A NATIONAL TOWN MEETING ON
demand response
smart grid
presented by ADS
MAY 19-21
2014

Microgrid Workshop

Overview, Background, and Tutorial

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In the news

- **Connecticut Plans Nation's First State-Wide Microgrid**
  - August 2013 - Nine microgrid projects across the state of Connecticut have been awarded $18 million as part of the state's innovative strategy to keep critical buildings up and running during electric grid outages.
- **DOE and New Jersey Developing First US Transit System Microgrid**
  - August 2013 - The **US Department of Energy (DOE) announced** it will partner with New Jersey to share **military microgrid best practices** and develop a conceptual plan for the first-ever transit system microgrid as part of Superstorm Sandy recovery efforts.
- **Minnesota Microgrids: Barriers, Opportunities, and Pathways Toward Energy Assurance**
  - September 2013 - The Minnesota Department of Commerce (Commerce), Division of Energy Resources, commissioned a White Paper to identify regulatory barriers to and opportunities for microgrid development for energy assurance in the state of Minnesota, with recommendations to address barriers
- **New York Plans $40M in Prizes for Storm-Resilient Microgrids**
  - January 2014 - New York governor Andrew Cuomo has put $40 million in prize money behind his push to bolster the state's post-Hurricane Sandy storm resilience with community microgrids.
- **University Of Southern California**
  - March 2014 - there is a need to develop the existing distribution system in University of Southern California for fitting the new technology and offer Smart Grid research conditions for faculty, staff and students
- **California Public Utility Commission - Microgrids: A Regulatory Perspective**
  - April 2014 - Microgrids are being investigated across the country as a solution to support greater reliability, resiliency, and security of supply, but microgrids can be much more. We need to take care not to pigeon-hole microgrids as only a set of technologies capable of keeping the lights on specific locations. Rather, microgrids can provide far more benefits, not only to the customers of the microgrid, but to the grid as a whole. Encouraging and realizing these benefits should be investigated and considered as beneficial to the state and its customers.

About General MicroGrids

- General MicroGrids, Inc is an international microgrid developer, working with governments, industrial customers and sustainable communities. We focus on renewable energy technologies and transformational microgrid construction.
- As an end-to-end energy consulting and services company, we deliver renewable energy technologies and transformational microgrid construction.
- Safe, controllable and reliable MicroGrids integrating renewable generation are complimentary infrastructure with customer assets that increase grid reliability, stabilize long-term energy costs, and mitigate negative environmental impact.

Specifically…

- GMI provides governments policy and regulatory approaches for reliable, resilient energy resources.
- GMI optionally builds, owns, operates or maintains distributed energy resources at customer locations
  - Engineering
  - Energy Efficiency
  - Demand Management
  - Power Production and Storage
  - Energy Arbitrage
  - Microgrid Management









Definition

- A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid.
- A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode.

Industrialized World

- Increased penetration of renewable energy into the generation mix
- Technology upgrades within the utility
- New systemic impact occurring behind the meter
- Distributed energy resources will likely become the normal state; therefore, how do we integrate:
  - analog-centric power system
  - digital-centric information infrastructure
- Responding to these issues requires a new approach

Developing Countries

- Strategically deploy microgrid technologies (Distributed Energy Resources - generation, storage, controls, distribution, building automation)
- Establish standard approach for physical and cyber interconnections
- Create capacity for maintenance of the system
- Integrate resources and future requirements for sustainability – design to scale

What Problems Microgrids Solve

- **PRICE STABILITY**
  - Provides protection from market fluctuations
- **RELIABLE ELECTRICITY**
  - Always available and not subject to utility grid shutdowns
- **ELECTRICAL EFFICIENCY**
  - On-site generation and systems to maximize usage efficiencies
- **SECURITY OF ELECTRICITY SUPPLY**
  - Protected from external forces or incursions
- **ENVIRONMENTAL CONSERVATION**
  - Can use multiple sources or renewable and green energy
- **SCALABILITY**
  - Horizontal (population growth) & Vertical (increasing use)

Microgrid Strengths

- Absence of power
- Unreliable power
- Mixed utility integration (water, phone, gas)
- Rising grid energy costs
- Regional or national emission standards
- Expensive and delayed grid support
- Dispersed rural loads or supplies
- Reduce fuel usage

Complements Smart Grid

- High use of renewables – 20% – 35% by 2020
- Distributed generation and microgrids
- “Net” metering – selling local power into the grid
- Distributed storage
- Smart meters that provide near-real time usage data
- Time of use and dynamic pricing
- Ubiquitous smart appliances communicating with the grid
- Energy management systems in homes as well as commercial and industrial facilities linked to the grid
- Growing use of plug-in electric vehicles
- Networked sensors and automated controls throughout the grid

Microgrids

- Non-proprietary MicroGrid architecture
- Grid-level agents, Site-level agents and Device-level agents
- Built in decision support for policy based workflow
- Embedded behaviors for power analytics
- Agents operate autonomously
- Real-time, deterministic domains
- Performed using Smart Grid standards

Microgrid Classifications by Energy Generation

1. **Single Facility (<2MW)** - Smaller individual facilities with multiple loads, e.g., hospitals, schools, hotels complex.
2. **Multi-Facility (2-5MW)** - Small to larger traditional CHP facilities plus a few neighboring loads exclusively C&I.
3. **Feeder (5-20MW)** - Small to larger traditional CHP facilities plus many or large neighboring loads, typically C&I.
4. **Substation (>20MW)** - Traditional CHP plus many neighboring loads. Will include C&I plus residential.
5. **Rural Electrification (various size MW)** - Rural villages of many emerging markets of India, China, Brazil etc., as well as rural settlements found in Europe and North America, Indian reservations, remote geographical locations.

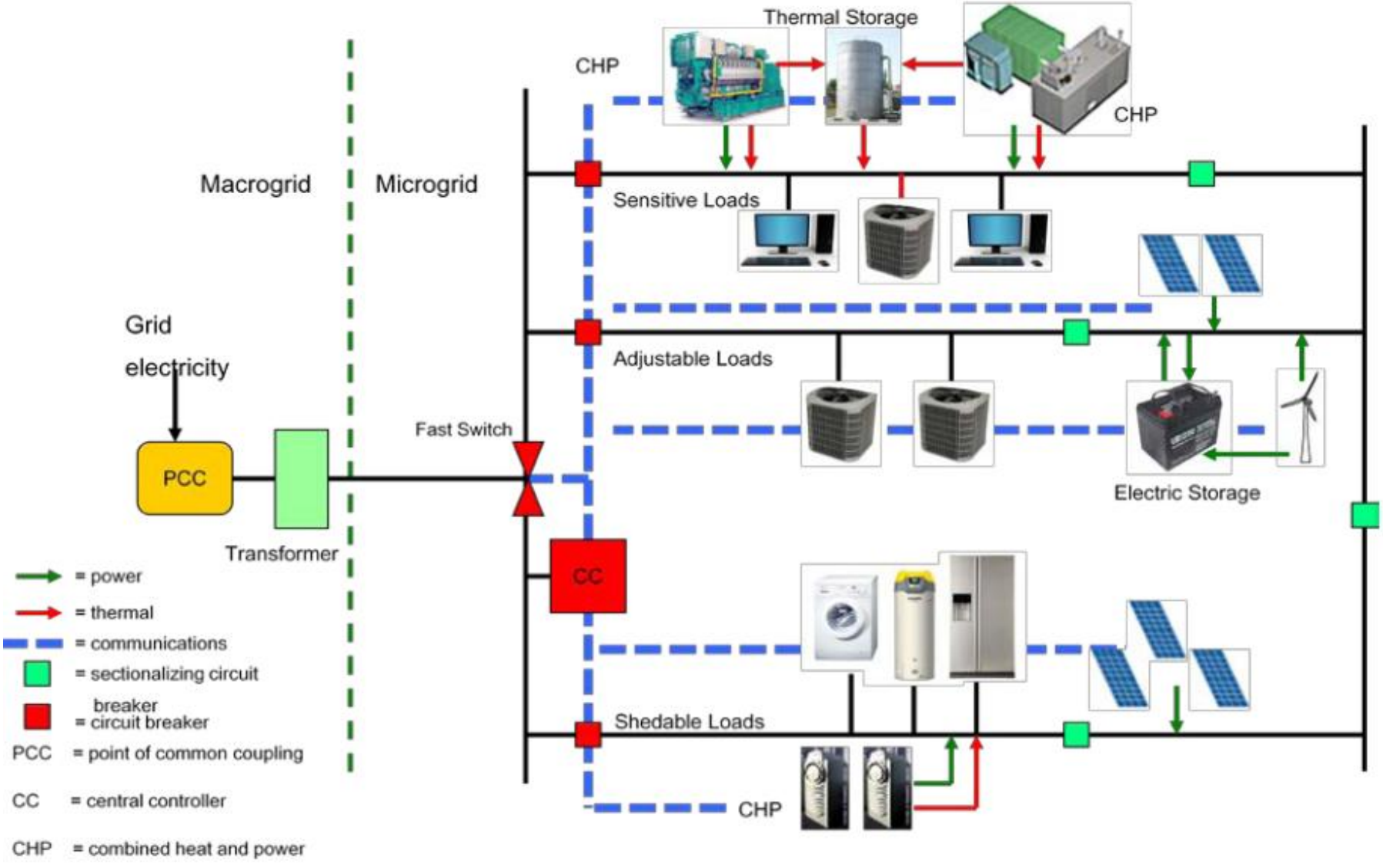
Different than "the grid"

- Consumer engagement with resources to solve power issues locally
- High penetration of local renewables in residential, commercial, and industrial
- Not passive but active control in distribution
- Two-way power flow in distribution
- Distribution can become a transmission resource
- Components are part of a cohesive system – high dependency on standardization (physical and data)

Microgrid Islanding

- Smoothly transition between Main Grid-connected operations and disconnected operations for various reliability and economic reasons.
- Business Value:
  - Continuity of service in the face of reliability challenges
  - Better manage cost of service for the consumers in the microgrid community
  - Solve performance issues leading to better reliability metrics
  - Improved customer satisfaction
- Scenario 1: Unplanned Islanding (Loss of Transmission)
- Scenario 2: Synchronizing with Main Grid
- Scenario 3: Planned Islanding

Microgrid Concept Diagram



Microgrid "Cells"

- Ideal for…
  - Village
  - Rural Community
  - University Campus
  - Business Park
  - Electric Cooperative
  - Municipality
  - Utility Distribution
  - Military Base
- Owned by…
  - Customer
  - Developer
  - Utility
  - Investment trusts

Communities of Microgrids

- Networked Microgrids
- Aggregated Microgrids
- Participate in grid and market support
- Transactive markets
- Individually, each offers unique capabilities
- Central management

Energy Network

- Consumer engagement with resources to solve power issues locally
- Increased, local renewables in residential, commercial, and industrial
- Two-way power flow in distribution
- Transform from passive to active control in distribution
- Distribution becomes a transmission resource

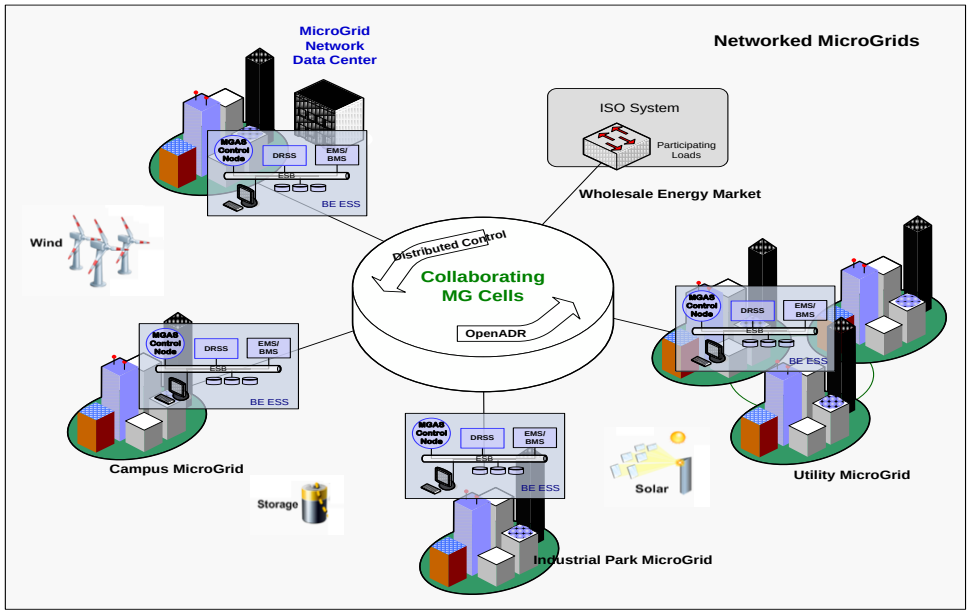
Electric Grid

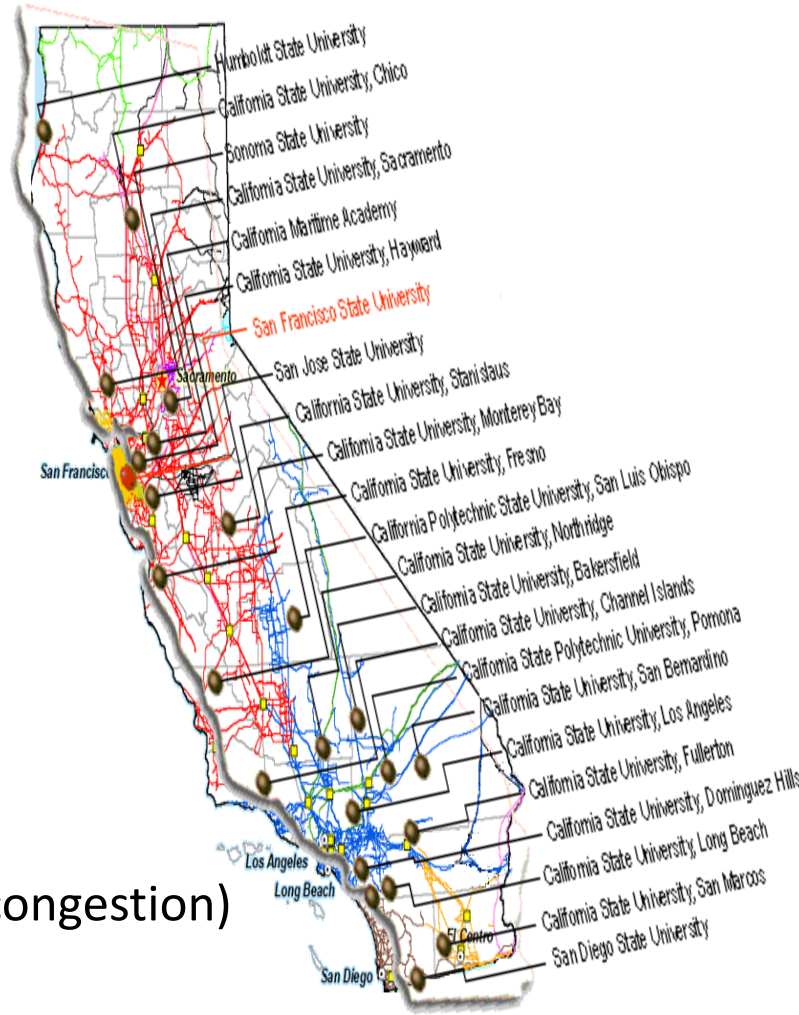
- 100 year old infrastructure
- Transmission over capacity and expensive to fix or extend
- Distribution designed for one-way delivery and subject to local failure
- Central power production is inefficient and expensive to build, operate, maintain

Value Proposition

- Balance energy between demand (load) and onsite generation in real-time
- Balance between distribution grid and microgrid
- Ability to island microgrid
- Manage procurement of energy from grid if necessary

Networked MicroGrids

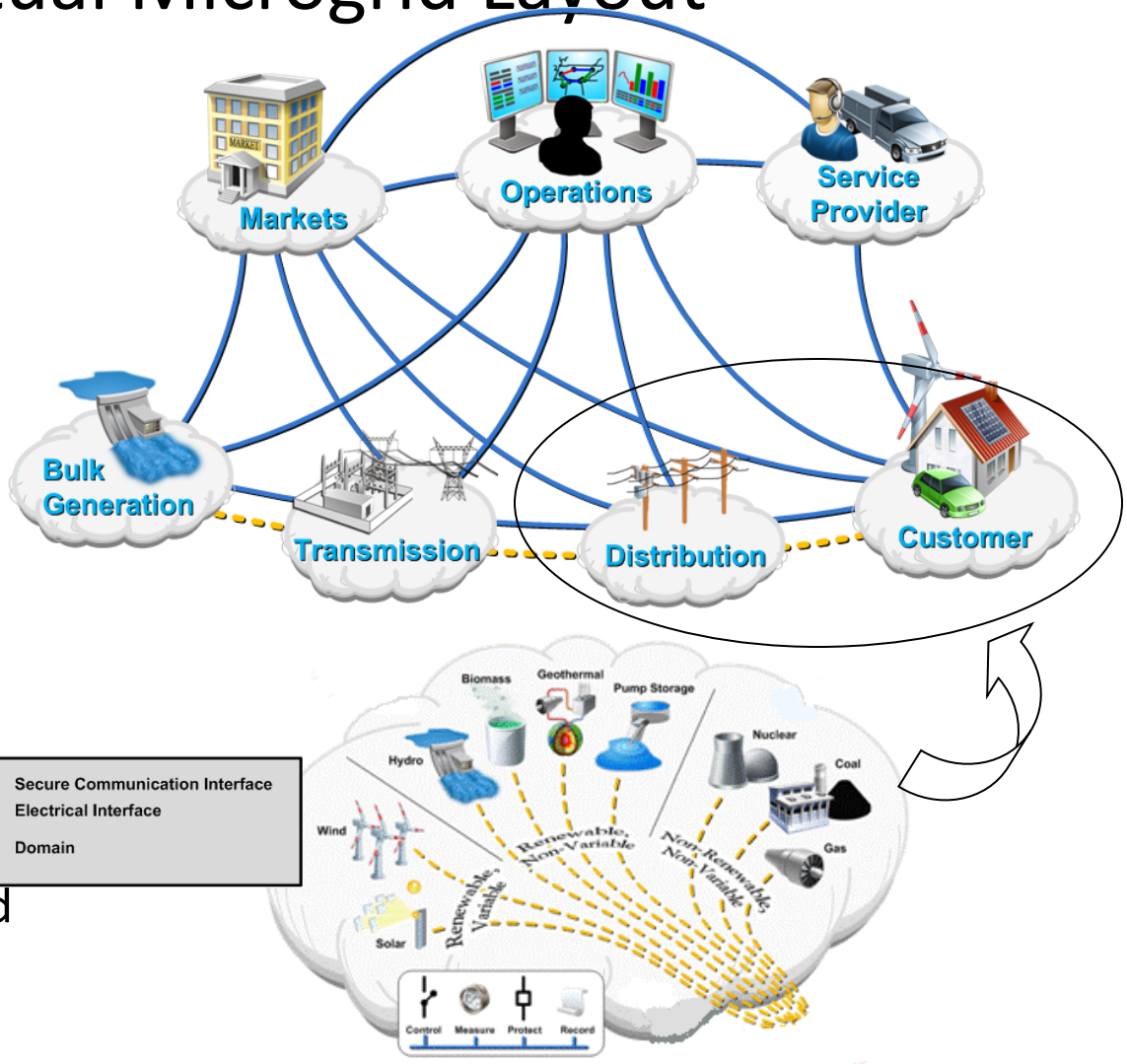




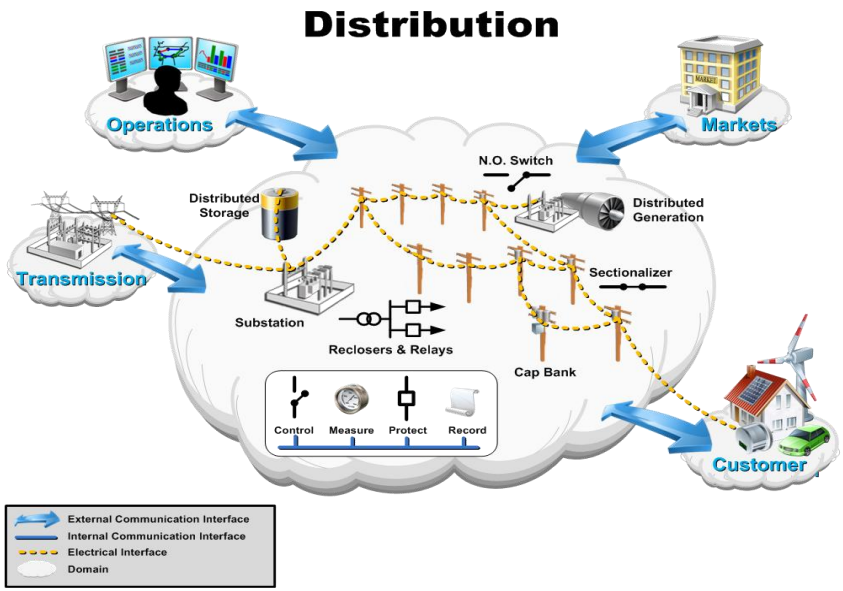
- Neighborhood storage
- Between communities
- Within municipality districts
- Aggregated locally (feeder) or geographically (congestion)
- May need some changes to regulatory policy

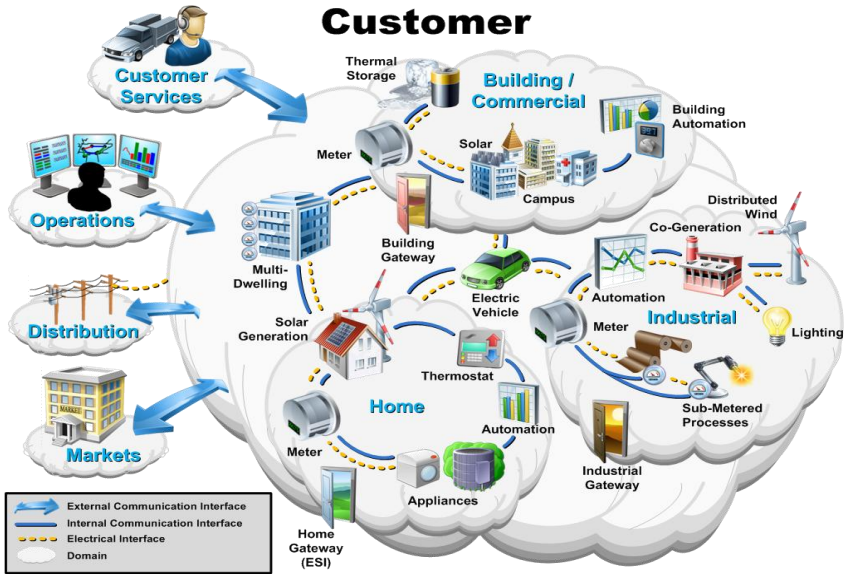
Conceptual Microgrid Layout

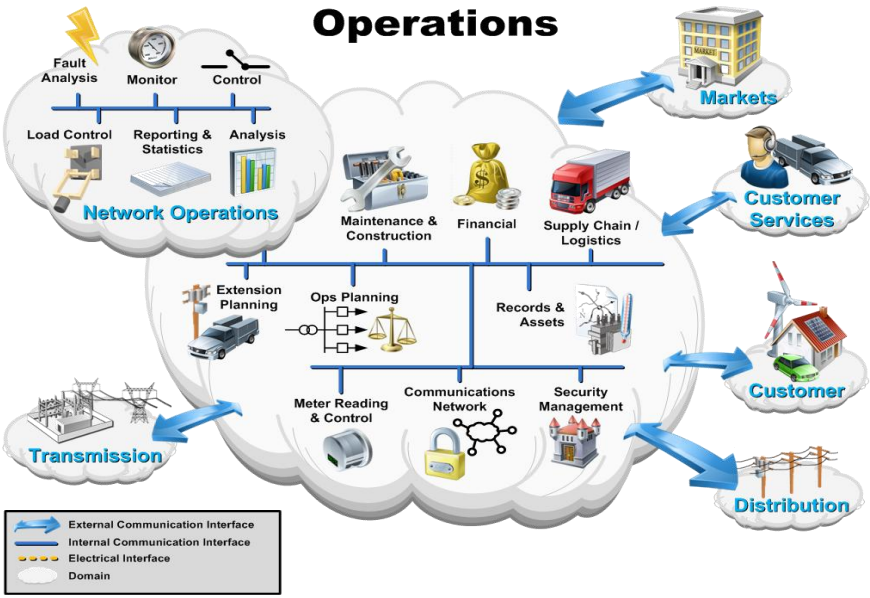
- The Conceptual layer defines all possible domains that may be engaged in the operation of a microgrid
- New thinking on microgrids relies on a scaling of capability with appropriate utilization of renewables to meet the end-customers needs
- Integrates end-use applications with localized generation and storage

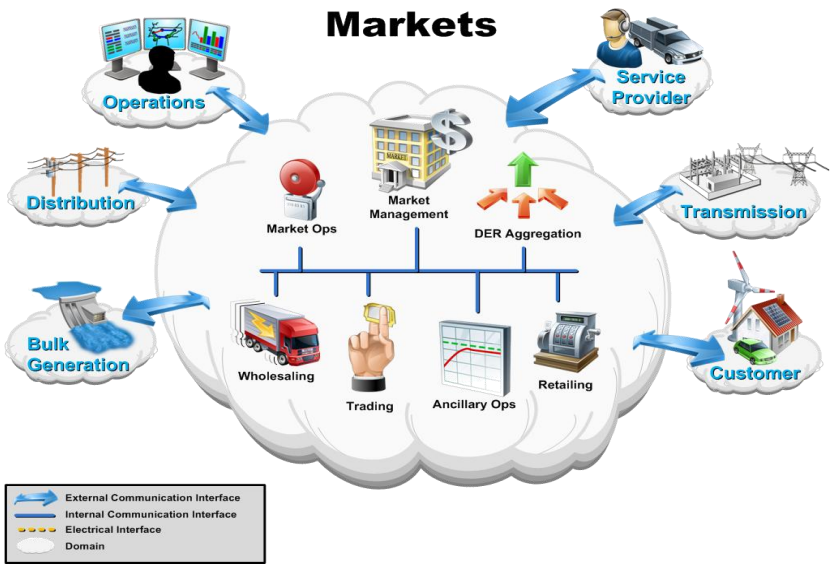


Microgrids In A Complex System



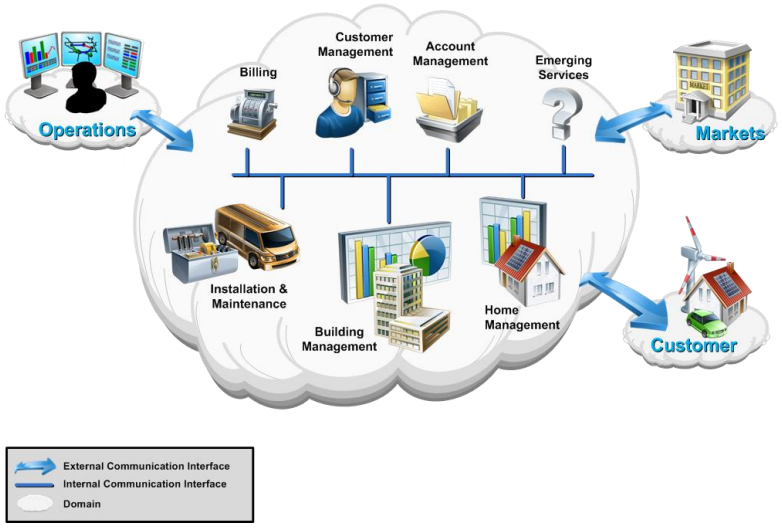




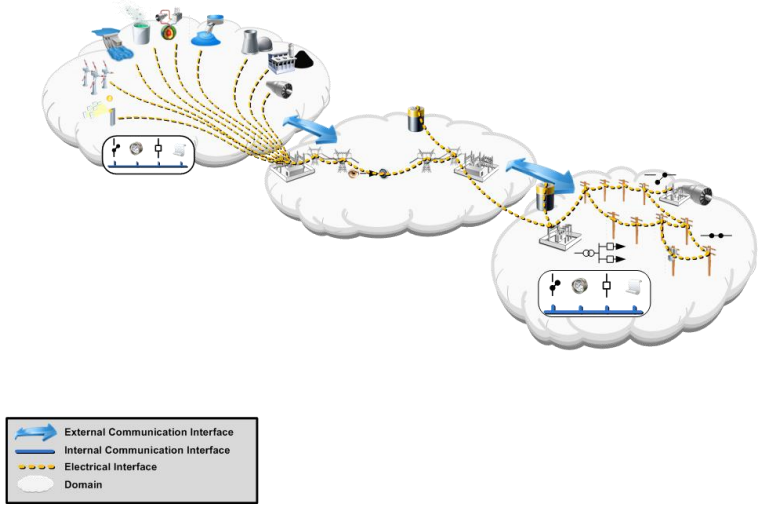


Part Of The Microgrid Plan

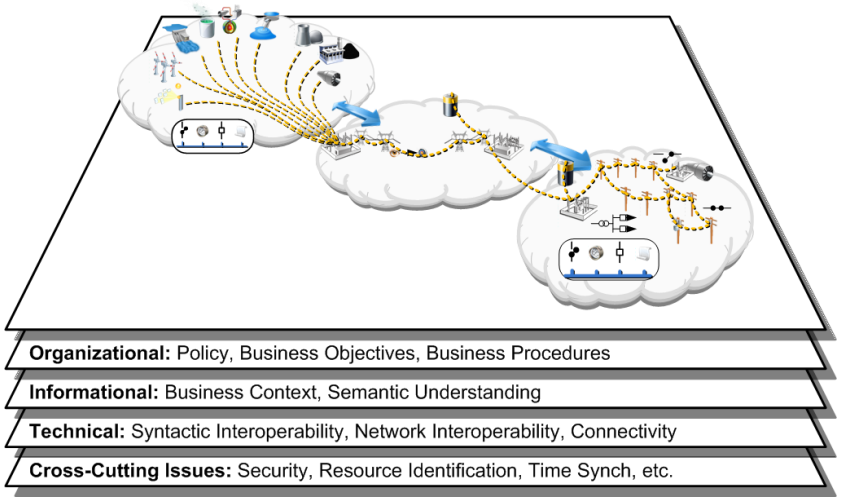
Service Provider



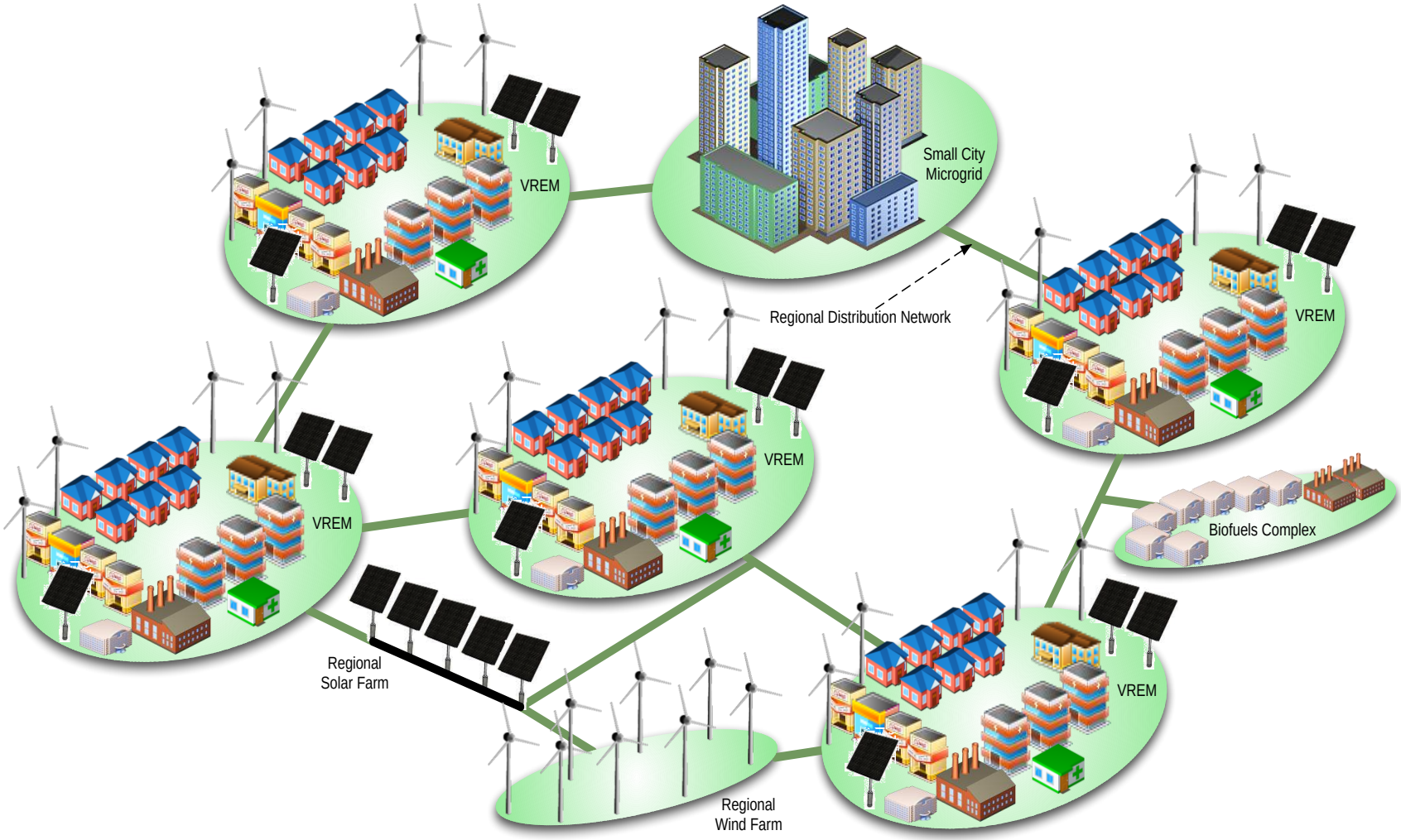
Use Cases: Paths Through the Model



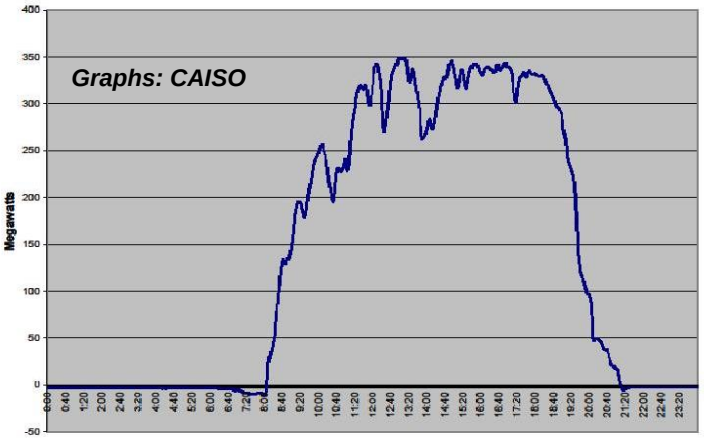
Interoperability Layers and the Model



Interconnected Village Renewables-Enabled Microgrids

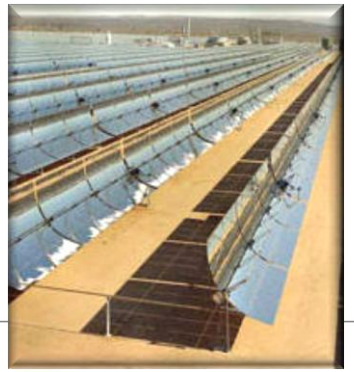


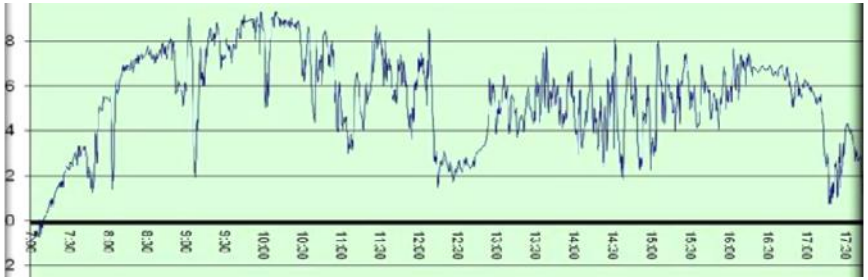
Variable Solar and Wind Energy Production

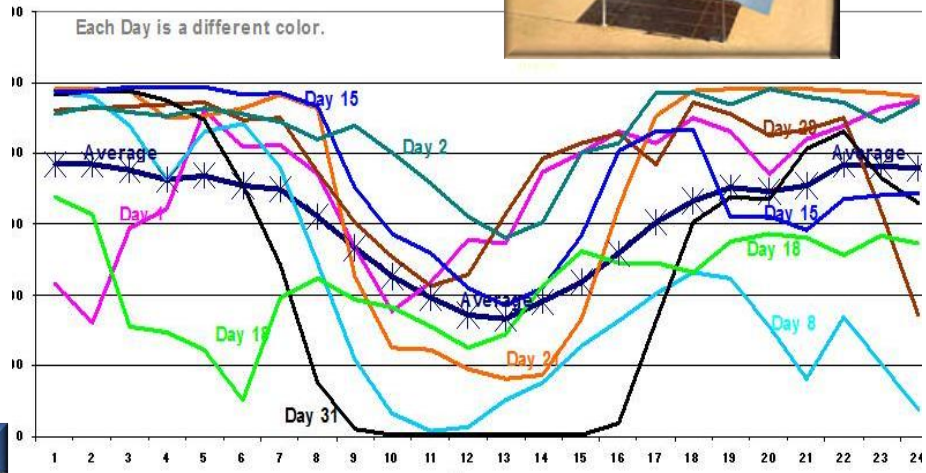


CSP Images: NREL













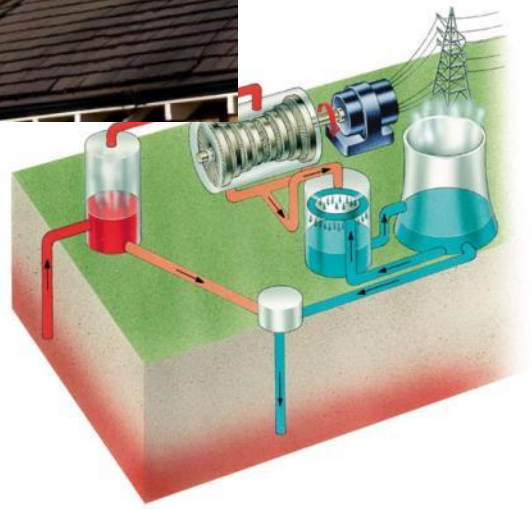


Microgrid Generation Types

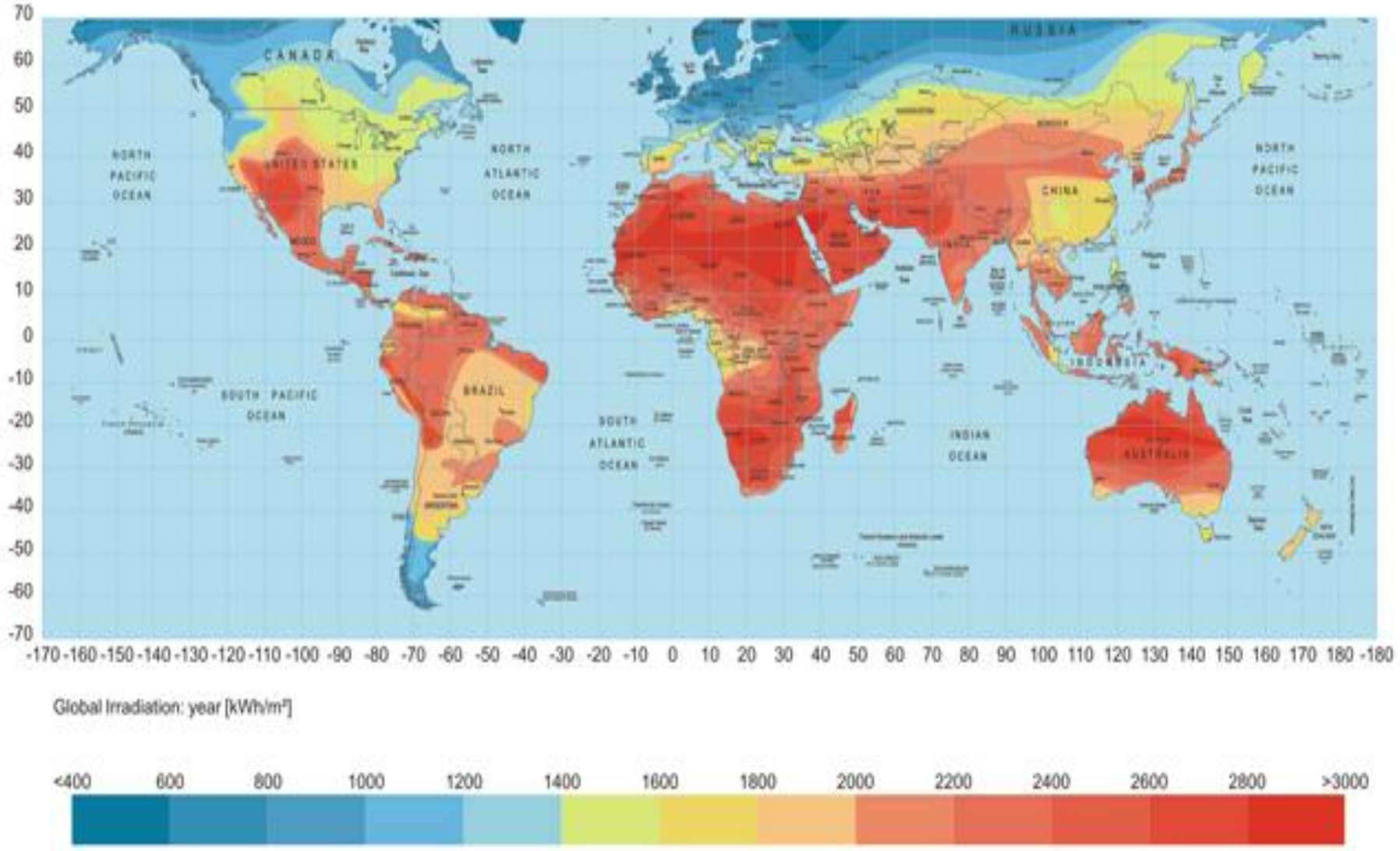
- Technology neutral
- Various renewable generation sources may be integrated:
  - Solar
  - Wind
  - CHP
  - Waste-to-Energy
- Geothermal – small, modular and portable units may provide the foundation for microgrid generation
- Low temperature geothermal requires less deep well steam and may be installed quickly







Solar Power Potential



Ownership Models

- Utility model – the distribution utility owns and manages the microgrid to reduce customer costs and provide special services (e.g. high power quality and reliability) to customers on the system.
- Landlord model – a single landlord installs a microgrid on-site and provides power and/or heat to tenants under a contractual lease agreement.
- Co-op model – multiple individuals or firms cooperatively own and manage a microgrid to serve their own electric and/or heating needs. Customers voluntarily join the microgrid and are served under contract.
- Customer-generator model – a single individual or firm owns and manages the system, serving the electric and/or heating needs of itself and its neighbors. Neighbors voluntarily join the microgrid and are served under contract.
- District Heating model – an independent firm owns and manages the microgrid and sells power and heat to multiple customers. Customers voluntarily join the microgrid and are served under contract.

Sustainable Communities

- Integrated Electric, Water, Building location
- Planned communities are more efficient
- Buildings participate with energy supply
- People take a proactive role in their community
- Improved economic output compared to unplanned communities
- Incorporates all consumer requirements

Development Phases

- Project scope ($--K)
  - Assessment of sustainable energy opportunities
  - Site visit
  - Feasibility study
  - Integration challenges (policy, physical)
- Project definition ($---K)
  - Design approach
  - Investment, policy, business and technical plans
  - Security: physical & cyber
  - Asset management
- Project implementation ($--M)
  - RFP, contracts, permits
  - Final project plan
  - Workforce training, revenue operations, maintenance
  - Construction
  - Testing
  - Go-live
- Operate
  - Continuous improvement
  - External monitoring
  - Technology refresh

Planning Approach

Methods

- Plan review
- Regulatory analysis
- Site visit
- Stakeholder sessions
- Energy mapping
- Scenario development
- Economic analysis



Objectives

- Characterize energy usage
- Prepare alternative scenarios
- Compare energy alternatives and technologies
- Prioritize measures
- Funding strategies

Developing Economies

- The world microgrid market reached $4 billion last year with North America claiming 74% of 2010's total industry share, finds market research publisher SBI Energy. Fueled by rapidly growing solar, renewable energy and smart grid markets, the microgrid has become a viable solution to supply energy to local communities.
- Microgrid installations around the world include everything from diesel generator-based rural electrification projects that supply electricity to small rural communities to large, futuristic cities and theme parks using the newest microgrid technologies.

Sustainable Energy for All

UN Secretary-General Ban Ki-moon calls on governments, businesses, and civil society to make significant commitments to accomplish three objectives by 2030:

1 ENSURE *universal access* TO MODERN ENERGY SERVICES.

2 DOUBLE THE GLOBAL RATE OF IMPROVEMENT IN *energy efficiency.*

3 DOUBLE THE SHARE OF *renewable energy* IN THE GLOBAL ENERGY MIX.

High-Impact Opportunity Areas

Seven Action Areas:

(1) modern cooking appliances and fuels;

(2) distributed electricity solutions – mini & micro grids;

(3) grid infrastructure and supply efficiency;

(4) large-scale renewable power;

(5) industrial and agricultural processes;

(6) transportation;

(7) buildings and appliances.

Four “Enabling” Areas:

(1) energy planning and policies;

(2) business model and technology innovation;

(3) finance and risk management; and

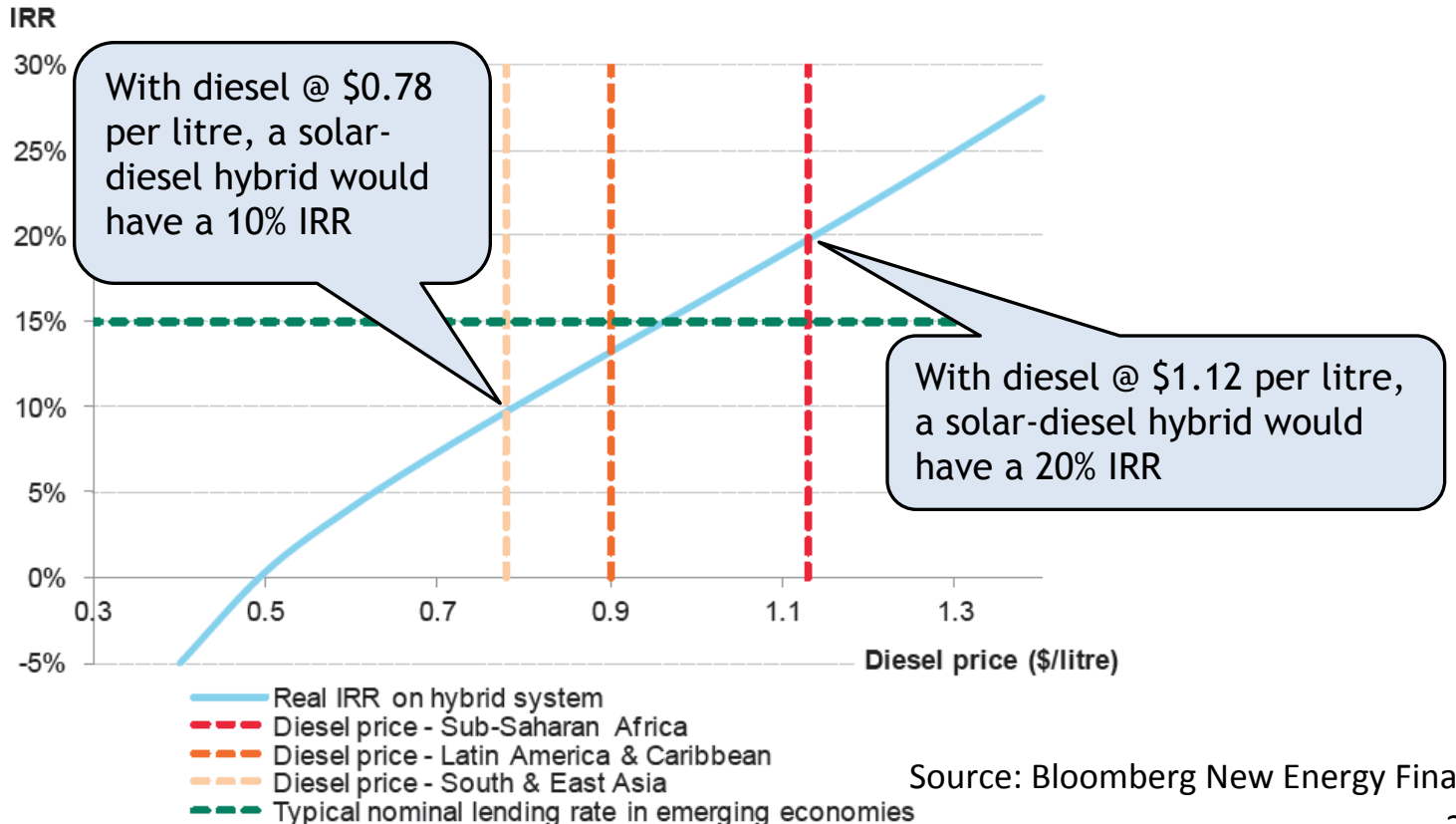
(4) Capacity building and knowledge sharing.

Hybrid Power Technology

- "The Time" for on-grid renewable energy has already come …
  - Utility-scale (> 1.5 MW) onshore wind = 6 to 12 cents/kWh
  - Medium-scale (100 kW – 500 kW) wind = 14 to 25 cents/kWh
  - Solar photovoltaic, grid tied = 14 to 22 cents/kWh
- … and "The Time" for hybrid technology is approaching:
  - Hybrid involves any combination of renewable generation, diesel backup and/or storage **providing reliable, steady power**
  - System size ranges from small (100 kW peak) to large (>20 MW peak) where the renewables can displace anywhere up to 90% of diesel fuel use
- Hybrid systems have a proven track record:
  - In Alaska: 16 communities with wind-diesel hybrids totaling 13 MW
  - Many systems in other remote locations: Australia, Antarctica
  - Many systems have been operating for over 10 years

Hybrid Power Costs

- In sites with a) good wind/solar/biomass resource and b) high diesel costs or unreliable grid - hybrid systems can represent a sound investment:



Source: Bloomberg New Energy Finance, 2012

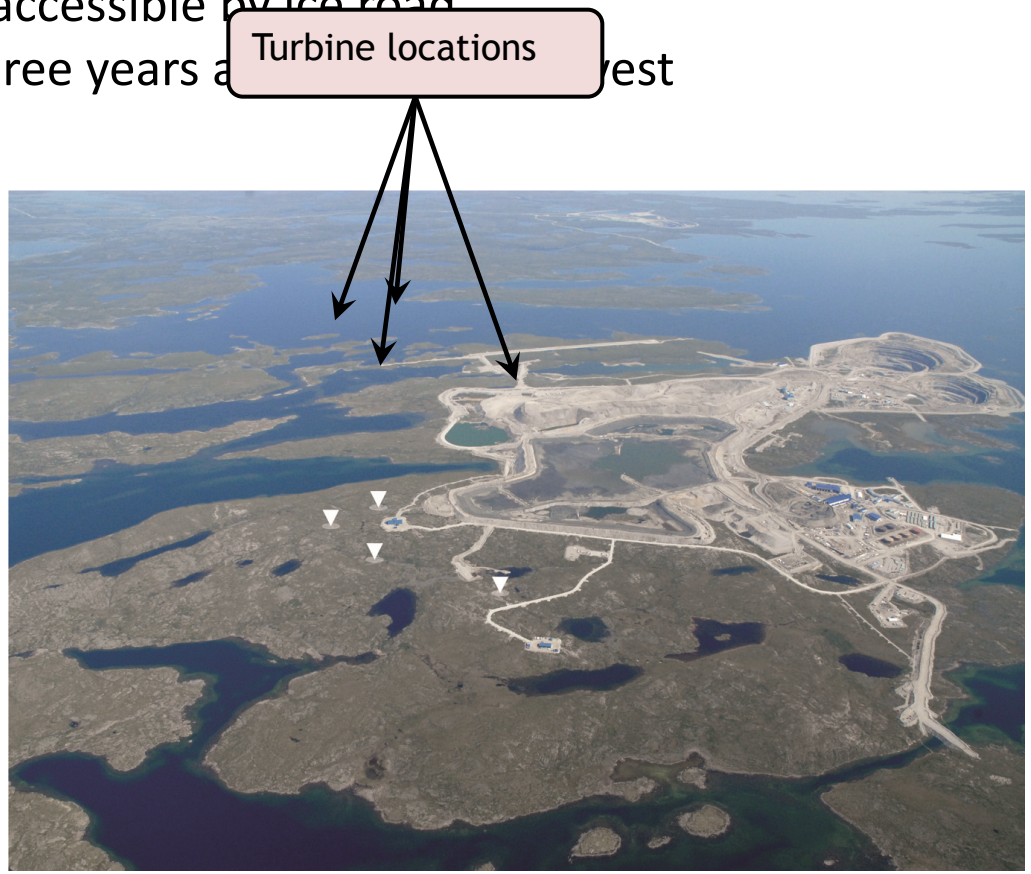
Case # 1 – Solar/Diesel for Marble Bar, Australia

- How to provide reliable 24/7 power for a remote location?
  - Community in Australia was 100% powered by diesel generators = high power costs and frequent power outages
  - PowerCorp (now owned by ABB) brought in to develop alternative
- Solution:
  - System consisting of 1.6 MW Diesel, 300kW PV and 500kW flywheel
  - PV/Diesel system without need for battery storage
  - Load control to maximise PV



Case Study # 2 – Wind-Diesel for Diavik Mine, Canada

- How to reduce costs at a diamond mine in northern Canada?
  - Large diamond mine majority powered only by diesel
  - Site 300 km north of grid; only accessible by ice road
  - Company measured wind for three years a[illegible]est
- Solution:
  - Four 2.3 MW turbines adapted for low temperature operation (-40 degrees C)
  - Turbines will provide 10% of power and displace 4 million litres of diesel per year
  - Estimated payback < 5 years
  - Reduced risks from diesel supply disruptions



Case Study # 3 – Wind/Diesel in St. Paul Island, Alaska

- How to provide reliable power for a remote airport and commercial facility?
  - Island of Saint Paul was having reliability issues for airport power
  - Average Load: 70kW electrical & 50 kW thermal
  - Worked with utility and State to find an alternative
- Solution:
  - 3 Vestas turbines for total of 675 kW
  - Average wind penetration: 55%
  - Average Capacity Factor: 32%
  - Simple Cost of Electricity = 8 US cents /kWh
  - In some months, the diesel gensets run only one-quarter of the time



DOD / Microgrids Market Opportunity

Opportunity size

- 440 Military Bases in the continental US*
- Major bases include:
  - 48 Army Bases
  - 71 Air force Bases
  - 15 Marine Bases
  - 62 Navy Bases
  - 14 Coast Guard

Microgrids

- Advantages of microgrids that can be run independently of the larger grid infrastructure when necessary, isolating themselves to keep electrons flowing when their users would otherwise experience brown outs or black outs.
- For the US, if deployed widely in many if not most communities, it would greatly curtail the threat of large, regional power-loss events.

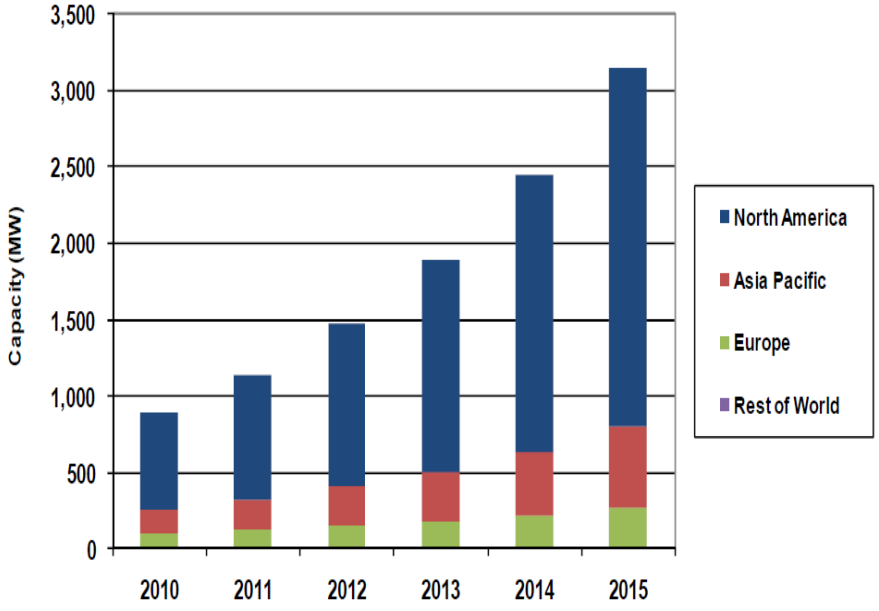
The need

- DSB 2008 energy report warned, bases have made themselves far too dependent on the often unstable grid.
- The micro grid concept applies when thinking about bases as power islands, being able to run their own critical mission systems during local or regional blackouts
- For DOD, this would help solve the Defense Science Board (DSB)-identified challenge of bases' reliance on the brittle national grid.

*Source: Internet

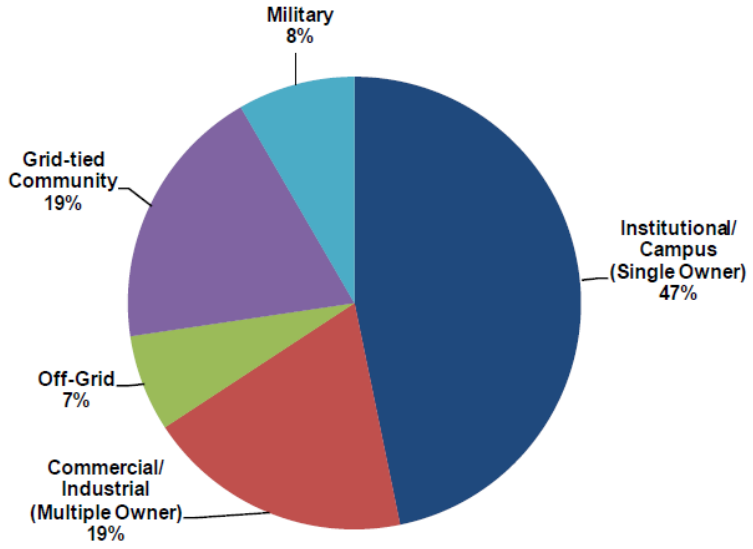
MicroGrid Market

- Worldwide Capacity



(Source: Pike Research)

- Market Sector Breakdown



(Source: Pike Research)

Lessons - Microgrid Characteristics

- Most interest is behind the meter
- Economically viable
  - Commercial & Industrial consumers – 4 to 40 MW
  - University campuses – 2 to 40 MW
- Significantly improves on-site reliability; a MUST
- All solutions (to date) reduce emissions footprint, but not the major objective
- All solutions (to date) include energy storage and 3 to 6 other resource types
- All solutions (to date) include integration to building controls and price-driven load management
- Most selected Scenario: Maximum Savings
  - 80% to 86% self-generation, rest from grid
  - Always grid connected
  - Sales to grid: zero to minimal

Ancillary Microgrid Services

- Aggregate markets
  - New business operators
  - Utilities are enablers
- Geographically strategic storage

Centralized Control Goal (System Automation)	***Constraints***
Demand Response	*Dynamically orchestrate the shedding and adding of load and generation.* *Dynamically orchestrate the connection of power generation and storage devices.*
Distributed Generation	*Control and optimize the generation of power based on cost of energy, reliability and environmental constraints.*
Energy Storage	*Control and optimize the storage of energy based on cost of energy, reliability and environmental constraints.*
Energy Metering	Measure, aggregate, analyze and publish energy usage.
Energy Forecasting	*Analyze and predict consumption, price, generation and failure risk.* *Generate system and power profile optimization programs.*
Energy Market Trading	*Perform price monitoring, negotiation and settlement.*
System Monitoring	*Analyze cyber security, information flow, information quality, business processes and topology.* *Generate reports and programs to optimize system performance and provide control center visualization.*

Summary

- Economic, sociologic and environmental pressures require us to examine a new energy management model
- Distributed resources meet individual requirements and offer larger grid support
- MicroGrids allow generation, storage, and loads to operate autonomously, balancing out voltage and frequency issues
- MicroGrid cells are scalable and can be clustered locally as well as market opportunities
- MicroGrids are a new commercial growth area
- Competition will drive need for conforming architecture and standards

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General MicroGrids Balance Energy

Thank You

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