IMPROVEMENTS IN DIESEL ENVIRONMENTAL PERFORMANCE AND A ROADMAP TO A GREENER FUTURE

2020 saw record demands for computing power, with the global pandemic driving a 44% increase in the amount of data created globally. This surge was not evidence of a new trend, rather an acceleration of an existing one, with more people relying on digital platforms such as Zoom and Microsoft Teams to work remotely. At the same time, subscriptions for a wide spectrum of on-demand services increased as households entertained themselves and their children during the various lockdowns. This growth is not a one-off event either, Gartner is forecasting a continuing increase in end-user spending on public cloud services - reaching $482 billion in 2022, up from 2021's $396 billion – already over 18% higher than 2020's figure.

The Covid-19 crisis both demonstrated and intensified the ongoing digitization of the global economy and, the more digitized the economy becomes, the more it will rely on the support of data centers. There were an estimated 7.2 million data centers in existence globally in 2021[1], slightly fewer than in 2020, reflecting the consolidation of computing infrastructure into larger facilities. Between 2015 and the end of 2021, the worldwide number of hyperscale data centers, (defined as exceeding 5,000 servers and 10,000 square feet), more than doubled, to reach 700.

Due to the growing infrastructure, the data center industry is also increasing its environmental profile. In fact, some estimates[2] calculate that data centers are responsible for almost 1% of global electricity demand and 0.3% of all global CO2 emissions. As the demand for computing power continues to grow, so too will the importance of sustainability measures for data center operators.

This white paper looks at the steps being taken to improve the sustainability of data center operations worldwide and, in particular the impact of these measures on the diesel generator, a critical component of data center continuity.

DECARBONIZING THE DATA CENTER

The world's big Tech companies consume vast quantities of electricity to power their data centers and keep their servers cool. The combined power use of the big five, or GAFAM companies – Google, Apple, Facebook (Meta), Amazon, and Microsoft – has been estimated at 45 terawatt-hours per annum,[3] about the same level of consumption as New Zealand. If left unchecked, this amount will only grow as the increased use of artificial intelligence and machine learning drives a corresponding increase in demand for computing power.

The significant and growing environmental impact of data centers has, until now, largely escaped the attention of global regulators, but this is beginning to change. Singapore has an installed base of 70 data centers, consuming around 7%[4] of the country's electricity, most (96%) of which is generated by natural gas. With the country's data center operators unable to meet green energy commitments, the government imposed a moratorium on new installations in 2019. This has only just ended but a series of restrictions have been introduced, with the Ministry of Trade and Industry mandating that any new data centers must be "best in class in terms of resource efficiency."

Elsewhere, most regulators have yet to declare firm policies and in Europe, the Climate Neutral Data Centre Pact, a movement representing 90 per cent of Europe's cloud and data center sector, has submitted a "Self-Regulatory Initiative Proposal" to the European Union. The initiative contains 19 separate proposals aimed at making the sector carbon neutral by 2030.

These proposals leverage the proactive approach to sustainability which is already in place among the world's largest data center operators. Starting in 2010 when Google signed its wholesale clean energy deal, sustainability has become a source of rivalry between the big tech companies. Microsoft has announced a target to be carbon negative by 2030, launching initiatives such as its direct air capture program and an internal carbon pricing policy. At the same time, Google has pledged to power all of its data centers with carbon free electricity by 2030 and has announced plans to launch its innovative "carbon-intelligent computing platform". Starting this year the platform will move non-production computing workloads between data centers, based on the availability of renewable energy.

But what impact will these initiatives have on the diesel generator, which has long been the mainstay in the provision of essential backup power?

THE DIESEL GENERATOR IN THE DATA CENTER

To ensure that mission-critical applications never go offline, data centers deploy redundant electrical infrastructures with uninterruptible power supplies, (UPS), and emergency backup generators at their heart. One of the most critical points in the digital infrastructure power chain, the operational advantages of diesel generators has ensured their adoption in most data centers.

Diesel generator sets ensure a highly reliable response when the local electricity grid fails; diesel is readily available and safe and easy to store on site, and spares and servicing are relatively easy to procure. In addition, modern, higher power, 4 MW, units deliver high levels of performance in a small footprint, a critical attribute as pressures on energy densities increase.

The nature of their role in the backup chain means diesel generators are used infrequently, limiting emissions of carbon dioxide and other particulates. Microsoft’s Chief Environmental Officer, for example, estimates that diesel emissions account for less than 1% of their overall emissions. However, with the accelerating trend to decarbonize data center operations, the diesel generator is coming under pressure with other technologies such as batteries, fuel cells and hydrogen being considered as replacements.

Although these technologies may become viable in the longer term, the reality is none are currently able to match the cost, performance, and scalability of diesel generators. Given the massive investments in generators by data center operators and service providers, the installed base is unlikely to be replaced in the short term and a more pragmatic, evolutionary approach is emerging.

EVOLUTIONS IN DIESEL GENERATORS

Acutely aware of the need to exceed the sustainability expectations of their customers, manufacturers such as Kohler are continually improving the environmental performance of their generators. Emissions reduction technologies can be grouped into either in-cylinder or after-treatment categories, where in-cylinder techniques reduce the pollutants emitted by an engine and after-treatment further reduces these pollutants by treating the exhaust stream of the engine.

IN-CYLINDER - ENGINE OPTIMIZATION

Advancements in computer-aided engineering tools and computational fluid dynamics enable improved engine behavior modelling, allowing optimization of the entire system for fuel consumption, pollutant emissions creation, torque, power, and transient performance. Finer piston and ring assembly tolerances reduce the amount of fuel escaping the combustion chamber, resulting in increased engine burn efficiency, significantly mitigating the conditions that lead to wet stacking. Common rail fuel injection systems coupled with engine monitoring systems ensure better fuel atomization and enable “fuel mapping,” where the combustion process is better tailored to the requirements of emissions and/or cylinder temperatures.

“Wet stacking” is a familiar problem for operators of diesel generators. Typically occurring when generators are run on low loads, unburned fuel builds up in the engine’s exhaust system, fouling fuel injectors, causing excessive valve guide wear, and ultimately leading to damaged pistons, piston liners, and rings. Wet stacking can also compromise the effectiveness of the generator’s emission control, or after-treatment technologies, causing emissions targets to be missed.

Wet stacking has traditionally been addressed by running the generators at 30% of rated capacity at monthly intervals, to burn off the unused fuel. This is a costly procedure however and results in higher emissions as the generators are run more frequently.

The highly optimized internal engine design of modern generators, such as the KOHLER KD series, addresses the wet-stacking problem, reducing the need for artificial load during exercising and enabling operators to adjust their maintenance schedules.

These and other efficiency improvements enable generator operators to perform their monthly generator tests with no load, only performing an annual load test. Such changes to long-standing maintenance procedures can enable significant fuel savings and reduce annual emissions by up to 85% while still complying with relevant regulations. Ongoing development could also allow for annual testing without the need for monthly testing with no load.

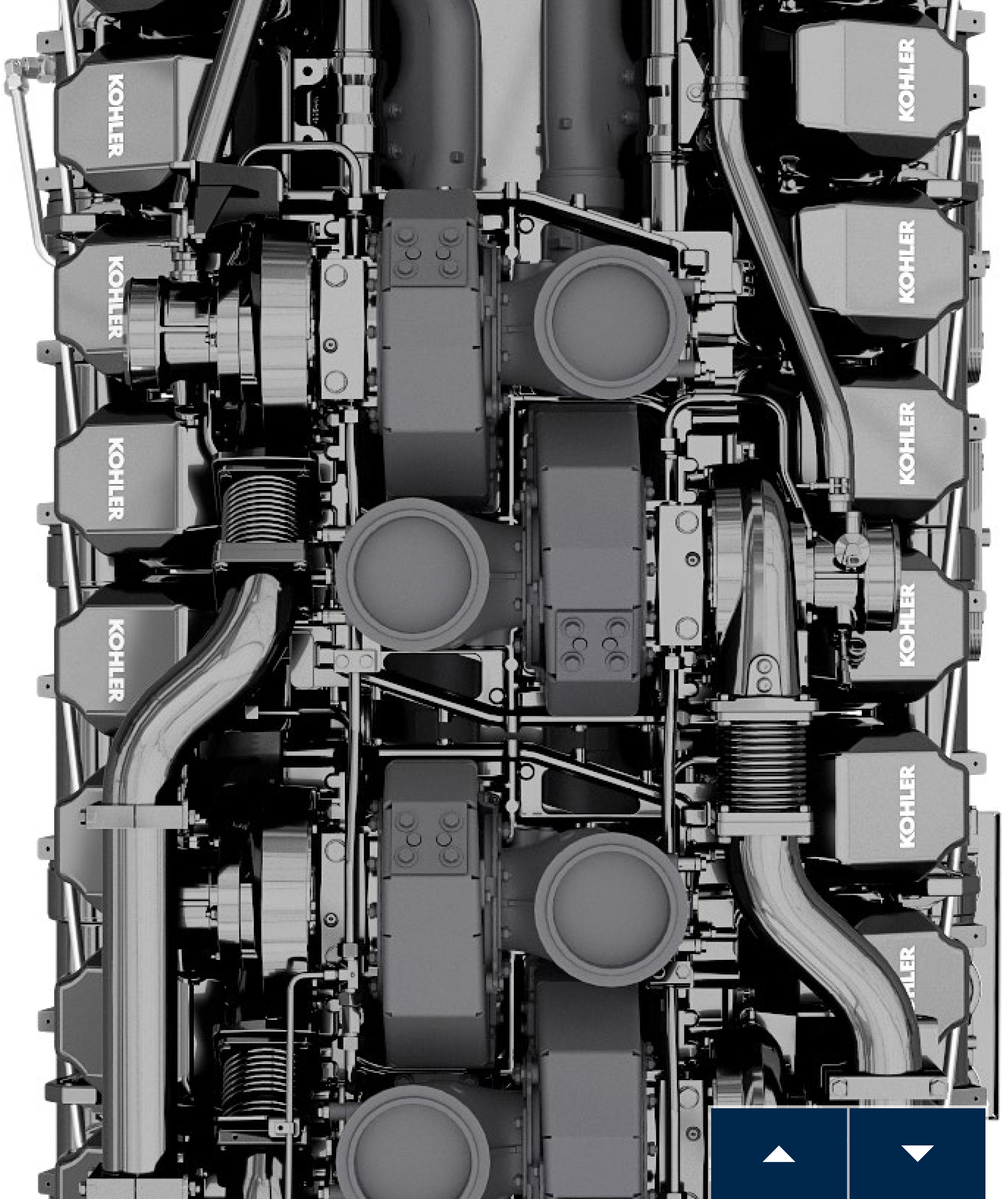
AFTER TREATMENT

In-cylinder control technologies can only reduce pollutant formation to a certain point given the inverse relationship between nitrogen oxides emissions, (NOx), and particulate matter, (PM). NOx forms with high cylinder temperatures and PM forms with low cylinder temperatures therefore one, or sometimes both, have to be treated within the exhaust stream to meet Tier 4 levels or levels required by local regulations. After-treatment systems are add-ons to the diesel engine, although, EPA regulations that certify the pollutant emission levels consider after-treatment device an integral part of the engine, and the engine cannot operate without it. After-treatment devices include Diesel Oxidation Catalysts, (DOC), Diesel Particulate Filters, (DPF), and Selective Catalytic Reduction, (SCR).

Diesel Oxidation Catalysts (DOC), reduce CO, HC, and the soluble organic fraction, (SOF), of diesel particulates. The DOC uses heat and catalyst materials to instigate oxidizing chemical reactions which produce carbon dioxide (CO_2) and water (H_2O). DOCs are easy to implement, add relatively low cost and require little maintenance. DOCs however do not effectively reduce levels of PM or NOx, which are the main reductions required by current regulations, therefore usually need to be deployed with another after-treatment device, such as a DPF or SCR.

Diesel particulate filters (DPF), filter the PM emitted by the engine, usually seen as soot and black smoke. Small pores in the ceramic substrate of the filter, trap the PM as exhaust gases pass through. DPFs need to be regularly regenerated to burn off the layer of trapped soot which builds upon the filter, increasing back pressure on the engine. Regeneration systems need minimum exhaust temperatures, sometimes requiring the addition of fuel or some other heat additive, which may mean the addition of a load bank to the system.

Selective Catalytic Reduction (SCR), is currently the best commercially available technology for the reduction of NOx emissions. SCR injects diesel exhaust fluid (DEF), a mixture of urea-derived ammonia and water, into the exhaust stream. The NOx in the exhaust stream is reduced to nitrogen (N_2) and water (H_2O) by reacting with the ammonia in the presence of a metal-based catalyst, such as tungsten and vanadium, which increases the rate of the reaction. SCR systems commonly include DEF storage tanks, DEF pumps, DEF controls, DEF filters, DEF lines, DEF injectors, mixing chambers, and catalysts. SCRs need to be carefully designed and deployed, taking into account factors such as operating temperatures, DEF storage conditions and load profile. DEF fluid maintenance is critical to an SCR system as it is highly corrosive and has a freezing point of 12°F (-11°C).



RENEWABLE FUELS - ALTERNATIVE FUELS

The ongoing drive towards decarbonization is causing a resurgence in interest in renewable fuels or biofuels. First-generation biofuels had the disadvantage of being derived from food sources or of using land that could be used for food production. Hydrotreated Vegetable Oil (HVO), or renewable diesel as it also commonly referred to, however, is a second-generation biofuel that is produced from waste and residual fat fractions coming from the food industry, as well as from non-food grade vegetable oils.

A renewable fuel, HVO is a “slot-in” replacement for regular diesel, giving up to 90 per cent reduction in carbon emissions without the need for engine modifications or additional fuel tanks. In North America, HVO complies with the ASTMD975 fuel standard while in Europe it comes under the EN15940 standard for “Paraffinic Diesel Fuel from Hydrotreatment”. The fuel can be mixed with diesel in any proportion[5] without affecting engine performance and, unlike previous biofuel generations, can be stored for up a number of years without degrading.

HVO manufacturing is already a mature, commercial-scale process but is currently concentrated in localized markets such as California where its use is mandated. Global production capacity is expected to grow however as demand evolves, ensuring supply chains that are local to key data center markets.

HVO clearly offers an immediate opportunity to further reduce diesel engine emissions and Kohler’s KD Series engines have been tested and certified to operate with HVO100 biofuel. The company is also working with some of the key players in the biofuel industry to develop supply chains for their customers while, at the same time, continuing to analyze and assess other new types of cleaner fuels.

HVO

APPROVED FOR HVO RENEWABLE FUEL

FUTURE TECHNOLOGIES

The above sections described evolutionary developments in diesel generator technologies that have been driving down emissions. In the long term, however, global commitments to eradicate the use of hydrocarbons in the data center will drive the adoption of commercial scale solutions based on emerging technologies such as batteries and fuel cells.

Lithium-ion battery prices have dropped by about 80 per cent over the last 5 years, prompting Hyperscale operators such as Google to research megawatt-scale battery systems. Google plans to replace the generators in one of its data centers in Belgium with large batteries, as a first step towards its vision of “a world in which backup systems at data centers go from climate change problems to critical components in carbon-free energy systems.”

Hydrogen fuel cells also present opportunities for environmentally friendly backup power solutions. In July 2020 Microsoft announced that it had powered a row of ten racks of Azure cloud servers for 48 hours using a 250-kilowatt hydrogen-powered fuel cell system. With the majority of power outages lasting less than 48 hours, this trial demonstrated the viability of fuel cells as a replacement for diesel generators during a utility outage.

Alternative technologies such as battery and fuel-cell solutions currently face significant scalability and cost challenges. However, although neither technology can currently match the availability and energy density characteristics of the diesel generator, numerous ongoing research and development initiatives aim to overcome these limitations.

COMMITMENT TO SUSTAINABILITY NEEDS SERIOUS INVESTMENT

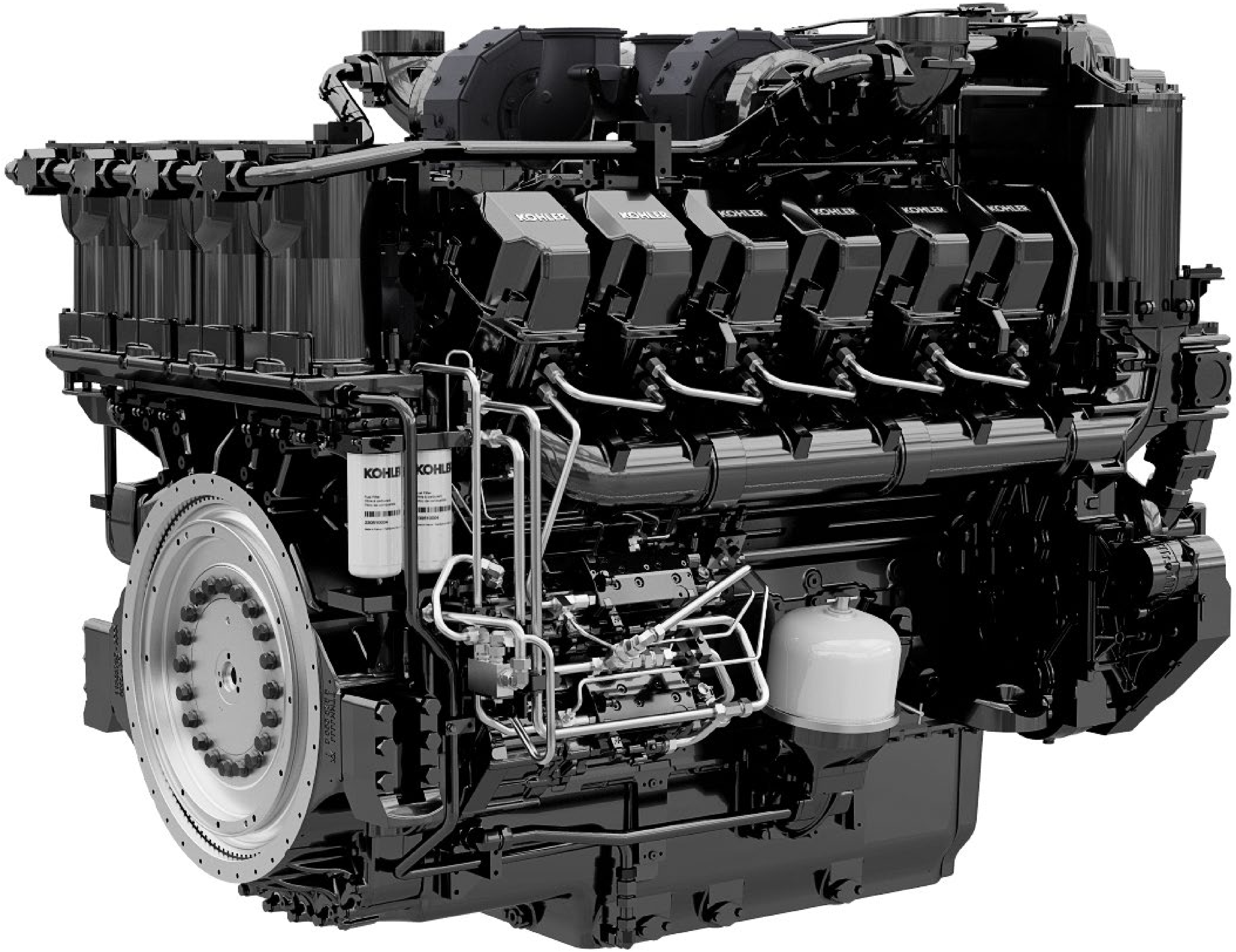
These Research and Development activities require significant investment in resources and facilities such as R&D laboratories and test cells. As a global player providing critical power backup solutions to the data center industry, Kohler is committed to sharing its customers' visions of a future powered by clean energy and is ideally placed to drive the development of new technologies.

Kohler's commitment to the market is demonstrated by recent major investments in its facilities in Brest, France and North America. These state-of-the art facilities give Kohler the resources to embark on collaborative trials of both battery and fuel cell solutions. Later this year Kohler will be announcing details of a portable battery solution and an ongoing project with an industry-leading engine manufacturer is developing a prototype 60 kW hydrogen generator using Polymer Electrolyte Membrane fuel cell technology as part of a research effort to analyze performance and understand the challenges of developing the technology at scale.

ADVANCES IN DIESEL GENERATOR TECHNOLOGY ARE PAVING THE WAY TO A SUSTAINABLE FUTURE

Led by the Hyperscalers, the global data center industry is committing itself to a carbon-free future. Evolving battery and fuel cell technologies show great promise in, ultimately, replacing the diesel generator as the mainstay of mission-critical backup power. Although significant resources are being invested in the development of these technologies, both are still relatively immature and it will be some time before they can scale to meet the availability and power density demands of the world's data centers.

Until that time, ongoing evolutions in the environmental performance of the diesel generator will contribute to reductions in data center emissions. At the forefront of sustainability efforts in data center power, Kohler has the resources and commitment to deliver not only these evolutions but also the revolutionary technology that will lead to a cleaner tomorrow.



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