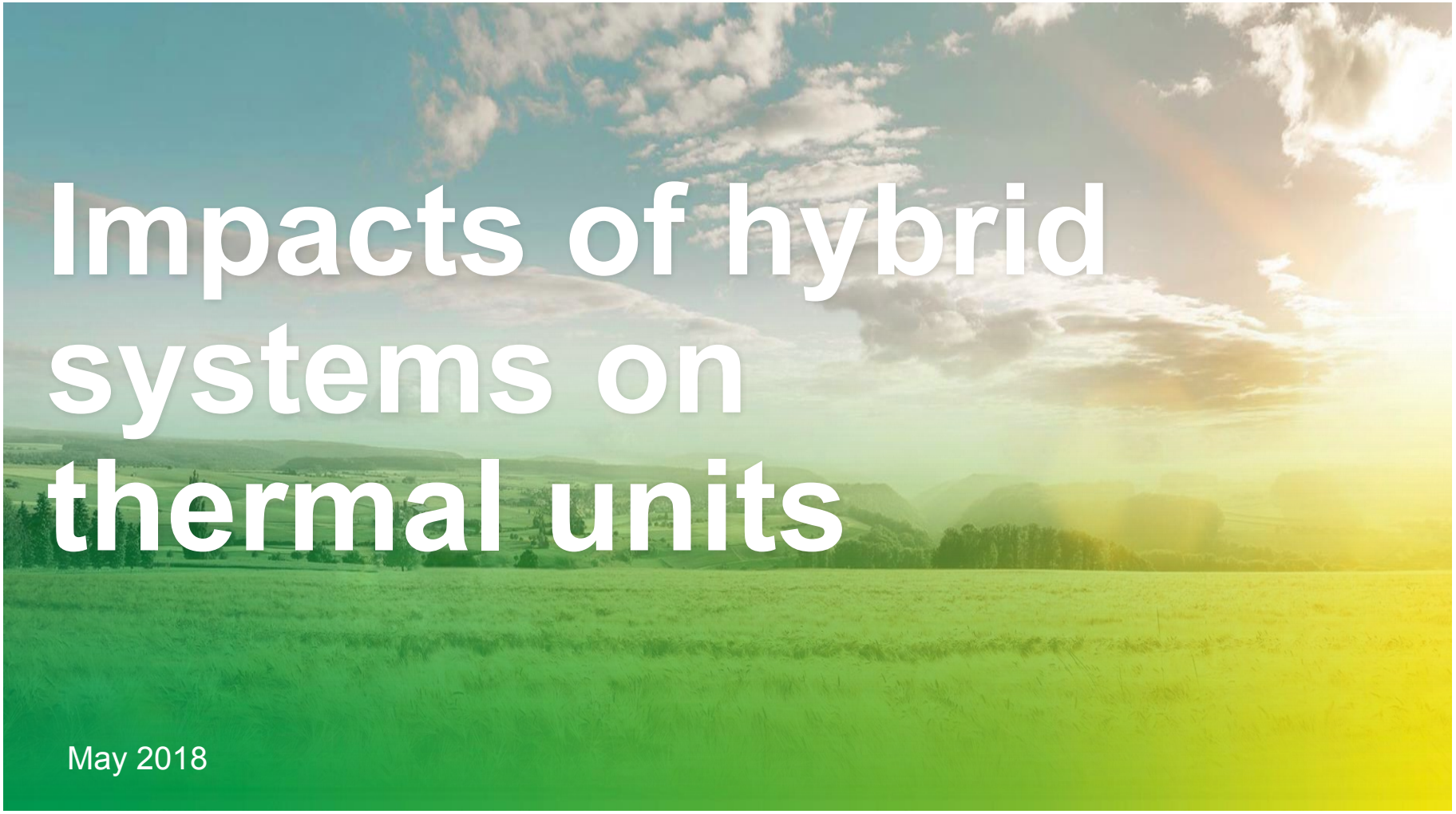


Impacts of hybrid systems on thermal units

May 2018

BayWa r.e. renewable energy

oneSHORE

r.e.think energy

BayWa r.e. in figures – dynamic growth and sustainable profitability

BayWa r.e.
renewable energy

Turnover 2017

€ 1,366.7 million Euro

EBIT 2017

€ 66.6 million Euro

Employees

1,300

Founded

2009

Gathering our combined market experience under the BayWa r.e. umbrella

Experience

2,000 MW

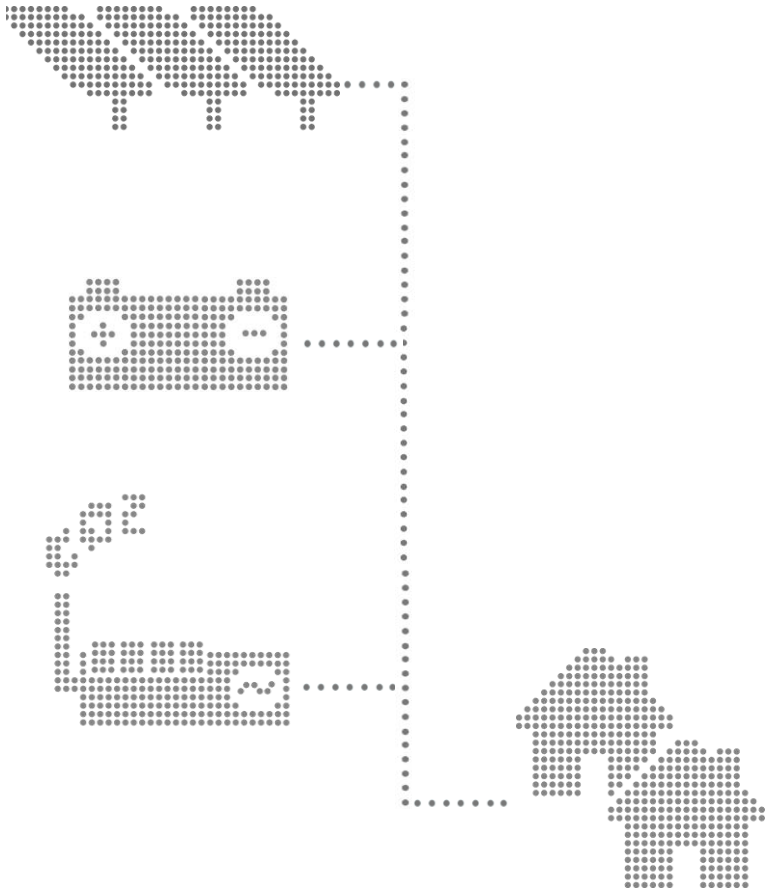
Development and realization of projects in the area of solar, wind power, bioenergy and geothermal energy

Company

Wholly owned subsidiary **of BayWa AG**

Stronger emphasis on developing hybrid projects through the acquisition of OneShore Energy

- Founded in 2013
- Based in Berlin, Germany
- Exclusive focus on hybrid systems on islands and in remote areas
- Reference projects in
  - Rwanda
  - Senegal
- Support of development of the largest hybrid system of the world at Essakane Gold Mine
- Acquired by BayWa r.e. in 2017

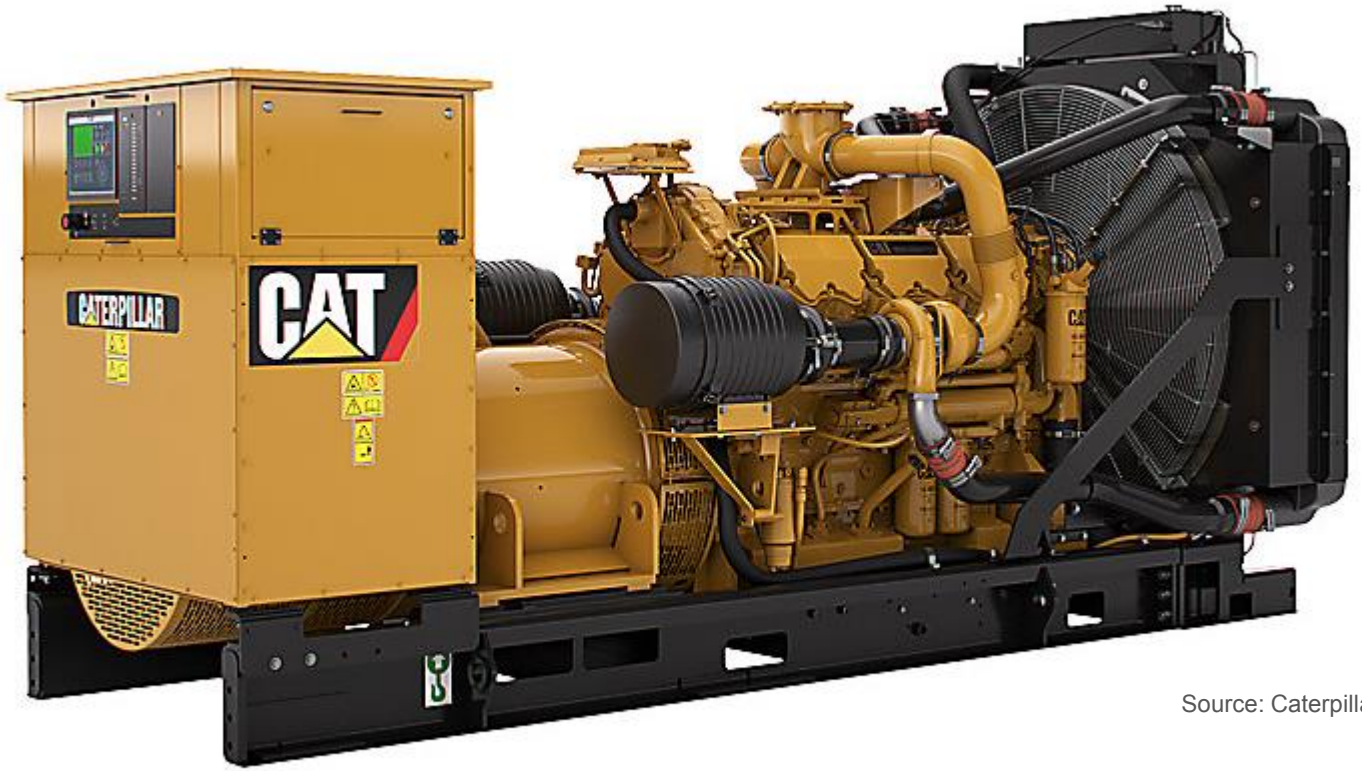


AGENDA

- Diesel generator sets
- Operational constraints
  - Generator health
  - Efficiency
  - Runtime
  - Starts and strop
- Case study
- Conclusion

“Impacts of the implementation of hybrid systems with high renewable penetration on the operation of thermal units in isolated grids “

Diesel generator sets are the prime source of power in many isolated grids



Source: Caterpillar

Loading: Ratio of the genset's current output to its rated output

Spinning reserve: Difference between genset's current output and rated output

Running gensets at low loadings for prolonged times can lead to severe damage

Operation of a genset below its minimum loading leads to incomplete combustion and problems such as:

Wet stacking	Sooting	Bore glazing
unburnt fuel condensing in the exhaust system	carbon deposits settling on injectors, pistons, valves and turbochargers	unburnt fuel and oil derivates surfacing the cylinder liner and hindering lubrication condition

Results are:

- Reduced performance
- Increased wear and tear
- Frequent replacement of engine parts

! Some effects of low load operation can be undone by regularly operating at higher loadings

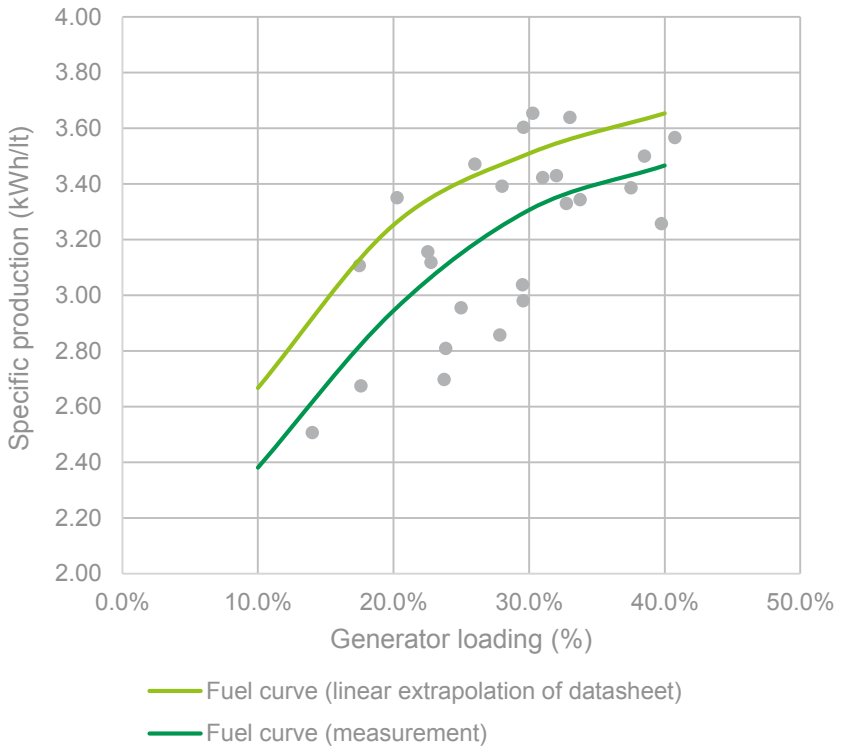
At low loadings genset efficiency significantly decreases

OneShore field study

- Gensets have their maximum efficiencies between 50 and 100%, only little information about low load efficiencies available
- OneShore have carried out a field study to evaluate this range of the fuel curve
  - Installation of a power analyser and fuel sensor at a 400 kW genset

Results

- Linear extrapolation of datasheet fuel curve acceptable, but further derating required
- Between 40 and 20 % loading specific production can drop by 0.5 kWh/l (-15%)



Integration of renewable energies has an impact on the operating patterns of diesel generators

Diesel generator runtime

Genset maintenance is based on running hours

- General inspections
- Cleaning
- Lubrication
- Service of air, fuel and cooling system
- Battery test and replacement

Reduction of running hours can help to increase service intervals for the gensets

> Over the year use of consumables such as oil, grease, etc. can be decreased leading to cost savings in addition to the fuel savings

Diesel generator starts and stops

Diesel generators in prime power applications are regularly started and stopped based on

- Demand changes
- Running hour balancing
- Faults and maintenance breaks

Varying production of renewable energies over the day can lead to increased switching operations for the gensets to adapt to the demand

Switching operations cause stress on battery, bearings and starting system

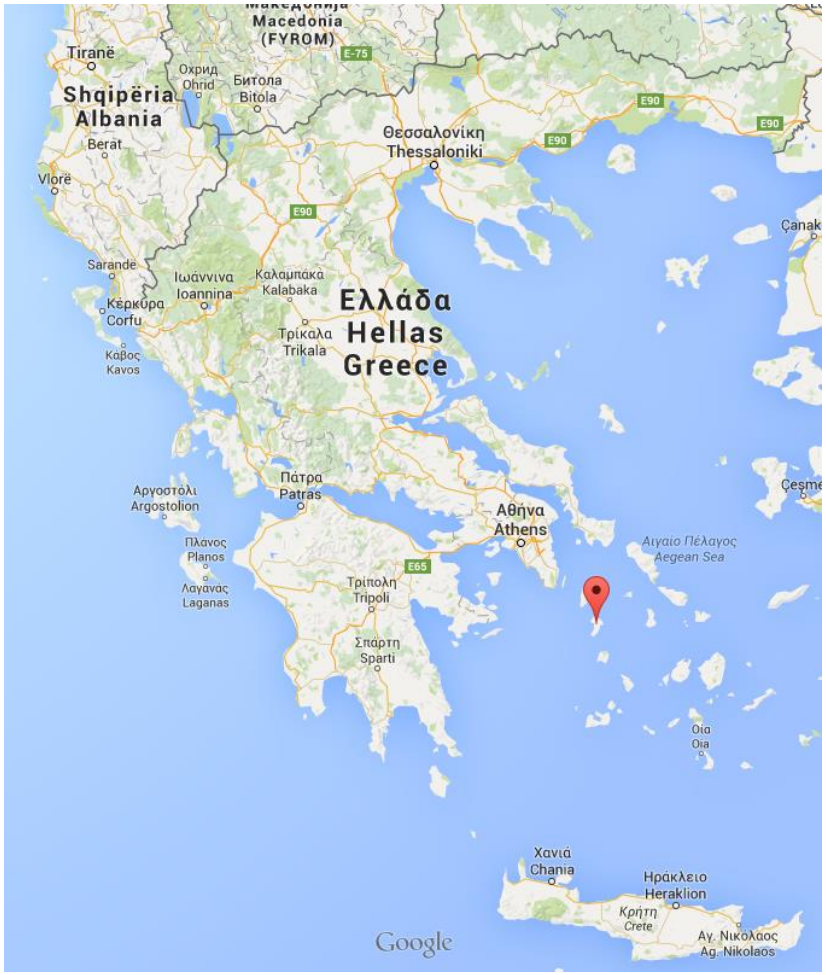
> A limit when starting operations begin to have an impact on engine health could not be determined and needs to be further researched

The impact of integrating PV and storage on operation of the diesel generators is analysed in a case study

Site description

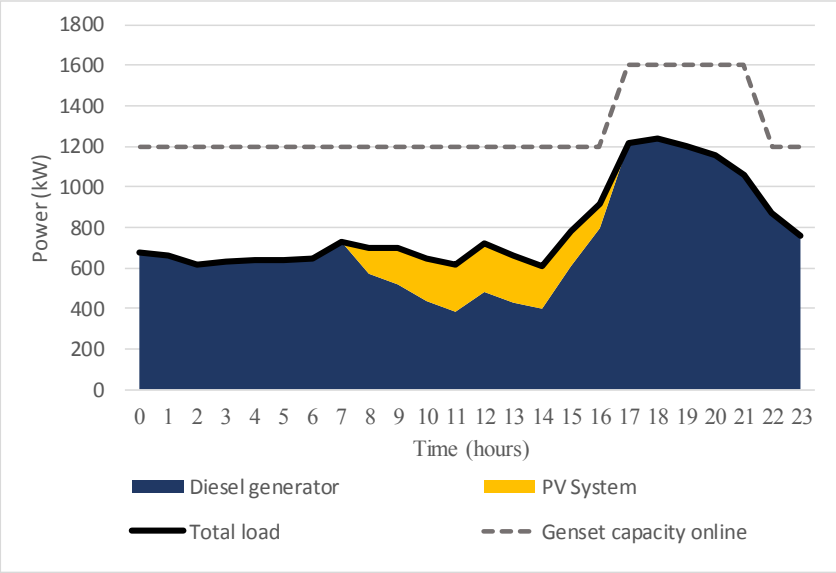
- Cyclades island of Kythnos
- Not interconnected with mainland
- Diesel generator setup
  - 3 x 1,200 kW
  - 5 x 400 kW

- Previous experience with hybrid systems



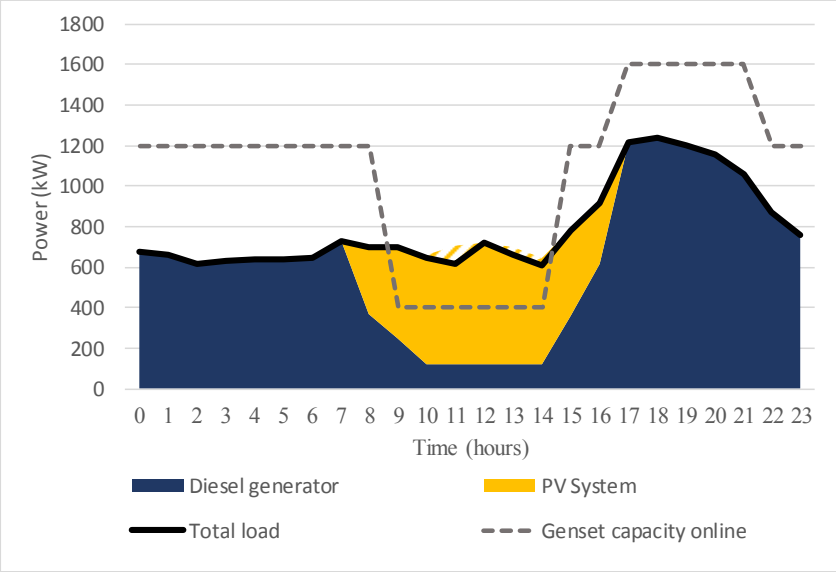
Two scenarios have been created for the analysis

Scenario 1



PV: 450 kWp
SST*: none

Scenario 2



PV: 1,000 kWp
SST*: 500 kW

*Short term storage, e.g. 2C Lithium-Ion battery container

Short-term storage allows a substantial increase of renewable integration into the network

Item	Scenario		
	Base case	Scenario 1	Scenario 2
Genset production	7,943 MWh	7,206 MWh	6,397 MWh
Solar share	0 %	9 %	20 %
Genset average loading	63 %	57 %	64 %
Fuel consumption	2,377k l	2,211k l	1,908k l
Fuel reduction	-	7 %	20 %
Genset runtime (total)	11,481 h	11,423 h	10,127 h
- thereoff (1200 kW)	9,986 h	9,967 h	7,337 h
- thereoff (400 kW)	1,495 h	1,456 h	2,790 h
Number of genset starts	561	559	917

In scenario 1 fuel savings are significantly lower due to frequent low load operation

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	Base case	Scenario 1	Scenario 2
Genset production	7,943 MWh	7,206 MWh	6,397 MWh
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Overall running hours can be decreased in scenario 2, but there is mainly a shift from large to small gensets

Item	Scenario		
	Base case	Scenario 1	Scenario 2
Genset production	7,943 MWh	7,206 MWh	6,397 MWh
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Number of starts and stops doubles in scenario 2

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	Base case	Scenario 1	Scenario 2
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Genset low load behaviour is a critical factor

Conclusion

- Decreasing genset efficiency at low loadings reduces achievable fuel savings in high penetration systems
- In green-field projects special emphasis should be placed on high efficiency over a large output range
- Impacts of low load operation on engine health can be mitigated by enforcing regular operation of the engines at high loadings to “clean” the system
  - Residential load profiles typically show an increase of demand during evening hours, which can help for that purpose

- Changing production profiles for the gensets after integration of PV can have a significant impact on dispatch
- Reduction of electricity generation and genset running hours are not necessarily equal, especially when differently sized gensets are operated

> Every site is different and needs to be analysed individually

> Speaking to local personnel is crucial to determine savings potential in operations beyond the reduction of fuel consumption

Our Vision

Driving unsubsidised renewable energy generation for isolated grids.

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