



Renewables & Energy Storage

Renewables and energy storage solutions in mining

International Hybrid Power Systems Workshop, 4th Edition 2019

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company presentation - Fields of Activity

■ POWER SUPPLY

– OFF - GRID SYSTEMS

- Solar Photovoltaics Systems
- Wind Power Systems
- Energy Storage Systems
- EV charging Systems

– GRID CONNECTED SYSTEMS

- Solar Photovoltaics
- Wind Power Systems
- Small and Large hydroelectric systems
- Solid and liquid biomass energy systems
- Biogas energy systems
- Co-generation systems
- Diesel, Petrol and Gas Generators systems
- Energy Storage Systems
- EV charging System

■ LIGHTING PV SYSTEMS

■ SOLAR STRUCTURES

- CAR PORT (ENERPORT)
- WAREHOUSE AND SOLARHOUSES

■ SERVICES SUPPLIER

– SERVICES

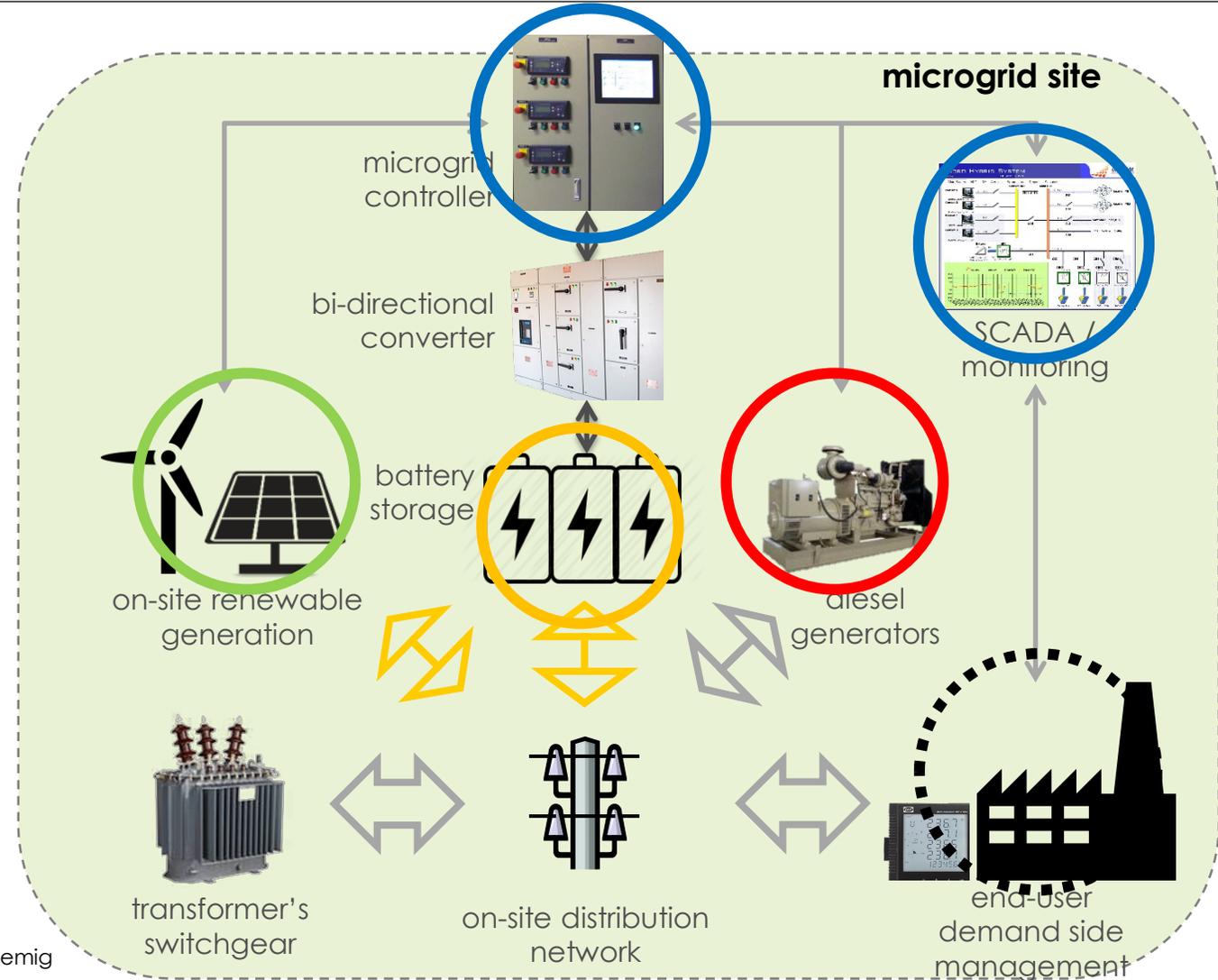
- Engineering Services
- Financing Services
- Due Diligence Services

main components of microgrid systems

- System components

- Classification

-  Microgrid controller
-  Conventional Generation
-  Renewable Generation
-  Battery Energy Storage System
-  Demand



Source: Renemig

renewable penetration, excess energy, diesel consumption / grid power use

- Excess energy: loss and use

- **Definition of excess energy**

- The energy that cannot be used from the system in a period of specific time

- **Definition of excess power**

- The power that cannot be absorbed instantaneously from the system

A system that can absorb the excess energy does not mean that it can absorb the excess power

- **Managing excess energy**

- Additional ESS energy capacity is required
- ESS with important depth of discharge are used
- ESS with low cost of capacity

- **Managing excess power**

- Additional ESS power capacity is required
- ESS with high C rates are used
- ESS with low cost of C rates

- **Use of excess energy**

- Deferrable loads
- Battery charging

- **Use of excess power**

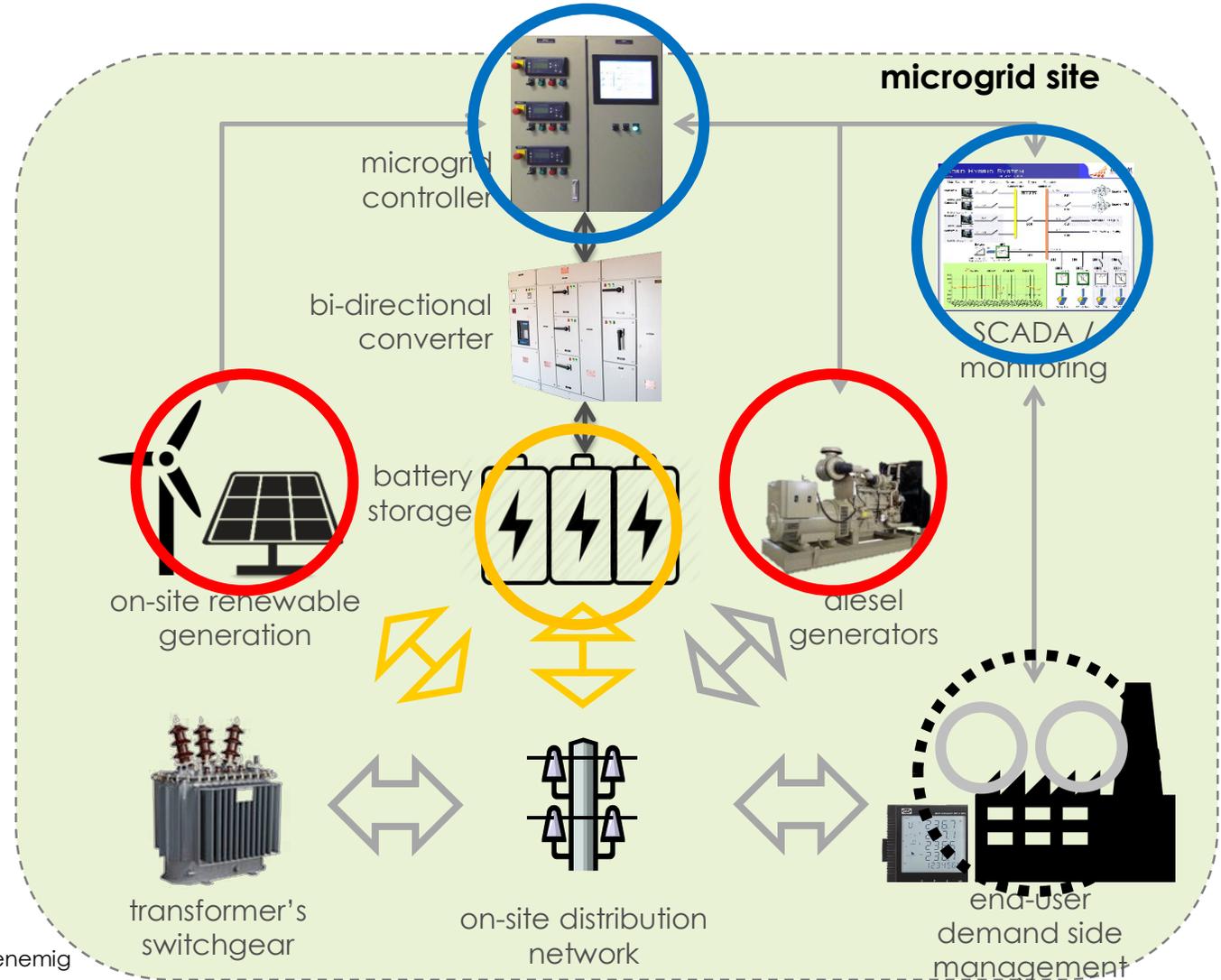
- Dump loads

main components of microgrid systems

- Controls

- Classification

- Energy management system (microgrid controller)
 - Generation controls
 - Battery Management System
 - Load controls
 - External units controls



Source: Renemig

system revenues, operating costs and cashflow

- Forms of revenue
 - **FIT**
 - Fixed (uniform, reverse auction)
 - Indexed on the electricity market exchange price

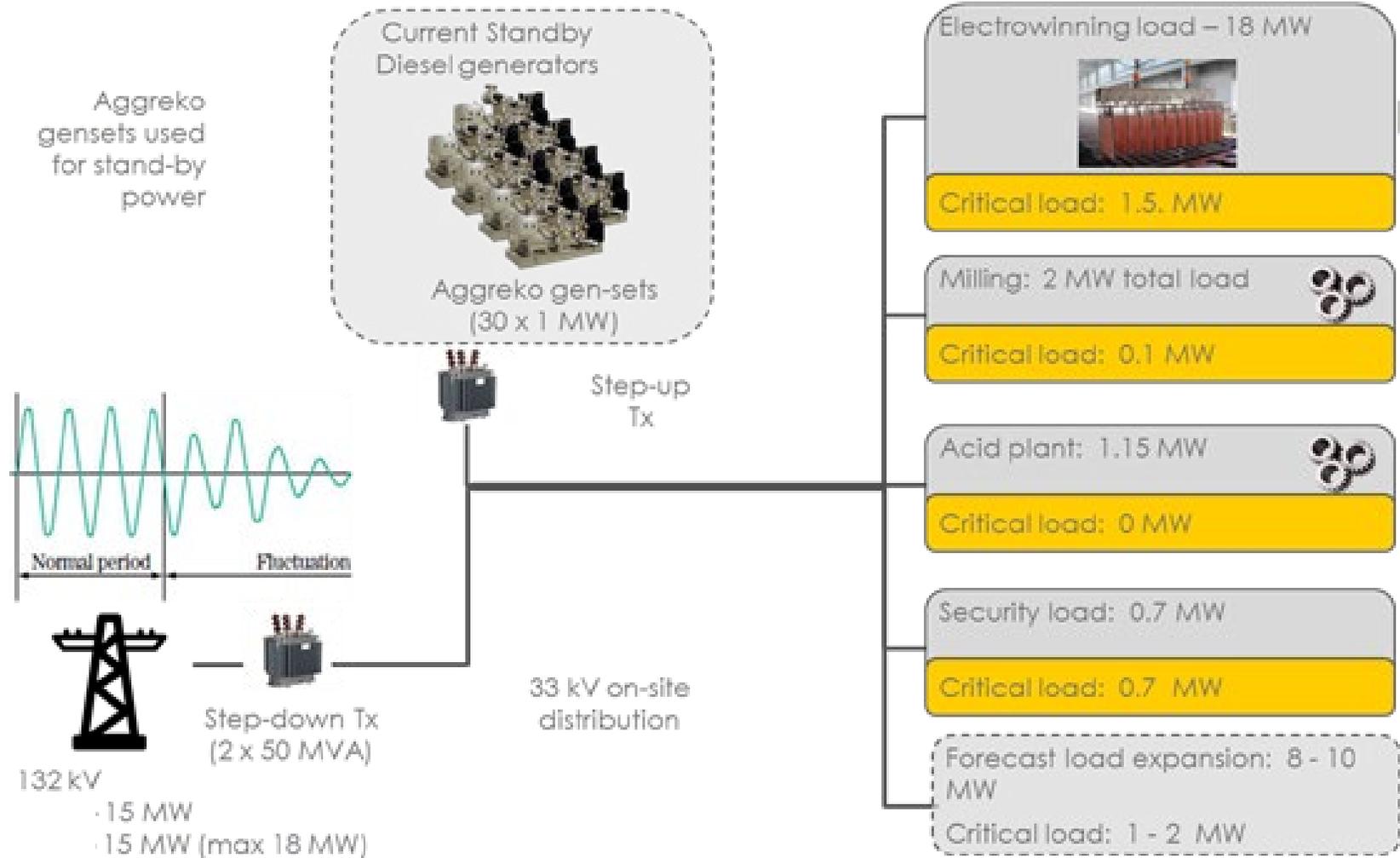
 - **PPA**
 - Fixed price
 - Indexed on the electricity market
 - Indexed on a fuel price
 - Performance based (RES fraction, power quality, number of outages)

 - **Savings**
 - Grid cost savings
 - Fuel consumption savings
 - Operation savings (power quality improvement, outages elimination)
 - Maintenance savings
 - Emissions savings

power quality improvement at a grid connected mine

Input data

- **Location:** East Africa
- **Load:** 219 GWh/y | 25 MWa | 29 MW peak
- **Initial configuration**
 - Diesel Generators: 30 MW
 - Grid connection: 33 MW
 - Diesel 0.33 USD/kWh
 - Grid: 0.165 USD/kWh
- **Approach:** eliminated diesel spinning reserve, improve power quality
- **PPA Duration:** 5 years

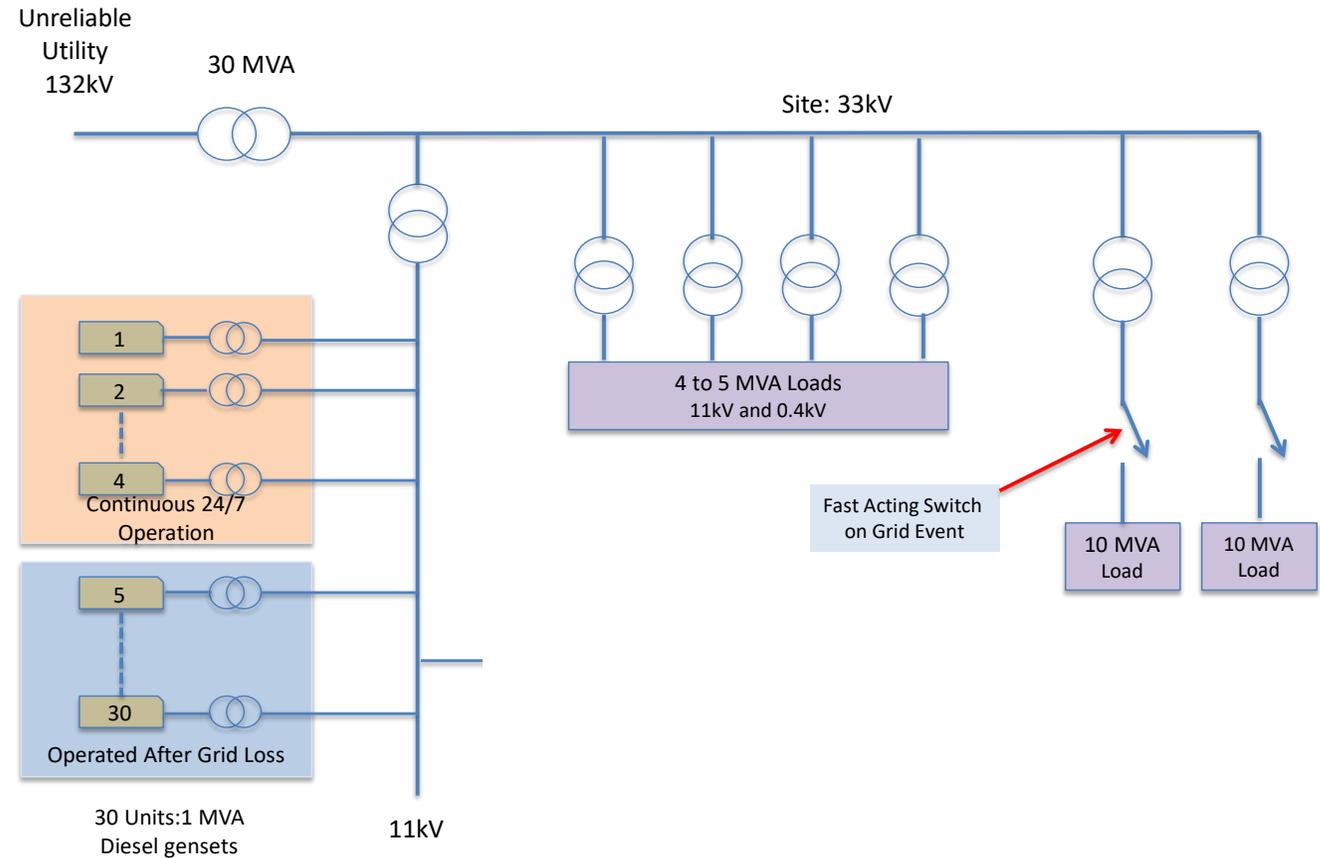


power quality improvement at a grid connected mine

- Operation data

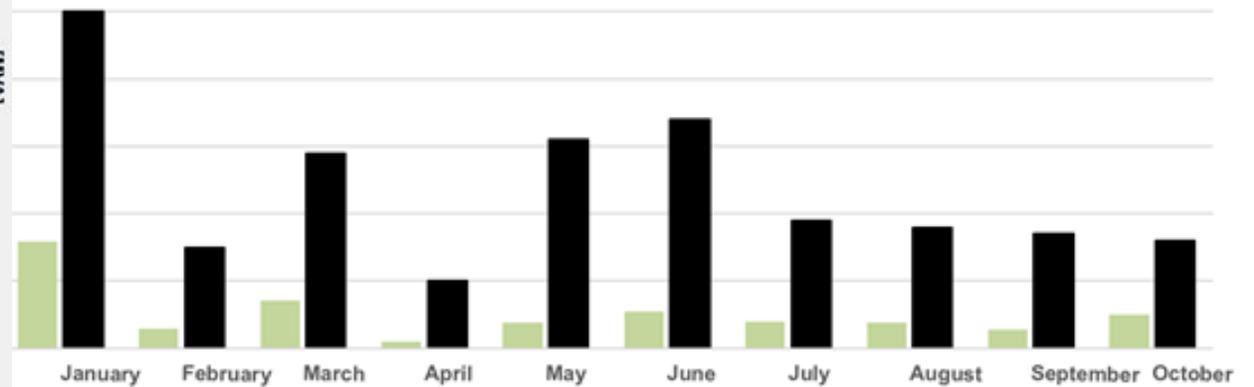
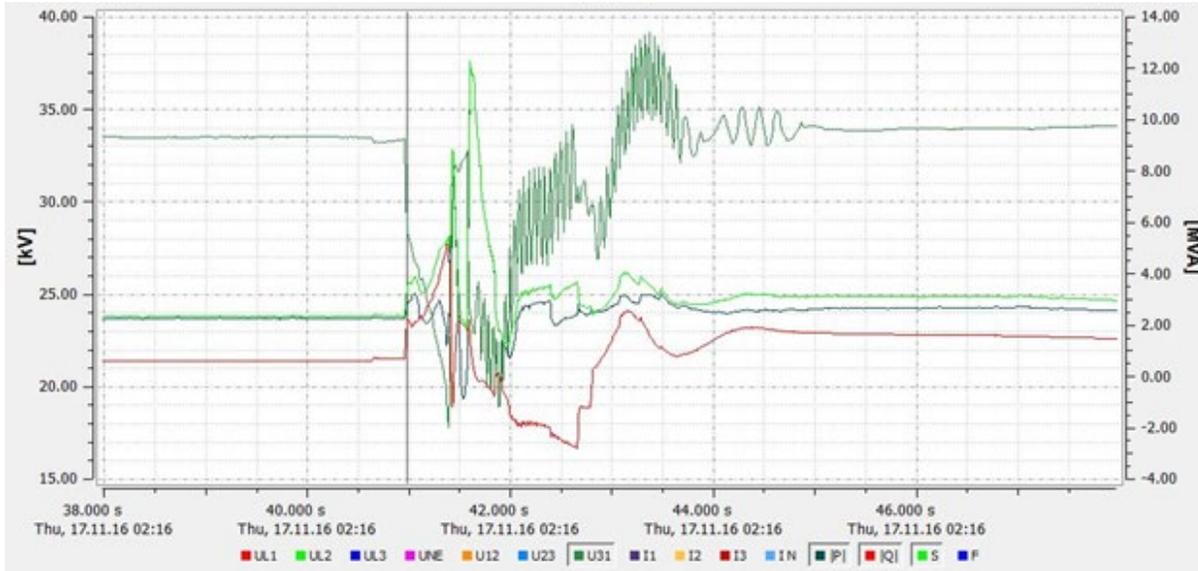
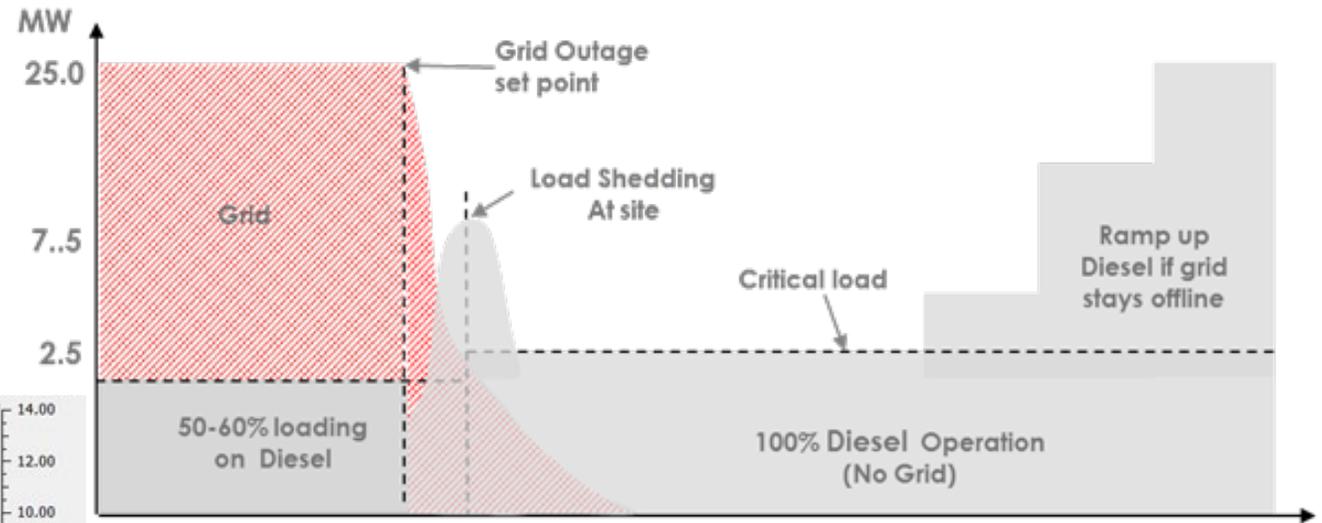
- **Spinning reserve:** 2.5 MW
- **Spinning reserve energy:** 13.7 GW
- **Spinning reserve cost :** 4.53 M USD/y
- **Power quality:** during outage severe frequency and voltage variation
- **Outage impact:** rectifier transformers breakdown, loss of production during 1 h at (50 k USD/h)

Power System Basic Layout



power quality improvement at a grid connected mine

- Outages analysis with diesels
 - Peak power of diesel gensets within 500 ms
 - Voltage drop
 - Stabilisation in 2 sec
 - Capability of diesel gensets to withstand this variation

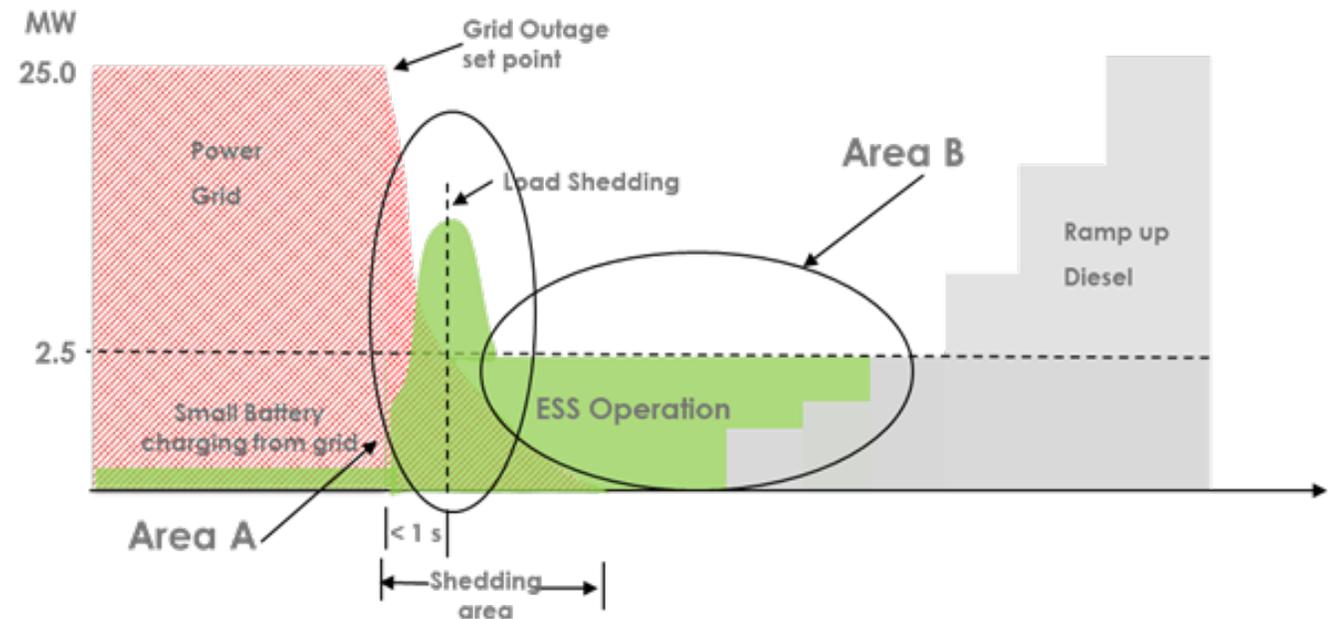


■ Total Hours of Outage ■ Total Number Outages

power quality improvement at a grid connected mine

- Outages analysis with BESS
 - An ESS operating at 2.5 MW constantly shall allow for less than 1 sec
 - up to 10 MW power
 - a voltage from of 25% and more
 - a frequency variation of up to 20 Hz

 - Using a specially configured inverter a system can withstand a sever voltage and frequency variation

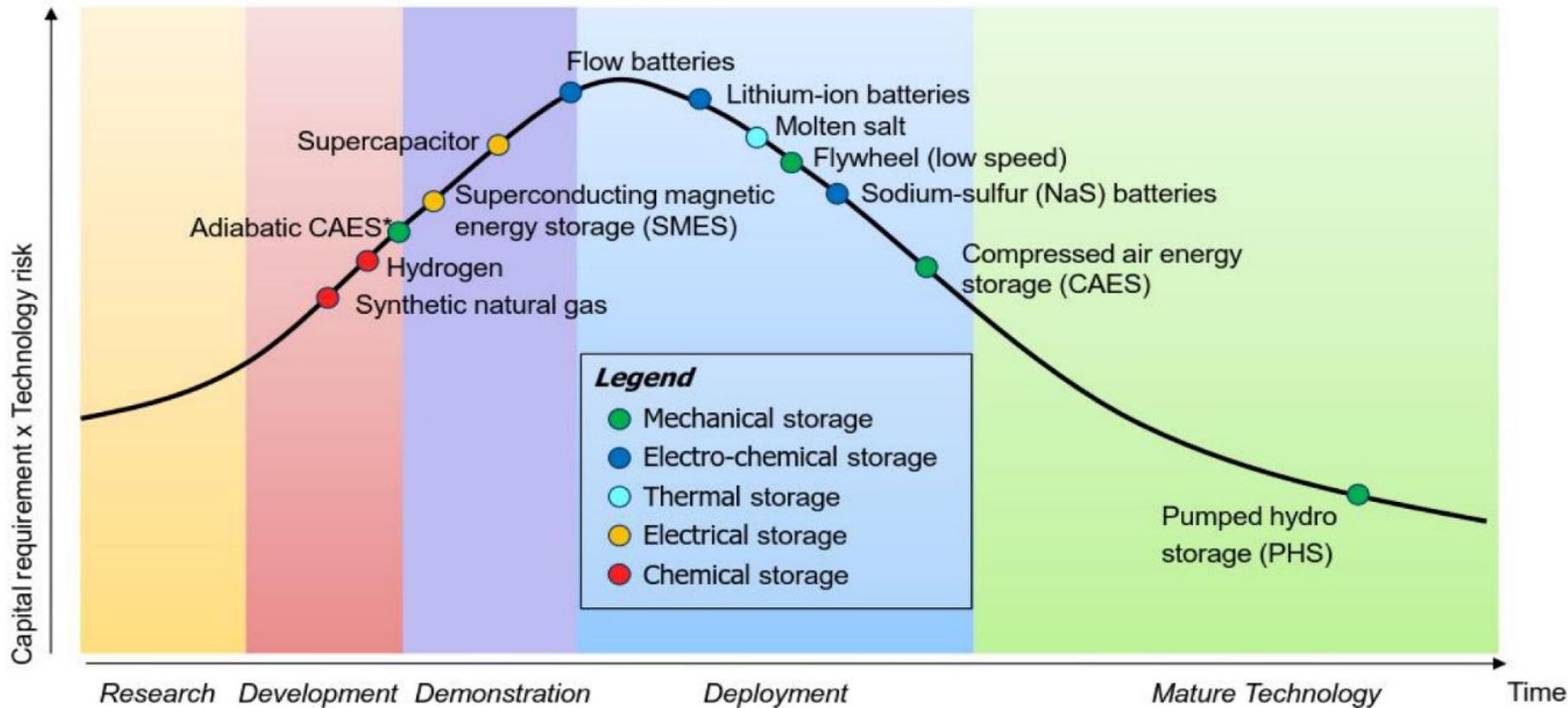


power quality improvement at a grid connected mine

- BESS selection criteria
 - BESS technologies candidates
 - Lead acid
 - Standard lead acid
 - Advanced lead acid (lead carbon)
 - Lithium ion
 - Lithium Nickel Manganese Cobalt (NMC)
 - Nickel Cobalt Aluminium
 - Lithium Cobalt
 - Lithium Iron Phosphate (LFP)
 - Lithium Titanate (LTE)
 - Flow
 - Vanadium Redox
 - Zinc Bromide
 - Non-chemical storage
 - Ultra-capacitors
 - Fly-wheels
 - Hydrogen fuel cells
 - Compressed Air Energy Storage (CAES)
- | | |
|-------------------------|---|
| Cost | <ul style="list-style-type: none">• Lowest total cost of ownership |
| Functionality | <ul style="list-style-type: none">• Ability to address power and energy needs• Operational requirements of technology |
| Suitability | <ul style="list-style-type: none">• Simplicity of solution• Robustness of technology• Climate and condition performance |
| Other Advantages | <ul style="list-style-type: none">• Other uses• Expandability |
| Risks | <ul style="list-style-type: none">• Maturity of technology• Potential safety issues• Implementation in similar applications• Suitable and bankable suppliers |

power quality improvement at a grid connected mine

- technology maturity curve



Source: AECOM Australia

power quality improvement at a grid connected mine

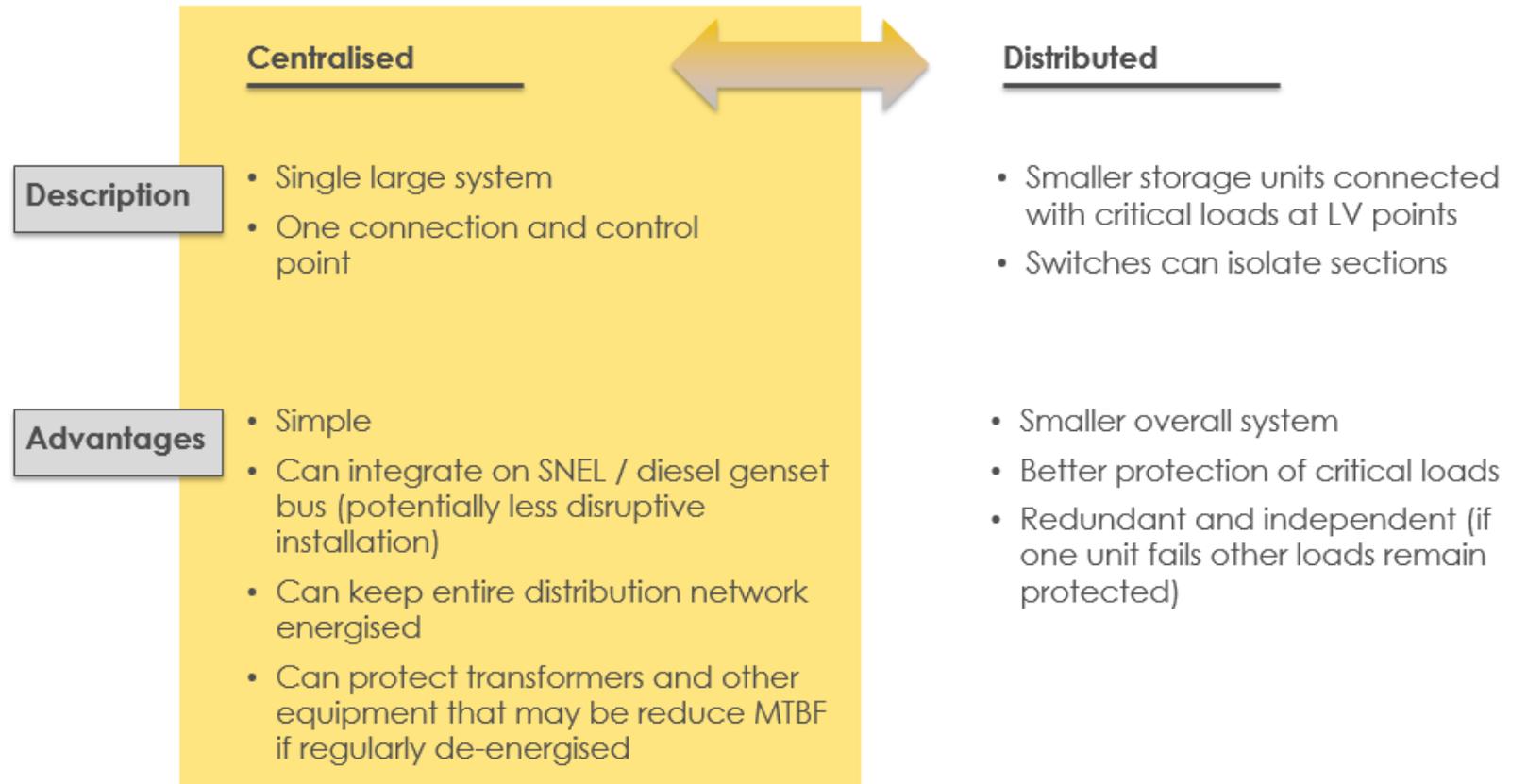
■ BESS siting implementation

– Centralised

- easier to control
- energisation of distribution system
- bigger system requirement

– Distributed

- better protection to critical loads
- redundancy
- more complex control
- partial system energisation



power quality improvement at a grid connected mine

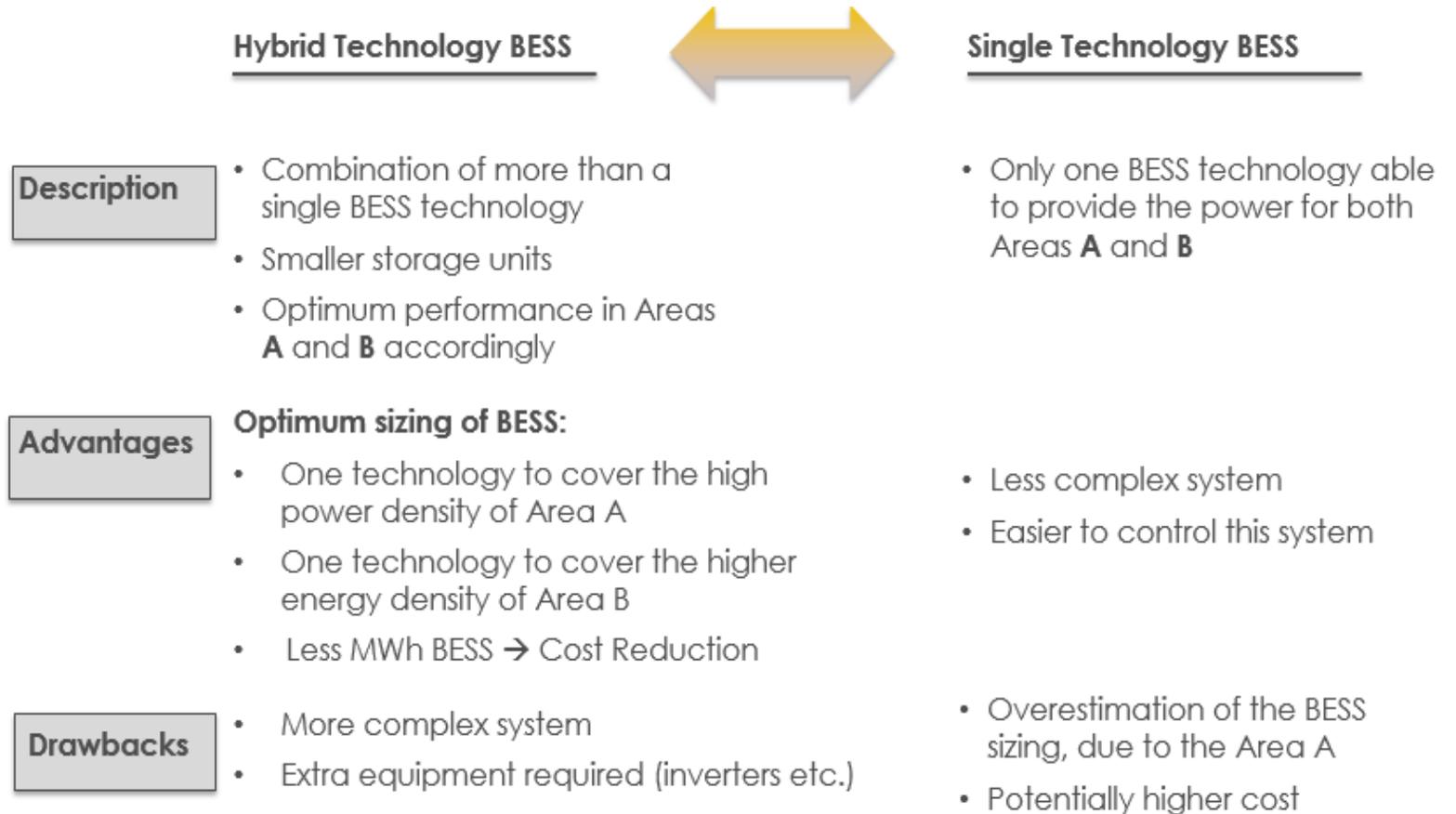
■ hybrid vs single technology

– hybrid

- combination of more than one technologies
- less cost
- higher complexity
- more equipment

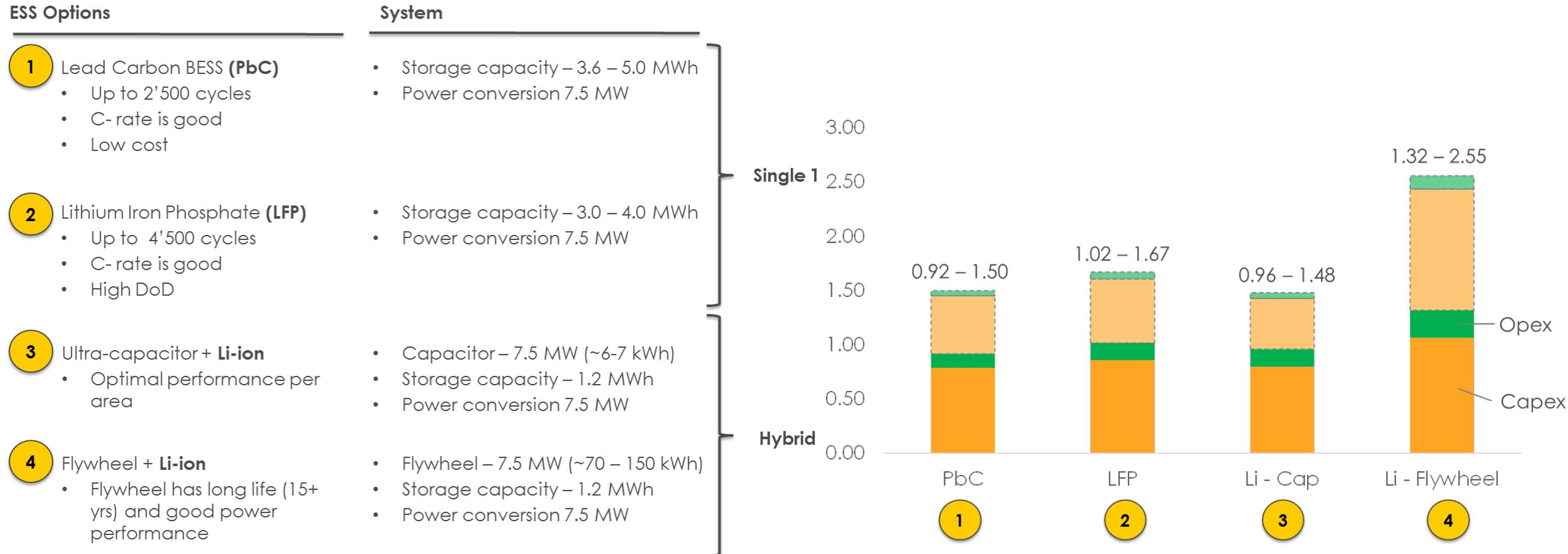
– single

- simpler configuration
- easier control
- higher cost



power quality improvement at a grid connected mine

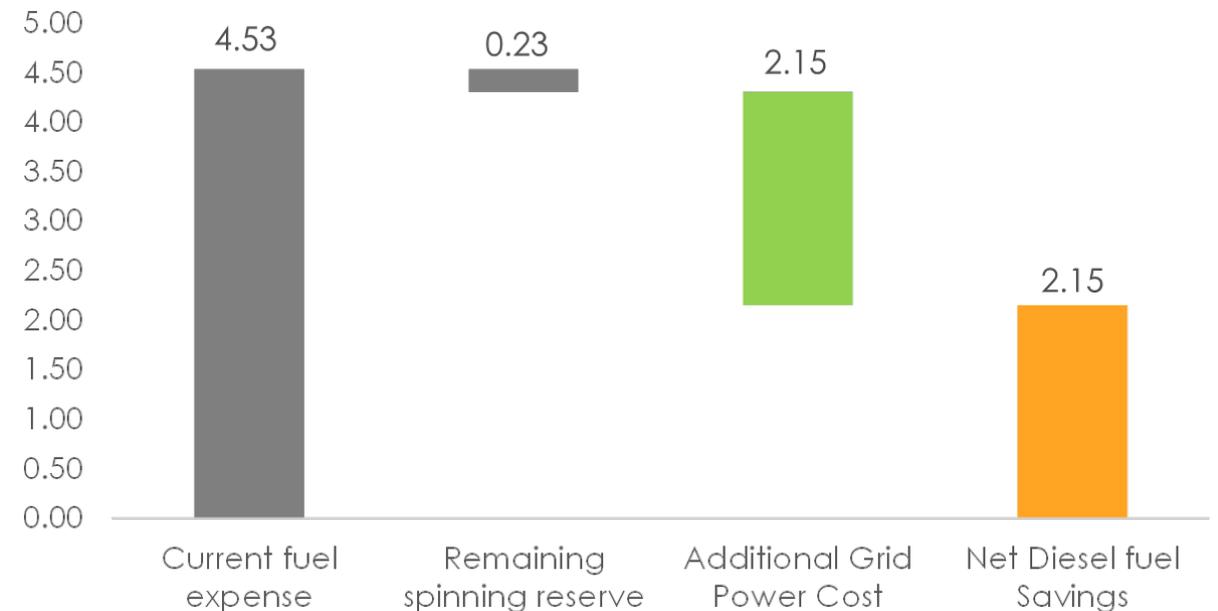
proposed solutions



power quality improvement at a grid connected mine

■ BESS economics

- spinning reserve can be saved up to 95%
- the saved energy will be bought from the grid
- additional costs
 - additional grid power to replace the diesel power provided by the generators running as spinning reserve
 - additional grid power to account for the energy losses in the ESS
 - operations and maintenance of the ESS
 - insurance for the system
 - financing costs for the system
- approximate payback: 2 years



diesel displacement at an off-grid mine

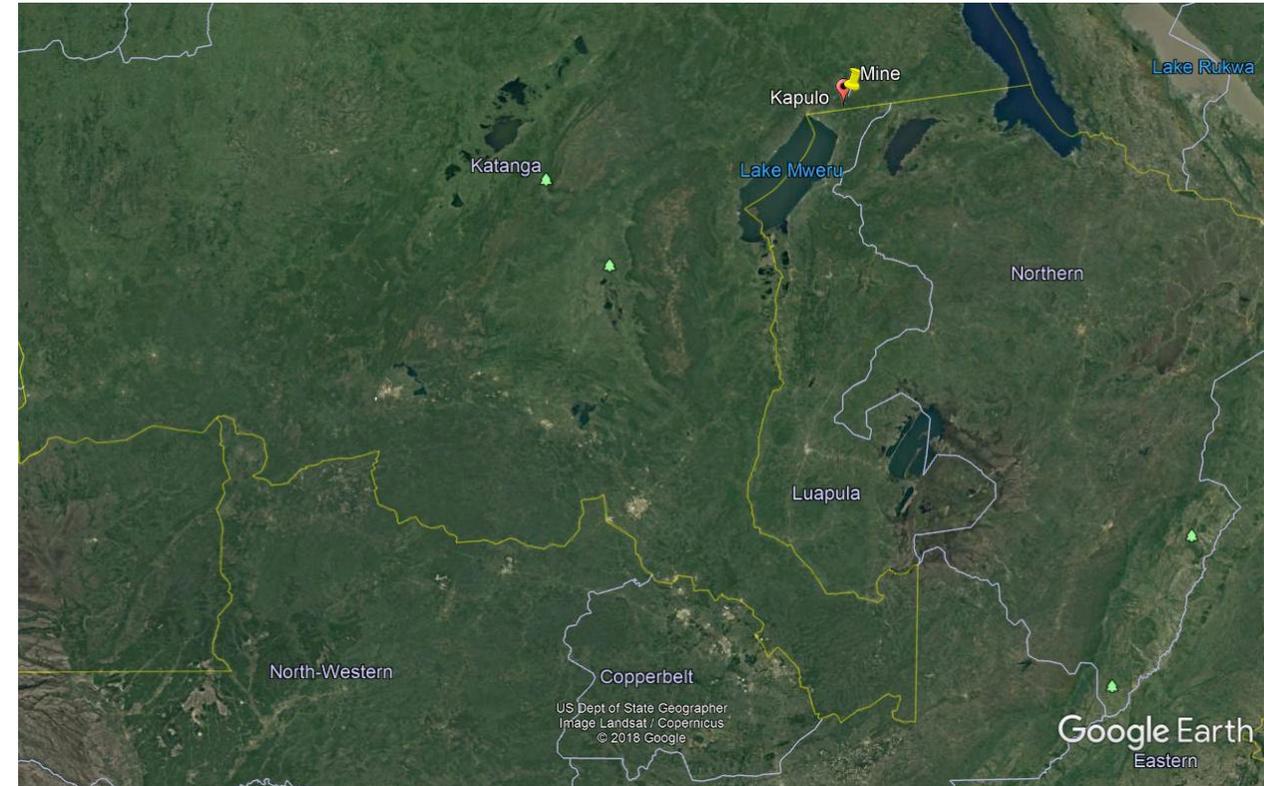
- Mine
 - **Location:** East Africa
 - **Load:** 48.2 GWh/y | 5.5 MWa | 6.1 MW peak
 - **Initial configuration**
 - Generation: 10 MVA diesel generators
 - Power cost: 0.38 – 0.44 USD/kWh (1.2 USD/l) (calculated – on the field)
 - **Approach:** specific budget, redeployable
 - **PPA Duration:** 10 years

 - **Solution A**
 - 30% of PV penetration => 1.65 MWp
 - No ESS
 - CapEx: 2.6 M USD
 - Comments:
 - Pros: low cost, lower maintenance
 - Cons: irregular generator usage, lower fuel efficiency, lower power quality
 - **Solution B**
 - 110% of PV penetration => 6.1 MWp
 - ESS = 3 MWh (stability purposes mainly) Lithium
 - CapEx: 10.7 M USD
 - Comments:
 - Pros: low cost, lower maintenance, better generator usage
 - Cons: higher CapEx,

diesel displacement at an off-grid mine

- Mine
 - **Location:** East Africa
 - **Load:** 48.2 GWh/y | 5.5 MWa | 6.1 MW peak
 - **Initial configuration**
 - Generation: 10 MVA diesel generators
 - Power cost: 0.38 – 0.44 USD/kWh (1.2 USD/l) (calculated – on the field)
 - **Approach:** specific budget, redeployable
 - **PPA Duration:** 10 years

Area	Peak [kW]	Average [kW]
Crusher	227	204
Ball Mill	1,551	1,392
Grinding pumps etc.	287	257
Flotation cells and pumps	3,357	3,013
Fuel farm, Offices, Tailings	124	111
Laboratory, Camp etc.	539	483
TOTAL:	6'085	5'461



diesel displacement at an off-grid mine

- Diesel generation cost
 - **Diesel fuel:** 1.2 USD/l
 - **Initial diesel generator fuel consumption:** 0.258 l/kWh
 - **Actual diesel generator fuel consumption:** 0.275 l/kWh
 - **Actual diesel generator fuel cost:** 0.33 USD/kWh
 - **Operation and Maintenance cost:** 0.035 USD/kWh
 - **Actual diesel generator marginal cost:** 0.365 USD/kWh

- Additional diesel generation costs
 - Not optimal operation of diesels
 - Power variation
 - Operation in lower regimes
 - Inadequate maintenance
 - Fuel theft
 - Unforeseen maintenance requirements
 - Spinning reserve requirements

- Solutions for diesel performance measuring
 - Power metering system
 - Fuel monitoring
 - Fuel analysis
 - Generator performance test

diesel displacement at an off-grid mine

- Project specific constraints
 - No metered data available
 - 24/7 operation
 - Preferably uninterruptable power supply
 - Low maintenance requirements
 - Large load variations

- Solutions proposal
 - **Solution Generators + PV**
 - 30% max penetration: 1'650 kWp PV
 - Max. expected RES power: 1'485 kW PV
 - Max. expected RES power variation: 1'188 kW PV
 - At all times there must be a spinning reserve of: 1'188 kW
 - **Solution Generators + PV+ Battery**
 - 110% max penetration: 6'100 kWp PV
 - Max. expected RES power: 5'490 kW PV
 - Max. expected RES power variation: 4'932 kW PV
 - At all times there must be a spinning reserve of: 4'932 kW

 - **CapEx**
 - 2.6 M USD
 - **CapEx**
 - 10.7 M USD

diesel displacement at an off-grid mine

- Solutions analysis

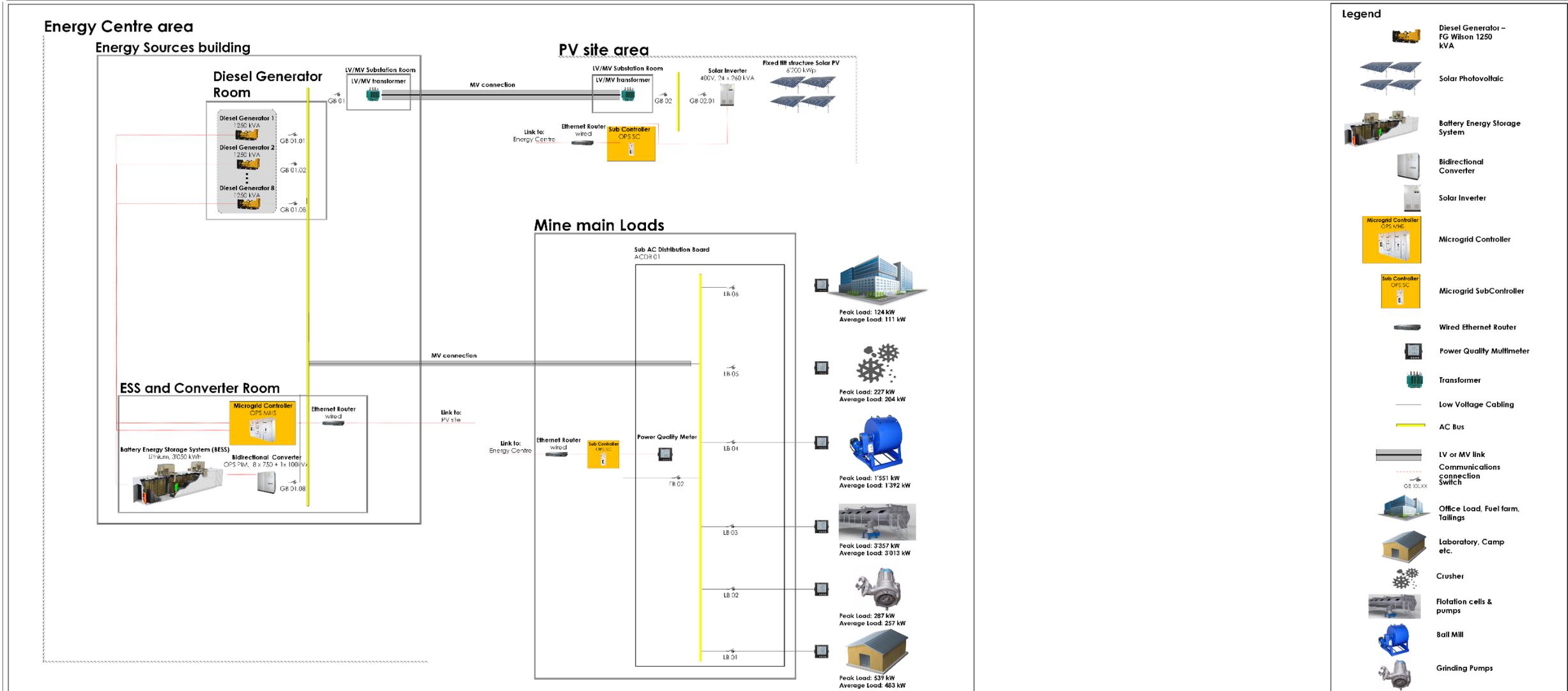
- Solutions analysis

	Diesel	PV	ESS	Battery Inverter Capacity	CapEx
	[-]	[kWp]	[kWh]	[kW]	[kUSD]
Diesel Only	X	-	-	-	
PV Hybrid (30% pen)	X	1'650	-	-	2'578
PV-battery Microgrid (110% pen)	X	6'100	3'000	6'100	10'734

- PV-Hybrid

- PV-Hybrid + Battery

diesel displacement at an off-grid mine



Legend

- Diesel Generator – FG Wilson 1250 kVA
- Solar Photovoltaic
- Battery Energy Storage System
- Bidirectional Converter
- Solar Inverter
- Microgrid Controller
- Microgrid SubController
- Wired Ethernet Router
- Power Quality Multimeter
- Transformer
- Low Voltage Cabling
- AC Bus
- LV or MV link
- Communications connection Switch
- Office Load, Fuel farm, Tailings
- Laboratory, Camp etc.
- Crusher
- Flotation cells & pumps
- Ball Mill
- Grinding Pumps

diesel displacement at an off-grid mine

- Project economics diesel + PV

- **CapEx:** 2.6 M USD
- **LCOE:** 0.22 USD/kWh
- **Fuel savings:** 255 k USD / year

- **Sensitivity analysis of LCOE [USD/kWh]:**

- lifetime [y] vs cost of capital [%]

Levelised cost of power (USD / kWh)

		10.0%	12.5%	15.0%	17.5%	20.0%
Lifetime	6	0.244	0.260	0.277	0.294	0.311
	8	0.205	0.221	0.239	0.256	0.274
	10	0.182	0.199	0.217	0.236	0.255
	12	0.168	0.186	0.204	0.223	0.243

Annual fuel savings

		10.0%	12.5%	15.0%	17.5%	20.0%
Diesel cost	0.30	291'766	249'404	205'255	159'469	112'193
	0.32	341'328	298'966	254'817	209'031	161'755
	0.34	390'891	348'528	304'379	258'593	211'317
	0.36	440'453	398'090	353'941	308'155	260'879
	0.38	490'015	447'652	403'503	357'717	310'441
	0.40	539'577	497'214	453'065	407'279	360'004

- **Sensitivity analysis of fuel and O&M savings:**

- Fuel cost [USD/l] vs cost of capital [%]

diesel displacement at an off-grid mine

- Project economics diesel + PV + BESS

- **CapEx:** 10.7 M USD
- **LCOE:** 0.28 USD/kWh
- **Fuel savings:** 623 k USD / year

- **Sensitivity analysis of LCOE [USD/kWh]:**

- lifetime [y] vs cost of capital [%]

Levelised cost of power (USD / kWh)

		10.0%	12.5%	15.0%	17.5%	20.0%
Lifetime	6	0.312	0.333	0.354	0.376	0.398
	8	0.262	0.283	0.305	0.328	0.351
	10	0.233	0.255	0.278	0.302	0.326
	12	0.215	0.237	0.261	0.286	0.311

Annual fuel savings

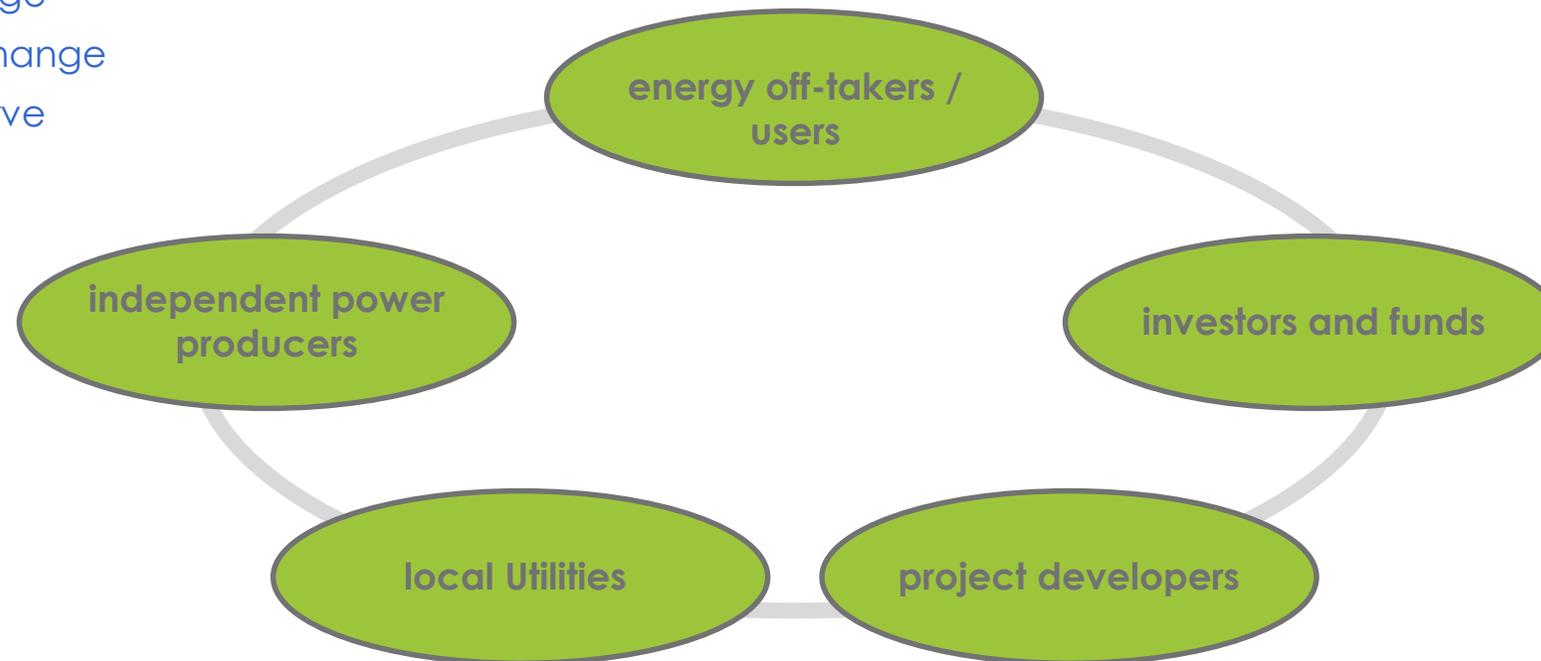
		Cost of capital				
		10.0%	12.5%	15.0%	17.5%	20.0%
Diesel fuel cost (USD / kWh)	0.30	845'021	648'431	443'551	231'075	11'685
	0.32	1'024'586	827'996	623'116	410'640	191'250
	0.34	1'204'151	1'007'561	802'681	590'205	370'815
	0.36	1'383'716	1'187'127	982'247	769'771	550'381
	0.38	1'563'281	1'366'692	1'161'812	949'336	729'946
	0.40	1'742'846	1'546'257	1'341'377	1'128'901	909'511

- **Sensitivity analysis of fuel and O&M savings:**

- Fuel cost [USD/l] vs cost of capital [%]

project risk analysis

- Country risk
 - Credit rating
 - Debt provision
 - Strategic stability
- Regulatory risk
 - PPA price change
 - PPA duration change
 - Dispatching curve
- Counterparty risk
 - Shareholders
 - Insurance capability
- Technology risk
 - Technology maturity





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