THEnergy-Triogen Report:
System optimization of renewable energy microgrids with heat-recovery in remote mining

TRIOGEN

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System optimization of renewable energy microgrids with heat-recovery in remote mining

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About Triogen

Triogen B.V., based in the Netherlands, is a leading supplier of decentralized power generation equipment derived from the steam turbine process. With over 1 million operating hours in 11 countries and on 50 sites, this technology is already mature. Triogen won the Colorado Mining Cleantech Challenge in 2017 for its innovation in reducing fuel consumption.

When applied to remote diesel/gas engines, landfill sites, digesters, biomass burners, furnaces, etc., the Triogen solution produces valuable emissions-free electricity.
http://www.triogen.nl/

About THEnergy

THEnergy is a specialized business consultancy that focuses on innovation in the energy sector, such as microgrids, solar-diesel hybrids, energy storage and hydrogen. THEnergy has developed sophisticated tools to support its clients in product launches and growth acceleration. During the last six years, THEnergy has consulted leading multinational utilities, oil and gas companies, and start-ups regarding strategy, due diligence, market intelligence, and communication. www.th-energy.net

Content

1 Renewable energy conquers remote mining

Mining plays in important role in the global CO2 discussion and energy transition. On the one hand, the global energy transition requires much more metals and minerals than the traditional power generation approach because it is much more infrastructure intense. This is also valid for battery energy storage systems.

In 2019, the World Bank has predicted significant production increases for metals such as lithium, cobalt, indium, and silver and the mineral vanadium due to the energy transition (see figure 1).[1]

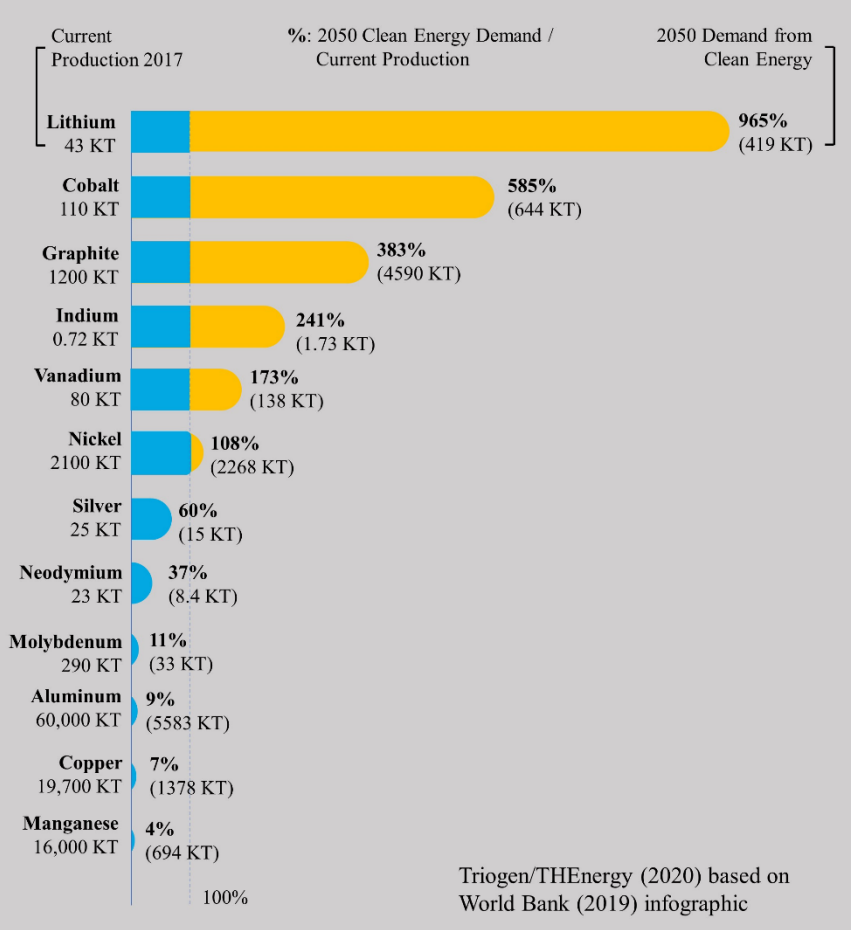

Figure 1: Energy Transition to increase mining production

On the other hand, the mining industry is already today a major energy consumer and is responsible for more than 10% of the total global final energy consumption.[2] With further growth expected these numbers are likely to increase. It is obvious that optimizing the energy use in mining will also play a key role in the energy transition.

Manifold efforts show that decarbonization will also play an important role in mining. Here are some examples:

- Rio Tinto announced that it would achieve a 65% CO2 reduction at its Kennecott Utah copper mine by shutting its coal power plant and purchasing renewable energy certificates

[1] World Bank infographic, https://www.worldbank.org/en/news/infographic/2019/02/26/climate-smart-mining, (accessed: January 22, 2020).
[2] McLellan, B., Corder, G., Giurco, D., Ishihara, K., Sep. 2012. Renewable energy in the minerals industry: a review of global potential. Journal of Cleaner Production 32, pp 32–44.

- Antofagasta plans to make its Zaldívar mine the first Chilean mine to operate with 100% renewable energy
- BHP has signed four power purchase agreements (PPA) to secure electricity from solar, wind and hydropower for its copper operations in Chile

This is not only valid for large grid-connect mines, but equally for remote offgrid mines. Traditionally, remote mines are often powered by diesel power plants. Recently, more and more mining companies have decided to add renewable energy systems to their remote mines. First and foremost, solar arrays are added which reduce diesel consumption during daytime. Diesel gensets still play an important role by balancing intermittency on the energy supply and load side. On the supply side, the intermittencies are mainly caused by fluctuations in solar irradiation.

The prices of solar and battery storage solutions were still rather high half a decade ago. On the technical side, the technology to integrate renewables has evolved during the last years. Several flagship projects have demonstrated the technical feasibility of integrating solar and wind plants to diesel power plants. The fear of production losses due to power failures has decreased considerably.

These developments have also changed the mindset of many miners who are more open toward innovative energy concepts.

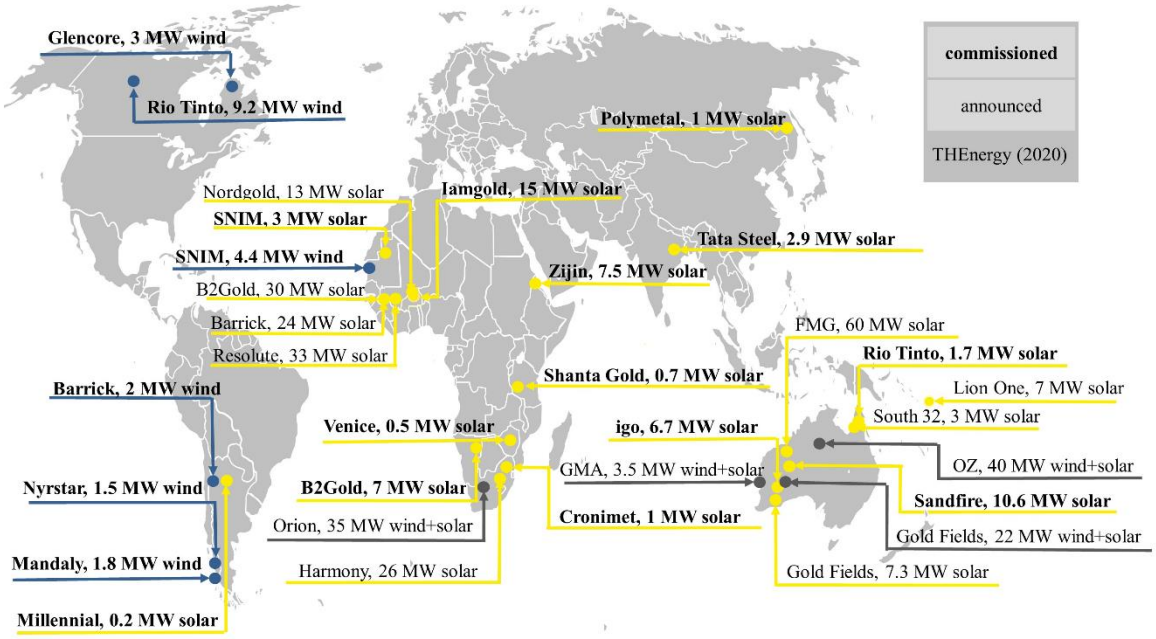

Figure 2: Major on-site solar and wind power projects in mining

Geographically, Africa and Australia are the two regions where renewables have been gaining momentum quickly at remote mine sites.

[suggestion: use different bubble sized to show the scale. Right now, the projects in AUS look similar to what's going on it Asia]

2 Main characteristics of adding solar to diesel gensets

In hybrid power plants, the attention is typically focused on the renewable energy part. The indication of the rated power output of the different components can be misleading. Normally the operating hours of diesel gensets are much higher than those of solar or wind assets. Most of the onsite

renewable energy projects at remote mines contribute between 10% and 20% of the actual generated electricity. This is to a large extent due to the fact that solar and wind have to cope with considerable intermittencies due to changes in solar irradiation and wind speed. These intermittencies do not correlate with the actual load requirements. That means that diesel gensets still play a major role in matching generated power and load by providing the power gap. Alternatively, energy storage could provide these auxiliary energy services.

Diesel gensets also have advantages over solar regarding the following aspects:[3]

- Management of power factor variations
- Grid frequency and inertia management
- Short circuit currents

From a technical perspective, energy storage can take over some of these auxiliary energy services. Relatively high battery costs are still slowing down this process.

3 Power requirements in remote mining

Mines have particularly strict requirements regarding power supply security. On the one hand, this is due to safety requirements. E.g. in underground mining, the safety of workers depends greatly on a continuous electricity supply.

On the other hand, the miners' need for a secure energy supply is related to economic reasons. Energy outages mean production losses which might go beyond the actual downtime. After the power resumes, crushers or conveyers can only be restarted after most of the material is taken out, which is a time-consuming activity and also waste of material.

Typically, diesel power plants work very reliably and minimize downtimes. Reliability of energy supply is normally not an issue while potential cost savings might appear very attractive to most mining companies. Energy is an important cost factor in mining. Energy typically amounts to approximately 20–30% of the operating costs of a mine. Generating electricity with diesel is relatively expensive – especially in remote locations, where transport through challenging areas is a significant cost-factor. Moreover, losses and theft add to the total costs of electricity. In addition, diesel price fluctuations make long-term cost planning rather difficult. It is no surprise that mining companies are interested in reducing their dependency on diesel. Diesel-saving has been the main value proposition of renewable energy companies for mines for years.

Renewable energy assets, both wind and solar, are meant to last for several decades – typically for 25 years or more. This often does not correspond to the lifetime of mines or the duration of mining permits. Even if the resource deposit of a mine would allow for long-term production, mining permits are often restricted to a time period of less than 10 years. In some cases, this could mean a formal issue for long-term renewable energy commitments. There is also a mismatch if the world market price for a metal or a mineral does not allow for a cost-covering production during certain time periods.

[3] Vyas, P, 2019, COMPARING DIFFERENT FUEL SAVING SOLUTIONS: A WHITE PAPER ON SOLAR, BATTERY AND TRIOGEN E-BOX TECHNOLOGY.

4 Traditional concept of remote power generation is under consideration

In traditional diesel power plants, the main cost factor is fuel – not the power plant. That means that costs occur when the electricity is generated and when the mine produces. This is different for renewables. Almost all the costs occur for the power plant. As many mining companies would not consider power generation as a core competence, they have shown themselves to be open to outsourcing power generation activities to third-party providers – so-called independent power producers (IPPs).

IPPs are highly specialized in power generation. They are typically willing to accept higher capital expenditure (CAPEX) than mining companies. Their business model is often based on a broad customer portfolio which enables them to relocate redeployable power plants. The emergence of renewable energy IPPs in the mining sector has led to a change of mindset. The approach of using standard diesel gensets for powering remote mines is under consideration. Dedicated IPPs aim to optimize the entire power plant. This is how renewables have opened the door for new solutions.

Diesel gensets convert only 40% of the energy input to electricity. The rest is wasted. The changing paradigms of power generation and the new efficiency focus have also put the spotlight not only on saving diesel through adding renewable energy systems, but also on increasing the conversion efficiency of diesel gensets.

5 Heat-recovery approach for fuel saving

The Dutch manufacturer Triogen has developed a heat-recovery solution that is based on an automated steam-turbine system.

Figure 3: Triogen's heat-recovery solution

It allows heat recovery from lower temperature sources. In diesel gensets, it can be used to convert low-temperature waste heat into electricity. The technology has been used for decades in applications such as:

- engine exhaust gas heat recovery
- biomass combustion
- industrial waste heat
- geothermal heat

The following image gives an overview of Triogen's fuel-saving approach for diesel gensets. The technology is relatively simple and mainly consists of heat exchangers, a turbine, a generator, a pump and power electronics.

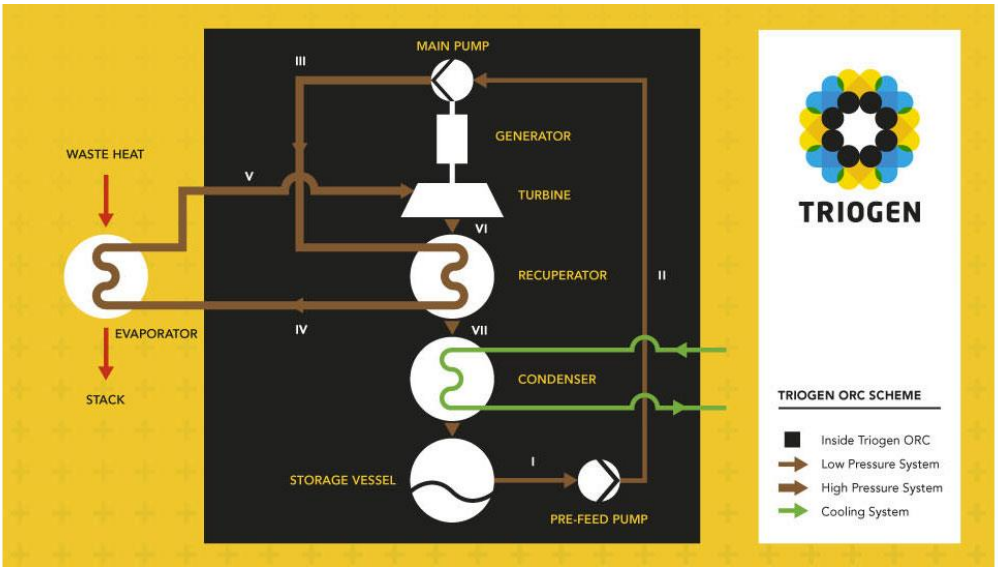

Figure 4: Overview of Triogen's fuel saving approach

The solution is tailor-made for the requirements of the mining industry. The mining package called "e-box" comprises two 20' stacked ISO containers, and is rated at 150kW per set of containers. A typical configuration would consist of two 1MW diesel engine gensets ducted to one e-box. A single e-box saves a remarkable 300,000 l of fuel per year.

The Triogen e-box is a containerized development of established Triogen technology with over 1 million operating hours. The containerized Triogen solution is configured to allow easy coupling to the exhaust ducts of diesel engines.

It comes with the following features:

- Easy installation: control and electrical integration is simplified as the e-box units do not alter the mode of operation of the diesel plant
- Quick ad-hoc solution for fuel and emission reduction
- Designed for retrofitting existing diesel power stations
- No impact on the engines (no requirement for derating or any engine maintenance or warranty implications)
- Containerized solution is extremely mobile and can be relocated
- Zero-carbon technology
- Quick payback-time

A detailed study that includes a simulation shows that heat-recovery approaches are low-hanging fruit in the path to reducing diesel consumption and associated emissions.[4] The payback time for Triogen's e-box is in the range of 1.6 years, while the payback time of solar PV is in the range of 2 years and solar plus storage slightly below 3 years. This short payback time in combination with the re-deplorability of the Triogen solution de-risks investments significantly in the case that mining operations are discontinued.

6 Advantages of combining solar and diesel exhaust heat-recovery

The white paper "Comparing different fuel saving solutions" has shown (as described in the previous chapter) that heat-recovery solutions for diesel gensets are a natural first step in the fuel reduction and decarbonization process of remote mine sites. However, this does not mean that installing heat-recovery systems would crowd out renewable energy solutions. After upgrading, a diesel plant might equally be converted into a hybrid power plant. There is no adverse effect regarding low load operations.

Hybridizing diesel gensets with solar or wind normally reduces the fuel consumption in the range of 10-20%. The diesel genset still generates the vast majority of the electricity. Typically, a diesel plant consists of several gensets in order to provide redundancy in the case that a single genset trips or to create redundancies for maintenance. Typically, the number of diesel gensets is not reduced by adding solar or wind systems without energy storage.

There is a marginal cannibalization effect when both heat-recovery systems and renewable energy plants are added to diesel plants. This is due to the fact that full-load hours of diesel gensets with solar or wind are lower.

In this context, it is worth mentioning that not all individual diesel gensets must be upgraded with heat-recovery systems. The ideal upgrading approach is a function of how the individual diesel gensets are operated.

Ideally, both solar and heat-recovery system options are optimized synchronously. Combining solar and ORCs can save almost as much fuel as solar and batteries in a hybrid system – at much lower costs.

Adding energy storage for auxiliary services to a solar-diesel or wind-diesel hybrid power plant increases the full-load hours and reduces the wear of the diesel engines. For the overall optimization of a hybrid power plant with renewables and heat-recovery systems additional storage capacity has a positive effect that might be further analyzed in a separate study.

7 Summary and outlook

Renewable energy solutions are being established in the off-grid mining market. They can provide significant cost savings, are a solution to the miners' dependency on fluctuating diesel prices and also improve the carbon footprint at remote mine sites. At the same time, they are likely to trigger fundamental market changes by shifting the attention to more capital-intense power generation solutions.

At the same time, renewable energy solutions open the door to fuel saving with heat-recovery approaches that allow for significant efficiency improvements of diesel plants. In traditional markets,

[4] Vyas, P, 2019, COMPARING DIFFERENT FUEL SAVING SOLUTIONS: A WHITE PAPER ON SOLAR, BATTERY AND TRIOGEN E-BOX TECHNOLOGY.

the main obstacle for a broad diffusion of heat-recovery systems at remote sites was that they required relatively high capital expenditures. In comparison to solar and wind investments these capital expenditures are, however, quite low. This results in very short payback times. The technology is already established in sectors such as biogas engine heat recovery, biomass combustion, industrial waste heat, and geothermal heat. The Dutch manufacturer Triogen has developed a heat-recovery solution that is tailor-made for the requirements of remote mines. It is no surprise that

- genset OEMs and
- rental companies

are gaining interest in Triogen's solution and have been conducting thorough tests during the last months.

The new solution is quick and easy to install and operate. It is compatible with virtually any genset type that is available on the market. It can also easily be combined with renewable energy solutions.

Figure 5: Key characteristics of Triogen's e-box

In times when cost optimization and carbon mitigation are gaining importance, the question is not which of the two solutions to choose. The answer is to combine both solutions together. If additional energy storage capacities for auxiliary services are added this will further improve the performance of the heat recovery approach in the overall system.

More and more independent power producers are competing in the mining markets with relatively comparable solar or wind solutions. Combing diesel gensets with heat recovery and renewable energy systems for diesel saving could enable power producers to obtain substantial competitive advantages. The simplicity of the heat recovery solution makes it very likely that an overall optimized system will become the new standard for generating electricity efficiently at remote mines.

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