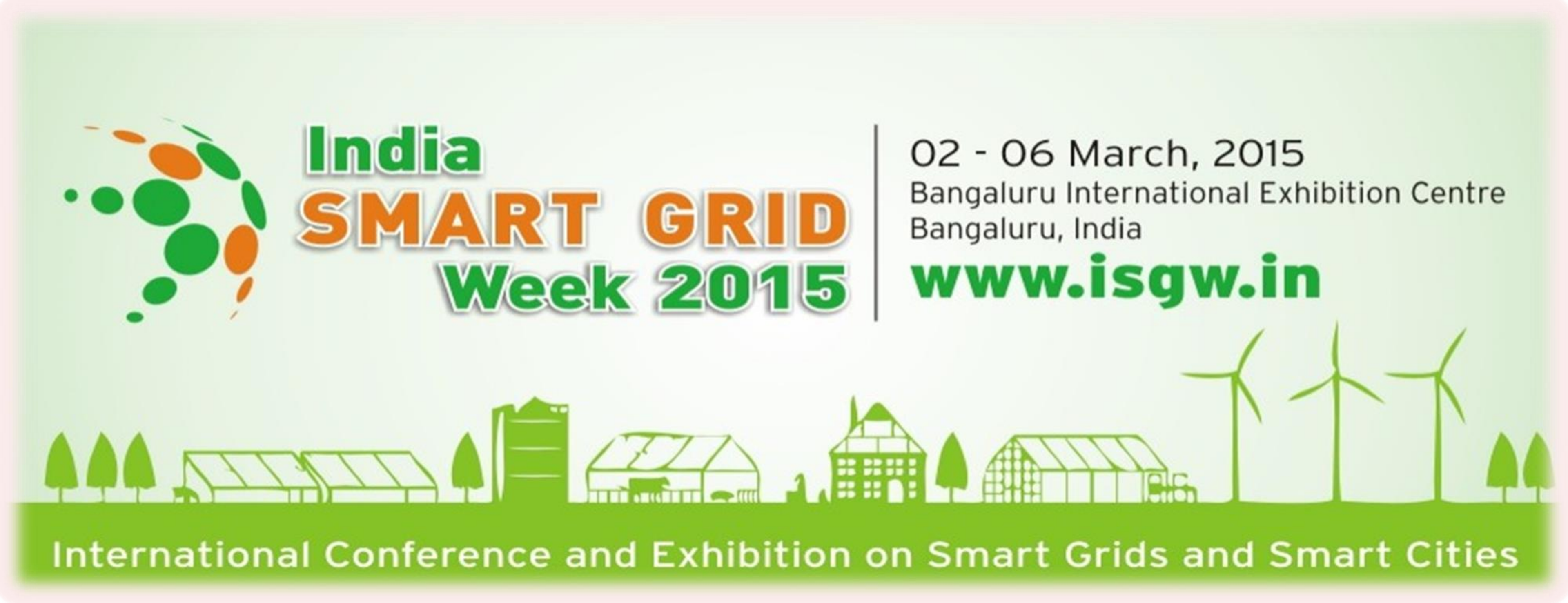

Smart Microgrids – A systems approach to add renewable energy

Terry Mohn

CEO, General Microgrids

Chairman, Microgrid Alliance

Chairman, UN Foundation WG

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About General MicroGrids

- General MicroGrids, Inc is an international microgrid developer, working with governments, industrial customers and sustainable communities. We focus on a standardized approach to 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.
- We have active presence in India, Kenya, Uganda, Dominican Republic and the USA.

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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.
- A smart microgrid is built upon Smart Grid.

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What Does the Smart Grid Look Like?

- 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

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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

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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

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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)

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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

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Complements Smart Grid

- High use of renewables – 20% – 35% by 2020
- Distributed generation and microgrids
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Smart 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

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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.

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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)

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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

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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

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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

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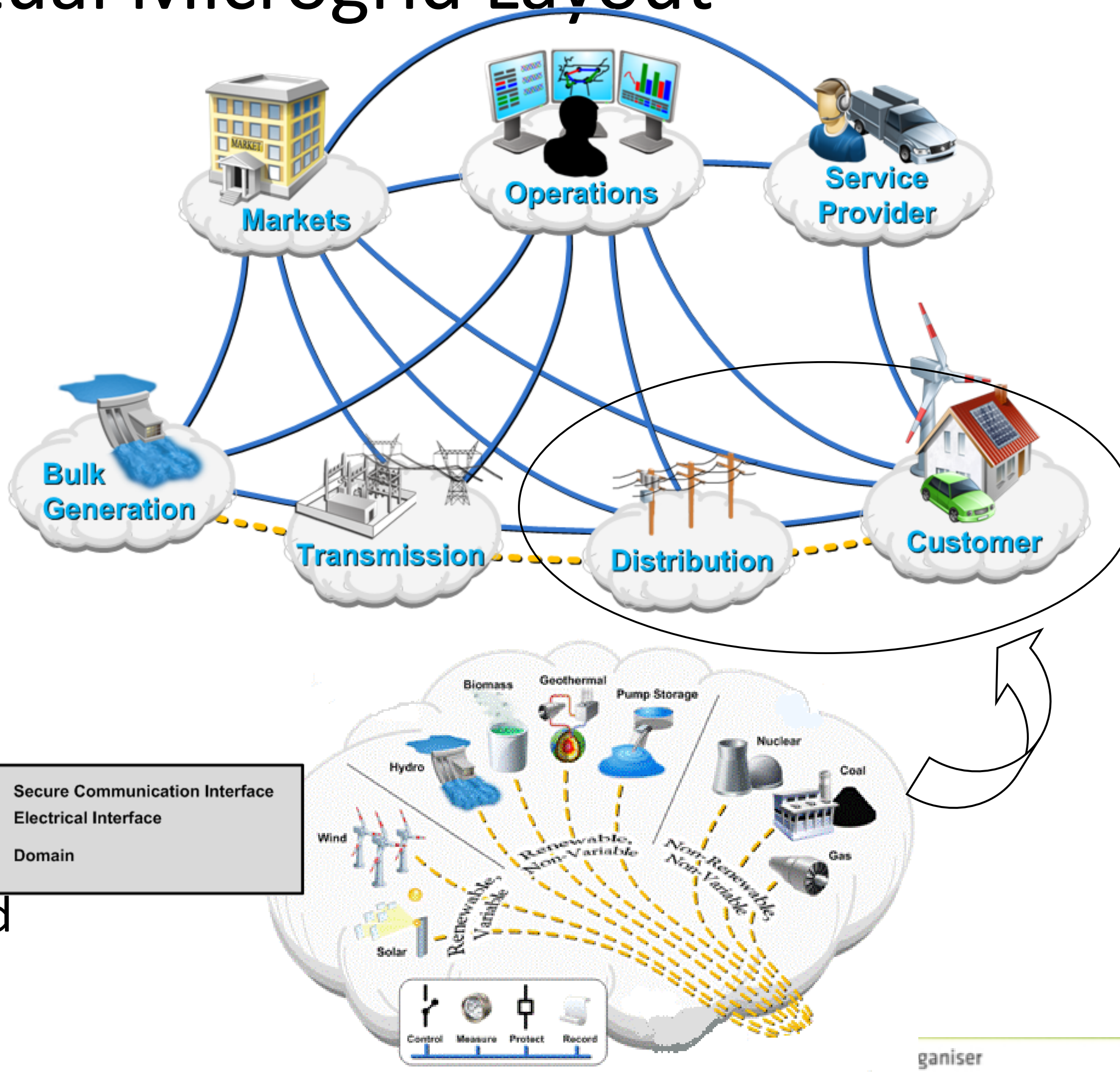
Conceptual Microgrid Layout

- 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



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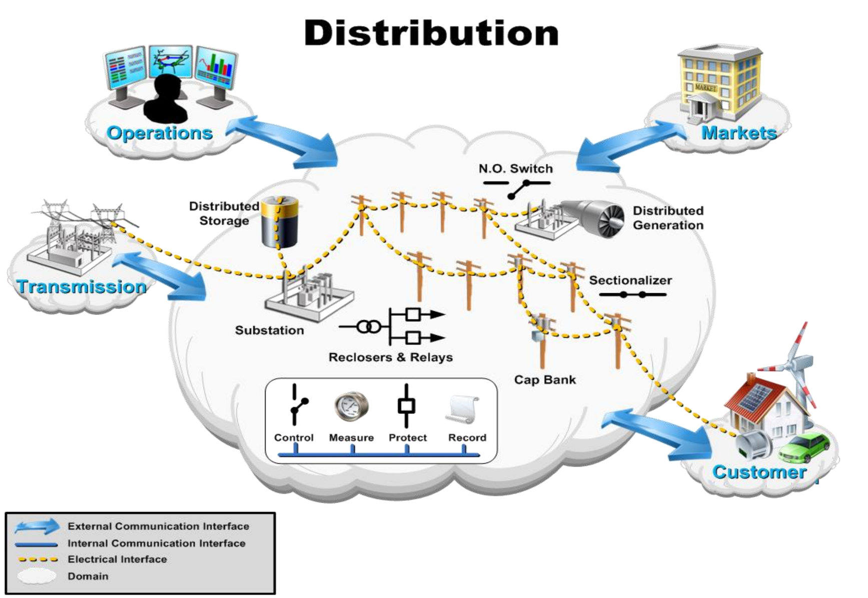
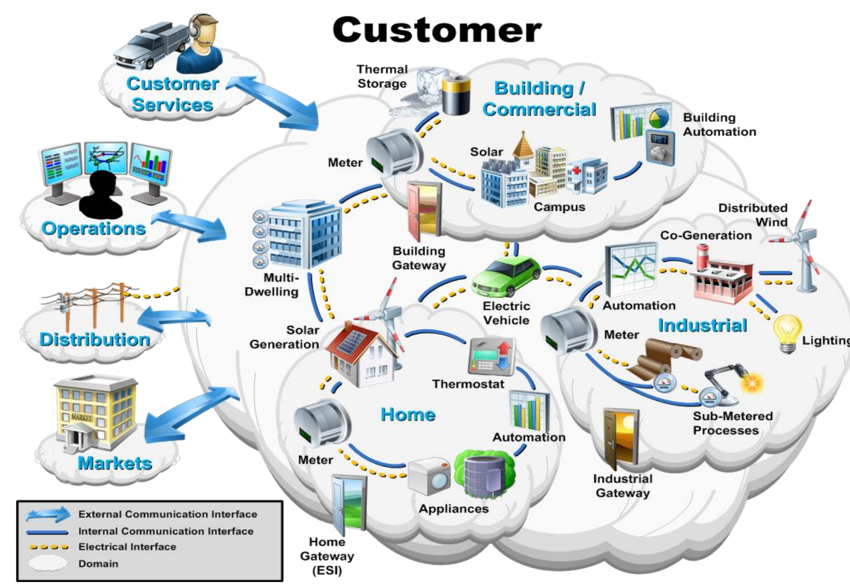
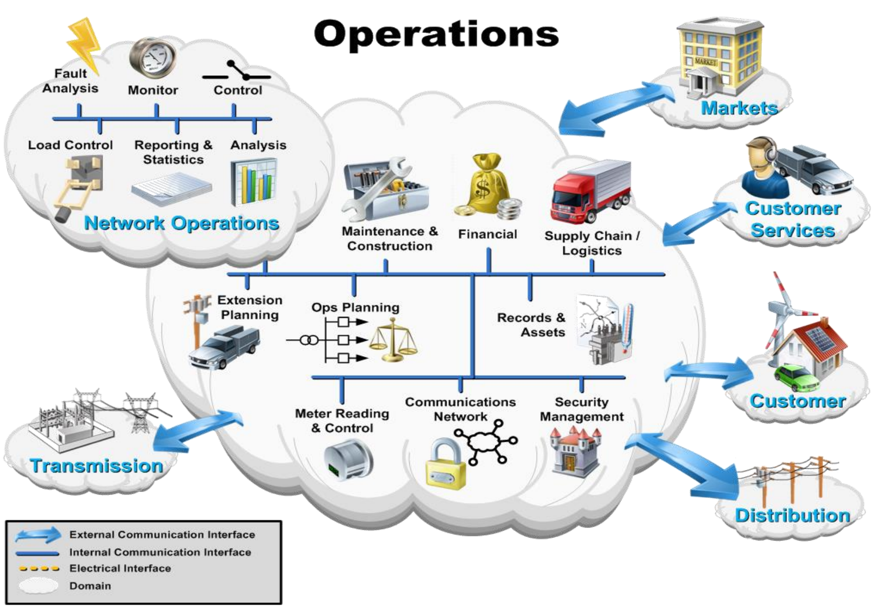
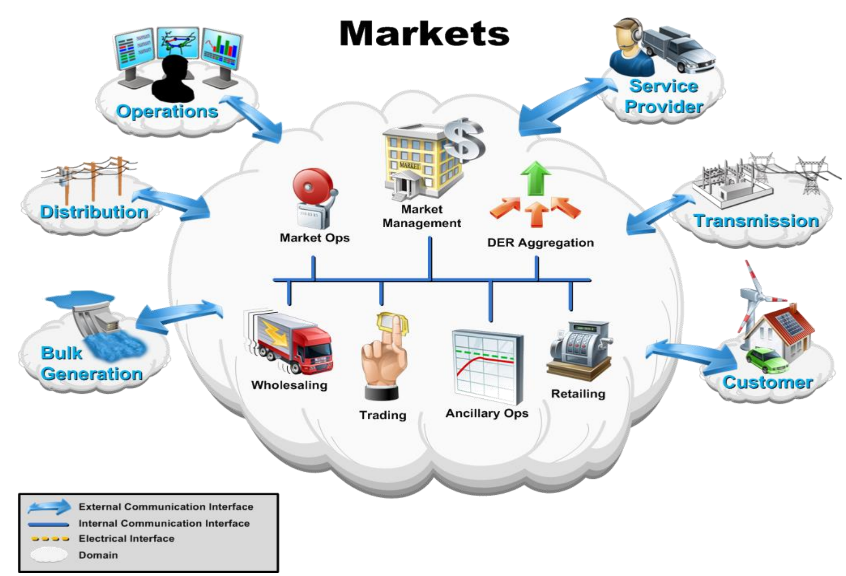
Microgrids In A Complex System



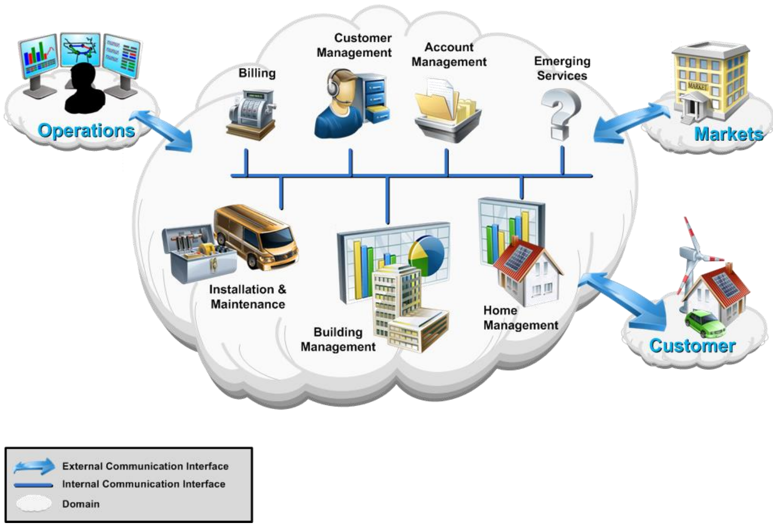




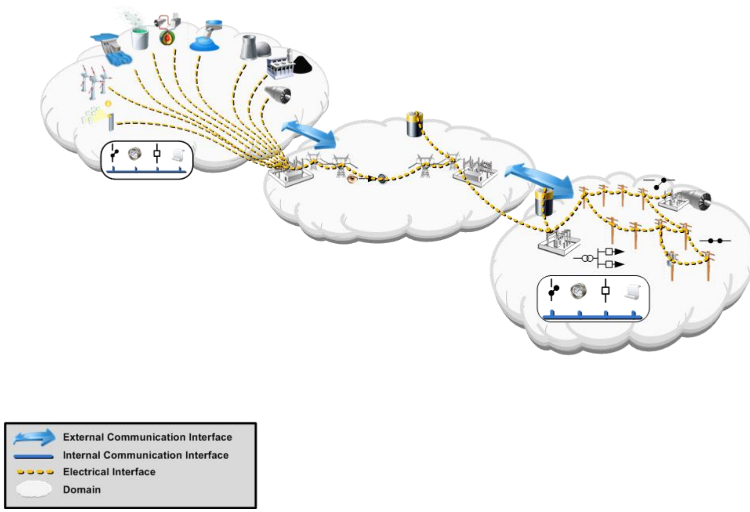


Part Of The Microgrid Plan

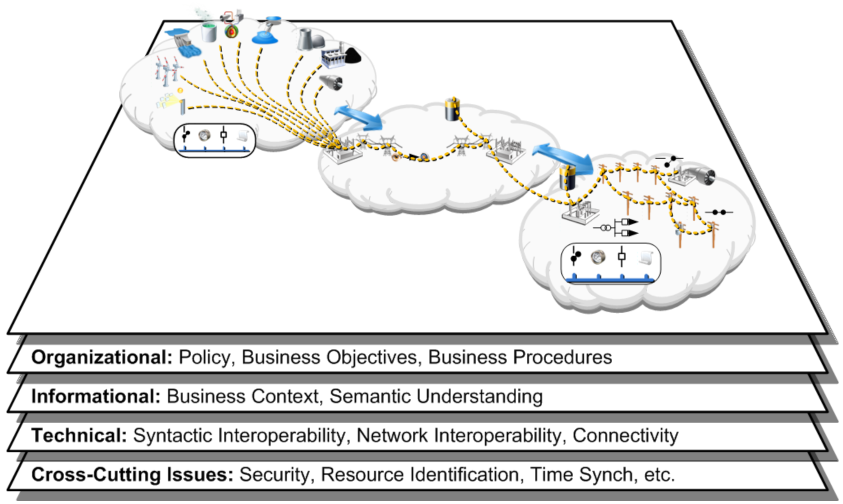
Service Provider



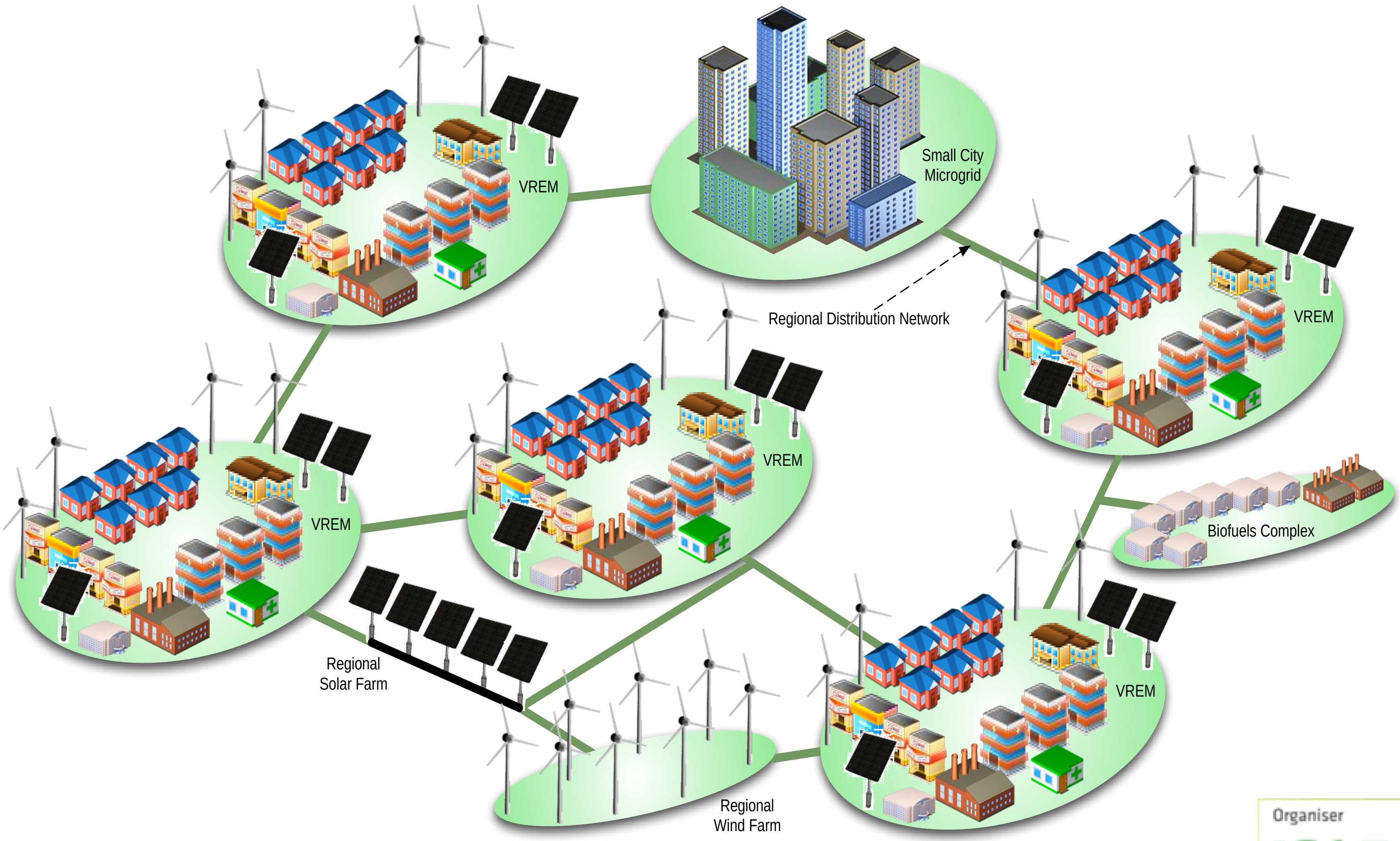
Use Cases: Paths Through the Model



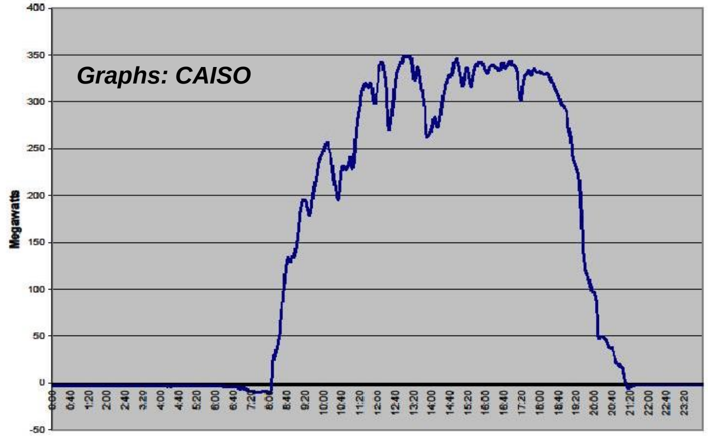
Interoperability Layers and the Model



Interconnected Village Renewables-Enabled Microgrids

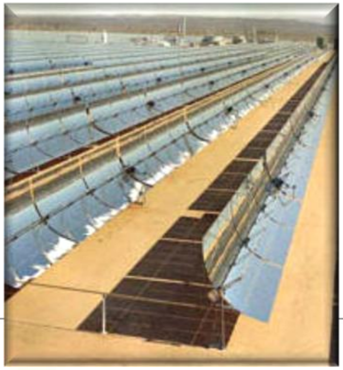


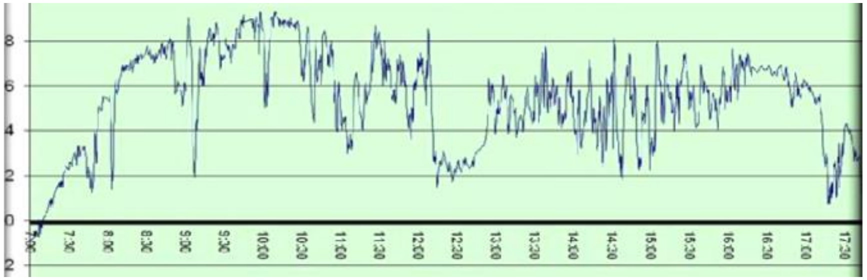
Variable Solar and Wind Energy Production

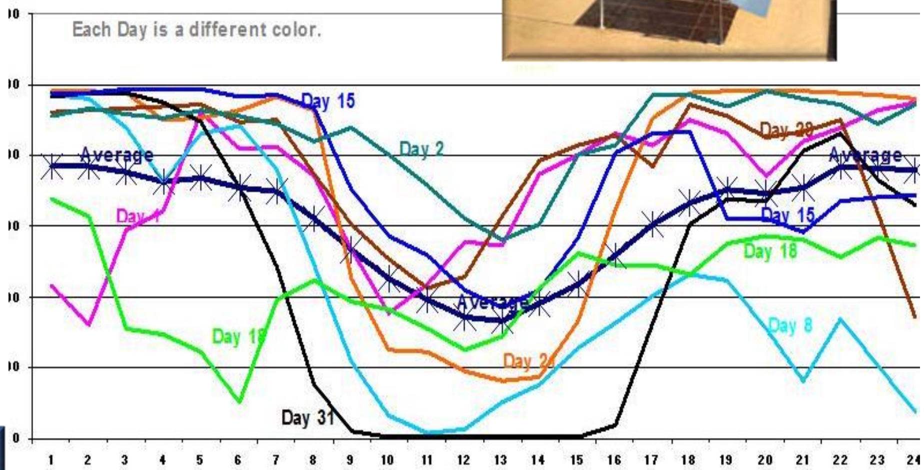


Graphs: CAISO

CSP Images: NREL





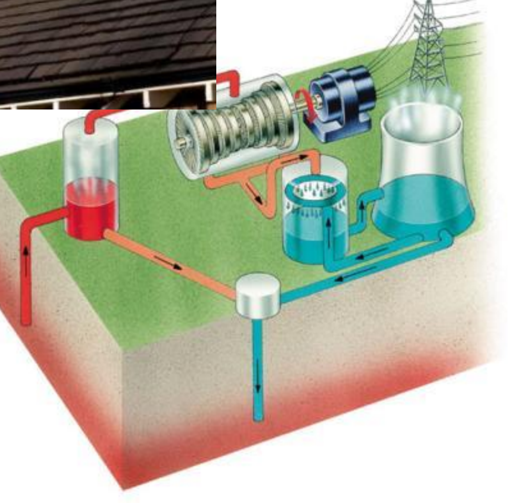


PV Images:
US DOE

Wind Image: SCE

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



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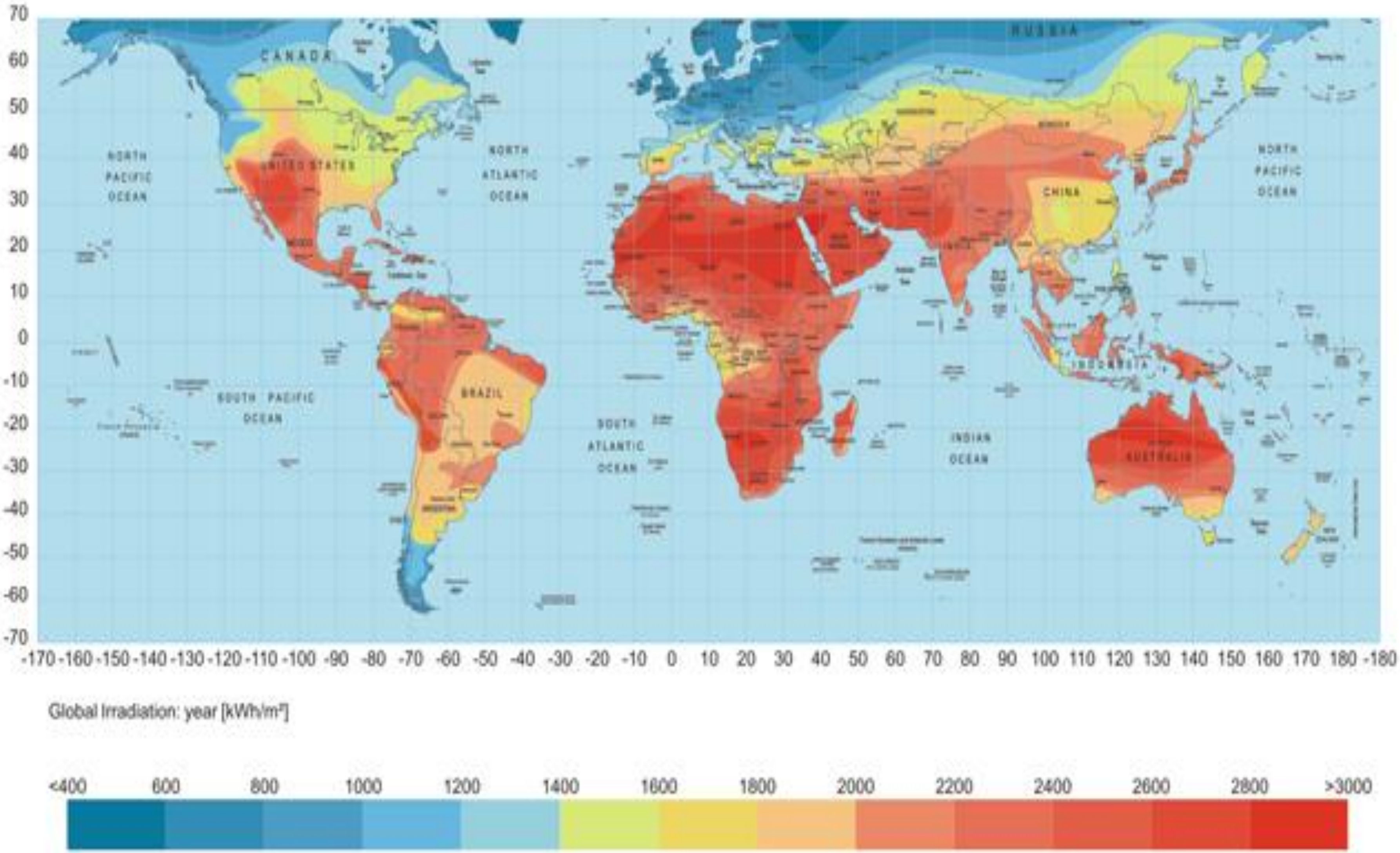
Solar Power Potential



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.

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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

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Smart Microgrid Resiliency

- Zero fault current or voltage instability issues
- Well-behaved load with limited harmonics
- Outage ride-through: Generators don't trip off
- Loads are de-coupled from distribution system
- Real-time adjustment of exports, with hard limits
- Ancillary services
- Can export into sectionalized grid during

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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.

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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.

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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

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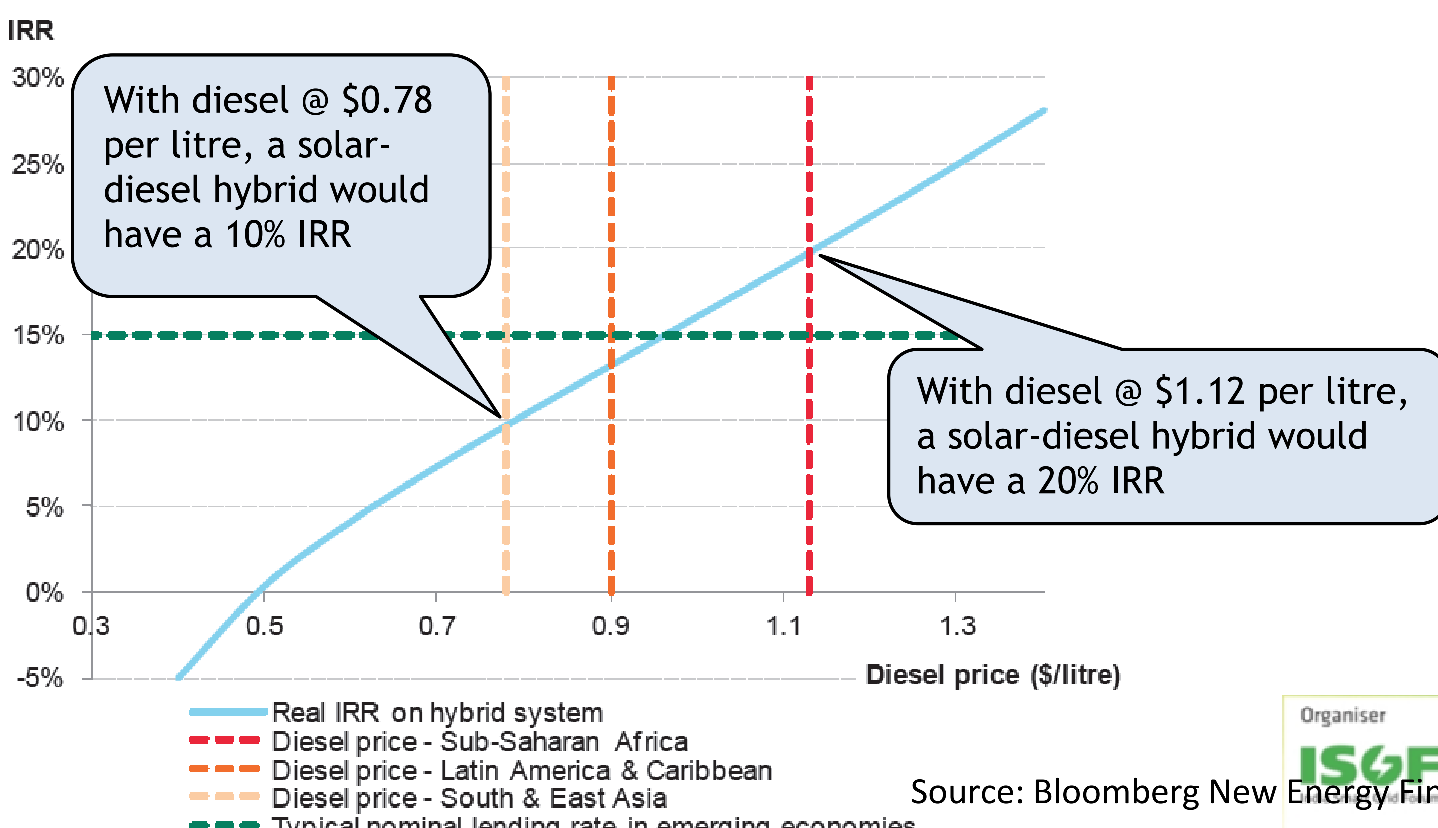
Hybrid Power Costs

- 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, 2013

Smart Districts

- 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

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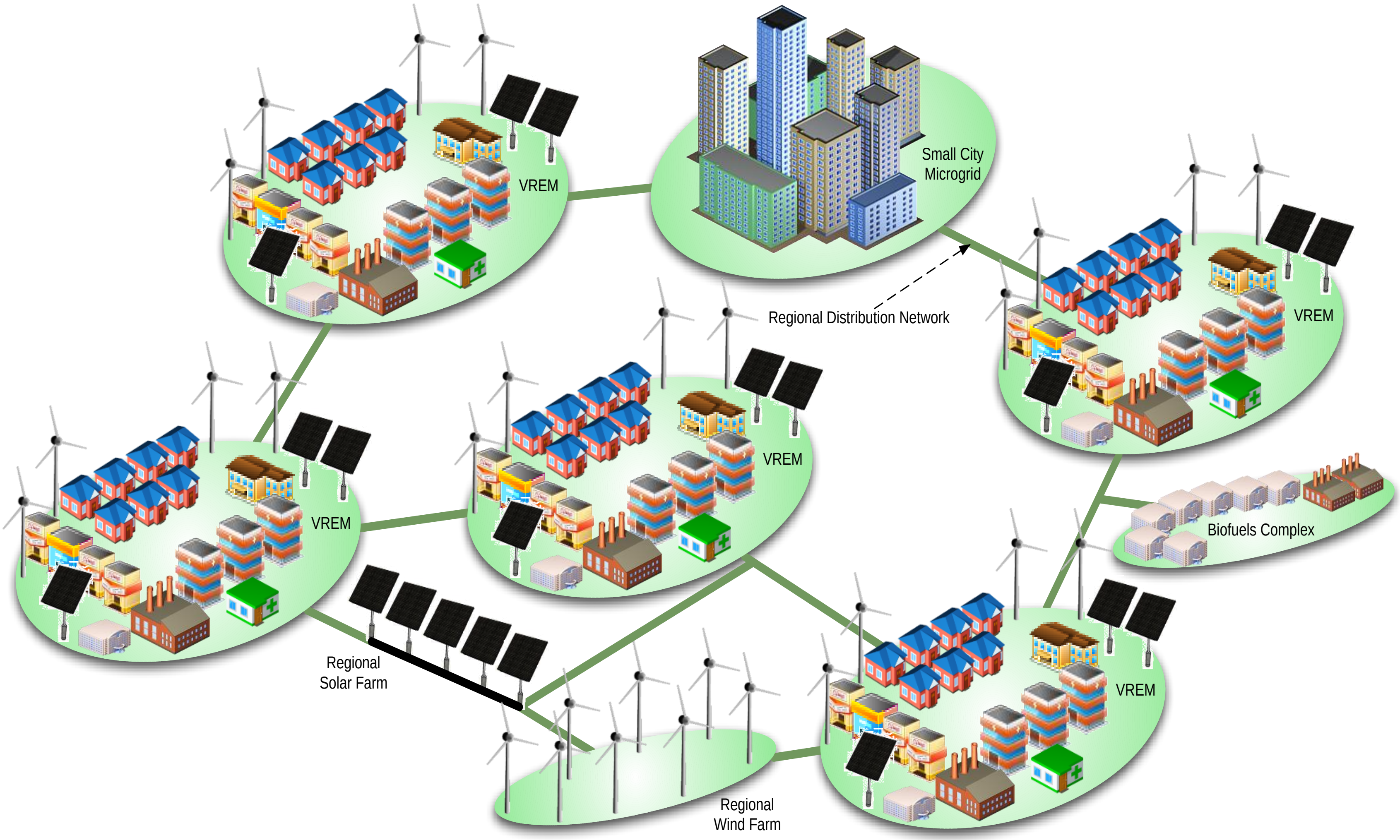
Interconnected Smart Districts



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Microgrid/District Energy Synergies

- Given the inherent benefits from each (Microgrids & District Energy), the sum of the parts is greater when combined than if separate
- Underground work excavated only once
- Optimized CHP placement minimizes real estate allocation costs
- Reduced losses (thermal and electrical)
- New storage approaches improves efficiency
- Newer technologies offer lower operating costs
- Increased telemetry increases asset life (condition-based maintenance vs scheduled)

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Microgrids applied to Smart Cities

- Phase 1 (individual service level): ICT to improve individual city operations, such as real-time bus schedule
- Phase 2 (vertical service level): integrates related processes and services by smart technology, such as citizens offered information on transportation system's real-time activity and emergencies, road conditions, road repairs and detours.
- Phase 3 (horizontal service level): no distinction between different service areas, with all parts now seamlessly integrated within an efficient smart city ecosystem.

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Rationale

- Growing Energy Demand in Mega-Cities.
- Easier energy management in City due to its concentrated demand and higher electrification rate.
- Keys for Energy Management in Cities.
  - Electricity Storage
  - Thermal Storage
  - Regional Demand Control
  - Electrification of Transportation
- Mega-Cities and isolated Rural Areas can cooperate in Energy Supply & Demand, and Green Energy Investment.

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Toronto Airport

104MW Microgrid

- 22 MW Net Consumption
- 80MW Bid to open market

GTAA Distribution Project/Network Statistics

Drivers:

- *New Airport Terminal Addition*
- *New Runway Addition*
- *New Infield Terminal Addition*

6 major switchyards with 41 circuit breakers

46 Vista units

Approximately 60 km of 28 kV cable

Approximately 90 power transformers

85 microprocessor based protection relays

Approximately 20 km of Fiber Optic Cable

Electrical demand of over 30 MW

104MVA co-generation to meet electrical demands to 2020

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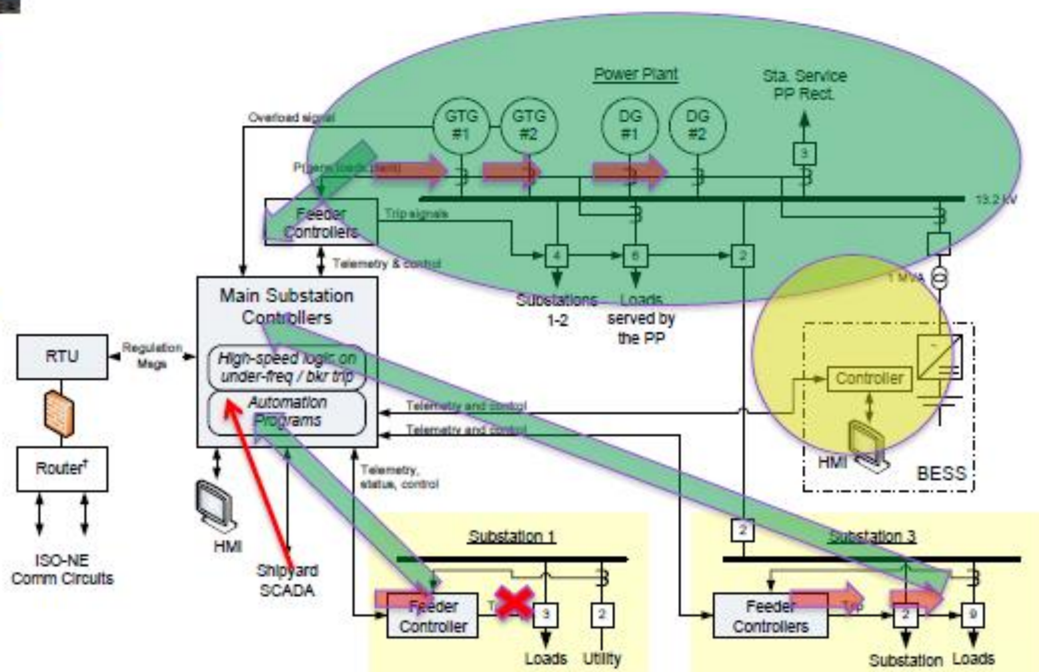
Portsmouth Naval Shipyard

Use Case 1 – Loss of Utility

1. Islanded Operation
2. Dynamic Load Shed
3. Energy Storage with ISO frequency regulation

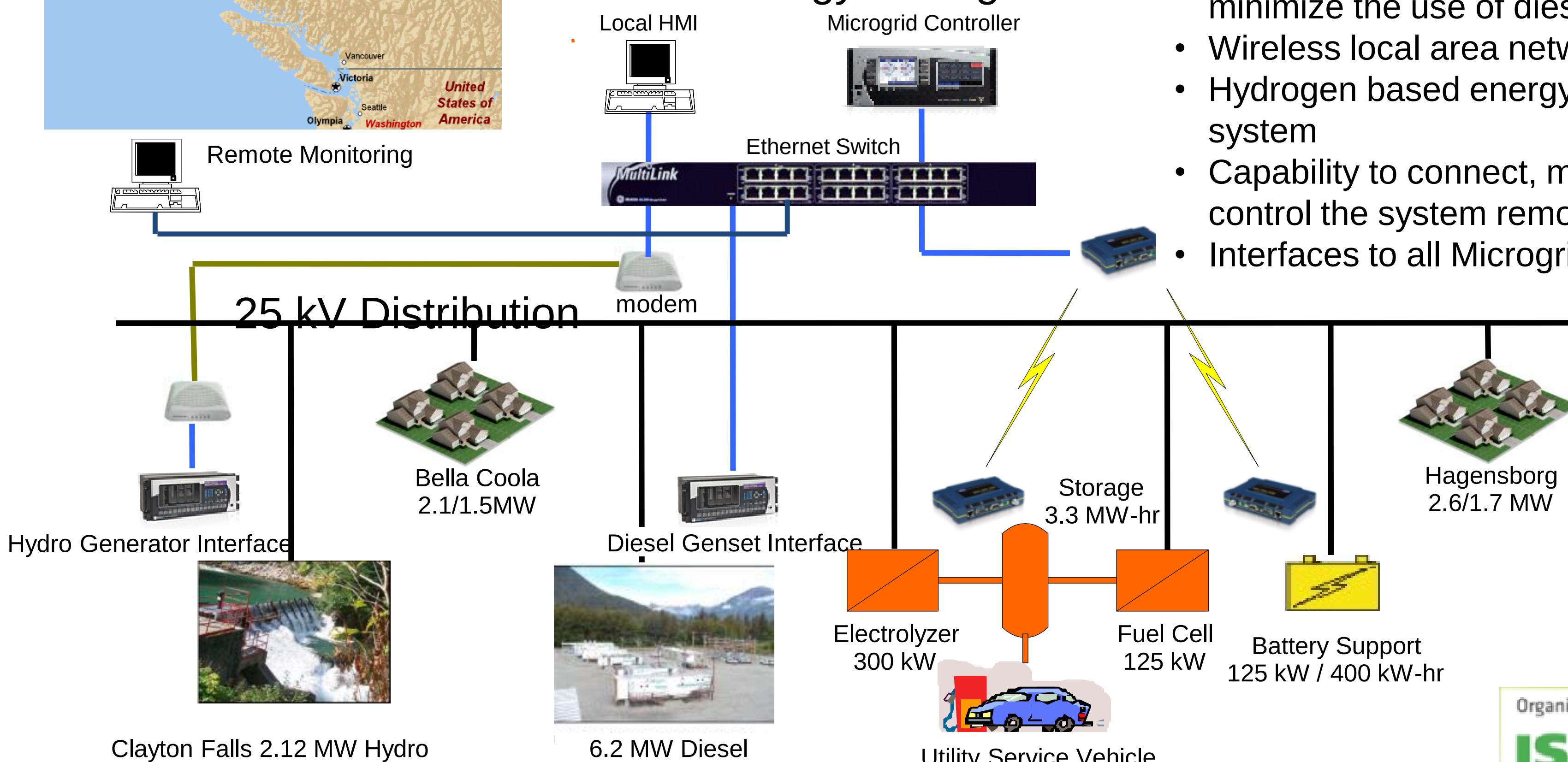


General MicroGrids Balance Energy

Bella Coola

Off-grid microgrid

Ah Sin Heek Diesel Energy Storage Site



Microgrid Features:

- Centralized Supervisory control to optimize the use of renewables and minimize the use of diesel
- Wireless local area network
- Hydrogen based energy storage system
- Capability to connect, monitor and control the system remotely
- Interfaces to all Microgrid elements

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Marble Bar, Australia

- Reliable 24/7 power for a remote location
  - Community in Australia was 100% powered by diesel generators = high power costs and frequent power outages
  - Microgrid consisting of 1.6 MW Diesel, 300kW PV and 500kW flywheel
  - PV/Diesel system without need for battery storage
  - Load control to maximise PV penetration

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Diavik Mine, Canada

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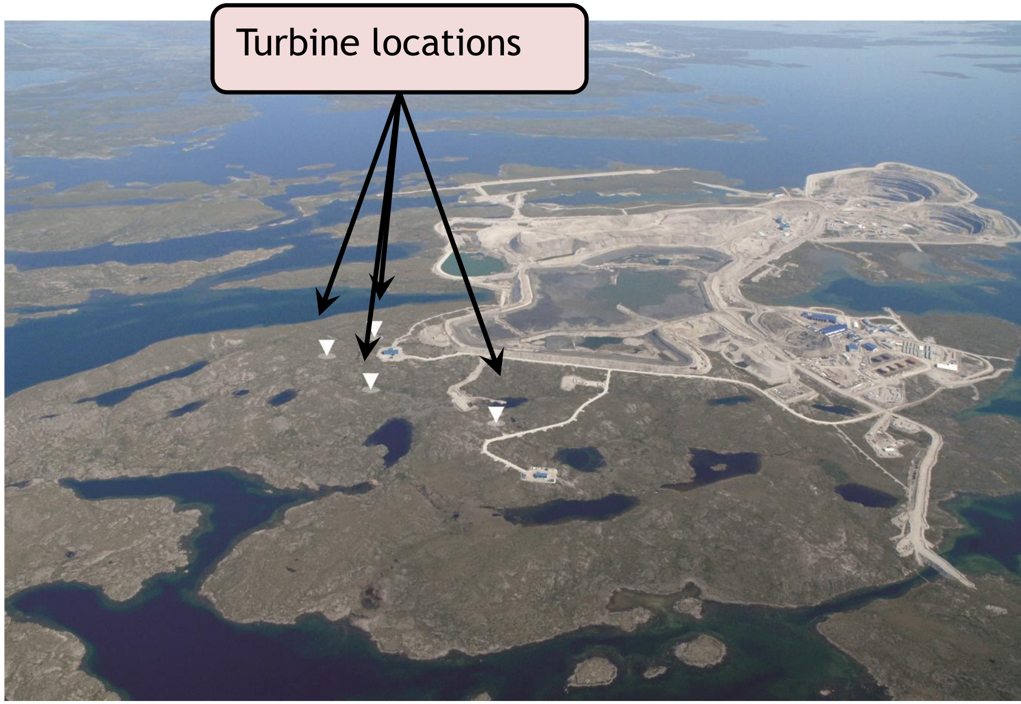
- Reduce costs at a diamond mine
  - Large diamond mine majority powered only by diesel
  - Site 300 km north of grid; only accessible by ice road
  - Company measured wind for three years and decided to invest
  - Four 2.3 MW turbines adapted for low temperature operation (-40 degrees C)
  - Turbines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



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St. Paul Island, Alaska

- 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
  - 3 wind 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

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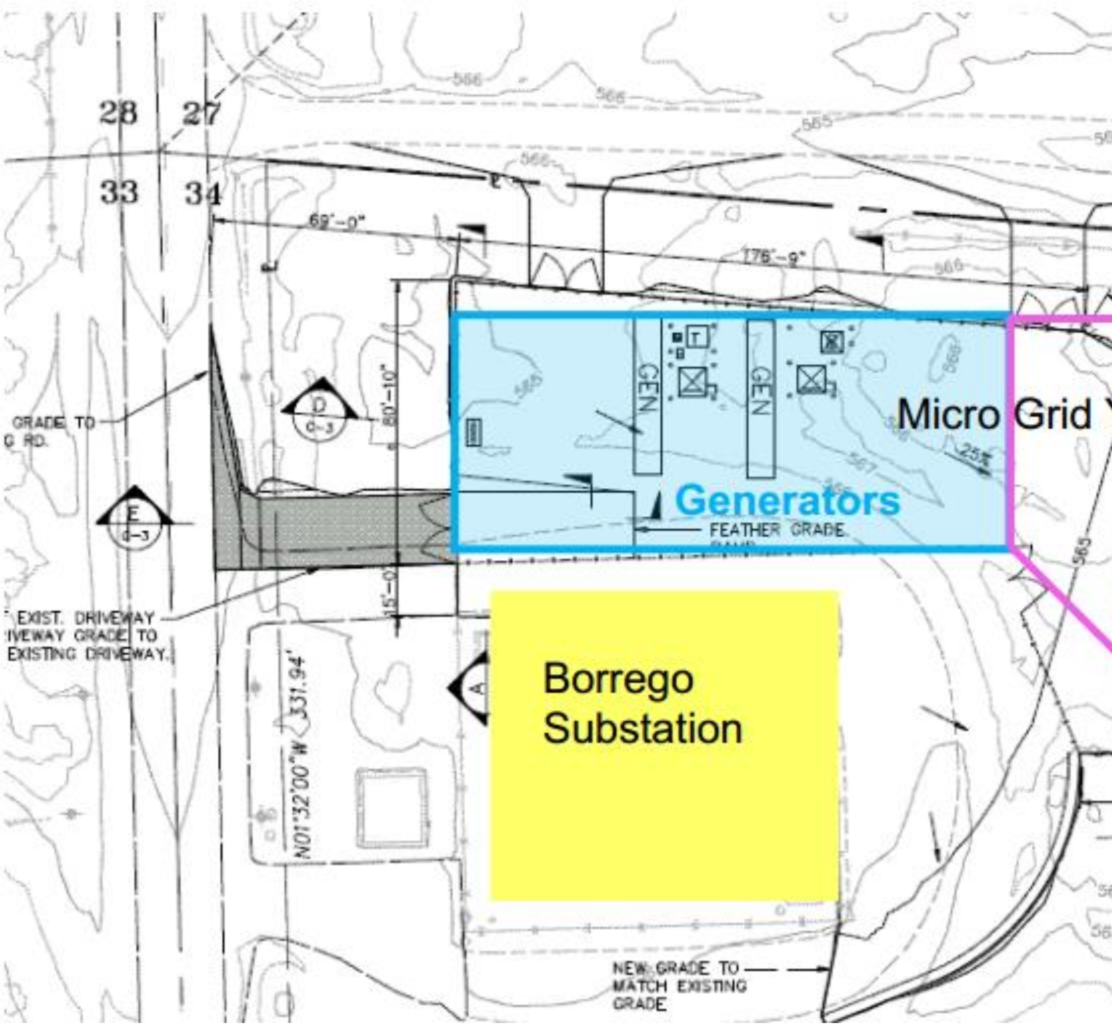
Borrego Springs



- **Substation Energy Storage (SES)**
  - One 500 kW/1500 kWh battery at Borrego Sub
- **Community Energy Storage (CES)**
  - Three 25 kW/50kWh units on circuit 170
- **Home Energy Storage (HES)**
  - Six 4 kW/8kWh units

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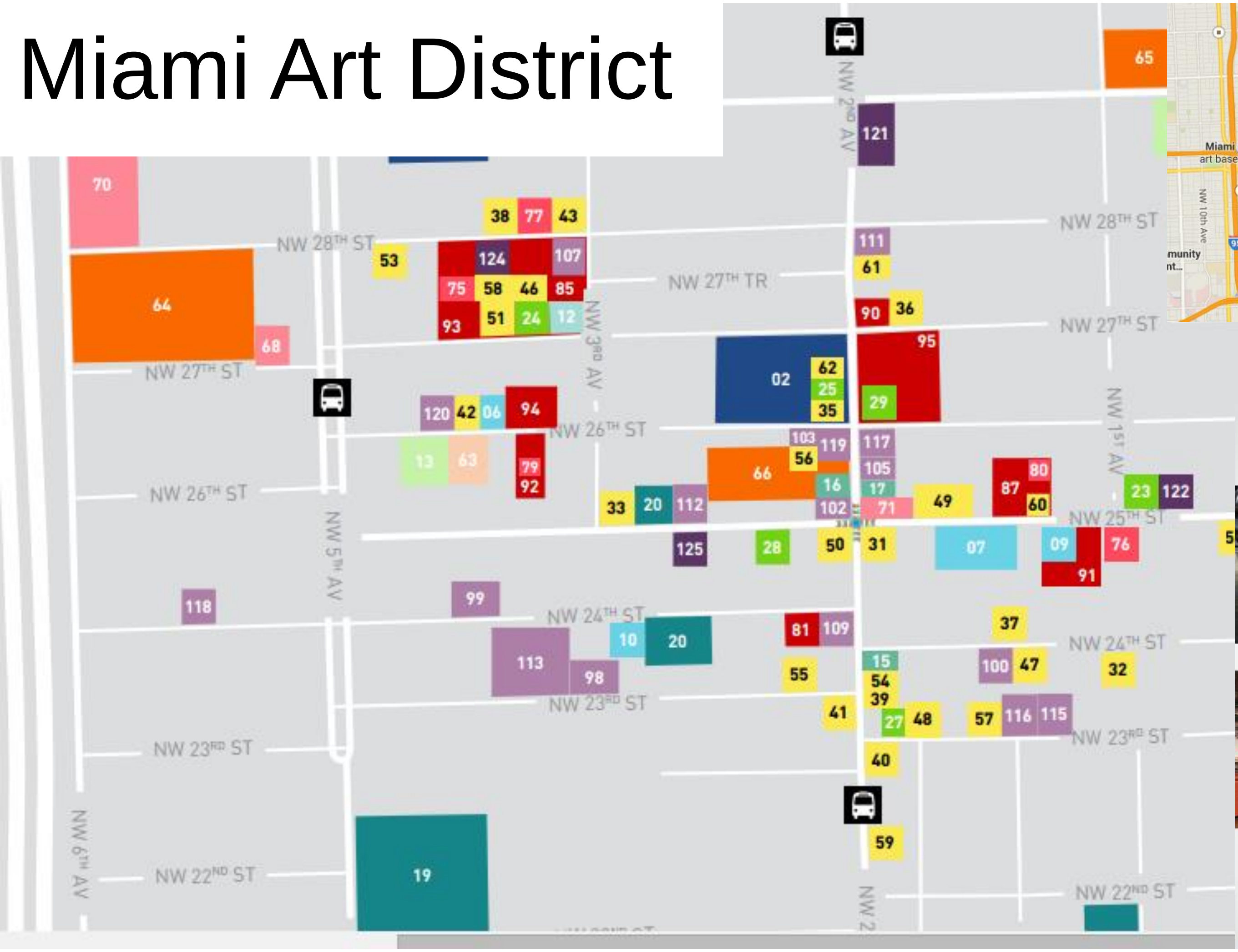
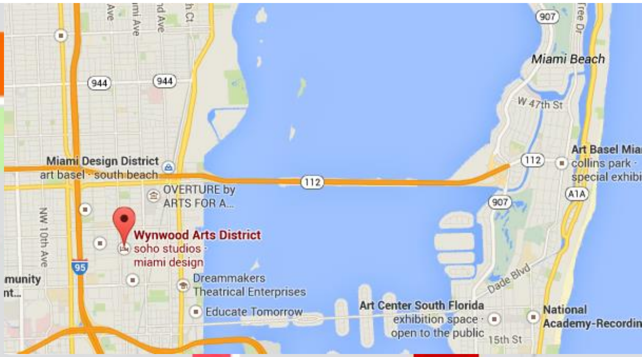
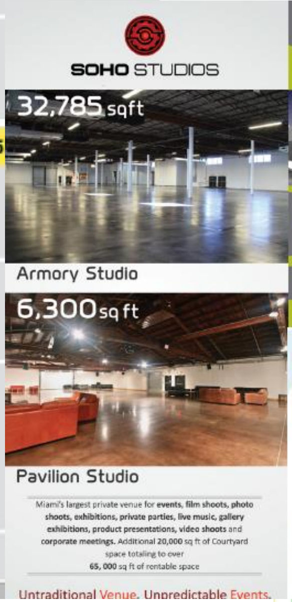
Examples – Smart Districts

Miami Art District







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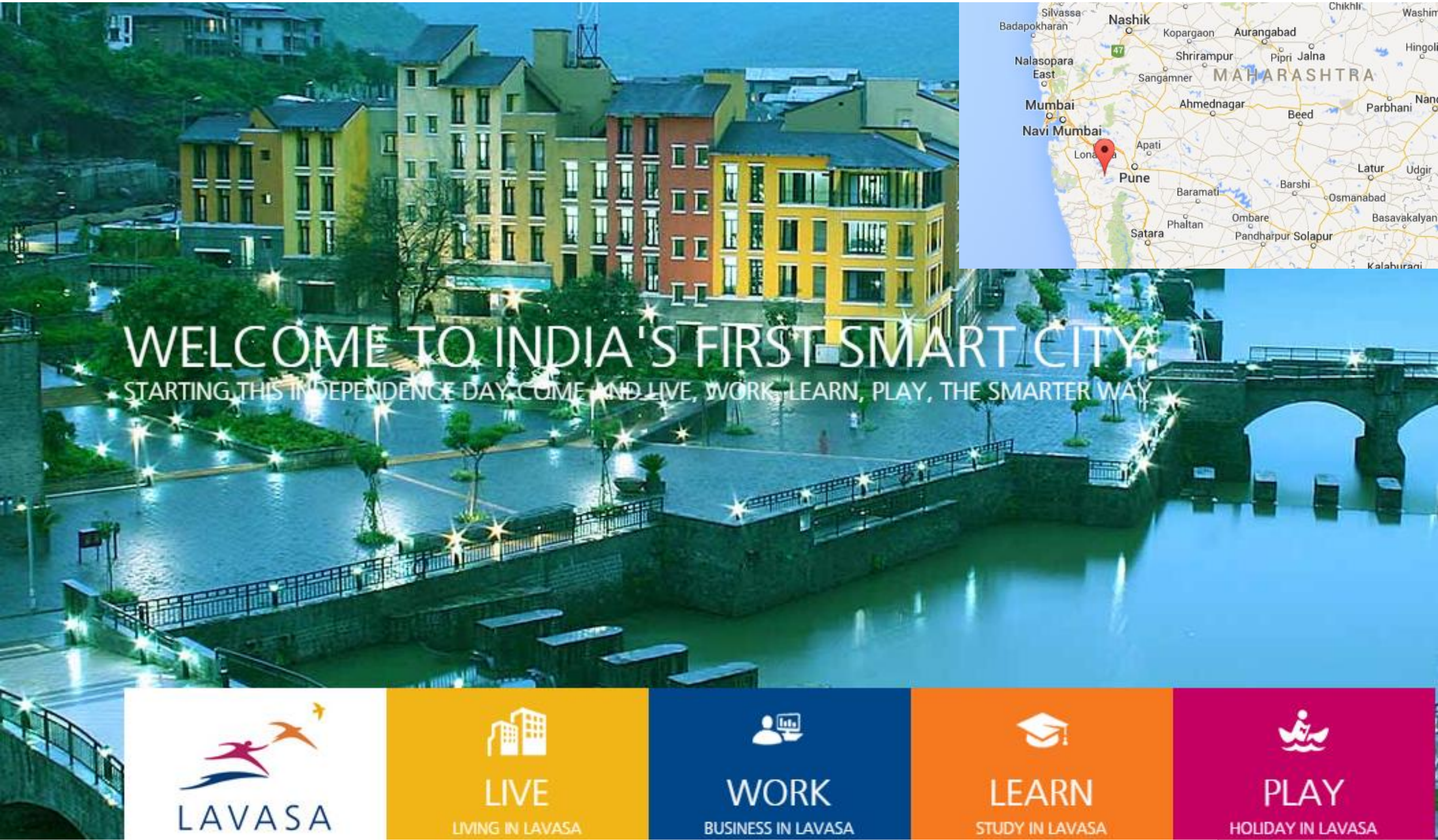
Lavasa, India's 1st "Smart City"



Barcelona Smart City

Nice Grid Eco City

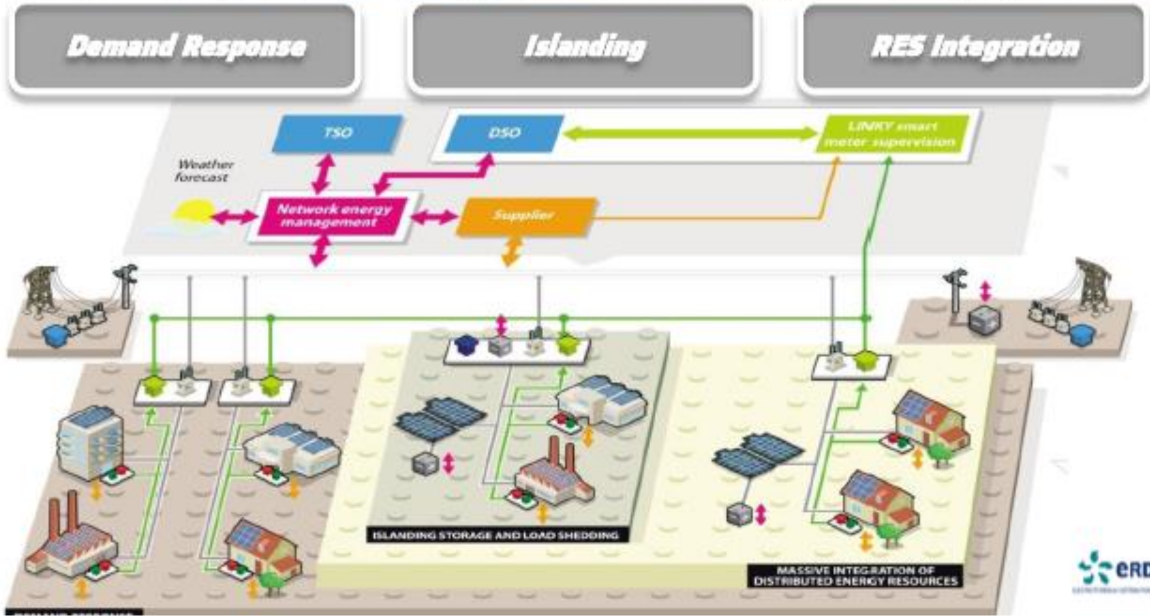
Duration: 4 years 2011 - 2016

Budget: €30 million overall,

Participants: up to 1,500

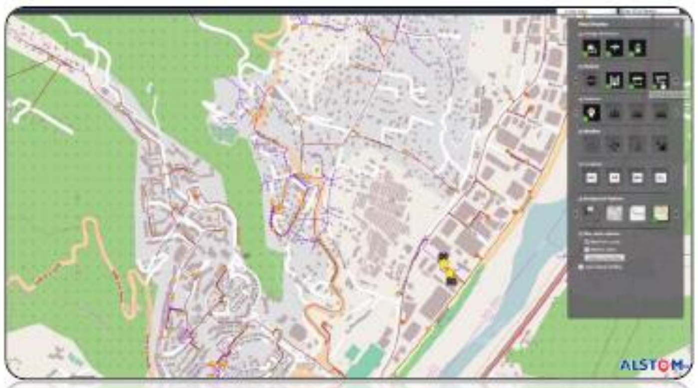
- Up to 200 sites equipped with photovoltaic panels with 2.5 MWp of capacity
- Solar generated power above 1 MWp

Visitors : +3000 people



ALSTOM Network Energy Manager (NEM)

DR Portal & DER Forecast & Network Battery Manager



New business model between Urban area and Rural area

➢Mega-Cities and isolated Rural Areas can cooperate in Energy Supply & Demand, and Green Energy Investment.

Rural Area

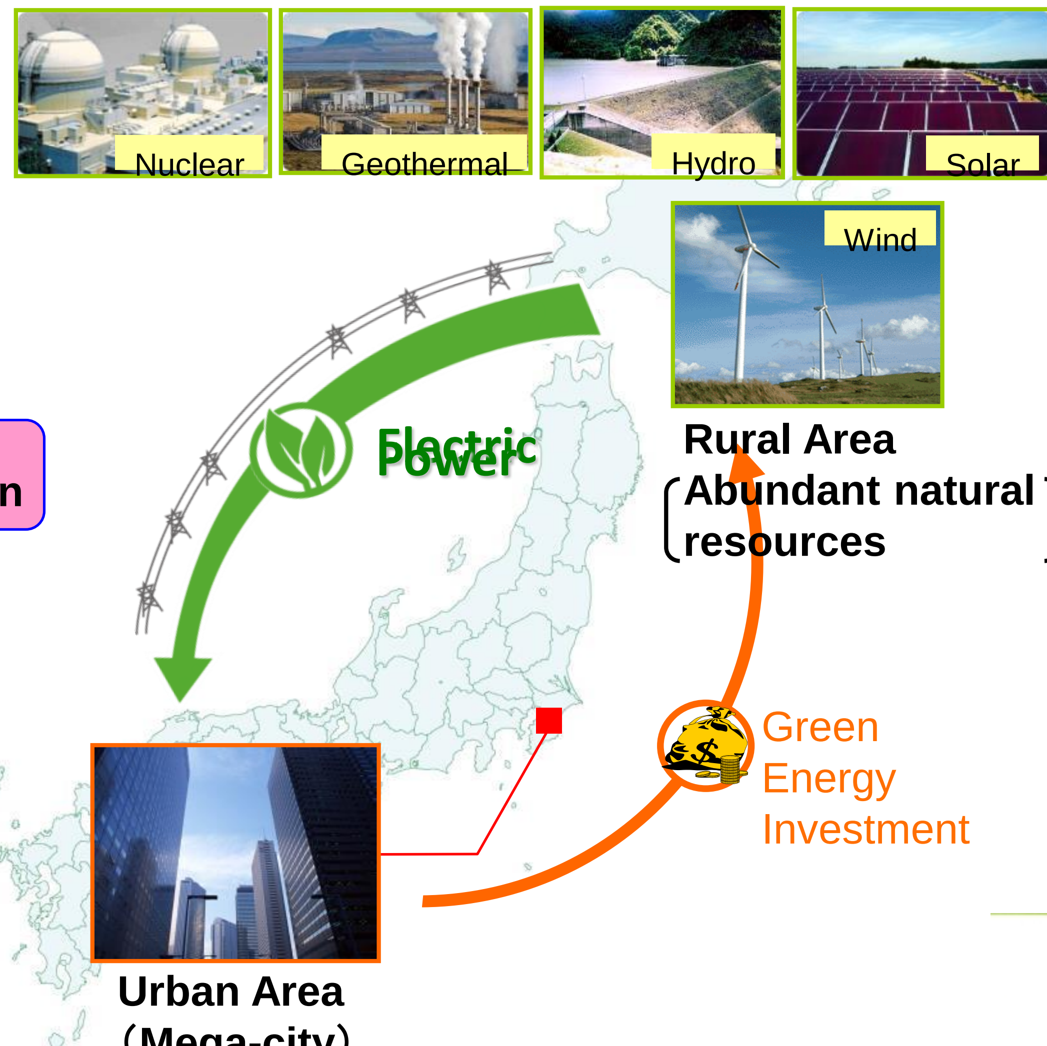
- Introduction of renewable energy
- Green power supply

CO_2 Reduction

Economic Revitalization

Urban Area

- Concentration of energy demand
- CO_2 emissions increase



Summary

- Economic, sociologic and environmental pressures require us to examine a new energy management model
- Smart Districts within Smart Cities meet individual requirements and offer larger grid support
- MicroGrids and Smart Districts allow generation, storage, and loads to operate autonomously, balancing out voltage and frequency issues
- MicroGrid cells are scalable and can be clustered and aggregated locally
- MicroGrids are a new commercial growth area
- Competition drives need for standard architectures, technologies, policies and financing

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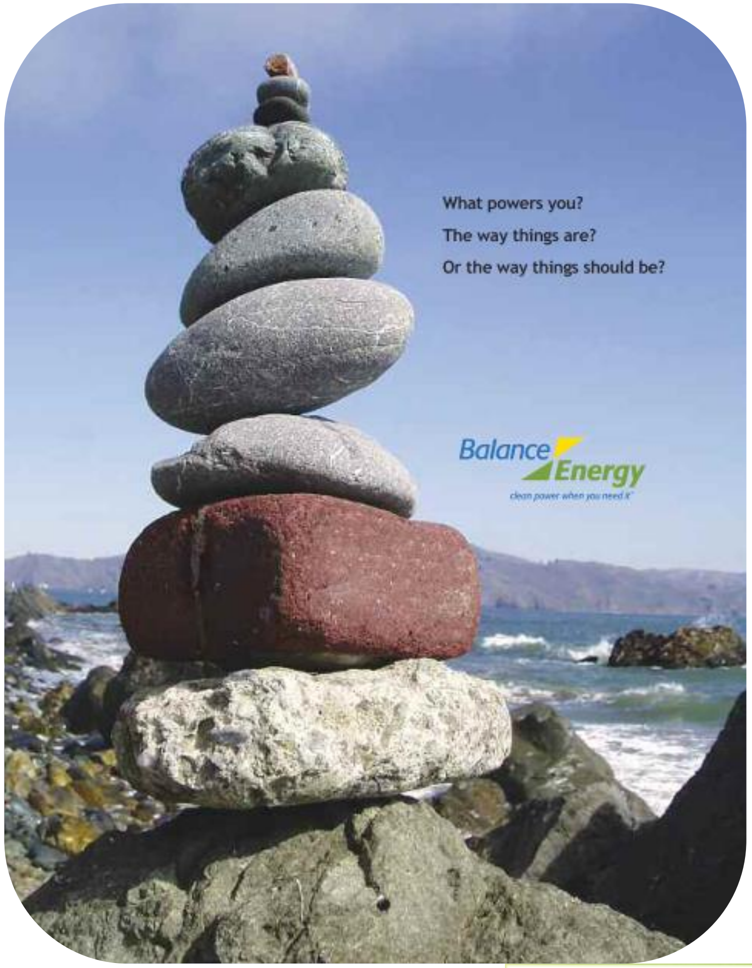
Thank You

Balancing Energy for a smarter, renewable-driven grid

Terry Mohn, CEO
terry.mohn@generalmicrogrids.com



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