6. Micro Grid and Micro-Power System Concept

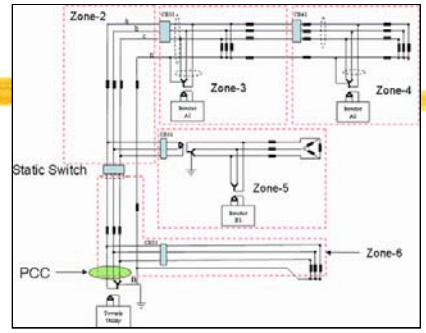
Charles Kim, "Lecture Note on Analysis and Practice for Renewable Energy Micro Grid Configuration," 2013. www.mwftr.com

Microgrid

- Microgrids incorporate distributed energy generation, both from renewable as well as fossil fuel power sources, into the larger electrical distribution system.
- Microgrids can be either operated in conjunction with, or "islanded" from, the utility power grid.
- Microgrids are utilized in a variety of settings including commercial applications, community/utility deployments, institutional power systems, military installations, and off-grid microgrids that provide electricity to remote villages and other sites.
- Pike Research reported that more than 160 microgrid projects are currently active around the world, with power generation capacity totaling more than 1.2 gigawatts (GW).
- Up to 2009: majority of microgrids have been pilot projects and/or research-related experiments.
- 2010 - shift to commercial-scale microgrid projects
- 2011: IEEE islanding standards in 2011

Micro Grid Overview

- Interconnected network of distributed energy systems (loads/resources) that can function connected to or separate from grid
  - During a grid disturbance, a micro grid isolates itself from the utility seamlessly with no disruption to loads within;
  - automatically resynchronizes and reconnects to grid seamlessly when grid conditions return to normal
- Existing projects
  - CERTS Micro grid Test Bed (AEP) - Testing started 11/06
  - GE demo -Advanced controls, energy management and protection technologies
  - US Army CERL/Sandia Labs Energy Surety Project -Controls, optimization of resources and storage
  - More than 160 Microgrid project are currently Active around the world [as of May 2011]



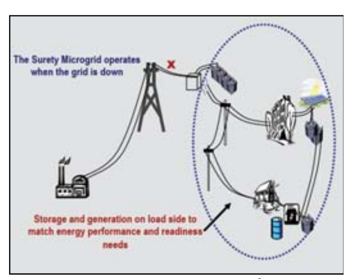
US Army Corps of Engineers®
Engineer Research and Development Center

DOE Microgrid Perspective - 2012

- **Definition** (by Microgrid Exchange Group): “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.”
- **Microgrid Configuration**
  - Consumer Microgrid—single consumer with demand resources on consumer side of the point of delivery, (e.g. sports stadium)
  - Community Microgrid— multiple consumers with demand resources on consumer side of the point of delivery, local objectives, consumer owned, (e.g., campus, etc.)
  - Utility Microgrid—supply resources on utility side with consumer interactions, utility objectives

Key Attributes

1. Grouping of interconnected loads and distributed energy resources
2. Can operate in both island mode or grid-connected
3. Can connect and disconnect from the grid
4. Acts as a single controllable entity to the grid



Micro Grid Control & Optimization

- Micro grid Control System **automates and optimizes** the use of distributed energy resources (DER) such as conventional generations, renewable-based generations, energy storages, and dispatchable loads.
- **Optimization** of a microgrid involves coordinating the timing and selection of dispatchable DER with the non-dispatchable ones (such as renewable resources) to minimize **energy cost** or **emission**.

Micro Grid Optimal Dispatch

- Micro grid controller determines a set of dispatch decisions by applying the **cost objective** against the **constraints**, and the **dynamic state** of micro grid such as
  - the current output power levels of **generators,**
  - the input/output power levels **of storage**
  - **the state-of-charge** of each energy storage unit, etc.
- The decisions are translated into **specific DER actions** such as **on/off control** and power reference set-points.
- The optimization process is **performed periodically** to follow the evolving dynamics of the micro grid.

Micro Grid at Palmdale

- Palmdale Water District (Palmdale) in California
- 1000kW Diesel back-up genset; Pump station loads: 760 kW
- Use of ultracapacitor energy storage module; 450 kW
- Distributed energy resources: 950 kilowatt wind turbine, a 200 kilowatt natural gas generator, and a 250 kilowatt water turbine generator

California

Micro Grid in UAE

- Abu Dhabi (UAE) Project
- Powered by renewable electricity --- island based renewal microgrid
- Plan: Control system, energy storage, DC distribution, Solar PV, Wind, and Biofuel.
- Cooperation with South Korea's Research Institute for industrial Science and Technology, and is being supported by around $1 million in funding from steel producer POSCO.

Global Green Growth Institute

UAE-GGGI launches a Public-Private Partnership Project to Design 100% Renewable Energy Micro-grid

Abu Dhabi-UAE: 16 September, 2012

Micro Grid in UAE with GGGI

Elements for UAE Microgrid System

Global Green Growth Institute

Elements		Functions & Remarks
Energy Sources	PV power	- Zero emission power source - Consideration of climate and geometric condition
	Wind power	- Small wind power
	ESS	- Night time energy source (Energy storage and grid stabilizing)
	Micro turbine	- Emergency dispatch power source (using bio diesel from Algae farm)
Smart Meter		- Real-time remote metering - Bi-directional information exchange and consumer load control
EV Charging Station		- zero emission vehicle and Boat
Energy Management System (EMS)		- Macro grid connection control - Consumer demand monitoring and demand response control - Weather information based demand prediction - Grid operation optimization and stabilization - Battery storage control (charge and discharge control) - Desalination plant operation using surplus energy
Network & Security		- Full connectivity for each unit (information & control network) - Economic and expandable network configuration
Desalination plant		- To use surplus energy efficiently - Water storage
Bio energy plant		- Algae farm and Bio-fuel production

Micro Grid Project – SDG&E

MicroGrid Selected Site: Borrego Substation

Sempra Energy utilities

Key Characteristics:

Strengths:

- No residences nearby, plenty of land
- More Existing Solar Customers
- Large Reliability Improvements Possible
- Possibility of 'Islanding' Entire Community
- Great learning environment
- Extendable to service territory

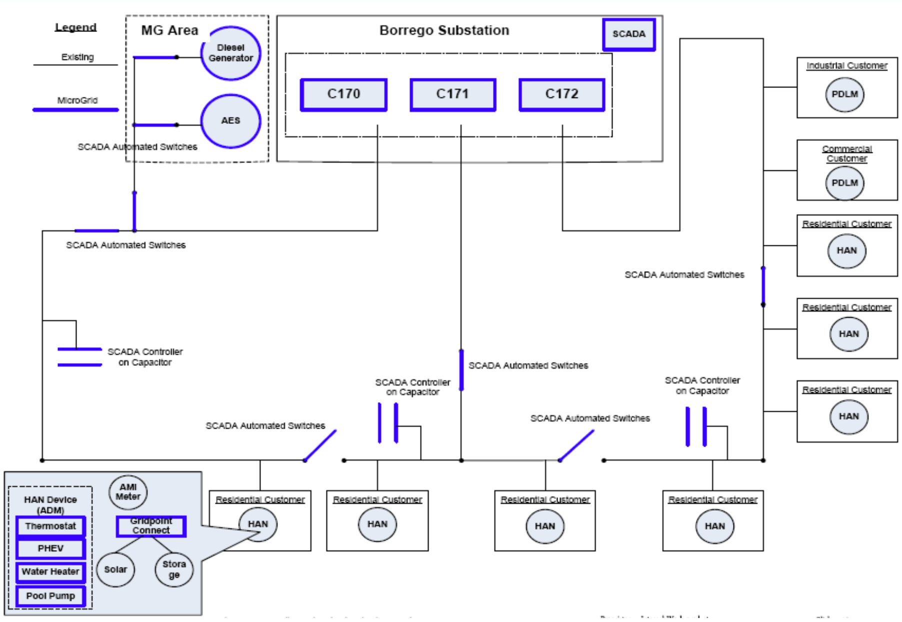
Challenges:

- Remote Area
- Challenging Communications Environment
- New Fencing Required
- Requires Accelerating schedule for Condition Based Maintenance and AMI Deployment

Borrego offers SDG&E an opportunity to be the leader in the Micro Grid area, with the possibility of being able to island an entire substation with peak load of over 10 MW.

Circuit Diagram - Illustration

- Target: >15% peak load reduction
- Two(2) 1.8 MW Diesel Generators (200 hours per year)
- AES System Battery: 1.0 MW power output and 6.0MW-Hr of energy
- 25-50kW 1-3 Hour storage Battery
- 100-300kW 3 hour storage battery

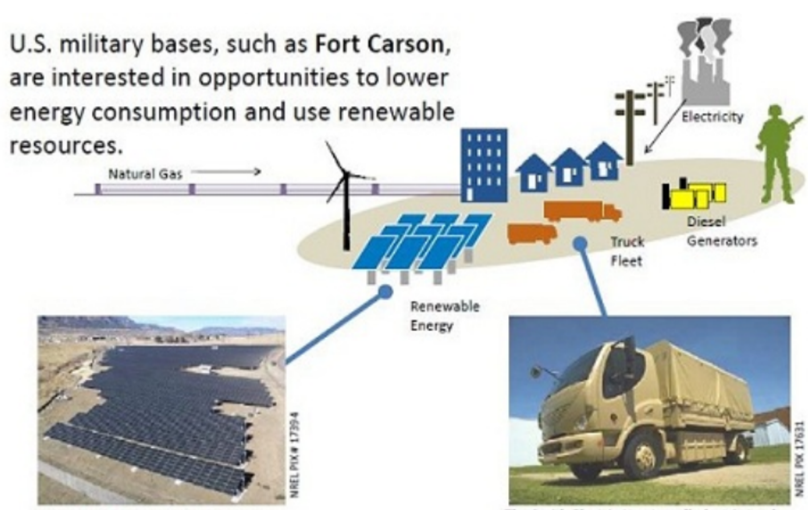


Military Micro Grid

- Fort Carson Base in Colorado
- Electric Car batteries as energy storage
- Solar power as alternative energy source
- The base has one of the Army's largest solar arrays on base proving more power than the base's needs.

U.S. Military Testing EVs As Battery Backups For Bases

DECEMBER 5, 2012 BY CHRISTOPHER DEMORRO 1 COMMENT



Fort Carson Photovoltaic Installation
Courtesy of U.S. Army Fort Carson

The Smith Electric Newton all-electric truck
Courtesy of Smith Electric Vehicles

Micro grid & Smart Grid

- As a source/load to the distribution system

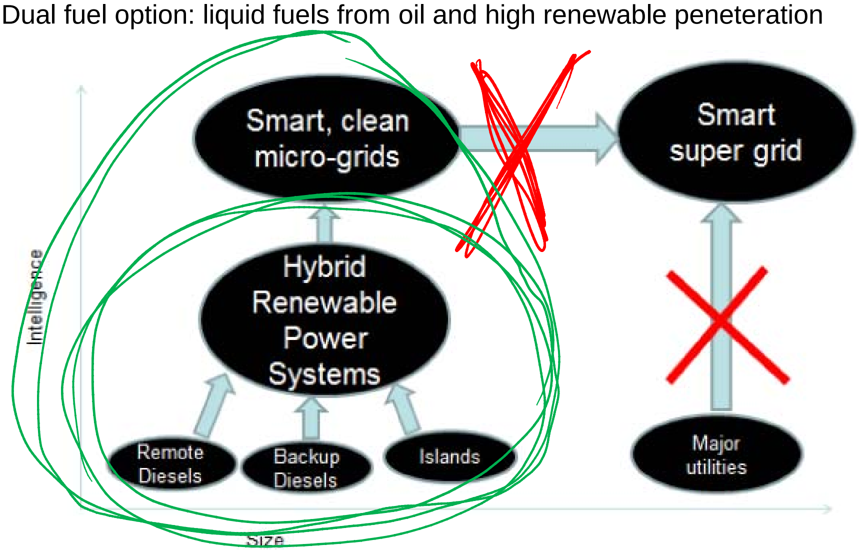
Future Smart Grid with Micro Grids

- Plug-and-play integration of smart micro-grids
- Communication, data, and power exchange

Future Distribution Architecture

A new way-out (from the Smart Grid bubble?)

- Large utilities' position on renewables
  - Obligation
  - Security obstacles
  - Regulatory obstacles
- Smaller System
  - Dual fuel option: liquid fuels from oil and high renewable peneteration



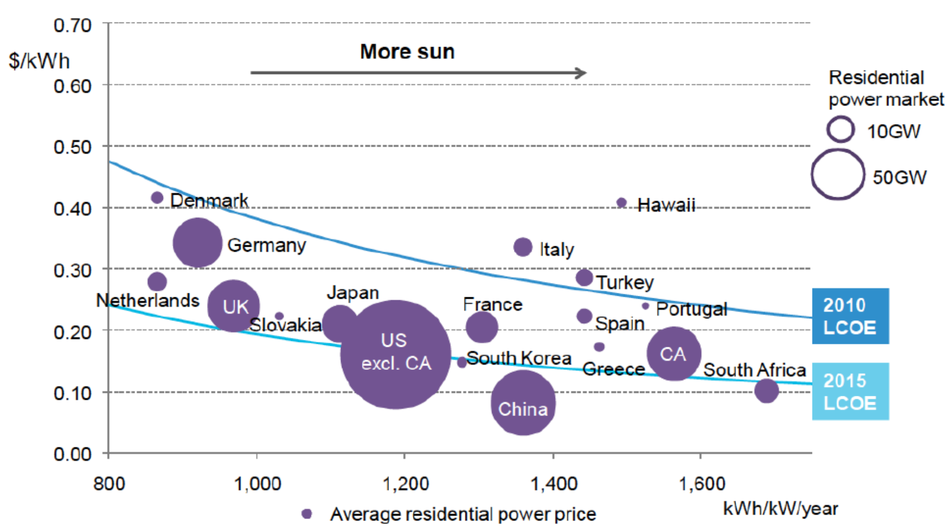
Island Micro Grid

- Why islands?
  - Renewables compete with oil, not gas
  - Power being used at point source without regulation
  - Wind (Solar)-Diesel: for large communities of facilities with large loads
  - Don't need incentives or subsidies
  - Don't need transmission access
  - High renewable contributions
  - Challenges
    - Patience with new technology
    - Logistics
    - Cultural issues

Future on Islands

- Islanders: high and variable energy costs; Excellent access to renewables
- LCOE: Levelized Cost of Energy

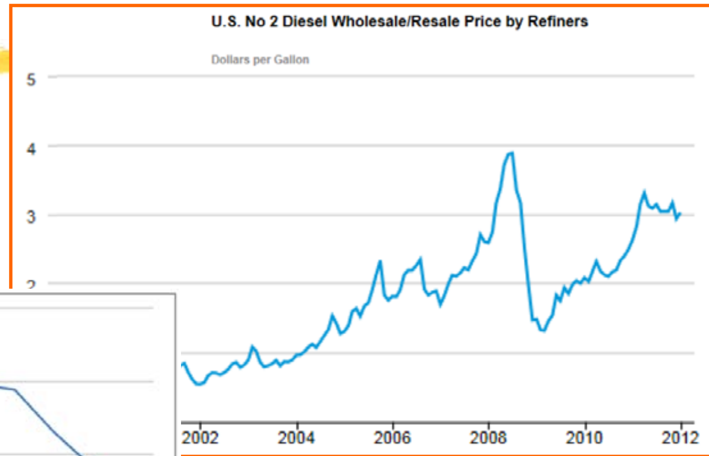
Islands can lead the way



Michael Liebreich, Bloomberg New Energy Finance

PV Diesel Cost -- Projection

- Where are the prices going?



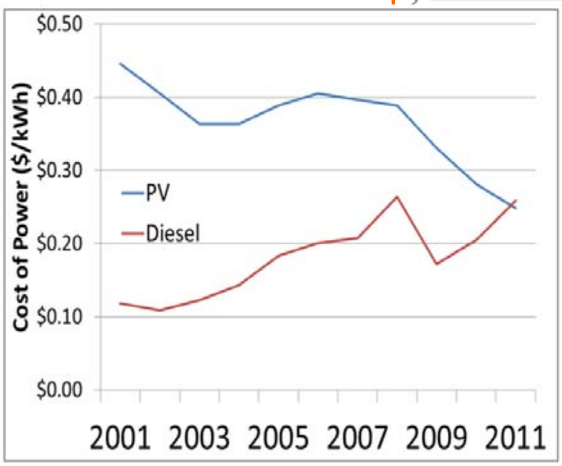


Table of fuel oils

Name	Alias	Type	Chain Length
No. 1 fuel oil	No. 1 diesel fuel	Distillate	9-16
No. 2 fuel oil	No. 2 diesel fuel	Distillate	10-20
No. 3 fuel oil	No. 3 diesel fuel	Distillate	
No. 4 fuel oil	No. 4 residual fuel oil	Distillate/Residual	12-70
No. 5 fuel oil	Heavy fuel oil	Residual	12-70
No. 6 fuel oil	Heavy fuel oil	Residual	20-70

Island Interconnection

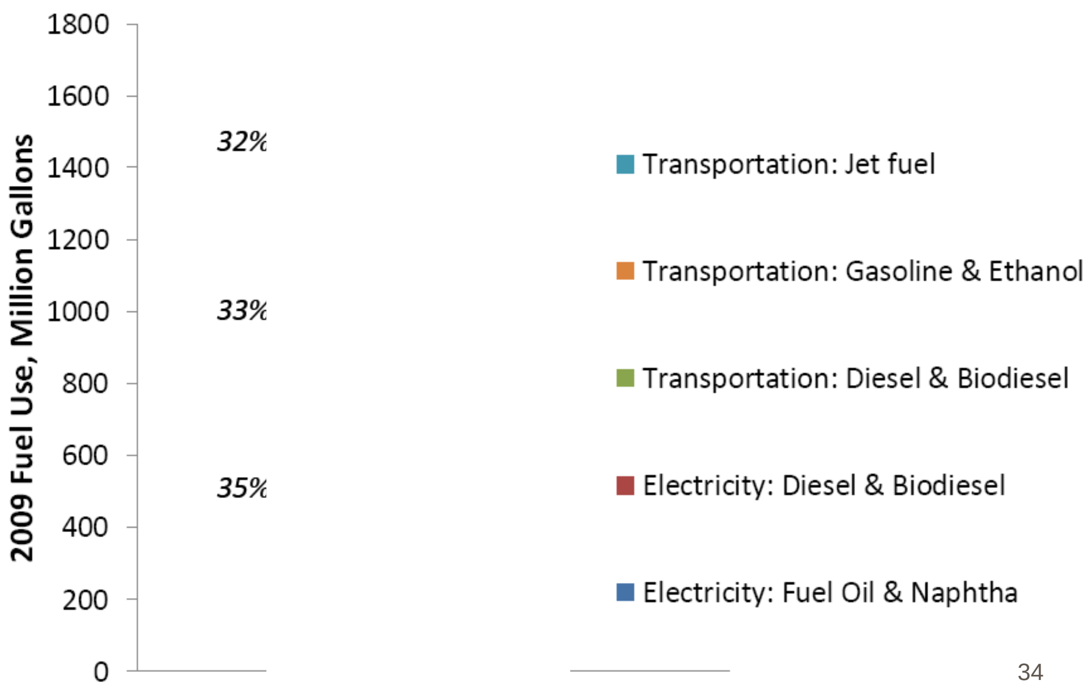
- Deliver lower cost power from one island to another
- Transmit renewable generated energy to an island that otherwise does not have access to less expensive renewable power
- Increased reliability, better power quality, better hurricane resilience

Island Interconnection - Example

- Caribbean Grid (World Bank)
- Puerto Rico – USVI - BVI (DOE)
- Nevis – USVI – Puerto Rico (U.S. Dept. of State / OAS)
- Puerto Rico – Dominican Republic (World Bank)

Hawaii Example

- Regional-focused energy strategies

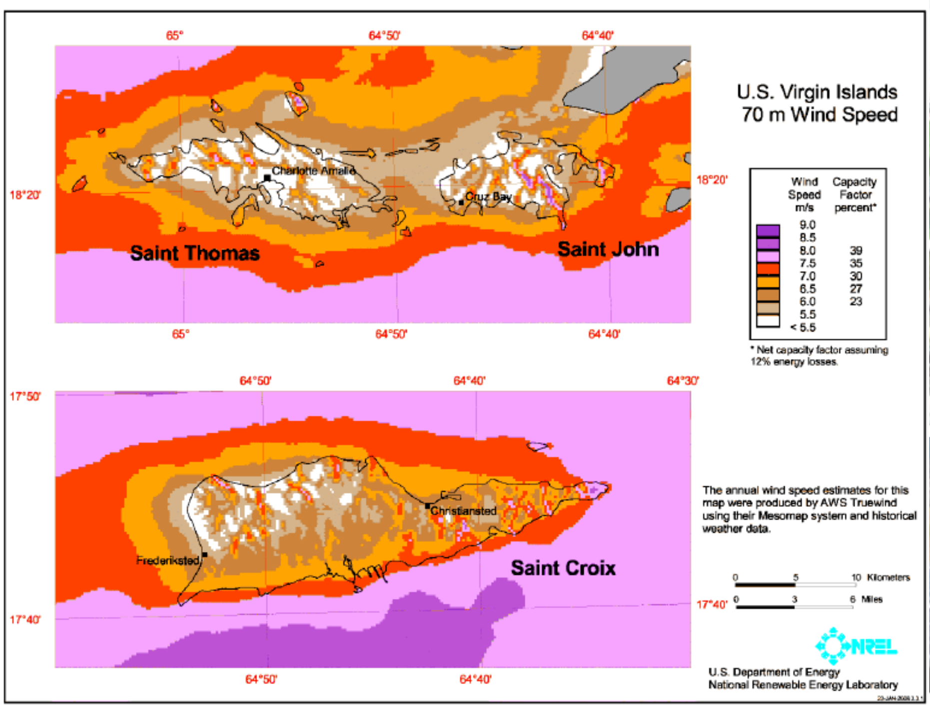


Hawaii Projects

- **US-Japan Maui Smart Grid**
  - integration of variable renewable energy resources on islanded grid with widespread adoption of electric vehicles
  - International cooperation – public/private partnership
  - 200 EVs with home charging + public fast charger network
- **Hawaii – Korea Smart Grid Proposal**
  - Collaboration with hotel industry on Oahu
  - focus on energy use in large commercial buildings with integrated renewable energy and electric vehicle charging

Virgin Islands under study

- Resources (Wind Speed)



Ieodo Island

⌘ December 8, 2013

World »


AFP

South Korea Announces Expansion of Its Air Defense Zone

New York Times - 2 hours ago

SEOUL, South Korea - Defying both China and Japan, South Korea announced on Sunday that it was expanding its air patrol zone for the first time in 62 years to include airspace over the East China Sea that is also claimed by Beijing and Tokyo.

Ieodo Science Center

- ⌘Solar Panels
- ⌘Wind Turbines

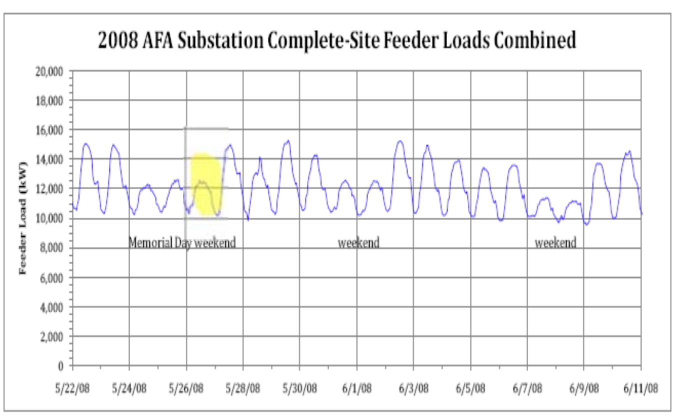
32.1230° N, 125.1824° E

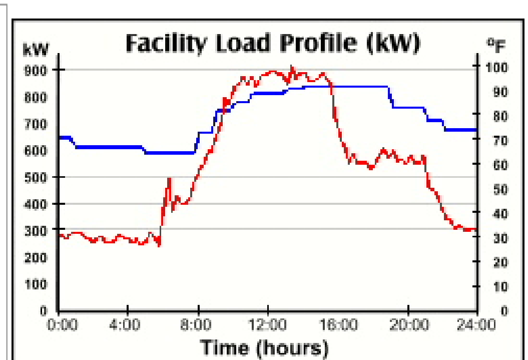
Micro Grid ("Micropower System") Planning & Design

- 1. Identify Site:
  - Clarify the goals of the microgrid:
    - What are the critical facilities that must be included in the microgrid?
    - What are the thresholds and how long should a utility disturbance persist before transitioning to islanded mode?
    - What is the maximum amount of time the microgrid must operate?
  - Factors impacting microgrid Capabilities:
    - Site mission
    - Geographic relationship of facilities and site electrical distribution system layout/characteristics
    - Existing standby generation capacity and controls
    - Availability and feasibility of renewable resources
    - Building management & control systems/ load control schemes
    - Utility standards and response to microgrid proposal

Load Profile

- 2. Load Study
  - Load Profiles – annual and daily peak and seasonal behavior
  - Operational equipment data
  - Critical and Sensitive load to power quality
  - Flexibility of load to adjust and match available generation

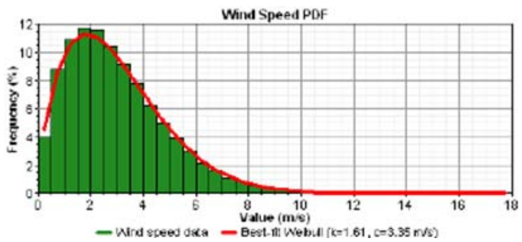


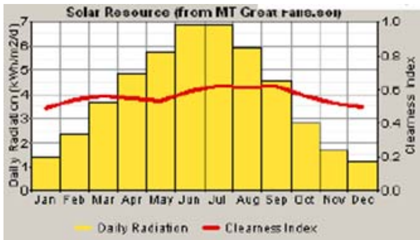


DG Resources

⌘3. DR and Energy Storage Study

- PV, Wind, etc for renewable sources
- Coverage required for microgrid footprint
- Existing standby generation characteristics
- Proposed/funded generation projects
- Fuel inventory and duration requirements
- Dispatchability to intermittency ratio
- Distributed storage considerations –location, technology, capacity, & duration

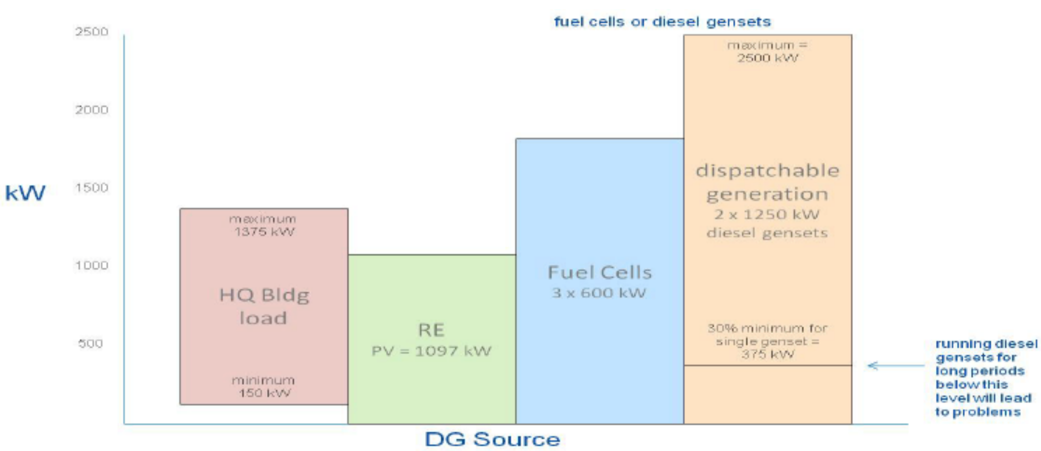




Meeting the Load

⌘ 4. Generation-Load Match Study

- Can existing/projected generation capacity meet the proposed peak load and daily operating requirements?
- Can dispatchable resources handle transient disturbances on the system while maintaining satisfactory voltage and frequency?
- Can existing dispatchable generation compensate for the variability of renewable resources?



Control Methods

⌘ 5. Develop Control Strategy
- Appropriate control strategies for self regulation - **load and generation** dispatch
- Include both **grid–connected** and **islanded** conditions
- Control of utility interface (i.e., static transfer switch) to handle seamless separation and reconnection to utility power
- Utility requirements (monitoring and/or control of interface)
- Local /central control schemes to monitor & control DR and loads
- Interface with building energy management system(s)
- Integration with existing **legacy communication systems/software**
- Address security concerns –cyber & physical
- Integration with existing **protection schemes**

Component Study

⌘ 6. Equipment Study
- Engineering analysis
- Modeling and Simulation under various scenarios
- Now, HOMER finally comes in here !!!