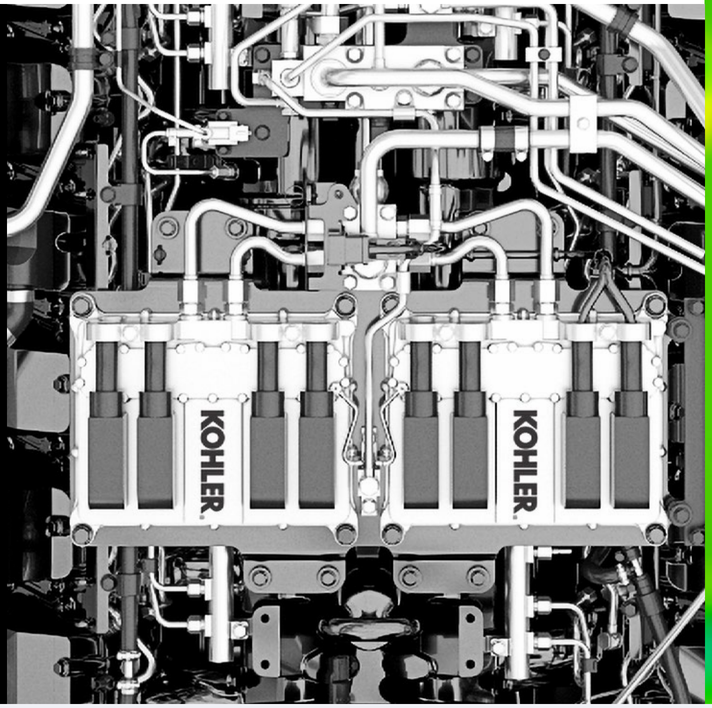
KOHLER®

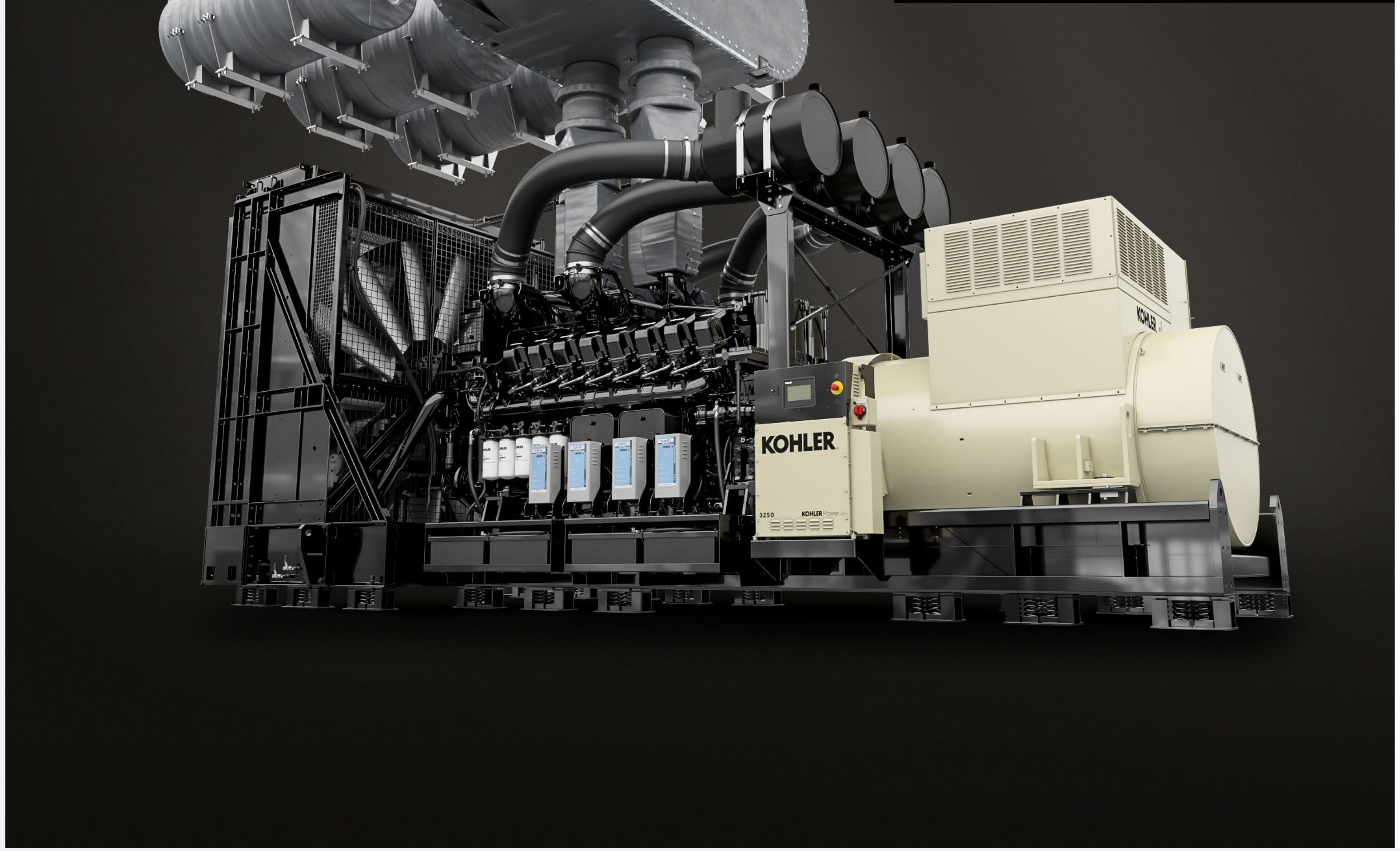
# Delivering more *sustainable* mission-critical generators - now and in the future

The threat of climate change has resulted in urgent demand for more sustainable mission-critical power technologies. Generator manufacturers and their industrial partners have responded with an intense period of engine optimization that has significantly reduced the release of harmful pollutants.

Now, new maintenance techniques and the introduction of renewable fuels such as Hydrotreated Vegetable Oil (HVO) are also improving the environmental performance of generators before revolutionary technologies such as batteries and fuel cells become broadly available.

APPROVED FOR HVO RENEWABLE FUEL




# $23.6B

GLOBAL GENERATORS SALES ARE EXPECTED TO GROW TO $23.6 BILLION BY 2025[1]

The world relies on resilient mission-critical power for business, health, safety, and security. At crucial times, it allows hospitals to provide life-saving procedures, water plants to supply consistent purification standards, and smart grids to maintain the provision of heating and lighting. Furthermore, back up power is needed to underpin essential communications networks, such as data centers and cell towers. In short, mission-critical power is vital to many aspects of our daily lives.

Mission-critical power is often delivered by diesel generators, representing a tried and trusted technology. When an outage occurs, generators detect the loss of electricity in seconds, switching on quickly and reliably to allow continuity of operation. The proven ability of generators to perform consistently and resiliently when needed means they remain a popular solution in markets worldwide. Indeed, the estimated total industrial generators market (diesel, gas, marine) is predicted to reach $23.6 billion by 2025[1], with many of these products being used for mission-critical applications.

So, why are generators deemed so suitable across so many sectors? Firstly, they offer flexible outputs across a broad range of power nodes and can be accurately sized within a small footprint to carry out the task at hand. Diesel provides an efficient and readily available fuel that can be stored safely on-site and works well in most climates. And finally, most generator suppliers offer well-established maintenance and spares support, ensuring end-users with peace of mind over the long term.

Also, diesel generators are the only option for some mission-critical power environments, particularly in remote areas where the grid is unreliable and there is a lack of supporting energy infrastructure. Here, these machines represent a lifeline to local communities and cannot realistically be replaced by any other alternative technology.

# Reducing harmful emissions

The concern around generators, of course, comes with their impact on the environment. Burning diesel creates carbon dioxide and emissions of particles such as soot. However, power outages are rare in many locations, meaning that mission-critical diesel generators are only used occasionally and for short periods – therefore emissions are relatively low. That said, there is a genuine desire for more sustainable operations, from OEMs and end-users alike, and generator manufacturers have invested heavily in pursuit of more environmentally friendly technologies.

The bulk of this development has been concentrated on the engine, with environmental standards such as EPA Tier 4 in the US and Stage V in Europe challenging engineers to rethink engine architectures to reduce NOx and particulate matter levels. Emissions reduction technologies have been advanced to reduce the amount of pollution created, via in-cylinder reductions, and to treat created pollution before it enters the environment through the application of after-treatment technologies. Additionally, engineers have deployed advanced computer-aided tools and computational fluid dynamics to predict performance and optimize designs.

For example, high-pressure common rail fuel injection systems increase the injection pressure of diesel fuel, allowing for finer atomization, improved air-mixing, and greater control of injection timing. Meanwhile, electronic fuel injection means the engine can be programmed to inject fuel at the ideal time during the combustion cycle – with multiple injections carried out within milliseconds. By using closed-loop feedback controls, the engines can also adjust the fuel injections to account for transient events, steady-state operation, or environmental operating conditions.

Exhaust gas recirculation (EGR) is also commonly deployed to reduce NOx. During operation, exhaust gases are recycled back into the combustion chamber. The exhaust gases are mixed with the intake air to reduce oxygen content and therefore combustion temperature.

Significant advances have also been made in after-treatment technologies. Diesel oxidation catalysts, consisting of a precious metal coated honeycomb structure in a stainless-steel housing, cause a reaction in the hot diesel exhaust flows as it passes through, breaking down pollutants into less harmful components. Other technologies such as diesel particulate filters and selective catalytic reduction can also be deployed to reduce the release of contaminants.

# Introducing renewable fuels

Engine optimization and advances in maintenance techniques are also being supplemented by the development of renewable fuels that offer a step-change in sustainability. HVO, for example, is a liquid fuel that is synthesized from waste vegetable oils or animal fats using a special hydrotreatment process. Unlike first-generation biodiesels, HVO is an entirely renewable energy source that does not impact crop resources, and it can translate into up to 90 percent fewer greenhouse gas emissions over its entire lifecycle.

Furthermore, HVO delivers many advantages to the mission-critical end-user. Most importantly, the production process is such that the final product is similar in grade and quality to traditional diesel, and hence can be used as a drop-in without modification. HVO is also completely compatible with the standard mix of petroleum-derived diesel fuels, and therefore it can be used as a blend with traditional fossil diesel. The ability to mix HVO and conventional fuels provides flexibility to the end-user, who could introduce HVO as a renewable fuel and then revert to diesel should the need arise.

Additionally, HVO is a high cetane fuel, with a cetane number of 70-90 compared to first generation biodiesel's 50-65 and fossil diesel's 40-55. High cetane brings significant performance advantages for the end-user, including better combustion, better cold start, and reduced emissions levels. Also, HVO does not oxidate or absorb water. It is resilient in cold weather to -32 degrees C so that it will flow easily right through the harshest winters. It has a minimum flashpoint of 61 degrees C, which makes it safe in warmer conditions. Finally, HVO is more stable than diesel, allowing it to be stored for ten years. By comparison, traditional biodiesel can only be held for 6 - 12 months. The development of HVO means the user of generators for mission-critical power applications has a simple and efficient renewable alternative to fossil diesel that can be used right now. The KOHLER® KD Series of generators is fully HVO ready – providing the market with a low-carbon solution. In recent months, international organizations such as Chevron and Neste have made significant investments in the global supply chain for HVO, ensuring that the fuel is readily available.

# Technologies of the future

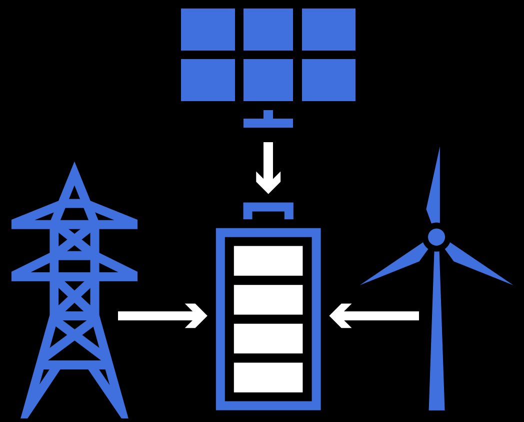
So far, the focus has been on sustainable solutions that can be deployed from today. However, Kohler's technical teams are also evaluating the potential of revolutionary technologies for mission-critical power, such as batteries and fuel cells, that might be deployed in the medium term.

Battery performance has matured rapidly in recent years, and the technology is already available with an efficiency of close to 90 percent. Kohler has already forged several joint ventures with industrial partners to develop battery-powered generators. In one partnership, a collaborative effort with a leading power grid operator in Europe is set to produce a 400-600 kWh lithium iron phosphate battery prototype that will then undergo extensive trials and evaluation.

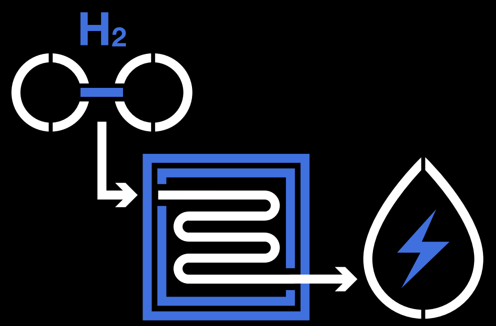
The challenge with batteries comes with deploying the technology at scale. The power outputs required for mission-critical applications would require a substantial number of large battery packs – presenting cost, complexity, and footprint challenges. Also, batteries contain high levels of rare metals, which are becoming more difficult and expensive to acquire. It might prove to be the case that battery technology is better suited for shorter periods of energy storage and dedicated to rental/events or for maintaining grid frequency, rather than mission-critical applications.

Fuel cells, meanwhile, are also attracting much attention. They have a lower footprint compared to batteries, and the possibility of quick refuelling with pressurized or liquid H2. These factors mean fuel cells could be adapted for backup applications and more extended storage periods.

However, fuel cells bring their own challenges. These devices can only really be considered 'green' if the hydrogen used to power them comes from sustainable sources such as renewables, nuclear, or biomass. At present, though, around 95 percent of hydrogen comes from natural gas – and making 1kg of this 'grey' H2 emits around 11 kg of CO2. 'Blue' hydrogen is produced the same way, but the CO2 is captured and stored – but suitable storage sites are few and far between, so availability is limited. The long-term solution comes with "green" H2 made from renewable energy such as solar. But this approach is many years away from being practically available at scale, and the H2 produced is hard to store in bulk without significant investment in associated infrastructure.



FUTURE BATTERY BACKUP PROVIDES 100% CLEAN POWER STORED FROM RENEWABLE ENERGY STORES




FUTURE FUEL CELLS HAVE NO EMISSIONS WITH USE OF "GREEN" HYDROGEN

# Long-term commitment

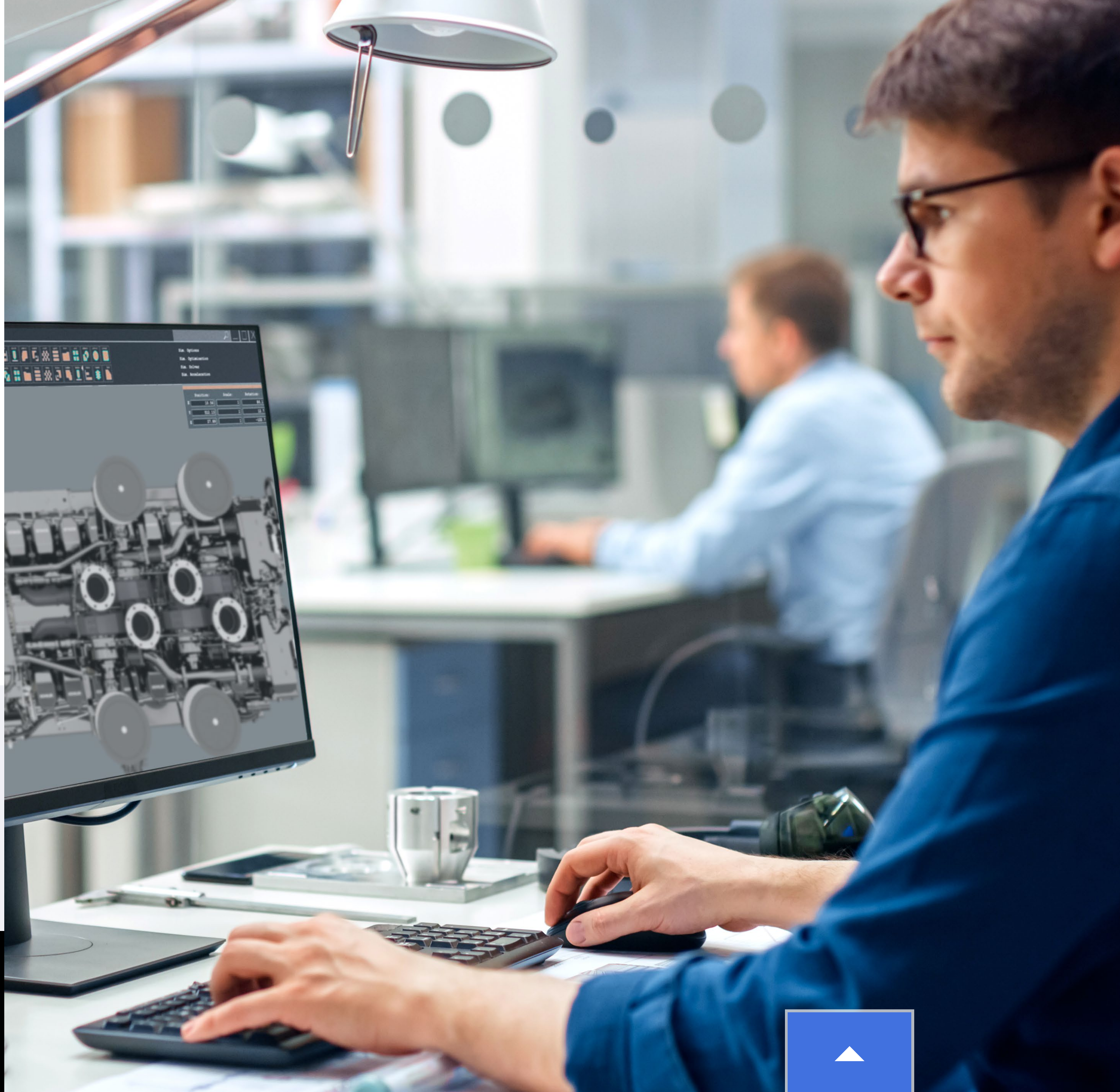
The challenges presented by adopting these new solutions show that the route to cleaner mission-critical power will be achieved through a transition period – it will not happen overnight. However, Kohler is fully committed to long-term investment in research and development to provide end-users with a diverse range of technology options.

In some circumstances, diesel will always represent the best technology and remain the power source of choice. But in other applications, renewable fuels such as HVO will offer generator users the chance to switch to more flexible alternatives without compromising performance. And in the future, fuel cells and batteries could present a step-change in sustainability, with little or no at-source emissions.

Kohler will be a partner on this journey through innovation and collaboration - providing today's generators for tomorrow's generation.


**References**

1. Source: Powergen Statistics

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