Off-road Decarbonisation & Energy System Integration
juwi Facts & Figures

$10.7 billion Investment
5,700 MW Installed
6.8 M. tons CO₂ / year saved
1,750 Solar Systems
1,000 Wind Turbines
1,150 employees
Offices worldwide

Americas: USA

EMEA:
- Germany,
- Greece,
- Italy,
- South Africa

APAC:
- Australia,
- India,
- Japan,
- Philippines,
- Singapore,
- Thailand,
- Vietnam

Project business in Germany
Project business in EMEA
Project business in Americas
Project business in Asia
80% of all new capacity additions from renewables

Source: IRENA (International Renewable Energy agency)
juwi’s hybrid / mining project timeline

Australia

- 2016: DeGrussa: 10.6MW Solar + 6MW BESS + Diesel
- 2018: Heron Island: 0.4MW Solar + 0.6MWh BESS + Diesel
- 2019: Agnew: 4MW Solar + 18MW Wind + 12 MW BESS + Gas
- 2020: Esperance: 9MW Wind + 4MW Solar + 5.5MW BESS + Gas
- 2021: Weipa: 5MW Solar + Diesel
- 2021: Gruyere: 13.6MW Solar + 4.4MW BESS + Gas
- 2021: Jabiru: 4MW Solar + 4MW BESS + Gas
- 2021: Jacinth Ambrosia: 3.4MW Solar + Diesel
- 2022: Northern Goldfields: 38MW Solar + 10MW BESS + Gas

Africa

- 2021: Elikhulu (South Africa): 11.8MW PV + Grid
- 2021: Sukari (Egypt): 36MW PV + 7.5MW BESS + Diesel
Path to Carbon Neutrality
Gold Mining

Operational Emissions

- 55 - 90% Electricity Consumption
- 5 - 35% Diesel fuel for plant
- 5 - 10% Other
Hybrid systems - Today

Sukari Gold Mine
2021/22

36 MWp

0 MW

7.5 MW
3.5 MWh

89 MW

48 MW

25% RE fraction
$9-13 mil / a saving
Hybrid systems - NEXT

Off-grid Gold Mine
2022 / 23

36 MWp
0 MW
7.5 MW
89 MW
48 MW
14 MWp
24 MW
13 MW
15 MW
13 MW

25% RE fraction
$ 9-13 mil / a saving

85% RE fraction
$ 14 mil / a saving
Daily wind generation profile
Daily solar and wind generation profile
Adding Battery and Diesel to fill gaps

Power [MW]

Wind  PV  BESS  Diesel power  Load
Load Step Issues – Gas vs Diesel

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Time Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>&lt;20 Sec</td>
</tr>
<tr>
<td>Recip Gas (Rich)</td>
<td>&gt;5 min</td>
</tr>
<tr>
<td>Recip Gas (Lean)</td>
<td>&gt;10 min</td>
</tr>
<tr>
<td>Turbine Gas</td>
<td>&gt;15 min</td>
</tr>
</tbody>
</table>
Fuel Efficiency – Diesel & Gas similar at low load
Renewable energy & electric fleets are partners

- Significant reduction in CO$_2$ emissions
- Lower fleet maintenance costs
- Less underground ventilation
- Less underground cooling
- Healthier work environment

- Electric fleets can act as flexible loads
- Fleet batteries can reduce stationary battery needs
- Electric fleets add economies of scale for renewables

Image credit: Epiroc
A greenfield mine site in development issued a study into the options to fully power a site in the arctic with renewables.

1. Even in the arctic a 90% RE system would provide the lowest cost of energy for stationary power and fleet.

2. 100% renewable energy would cost only ~23% more than a full diesel option.

3. RE costs could be further reduced with an enhanced variable mining design.

4. High contribution RE systems are cheaper, but their higher CAPEX is a hurdle.

5. Fossil fuel is more costly but OPEX driven, with less CAPEX upfront.
Lessons learned

- Batteries provide synthetic inertia up to full genset off-mode
- Gensets with high step load capability are beneficial (diesel)
- Gensets with lower minimum genset loading are beneficial
- Consider variable operations to fully utilize solar and wind
- Evaluate fleet charging with excess renewable energy

High renewable energy

1. Deliver the lowest costs
2. Mitigate fuel price exposure
3. Increase resilience
juwi Hybrid IQ

- Adapts to changing power system and operational methods
- Optimizes for lowest cash operating cost and CO₂ savings
- Enables electric fleets
- Provides detailed reporting and analysis
Does it work in practice?

James Koerting
Manager: Energy
Gold Fields

“juwi delivered the solar PV system, which included a cloud forecasting and a microgrid control system for the solar farm integration. This was completed on-time and provided the expected fuel savings without hindering system reliability. Gold Fields is very happy with the flagship Agnew project, which serves as a case study for similar projects in the mining sector.” (2020)

Peter Gordon
Electrical Superintendent
Sandfire Resources

“Now after more than 1 year of operation I can confirm that the hybrid system is running smoothly, delivers substantial diesel savings and the power quality and reliability are as good or better than before.” (2017)
Future Developments

- Above ground & heavy haulage fleet decarbonisation
- Electrification vs H2
- Battery vs trolley based power
- Battery charging vs battery swapping
- Battery chemistries
- Thermal & gravity energy storage
- Usage of sourced H2 vs on site green H2 production
- On site hydrogen usage in reciprocating engines vs fuel cells
Thank You

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