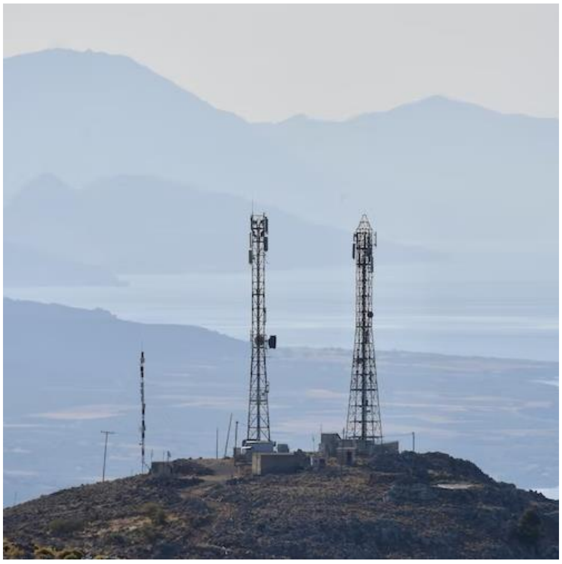
THENERGY-GENCELL REPORT

# Renewables plus hydrogen or ammonia for decarbonizing telecom towers

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# THEnergy-GenCell Report: Renewables plus hydrogen or ammonia for decarbonizing telecom towers

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Munich, Petah Tikva – January 2023

# 1 Introduction

Telecom networks are energy-intensive. While energy efficiency is constantly improving, the total amount of data that is transmitted is increasing as digitalization advances and conquers more and more sectors of our private lives and business applications. Cloudification and the introduction of 5G are related to this development. This is why the total energy consumption is still rising despite significant energy efficiency efforts.

Telecommunication companies are also rushing to cut their carbon emissions. Pressure comes from customers, investors and other operators from the industry that are leading the way. Younger generations, in particular, make clear that they are serious about the environment. Young people are an important target group for telecom companies in many countries. Therefore, it is crucial for them to show that they are willing to decarbonize. This is also important when positioning themselves as attractive employers.

In recent years, powerful initiatives have paved the way towards a carbon-neutral future. Several telecom market leaders have signed the RE100 commitment which obliges them to become completely carbon-neutral before 2050.

*Figure 1: A GenCell containerized fuel cell in the Israeli desert*

Key market players like AT&T, T-Mobile, BT, Euskaltel, and Telstra have closed some of the biggest green corporate power purchase agreements (PPAs) to date. Typical corporate PPAs are a valuable purchase option for grid-connected applications such as data centers or urban telecom tower sites. However, even these assets cannot fully rely on the power grids as the requirements regarding reliability are extremely strict. They typically also come with onsite backup power infrastructure such as diesel gensets in combination with traditional uninterruptable power supply (UPS) systems or battery energy storage systems.

Remote towers are increasingly vulnerable today to power outages because they are under increasingly higher risks of storms, floods and other extreme weather events that are increasingly severe and frequent because of climate change. Climate resilience becomes an increasingly important topic for telecom companies.

Even more obvious is the need for onsite power generation at remote telecom tower sites that are not connected to the national grids. While historically, they run on diesel gensets only, small-scale renewable energy power plants have since been added – mainly solar arrays. Solar is an intermittent energy source that needs to be balanced. In this report, different solutions such as a dynamic use of diesel gensets, batteries and fuel cells are introduced and compared.

Energy related questions are an important topic as energy costs are a substantial cost block for telecom operators. Already before the current global energy crisis they accounted for approximately 5% of operating expenditures.[1]

# 2 Power-supply for off-grid telecom towers

Reliability is key in telecommunications. Unplanned power outages can mean a loss of service to critical customers which can translate into a loss of huge amounts of money or even the loss of lives. This is why telecommunication infrastructure must be powered extremely reliably – also in remote locations where valuable 5G IoT applications such as for mining, tourism and agriculture are expanding.

## 2.1 Diesel gensets

In remote locations, telecom towers are typically powered by diesel gensets. Diesel generators are very flexible, meaning that they can easily adapt to load changes of the telecom tower. However, diesel gensets also come with several severe problems. They require regular maintenance which can be particularly costly at remote sites, and they are much less efficient than large-scale grid-connected power plants.

Diesel is facing full market exposure and can be very expensive during times of high oil prices. Many telecom companies have experienced significant issues with spiraling diesel prices and uncertainty caused by the war in Ukraine. In the future, carbon taxes and CO2 certificates will further increase the prices of diesel. Generating power onsite with renewables will make telecom companies independent of this market price exposure.

The main issue with diesel is that it is not environmentally friendly. This is valid in different dimensions. Diesel is carbon-intensive and contributes significantly to climate change.

Additionally, diesel also comes with onsite pollution, from noise to hazardous emissions that can cause cancer. Diesel power also faces loss/theft issues when it is used for powering remote sites. It can be easily used for other applications such as passenger cars or transporters.

For all these reasons, telecom companies want to reduce their diesel exposure.

[1] https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/the-case-for-committing-to-greener-telecom-networks

## 2.2 Solar-diesel hybrid

Solar – and more seldomly also small-scale wind turbines – might be used at remote telecom towers to crowd out diesel. As renewable energy sources both, solar and wind energy are carbon-neutral and do not require any fuel. However, they are also extremely intermittent energy sources, and their output depends on solar irradiation or wind speeds.

This means that they cannot match the energy loads that remote telecom towers require. This is why diesel gensets are not really replaced but rather operated at lower loads whenever the sun is shining, or the wind is blowing.

*Figure 2: A solar array at a telecom tower at a remote island in Nicaragua*

Diesel gensets can quickly respond to power losses due to a shading of the solar arrays or stopping winds by increasing their load. Operating diesel gensets in such a dynamic way increases the maintenance needs as they are typically optimized for operating at rather high loads.

So-called solar diesel hybrid solutions reduce the diesel consumption typically in the range of 15-25%. They can contribute to decarbonization. It is important to deploy as many solar-diesel hybrid solutions as possible at remote telecom sites, but at the same time it is obvious that this approach is far from being carbon-neutral.

## 2.3 Solar-diesel hybrid plus batteries

At remote telecom sites, batteries might be added in a way that diesel gensets can be switched off during sunny and/or wind days. While the diesel gensets are switched off, the batteries balance the gap between the intermittent renewable energy source and the requirements from the telecom tower.

Batteries can also reduce the wear on diesel gensets by running them more steadily. Batteries might also work as a bridge-for-backup – meaning that they provide energy until the diesel genset is started which might take up to a couple of minutes.

Large modern batteries such as lithium-ion and even more long-duration energy storage systems such as redox-flow batteries can even go one step further and provide electricity during nighttime or on some low solar or wind-yield days. In many regions, weather seasonality is however so big, that diesel gensets are still being used as a back-up power system for longer time periods with limited solar irradiation and/or wind speeds.

The share of renewables is seldomly beyond 50%. Even for such a modest looking renewable energy share, the capital requirements for batteries are rather high.

## 2.4 Hydrogen and ammonia for powering remote sites

When dealing with seasonal fluctuations on the supply side (for instance weather-based) or the demand side, especially long-duration energy storage systems or fuel-based solutions must be used.

Hydrogen can be both an energy storage solution and a fuel. When hydrogen is produced onsite from solar or wind energy and converted in electrolysis plants to hydrogen, stored in tanks and then re-converted into electricity, hydrogen assumes the role of an energy storage system.


*Figure 3: GenCell off-grid solution during a field test in Iceland*

Sometimes it might be too complex to run a small-scale electrolyzer on-site to produce green hydrogen locally. Therefore, green hydrogen as a carbon-free fuel can still contribute to decarbonizing remote microgrids – for example telecom sites. Typically, hydrogen is transported in liquid form in specialized trucks to the remote sites.

Transportation costs could be decreased if the hydrogen-dense derivative ammonia is used instead of hydrogen itself. Ammonia is a pungent gas that is widely used for agricultural fertilizers. As green hydrogen, green ammonia is when the production is carbon-free because it is based on 100% renewable energy.

The standard way of making green ammonia is using hydrogen from water electrolysis and nitrogen separated from the air to feed them in the so-called Haber-Bosch process in which they react together at high temperatures and pressures to produce ammonia, NH3.

For remote applications, relatively small amounts of green ammonia are needed while around the world huge green ammonia production sites are being built – mainly for the fertilizer industry, but also for refineries and the transport sector. Green ammonia can be used in fuel cells to provide power in remote locations.

Powering remote telecom sites by fuel cells is a more robust solution than using diesel gensets. This becomes particularly important as we are facing the consequences of climate change such as a higher risk of storms, floods, and other extreme weather events.

# 3 Different fuel cell technology for remote applications

Instead of burning fuel to create electricity, fuel cells rely on an electrochemical reaction that does not create any greenhouse gases and only clean vapor as local emissions.

The modern development of fuel cell technologies dates back to the end of the 1950s and the beginning of the 1960s. The two main technologies are proton exchange membrane (PEM) and alkaline fuel cells (AFCs).

## 3.1 PEM fuel cells (PEMFC)

PEM fuel cells have been the most widely known and used low-temperature fuel cells so far. They were invented in the early 1960s for use in NASA’s Gemini space missions. PEM fuel cells are low temperature fuel cells and operate at 80-100 degrees Celsius. As they are relatively small and lightweight, PEMFCs have a high peak power density and they are well suited for transportation applications such as buses, trucks, cars, and also forklifts. PEM fuel cells consist of two electrodes (an anode and a cathode) with a thin platinum layer of catalyst, bonded to either side of a proton exchange membrane. Their acidic nature requires the use of platinum cathodes. If water and the heat of the fuel cells are not carefully managed the performance of the membranes will start to dry out and conductivity will decline, or condensation could flood the electrodes.

Membrane fuel cells typically require water for membrane hydration and therefore must be operated in conditions above freezing or be placed in a heated and insulated enclosure.

The requirement of expensive electrocatalysts, typically made of platinum, to support the reactions that occur at low temperatures are an important factor that drive costs of PEMFCs.

## 3.2 Alkaline fuel cells (AFC)

The term alkaline fuel cells comes from the use of an alkaline electrolyte such as potassium hydroxide (KOH) in water. AFC are particularly efficient - reaching up to 60% efficiency and up to 87% for heat and power combined.

The circulating liquid electrolyte offers many benefits over more common low temperature membrane-based fuel cells like PEM.

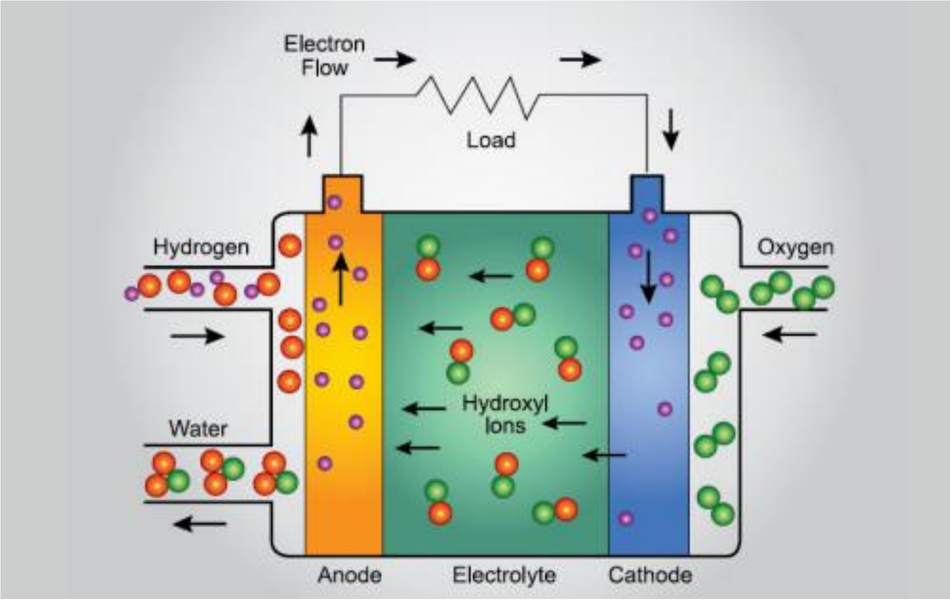


*Figure 4: The electrochemical process of an alkaline fuel cell*[2]

The electrolyte (KOH) used in alkaline fuel cells has a freezing temperature of below -40 degrees Celsius allowing the start up in sub-freezing conditions. Liquid electrolyte also avoids many of the challenges with membrane humidification including limited operation in certain high and low humidity conditions. That means that AFCs can operate in a greater range of temperature and humidity conditions. They also feature a short start up time needed by many target applications. The liquid catalyst makes AFCs relatively heavy. As they are also larger than PEMFCs, they are hardly used for mobile applications. However, thanks to their advantages regarding efficiency, reliability, and operability, they managed to replace PEM fuel cells at NASA for use in the Apollo, Skylab and Space Shuttle programs despite the importance of space and weight in astronautics.

For stationary applications they are a logical choice as size and weight are typically not so important and especially at remote locations reliability and operability are key features. The significantly higher efficiency also translates into fuel savings and lower transportation needs and costs.

The main issue that remains with standard AFCs is the alkaline electrolyte which is quite sensitive to any CO2 in the fuel or oxidant stream. The AFC has been used for many years in Space and defense applications employing hydrogen as a fuel and pure oxygen as an oxidant. The hydrogen-oxygen (anaerobic) AFC achieves an efficiency significantly higher than that of other types of fuel cells. In civil applications, the AFC uses ambient air as an oxidant, with a concentration of CO2 of 300-450ppm. In the presence of CO2, KOH electrolyte degrades, forming carbonates, which ultimately affect the durability and longevity of the AFC's operation. This problem is typically resolved by means of air scrubbers (regenerative and non-regenerative) that reduce the CO2 concentration in the incoming air.

## 3.3 Other fuel cell technologies

The current fuel cell discussion also concerns new technologies. The main ones are:

- Phosphoric Acid (PAFC)

[2] Source: GenCell (2018).

- Molten Carbonate (MCFC)
- Solid Oxide (SOFC)

The main advantage of MCFC and SOFC technologies are their fuel flexibility as they cannot run only on hydrogen but also on natural gas, methanol, ethanol, biogas, and coal gas. However, they are operated at high temperatures of 600 - 700°C (MFC) and 500 - 1000°C (SOFC) which implies operational issues – especially critical at remote locations – and long start up times of up to 2.5 hours.

PAFC are operated in a medium temperature range of 150 - 200°C but also come with issues such as long start up times, low efficiencies, and high costs due to expensive catalysts which make them unsuited for remote stationary applications.

## 3.4 GenCell's innovative Alkaline fuel cells (AFC)

GenCell has made several patented improvements in AFC technology that optimize their fuel cells for stationary applications. Capital costs have substantially been reduced by using non-precious metal catalysts instead of precious metal catalysts – typically made of platinum or platinum alloys.

A simple, effective, and inexpensive carbon dioxide scrubbing technology enables GenCell's AFCs to use ambient air everywhere containing both oxygen and CO2—instead of pure oxygen. The patented method allows for removal of CO2 from the air.

Like other AFCs, GenCell fuel cells tolerate lower-grade hydrogen and they are not affected by other impurities in the less pure hydrogen. The robust GenCell AFC can run on industrial grade hydrogen (purity >99,95%) instead of medical-grade hydrogen (purity of >99,995%) which makes it much more attractive for stationary applications such as telecom power – it eliminates availability issues and lowers the operational costs significantly due to lower fuel prices.

If the fuel cells will be powered by locally generated green hydrogen this means that the requirements for the electrolysis process and hydrogen storage are lower regarding the purity of hydrogen. This could turn into another important cost advantage.

Significant efficiency improvements that come with GenCell's innovative approach are also lowering operational costs.

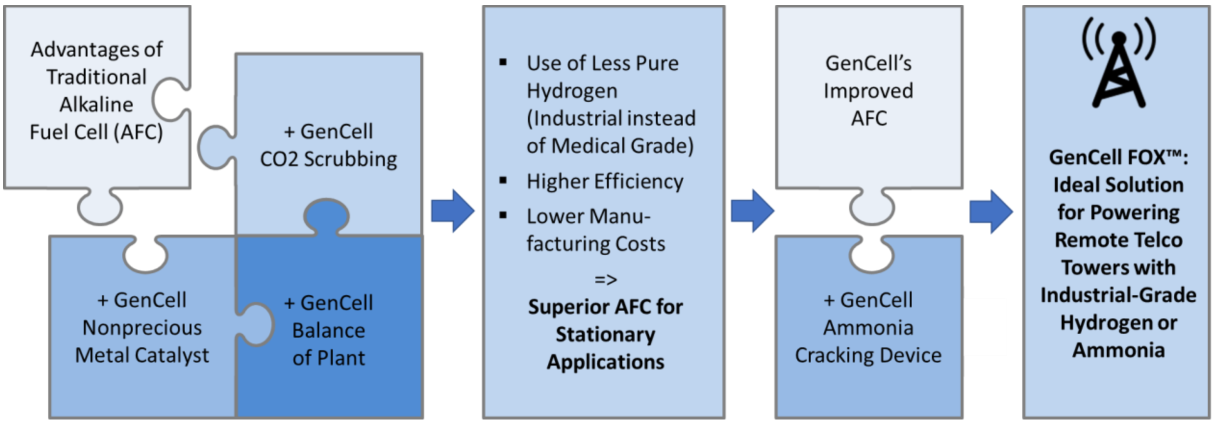


*Figure 5: The GenCell approach for powering remote telco towers*

Transporting and storing hydrogen at remote sites remains a challenge and this is where ammonia comes into play. It is one of the most effective and energy-dense carbon-free hydrogen carriers, with only water, nitrogen, and heat as by-products when hydrogen is extracted from ammonia and fed into the fuel cell.

Liquid ammonia is less flammable than gasoline, propane, hydrogen, or natural gas and emits a strong odor that makes leaks rapidly detectable. When handled in accordance with regulations and proper equipment, liquid ammonia achieves excellent safety records.

Ammonia is less expensive and cleaner than diesel as it only emits water vapor and extremely low concentrated NOx (less than 1ppm - NOx in untreated diesel exhaust is typically between 50 and 1000 ppm). The level of NOx formation from ammonia primarily depends on the (exhaust) temperature; as GenCell has succeeded to reduce the exhaust temperature to below 600°C, the NOx levels can be maintained below 1 ppm.

Green ammonia is carbon-free as it relies on green hydrogen. Green ammonia production facilities have become increasingly common around the world – these are used mainly for fertilizer, refining, and transport applications. Due to cost degressions this still means that the price for green ammonia will come down significantly. It is likely that green ammonia will be much less expensive than diesel in the near future.

Ammonia is also a good solution for another issue that can be frequently observed at remote locations: “loss”. Most of the time theft would be the correct expression. The use of ammonia is relatively specialized, so it is unlikely to be stolen.

For these reasons, GenCell has developed an onsite ammonia cracking device that extracts the hydrogen from the ammonia. The ammonia cracker is highly efficient as it needs no external energy source to start the reaction. Only 17% of the hydrogen is consumed for running the cracking process. In principle, that means 83% are fed into the AFCs for conversion into electricity. Fuel requirements are technical grade anhydrous ammonia (purity of >99.5%) which is extremely efficient: depending on the size of the load, typically, a single 12-ton tank of ammonia can fuel a base station 24 hours a day, 365 days a year.

For telecom companies, GenCell offers integrated solutions that consist of:

- innovative alkaline fuel cell
- ammonia cracker
- energy bridge for regulating power output
- heat utilization unit for dissipating excess heat

The Hydrogen-to-Power telecom backup solution is called the GenCell BOX™ while the integrated Ammonia-to-Power off-grid primary power solution is called GenCell FOX™. It is ideal for remote locations that lack grid access or where the grid is unstable and independent power sources must run for long durations.

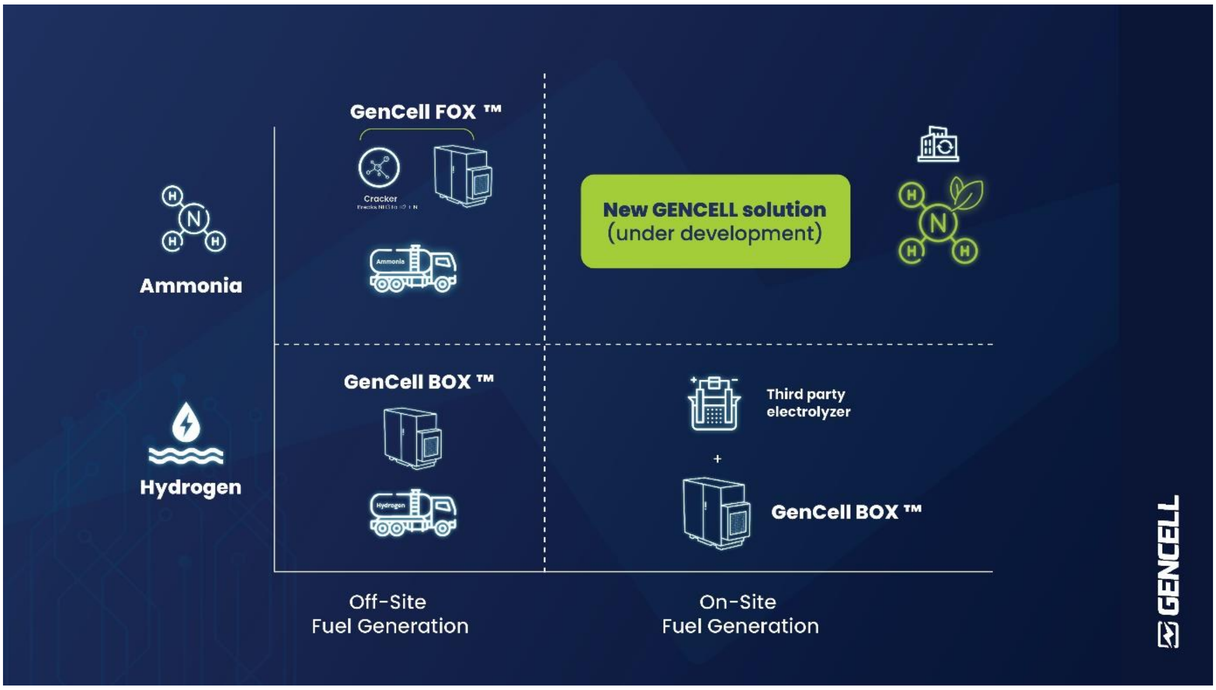


*Figure 6: An overview of on-site and off-site fuel generation solutions fueled by hydrogen and ammonia*

GenCell's product range is especially weather-resistant – which is especially important as we are increasingly facing the consequences of climate change such as higher risks of storms, floods, wildfires, and other extreme weather situation.

In comparison to diesel gensets, the software of GenCell AFC solutions is another plus. The GenCell software offers operational intelligence: it enables remote operations and monitoring so that no personnel need be onsite under normal conditions.

## 3.5 Radar chart analysis for different fuel cell technologies at remote telecom towers

The following radar chart shows the requirements for fuel cells at remote telecom towers and the GenCell hydrogen and ammonia fuel-cell based solutions almost perfectly match.

The disadvantages of greater weight and volume that come with alkaline fuel cells are not relevant in remote stationary telecom tower applications. They are typically ground-mounted, and space is not a major limiting factor at a telecom tower.

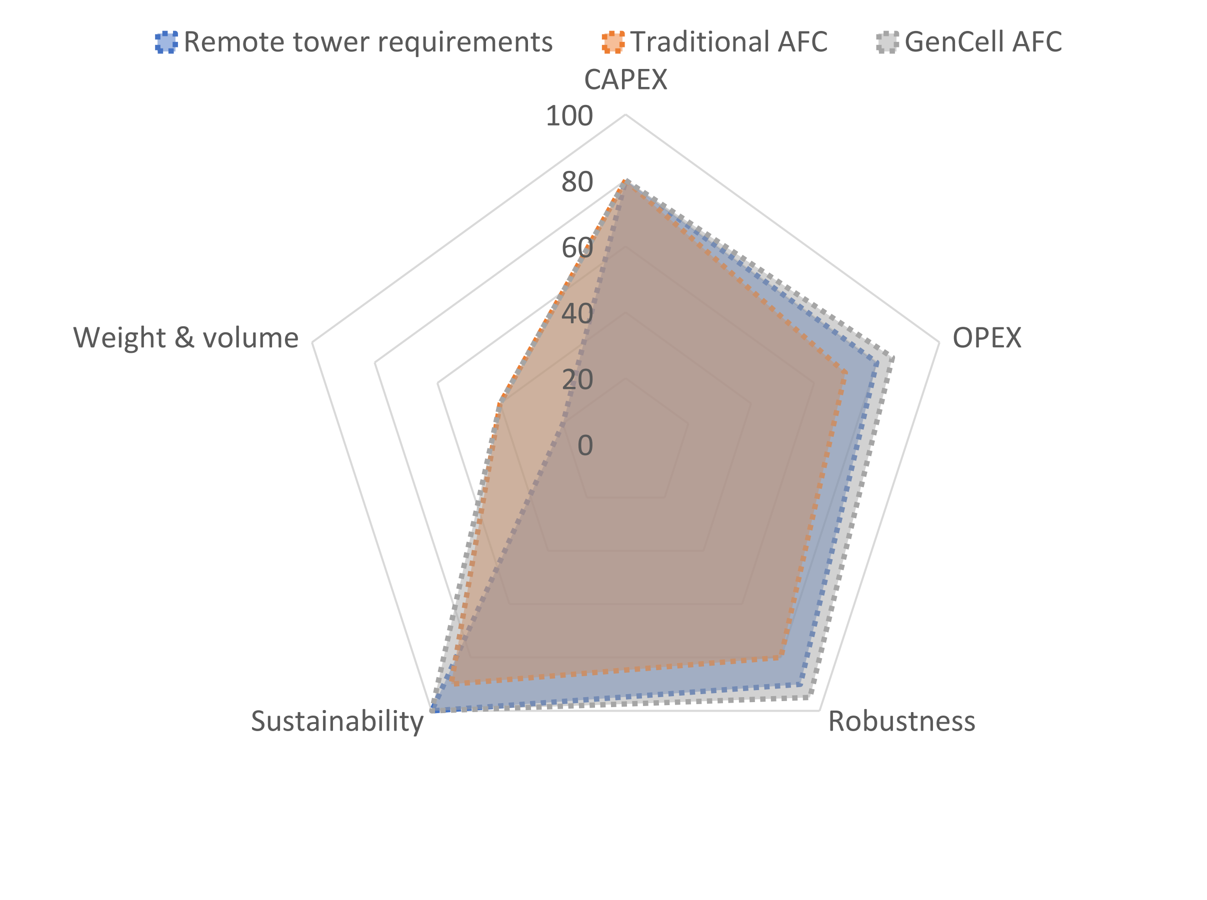


*Figure 7: Radar chart of requirements at remote telecom towers vs. alkaline fuel cells*

The radar chart also shows that the improved efficiency and reduced OPEX that come with the GenCell innovation fit extremely well with the requirements of telecom towers.

## 3.6 Applications of the GenCell hydrogen and ammonia solutions in the telecom sector

The GenCell FOX™ does not only apply to telecom applications in theory, but it has also been tested in practice.

GenCell has successful completed a joint lab test of its hydrogen-based backup (GenCell BOX™) power solution with Deutsche Telekom. This test, conducted at GenCell's Tel Aviv facility under the supervision of Deutsche Telekom, one of the world's leading integrated telecommunications companies, was part of a strategic innovation cooperation between the two companies to test and validate GenCell's zero-emission fuel cell solutions for a carbon-neutral power supply of Deutsche Telekom's mobile sites. It was followed by testing of the integration of the GenCell BOX at other hybrid renewable power sites in Germany as well as by an evaluation of the GenCell FOX off-grid solution.

In a second project, a GenCell FOX™ ammonia-based off-grid power solution was deployed in a field test at a mobile telecom tower site in Romania, operated by Vodafone, a global telecom provider committed to its sustainable business strategy.


*Figure 8: A GenCell FOX™ ammonia-based off-grid power solution in Romania*

The objective of the field test was to evaluate the ammonia-based power solution's performance, resilience, and cost-saving potential over a six-week timescale. Initial results from the test indicate that the system operated reliably, providing required power output throughout the entire test period. The system was operated autonomously and minimal intervention from GenCell personnel was required.

The GenCell backup solutions have also been proven for their resilience under extreme weather conditions at the Icelandic emergency communications system operated by Neyðarlínan ohf, the state-owned Icelandic telecom provider that operates 112, the National Emergency Number, the National Tetra Telecommunication Service and the Icelandic Maritime Service. The off-grid power system, installed in a compact container housing the ammonia cracker integrated with the AFC generator, has successfully completed an important milestone of running for 1500 continuous working hours in inclement weather conditions including sub-zero temperatures (-10$^{o}$ C) compounded by heavy rains and strong winds.

## 4 Conclusion and Outlook

Sustainability, costs, and resilience are the key factors for telecom operators when they address energy these days. There is a strong need to decarbonize and to maintain almost 100% availability for the network infrastructure - while at the same time economic restrictions must be respected.

The report shows that powering remote telecom sites with ammonia and hydrogen can already be a reality today. The GenCell portfolio based on Hydrogen-to-Power and Ammonia-to-Power technologies comprises the key components that are necessary for remote and emergency power solutions. GenCell's AFCs come with huge advantages for stationary applications such as high efficiency, and the capability to cope with less pure hydrogen which represents the potential for significant cost reduction. Availability and prices of industrial-grade hydrogen are much better than those of medical-grade hydrogen.

For remote, back-up and emergency power applications, onsite storage of hydrogen plays a key role. Ammonia can be stored much more easily than hydrogen. This is why GenCell has developed an onsite ammonia cracking solution which allows to feed their advanced AFCs with ammonia instead of hydrogen, significantly reducing fuel transport costs.

The development does not stop with purchasing and transporting hydrogen or ammonia to remote sites. The future of hydrogen will be very much about onsite generation of green hydrogen and ammonia.

For hydrogen, this is already possible today with GenCell's AFCs and small electrolyzers for onsite hydrogen production powered by renewables such as solar and wind energy.

GenCell is developing a comprehensive solution for producing and reconverting onsite hydrogen in green circular economies at distributed sites anywhere – completely eliminating transport costs – a development which they have named "Water to Power" and appears to be the next milestone for decarbonizing telecom networks.

However, in the present it makes sense for mobile network operators to start at least with some test installations to become familiar with the advantages of hydrogen and ammonia for remote sites or emergency power. For MNOs to understand the advantages of being fully energy self-sufficient with onsite ammonia, they can take the first step by installing a GenCell FOX and enjoy the advantages of ammonia such as lower costs, reliability, and decarbonization. Even if they do not have full access to green ammonia supply, it absolutely makes sense to be amongst the hydrogen and ammonia pioneers and switch to fuel cell-based solutions for their telecom towers now.

Early adoption will also help them to position themselves as environmentally conscious and progressive towards key stakeholders such as their customers, employees and investors.

## About THEnergy

THEnergy is a specialized business consultancy that focuses on innovation in the energy sector, such as hydrogen, microgrids, solar-diesel hybrids, and energy storage. During the last six years, THEnergy has consulted leading multinational utilities, oil and gas companies, and start-ups regarding strategy, due diligence, business intelligence, and marketing. www.th-energy.net

## About GenCell

GenCell Energy (TASE: **GNCL)** develops total green power solutions based on reliable, zero-emission alkaline fuel cells, hydrogen and green ammonia-to-energy technologies which deliver uninterrupted power to help the world #SayNoToDiesel and transition to clean energy. The ability to produce not only clean power from GenCell's fuel cells, but also the green fuel on which the fuel cells run, sets GenCell in a far superior position as a well-to-wheel total green energy solution provider. GenCell delivers resilient, robust and weather-resistant backup power for utilities, telecom, EV charging and other mission-critical applications which have been deployed in 22 countries. Our ammonia-based hydrogen-on-demand solution provides primary power for off-grid and poor-grid sites, as well as for rural electrification. GenCell Energy numbers some 150 employees, including veterans of space and submarine projects. The Company is headquartered in Israel with a worldwide distribution and support network and retains unique intellectual property that includes patents, trade secrets and know-how. http://www.gencellenergy.com/

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