HONEY, I SHRUNK THE GRIDS: THE EMERGENCE OF NANOGRIDS

MAKING SENSE OF NEW DER BUSINESS MODELS

MAY 18, 2016

NAVIGANT
RESEARCH

NAVIGANT RESEARCH INTRODUCTION

NAVIGANT RESEARCH PROVIDES IN-DEPTH ANALYSIS OF GLOBAL CLEAN TECHNOLOGY MARKETS.

The team's research methodology combines supply-side industry analysis, end-user primary research and demand assessment, and deep examination of technology trends to provide a comprehensive view of the Energy Ecosystem.

RESEARCH PROGRAMS:

Energy Technologies
Utility Transformations
Transportation Efficiencies
Building Innovations

RESEARCH OFFERINGS:

Research Reports

Subscription Research Services

Custom Market Research

- Custom Market Analysis
- Market Sizing and Forecasting
- Primary Research
- Go-to-Market Services
- Strategic Advisory Sessions
- Commercial Due Diligence
- Technology Evaluation

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RESEARCH SERVICES

ENERGY TECHNOLOGIES

- Wind Energy
- Grid-Tied Energy Storage
- Advanced Batteries
- Microgrids
- Distributed Natural Gas
- Distributed Renewables

UTILITY TRANSFORMATIONS

- Grid Networking and Communications
- Grid IT Systems and Analytics
- Grid T&D
- Residential Energy Innovations
- Demand-Side Management
- Utility Innovations
- Utility Technology Disruption

TRANSPORTATION EFFICIENCIES

- Electric Vehicles
- Natural Gas Vehicles and Infrastructure
- Advanced Transportation Technologies
- Mobility
- Transportation Forecast

BUILDING INNOVATIONS

- Intelligent Building Management Systems
- Energy Efficient Buildings
- Lighting Innovations
- Smart Cities

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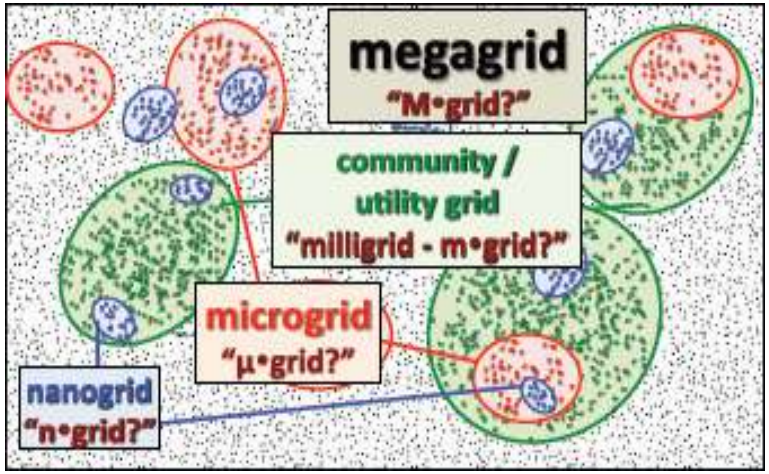
WHAT IS A NANOGRID?

- **Navigant Research definition (grid-tied systems):**
  - *"A small electrical domain of no greater than 100 kW connected to the grid and limited to a single building structure or primary load, representing devices capable of islanding and/or energy self-sufficiency through some level of intelligent DER management or controls"*
  - Most grid-tied systems are uninterruptable power supply (UPS) systems
    - Compete with microgrids
    - Rely upon "old school" diesel and lead-acid battery technologies
  - Emergence of new grid-tied market
    - Pairing of rooftop solar PV with batteries
    - Lithium ion (Li-ion) technology of choice
- Most nanogrids today are off-grid systems
  - Often deployed in concert with microgrids in developing world
  - Majority of capacity today: off-grid cell phone towers
  - Off-grid solar PV is distributed generation (DG) technology of choice



(Source: Lawrence Berkeley National Laboratory)

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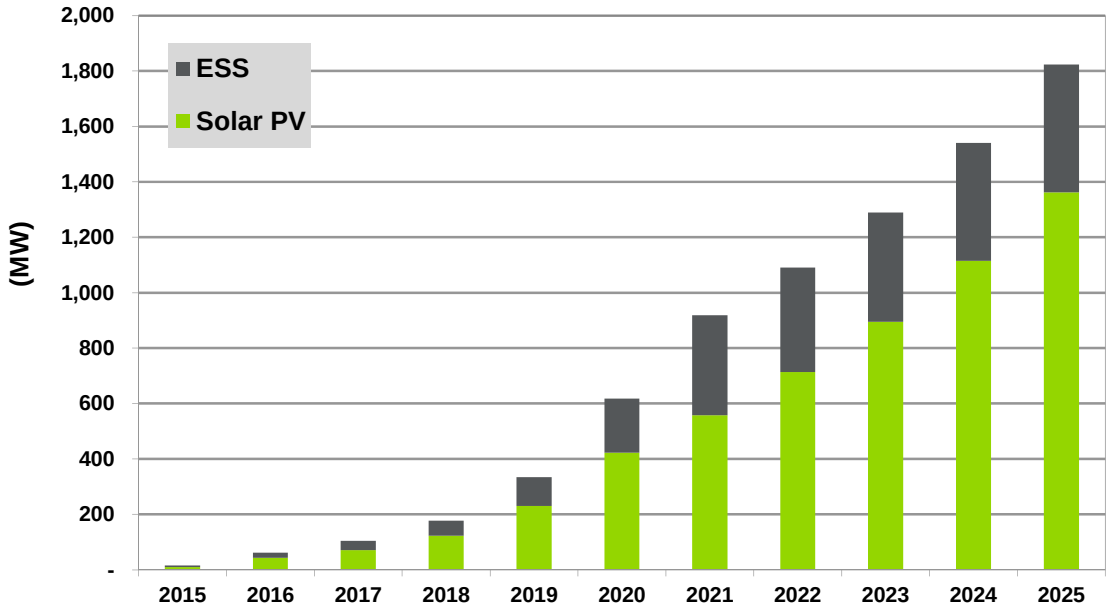
HOW FAST IS THIS NANOGRID MARKET GROWING?

Solar PV plus Energy Storage Nanogrid Capacity, North America: 2015-2025



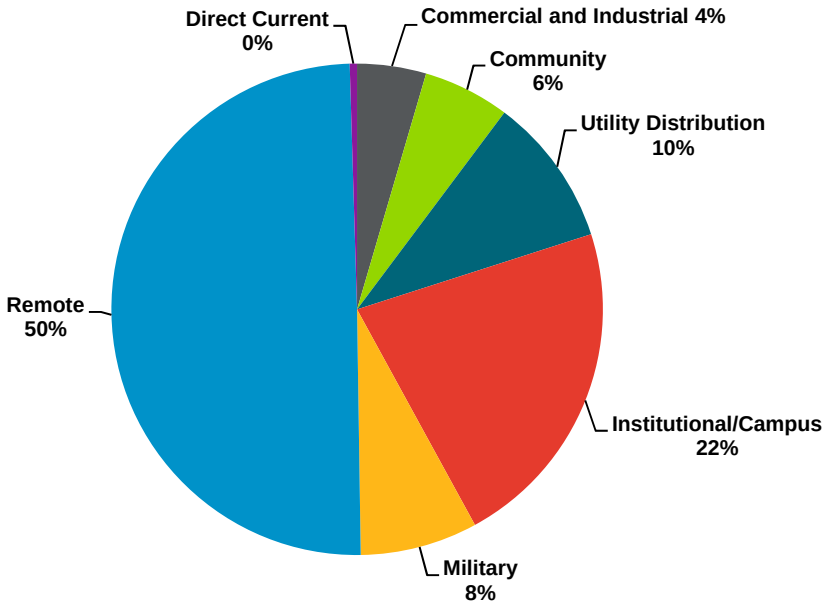
(Source: Navigant Research)

WHAT IS A MICROGRID?

- **U.S. Department of Energy definition:**
  - *"An integrated energy system consisting of distributed energy resources (DER) and multiple energy loads operating as a single controllable entity in parallel to or islanded from the existing power grid"*
    - Navigant Research also includes remote microgrids in its analysis
    - These off-grid systems exist primarily in the developing world
- Primary segments (grid-tied):
  - Campus/institutional
  - Commercial & industrial (C&I)
  - Community
  - Community resilience—also called public purpose microgrids
    - Supported by state programs
    - May include mixed customer classes, critical facilities
  - Direct current—may overlap with other applications
  - Military—U.S. stationary base systems
    - Not off-grid forward operating bases
  - Utility distribution microgrids—recent phenomenon

LARGEST MICROGRID MARKET TODAY IS REMOTE SEGMENT

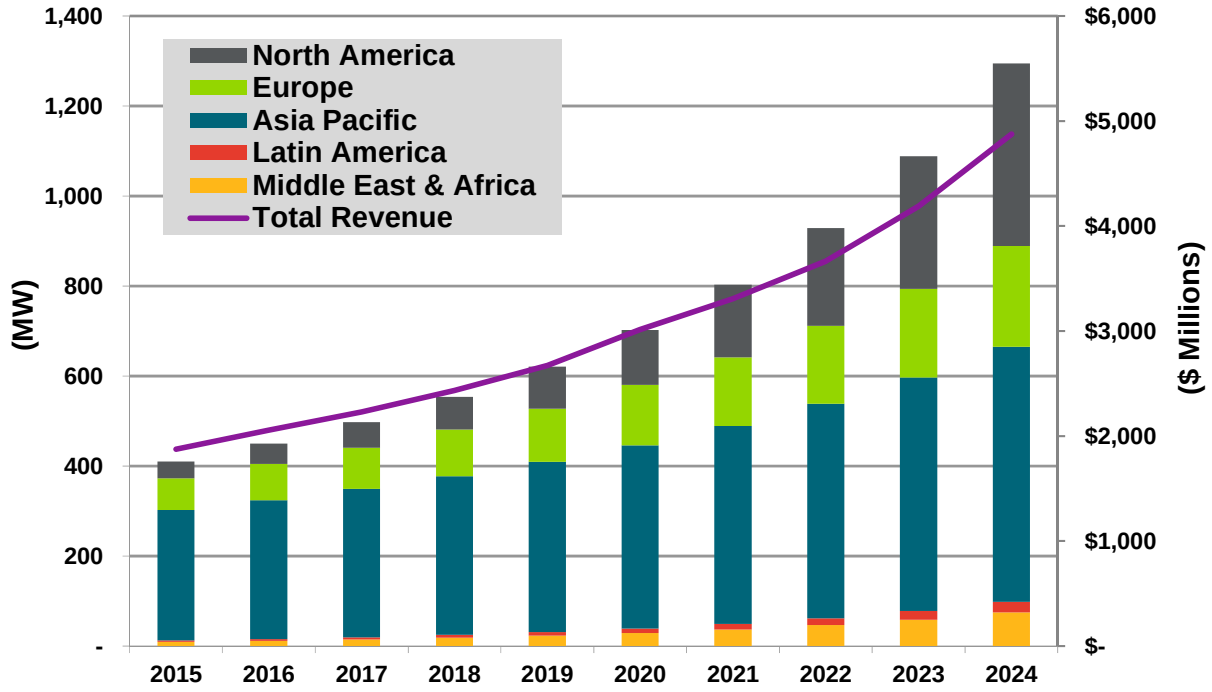
Total Identified Operational Microgrid Capacity, North America: 2Q 2016



(Source: Navigant Research)

UTILITY DISTRIBUTION MICROGRIDS

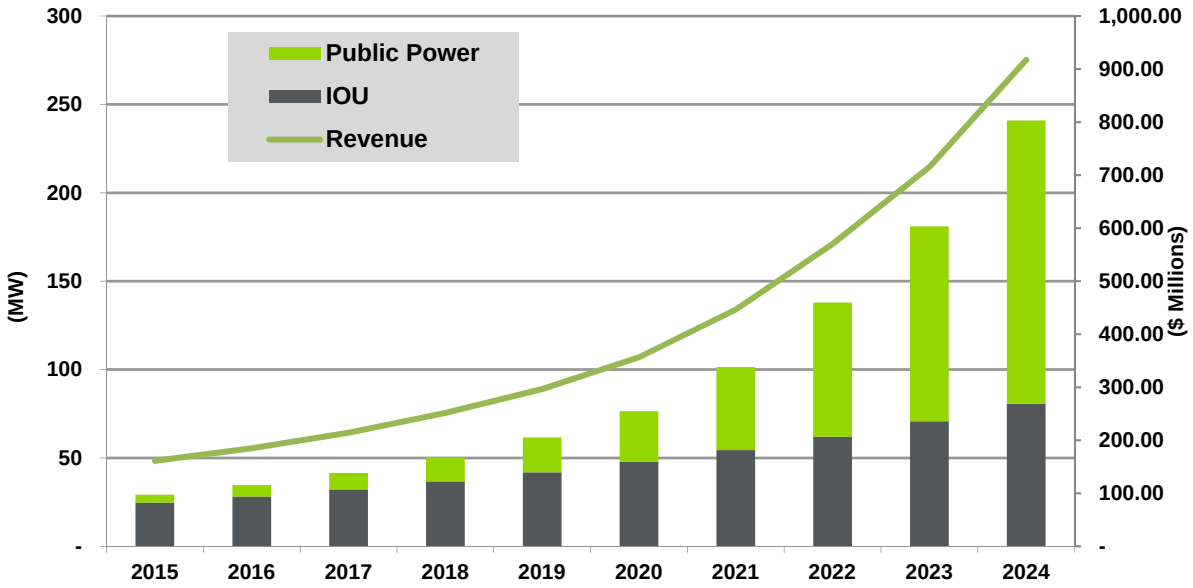
Annual Utility Distribution Microgrid Capacity and Implementation Revenue by Region, World Markets: 2015-2024



(Source: Navigant Research)

HOW DOES PUBLIC POWER STACK UP ON MICROGRIDS?

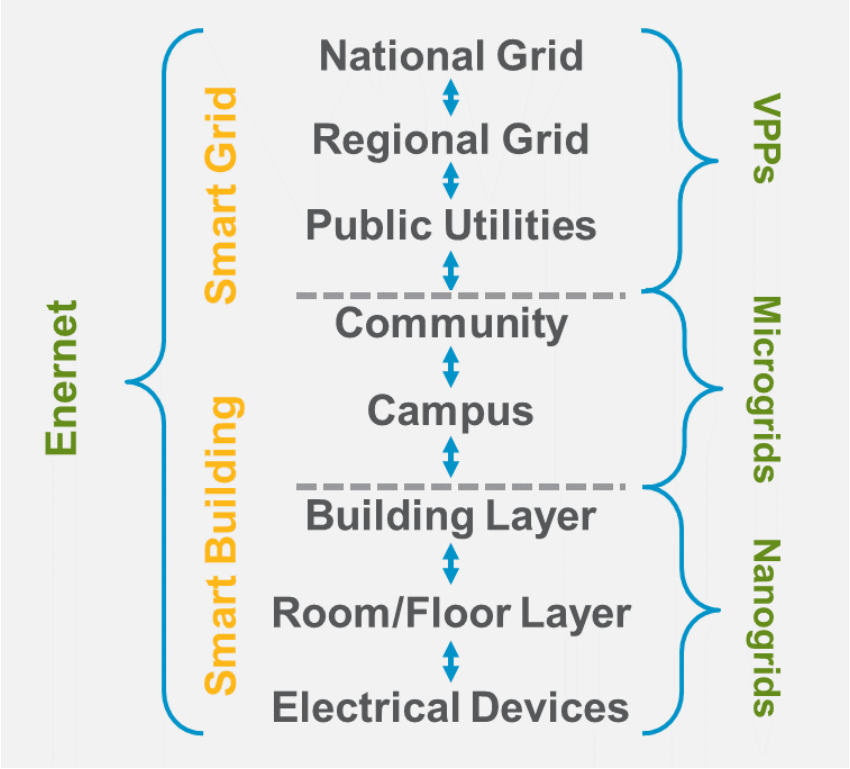
UDM Capacity & Revenue, United States: 2015-2024



(Source: Navigant Research)

THE EMERGING ENERNET LANDSCAPE

Enernet Links Up Nanogrids to Microgrids



(Sources: EMERGE Alliance, Navigant Research)

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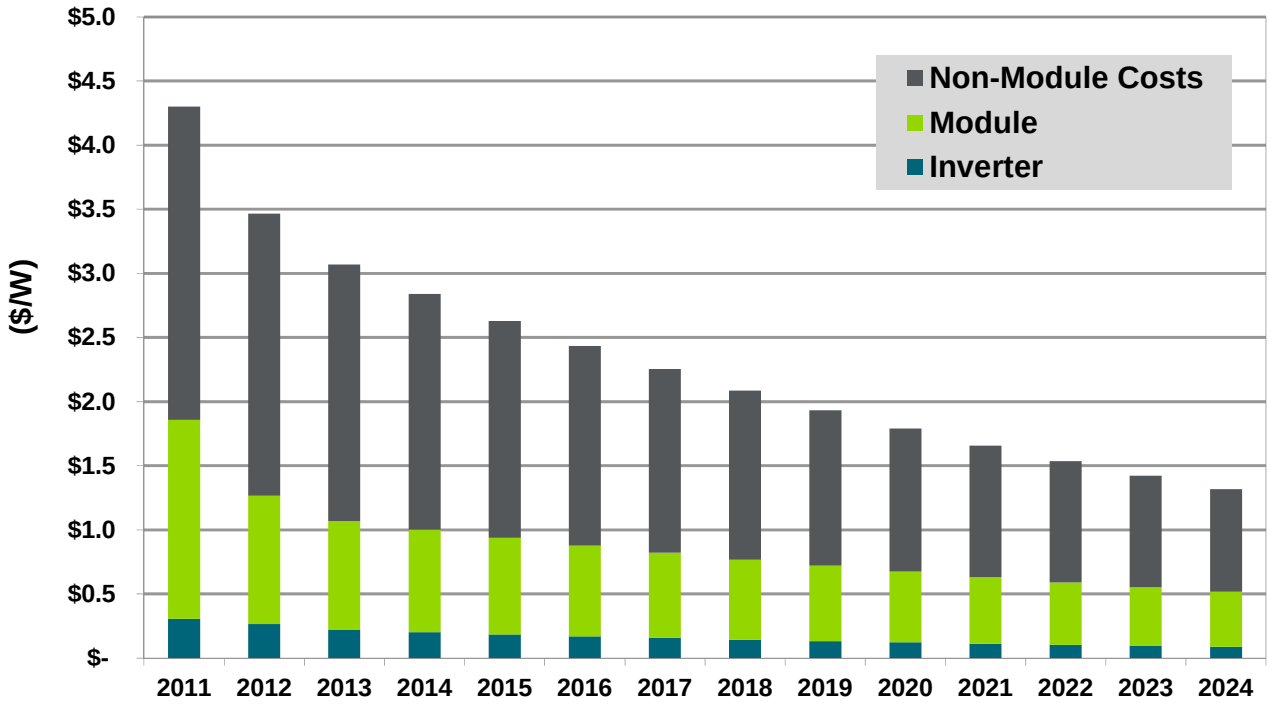
DISTRIBUTED SOLAR PV COSTS DECLINING RAPIDLY

Distributed Solar PV Installed System Prices (Non-Weighted Average) by Component, World Markets: 2011-2024



(Source: Navigant Research)

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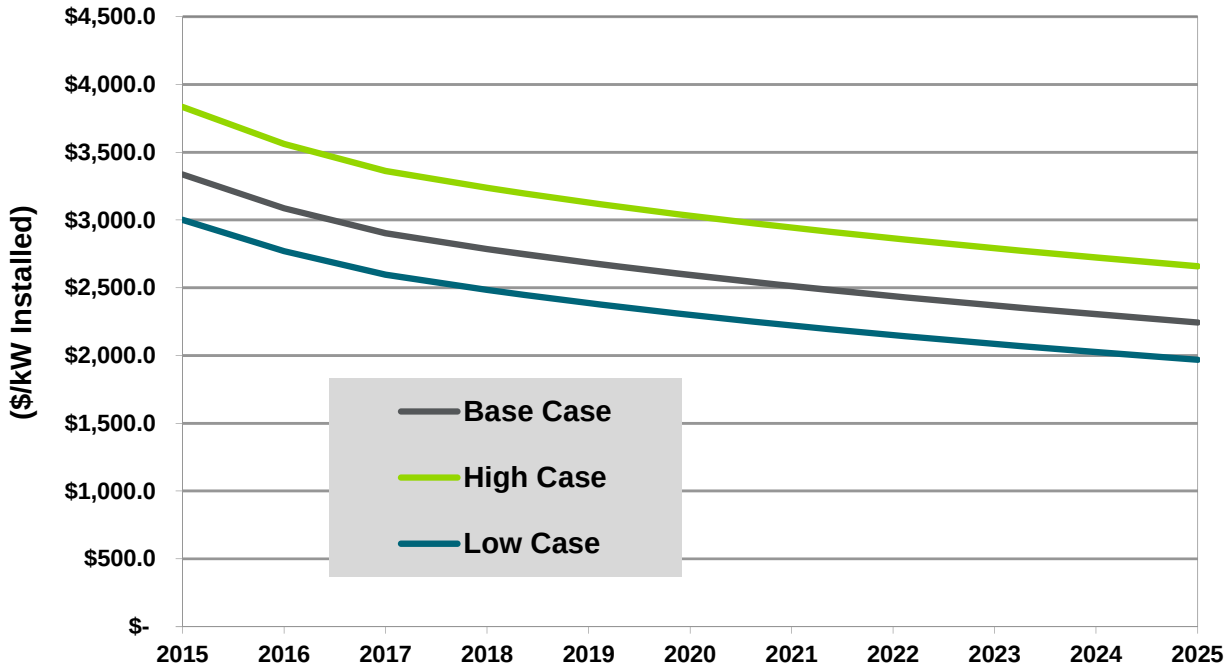
WHAT ABOUT RESIDENTIAL ROOFTOP SOLAR PV?

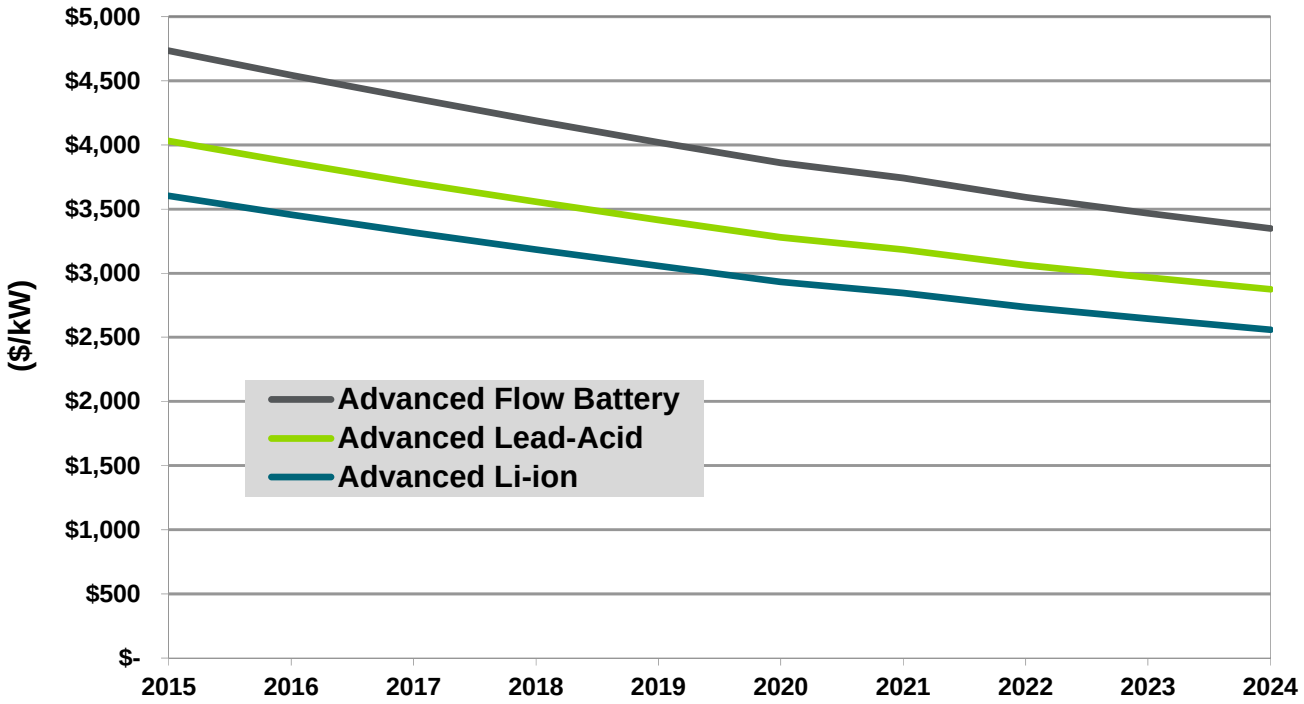
Residential Solar PV Price Range, All Scenarios, United States: 2015-2025



(Source: Navigant Research)

DISTRIBUTED ENERGY STORAGE FOLLOWING SIMILAR DOWNWARD COST TRAJECTORY

Average Installed Energy Storage System Cost for Distributed Applications by Technology, World Markets: 2015-2024



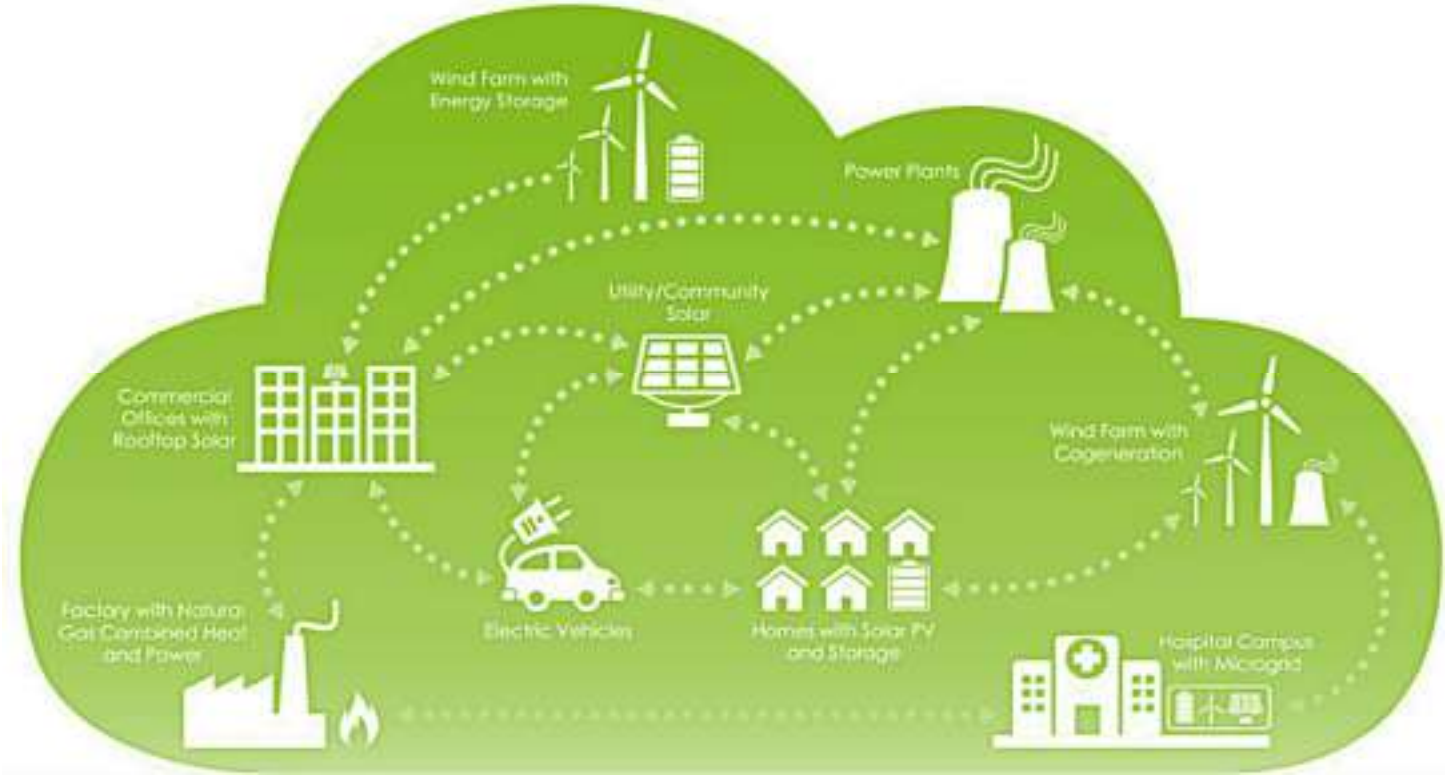
(Source: Navigant Research)

VIRTUAL POWER PLANTS? DO THEY REALLY EXIST?

- No widely acknowledged or precise definition of a virtual power plant (VPP)
- The use of the term virtual connotes something not solid or something temporary, which is (partially) accurate with a VPP
- Navigant Research definition:
  - *"A VPP is a system that relies upon software and a smart grid to remotely and automatically dispatch and optimize distributed energy resources via an aggregation and optimization platform linking retail to wholesale markets."*
- Many VPPs in the United States have no generation at all—just DR resources
- Leading model in Europe has focused on supply-side renewables integration
- The end goal of VPPs: Integration of all forms of DER into temporary solutions in real time that bring value from distribution to transmission level networks
- **Latest trend:** aggregation of solar PV plus energy storage nanogrids into VPPs providing value to utilities and transmission system grid operators

IS THE VPP THE ULTIMATE EXAMPLE OF THE ENERGY CLOUD?

Emerging: The Energy Cloud



(Source: Navigant Consulting)

FROM NANOGRIDS TO MICROGRIDS TO VPPS

Capabilities Comparison: DER Platforms

Capabilities	Nanogrids	Microgrids	VPPs
Grid-tied	Sometimes	Sometimes	Always
Islanding	Usually	Yes	No
Storage	Most of the time	Often	Sometimes
Geographic range	Confined to load	Confined to network	Wide and variable
Resource mix	Static	Static	Mix and match
Grid connection	Mostly behind the meter	Mostly behind the meter	Mostly transmission node
Market impact	Retail	Retail first then wholesale	Wholesale first then retail

(Source: Navigant Research)

WHY NANOGRIDS OVER MICROGRIDS?

- Nanogrids face less regulatory issues
  - Single buildings/single loads = less complexity
  - Control schemes can be simplified, leveraging power electronics advances
- Nanogrids do not challenge utility franchise issues since they do not send power over public rights of way
  - That is why Massachusetts has given priority to nanogrids over microgrids in community resilience funding
- Nanogrids can serve as building blocks for future microgrids
  - Or can compete for resiliency services with microgrids today
- Nanogrids can also serve as building blocks for VPPs
  - Deployments already underway in the United States, Canada, Germany, Australia, and Japan
- Unlike larger networks, nanogrids can be deployed today without additional major regulatory support (though barriers still remain)
  - They also foster innovation with direct current applications for C&I customers

WHY MICROGRIDS OVER NANOGRIDS?

- Microgrids can leverage efficiencies of aggregating and optimizing multiple and diverse DER, reducing emissions by subbing renewables for diesel
- Microgrids can capture economies of scale with networks as large as 100 MW-200 MW in size
  - And blend legacy assets with new and cleaner DG plus energy storage
- Long list of major technology firms are active in the microgrid space, bringing credibility and significant investment to the table
  - ABB, Eaton, GE, JCI, Lockheed Martin, Schneider Electric, Siemens, Samsung, Toshiba, etc.
- Long list of smaller innovators accelerating innovation in controls and new business models too
  - Among them software innovators also active in VPP markets
- Several states have launched specific programs promoting microgrids
  - They range from New York and rest of eastern seaboard to California
- Utilities are expanding their roles in the microgrid market, signaling commercial opportunities among market players historically opposed to microgrid concepts

WHY VPPS OVER MICROGRIDS?

- VPP model avoids the following concerns about microgrids:
  - Safe intentional islanding
  - Violations of utility franchise issues
  - Allocation of costs/benefits between hosts, third-parties, and utilities
- Some VPP segments—such as DR—have wide stakeholder support, including among utilities and independent system operators (ISOs)/regional transmission organizations (RTOs)
- Increasing reliance upon variable renewable DG requires aggregation and optimization schemes that provide value to the larger grid—not just onsite consumers/producers (prosumers)
- VPPs provide clear bidirectional value from the smart grid
  - Countering the negative perceptions of smart grid technologies among skeptics
- VPPs harness value from assets over wide geographies
  - Microgrids are confined to a static set of resources within defined boundaries

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