

***ACHIEVING  
STAGE V  
COMPLIANCE  
WITH RENTAL  
AND INDUSTRIAL  
GENERATORS***

**KOHLER®**  
IN POWER. SINCE 1920.



**The European Union's ambition to improve air quality for its citizens has led to the introduction of Stage V emissions regulations for certain types of non-road mobile machinery, including diesel generators. These standards have resulted in the addition of new systems such as particulate filters and other associated equipment to limit the release of harmful particles into the atmosphere. This whitepaper looks at how Kohler has invested heavily into research and development to produce a range of advanced generators across power nodes that meet the requirements of Stage V.**

## **INTRODUCTION: THE EU'S COMMITMENT TO CLEANER AIR**

Air pollution from engine emissions has long been recognized as a threat to public health in towns and cities across the continent. Part of the EU's response to this has been to introduce increasingly stringent emission standards for engines used in new non-road mobile machinery (NRMM). These have progressed from 1997's Stage I to Stage V, implemented in 2019-20 and currently in force. Stage V regulation introduces a new requirement to reduce Particulate Number (PN) alongside continued control of particulate matter (PM) and nitrogen oxide (NOx).

The European Commission proposed the Stage V regulation after concluding that engines contribute significantly to air pollution and are accountable for roughly 15% of the NOx and 5% of the PM emissions in the EU. This is set against recent

conclusive evidence on the adverse effects of diesel exhaust emissions, especially particulate matter (diesel soot).

A key finding is that particle size crucially impacts observed health effects. This can only be addressed by limit values based on a particulate number count. Therefore, and in line with the road sector, introducing a new emission stage (Stage V) to target particle number limits as well as particle mass limits seemed appropriate<sup>1</sup>.

Accordingly, all engines, with no power limit, designed for use in the UK and European Union and manufactured from January 1st, 2019, must be Stage V compliant. This regulation concerns all off-road mobile motorized equipment, especially mobile generating sets.





# UNDERSTANDING STAGE V REQUIREMENTS

The Stage V standard was proposed in 2014 and finalized in 2016. The standard became effective from 2019 for engines below 56 kW and above 130 kW, and from 2020 for engines between 56 and 130 kW<sup>2</sup>.

The scope of regulated engines was also widened to include compression ignition (CI) engines below 19 kW, and above 560 kW, spark-ignited (SI) engines above 19 kW, and other previously unregulated engines. This includes Category NRG – generator set engines above 560 kW.

Fig.1 below summarizes the Stage V emission standards over the various engine power ranges, from 0 kW through to 560 kW and any higher power rating.

ENGINE POWER	STAGE V EMISSION STANDARD (g/kwh)
From 0 to 8 kw	7.5 NOx+HC / 8.0 CO / 0.4 PM
From 8 to 18 kw	7.5 NOx+HC / 6.6 CO / 0.4 PM
From 18 to 37 kw	4.7 NOx+HC / 5.0 CO / 0.015 PM
From 37 to 56 kw	4.7 NOx+HC / 5.0 CO / 0.015 PM
From 56 to 130 kw	0.4 NOx / 0.19 HC / 5.0 CO / 0.015 PM
From 130 to 560 kw	0.4 NOx / 0.19 HC / 3.5 CO / 0.015 PM
> 560 kw	0.67 NOx / 0.19 HC / 3.5 CO / 0.035 PM

*Fig.1: Range of engine powers and related Stage V emission standards*

# OVERVIEW OF EMISSION REDUCTION TECHNOLOGIES

To fully understand the requirements of Stage V, it is worth reconsidering some of the important fundamentals of the modern combustion engine. When an engine burns a hydrocarbon fuel such as diesel, the hydrogen combines with oxygen to create water. Carbon particles and smaller amounts of oil and other elements, especially nitrogen oxide, are also released. The carbon particles can be captured in a filter and burned to create CO<sub>2</sub> for release into the atmosphere. The other elements must also be filtered and then aggregated over the engine's life or removed by cleaning the filter – they cannot be burned away.

The demands of Stage V regulation mean that to be compliant, engines must have an after-treatment system to provide the required filtering efficacy. The Kohler approach to achieving Stage V compliance is to integrate different systems to reduce microparticles and nitrogen oxide.

The strategy starts with a **Common Rail injection system** with optimized computer calibration to minimize pollutant production. Then, an **EGR valve (Exhaust Gas Recirculation)** manages the quantity of exhaust gas, re-injects a part of it, which is cooled via a heat exchanger, into the engine intake to be burned. This principle limits NO<sub>x</sub> production.

Two post-treatment systems are then used. A **DOC (Diesel Oxidation Catalyst)** has a honeycomb structure covered with catalyst metals. Some of the carbon monoxide gases, hydrocarbons and nitrogen oxides are transformed into water, carbon dioxide and nitrogen dioxide, therefore being reduced to the mandatory limit values. The remaining particles pass through a **DPF (Diesel Particle Filter)**, which collects and burns them using heat from the engine and DOC.

When the DPF has accumulated a large mass of particles, it must perform a regeneration. Regeneration can be passive when the exhaust temperature is sufficient to burn the remaining particles. However, if the charge is not high enough, the particles accumulate. Active regeneration is necessary when the engine's internal combustion alone does not generate enough heat. This comprises a device injecting a fine fuel mist into the exhaust line to increase the exhaust gas temperature and burn the soot (particles). Passive regeneration

and active regeneration occur automatically (via the engine controller) during regular generator operation, without operator intervention.

When the engine operates so that these two regenerations are no longer enough, a forced stationary regeneration must be carried out, triggered by the operator using a switch located behind the front of the generating set control command.

However, Kohler's technology minimizes the number of operator interventions. Running the generator at low power (<15%) and in a cold environment disrupts the automatic regeneration of the DPF. Kohler's solution uses a ballast - a resistance device that automatically creates a minimum load, regardless of the use made by the operator, to space DPF regenerations. This dramatically reduces the number of operator interventions to regenerate the filter. This system avoids the need for forced regeneration in maintenance.

Kohler uses a further after-treatment stage for engines of 58 kW or higher power, performing final NO<sub>x</sub> reduction through **selective catalytic reduction (SCR)**. This approach utilizes a urea-based additive called diesel exhaust fluid (DEF). This has been introduced when the infrastructure for DEF is more established, and its use is more accepted by equipment owners in highway applications.

The ammonia in the urea mixes with engine exhaust gases in the SCR catalyst to reduce NO<sub>x</sub>, converting it to nitrogen, carbon dioxide and water vapor. The vapor is expelled through the exhaust pipe.

With involvement in the power industry since 1920, Kohler is well-experienced in tackling engine performance issues. Based on our experience in manufacturing generators driven by Stage III engines, we have invested heavily into research and development to produce a range of Stage V engines across all power ratings. This is an ongoing process, with four new generators to appear by the end of the year. The Stage V products are the least-polluting engines available within their target utility and construction applications. The range covers offerings for both the rental and industrial markets.





# KOHLER® STAGE V RENTAL GENERATORS IN MORE DETAIL

The new series uses KOHLER and John Deere engines with low fuel consumption. This results in low operating costs, especially for gensets providing continuous power production. The power range starts with the KOHLER engines driving a 20 kVA to 50 kVA Standby Power (ESP) generator set. For higher power capacity, this range offers John Deere engines for generator sets with a 110 kVA to 550 kVA ESP.

The lineup already includes the R20C5, released in October 2019, and the recently introduced R50C5 and R330C5. By the end of the year, four new products (R110C5 / R165C5 / R220C5 / R550C5) will be released to complete the Rental Stage V range from 20 to 550 kVA standby. Accordingly, there are now three generators in the range, which will expand to seven.

The R20C5 does not need after-treatment, regeneration, or urea injection, while the R50C5 uses an EGR valve, DPF, DOC and regeneration – but not urea injection. The R330C5 uses the same emission reduction technology as the R50C5, plus selective catalytic reduction with urea injection. In general, engines below 56 kW do not need an after-treatment system, while the largest sizes need an entire pollution reduction technology package.

Kohler has a long-established relationship with John Deere and worked closely with its engineers to handle issues like the system packaging. Reducing processes' noise levels was challenging, yet success provided a significant market advantage; silent operation is essential at events and increasingly demanded on industrial sites.

While the addition of after-treatment systems increases maintenance requirements and genset services such as filter changing, it is unavoidable for all manufacturers seeking to comply with Stage V

requirements. Kohler's technology, however, also helps to reduce the cost of ownership. Below, we look at the features of each model and then at the overall advantages of the entire range.

The R20C5 genset has a 3-cylinder KOHLER engine, with a G2 performance class according to the ISO 8528 (BS7698) part 6 standard for test methods of engine-driven gensets<sup>3</sup>. It complies with Stage V standards using a setting on the engine's injection system. It consumes 4.8 l/h of fuel at 100% Prime Power (PRP) load and 5.1 l/h at 100% Emergency Standby Power (ESP) load.

The genset acoustic pressure level at 7 m at 75% PRP is 62 dB(A) at 50 Hz. Furthermore, electrical output is 18,2 kVA of PRP power (20 kVA ESP) at 400/230 V, 50 Hz.

The R50C5 has a 2.48 L 4-cylinder inline engine, providing 45 kVA of PRP power (50 kVA ESP) with a G3 performance class. At 75% load PRP, it has an 8.8 l/h fuel consumption and its sound levels are 67 dB(A) at 7 m, and 79 dB(A) at 1 m.

The R330C5 is a six-cylinder engine with a 300 kVA PRP (330 kVA ESP) power output, built with a high-pressure common-rail fuel system and full-authority electronic controls. In addition to its DOC and DPF exhaust filters, it uses a proven PowerTech Plus technology with series turbochargers and an optimized SCR system. The regeneration is also automatically managed by the engine controller and the KOHLER® APM403 user interface controller. The R330C5 does not need ballast; the thermal exchanges are high enough to burn the remaining particles. The Performance Class G3 R330C5 consumes 48.3 l/h of fuel at 75% load. Sound levels are 66 dB(A) at 7 m (76 dB(A) at 1 m).



## OVERALL, KOHLER'S RANGE OF STAGE V RENTAL GENERATORS OFFERS SOLID PERFORMANCE TO FIT THE FIVE FUNDAMENTALS OF THE RENTAL MARKET:

### ROBUSTNESS

The impact-resistant design guarantees performance in the most demanding conditions. It includes large and strong-bounded frames with a retention bund sized for 110% of the generator liquids. It also provides a 24-hour autonomy fuel tank, a heavy-duty air filter with restriction indicator, auxiliary winding regulation excitation principle (AREP) alternator with double impregnation for extreme conditions, and a waterproof wiring loom and connectors.

### HANDLING

The gensets have several features to ensure easy handling during transportation to site and movement after delivery. These include an integrated lifting eye, forklift pockets, frame protection pads, and a traction bar to move the genset on the ground during positioning. The new models are slightly higher and longer than previous ones, but they have been kept as small as possible to meet space constraints during transportation and on-site. Overall, these models comprise one of the most compact offerings on the market.

### SAFETY

The generators are built to ensure user safety during their handling, connection, and operating phases. Protection of the generating set is also guaranteed to improve its service life. Features include door retainers, large engine access doors with an anti-opening lock system to avoid opening during transport, and a water and dustproof control power box integrating electronic and electric devices.

### USABILITY

The machines are designed to ease use and provide extra user comfort during both connection and operating phases. They provide dedicated access to the controller and power connections, including the power busbar, located on the base. The plug-and-play generators can be powered up exceptionally quickly, and the various power sockets give operators flexibility in using the power supply.

### MAINTENANCE

The generators' structured design allows quick, easy access to consumable and mechanical parts during cleaning and maintenance. A radiator access door at the front of the genset enables easy cleaning of the radiator. Additionally, an easy lift canopy facilitates access to the engine and alternator for deeper maintenance.

Managing and optimizing the generator sets' performance is facilitated by the KOHLER APM403 controller. This displays all the data related to post-treatment: soot rate and ash rates in the particle filter, type of regeneration in progress, alerts, and other information. It also manages the load distribution on the ballast.

Additionally, the APM403's remote management option allows rental companies to monitor the real-time performance of the generating set remotely, together with information related to group maintenance or the level of fouling of the particle filter. The optional APM403P also offers the possibility of synchronizing several generators, allowing rental companies more flexibility.

Remote overview, control, and command of a generator – or an entire fleet of generators – becomes possible by adding an optional Ethernet or 4G card to the controller and installing the app on a smartphone, computer, or tablet. Functions include remote control, geolocation of the generators, data archiving, and email or SMS notification of any anomaly detected. The user-friendly and customizable interface also allows operators to view all electrical and mechanical values, curves, and data records.

Two access levels are available: the first, with limited tools, is free, and the other, which is chargeable, gives full access to all available tools and allows customization.

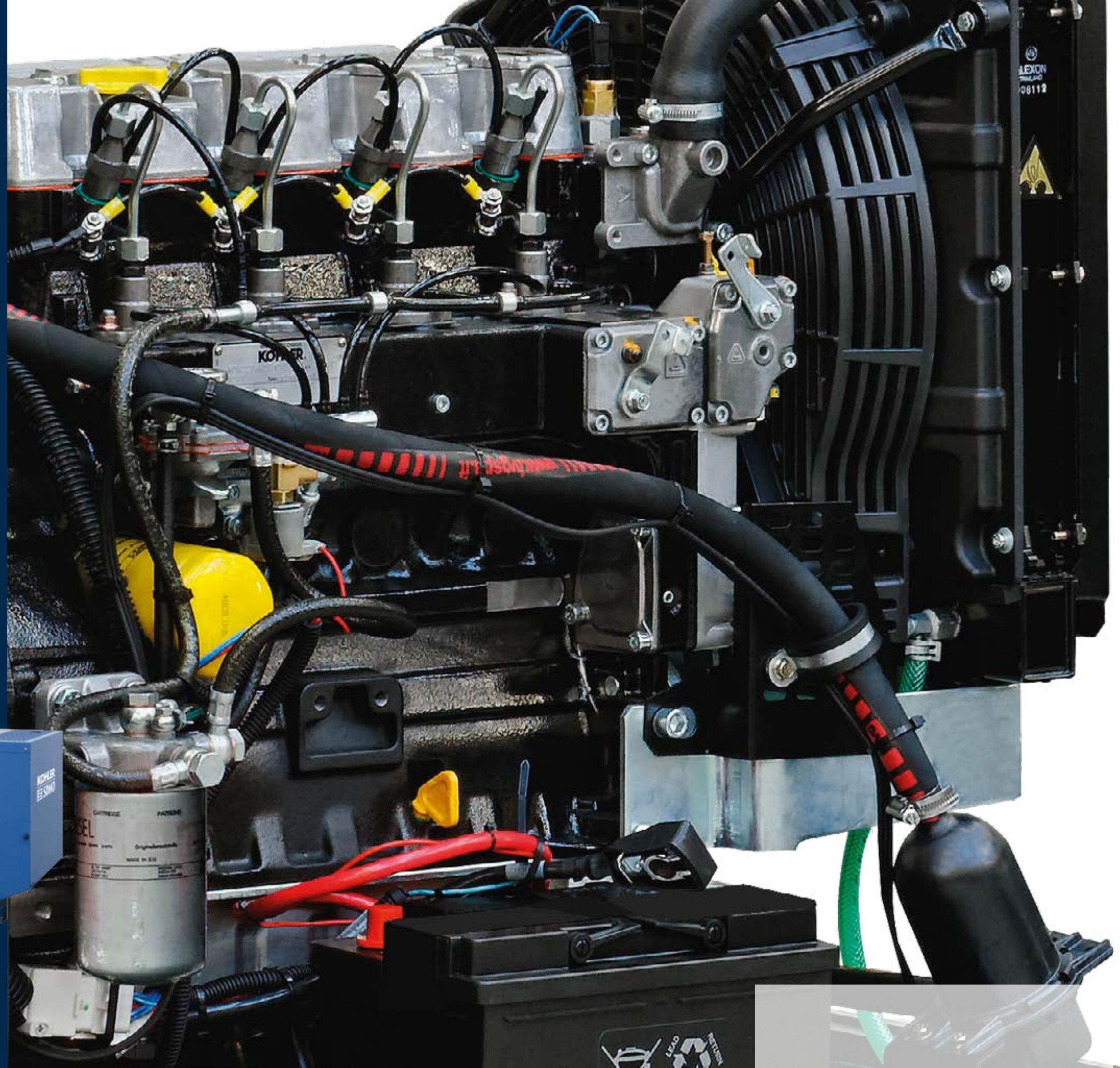


# KOHLER® STAGE V INDUSTRIAL GENERATORS

Kohler offers its Clean Power industrial 2016/1628 EU Stage V-compliant generator range to complement its rental products. The range, powered by KOHLER engines, comprises the K12C5, K16C5, and K20C5, and all are now available as standard products. These Italian-manufactured engines do not require post-treatment, as they can achieve Stage V compliance by adjusting the injection system settings.

Accordingly, the generators can be used in mobile applications. Built into the M126 canopy, they offer a range of dedicated options, including the socket panel and road trailer. These new products are intended, for example, for construction companies, municipalities, police or fire stations, or any other use requiring road mobility. They are also suitable for stationary backup and production applications that require the lowest level of polluting emissions.

The K12C5 delivers 9.5 kVA PRP power (10.5 kVA ESP); The K16C5 delivers 13.3 kVA PRP (15 kVA ESP), and the K20C5 produces 18.2 kVA PRP (20 kVA ESP).





# CONCLUSION: MEETING ALL YOUR STAGE V NEEDS

These generators demonstrate Kohler's commitment to supporting its customers and keeping them abreast of Stage V regulations. As a market leader, Kohler has the knowledge and resources to develop compliant and optimized products backed by the technical data written into its specifications.

We offer a reliable and extended distribution network, backed by its comprehensive aftermarket support services – including training, commissioning, spare parts - and world-leading product availability and delivery times. Kohler can always be relied upon as a trusted partner.

## References

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