CONFIDENTIAL

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Reducing energy costs and environmental impacts of off-grid mines

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Agenda

1. Microgrid for Island Utilities
2. Overview of off-grid mining electricity operations
3. How microgrids create value in mining
4. What ABB has to offer
5. Mining microgrid case study
6. The pitch: creating microgrid opportunities

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Island utilities

Jamaica Public Service (JPS), Wind/PV

About the Project

- **Project name:** JPS Grid Stability
- **Location:** Jamaica
- **Customer:** Jamaica Public Services Company Ltd
- **Year:** 2018

Solution

The resulting Microgrid system consists of:
- PowerStore Battery (21.5 MW / 16.6 MWh)
- PowerStore Flywheel ((3 x 1) MW / 16.5 MWs)

Customer Benefits

- Maximum utilization of solar and wind energy
- Reliable power to 5 million populace in the island
- Power availability during intermittency of renewable sources
- Reduced dependency on fossil fuels and lower carbon footprint

JPS | Press Release

Island utilities

WEB Aruba, Wind/PV/Thermal

About the Project

- **Project name:** WEB Aruba
- **Location:** Aruba, Southern Caribbean
- **Customer:** WEB Aruba N.V

Solution

The resulting Microgrid system consists of:
- Microgrid Plus Control System
- Solar PV (1 x 6 MW_P)
- Wind (20 x 3 MW)
- Steam turbine (1 x 136 MW)
- Gas turbine (1 x 20 MW)
- Reciprocating engine (10 x 9 MW)

Customer Benefits

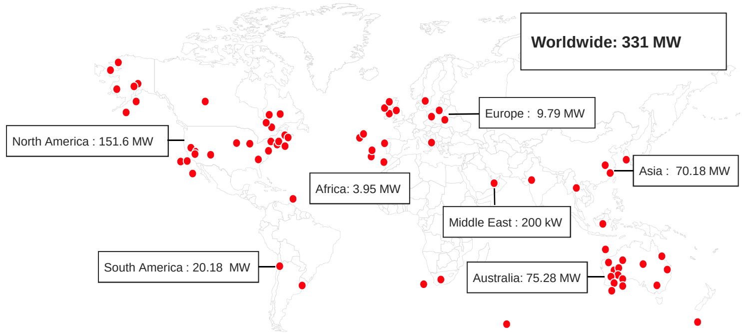
- Integration of complex energy mix - Wind, PV and Thermal
- Maximum utilization of renewable energy
- 24 hour forecast of both renewable output and system load
- Manage the peak demand, 134 MW

WEB | Press Release
Infographic
Video

The microgrid solution allows for integration of a complex energy generation portfolio and maximizes the use of renewable energy; enabling WEB Aruba to meet the peak demand (134 MW) of the tourist island

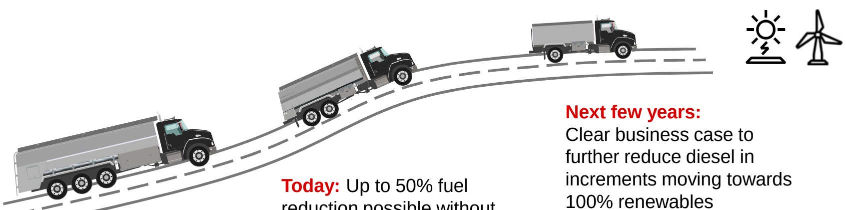
Global installed base

Microgrids and BESS



Energy transformation of off-grid mining

Incremental hybridization to low carbon & energy cost future using renewables and storage



Status quo: Diesel or gas generation main provider off-grid mine electricity

Today: Up to 50% fuel reduction possible without subsidies leading to increased shift to renewables

Next few years: Clear business case to further reduce diesel in increments moving towards 100% renewables

ABB supports mining customers to capture the economic and operating benefits along the transformation

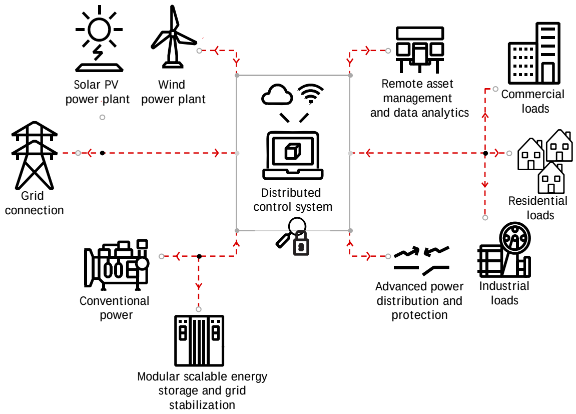
Microgrid

Generation at the point of consumption and always available

Microgrid definition

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.

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



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

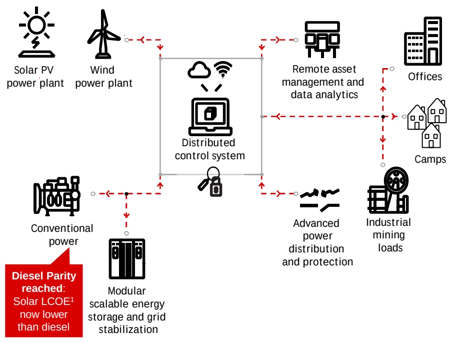
How microgrids create value in off-grid mining

Key drivers of value creation and cost savings

Operational goals

- **Providing essential off-grid quality power** with blackstart capability
- **Improving resiliency** by having storage, generation and loads optimally coordinated
- **Reducing reliance on diesel** and associated **supply chain risk** and **CO_2 emissions**

Lower operating costs, higher up-times and higher gross margins for mines



[1] LCOE: Levelized Cost of Energy per kWh over the life of the asset including all installation, financing and running costs

What ABB has to offer

ABB - the global microgrid solution partner

Leading global expertise

25+	25+ years experience 40+ executed projects
	25+ years experience 40+ executed projects
	25+ years experience 40+ executed projects

AND

Broad portfolio of products & services

- Renewable power
- Conventional power
- Microgrid control system
- Energy storage and grid stabilization
- Power distribution and protection

Consulting

Service

3rd party financing

What ABB has to offer

Customer reference – ABB provided a complete renewables integration solution

Project name
- DeGrussa Copper-Gold Mine

Location
- Western Australia, Australia

Customer
- juwi Renewable Energy

Completion date
- 2016

Solution

The resulting microgrid system consists of:
- ABB: PowerStore Battery (2 x 2 MW/1.4 MWh) with Transformer and RMU
- ABB: Microgrid Plus Control System
- ABB: Solar PV (10.6 MWp) with ABB Transformer and RMU
- Existing: Diesel (22 MW)

Customer Benefits

- Expected diesel fuel saving of 5 million liters per year – reduction by 20%
- Expected CO_2 reduction: 12,000 tons
- Grid stabilization, spinning reserve, STATCOM features
- Load smoothing

About the Project

- The new hybrid solar facility is the largest integrated off-grid solar and battery storage plant in Australia

-32%

ABB microgrids deliver 30 to 50% fuel reduction

Future projects benefit from lower PV prices

ABB references already show 30 to 50% fuel reduction possible with subsidies

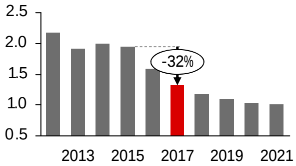
DeGrussa Min, PV/ Diesel stabilizing system
- ~50% diesel saving opportunity
- 10MW Solar PV
- 4/6 MW battery stabilizing system

Marble Bar & Nullagine, PowerStore/ PV/ Diesel
- Generates 1,048 MWh PV/ year
- Saves **35-40**% diesel consumption per year

Johannesburg, PowerStore/ PV/ Diesel
- **Up to 50%** reduction in electricity bills and fossil fuel consumption

Decreasing Solar PV costs to improve future business cases

Global Large Commercial PV system prices (1 to 5MW) USD/ Wp



- PV prices have reduced over 30% in past 2 years and continue to fall globally
- Commercial and utility scale systems reducing faster than household solar with the $1/ Wp already reached for utility scale[1]

Source: IHS PV Demand Market Tracker - Q2 2017
[1] https://www.greentechmedia.com/articles/read/Sunshot-1-Per-Watt-Solar-Cost-Goal-Mission-Accomplished-Years-Ahead-of-S

Mining microgrid case study

Various solar and storage scenarios tested using HOMER[1] optimization tool

Example: remote brownfield gold mining operation

Power System
- 5 MW average load
- 6.3 MW peak load
- 6 x 1.2 MW diesel generators

Business Case
- Delivered Fuel Cost: $1US/ l
- Solar installed cost: $2US/ Wp
- Average cost of capital: 11%
- Subsidies: none

Goal of the study

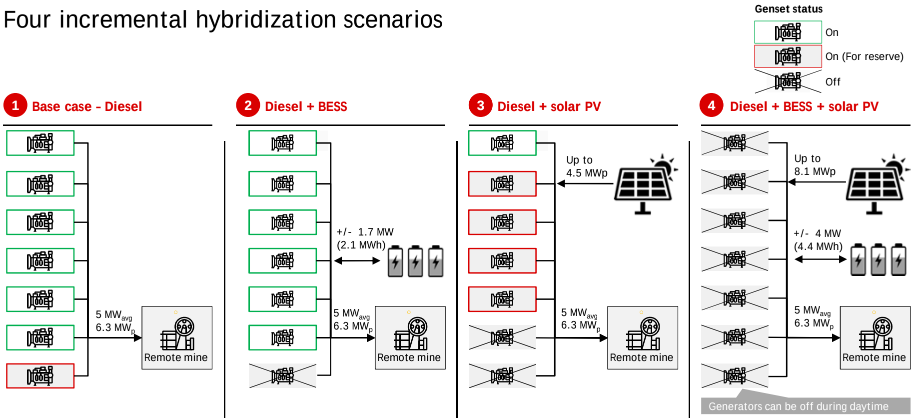
Determine when the Levelized Cost of Energy (LCOE) of 3 scenarios is lower than the diesel only base case
- Diesel & Storage
- Diesel & Solar PV
- Diesel & Solar & Storage

[1] HOMER : http://www.homerenergy.com/, a simulation and optimization tool for energy systems

-32%

We analyzed the benefits of a hybrid power system

Four incremental hybridization scenarios



1 Base case - Diesel
- 6 generator system (1.2 MW each)
- 1 generator equivalent required as operating reserve at all times
- All generators that are on typically operate at same level

2 Diesel + BESS
- BESS removes need for operating capacity
- BESS can also delay or remove need to start up a generator during short term peaks

3 Diesel + solar PV
- Solar PV size limited in this case due to generator ramping limitation
- Additional generators must stay online in case of shading for 75% of solar production (potential reductions when using advanced forecasting)

4 Diesel + BESS + solar PV
- BESS provides required ramping
- During daylight hours all generators can be shut down completely

Mining microgrid business case

Up to 28% reduction in fuel and CO2 possible when combining diesel with BESS and solar PV

	Base case - Diesel	Diesel + BESS	Diesel + solar PV	Diesel + BESS + solar PV
Fuel consumption (ML)	11.6	11.4 (-1.4%)	9.8 (15%)	8.4 (-28%)
Investment ($M)		1.5	9.0	19.5
IRR (%)	-	36%	16%	16%
LCOE[1] ($/MWh)	304	296 (-1.4%)	289 (-5%)	273 (-11%)
Payback (years)	-	2.7	5.2	5.2

Source: Based on Homer analysis using proprietary Homer Pro Software; all numbers in USD
[1] LCOE: Levelized Cost of Electricity

-32%

Sensitivity analysis - Key driver of LCOE saving

Diesel price the largest single driver of LCOE savings, followed by solar PV price

Sensitivity driver	Low case	Base case	High case	LCOE *savings* impact (pp) – Low case	LCOE *savings* impact (pp) – High case
Diesel price (USD/ L)	0.5	**1.0**	1.5	-6.5	6.5
Solar PV price - Installed (USD/ Wp)	1.5	**2.0**	2.5	4.0	-3.5
Solar irradiation (kWh/ m2/ day)	4	**5**	6	-3.7	2.7
Installed battery price excl. converter ($/ kWh)	300	**400**	500	0.4	-0.5

Base case LCOE savings = 11%

 NOTE: Modelled using the Homer software

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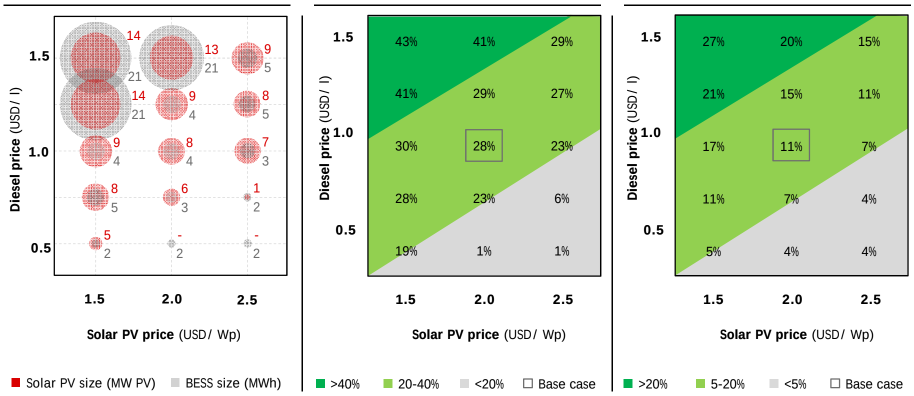
Mining microgrid case study

Low solar PV price and high diesel price leads to large systems with up to 40% fuel saving



 NOTE: Modelled using the Homer software

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The pitch: creating microgrid opportunities

Three questions to ask your customer

1 How are you generating power at your mine site?
- IPP versus InHouse; when do contracts expire
- Diesel versus Gas; who carries the fuel supply risk?

2 What is the current cost and quality of energy supplied?
- $/ MWh including O&M and replacement cost
- Outages? Cost per outage and how often

3 What is the corporate energy efficiency, CO_2 and cost reduction target?
- CO_2 reduction targets; extra corporate funds
- Energy efficiency targets?

Next Step: Lead qualification through high level assessment tool

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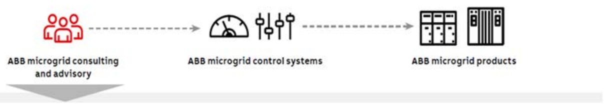
ABB Microgrid Advisory Services

Microgrid End-to-end Solution



Microgrid Market Analysis
- Trends in energy price, tariffs
- Drivers for energy storage as peak shaving, self-consumption vs feed-in, and energy arbitrage.
- Market participation revenues

Microgrid economic Analysis
- Optimum size and operation of DER
- Cost of energy, ROI, and payback
- Fuel savings and environmental impacts
- Sensitivity analysis on drivers
- Value stacking
- Ownership models

Microgrid technical Analysis
- Stability and dynamic studies
- Contingency analysis
- Power quality and reliability
- Frequency and voltage ride though

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