Developing Economically Viable and Resilient Microgrids

GE Distributed Grid Solutions

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What's a Microgrid?

What about Grid Resilience?

re·sil·ience
riˈzilyəns/

noun

1. the ability of a substance or object to spring back into shape; elasticity.

2. the capacity to recover quickly from difficulties; toughness.

Grid Resilience…

The degree to which an electrical grid is reliable, recoverable, & efficient

imagination at work

Two ways of looking at resilience…

Tenacity

Wisdom

By wisely planning your energy system you can avoid being forced to rely on your capacity to react

imagination at work

Trends Disrupting the Power Sector from Generation to T&D

DECARBONIZATION

By 2040, **RENEWABLES will represent 30%** of global net electricity

IMPACT

- Generation is becoming difficult to forecast & variable
- Grid stability, Congestion Volatility on electricity markets

DIGITIZATION

GROWING THE NUMBER of **connected devices** & **smart sensors**

IMPACT

- Allowing decision making based on dynamic and nodal prices

DECENTRALIZATION

GROWING PENETRATION of **distributed resources** (renewable, storage, efficient devices)

IMPACT

- End user becomes an active actor of the power system ('pro-sumer')
- Growing complexity of distribution grids

ELECTRIFICATION
in energy ecosystem

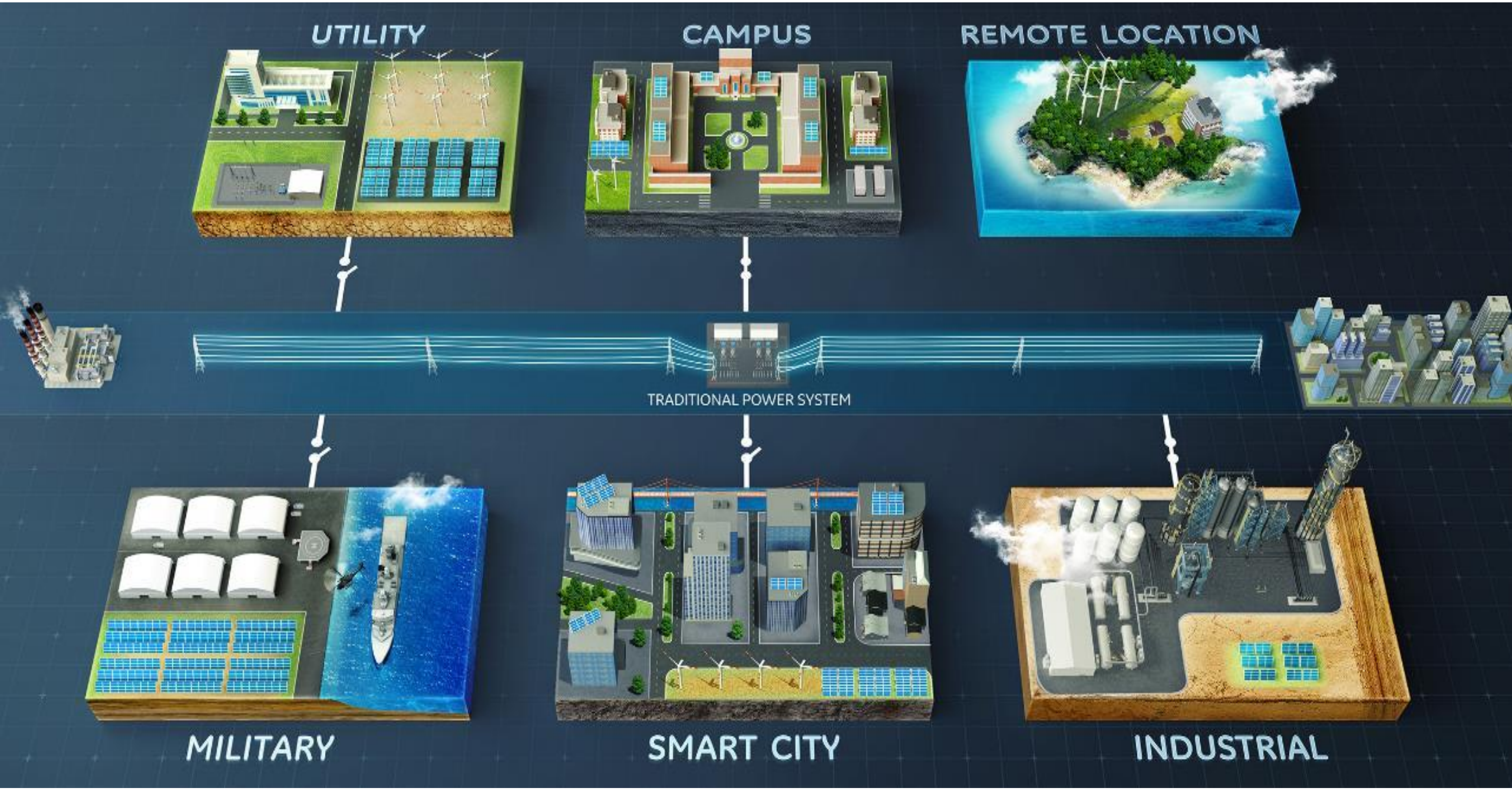
ELECTRIFICATION OF ENERGY USES, transport (EVs) and heating

IMPACT

- Growth of Electricity demand, and an acceleration of decentralization of the power sector

Microgrids In Many Forms

- Provides sufficient and continuous energy to meet internal demand
- Possesses independent digitalization that can island or reconnect with minimal disruption
- Presents itself as a single controlled unit to the bulk power system – revenue opportunities
- Offers flexibility in how the power delivery system is configured and operated
- Enables optimization of a large network of load, local Distributed Energy Resources and the broader power system



Key Challenges in Developing Microgrids

Complexity

- Integration of DERs
- Multiple stakeholders

Economics

- Cost
- Business model
- Financing…particularly with multi-user microgrids

Utility / Market Interaction

- Potentially competes with utilities
- Utility business models

Technical

- Voltage & Frequency Control…managing stability
- Islanding & grid integration
- Protection & Control

Regulatory

- Nascent regulatory environment
- Fragmented regulations

An holistic approach is essential in developing economically viable microgrids

Monetized interaction are necessary in order to pay for resiliency premium & attract private investment

Utility Needs

- Reliability and Stability Improvement
- Reduce System Losses
- Situational Awareness
- Optimal balance (supply and demand) of distributed resources to enable reliable and economic operation

Microgrids need to:

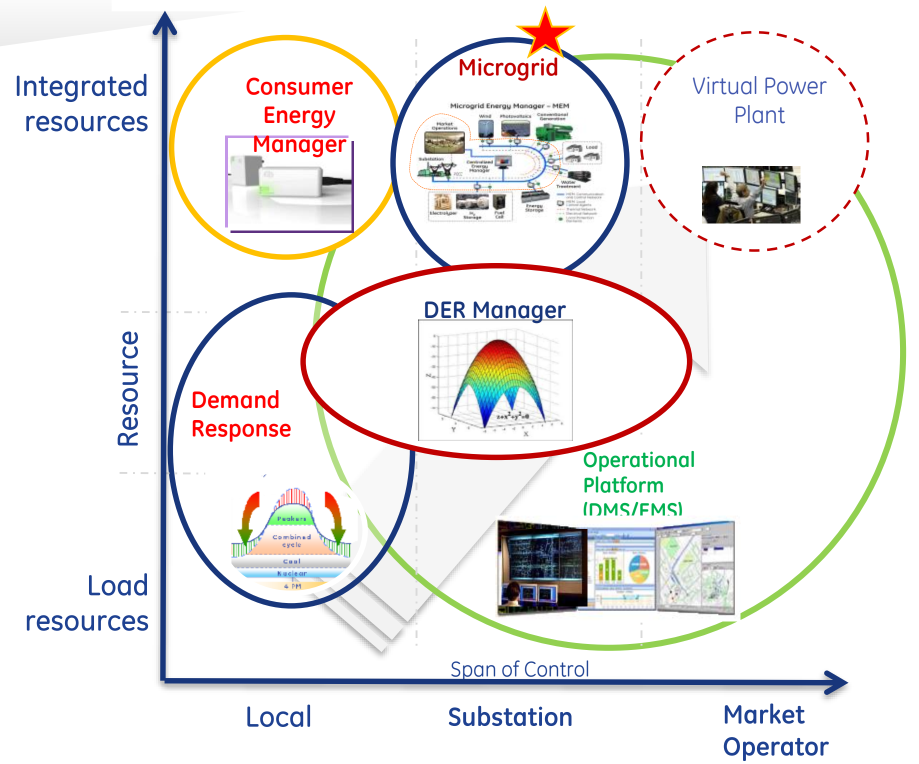
Provide solutions and services to plan, forecast, schedule, and dispatch

What

- *Load resources– dispatchable consumption*
- *Distributed generation - Renewable or non renewable generation*
- *Integrated resources – load and generation systems*

Where

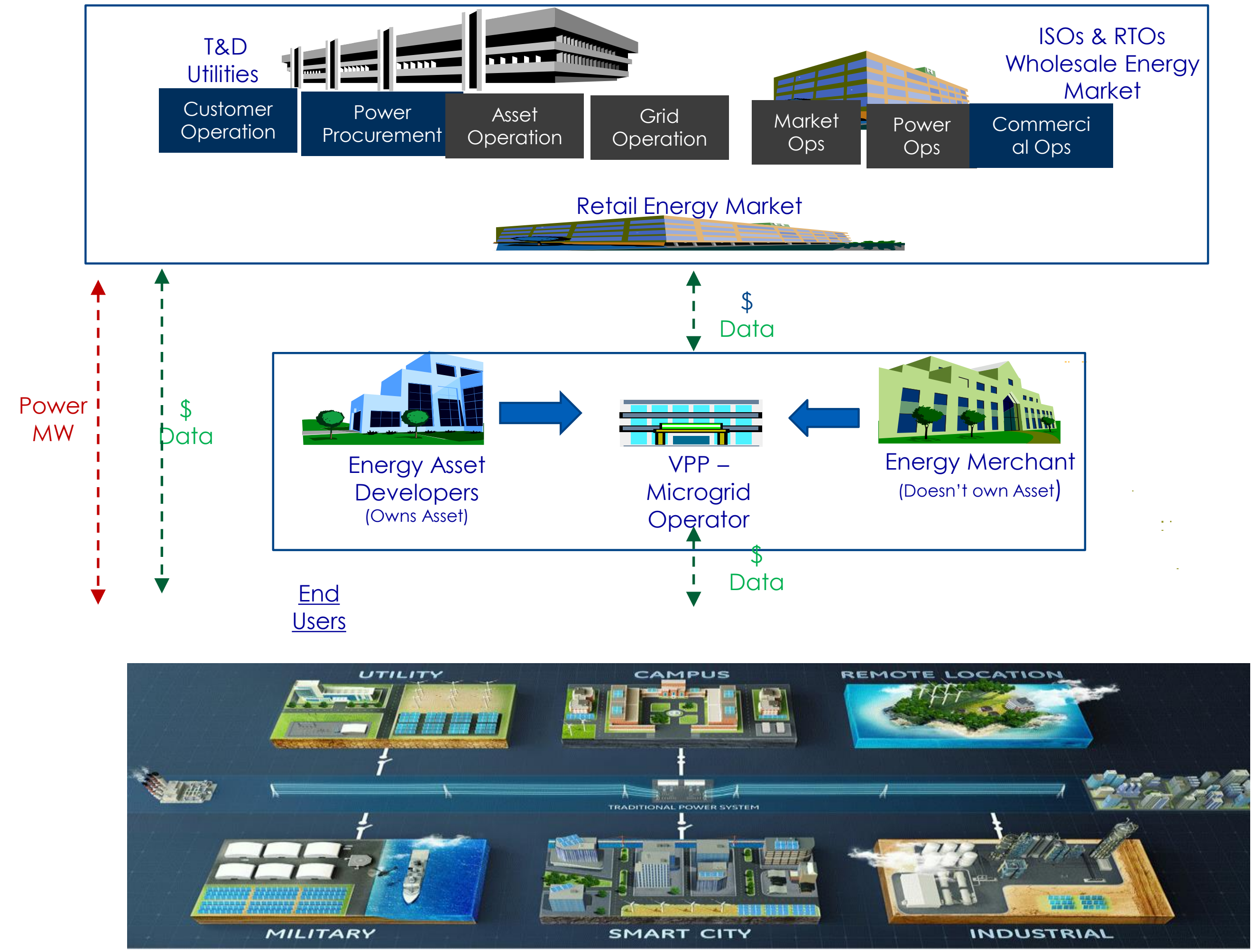
- *Local – residential, commercial, and industrial*
- *Substation /Feeder – distribution system*
- *Market Operator – electricity and balancing market*



Innovative business models at each level will drive market transformation

GE imagination at work

Revenue streams outside of the microgrid can help pay for the premium of energy surety



Market segments and drivers will drive the value proposition

Energy Surety — **Sustainability** — **Economic Value**

MILITARY
Bases w/ Critical Infrastructure

INDUSTRIAL
Mining/Refineries
Ports

ISLANDS
Remote Grid Communities

Institutional / District
University/labs
Hospitals
Utility Microgrids

DRIVERS

MILITARY	INDUSTRIAL	ISLANDS	Institutional / District
BASE ISLANDING	CRITICAL INFRASTRUCTURE	FOSSIL FUEL DEPENDENCE	RENEWABLES INTEGRATION
RENEWABLES INTEGRATION	RENEWABLES INTEGRATION	RENEWABLES INTEGRATION	COE REDUCTION
ENERGY EFFICIENCY	ENERGY RELIABILITY	ENERGY RELIABILITY	ENERGY RELIABILITY
CRITICAL INFRASTRUCTURE	ENERGY EFFICIENCY	ENERGY SECURITY	CRITICAL INFRASTRUCTURE
ENERGY SECURITY	ENERGY SECURITY	COE REDUCTION	ENERGY SECURITY
COE REDUCTION	COE REDUCTION	Industrial Efficiency	Microgrid R&D

Primary Drivers
Secondary Drivers

Convergence of environment, energy cost/efficiency, security, and system reliability prove to be the key drivers for Microgrids . . .

imagination at work

Correctly Design your Energy System

Aligning drivers, challenges, and resources to get to the correct type of system

End-user & Utility Challenges

Security

- Installation-wide energy & H2O security
- End-user operations resilience, assured fuel, reduced logistics tail, etc.
- Cyber security

Regulatory

- Compliance now & future planning
- Federal/state mandates & regulations, NetZero initiatives, carbon legislation

Financial

- Reduce cost through efficiency & intelligent system design
- Optimize energy-to-investment ratio
- Utility cost/benefit

End-user Drivers

1. Increased **energy independence** … leads to energy efficiency improvement projects
2. Multiple **recent regulations** instituted … forces planning for current/future regs
3. Growing **water scarcity** … drive water consumption reduction projects
4. Strong **operational performance** focus … need to optimize full life-cycle costs
5. Multiple other additional pressures …

Energy Surety | Sustainability | Economic Value

End-user & utility energy objectives will drive whether you will have a:

- *Natural gas based microgrid*
- *Renewables based microgrid*

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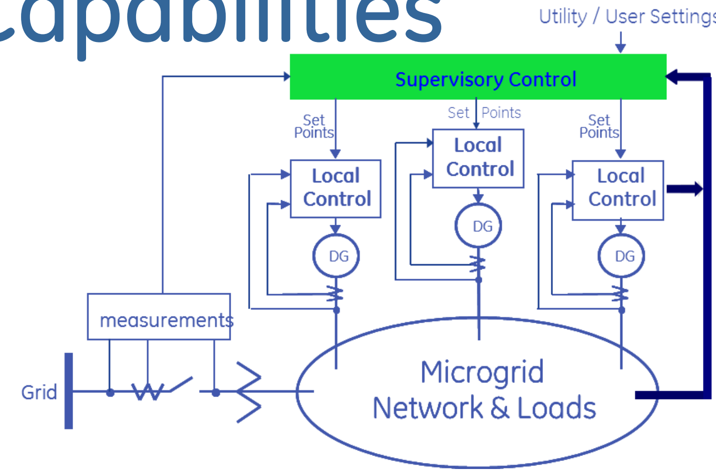
GE Microgrid Functional Capabilities



Supervisory Controls

- Optimal Dispatch to optimize electrical and thermal performance and cost
- Manage feeder connection to bulk grid
- Manage renewable intermittency
- Demand Optimization
- Integrated Volt / VAR Control

Power, Frequency, Voltage, VARs

Holistic Energy System

- Supply & demand
- Utility interaction/Cyber Security/IT Infrastructure

Optimal Dispatch

The process of allocating the required load demand between the available resources such that the cost of operation is minimized.

- The optimal dispatch algorithm implements *Model Predictive Control* using:
  - **Load** forecasts
  - **Renewable** generation forecasts (wind, hydro, solar, bio-mass)
  - and **Stored Energy**

Additional optimization constraints include:

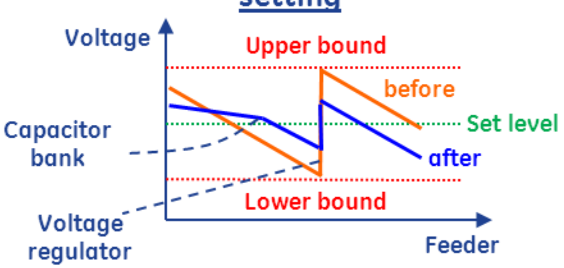
- Unit Commitment, Start/Stop
- Min/max power/thermal output
- Generator Efficiency, Storage Efficiency
- Speed to ramp up/down output
- Electricity–to-thermal ratio in Combined-Heat-Power (CHP) source
- Market price of electricity (if connected to the utility grid) and fuel for DER Assets

Demand Optimization

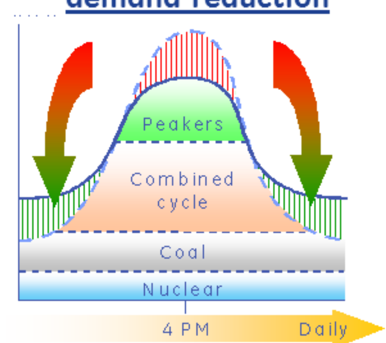
- **Emergency Load Shedding**
- **Load as a Resource**
  - **Building Energy Management**
  - **Backup Gensets**

Grid Optimization & Utility Interaction

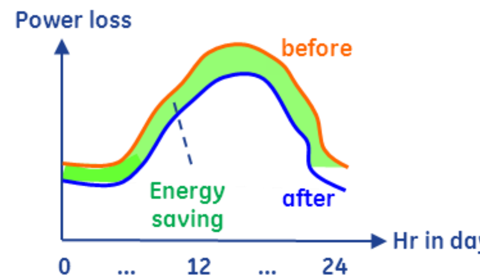
Flatten voltage around a desired setting



Energy Balancing w/ peak demand reduction



Power loss minimization



Leveraging microgrids as a foundation for economic development

Examples

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Pearl Street Microgrid (1882)

- Primary driver was selling lightbulbs
- Ten 27 ton 100Kw steam generators
- DC Power Microgrid
- Served 59 Customers
- Islanded operation
- HMI enabled

GE imagination at work

Modern day example
Urban vertical farming

- Eastern Japan 2013, **25000** Sq. Ft.
- 18 racks each 15 levels, **17000** LED fixtures
- **10000** heads of Lettuce per day (100 fold density increase from outside)
- Grows **2.5X** faster than outside
- Waste from **50% to 10%** compared to outside
- **1%** of water usage compared to outside
- LED **40%** less power than florescent light

The Philadelphia **Navy Yard**

Location: The Navy Yard

- Centralized location
- Access to:
  - Major highway
  - Intermodal freight system
  - International Airport
  - Center City, University City, 30th Street
  - Sports Complex

The Navy Yard **Then & Now…**

Philadelphia Navy Yard 1999, source PIDC

- **3,000** employees
- **10** Companies
- Limited private investment
- **20+** years deferred infrastructure

Philadelphia Navy Yard Today, source PIDC

- **12,500** employees
- **150+** companies; **3** Navy activities
- **7.5 million** SF occupied real estate
  $750+ mil of private investment
- **$150+** mil of publicly funded infrastructure upgrades

A New Model: The Smart City, Digital Urban Campus

THE NAVY YARD SMART ENERGY CAMPUS

The Challenge

Decaying Infrastructure

Avoid Higher External Supply Costs

Provide Energy choice Options
Renewable & Resilience

THE SOLUTIONS

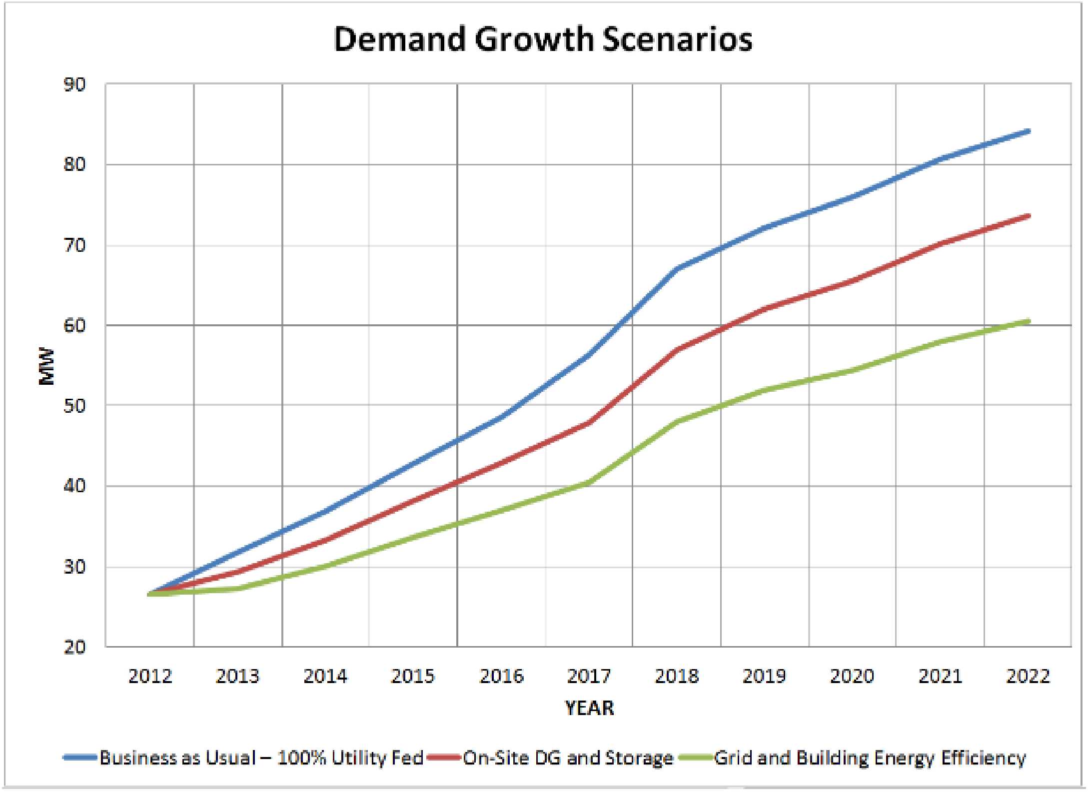
- Navy Yard Energy Master Plan
- GE Microgrid Controller & Solutions Team
- System that can acquire data & process with concluding actions
- A scalable platform for customer integration
    - 20% EE
    - 30% On-site DERs
    - PJM market participation

The Navy Yard **Energy Master Plan** "Constitution"

The Five Point Action Plan

- ✓ **Infrastructure**: Capacity, Generation/Supply, Technology Microgrid
- ✓ **Business Model**: Forecasts, Tariffs, Procurement, O & M, Capital
- ✓ **Building Owner Opportunities**: DG, EE, DR – Programs & Partnership
- ✓ **Test Bedding Outreach and R&D**: Energy Innovation Campus
- ✓ **Carbon Reduction and Sustainability**: Reduce Carbon Intensity

Reducing Demand & Usage Adding Supply Independence



Cumulative **usage** decrease – over 61,000 MWh

Business as Usual – 100% Utility Fed

- All PECO supply
- No On-site generation (DG)
- No proactive EE or DR effort

  Utility Demand - 82 MW

On-Site DG

Grid Programs:

- Natural gas DG
  - 6 MW Peak Reduction
  - 3 MW CHP (data center)
- 1 MW Solar PV
- 600 KW Fuel Cell

  Utility Demand - 72 MW

Demand Response & Energy Efficiency

Customer programs:

- 20% EE goal by 2022
- Navy DOD mandates
- B-T-M Demand Reduction

  Utility Demand - 60 MW

Key elements needed to successfully achieve economically viable microgrids

Energy Surety & Renewable Energy Objectives Require Differing Approaches

- **Energy Surety Goal:** Most cost effective method will lean towards natural gas generation microgrids
    - MG functionality: Islanding, fast load-shed, net metering, ancillary services
- **Renewable Energy Goal:** Most cost effective method will learn towards wind / biogas biomass/ landfill gas generation Microgrids
    - MG functionality: Optimal dispatch, firming, DSM, ancillary services

Utility Collaboration

- Microgrids need to interact and provide value to host utility
    - As well as supporting communities e.g. first responders, continuity of government, …
- Provide ancillary benefits (Supply/demand management, frequency regulation, …)
- Enable facility energy operator to contract with utility these services

Privatized & Monetized Structures

- ESCOs, IPPs, Utilities need to be able monetize the smart-grid features of the microgrid in order to offset cost of energy surety & attract investment
- Capitalization of existing assets can create opportunities for financial support

Unified Standards & Certification

- DOE needs to drive Microgrid/Smart Grid standards, interoperability, utility integration
- Cybersecurity & IT infrastructure standards
- Certification of technology, architecture, & functionality

Develop a long-term energy roadmap with off-ramps for incremental development

- Establish long-term vision with short-term requirements

Adoption, Policy, and Innovation Begins at the Local Level (You!)

"I'll be happy to give you innovative thinking. What are the guidelines?"