative after three large storms: Tropical Storm Irene (August 2011), Halloween nor'easter (October 2011) and Superstorm Sandy (October 2012).

A year later, in 2014, New York and Massachusetts followed suit with the NY Prize microgrid campaign and Massachusetts' Community Clean Energy Resilience Initiative.

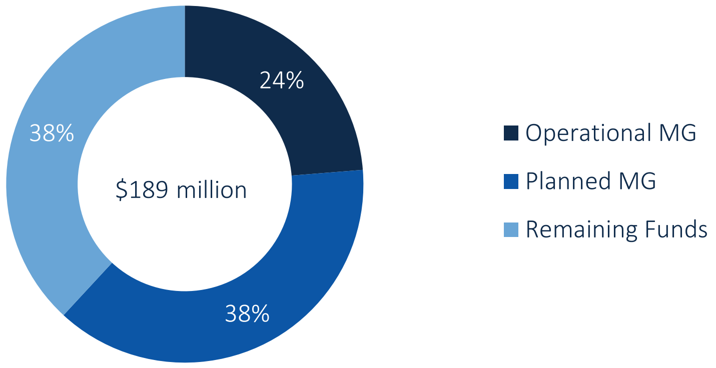
These states have continued to expand their programs and roll out community microgrids. Meanwhile, other states, including New Jersey, California and Washington, have started their own programs.

In addition to the funds captured here, New York and Connecticut both have Green Banks and New Jersey has a resilience bank, which can all fund microgrid projects through low-interest loans. These three banks fund various DERs that reduce greenhouse gas emissions and help build the clean energy market within the state; these DERs can be part of a microgrid.

Many federal funds have also contributed to microgrid development; in September 2017 the DOE announced another $50 million in grid resilience funding, of which over $12 million will go toward innovation on networked microgrids in Alaska and a project on accelerating deployment of microgrids using Open Field Message Bus (OpenFMB) interface layers.

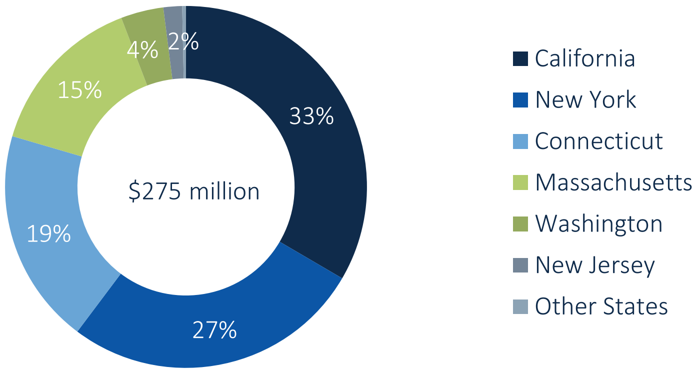
States Have Been Slow to Disperse Funds, Leaving Significant Incentives Available

Current Status of Funds to Build Microgrids Announced, 2012-2017



Source: GTM Research

Microgrid-Related Funding Announced by State, 2012-2017



Source: GTM Research

Since 2012, nearly $200 million has been announced in state funds to help build microgrids – this does not include funding just for feasibility studies or design studies. Of this $189 million, 24% (about $45 million) has resulted in the construction of microgrids from 2012 through 2017, and 38% ($72 million) is tied to planned microgrids

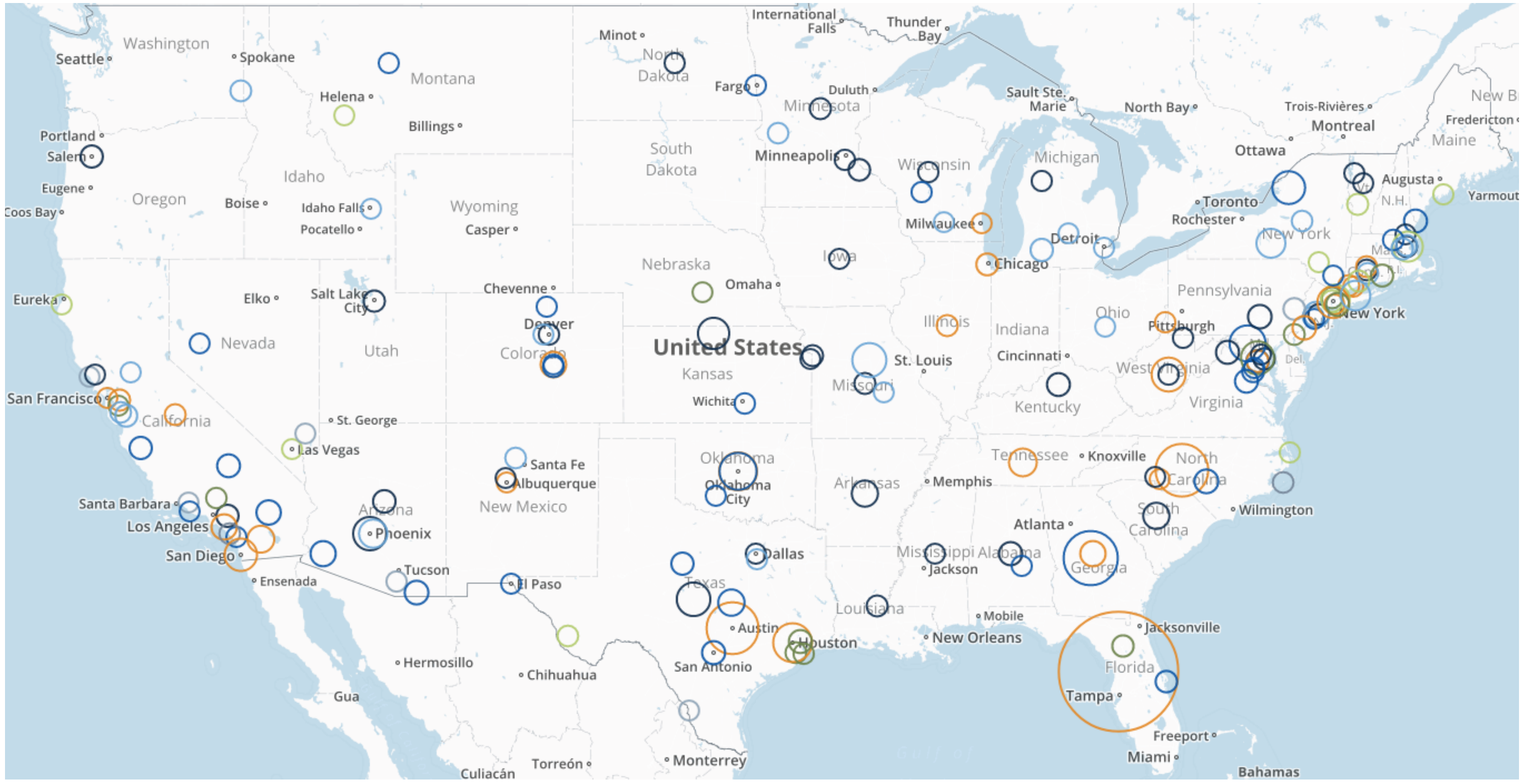
A total of $90 million is expected to be awarded next year in New York ($20 million for NY Prize microgrids), Connecticut ($26.5 million for Round 4 of Department of Energy and Environmental Protection's Microgrid Grant and Loan Program), and California ($44.7 million)

The remaining funds are for programs that are open, but have not distributed all of their funds; for example, Round 1 of Connecticut's program still has not disbursed all of its planned funds to microgrids that are complete, and at least one has been canceled. Most remaining funds have been rolled forward into subsequent rounds.

Not all funds distributed are expected to result in new capacity; an additional $86 million has been allocated to general resilience initiatives, microgrid feasibility studies that may not result in new microgrids, innovation funding for microgrid vendors, etc. Federal funding dollars are not included here.

Currently Operational Projects Total 1,623 and Counting

Map of Operational Microgrid Deployments by End-User Type Across the Continental U.S.*



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

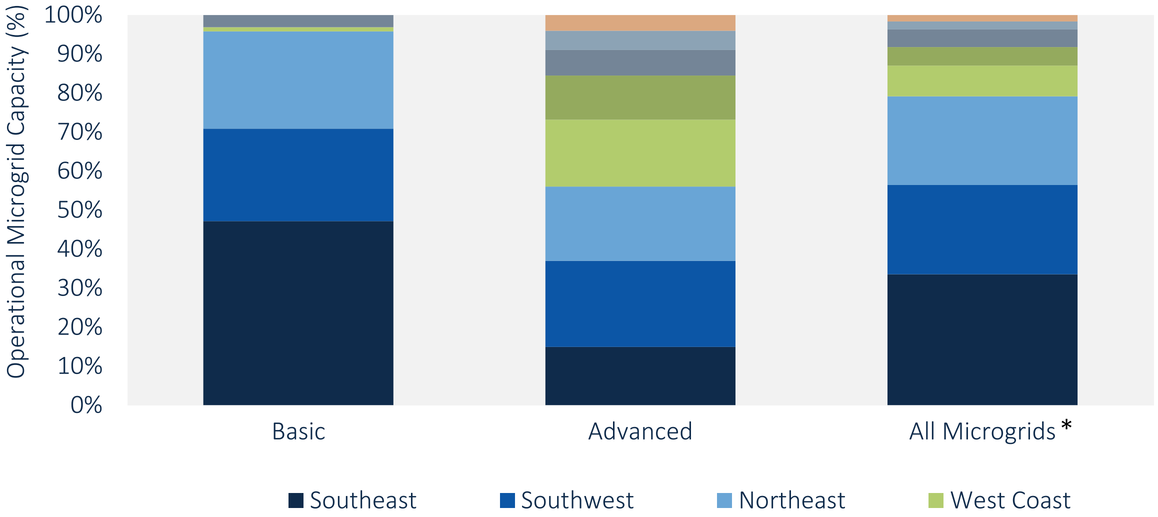
* The size of the bubbles correspond with the total capacity (MW) installed in that location.
** Microgrids are mapped based on city location; when multiple microgrids are in the same city they may get the multiple end user designation. In some cases for data privacy, data is given at a state or national level. In these cases, the microgrids are mapped at the center of the state.

- 1,623 microgrids are currently in operation, with a total generating capacity of 3,197 MW[1]
- The Southeast represents 34% of operational capacity and 76% of operational projects
- State hotspots in terms of number of projects include Florida (821), North Carolina (216) and Texas (78)

[1] Energy systems are considered to be microgrids if they meet at least the definition for basic microgrids, defined as a site with one deployed DER technology, with the ability to island for at least 24 hours, that can provide both power and energy services when in grid-connected or island mode. Given the recent increase in GTM Research's scope of the type of microgrids in this report, GTM Research does not currently cover the entire basic microgrid market.

The Southeast Leads in Operational Projects and Capacity With Basic Microgrids

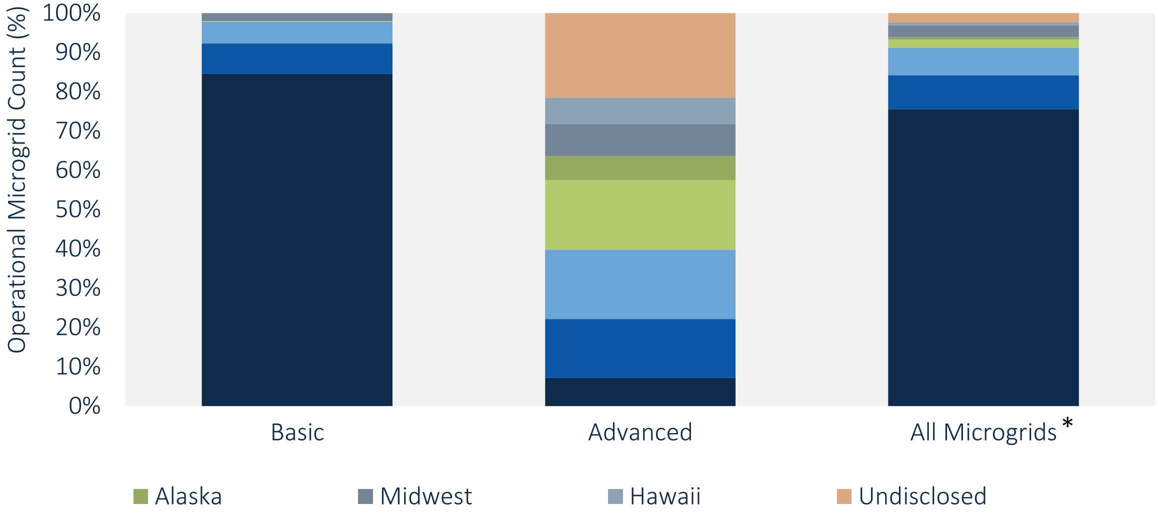
Operational Microgrid Capacity by Region and Complexity, Q3 2017 (% of Total)



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

*Includes 'Undisclosed' complexity microgrids

Operational Microgrid Count by Region and Complexity, Q3 2017 (% of Total)



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

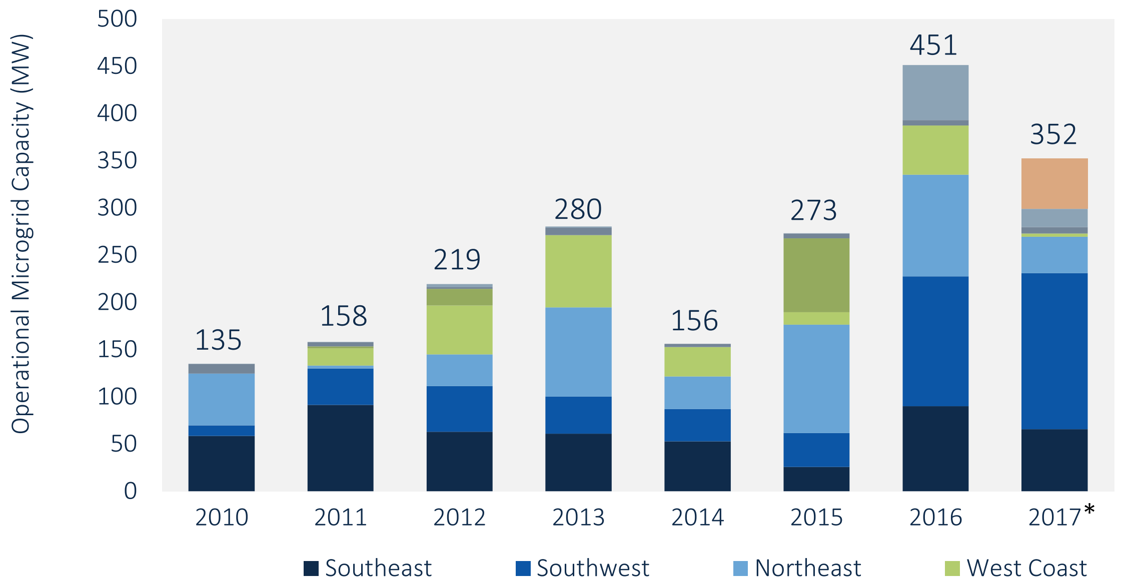
*Includes 'Undisclosed' complexity microgrids

- The Southeast leads in terms of overall projects (1,226 microgrids) and capacity (1,074 MW); however, the vast majority of microgrids in these regions are diesel- or natural-gas-only basic microgrids
- In the advanced microgrid market, the Southwest and the Northeast have the most capacity and projects
- The three top regions – the Southeast, Northeast and Southwest – all include states that have been hit by hurricanes in the past five years

Note: The initial report incorrectly classified a group of 45 projects, which account for 50 MW of completed and planned capacity in 2017, as advanced instead of basic. This correction was made in December 2017 and has been applied here.

Microgrid Installation Is Distributed Across All Regions Except the Midwest

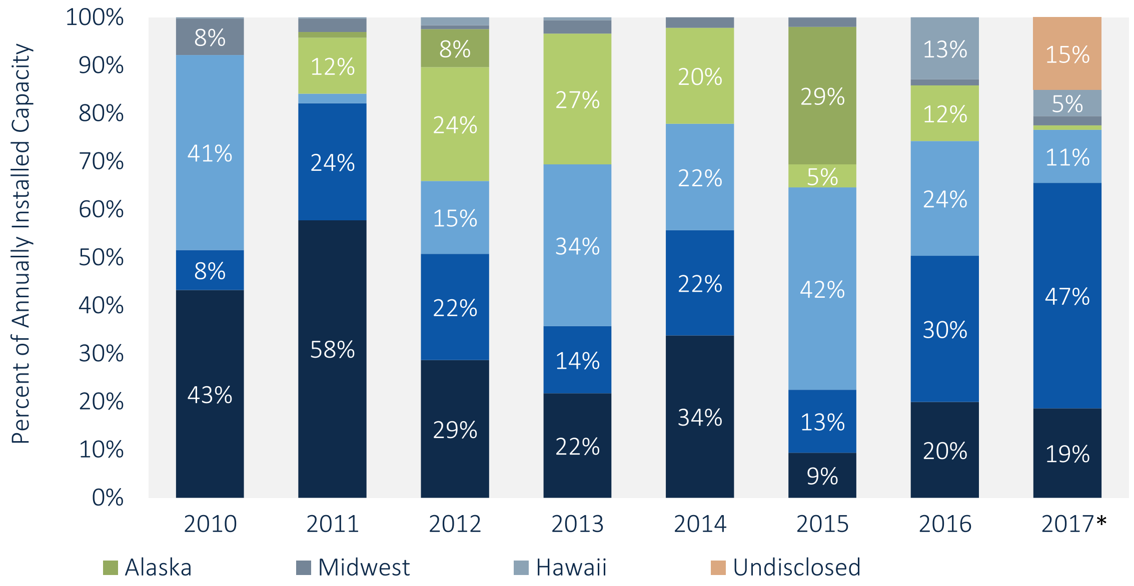
Annually Installed Microgrid Capacity by Region



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

* 2017 includes projects planned for completion

Percentage of Annually Installed Microgrid Capacity by Region



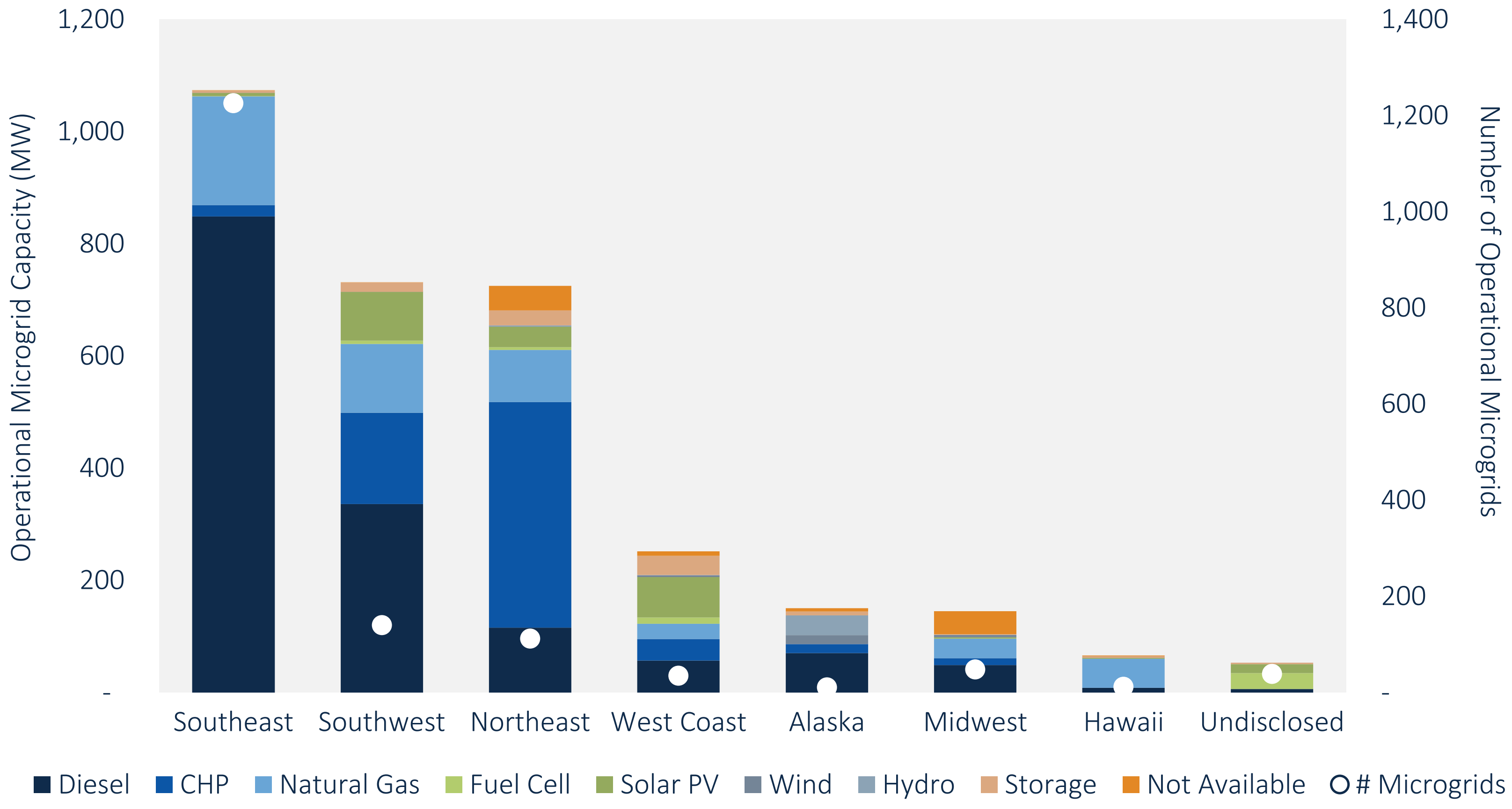
Source: GTM Research, U.S. Microgrid Tracker Q3 2017

* 2017 includes projects planned for completion

- The top three regions – Southeast, Southwest and Northeast – consistently make up over 60% of the annually installed capacity. While there is annual variability in which region has the plurality of installations, no particular region is growing more in comparison to others over time.
- Supported by a number of state microgrid and storage incentive programs, the Northeast consistently hosts new microgrid capacity year-over-year. While this year's capacity is lower, state grant programs across New York, New Jersey, Connecticut and Massachusetts are currently in feasibility, design or RFP stage and are expected to result in new microgrids in 2018 through 2020.
- The 2017 decline in Hawaii and the Northeast is largely attributable to the lack of new large military microgrid deployments in 2017. The one operational and two planned military deployments only make up a few megawatts in total, compared with over 200 MW last year.

The Northeast Drives CHP Deployments, While West Coast Focuses on Renewables

Operational Microgrid Generation Capacity by Region and Generational Type

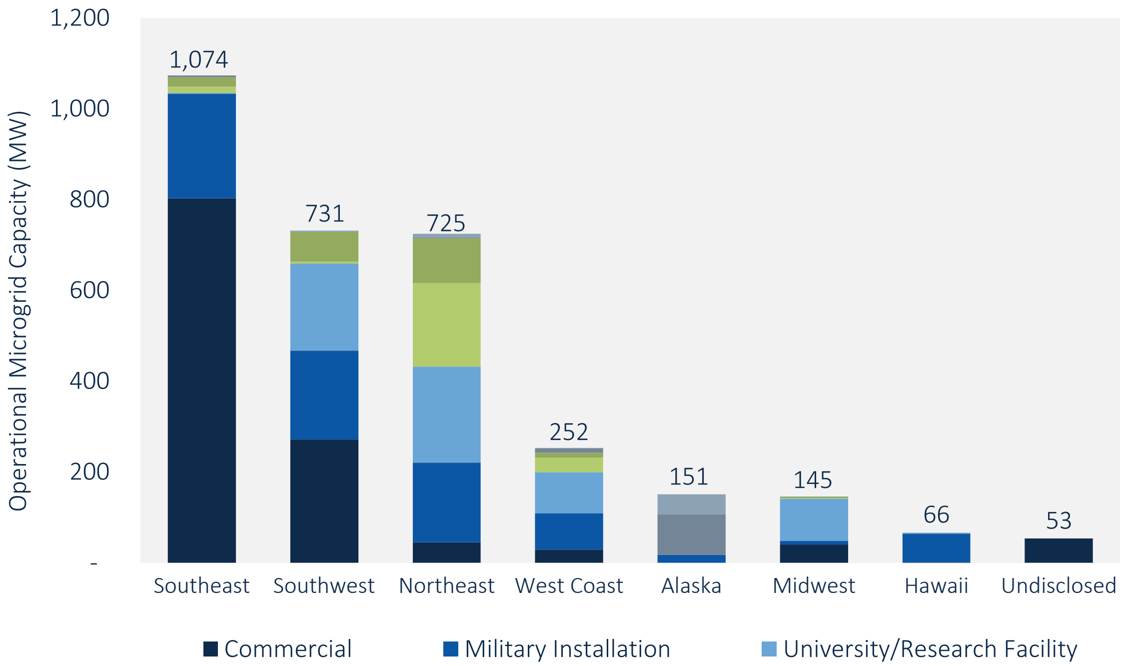


Source: GTM Research, U.S. Microgrid Tracker Q3 2017

- The Southeast and the Southwest rely primarily on fossil fuels for their microgrids, though the Southwest does have the largest overall solar capacity (87 MW).
- Highly dependent on both existing and newly deployed CHP generation, the Northeast represents over 62% of installed CHP capacity with 402 MW of CHP.
- The West Coast has the highest percentage of renewables deployed in microgrids (~50%) due to the West Coast’s favorable incentive programs, supportive regulatory environment, and progressive utilities.
- Alaska has the highest deployments of wind and hydro in its microgrids; renewables often get incorporated to supplement expensive diesel fuel.

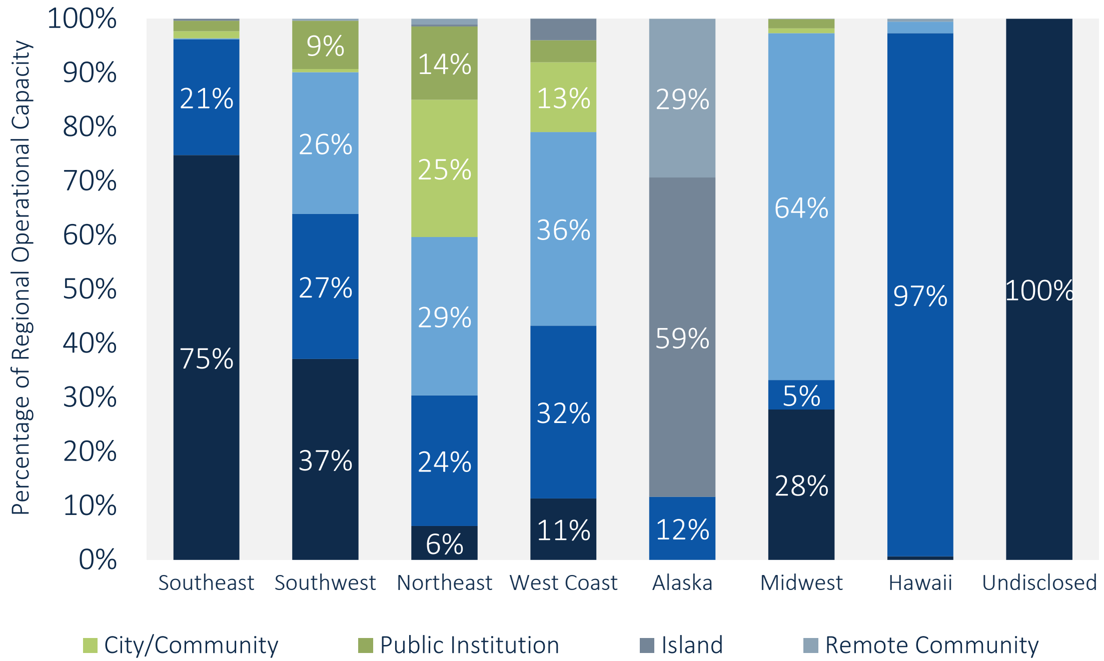
Commercial Microgrids Drive the Southeast Microgrid Market

Regional Operational Microgrid Capacity by End User



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

Percentage of Regional Operational Microgrid Capacity by End User

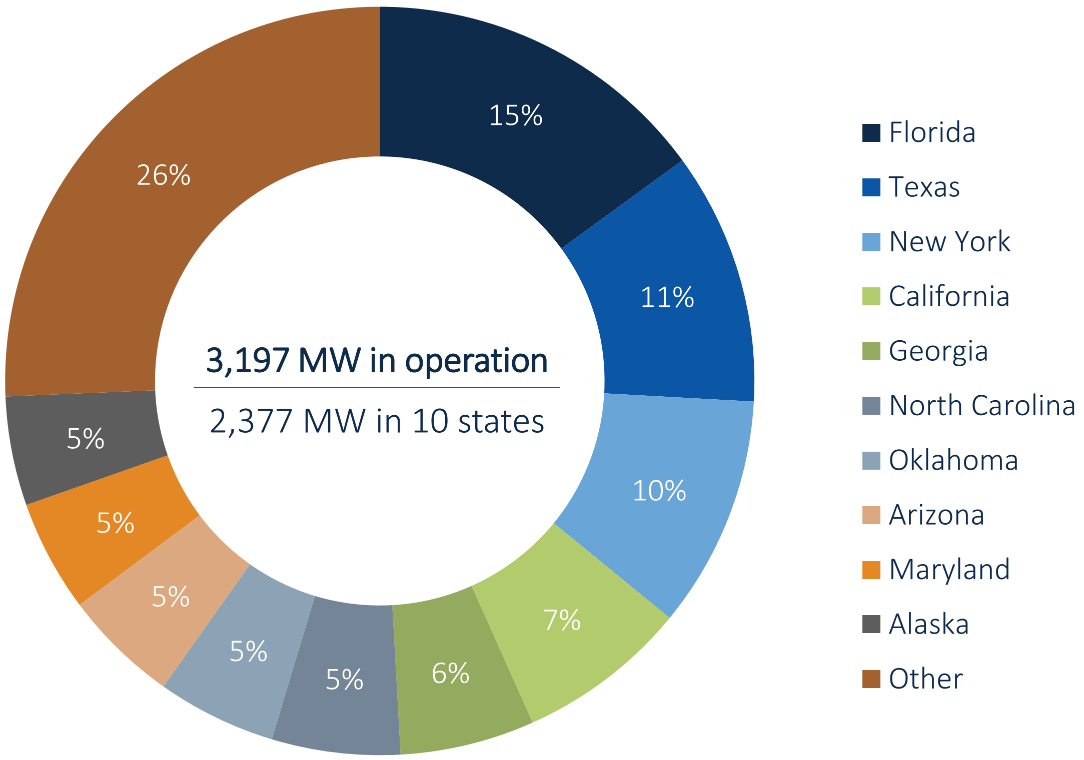


Source: GTM Research, U.S. Microgrid Tracker Q3 2017

- The Northeast, Southwest and West Coast are diversified across most end-user types. Northeast and West Coast states promote some of the most progressive advanced microgrid incentive programs, targeting community reliability, critical infrastructure, high renewable penetration and technology commercialization. Basic microgrids make up the majority of commercial microgrids in the Southeast and Southwest.
- The vast majority of Hawaii's operational microgrid capacity is military, led by the 52 MW project at Wheeler Army Air Field. Similar to several other large operational and planned military microgrids on Hawaii, HECO owns all or part (e.g., generation) of these projects, subsequently leasing them to tenants through long-term agreements (e.g., PPA).

Top 5 States Represent Almost Half of Total Capacity

Top 10 States by Microgrid Operational Capacity, Q3 2017

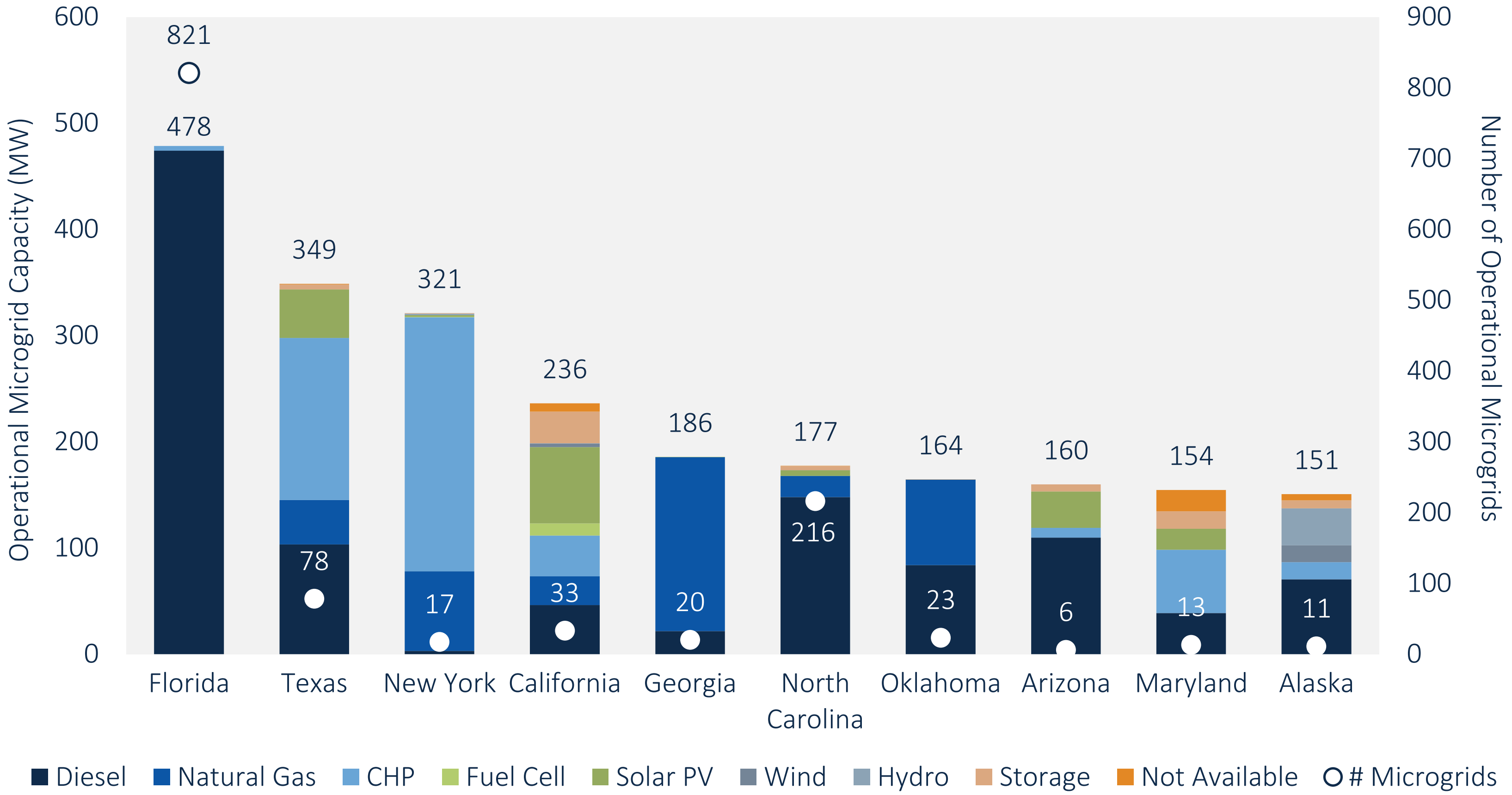


Source: GTM Research, U.S. Microgrid Tracker Q3 2017

- While the top 10 states represent 74% of overall capacity, the state mix is different from 2016 in large part due to the addition of basic microgrids to GTM's categorization framework. For example, Florida, the top state, was not in the top states last year; over 95% of Florida's microgrid capacity is in diesel-only microgrids supplied by PowerSecure.
- Texas replaced California as the second-ranked state due to increased deployment of natural gas and CHP microgrids and a new microgrid at the NASA Johnson Space Center.
- New York continues to show encouraging signs of sustained microgrid growth, further supported by a number of initiatives and trends including Reforming the Energy Vision (including NY Prize), DOE demonstration projects (e.g., Potsdam), NYSERDA CHP and solar incentives, RISE: NYC and others. NY Prize microgrids are expected to be installed in the 2018 through 2020 timeframe.
- California is expected to have increased deployments in future years given the August 2017 announcement of $44.7 million in funds for microgrids, along with aggressive renewable and energy storage targets, a successful state incentive program (EPIC), and a number of large military bases and university campuses.
- Future states with high potential include states with pipeline of projects, known utility interest in co-development or state policy initiatives, such as Hawaii or New Jersey.

Top 10 States Vary in Terms of Fuel Mix and Number of Projects

Leading States in Operational Microgrid Capacity, Segmented by Generation Source



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

- The 28 diesel-only microgrids deployed in Florida in 2017 continued a trend of basic microgrid development in a hurricane-prone region.
- New York continues to lead though it only has one new microgrid in 2017, the Marcus Garvey Apartments. NY Prize funds along with other REV initiatives are expected to increase this in future years.
- California dropped to fourth with two 2017 projects totaling 2.3 MW of generation and storage capacity. Texas overtook it with over 27 projects totaling 47 MW of capacity.
- Georgia's single 160 MW natural-gas-driven microgrid project at Robins AFB places the state fifth overall.
- Arizona's 63 MW diesel microgrid accounts for its rise into the top 10.

8. The U.S. Market by Customer Segment

Section Overview: Market Analysis Deep Dive

This section further segments the currently operational microgrid market based on the end customer's activities.

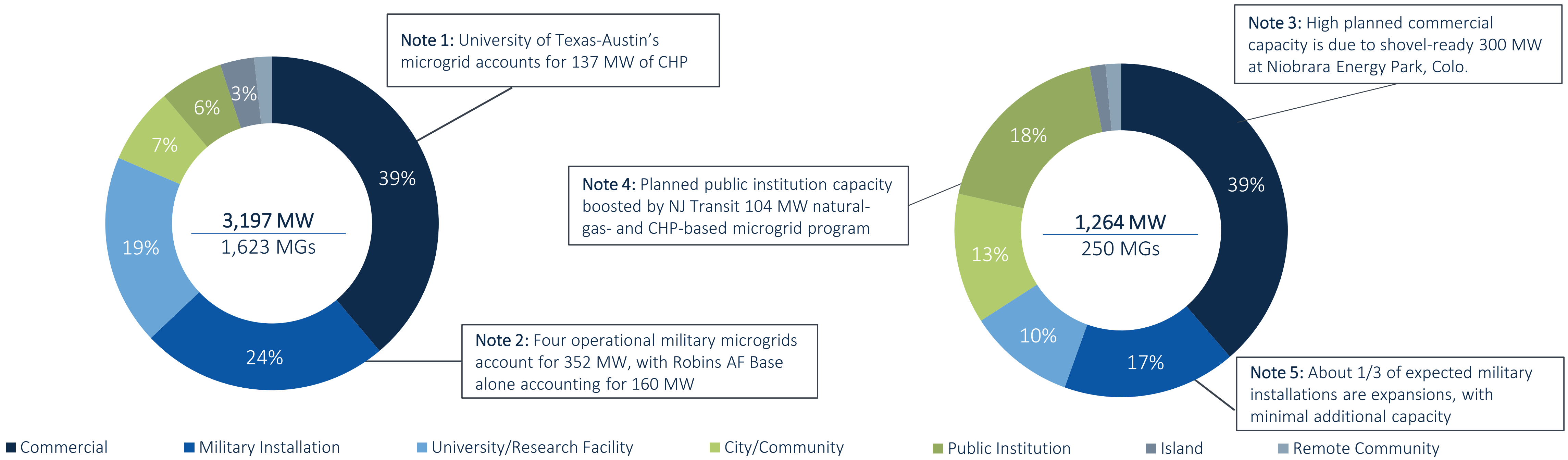
Takeaways:

1. The commercial sector has the largest capacity to date, as well as the largest pipeline; basic diesel- and natural-gas-only microgrids encompass 95% of the commercial operational microgrids. On average, commercial microgrids are smallest at 0.8 MW per project; commercial microgrids tend to have smaller systems, as C&I businesses, such as grocery stores, pharmacies and even laundromats look to be able to provide reliable power.
2. University/R&D facilities and the military continue to represent a large proportion of the market (43% combined), of which the majority are advanced microgrids. When excluding the largest microgrids (>100 MW), the university/R&D facilities represent the highest capacity per microgrid deployment (11.7 MW/project); there are two operational projects >100 MW: the military's Robin's Air Force Base in Georgia (160 MW) and University of Texas-Austin (137 MW).
3. The military has consistently deployed microgrid capacity, year-over-year, accounting for 23% of capacity deployed since 2010. The lack of large military deployments in 2017 is expected to result in a decline in new capacity compared with 2016 (99 MW lower); two of the 11 military projects deployed in 2016 made up 99 MW of capacity, 100% of the difference between the two years. So far this year, however, the university/R&D category only makes up 3% of capacity, potentially due to a purely coincidental lack of announcements to date or representative of a shift away from R&D as technology matures.
4. With the inclusion of basic microgrids, diesel has proven to be the microgrid generation source of choice, even with the 2015 EPA ruling requiring emergency demand response internal combustion engines to use cleaner fuel – ultra-low-sulfur diesel – to participate in more than 15 hours of demand response annually. Diesel is strongest in commercial microgrids, while CHP is deployed frequently in university/research facilities as well as in city/community microgrids.
5. Remote communities have historically depended on fast-ramping diesel gensets (73% of operational capacity), but recent state-level environmental policy shifts have made renewables (specifically wind) and storage increasingly attractive. In island microgrids, diesel makes up 43% of operational capacity, driven down by the increase of wind in Alaskan microgrids. These renewable resources are being added as supplemental resources, growing overall installed microgrid capacity; renewables help offset high diesel fuel costs and reduce downtime from diesel due to necessary O&M.
6. Commercial operations' mission-critical applications (e.g., data centers, emergency call centers, grocery stores) result in a greater willingness to pay for reliability and hence are considered a high-growth-potential market.

The Known Pipeline Indicates an Increase in Community and Public Microgrids

Known U.S. Microgrid Operational Capacity by End User, Q3 2017

Known (Announced) U.S. Microgrid Planned Capacity by End User, Q3 2017



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

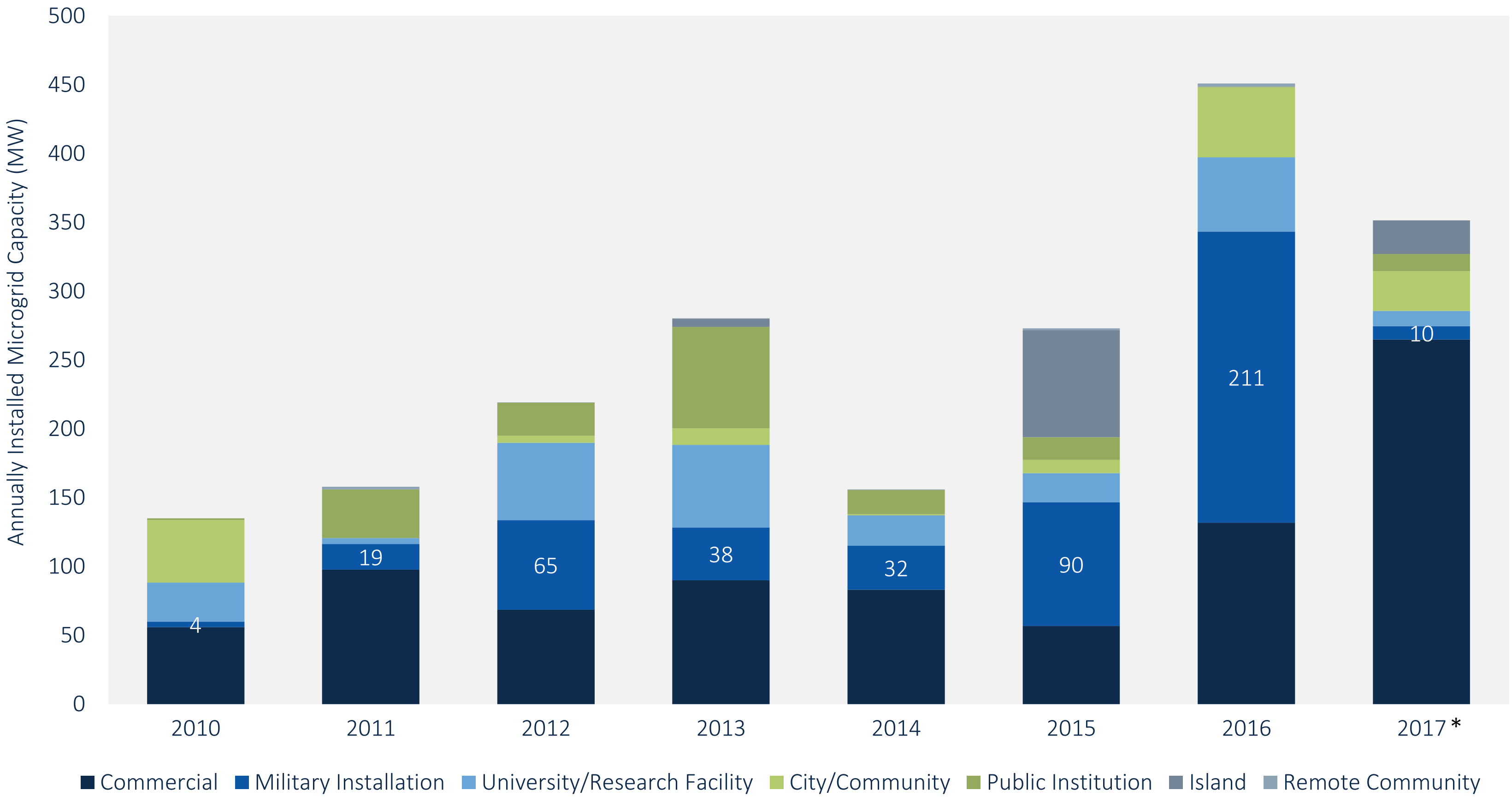
Source: GTM Research, U.S. Microgrid Tracker Q3 2017

The commercial sector has both the largest installed capacity to date and planned pipeline capacity; basic diesel and natural-gas-only microgrids encompass 95% of the commercial operational microgrids. University/R&D facilities and the military continue to represent a large proportion of the market (43% combined), of which the majority are advanced microgrids. Such institutional microgrids are often not entirely greenfield, installing microgrid components on top of existing assets, which can include wires, distributed automation devices, controls, software platforms and generation. The known project pipeline suggests an increase in city/community and public institution microgrids as local governments continue efforts to make communities more resilient to storms.

Note: The initial report incorrectly classified a group of 45 projects, which account for 50 MW of completed and planned capacity in 2017, as advanced instead of basic. This correction was made in December 2017 and has been applied here.

2017 Marked the Highest Non-Military Microgrid Deployments

Annually Commissioned Microgrid Capacity by End Customer, 2010-2017



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

* 2017 includes projects planned for completion

The military has consistently deployed microgrid capacity, accounting for 23% of capacity deployed since 2010.

The lack of large military deployments in 2017 resulted in an overall decline in new microgrid capacity compared to 2016. Military sites were nearly the majority (47%) of 2016 microgrid capacity; two of the 11 military projects deployed in 2016 made up 99 MW of capacity combined.

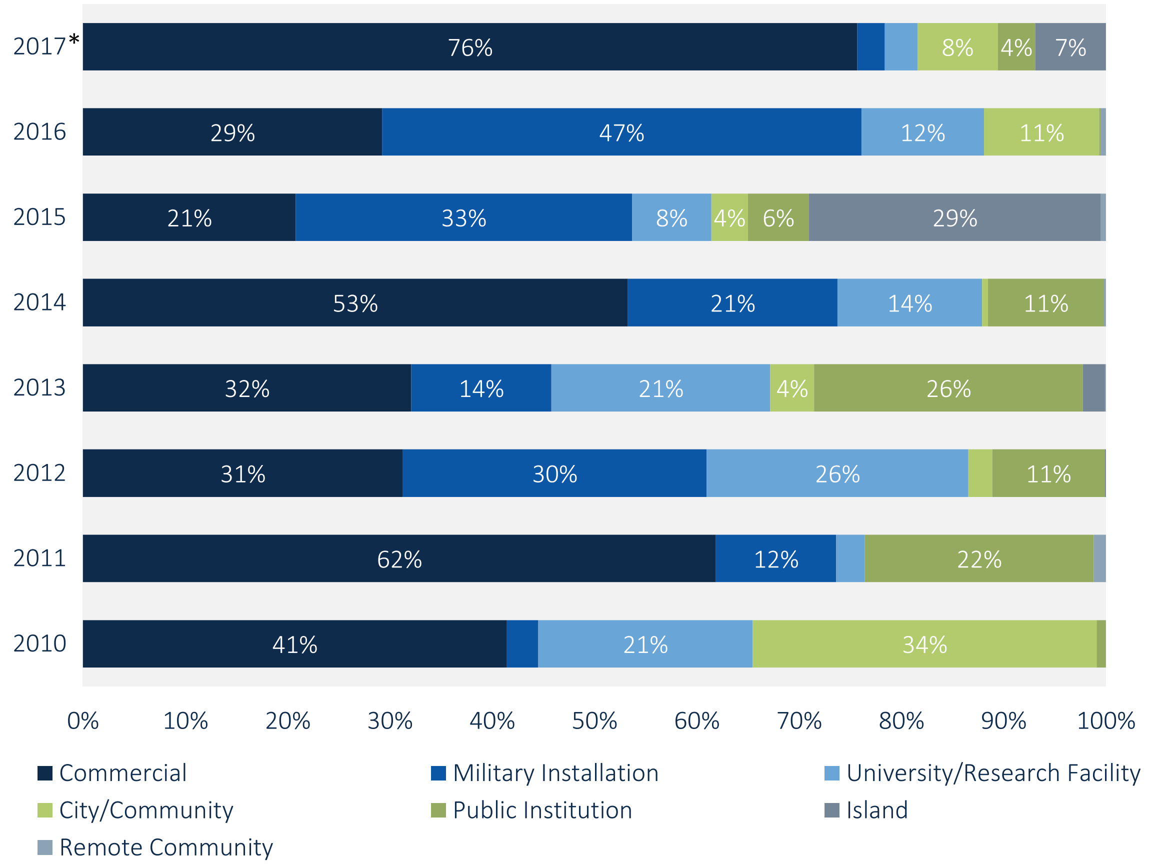
Excluding military microgrid deployments, 2017 is the most successful year with regard to the deployment of microgrid capacity to date. This indicates that microgrid-related technology is becoming more competitive in the commercial space as developers continue to refine business models and new technologies continue to decline in costs improving overall microgrid economics.

Commercial Projects Dominate Capacity and Projects in 2017

The mix of end users varies widely from year to year as large projects often skew totals in individual years.

- In 2017 commercial installations are expected to make up 76% of the total capacity deployed. Commercial projects have represented the plurality of capacity installed in six of the past eight years. The dominance of commercial projects is partially the result of successful business models for reliability of mission critical infrastructure.
  - Microgrid developers are offering a third-party-financed DER and microgrid control solution that generates value primarily through energy sales, reliability and flexibility or ancillary services. End users get access to reliability and, in some cases, reduced cost energy through PPA agreements. Investors take risks on the upside associated with ancillary services opportunities, capacity payments and, depending on the model, energy and demand charge arbitrage.
  - This model has been implemented at Arizona Public Service's microgrid at a data center (63 MW), as well as in Texas with Enchanted Rock's microgrids across grocery and convenience stores. Schneider Electric's Microgrid-as-a-Service model, which it has marketed to public institutions, is another example of offering reliability in exchange for third parties (Duke) getting other value streams. PowerSecure, the largest commercial microgrid developer to-date, has seen an increase in the percent of its commercial projects that are third-party owned from less than 10% pre-2011, to 10%-20% in 2011-2016, to 42% in 2017.

Percentage of Annually Deployed Capacity by End User, 2010-2017

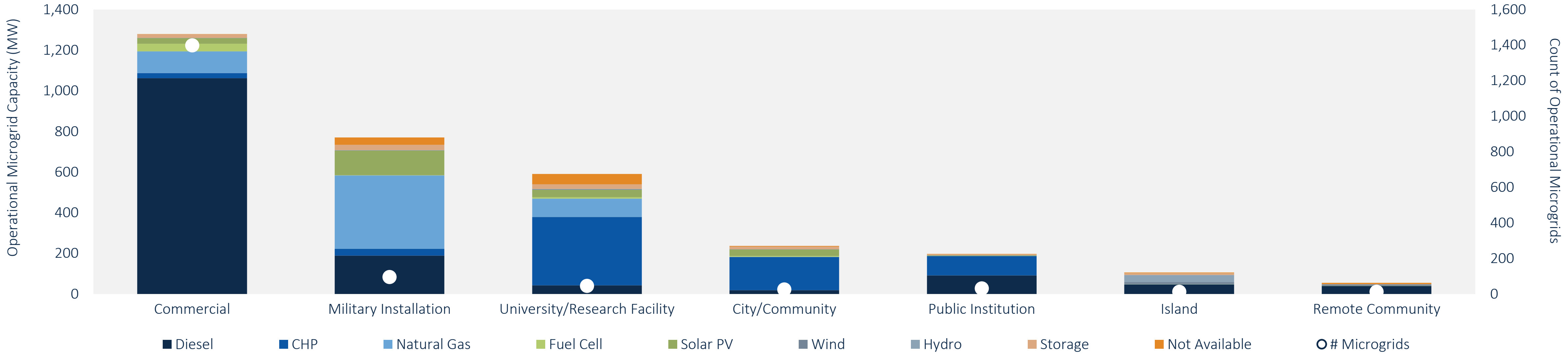


Source: GTM Research, U.S. Microgrid Tracker Q3 2017

* 2017 includes projects planned for completion

Fuel-Based Generation Provides Majority of Capacity Across All End-Customer Types

Operational Microgrid Capacity by End-User and Resource Type, Q3 2017



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

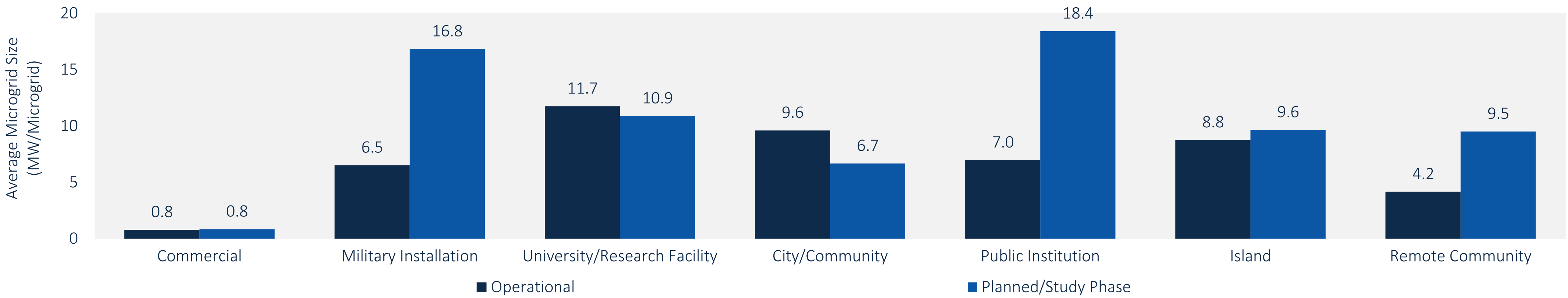
In general, fuel-based generation (CHP, natural-gas generators and diesel generators) has proven to be the microgrid generation type of choice. Diesel is strongest in commercial microgrids, while CHP is deployed frequently in university/research facilities as well as in city/community microgrids.

Solar deployments rank highest in military, university and city/community microgrids. For cities and universities, solar provides a low-carbon resource to help reach environmental goals and reduce energy costs; for the military, it helps reduce reliance on fuel supplies.

Remote communities and islands have historically depended on fast-ramping diesel gensets (57% of operational capacity), but as renewable and storage costs continue to decline, they are becoming increasingly attractive when compared to high diesel fuel and operational costs. Alaska’s small islands have driven wind and hydro deployments.

Average Microgrid Size Ranges From <1 MW for Commercial to 12 MW for Universities

Average Size by End User, Operational Versus Planned



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

Note: Large outliers (>100 MW) and microgrids with unknown capacity removed from this analysis.

- The average size of microgrids is easily skewed by large outliers; therefore, the above chart does not include microgrids greater than 100 MW or microgrids where the total capacity figure is not yet available.
- University and research facilities have the largest average operational size of 11.7 MW per microgrid; these microgrids tend to encompass several buildings and loads across campuses, encouraging a larger system size.
- The average size for military installations, even with the largest deployments removed, is expected to continue to increase as new deployments come in the following years.
- Commercial microgrids tend to be smaller, as C&I businesses, such as grocery stores, pharmacies and even laundromats look to be able to provide reliable power. The largest installed commercial microgrid currently is 63 MW and the largest currently planned (that is not over 100 MW) is 2.5 MW.
- Public institutions currently have an average size of 7.0 MW; the planned microgrid size is skewed upward by a 62 MW planned microgrid at a school in Hawaii.

9. A Rising Trend in Multi-Stakeholder Ownership

Section Overview: A Rising Trend in Multi-Stakeholder Ownership

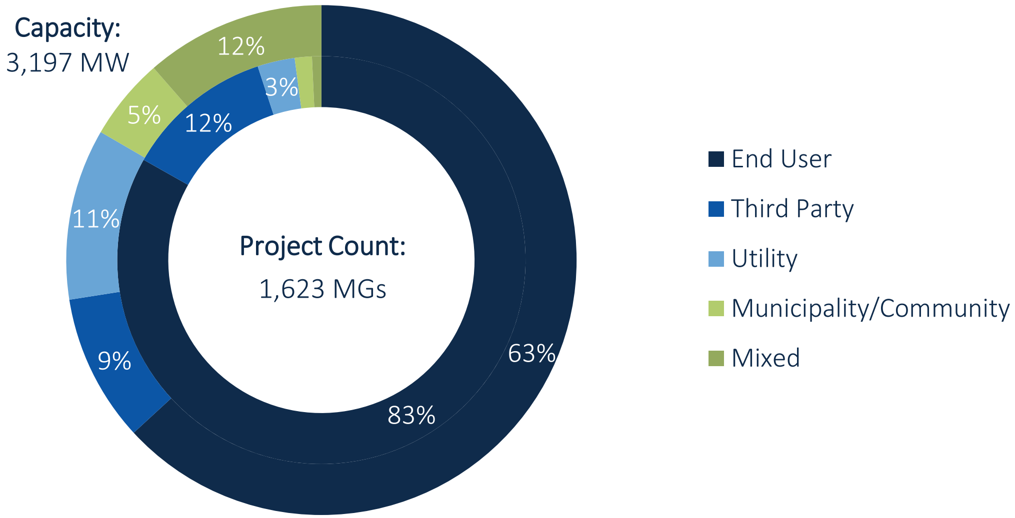
Customers are increasingly embracing alternatives to traditional end-user-owned microgrids. In 2017, for the first time going back to 2010, alternative ownership structures outpaced end-user ownership in installed capacity. However, end-user-owned microgrids remain the vast majority of projects.

Takeaways:

1. Share of end-user-owned microgrids overall is 63% of capacity and 83% of projects; end users own 85% of basic microgrids and 66% of advanced microgrids.
2. There has been an uptick in the past two years in third-party- and mixed-ownership projects as microgrid value streams for grid services become more reliable (see slide 65 for description of this business model).
3. Despite their traditional lack of involvement, there has been a recent surge in regulated utility interest in co-developing microgrids as a “non-wires” alternative to defer capital infrastructure investments. Simultaneously, major developers and ESCOs continue to increase investment and involvement in the development, ownership and operation of microgrids. Utilities tend to own projects with fast-ramping resources such as natural gas and storage.
4. Market data by capacity as well as project count shows an emergence of new business models with different ownership structures. Third-party- and mixed-ownership models often finance microgrids using power-purchase agreements (PPAs), microgrid-as-a-service (MaaS) and/or reliability-as-a-service (RaaS) models.
5. The emergence of alternative ownership models vary by region due in part to regional market differences, as well as different extreme weather experiences; the Southeast has more utility-owned models due in part to still having vertically integrated utilities. In the Northeast the focus on community refuge areas post-Superstorm Sandy has resulted in more community-owned microgrids.

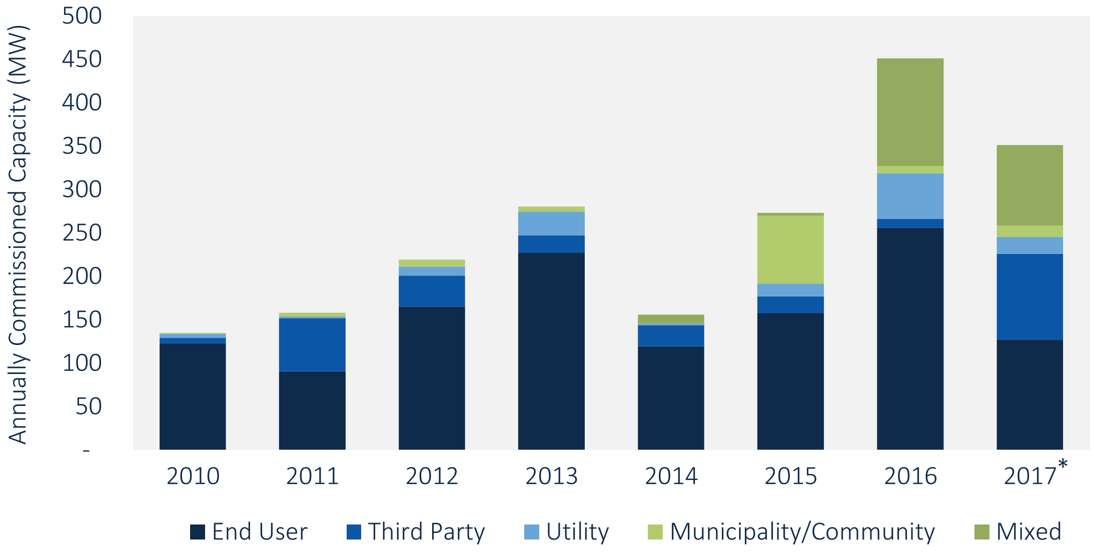
The Majority of Operational Microgrids Are Owned by End Users

Operational Microgrid Capacity and Count by Ownership



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

Annually Commissioned Microgrids Count by Ownership, 2010-2017



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

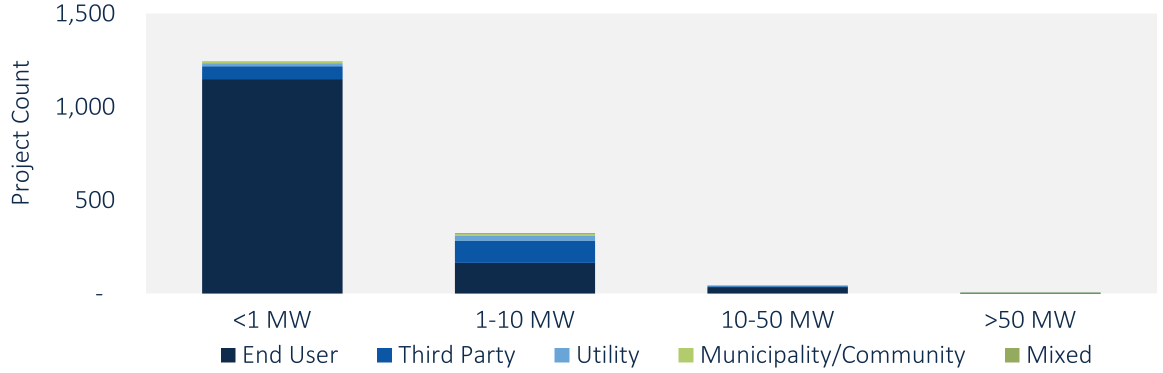
*2017 includes projects planned for completion by year's end

Given the lack of consistent business models for microgrids, it is not surprising that end-user-owned microgrids account for the majority of installed projects (83%) and capacity (63%). However, as deployments move beyond early-stage pilots and new business models gain popularity, a more diverse landscape is emerging.

- The recent uptick in municipality and community-owned microgrids is consistent with the rise of state-supported community microgrid grants in Connecticut, New York and elsewhere; while municipal interest in microgrids to support critical infrastructure will continue to grow, funding for community microgrids will remain dependent on local political climates.
- Historically, regulated utilities have piloted technologies at single sites and R&D facilities. Utilities, whether as the sole owner or part of a multi-stakeholder consortium, increasingly look to leverage microgrids as a "non-wires alternative" to T&D investments that address localized congestion, line capacity constraints, feeder-specific voltage and frequency challenges and renewable targets. There are currently three NWA microgrids. For example, RG&E's recently issued RFP calls for developers to propose solutions that provide distribution system load relief at its Station 43 substation.

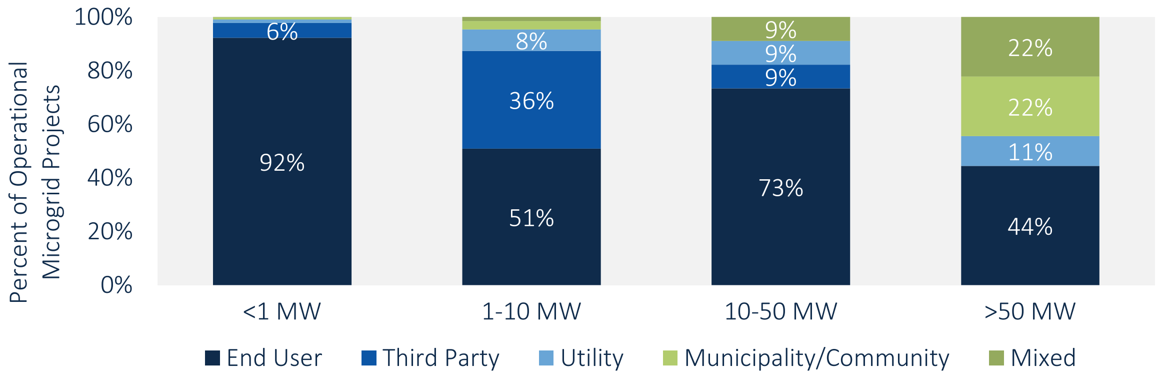
Mixed Ownership Focus on the >10 MW Microgrid Segment

Operational Microgrid Projects by Capacity Range and Ownership Structure



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

Operational Microgrid Projects by Capacity Range and Ownership Structure

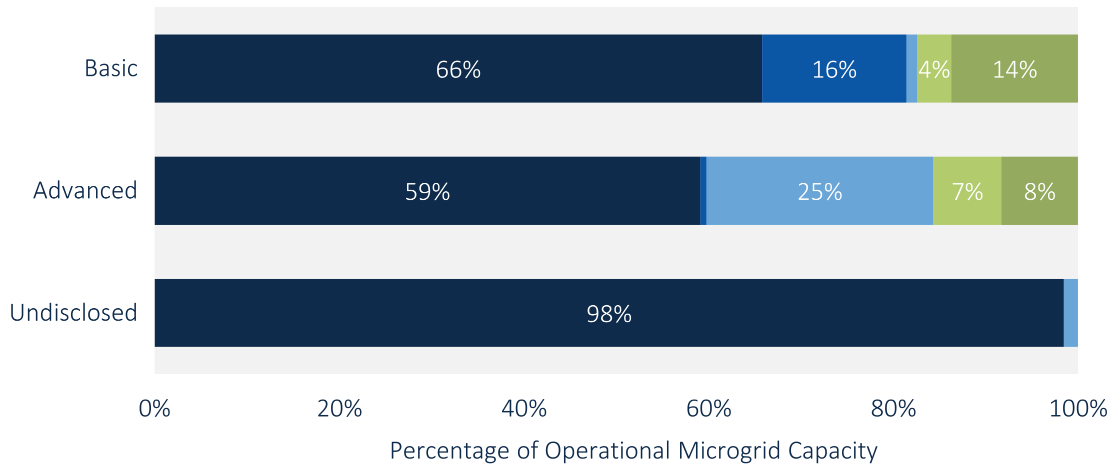


Source: GTM Research, U.S. Microgrid Tracker Q3 2017

- End users own the plurality of systems in all size levels, but in the very large projects (>50 MW), mixed ownership and municipality ownership have the highest shares after end users, with 22% ownership each.
- Third-party ownership has the highest percentage after end users in the 1-10 MW market (36%). TPO is helping end users defer investment in the microgrid, while gaining resilience from it. In most of these cases the other value streams are going to the third-party investor, including energy price and demand charge arbitrage as well as ancillary services. Third parties range from unregulated arms of utilities, to special purpose entities, such as Texas Microgrid LLC, created to invest in and own Enchanted Rock's projects.

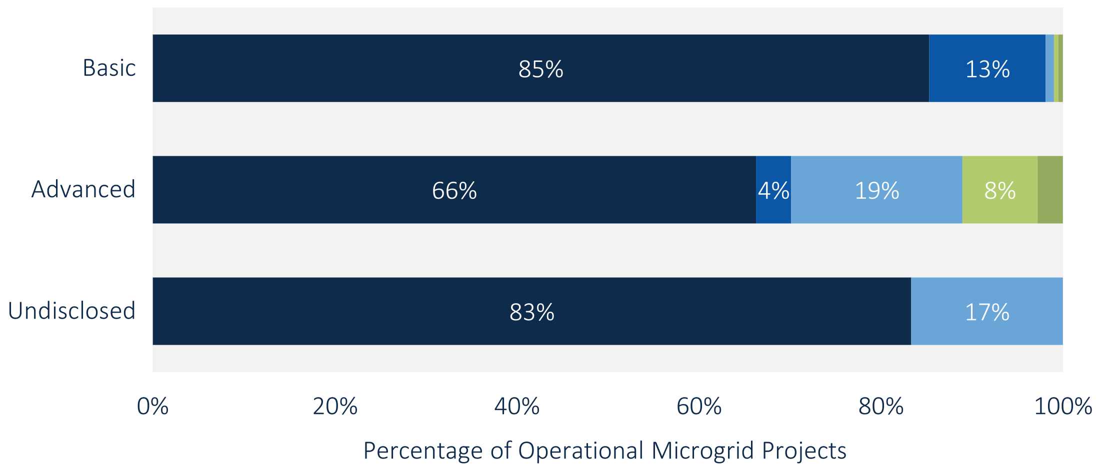
End Users Own Majority of Basic and Advanced Microgrids

Operational Microgrid Capacity by Microgrid Complexity and Ownership



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

Operational Microgrid Count by Microgrid Complexity and Ownership



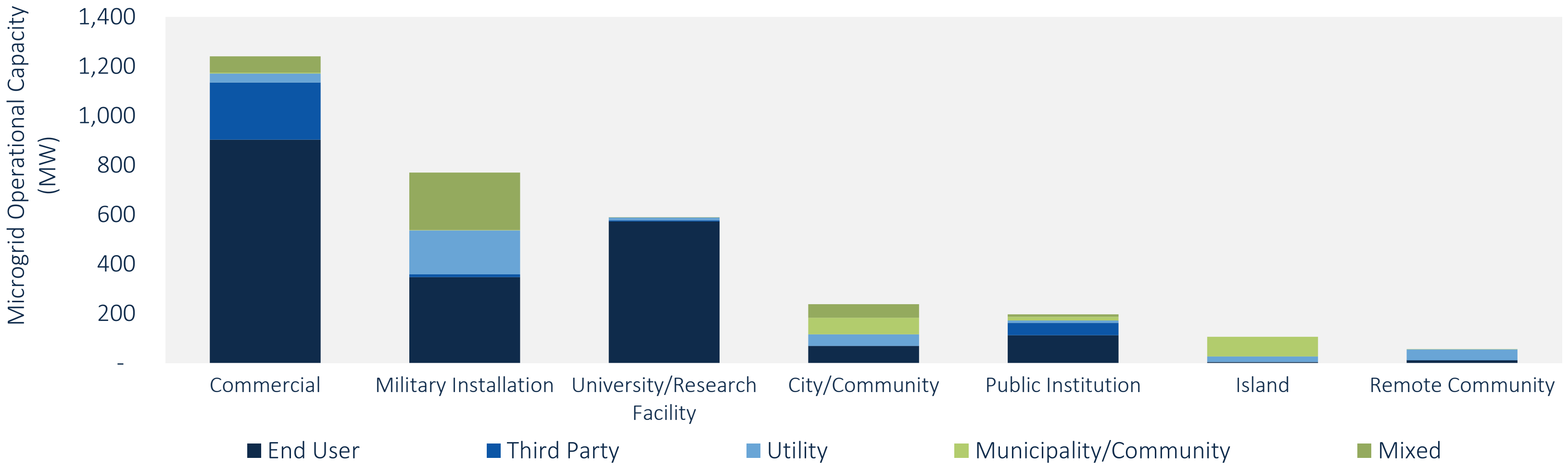
Source: GTM Research, U.S. Microgrid Tracker Q3 2017

End users own 85% of basic projects (66% of capacity) and 66% of advanced projects (59% of capacity); end users that own these larger, more complex projects are mostly large institutions with vested interest in owning, such as the military, or large corporate or university campuses where they have the upfront capital to make the investments. Basic microgrids that have third-party, municipality or mixed ownership are on average larger than end-user-owned projects. Utility-owned microgrids make up the second-highest proportion of advanced microgrids in terms of capacity (25%) and projects (19%); utilities tend to incorporate multiple technology types as they work to test microgrid structures and supply fuel diversity for increased resilience. Municipality and community-owned microgrids are more prevalent in the advanced market, which aligns with the increased complexity of community microgrids serving multiple stakeholders and often trying to incorporate renewables as part of local government sustainability plans.

Note: The initial report incorrectly classified a group of 45 projects, which account for 50 MW of completed and planned capacity in 2017, as advanced instead of basic. This correction was made in December 2017 and has been applied here.

More Diverse Ownership Models Are Emerging Across Microgrid Markets

Operational Microgrid Capacity by Ownership Structure and End-User Type, Q3 2017



Microgrid Owner	Commercial	Military Installation	University/Research Facility	City/Community	Public Institution	Island	Remote Community
End User	904 MW (1,201)*	347 MW (85)	573 MW (36)	69 MW (8)	112 MW (11)	4 MW (3)	10 MW (6)
Third Party	231 MW (176)	11 MW (2)	5 MW (3)	2 MW (1)	50 MW (8)	-	<1 MW (1)
Utility	38 MW (16)	178 MW (3)	11 MW (6)	44 MW (8)	11 MW (5)	21 MW (6)	44 MW (4)
Municipal	3 MW (3)	2 MW (1)	-	67 MW (5)	15 MW (7)	79 MW (4)	1 MW (2)
Mixed	66 MW (2)	232 MW (4)	1 MW (1)	55 MW (4)	10 MW (1)	-	-

Source: GTM Research, U.S. Microgrid Tracker Q3 2017

*Numbers in parentheses represent the number of microgrid projects

End users own the majority of commercial microgrids, but third party ownership plays an increasingly important role as investors become more confident in the value streams available to microgrids.

End users are the primary owners for university, military and public institutional microgrids. These institutions have been implementing microgrids for a longer period of time, driven by requirements for reliability and having larger endowments to invest. The military has more recently started partnering with utilities and third parties for more diverse ownership models.

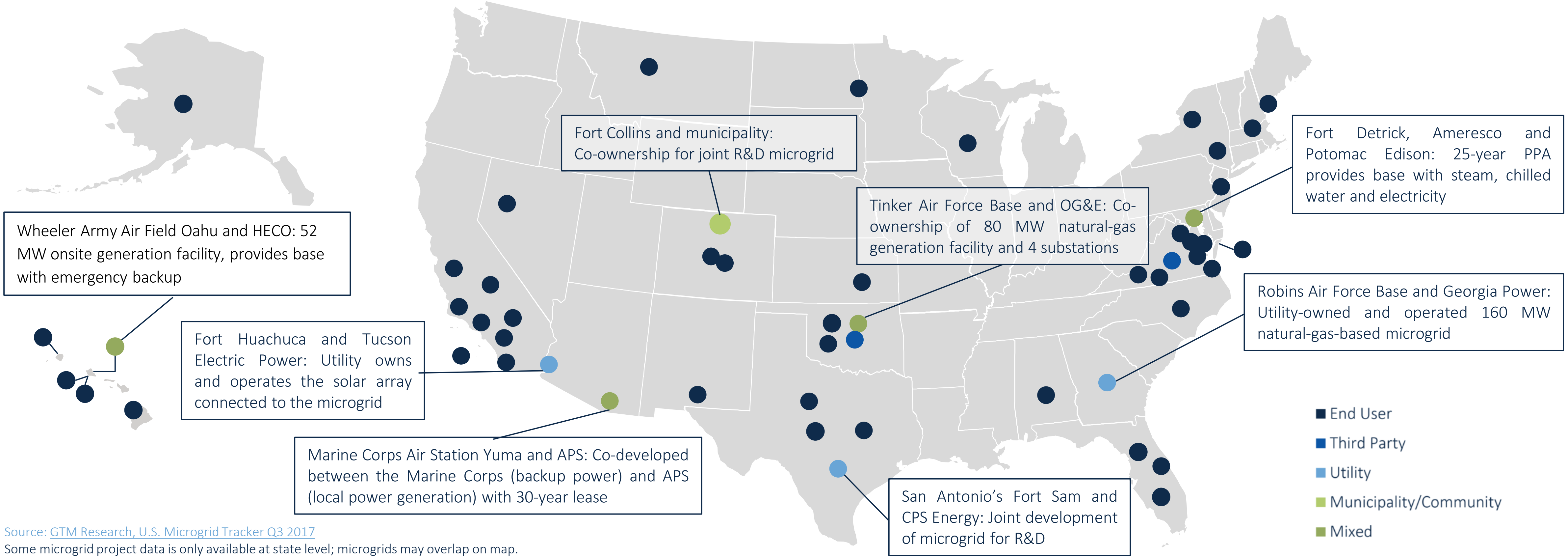
Island and remote community microgrids are largely driven and owned by the local municipalities and utilities, respectively. As non-wires alternatives continue to be an attractive method to defer investments in transmission and distribution, GTM Research expects utilities to drive creation of microgrids in remote communities.

Community microgrids have shown diverse ownership structures as the market develops. In these microgrids, the city or local utility is generally one of the owners, but there are mixed ownership models, as many of these microgrids involve multiple stakeholders.

This Utility and Military Partnership Is Playing Out Across the United States

Primarily driven to enhance energy security and cost efficiency, the military continues to aggressively target both renewable and microgrid deployments across its facility portfolio. Of the 95 currently operational military microgrids, eight have utility partnerships where the utility owns and operates at least part of the microgrid, two are entirely third-party owned, and the remaining 88 are end-user owned and operated. Four of these joint projects were installed in 2016 as military bases look at new and innovative ways of financing these projects. While 2017 had few installations, there are 21 projects totaling over 213 MW of deployment in the pipeline.

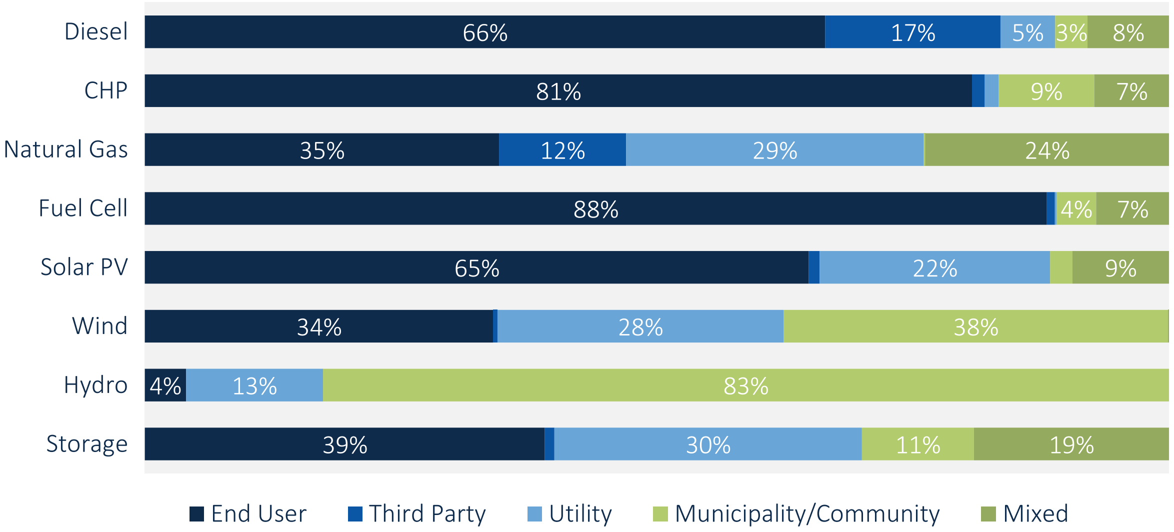
Map of Operational U.S. Military Microgrids by Owner



Source: GTM Research, U.S. Microgrid Tracker Q3 2017
Some microgrid project data is only available at state level; microgrids may overlap on map.

Fast-Ramping Natural Gas and Storage Have More Diverse Ownership Structures

Percentage of Operational Microgrid Capacity by Resource Type and Ownership Structure*



(MW)	Diesel	CHP	Natural Gas	Fuel Cell	Solar PV	Wind	Hydro	Storage
End User	990.5	526.4	194.1	45.0	143.3	8.3	1.5	37.6
Third Party	255.2	8.2	69.6	0.4	2.3	0.1		0.9
Utility	79.5	8.7	163.1	0.1	49.7	6.8	5.0	28.9
Muni/ Community	47.5	60.9	0.9	2.0	4.8	9.1	30.9	10.5
Mixed	118.4	47.5	133.6	3.6	20.8	0.0		18.3

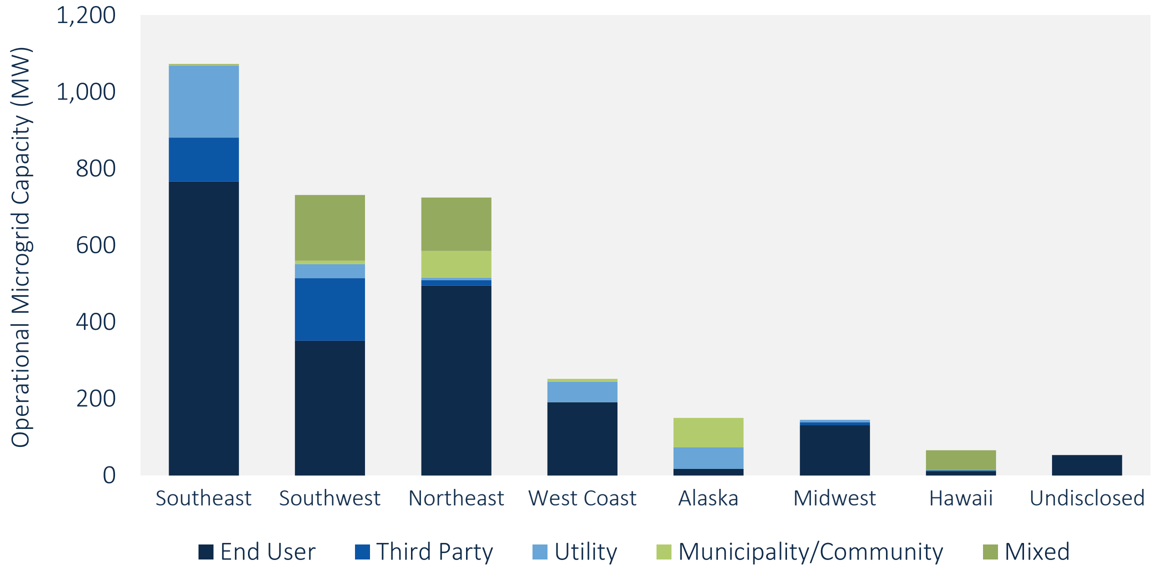
Source: GTM Research, U.S. Microgrid Tracker Q3 2017

*Sum of projects includes some those planned for completion by end of 2017; does not include 'Not Available' fuel type.

- Behind-the-meter customers favor direct ownership of fuel cells and CHP-based microgrids for heat and electricity more than other technologies. For CHP, historically, such deployments have leveraged existing onsite generators that can be very large (e.g., University of Texas' 137 MW CHP-based microgrid in Austin, the Food and Drug Administration's White Oak facility with 55 MW of CHP), skewing a capacity analysis in favor of end-user-owned categorization. A recent trend toward smaller CHP units, especially in New York and Texas, may change that trend over time.
- To address local distribution grid congestion, utilities are often more interested in fast-ramping resources, such as natural-gas gensets and various types of energy storage. Investment in clean energy may also exist in part due to local mandates on renewable procurement.
- The relatively lower capital expenditures for larger-scale deployment, coupled with the ability to provide multi-stakeholder benefits, has made natural-gas-based microgrids strong candidates for both utility- and mixed-ownership models. Examples include the 160 MW Georgia Power-owned microgrid at Robins AFB and 80 MW microgrid at Tinker Air Force Base that is owned and operated by both the military and Oklahoma Gas & Electric.
- The diverse multi-stakeholder benefits of energy storage make it an attractive investment for all stakeholders, and as such it is a more evenly distributed ownership model.

Microgrid Ownership Trends Vary by Region

Microgrid Operational Capacity by Regional Ownership Models



(MW)	Southeast	**Southwest**	Northeast	West Coast	Alaska	Midwest	Hawaii	Undisclosed
End User	766.3	351.5	495.3	191.5	17.5	131.7	11.8	53.2
Third Party	114.5	163.0	13.9			6.6	1.0	
Utility	188.1	36.4	7.1	52.8	55.6	6.7	1.0	
Muni/ Community	3.0	9.4	68.7	7.9	77.5			
Mixed	1.5	171.2	139.9				52.3	

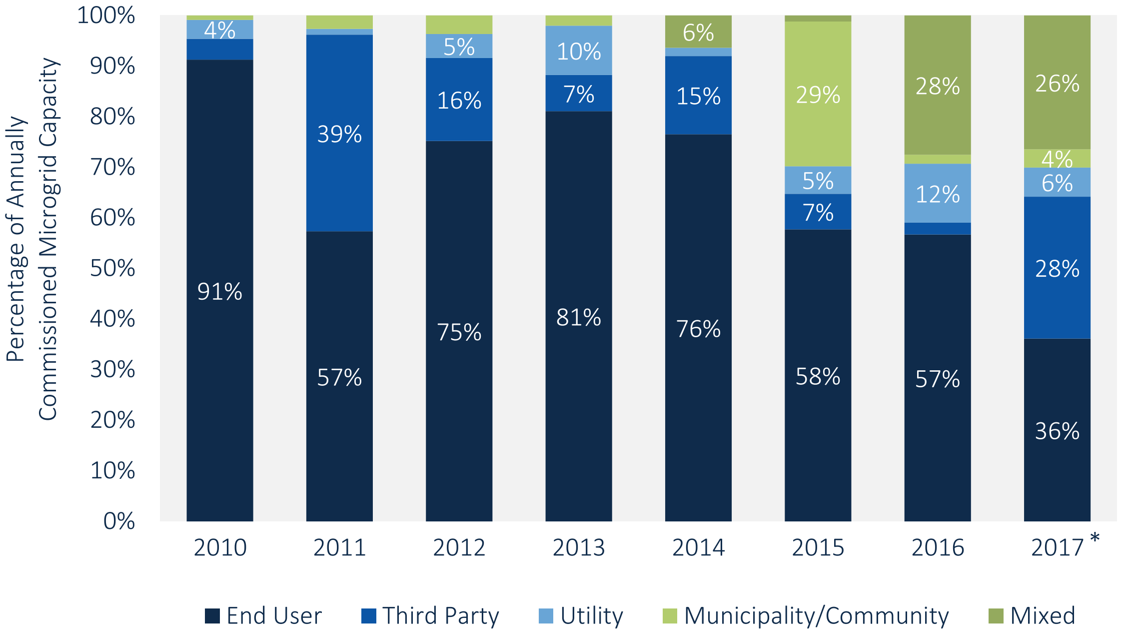
Source: GTM Research, U.S. Microgrid Tracker Q3 2017

Emerging trends when segmenting the market by regional ownership structure:

- Spurred by storm resilience efforts in the Northeast, state programs provide incentives for community microgrids that emphasize reliability at select critical infrastructure. We expect this trend to increase as microgrids from current grant programs now in process are actually built.
- The end-user-owned capacity in the Southeast is largely made up of PowerSecure microgrid systems. The high degree of utility-owned microgrid capacity in the Southeast can be attributed to large-scale projects with dispatchable generation (e.g., Robins AFB in Georgia and GRU South Energy Center in Florida).
- The Southwest is emerging as a region with multiple ownership models, which is in part due to Texas' various incentives for development in the ERCOT region.
- Remote microgrids deployed in isolated Alaskan communities are generally local municipality- or utility-owned. Additionally, out of necessity or as an alternative to tie-line capacity upgrades, remote communities often opt to expand microgrid projects in discrete phases to address growing electricity demand.
- As the Midwest is still a small microgrid market, it is mostly end-user owned, as many of the third-party incentives and financial models for ancillary services do not yet pencil out in the region.

Third-Party and Mixed-Ownership Business Models Continue to Evolve

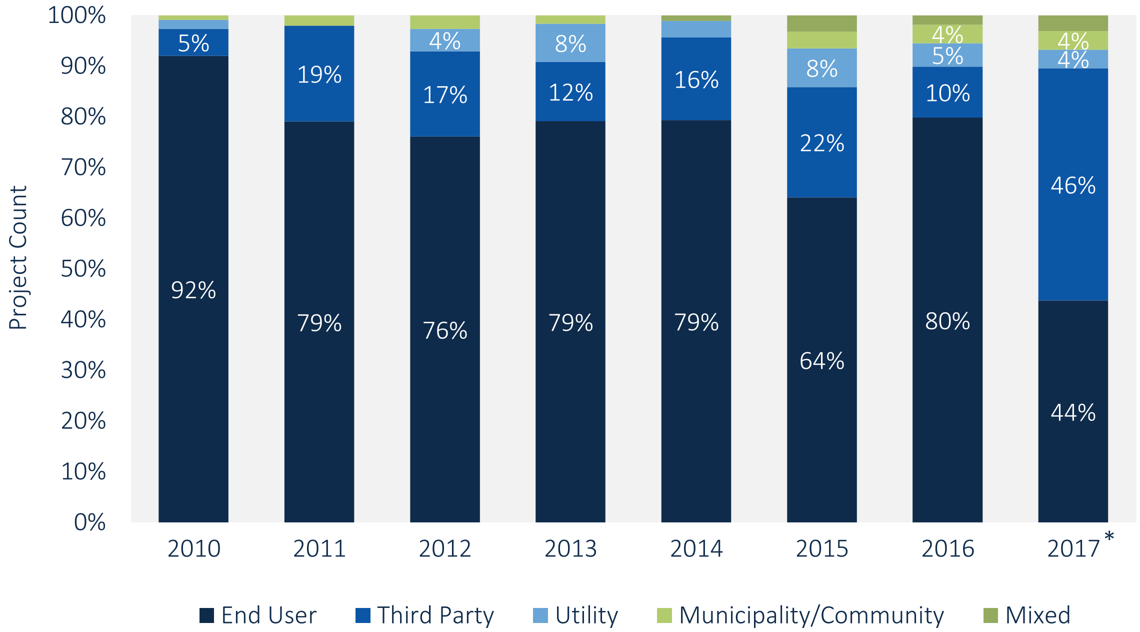
Annually Commissioned Microgrids Capacity by Ownership, 2010-2017



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

*2017 includes projects planned for completion by year's end

Annually Commissioned Count by Ownership, 2010-2017



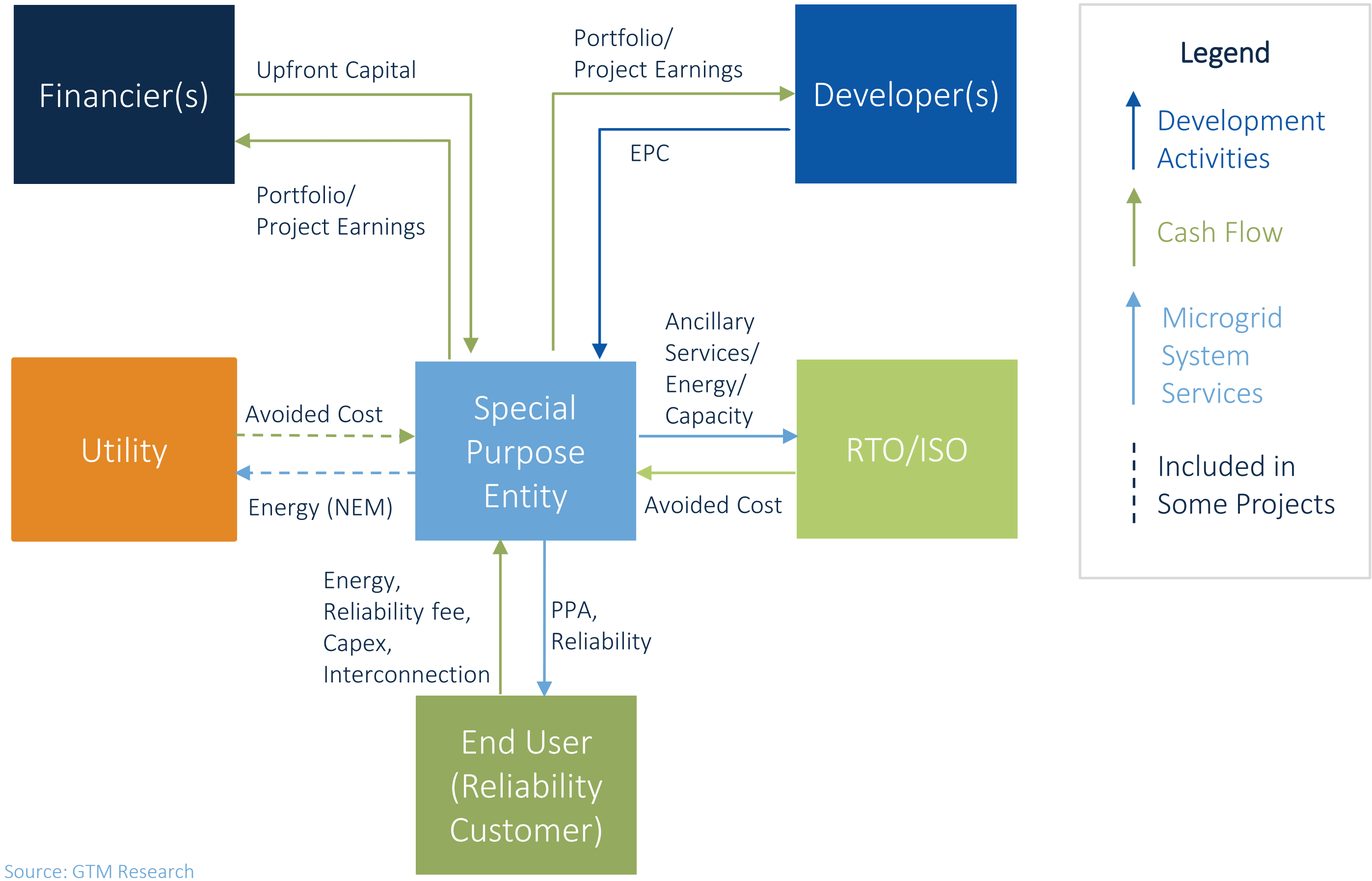
Source: GTM Research, U.S. Microgrid Tracker Q3 2017

*2017 includes projects planned for completion by year's end

Market data by capacity as well as project count shows an emergence of new business models with different ownership structures. Third-party and mixed-ownership models often finance microgrids using power-purchase agreements (PPAs), microgrid-as-a-service (MaaS) and/or reliability-as-a-service (RaaS) models. The following slide highlights how these business models function.

Business Model Highlight: Reliability-as-a-Service, Microgrid-as-a-Service

Microgrid Project Financing Structure: Third-Party Investors



Source: GTM Research

In recently deployed and prospective microgrid projects, we have seen the emergence of third-party investors who trade upfront capital for project earnings.

These business models vary, with the investor(s) covering project costs, including design, permitting, finance, construction and O&M, in exchange for receiving value streams associated with selling services to the grid when the microgrid is not in island mode. In these models, the end user where the microgrid is sited gets reliable backup power at a significantly reduced price (or in some cases free); in some models, the end user also gets the right to purchase power from the on-site DERs through a power-purchase agreement (PPA).

In this emerging model, the financier and/or the developer create a special purpose entity (SPE) that owns the microgrid and some or all of the associated DER assets. The developer handles customer acquisition and is responsible for the engineering, procurement and construction of the project. The financier provides the necessary capital to pay for the project. The cash flow from the project is deposited into the SPE, taking the form of payments from the end user that receives the reliability benefit as well as service payments from RTO/ISO and utilities for services provided. Energy services usually cover the costs, while capacity and various local ancillary services provide the project profits to create additional value for the investors. Some projects involve a contract with a utility, including remuneration for grid services in the form of net energy metering. Once cash flows into the SPE, the money is then distributed between the financier and developer based on their initial agreement.

10. Energy Storage Emerges as Microgrid Cornerstone

Section Overview: Energy Storage Emerges as Advanced Microgrid Cornerstone

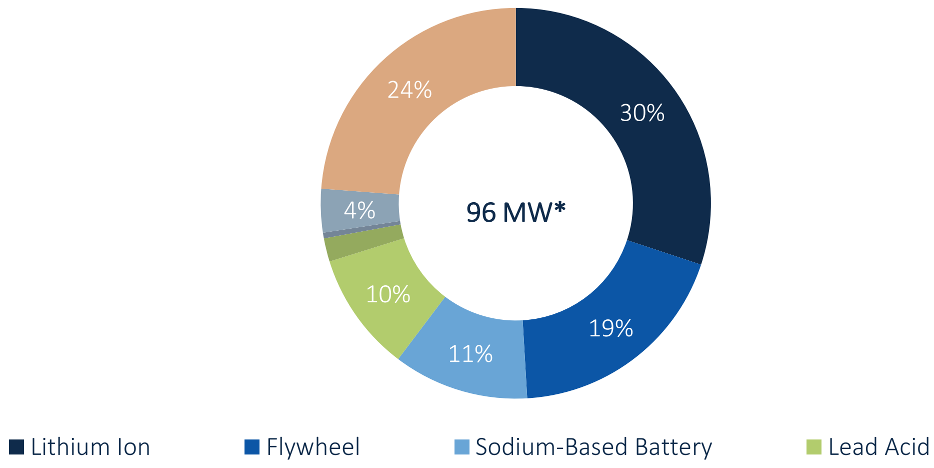
Seventy-four percent of operational advanced microgrids include some form of energy storage. The U.S. market offers storage-solution providers a unique opportunity to leverage high incentives and microgrid-specific subsidies to further develop technologies and underlying business cases that stack potential stakeholder values such as demand-charge reduction, peak shaving, backup power and renewables capacity firming.

Takeaways:

1. The total storage market in the U.S. is expected to be 558 MW by the end of 2017 across the utility, non-residential and residential sectors; storage in microgrids is expected to account for 104 MW, or 19% of the total forecasted 2017 U.S. storage market.
2. Microgrid storage is becoming increasingly attractive; the past five years have seen more annually commissioned microgrids with energy storage than without. Storage capacity in microgrids has more than doubled since 2014.
3. Of the 96 MW of known operational microgrid energy storage capacity, lithium-ion accounts for 30% while sodium-based and lead acid batteries account for 21% together. Flywheels, which are often used for a higher-power, shorter-duration dispatch account for 19% of storage power capacity.
4. Eleven projects have thermal energy storage, not included above because its thermal capacity is measured in ton-hours; the 11 microgrids with thermal storage contribute over 210,000 ton-hours of energy storage.
5. Military and university/R&D microgrids represent the highest storage capacity to date (28% and 24%, respectively). Community microgrids are expected to increasingly incorporate storage as prices come down and storage is able to work across DERs and amplify grid-firming services. Community microgrids make up 34% of the known pipeline.
6. In the past, remote-community microgrids have turned to diesel generators to better integrate intermittent renewable generation. More recently, microgrids are deploying energy storage to mitigate power fluctuations created by increasing dependence on renewables. For example, several remote microgrids in Alaska have adopted flywheel storage to help integrate large-scale wind generation. In 2016, flywheels accounted for the majority of energy storage deployments.
7. Falling prices for solar-plus-storage combinations make quasi-grid independence more attractive, leading to the increased likelihood of islanding upgrades to be offered as add-ons in regions with reliability concerns. Since 2014, storage has been included in over 80% of projects that have solar; storage helps smooth the intermittency of solar power as well as providing a stop-gap in power outages while fuel-based generators kick on.

Lithium-Ion Chemistries Prove to Be Microgrid Battery of Choice

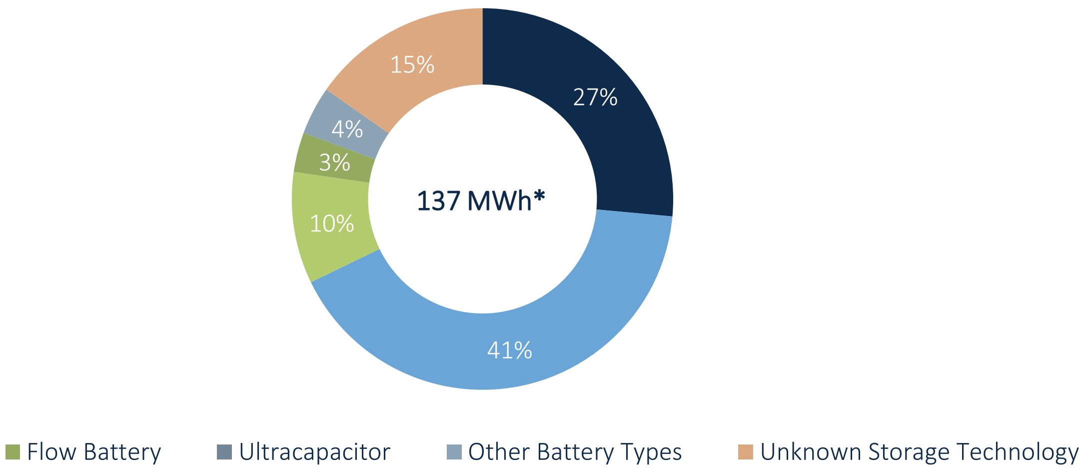
Known U.S. Microgrid Operational Storage Power Capacity (MW) by Technology



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

*This does not include thermal energy storage

Known U.S. Microgrid Operational Energy Storage (MWh) by Technology



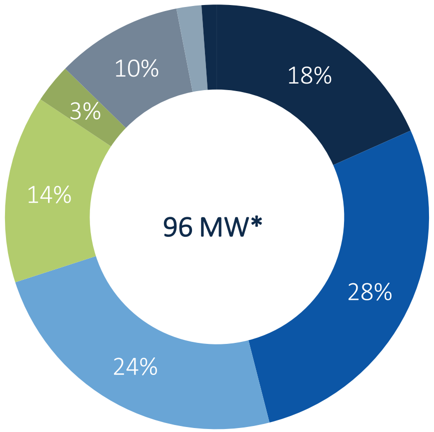
Source: GTM Research, U.S. Microgrid Tracker Q3 2017

*This does not include thermal energy storage

- For project developers and storage solution providers, the U.S. microgrid market offers an opportunity to further stack potential value streams to help build an economically viable business case for storage; demand-charge management, peak shaving, backup power and renewables capacity firming are storage services that microgrid controllers can accentuate and customize to the local electricity market environment, offering opportunities for both large- and small-scale storage deployments.
- Lithium-ion accounts for 30% of power and 27% of energy capacity. Sodium-based chemistries and flow batteries tend to be for longer duration dispatch, which is why their energy capacity is higher than their power capacity. The two flywheel microgrids only reported power capacity, but we expect their energy capacity is low as flywheels are generally meant to dispatch at high power over short time intervals.
- Eleven projects have thermal energy storage, not included above because its thermal capacity is measured in ton-hours; the 11 microgrids with thermal storage contribute over 210,000 ton-hours of energy storage.

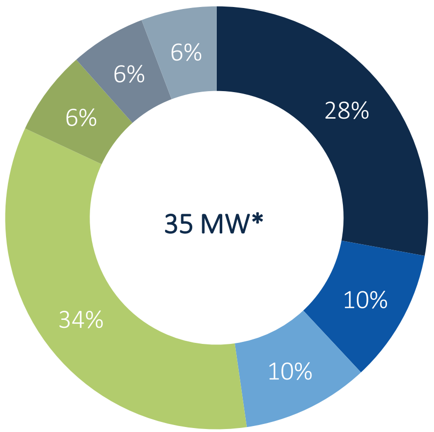
Energy Storage Is Incorporated Across Sectors

Known U.S. Microgrid Operational Energy Storage Capacity by End User**



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

Known U.S. Microgrid Planned Energy Storage Capacity by End User**



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

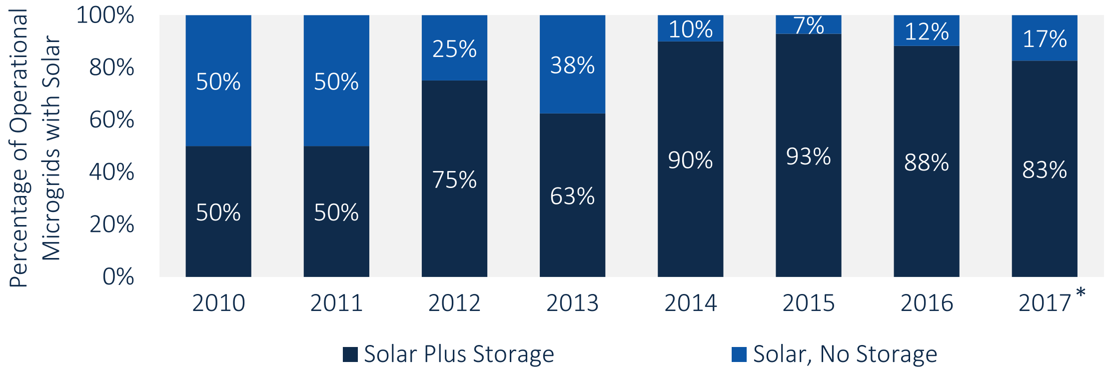
- The military and university/research facilities constitute most operating microgrid energy storage, but most known planned capacity growth is in city/community microgrids.
- Island and remote microgrid storage is most widely used for renewables integration and power quality smoothing (e.g., Cuttyhunk Island, Massachusetts).
- City and community microgrids are planning to adopt storage across all seven regions in the U.S.; these microgrids often have multiple technologies that batteries can often help smooth the renewables integration with the fuel-based generation.

*This does not include thermal energy storage

**End user order based on largest to smallest total microgrid capacity installed

Microgrids With Solar Often Include Energy Storage

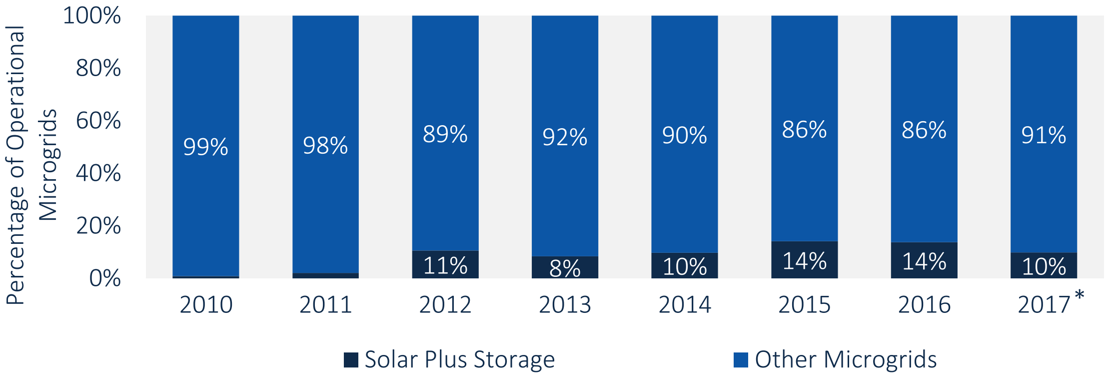
Percent of Solar Microgrid Projects That Include Solar + Storage



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

*2017 includes projects planned for completion by year's end

Percent of All Microgrid Projects That Include Solar + Storage



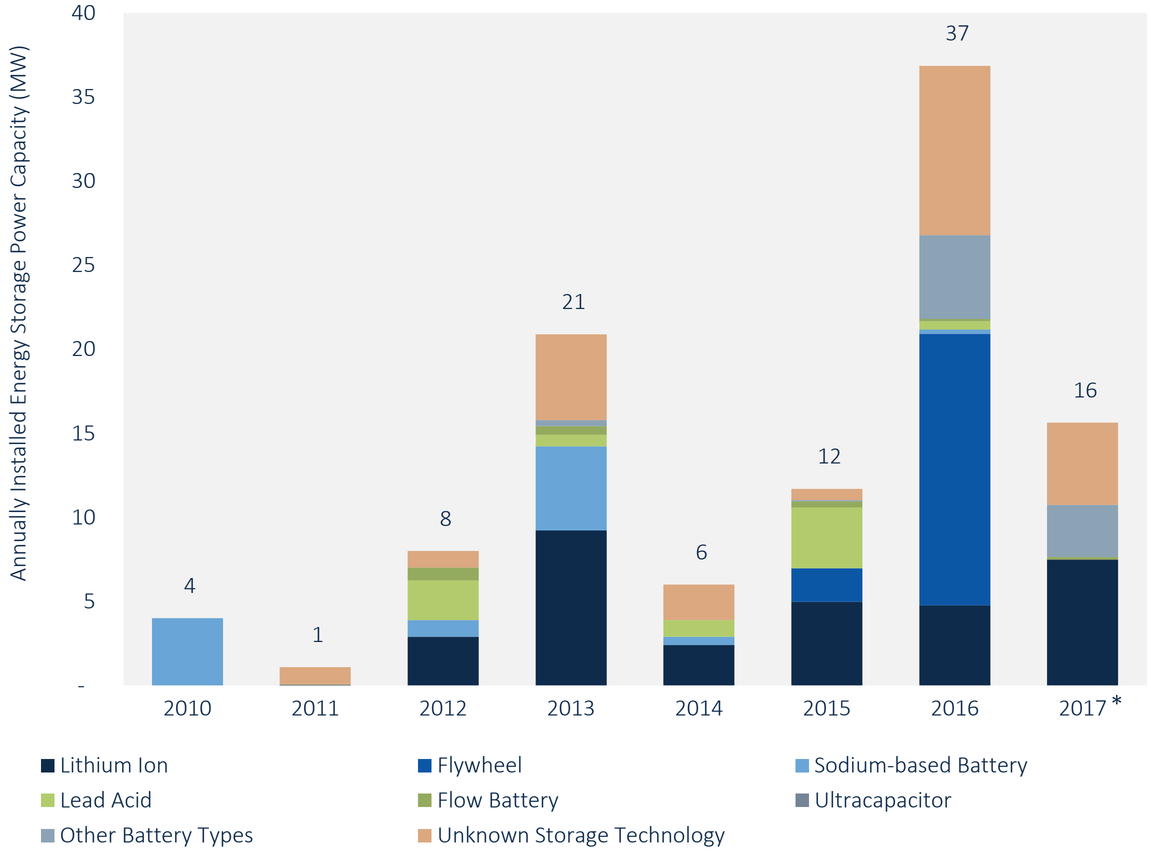
Source: GTM Research, U.S. Microgrid Tracker Q3 2017

*2017 includes projects planned for completion by year's end

- Solar on its own cannot form a microgrid, as it would not be a reliable source at night; even when paired with a battery the vast majority solar-plus-storage systems installed today cannot island and provide the majority of backup power for reliability during a storm that lasts for several days.
- However, storage is an important component of microgrid projects with solar, as it can help shift when solar power is used and provide grid forming capabilities, meaning it can maintain power quality, including voltage and frequency control.
- Since 2014, we have seen 83% to 93% of projects deployed with solar also include storage (56 microgrid projects). We expect this trend to continue and for more microgrids to include solar-plus-storage.
- Starting in 2012, solar-plus-storage has been established as a small, but consistent contingent of microgrids. GTM Research expects this trend to persist as solar-plus-storage costs continue to decline and solar-plus-storage deployments are expected to accelerate.

Lithium-Ion a Steady Storage Choice for Microgrids Since 2012

Annually Commissioned Microgrid Energy Storage Capacity by Technology



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

*2017 includes projects planned for completion by year's end

Storage is a recent but growing phenomenon:

- 74% of advanced operational microgrid projects include storage (by definition storage is not part of basic microgrids).
- A 16 MW flywheel deployed at Fort Detrick Central Plant Microgrid in Maryland in 2016 bolstered storage deployment in 2016. In 2015, flywheels were deployed largely in remote communities and island projects.
- Despite the low deployment of storage in 2017 compared with previous years, the past five years have seen more annually commissioned microgrids with energy storage than without it.
- Though sodium-based chemistries represented approximately 35% of the 2010 to 2013 microgrid storage capacity, lithium ion began to overtake the capacity in 2013 due in part to safety concerns of sodium sulfur batteries after the 2011 explosion of an NGK sodium sulfur battery. In 2014 and 2016, the sodium deployments were a different chemistry – sodium metal halide and sodium nickel chloride, respectively.
- GTM Research expects solar and storage costs to continue to decline in the coming years; this trend will make quasi-grid independence more attractive, leading to the increased likelihood of islanding capability upgrades to be offered as a value-add in regions with reliability concerns. These may not all, however, fall under the GTM Research definition of microgrids.

Note: The initial report incorrectly classified a group of 45 projects, which account for 50 MW of completed and planned capacity in 2017, as advanced instead of basic. This correction was made in December 2017 and has been applied here.

11. U.S. Microgrid Market Forecast

Section Overview: U.S. Microgrid Market Forecast

This section will outline our outlook on the microgrid market, highlighting expected growth trends in terms of capacity and market value.

Takeaways:

1. U.S. cumulative market capacity is expected to reach 6.5 GW by 2022, representing a CAGR of 14.1%. Microgrid growth will accelerate each year, driven by the emergence of more streamlined implementation strategies and spillover effects in high-potential regions.
2. GTM Research revised its future microgrid capacity growth expectations downward due to community microgrids taking longer to materialize than expected, as well as continued deployment of smaller commercial microgrids, which reduced 2017 capacity despite a 76% increase in the number of microgrids deployed compared to 2016.
3. Despite a decrease in added capacity in 2017, a number of increasingly favorable market trends continue to increase the future expected capacity additions: 1) A positive uptick in state incentive programs and policies; 2) adoption of merging business models that share benefits, costs and ownership among multiple stakeholders; 3) increased interest and activity from utilities and ESCOs; and 4) an uptick in discussions on creating more streamlined, plug-and-play microgrids to make the product more commercial.
4. Military microgrids will continue to play an important role, but city/community and commercial microgrids will increase substantially as state funding comes into play and with the growth of the MaaS model.
5. By the end of 2022, renewable generation and storage are expected to represent 23% of annually installed capacity; solar and storage are primed for strong growth over the next five years. (This forecast does not consider the potential negative impact of the current Section 201 solar trade case.)
6. Annual vendor revenues are expected to approximately double from $1.4 billion in 2017 to $2.8 billion in 2022. Combined six-year investments (2017E-2022E) are expected to exceed $12.5B, as generation (including storage) will continue to represent the greatest market opportunity (especially in greenfield projects), followed by distributed grid enhancements. This represents an increase from 2016 based on higher install costs, which may be due in part to an increase in new generation being installed as part of the microgrid; this forecast assumes all generation is greenfield, so it may be higher than actual investment seen.

5-Tier Methodology to Capture Microgrid Market Dynamics

The U.S. microgrid market forecast is based on five considerations, accounting for recent market trends and the sustained growth of DERs through 2022. The methodology also takes into account the current and future market potential composition, including existing customer-sited generation, as well as expected near-term capacity additions. The five considerations are outlined in more detail below:

1. **Increased project initiation rate.** Microgrid projects initiated in the past three years will gradually be completed between 2018 and 2020. The anticipated timing of capacity additions is largely based on each project's estimated completion date, when available, but also takes into account potential delays due to slow, incremental project development as well as anticipated new project announcements.
2. **Expected Change in DER markets.** GTM Research expects that the sustained growth of distributed energy resources will create a point of intersection between those DER installations and microgrid projects. For example, as solar and storage growth rates continue to rise, the new market situation is not adequately represented in past project initiations, and is accounted for separately in the forecast. This is accomplished by applying the non-residential distributed solar PV growth rate and the behind-the-meter storage growth rate to the installed PV and storage capacities respectively in microgrids.
3. **Existing DERs integration.** GTM Research expects that large portions of diesel, natural gas and CHP plants will be incorporated from existing backup generation on-site already. By comparing growth rates by fuel type of microgrids to expected growth rates by fuel types for DERs outside of the microgrid, GTM Research created growth multipliers to categorize incorporation of existing DERs into new microgrids.
4. **State and federal policies.** Many state and federal grant programs are coming up and will impact future growth both in terms of funding specific microgrids and also helping decrease regulatory and technical barriers. California's program also specifically has a goal of helping create more modular systems to reduce the high levels of customization currently available.
5. **Capacity disaggregation according to market potential.** Total capacity is disaggregated in generation technology types according to the current market potential. High-potential states have a stronger weight in the overall distribution, as GTM Research expects these regions to shape the overall future microgrid landscape.

Forecast Methodology Leverages Historical Data, Future Policies and Project Pipeline

Microgrid 2017-2022E Forecast Methodology

EQUATION

National 2017-2022 Generation Growth Rate by Fuel Type × Microgrid Annual Growth Rate Multipliers: Pipeline, Policies, Past Events × Microgrid Installed Capacity by Fuel Type = Forecasted Capacity by Fuel Type

NOTES

National 2017-2022 Generation Growth Rate by Fuel Type:

- **Source 1:** GTM Research Forecasts: CHP, Fuel Cells, Solar, Storage, Wind (MAKE)
- **Source 2:** EIA 861, 2012-2015 CAGR: Diesel, Natural Gas, Hydro

Microgrid Annual Growth Rate Multipliers:

- **Pipeline:** Planned 2018-2022 projects by fuel type
- **Policies:** Government policies create incentives specific fuels in microgrids, or microgrids in general
- **Past Events:** 2014-2016 Microgrid Generation CAGR by Fuel Type

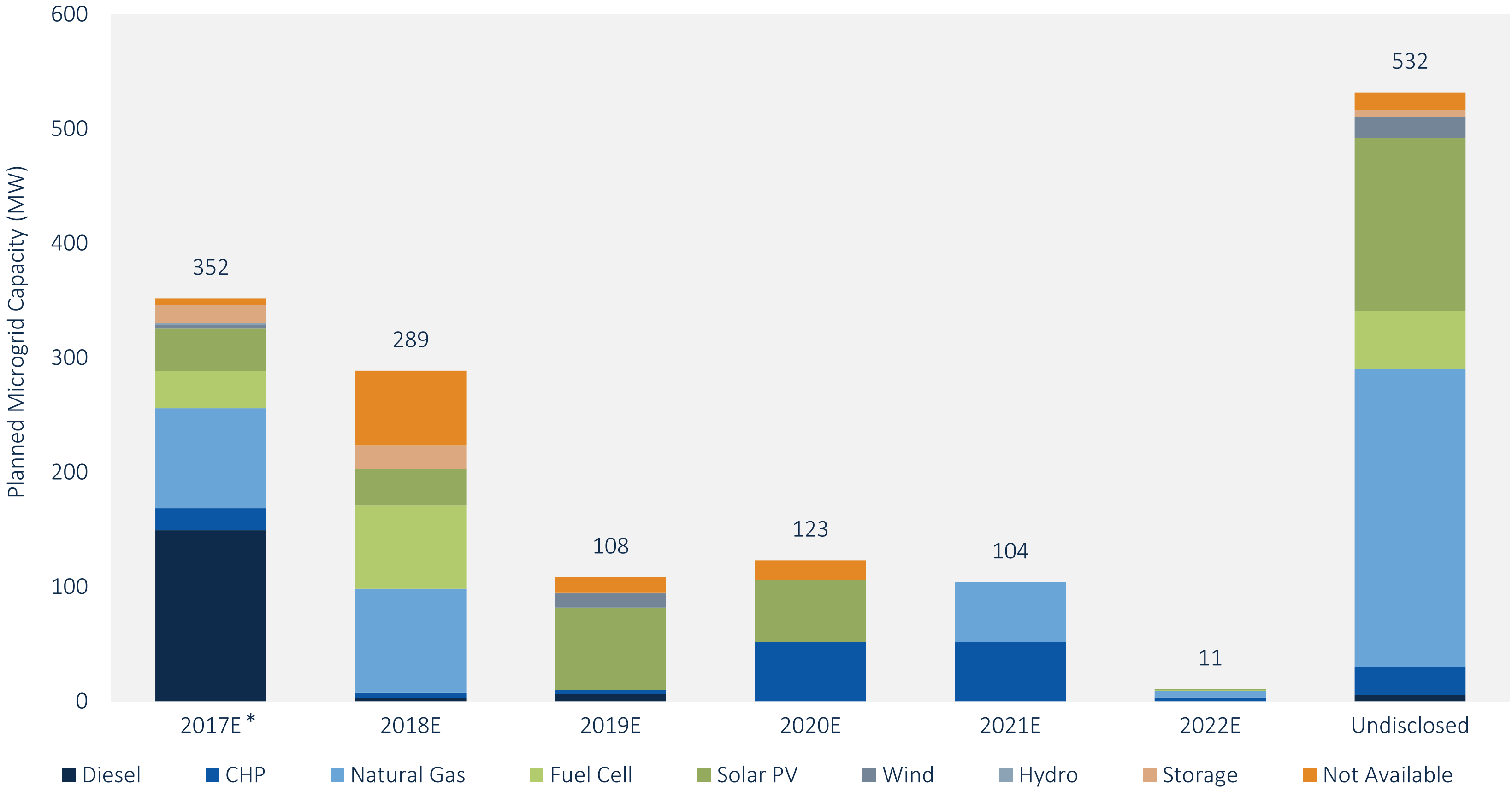
Microgrid Installed Capacity by Fuel Type:

- Start with 2016 installed capacity; each year use previous year as baseline

Source: GTM Research

2018 Pipeline for Completed Projects Is Already Close to 2017 Expected Capacity

Pipeline of Planned Projects by Resource Type, 2017E-2022E



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

*2017 includes projects that are already completed

The planned pipeline of microgrids only includes projects that have planned end dates. There are 634 MW of planned projects from 2018 through 2022.

An additional 532 MW of planned capacity exists without end dates – though 300 MW of this capacity is from the long-planned Niobrara Energy Park in Colorado, which is still searching for commercial customers.

The project pipeline does not directly feed into the forecast, but is used to check against forecasted results.

Top State Markets Assessed Using 9 Key Microgrid Growth Criteria

Nine Screening Criteria

Criteria Number	Criteria	Description + Scoring Criteria	Source
1	Top 10 Microgrid Capacity	Flag for top 10 states with highest installed capacity from 2007-2017	GTM Microgrid Deployment Tracker, Q3 2017
2	High Electricity Costs	Flag for states where average retail rate is higher than one standard deviation above the average	U.S. Department of Energy's EIA average retail rate, 2015
3	History of Outages	Any state that was in the top 10 outages due to weather/falling trees, classified as number of outages, for any year from 2014 to 2016	Eaton Outage Tracker 2016 Report
4	Hurricane in Past 5 Years	Any state hit by a hurricane in the past five years (2012-2017)	National Oceanic and Atmospheric Administration, National Hurricane Center
5	Isolated Communities	Hawaii and Alaska	N/A – two states with multiple islands and not connected to U.S.
6	Strong CHP Incentives	Any state where CHP has been growing consistently since 2010	DOE CHP Database
7	Strong Distributed PV Growth	Any state where CAGR or installed capacity was more than one standard deviation above the average	GTM Research, Non-Residential Solar Database
8	Strong BTM Non-Residential Battery Growth	States tracked separately in GTM Research's *Energy Storage Monitor* (7 states)	GTM Research Energy Storage Monitor
9	Microgrid Initiative	State with funding for microgrids or microgrid research ongoing	Various industry research

Source: GTM Research

GTM Research assessed each state according to nine criteria to determine its potential.

- High microgrid potential states included any state that fit two or more criteria; states with greater than 100 MW deployed in past 10 years were automatically included.
- Oregon was included despite only having one indicator because it has shown high growth in recent years and it does have some microgrid funding from a utility, but not the state.
- These quantitative assignments provided qualitative inputs into the forecast models, helping decide where and how often certain fuel types might be deployed.
- This process identified 20 key states, which make up the total addressable market and provide key market drivers for microgrids.

20 States Have High Potential Based on 9 Screening Criteria

Top 20 States and Determining Criteria

State	Top 10 State for Capacity Deployment (2007-2017)	High Electricity Costs	History of Power Outages (2014-2016)	Hurricane in Past 5 Years (2012-2017)	Isolated Communities	Strong CHP Incentives	Strong Non-Residential PV Growth	Strong Behind the Meter Battery Growth	State Microgrid Initiative
Alaska	○	●	○	○	●	○	○	○	○
Arizona	●	○	○	○	○	○	○	●	○
California	●	●	●	○	○	●	●	●	●
Colorado	●	○	○	○	○	○	○	○	○
Connecticut	○	●	●	○	○	○	○	○	●
Florida	○	○	●	●	○	○	○	○	○
Georgia	○	○	●	●	○	○	○	○	○
Hawaii	●	●	○	○	●	○	○	●	○
Maine	●	○	○	○	○	○	○	○	○
Massachusetts	○	●	●	○	○	●	●	●	●
Michigan	○	○	●	○	○	○	●	○	○
New Hampshire	●	●	○	○	○	○	●	○	○
New Jersey	○	○	○	●	○	●	●	●	●
New Mexico	●	○	○	○	○	○	○	○	○
New York	○	●	●	●	○	●	●	●	●
North Carolina	○	○	●	●	○	●	○	○	○
Oregon	●	○	○	○	○	○	○	○	○
Pennsylvania	●	○	●	○	○	●	○	○	○
Texas	○	○	●	●	○	●	○	●	○
Virginia	○	○	●	○	○	○	●	○	○

Source: GTM Research

● Fits Criteria ○ Does Not Fit Criteria

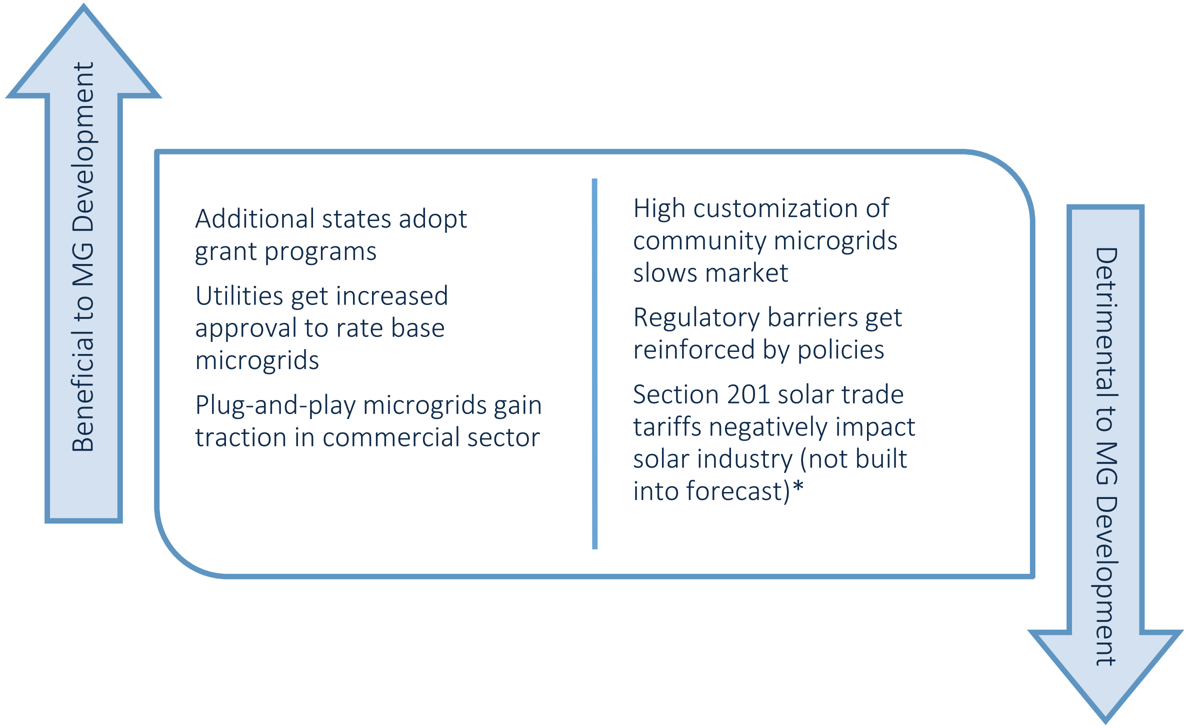
Forecast Accounts for Upside and Downside Growth Scenarios

Description of Base-Case, Low and High Forecast Scenarios, Q3 2017

The base-case, low and high forecasts incorporate a number of currently observable variables in the microgrid market. These variables are modeled to have a larger effect on the later years in the forecast, as future regulatory and legal developments create uncertainty.

- **Base Case**: Annual capacity additions are based on both deployed project trends and the known pipeline of planned deployments. The forecast also accommodates for the increasing overlap between distributed solar PV and storage growth. State microgrid and energy storage programs are assumed to meet target goals, sustainability, and energy security. End-customer initiatives are expected to gradually increase and modest growth in utility ownership is predicted over the next four years.
- **Low Case**: In the low case, U.S. state microgrid programs move forward, but does not result in streamlined microgrid installations, which makes it difficult for the market to scale beyond its current annual installation rate. Regulatory barriers remain in place, keeping utilities from expanding in the role of microgrid developer across many parts of the company.
- **High Case**: In the high case, several U.S. states are expected to simplify microgrid interconnection rules and regulatory treatment, leading to faster regional growth. The capacity addition compared to the base case is derived from accelerated growth in states like California, Hawaii, New Jersey, New York and Massachusetts, where ongoing microgrid initiatives will likely lead to substantial legal and regulatory improvements. Utility and third-party interest in co-developing microgrids will reduce customer financial burdens and thus contribute to a higher deployment rate. Ongoing federal and state-run programs are expected to surpass microgrid capacity targets, and new initiatives are optimistically assumed to materialize.

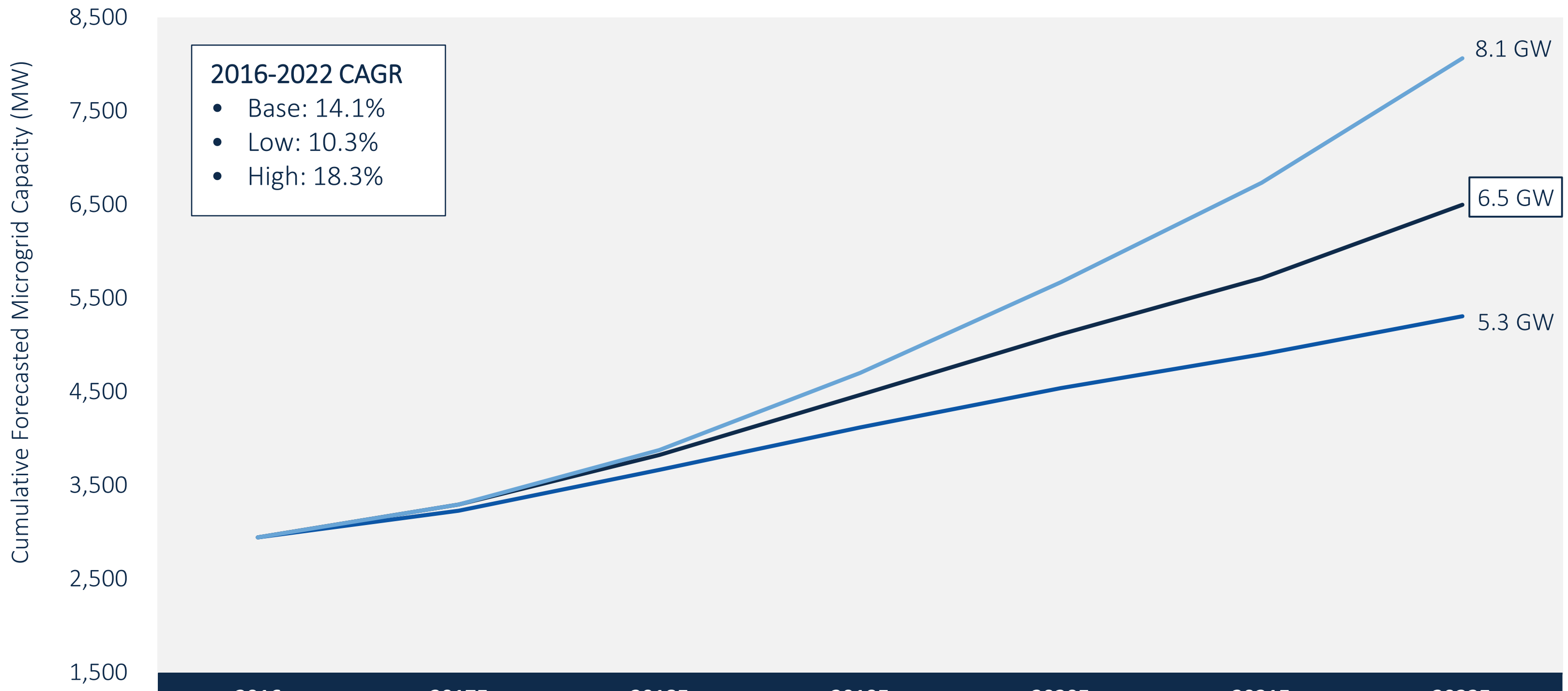
Factors that will Help or Hinder Microgrid Development



*On September 22, 2017 the U.S. International Trade Commission voted that injury occurred to U.S. solar manufacturers Suniva and SolarWorld due to imports of solar cells and modules; on October 31 the ITC commissioners recommended various tariffs and quotas for remedy. President Trump will make the final tariff decision by January 12, 2018. While the exact tariffs are unknown, GTM Research expects a net negative impact on the U.S. solar market should tariffs be imposed. The impact of these price increases could negatively affect the solar market within microgrids as well.

Microgrid Capacity Forecasted to Be 6.5 GW by 2022

Q3 2017 Microgrid Capacity Forecast, 2017E-2022E



	2016	2017E	2018E	2019E	2020E	2021E	2022E
Base	2,943	3,295	3,823	4,465	5,115	5,712	6,497
Low	2,943	3,229	3,667	4,119	4,540	4,900	5,308
High	2,943	3,295	3,878	4,701	5,670	6,733	8,064

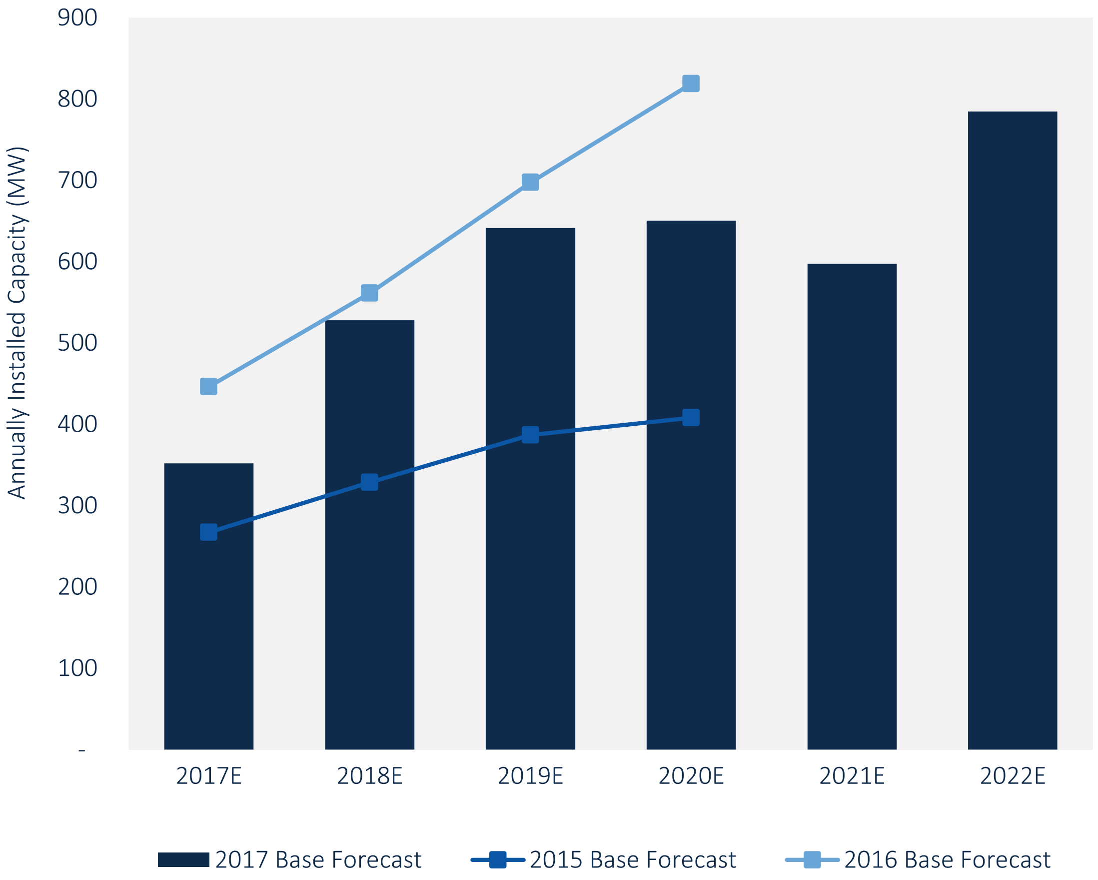
Source: GTM Research, U.S. Microgrid Tracker Q3 2017

Primary Drivers of Microgrid Growth

- The rise of multi-stakeholder-owned microgrids; this has taken off more slowly than anticipated, but is expected to further promote development, as the burden on individual end customers is reduced.
- Continued growth of basic microgrids, especially for commercial customers looking for reliability (e.g. grocery stores)
- Large commercial and military customers with mission-critical operations (e.g., data centers, Air Force bases) are partnering with regulated utilities (e.g., APS, HECO, Georgia Power) to deploy microgrids with large utility-controlled onsite generation.
- Regulated utilities in California, Illinois, Hawaii and New York are aggressively developing strategies for utility- and third-party-owned DER/microgrid systems. Moreover, a noticeable uptick in non-wires alternatives projects reiterates the diverse microgrid use case to defer T&D investments.
- Community/municipality grant programs in the Northeast and California focus on critical infrastructure to move beyond feasibility studies, while state legislation in Alaska promotes microgrids to meet growing electricity demand (and defer utility T&D investments).

Slower 2017 Capacity Deployment Prompts Downward Adjustment

U.S. Microgrid Year-on-Year Additions for 2015-2017 Base Forecasts



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

The 2017 forecast includes basic microgrids in the forecast marking a shift from previous methodologies due to the expanded scope of coverage. Despite this addition, the forecast has been revised downward from Q3 2016 forecast due to a decrease in installed capacity in 2017 compared with 2016 and slower-than-expected deployment of community microgrid projects.

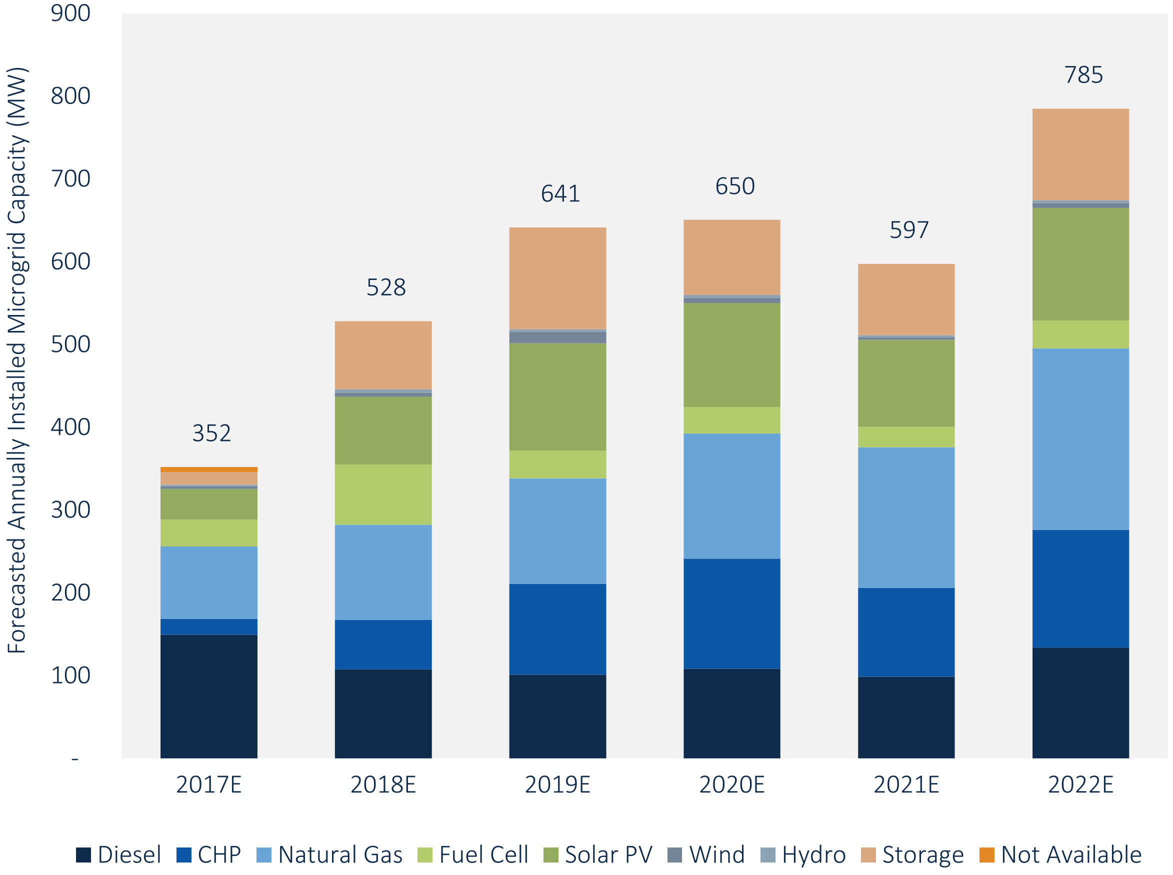
The U.S. microgrid market is not expected to slow in terms of number of projects, but is expected to have a greater number of smaller deployments, especially in the commercial sector, as more modular and plug-and-play systems come into effect.

Despite a slow-down in 2017, a number of increasingly favorable market trends continued to increase the expected capacity additions:

1. A positive uptick in state incentive programs and policies (e.g., Northeast and California Microgrid Grant programs, APS getting approval to rate base microgrid investment)
2. Emerging business models that share benefits, costs and ownership among multiple stakeholders
3. Increased interest and activity from utilities and ESCOs
4. An increase in discussions on creating more streamlined, plug-and-play microgrids to make the product more commercial

Fossil Fuels Make Up the Majority of Installations; Storage Sees the Biggest Increase

Annually Installed Microgrid Capacity by Resource, Base-Case Forecast, Q3 2017



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

- Natural gas and diesel generators are favored in co-ownership agreements with utilities and third-parties due to fast ramp rates and relatively lower costs to deploy at scale.
- CHP remains a strong generation source, underscored by large-scale adoption by individual institutional customers (e.g., hospitals, universities) and those in the Northeast.
- As economics continue to improve, solar is expected to represent 12% (136 MW) of 2022E installed capacity, a 26% CAGR from 2016 to 2022. This forecast does not account for the potential negative impact from the impending remedy of the Section 201 solar trade case currently under review by U.S. International Trade Commission.
- Declining storage costs combined with increased solar deployments are expected to increase cumulative storage capacity from 89 MW in 2016 to 598 MW in 2022, a CAGR of 37%.
- Wind and hydro will continue to be added to microgrids, but at a similar rate to what's observed to date, which will result in both becoming smaller proportions of newly installed capacity.

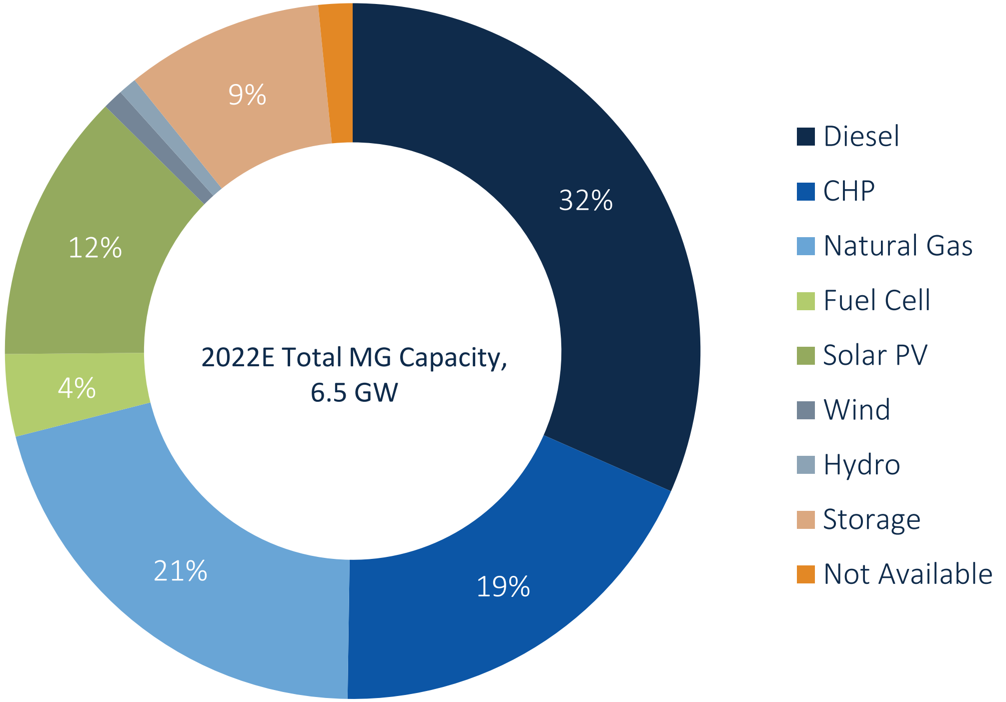
Microgrids will Have More Fuel Diversity, but Remain 72 Percent Fuel-Based Generation

Annually Installed Microgrid Capacity Forecast by Resource, Base Case, Q3 2017

(MW)	2017E	2018E	2019E	2020E	2021E	2022E
Diesel	149	107	101	108	99	134
CHP	19	60	110	133	107	142
Natural Gas	87	115	127	151	170	219
Fuel Cell	32	73	34	32	25	34
Solar PV	37	82	129	125	105	136
Wind	3	4	14	6	3	6
Hydro	2	5	3	3	2	3
Storage	16	82	123	91	86	111
Not Available	6	-	-	-	-	-
Total	352	528	641	650	597	785

Source: GTM Research, U.S. Microgrid Tracker Q3 2017

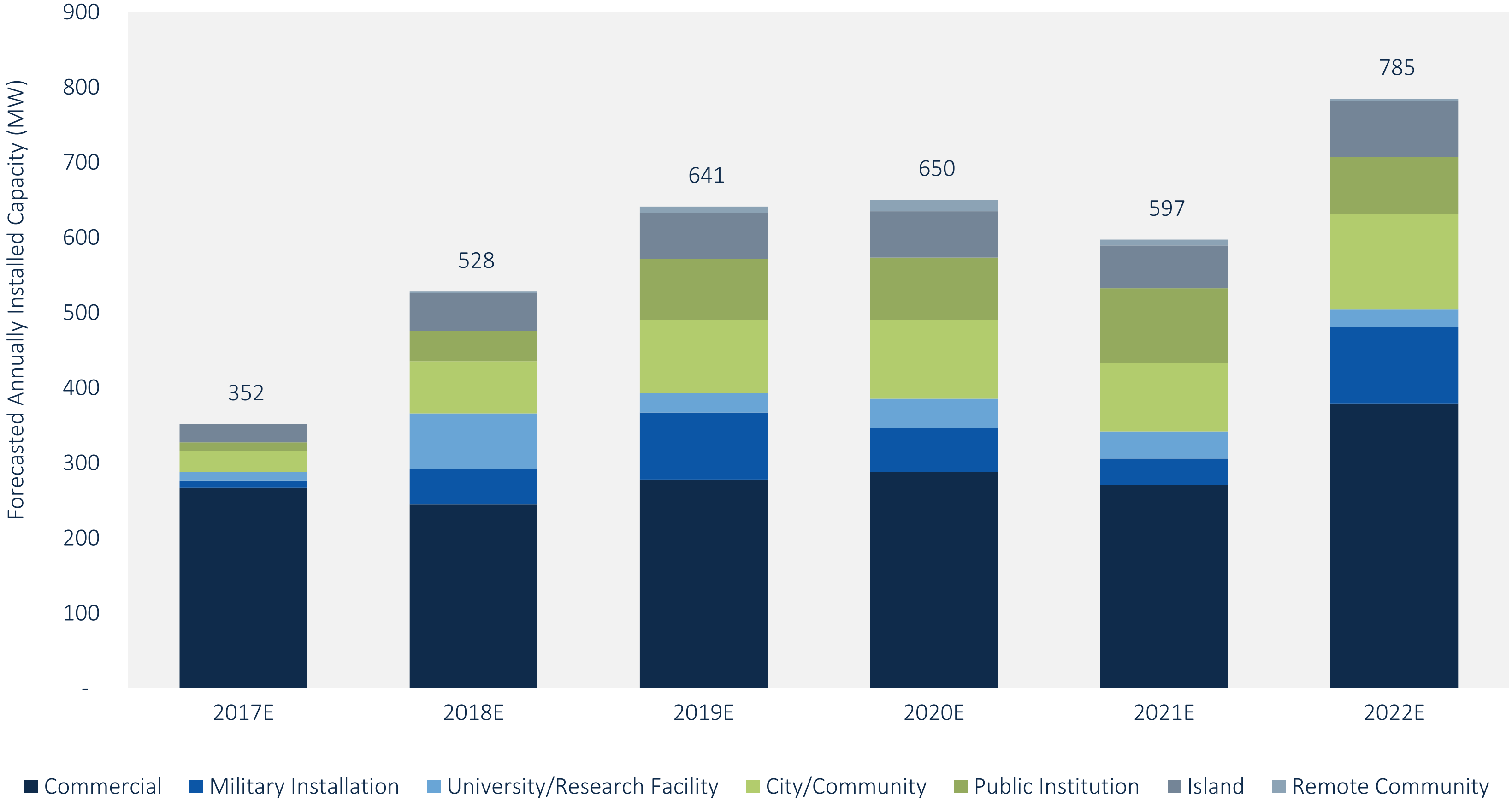
Expected 2022 Total Capacity Installed by Resource (MW, % of Total Expected)*



*End user order based on largest to smallest total microgrid capacity installed

Emerging Business Models and Funding Makes Way for a More Diversified Portfolio

Annually Installed Microgrid Capacity by End-User Type, Base-Case Forecast, Q3 2017

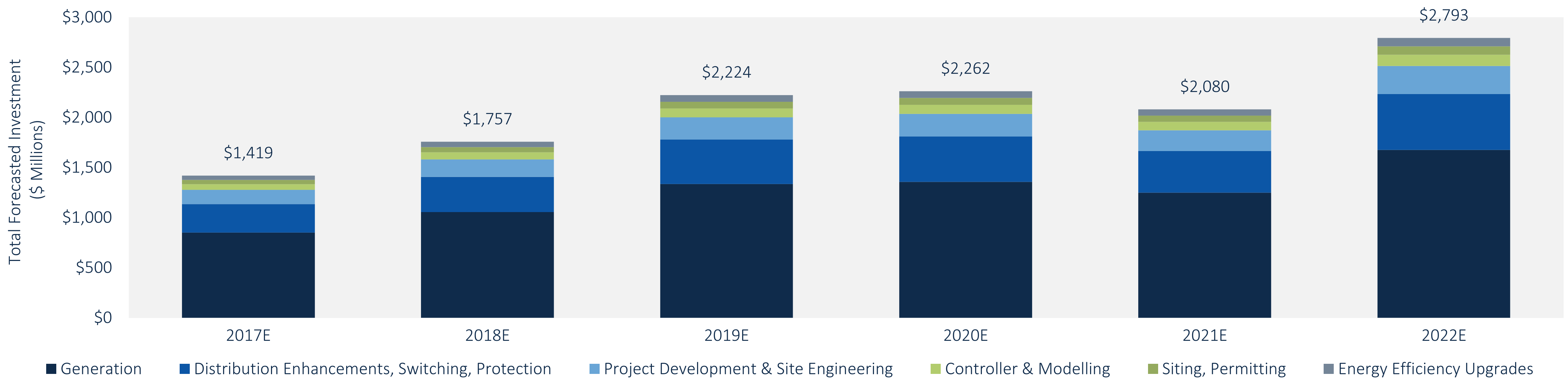


Source: GTM Research, U.S. Microgrid Tracker Q3 2017

- As state-funded community microgrid grant programs develop in the Northeast and California, critical-infrastructure-oriented, municipality-led microgrid development is expected to more than double starting in 2019 when projects start begin to reach fruition.
- Encouraged by the recent success of commercial microgrids in Hurricanes Irma and Harvey, commercial deployments are expected to continue to make up a large part of the market.
- Spurred by the increasing emphasis on energy security and renewables procurement, as well as recent interest in co-ownership contracts with regulated utilities (e.g., HECO, APS, etc.), the military is expected to continue to have consistent installments each year, either with new microgrids or expansions to existing ones, making up 13% of 2022 installed capacity. The military currently has 95 operational microgrids, 14 planned microgrids, and 416 more Department of Defense facilities where new microgrids could potentially be installed.

Forecasted 2022 Annual U.S. Market Opportunity to Reach $2.8B

Annual U.S. Microgrid Market Value, Base-Case Forecast, Q3 2017



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

- The combined six-year investments (2017E-2022E) are expected to exceed $12.5B. Generation (including storage) will continue to represent the most sizable market opportunity, especially in greenfield projects, representing approximately 60% of average project spend.
- As more projects have started including greenfield technology in their microgrids, the average cost of a microgrid has actually increased from 2016 values; to account for this, GTM Research recalibrated the percent breakdowns for the microgrid market using comparables from publicly available data. The generation percent increased from 40 to 60 percent, while the microgrid controller faced the largest downward shift, as its costs were becoming too high with larger system sizes since controllers scale more with complexity of systems than system size.
- As generation costs decrease and microgrid design is further standardized, average microgrid costs used by end-user type are expected to decrease 2% annually.

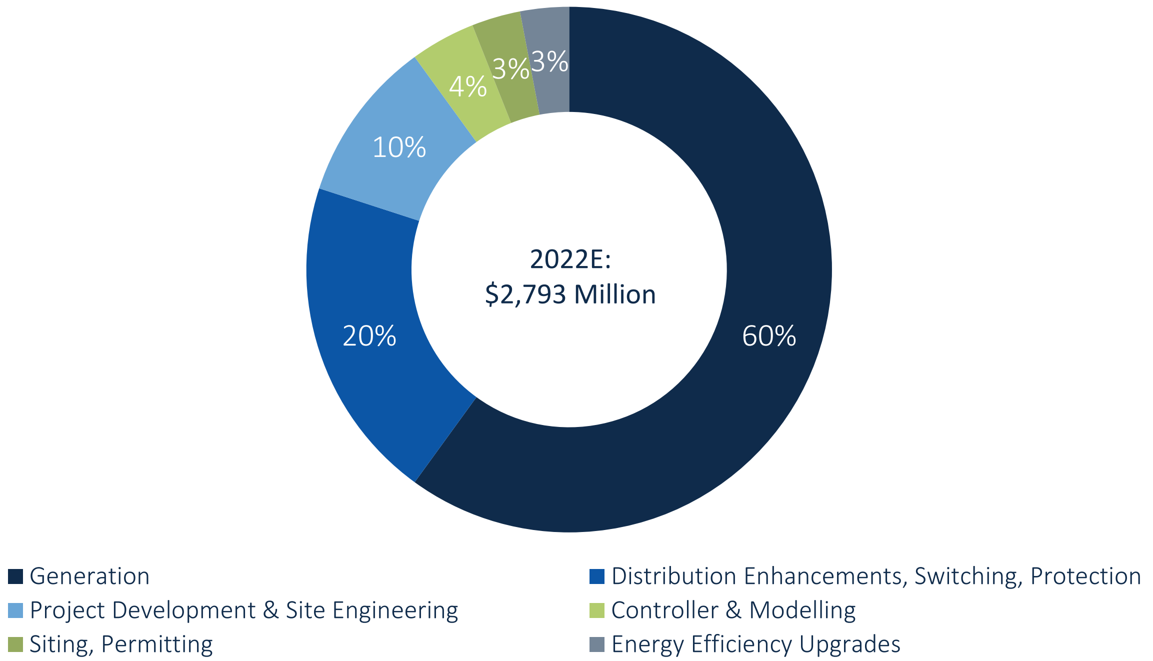
Generation Accounts for Largest Proportion of Project Costs

Annual U.S. Microgrid Market Value, Base-Case Forecast, Q3 2017

($M)	2017E	2018E	2019E	2020E	2021E	2022E
Generation	$851	$1,054	$1,334	$1,357	$1,248	$1,676
Distribution Enhancements, Switching, Protection	$284	$351	$445	$452	$416	$559
Controller & Modeling	$57	$70	$89	$90	$83	$112
Project Development & Site Engineering	$142	$176	$222	$226	$208	$279
Siting, Permitting	$43	$53	$67	$68	$62	$84
Energy-Efficiency Upgrades	$43	$53	$67	$68	$62	$84
Annual Total	$1,419	$1,757	$2,224	$2,262	$2,080	$2,793

Source: GTM Research, U.S. Microgrid Tracker Q3 2017

Expected Microgrid Market Opportunity by Market Segment ($M), 2022E



12. Conclusion

Conclusion

The microgrid market is undergoing a transformation from basic systems focused on reliability and resilience to advanced systems that provide multiple value streams

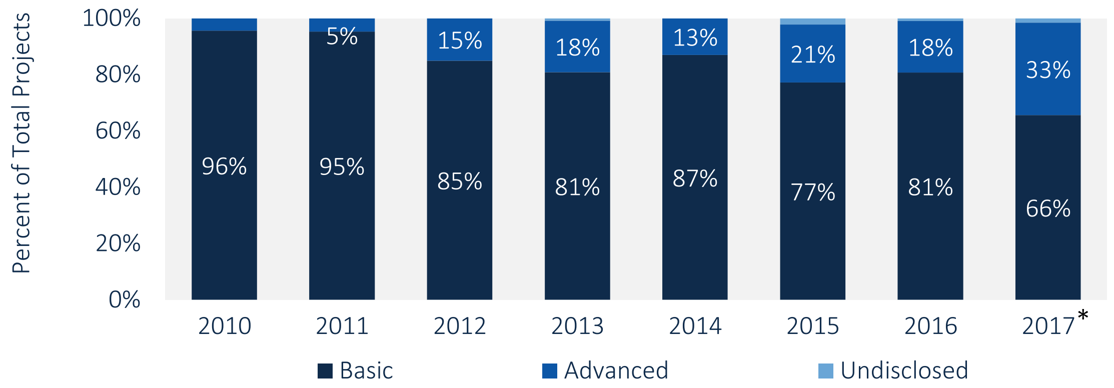
In 2017 there has been an observed increase in the proportion of advanced microgrid projects; 33% of projects were advanced, the highest percentage on record. Moving forward GTM Research expects the advanced microgrid sector to continue to grow as increasingly modular systems make the advanced systems more cost-competitive with basic microgrids, recognizing that advanced microgrids will have higher upfront costs on average, but also open up more value streams and provide enhanced resilience through fuel diversity.

The recent wave of announced state-level resilience programs is enabling further development and standardization of microgrid technologies for the next generation of advanced, more renewable-heavy projects. Substantial regulatory and legislative changes to utility franchise rights and rate structures are projected to increase microgrid value propositions, further accelerating adoption in the later years of the forecast period. As solar PV adoption rates increase, flexible microgrid solutions are becoming a significant component of renewable integration strategies in regions beyond high-penetration states like Hawaii and California, especially given California's $44.7 million grant program aimed at increasing renewable-based microgrids.

Public institution and community projects are expected to drive future utility adoption of the advanced microgrid concept. As for commercial projects, the rise of resilience-as-a-service through third-party and mixed ownership models is setting the foundation for future deployments that focus primarily on business continuity for the end-user and provide more regular cash flows to the microgrid investors. As barriers are overcome, projects that have a connection to public safety, business continuity and grid modernization are expected to be the next growth phase of microgrid development.

Note: The initial report incorrectly classified a group of 45 projects, which account for 50 MW of completed and planned capacity in 2017, as advanced instead of basic. This correction was made in December 2017 and has been applied here.

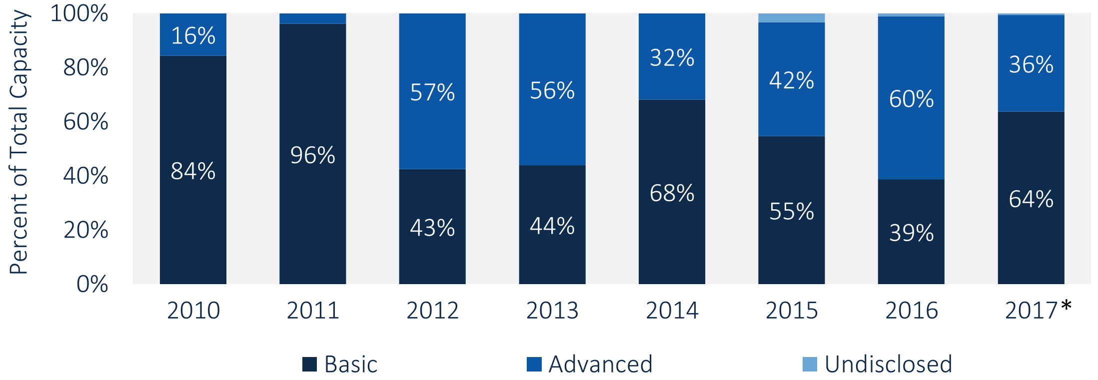
Microgrid Complexity by Year (Percentage of Projects Installed)



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

* 2017 includes projects planned for completion

Microgrid Complexity by Year (Percentage of Capacity Installed)



Source: GTM Research, U.S. Microgrid Tracker Q3 2017

* 2017 includes projects planned for completion

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