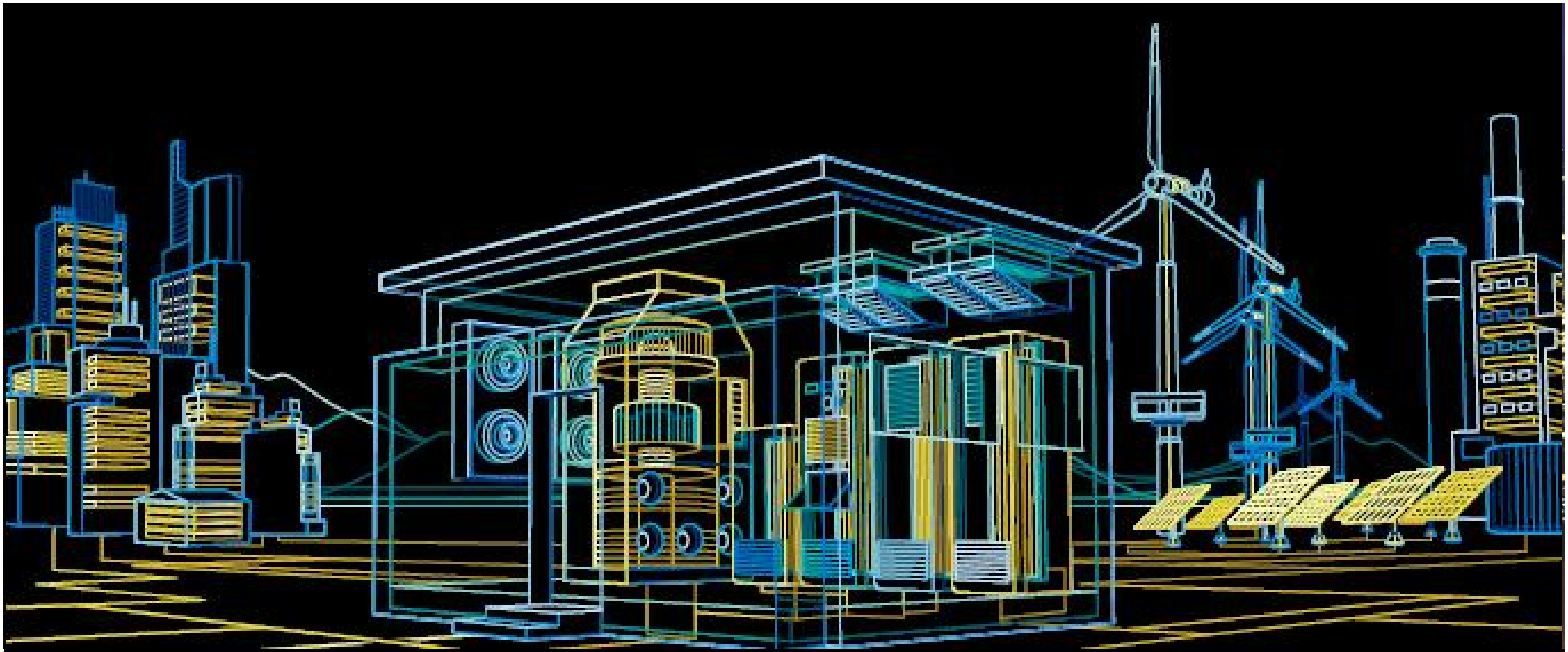


Pablo Astorga, ABB Power Generation, November 13 2015

Renewable microgrids

Reduced LCOE and secure power supply

Power and productivity
for a better world™

Renewable microgrids
Agenda

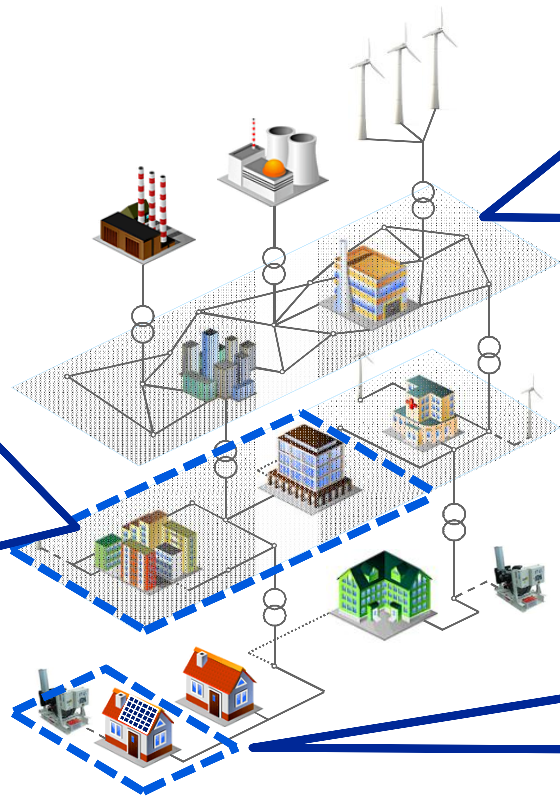
- Microgrid definition
- Renewable energy integration challenges
- Integration technologies
- Low, medium and high penetration
- Automation and grid stabilization
- Typical project scenarios

Energy and grid transformation
Microgrid participation

Microgrid

Distributed energy resources and loads that can be operated in a controlled, coordinated way either connected to the main power grid or in “islanded”* mode.

Microgrids are generation agnostic low or medium voltage grids without power transmission capabilities and are typically not geographically spread out.



Power grid

Power grids are larger conventional and spread out grids with high voltage power transmission capabilities.

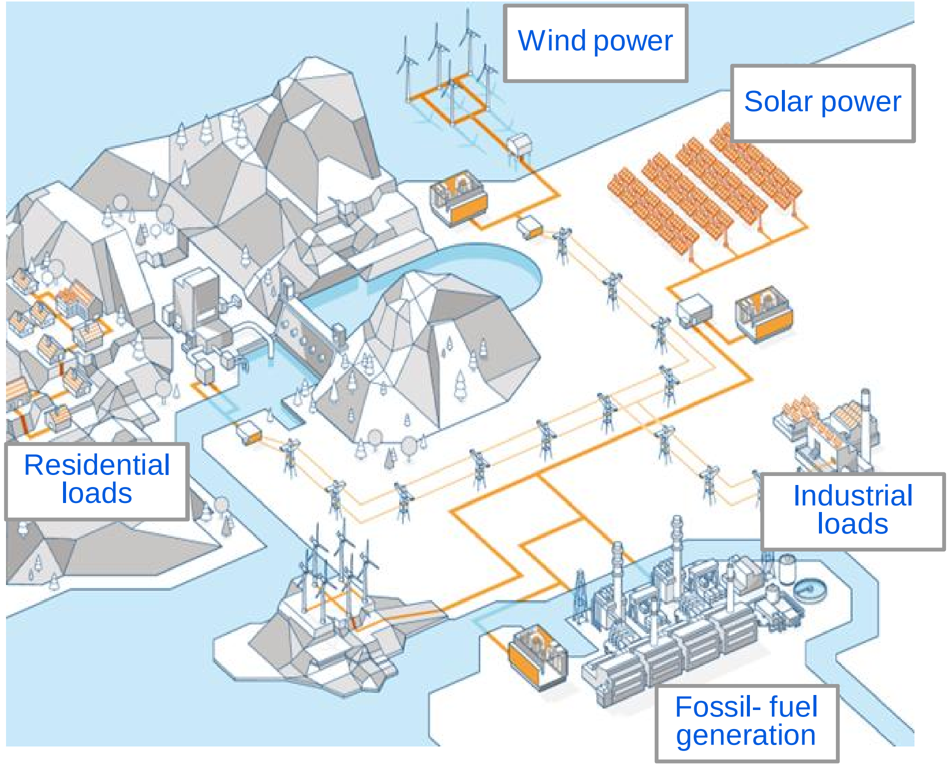
Microgrid technology can be applied to weak grids making the network more robust.

Nanogrid (<50kW)

Low voltage grids that typically serve a single building.

Islanded mode: ability to provide power independently from the main power grid

Sustainable access to electricity anywhere
Microgrids powered by renewable energy sources



Microgrids achieve secure power generation with grid-quality electricity while integrating renewable energy

Microgrid segments and main drivers
Covering a diverse range of applications

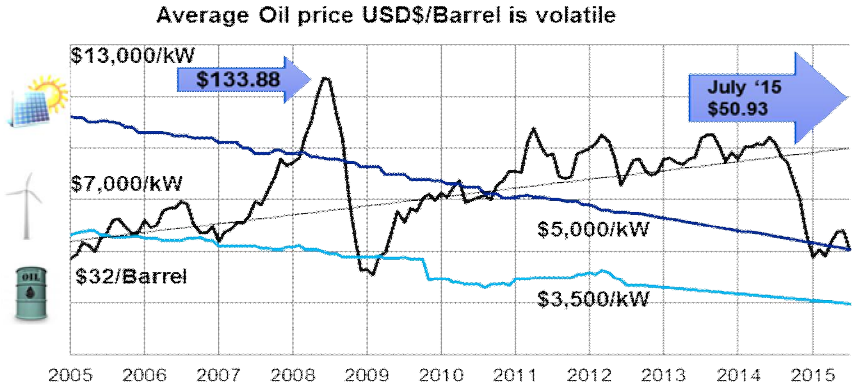
Off-grid
Weak grid
Grid-connected

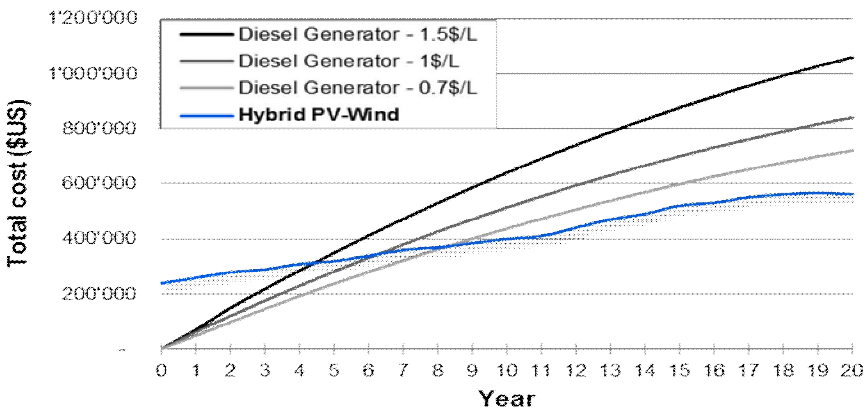
Segments	Typical customers	Main drivers: Social – Access to electricity	Economic – Fuel & cost savings	Environmental – Reduce CO_2 footprint and pollution	Operational – Fuel independence	Operational – Uninterrupted supply
Island utilities	(Local) utility, IPP*		✓	✓	✓	(✓)
Remote communities	(Local) utility, IPP, Governmental development institution, development bank	✓	✓		✓	
Industrial and commercial	Mining company, IPP, Oil & Gas company, Datacenter, Hotels & resorts, Food & Beverage		✓	(✓)	✓	✓
Defense	Governmental defense institution		(✓)	(✓)	✓	✓
Urban communities	(Local) utility, IPP			(✓)		✓
Institutions and campuses	Private education institution, IPP, Government education institution		(✓)	✓		(✓)

IPP: Independent Power Producer

✓: Main driver
(✓): Secondary driver

Fuel independence and lower LCOE
Secure power generation and fuel cost savings



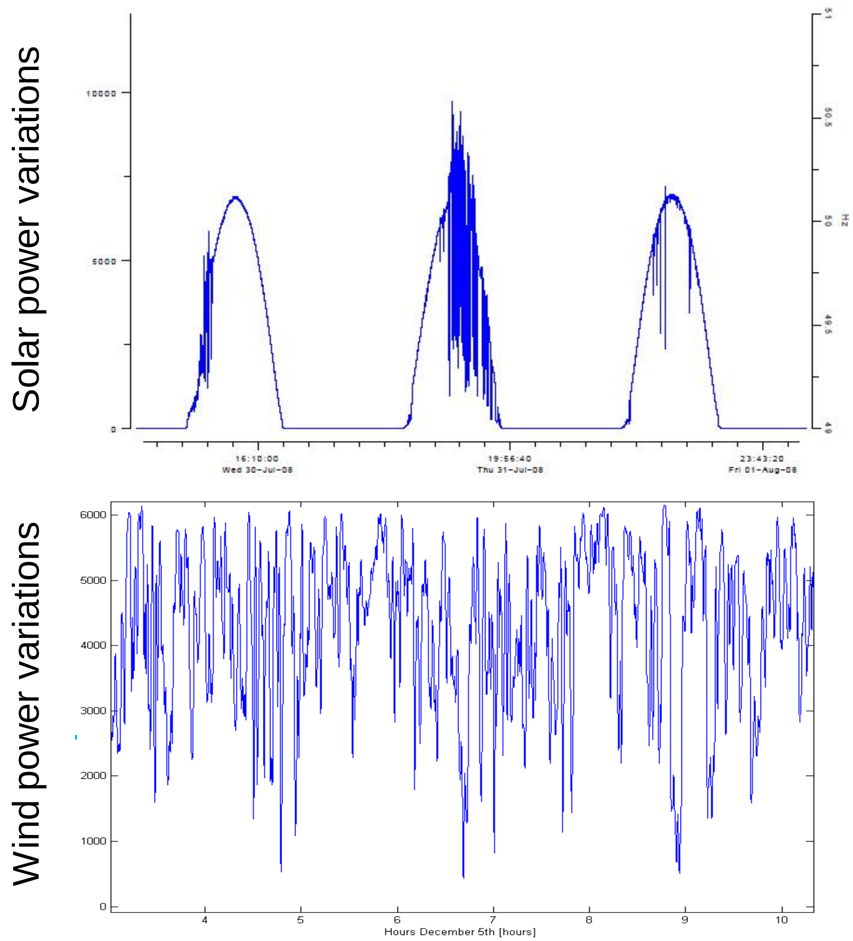


LCOE: Levelized Cost of Electricity

- Fuel cost is volatile
- Renewable energy cost is less volatile and decreases over time
- Renewable energy is economically competitive today
- Steady decline of renewable energy installation costs is opening new market opportunities
- An optimized energy mix leads to a lower cost of electricity

Sources: *1) US Energy Information Administration – Independent Statistics and Analysis*
http://www.cleantechinvestor.com/portal/fuel-cells/6422-mining-and-energy.html
2) Alliance for Rural electrification (ARE). Projections made from a case study based in Ecuador with real natural conditions.
http://www.ruralelec.org/fileadmin/DATA/Documents/06_Publications/Position_papers/ARE_TECHNOLOGICAL_PUBLICATION.pdf

Renewable energy integration challenges
Managing power output fluctuations



- Inherent volatility of renewable energy can compromise grid stability
- The renewable energy integration solution must address requirements traditionally fulfilled by diesel generation (base load)
  - Frequency and voltage control
  - Sufficient spinning reserve
  - Sufficient active and reactive power supply
  - Peak shaving and load levelling
  - Load sharing between generators
  - Fault current provision
- Renewable energy generation capacity should be sized to maximize ROI and fuel savings

ROI: Return on investment

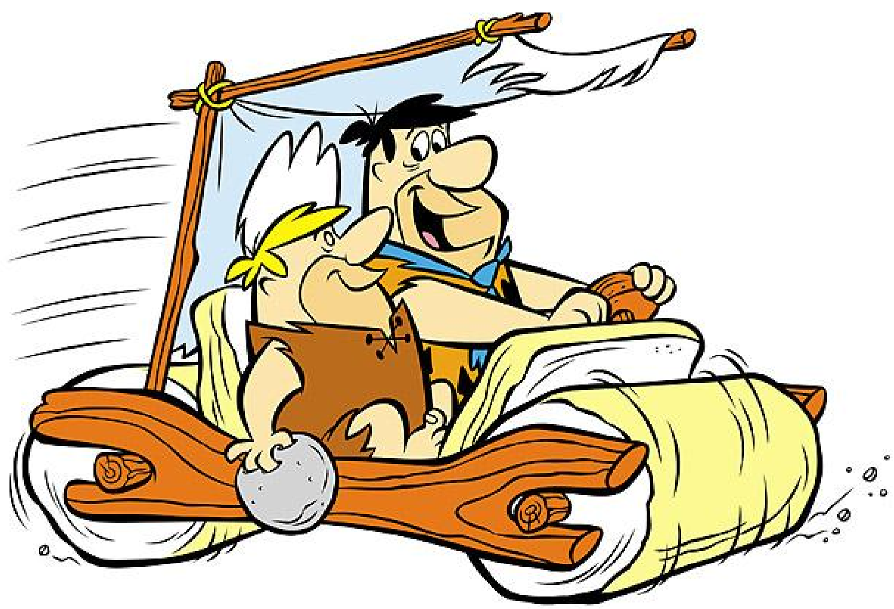
Renewable integration technology
Poor or no integration

Symptoms:

- Increased number of diesel start/stops
- Diesel generators trips on reverse power or overload
- Nuisance protection trips
- Power Quality; flicker, frequency and voltage variation

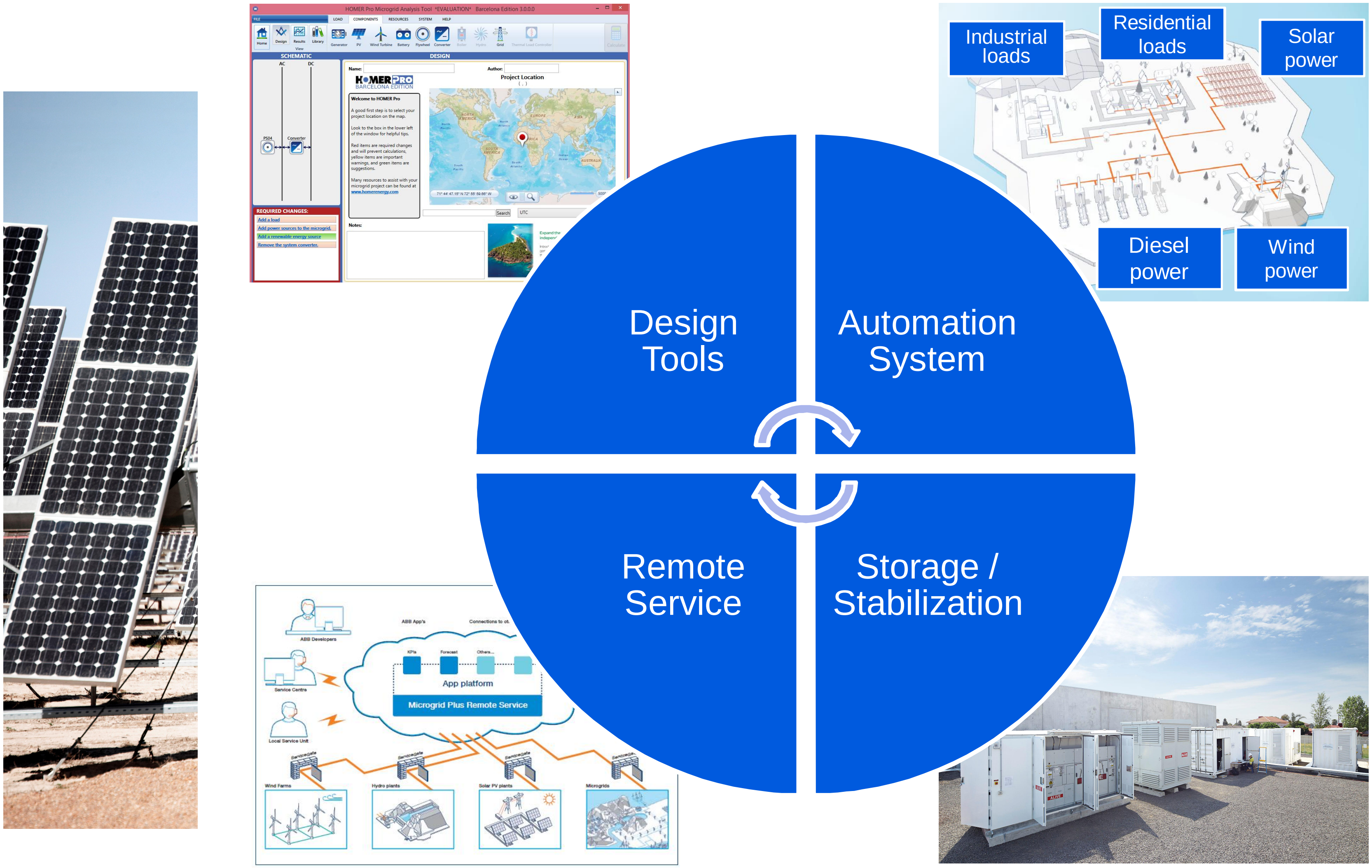
Consequence:

- Operator increases fixed diesel spinning reserve; diesel fuel consumption goes up
- Operator limits Solar PV or Wind plant output or switches entire plant off; no renewable generation
- Production loss due to blackouts

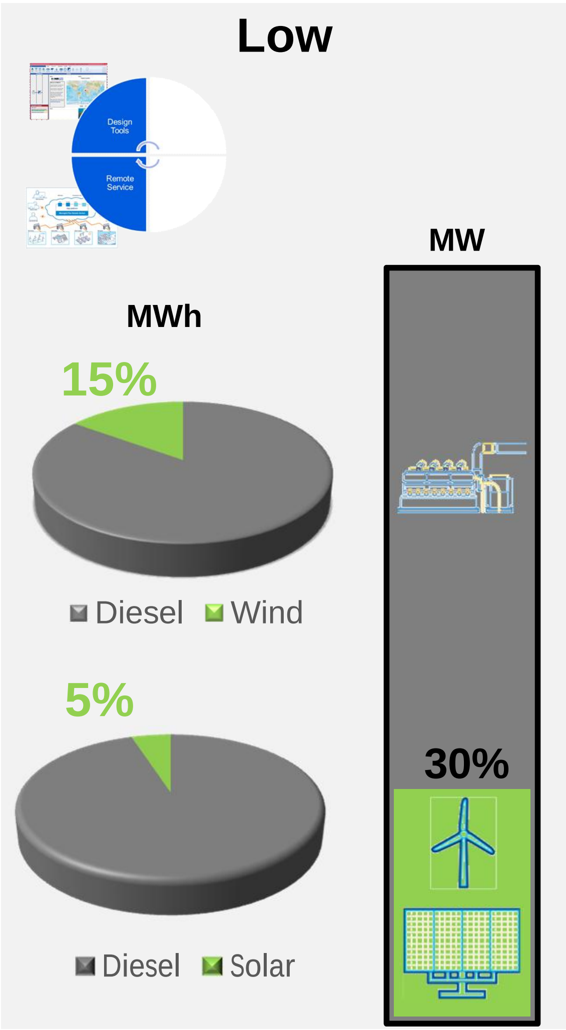


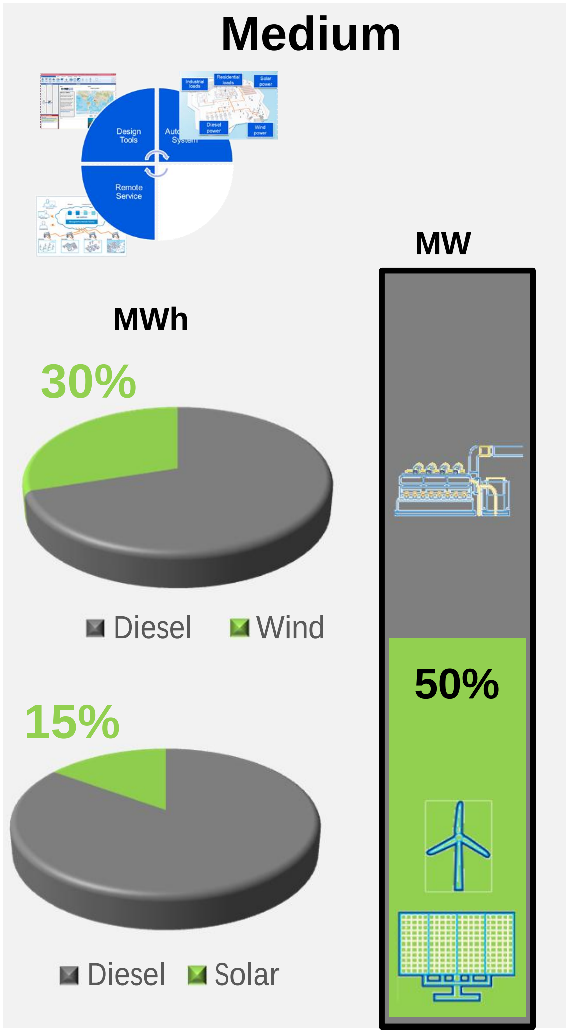
Back to Business as usual….. as in run the diesel

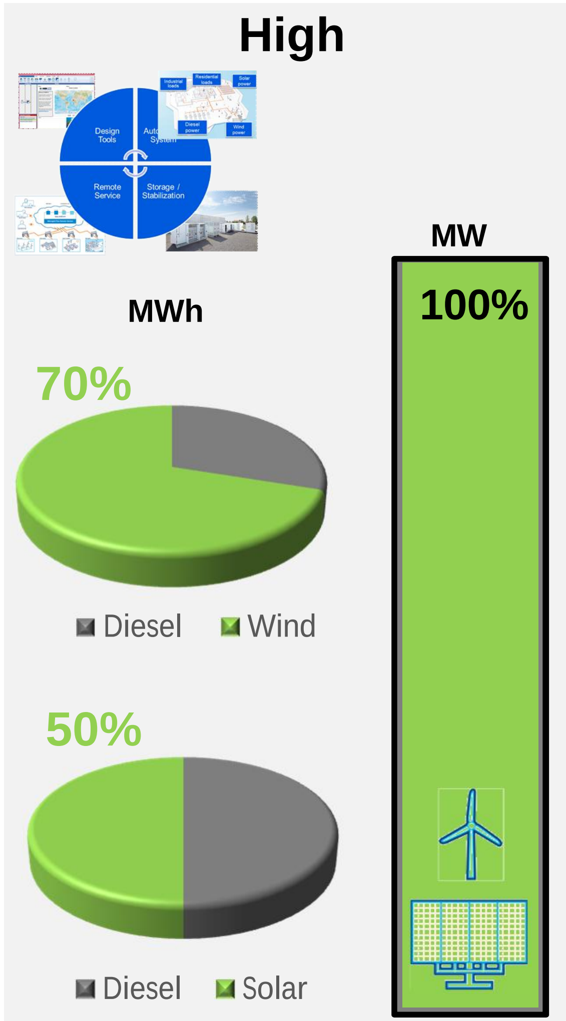
Hybrid power systems
Integration technologies



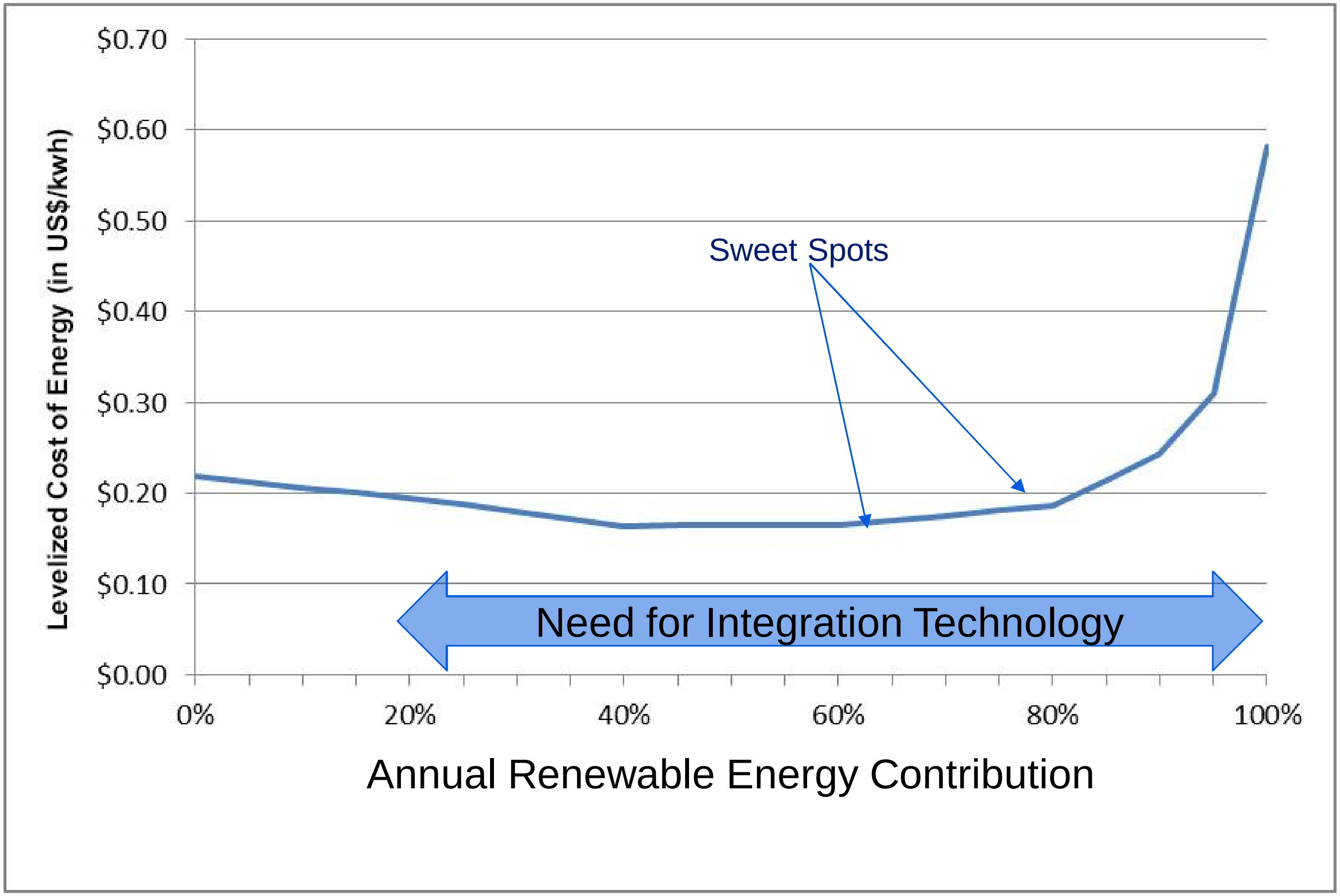
Microgrid technologies
Low, medium and high penetrations





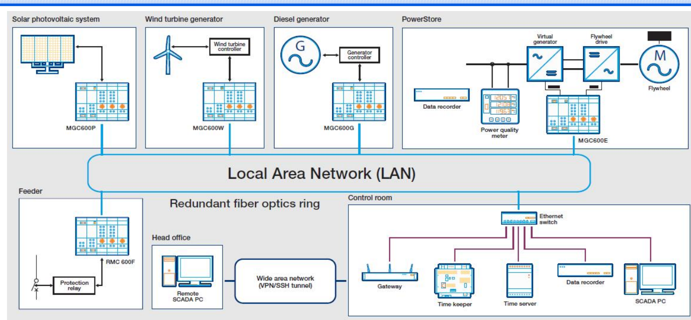


Integration technology
Defined by renewable penetration levels



Source: HOMER ENERGY Newsletter 06-2013

Automation and grid stabilization
Technology overview

<table>
<tr><th>Microgrid Plus system</th><th>PowerStore</th></tr>
<tr><td>Specially designed networked control system responsible for efficient and reliable power flow management</td><td>Compact and versatile grid stabilizing system capable of stabilizing power systems against fluctuations in frequency and voltage</td></tr>
<tr><td>


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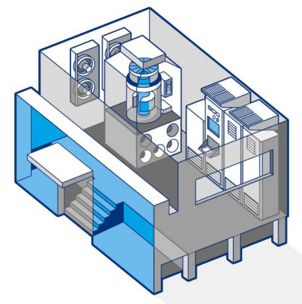
</td></tr>
<tr><td>• Maximizes fuel savings
• Optimizes use of renewable energy
• Guarantees optimum loading and spinning reserve in fossil fuel generators
• Distributed logic enhances reliability and scalability for future system expansions
• Modular and scalable</td><td>• Stabilizes an electricity network by rapidly absorbing/injecting power in order to maintain voltage and frequency
• Battery or flywheel based. Includes state-of-the-art inverters and virtual generator control software
• Applicable to isolated grids or in grid support mode</td></tr>
</table>

References – Hybrid power plant
Marble Bar, PV/Diesel

Australian Government
Department of Climate Change and Energy Efficiency

HORIZON POWER

Government of Western Australia
Office of Energy

Project name
Marble Bar
Country
Western Australia, Australia
Customer
Horizon Power
Government of WA
Completion date
2010

ABB solution

- PV/diesel Microgrid with PowerStore grid-stabilizing technology and Microgrid Plus System
- The resulting system consists of:
  - Diesel (4 x 320kW)
  - PV (1 x 300kW)
  - PowerStore-flywheel (1 x 500kW)
  - Microgrid Plus System

Customer benefits*

- Minimize diesel consumption, 405,000 liters of fuel saved annually
- Minimum environmental impact, 1,100 tonnes CO2 avoided annually
- Reliable and stable power supply
- 60% of the day time electricity demand is generated by the PV plant

About the project

Marble bar and Nullagine are the world`s first high penetration, solar photovoltaic diesel power stations

*For both Marble Bar and Nullagine projects

ABB

References – Integrated wind or PV plant
Ross Island, Wind/Diesel

Project name
Ross Island
Location
Ross Island, Antarctica
Customer
New Zealand's Antarctic Division
USA McMurdo Station
Completion date
2009

ABB solution

- Integration of wind turbines into the microgrid with PowerStore grid-stabilization and Microgrid Plus System
- Implement a frequency converter to connect a 50Hz network to a 60Hz one
- The resulting system consists of: Diesel (9 x 125kW), WTG (3 x 330kW), PowerStore-flywheel (1 x 500kW), Microgrid Plus System, frequency converter

Customer benefits

- Minimize diesel consumption
- Reduced environmental risk of transporting diesel
- 463,000 liters of diesel fuel saved annually
- 2,800 tons CO2 avoided annually
- Up to 70% wind power peak penetration

About the project

- Integration of the southernmost wind farm in the world into a dual 50 and 60Hz microgrid

References – Integrated wind or PV plant
DeGrussa Mine - Solar/Diesel

juwi

SANDFIRE RESOURCES NL

Project name
DeGrussa Copper-Gold Mine
Country
Australia
Customer
juwi Renewable Energy
Completion date
To be completed in 2016

ABB solution

- Integration of a new 10.6 megawatt (MW) solar PV field and a battery storage system with existing diesel generation to provide reliable base-load power.
- The resulting system consists of: PowerStore™ grid stabilization solutions (2 x 2 MW), solar inverter stations (5 x 2 MW), solar MV stations, a transformer (5 MVA) and the Microgrid Plus System

Customer benefits

- Expected diesel fuel saving is 5 million liters per year, cutting diesel consumption by 20%

About the project

- The new hybrid solar facility will be the largest integrated off-grid solar and battery storage plant in Australia.
- Once fully integrated, the plant will reduce CO_2 emissions by 12,000 tons.

ABB

References – Optimized microgrid integration
Faial, wind/diesel

Project name
Faial wind/diesel stabilization
Country
The Azores, Portugal
Customer
Electricidade dos Acores (EDA)
Completion date
2013

ABB solution

- Design, supply, installation and commissioning of a Microgrid Plus System
- The control system optimizes the wind penetration into the microgrid and helps dispatche the HFO generators optimally

Customer benefits

- Optimized wind penetration to ensure minimum fuel consumption and grid stability
- Reduced maintenance through automatic management of the wind farm power setpoint

About the project

The integration of wind energy combined with ABB's innovative solution will save an estimated 3.5 million liters of fuel per year

References – Ancillary power system services
Kodiak Island, grid stabilizing system

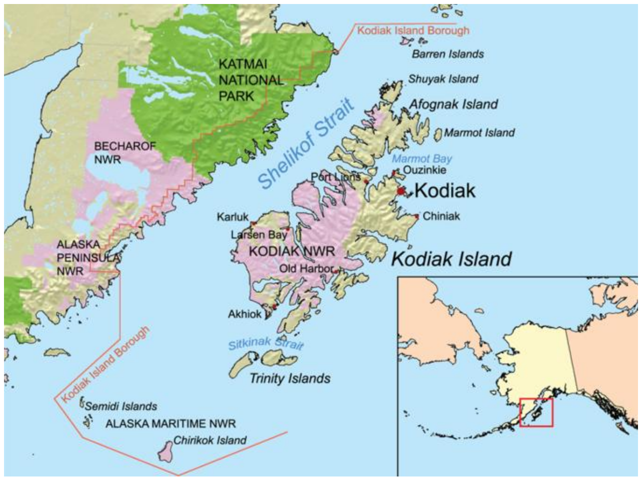

Image by, Karl Musser, created t based on USGS data. {{self|cc-by-sa-2.5}} Category:Maps of Alaska

Project name
Kodiak Island
Country
Alaska, United States of America
Customer
Kodiak Electric Association (KEA)
Completion date
Due to be completed in 2015

ABB solution

- Deliver two PowerStore-flywheel units to stabilize the power grid and increase renewable energy

Customer benefits

- Provide voltage and frequency support for a new crane
- Extend the life of the battery systems by up to 6 years
- Help to manage the intermittencies from a 9 MW wind farm
- Reduced reliance on diesel generators

About the project

- Two PowerStores act in parallel in order to deliver optimal grid stabilization on Kodiak island
- “Not only will the ABB PowerStores allow us to shave the peaks off our cranes’ load, it will also reduce the stresses placed on our battery systems and extend their lifespans, which was a key deciding factor to move forward with this project.” *Darron Scott, president and CEO of Kodiak Electric Association*

Ancillary power system services
Longmeadow, PV/Diesel/Battery

LONGMEADOW
Business Estate

Project name
Longmeadow
Location
South Africa
Customer
Longmeadow Business Estate
Completion date
2016

ABB solution

- PV/diesel microgrid with battery-based system to maximize solar contribution and ensure security of power supply at ABB's premises in Johannesburg
- The resulting system consists of:
  - 750 kWdc rooftop PV plant, including ABB PV inverter
  - 1 MVA/380 kWh battery-based PowerStore
  - Microgrid Plus System

Customer benefits*

- Reliable and stable power supply
- Optimized renewable energy contribution to the facility
- Ability to island from the grid in case of an outage
- CO_2 reduction: over 1,000 tons/year
- Up to 100% renewable energy penetration

About the project

The microgrid solution is for the 96,000 sqm facility houses hosting ABB South Africa's headquarters as well as manufacturing facilities with around 1,000 employees. The innovative solution will help to maximize the use of solar energy and ensure uninterrupted power supply.

Contact information
For any questions, please contact me

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