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Measuring and monitoring emissions at data centers: A practical guide to compliance and performance

Introduction

The rapid expansion of data centers, driven by artificial intelligence (AI), cloud computing, and digital infrastructure, is creating unprecedented demand for electrical power. In many regions, utility interconnection delays, transmission constraints, and the need to bring new computing capacity online quickly are driving data center developers to incorporate onsite power generation as part of their energy strategy. Natural gas-fired turbines, reciprocating engines, and other distributed generation assets are increasingly being deployed to supplement or, in some cases, serve as the primary source of power for new facilities.

As data centers evolve from purely electrical loads into power-generating facilities, they become subject to a range of air permitting, emissions reporting, and regulatory compliance requirements. Consequently, emissions monitoring has emerged as a critical component of both regulatory compliance and responsible facility operation. Facility owners and operators must balance the need for reliable power generation with increasingly stringent environmental requirements while maintaining operational performance and uptime.

This white paper provides a practical, technically grounded overview of emissions monitoring strategies for data centers with onsite power generation. It outlines the regulatory landscape, reviews common monitoring approaches, and discusses key system design considerations to help facility owners, operators, engineers, and environmental professionals develop effective compliance strategies while supporting the continued growth of digital infrastructure.

The growing importance of emissions monitoring

Data centers are emerging as one of the most energy-intensive components of modern infrastructure. Industry projections indicate that data center electricity consumption could reach between 7% and 12% of total US demand by 2028, driven largely by AI workloads and digital services expansion.[1] At the same time, global investment in data center infrastructure is expected to reach hundreds of billions of US dollars annually, indicating the scale and urgency of this growth.

This rapid expansion is increasing regulatory and public scrutiny of emissions. Facilities that rely on on-site power generation—whether for backup or primary use—must comply with a complex mix of federal, state, and local air quality regulations.

In addition to regulatory requirements, emissions monitoring is influenced by environmental reporting frameworks and stakeholder expectations. Investors, customers, and communities are demanding greater transparency in how emissions are measured and managed. As a result, monitoring systems must deliver not only compliance, but also data integrity and operational insight.

Understanding emissions sources and pollutants

Within data centers, emissions are primarily associated with combustion-based power generation systems, including gas turbines and backup generators. The most commonly regulated pollutants are nitrogen oxides (NO_x), carbon monoxide (CO), particulate matter, and greenhouse gases such as carbon dioxide (CO_2). These pollutants are subject to strict limits under air permits and are central to both compliance reporting and environmental performance.

Consistent and accurate measurement of these emissions is essential. Trustworthy measurements enable operators to verify compliance, optimize combustion processes, and maintain reliable system performance over time.

The role of periodic stack testing

For many smaller engines and emergency backup generators commonly found at data centers, emissions compliance is demonstrated through periodic stack testing. During a stack test, emissions are measured directly at the exhaust stack using EPA-approved methods to verify compliance with permit limits and applicable regulations.

Stack testing is typically performed by specialized third-party contractors and is conducted at initial commissioning and periodically thereafter at intervals specified by permits or regulations. For sources that do not require continuous monitoring, stack test results may serve as the primary basis for emissions reporting and compliance demonstrations.

Even for facilities that require a continuous emissions monitoring system (CEMS), periodic stack testing continues to play an important role. Regulatory programs often require annual or periodic relative accuracy test audits (RATAs) or similar evaluations, in which CEMS measurements are compared against reference method test results to confirm monitoring accuracy. These tests provide independent verification that the monitoring system is operating correctly and producing reliable emissions data.

Beyond regulatory compliance, stack testing can provide valuable insights into combustion performance, emissions control effectiveness, and equipment condition. As a result, periodic stack testing is a fundamental component of emissions monitoring programs, supporting both standalone compliance strategies and the long-term integrity of continuous monitoring systems.

While stack testing remains sufficient for many smaller sources, larger engines and turbines often require continuous monitoring to demonstrate compliance and provide real-time operational visibility.

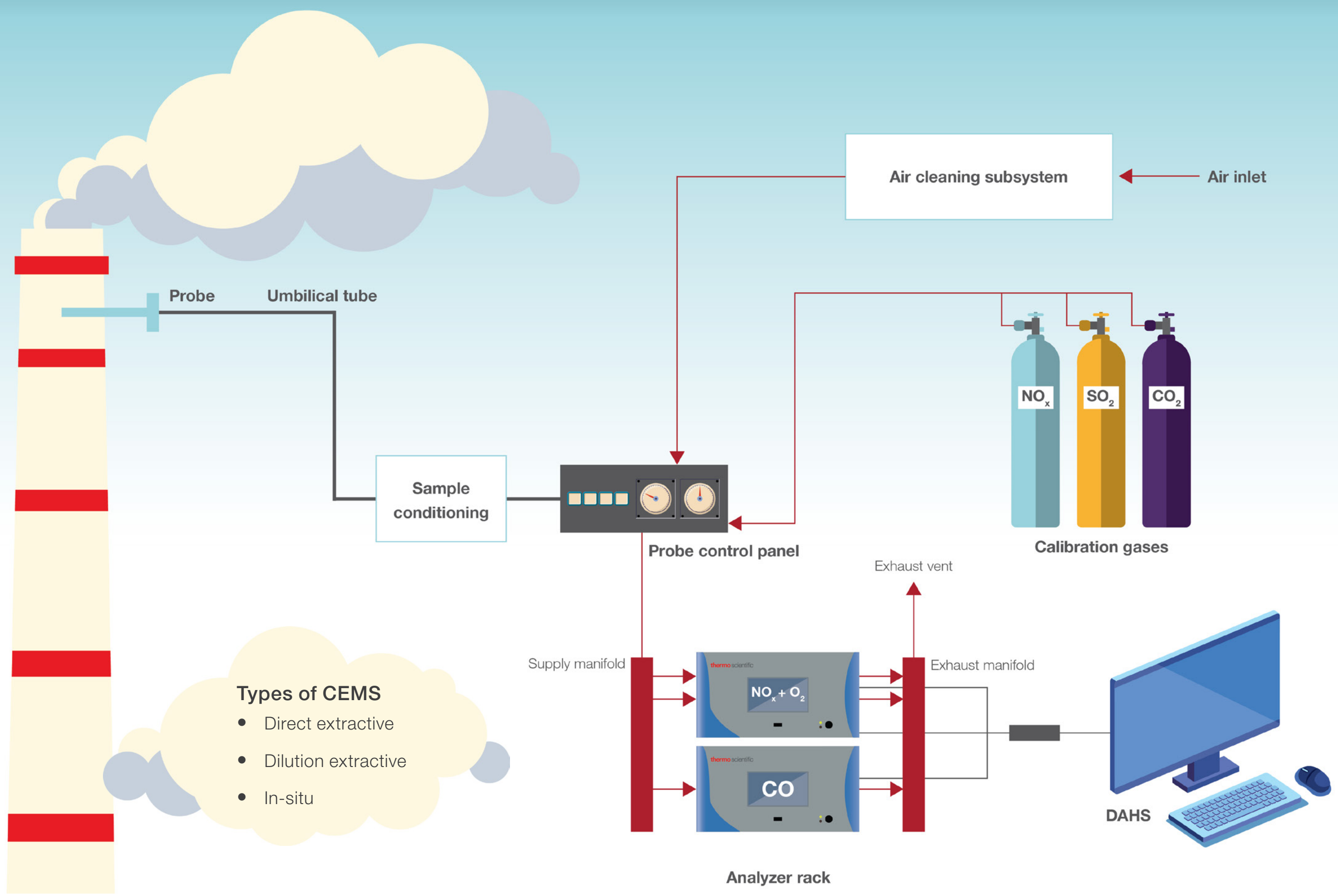

Figure 1. CEMS diagram depicting a typical direct extractive system architecture for natural gas turbines.

Continuous emissions monitoring systems: Delivering real-time compliance

CEMS are widely recognized as the most reliable and regulator-accepted method for measuring emissions in real time. These systems continuously sample exhaust gases and analyze pollutant concentrations using established, validated techniques.

A typical CEMS configuration includes sampling components, gas conditioning systems, analytical instruments, and data acquisition systems. Together, these elements provide a steady stream of emissions data that supports regulatory reporting and operational decision-making (Figure 1).

The primary advantage of continuous monitoring lies in its ability to deliver real-time visibility into emissions performance. Operators can quickly detect deviations, respond to operational changes, and ensure compliance with permit limits. This capability is particularly important in environments where uptime and reliability are critical.

Beyond helping to achieve compliance, continuous monitoring contributes to operational efficiency. By analyzing trends in emissions, facilities can identify opportunities to optimize combustion, improve fuel efficiency, and reduce overall environmental impact.

Design considerations for effective emissions monitoring

Implementing an effective emissions monitoring strategy requires a clear understanding of regulatory requirements, emissions sources, and operational objectives. Monitoring requirements should be evaluated early in the facility design process, as decisions related to permitting, monitoring methodology, and reporting can significantly impact project schedules and compliance costs.

System reliability and data quality are equally important. Monitoring equipment must deliver accurate, repeatable measurements while maintaining high uptime. Proper analyzer selection, routine maintenance, and effective data management practices help ensure compliance obligations are met and emissions data remain reliable.

By incorporating emissions monitoring into the overall facility design strategy, data center operators can streamline permitting and commissioning activities, reduce compliance risk, and support reliable long-term operation of onsite power generation assets.

Analyzer technology considerations for modern CEMS

Gas analyzers form the core of any continuous emissions monitoring system. These instruments rely on well-established measurement principles that are recognized by regulatory agencies worldwide. Chemiluminescence detection (CLD), as described in EPA Method 7E[2], is widely used for NO_x measurement due to its sensitivity, selectivity, and long-term stability. Similarly, non-dispersive infrared (NDIR) technology, as described in EPA Method 10[3], is commonly used for carbon monoxide (CO) monitoring. These proven measurement techniques are broadly accepted across federal, state, and local regulatory programs and provide the accuracy and reliability required for emissions compliance applications. Selecting analyzer platforms that are widely deployed and familiar to regulators, testing organizations, and CEMS integrators can further simplify implementation, helping facilities achieve a smoother commissioning process and faster path to compliance.

Within this context, modern analyzer platforms like the **Thermo Scientific™ 42iQ NO-NO_2-NO_x Gas Analyzer** and the **Thermo Scientific™ 48iQ CO Gas Analyzer** have been specifically designed to support continuous emissions monitoring applications. These systems deliver high sensitivity, low detection limits, and stable performance across a wide range of operating conditions. Both analyzers can also be configured with optional oxygen (O_2) measurement capability, providing a convenient and cost-effective solution for monitoring NO_x, CO, and O_2. This capability is particularly valuable in direct extractive CEMS configurations, where oxygen measurements are often required for emissions correction and reporting.

Seamless integration with data acquisition and handling systems (DAHS) is another key requirement for a modern CEMS. Analyzer platforms must support reliable data communication and interoperability, enabling consistent reporting and alignment with regulatory requirements.

Selecting the appropriate analyzer technology is a critical step in CEMS design. A well-designed analyzer solution not only supports compliance, it also contributes to long-term operational efficiency, reduced lifecycle costs, and confidence in emissions data.

Long-term compliance and operational benefits

Emissions monitoring should be viewed as an ongoing operational function rather than a one-time installation. Maintaining compliance requires continuous attention to system performance, data integrity, and evolving regulatory requirements.

Beyond the monitoring technology itself, long-term success depends on selecting proven analyzer platforms with internal diagnostics supported by thorough training programs and responsive technical support. Analyzer systems that can be serviced and repaired in the field help minimize downtime, reduce maintenance costs, and maintain continuous compliance.

Reliable technology, knowledgeable support, and proactive maintenance practices together enable facilities to reduce compliance risk, improve operational efficiency, and maintain confidence in their emissions data.

Key takeaways

As data centers continue to expand and deploy onsite power generation to meet growing energy demands, emissions monitoring has become an essential component of regulatory compliance and environmental stewardship. Both periodic stack testing and CEMS play important roles in helping facilities demonstrate compliance and maintain reliable emissions data.

Effective monitoring strategies are built on early planning, reliable system design, and strong alignment with regulatory requirements. Analyzer performance, system serviceability, and operational uptime are all critical factors in achieving long-term compliance and operational success.

Conclusion

The growth of data centers is reshaping both the power generation industry and the environmental landscape, bringing increased attention to emissions management. Monitoring technologies play a central role in ensuring that facilities can meet regulatory requirements while maintaining operational efficiency.

By adopting proven monitoring approaches, integrating systems early in the design process, and selecting high-performance analyzer technologies, organizations can build a strong foundation for long-term sustainability and regulatory compliance.

As regulatory expectations continue to evolve, emissions monitoring will remain a critical capability, enabling data centers to scale responsibly while supporting the demands of a digital-first world.

References

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