ENVIRONMENTAL ASPECTS OF NATURAL GAS POWER PLANT OPERATIONS

Energy Transformation Series

FOREWORD

Achieving aggressive carbon reduction goals requires a fundamental energy transformation that spans energy supply, delivery, and end use. To help address this challenge, the EPRI Generation Sector focuses research on four key elements of this transformation: energy supply, integrated systems, community and environment, and economy-wide decarbonization. With regard to the first of these elements, the energy supply mix has shifted from coal to natural gas and renewables over the last decade in many areas – a trend that will accelerate. This paper focuses on the expanded role of natural gas generation in this transition, and specifically, its ability to reduce not only carbon emissions, but also nitrogen oxides and sulfur dioxide emissions, compared to coal generation. The consequent public health benefits, as well as enhanced operational flexibility, makes natural gas generation a critical piece of the energy transformation.

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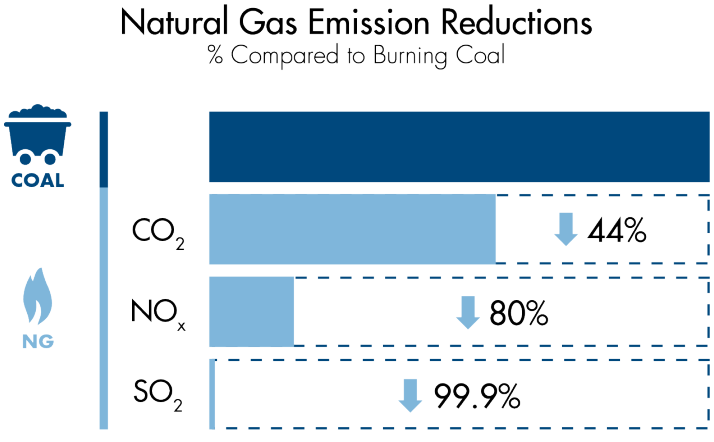
INTRODUCTION

THE SHIFT TO NATURAL GAS

Over recent decades, changes in fossil-fueled electric power production have reduced environmental and public health impacts. As coal-based generation decreases, natural gas-fueled power plants are coming on-line, adding value through flexible operation, balancing renewable generation and load changes. In the United States, this transition has also resulted in reduced costs with a stable domestic natural gas supply and decreasing prices.

The transition to natural gas significantly reduces emissions, compared to coal-fired generation (see Figure 1). With climate change a major societal concern, the 44% reduction in carbon dioxide (CO_2) is notable, in addition to reductions in nitrogen oxides (NOx) and sulfur dioxide (SO_2), all of which have direct public health benefits. These benefits aside, challenges remain, because natural gas generation does produce emissions (although at much lower levels), and public attention has begun to turn from coal to natural gas.



Source: U.S. Energy Information Administration (EIA)

Figure 1. Comparison of key emissions from natural gas, relative to coal-fired generation (Source: U.S. Energy Information Administration)

In addition to air quality concerns, the shift to natural gas has implications for water usage. Natural gas plants must contend with water availability and the consequences of water use, in terms of both plant equipment needs and water footprint, considering consumption volume and returned water quality. Although water usage for a natural gas power plant is less than that of a traditional coal-fired plant, an increasingly water-constrained future highlights the need for continued research and development for water conservation and management.

RESEARCH NEEDS

As the shift from coal to natural gas progresses, the industry needs improved understanding of the potential environmental impacts and benefits of these transitions. Accordingly, EPRI has identified the following critical research needs:

- Development and demonstration of more robust environmental control technologies
- Improved measurement accuracy for low-level emissions
- Enhanced dispersion and regional air quality models
- Assessment and application of new low-cost ambient air-quality sensors
- Comprehensive assessment of health effects attributable to natural gas power plant emissions
- Examining and documenting water usage trends and exploring and developing approaches to improve water management

DRIVERS

REGULATIONS

Operations affecting air quality and water use are governed under multiple regulatory programs. These must be understood in comprehensive and integrated ways, to properly inform decisions for strategic planning, system and plant operations, and technology deployment. Improvements in one area, made without awareness of impacts on other plant systems, can prove counterproductive. In the U.S., salient regulations for natural gas generation include the National Ambient Air Quality Standards, the National Emission Standards for Hazardous Air Pollutants, and the National Pollutant Discharge Elimination System.

The National Ambient Air Quality Standards (NAAQS) set allowable ambient concentrations for carbon monoxide (CO), lead, nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM), and sulfur dioxide (SO_2). Primary NAAQS are set to protect public health with an adequate margin of safety. Secondary NAAQS are designed to protect public welfare, for example by limiting nitrogen deposition effects in ecosystems. Reviewed every five years, these standards affect regulations at the federal, state, and local level. Other air toxics, such as formaldehyde and ammonia (NH_3), are governed under the National Emission Standards for Hazardous Air Pollutants (NESHAP), which establish emission standards for stationary sources. Changes in regulations must rely on accurate data that provide a better understanding of natural gas power plants' contribution to ambient air quality and associated health consequences.

The National Pollutant Discharge Elimination System (NPDES) is a comprehensive permitting program designed to address potential water pollution by regulating the operations of any facility that may discharge specified pollutants into a body of water. Permit requirements may be driven by water quality effluent limitations, technology constraints, or regional water quality criteria, as well as by the water quality of the receiving water body. Many factors that affect water use and bring increased scrutiny to power plant water withdrawals lie beyond a plant operator's ability to control.

SOCIETAL CONCERNS

Climate change, extreme weather, population growth, and a changing industrial mix in a region affect both air quality and water availability. Natural gas plant siting can be a touchpoint issue for some communities, sparking interest and debate on air quality impacts. Understanding ambient air conditions and other local or regional air quality factors will be critical to supporting such conversations. Similarly, quantifying power industry trends on U.S. water withdrawal and consumption, research on advanced water treatment systems, and identifying leading practices can help industry leaders prepare an agile response to a changing future.

Over the past few decades, evidence has accumulated of the disproportionate environmental and health burden of power plant operations on underserved communities. All stakeholders, including advocacy groups, community leaders, investors, and policymakers, recognize environmental justice as an important issue to address as the power industry shifts from coal to natural gas and other generation sources. Throughout this transition, it is imperative to ensure that research planning encompasses these considerations, as well as traditional assessment factors, in a modern, integrated manner.

RESEARCH AREAS

AIR QUALITY

With the relative increase in gas-fired generation, the electric power industry overall has observed significant reductions in emissions. As anticipated, NO_X, CO_2, and PM are greatly reduced, while natural gas presents negligible SO_2 emissions and eliminates emissions of mercury and other air toxics, compared with coal. Accurate quantification of low-level emissions and resultant health effects presents unique challenges but is critical to informing policy.

EPRI research objectives related to air quality issues fall in three main areas: environmental controls, ambient air quality, and health effects.

ENVIRONMENTAL CONTROLS

- **Emissions measurement and monitoring.** Develop and demonstrate advanced and novel instrumentation, improving accuracy and reliability and supporting plant operations.
- **Selective catalytic reduction (SCR) and CO oxidation catalysts.** Assess the benefits of multi-function catalysts, develop recommended practices, and resolve operating issues in anticipation of future NOx and CO control mandates.
- **Gas co-firing.** Evaluate impacts on heat rate, controllability, corrosion, and equipment management with long-term co-firing.

AMBIENT AIR QUALITY

- **Ambient air quality modeling and measurements.** Develop and evaluate existing and novel modeling and measurement technologies, models, and tools for ambient air quality.
- **Ecosystem impacts.** Study future contributions of natural gas generation to haze levels, nitrogen deposition, and primary and secondary fine particulate formation.
- **Air toxics.** Contribute research to the Toxics Release inventory and perform risk assessments of local contributions to hazardous air pollutants, such as formaldehyde, from natural gas generation.

HEALTH EFFECTS

- **Health studies.** Conduct and review local and regional epidemiological studies, with proposed research focused on health effects associated with specific PM compositions and lower exposure levels.
- **Environmental justice.** Conduct population studies of health effects of low-level emissions associated with natural gas generation.

RESEARCH AREAS CONTINUED

WATER MANAGEMENT

The electric power sector's freshwater consumption is 4% of the U.S. total, while the industry's share of withdrawals is 34%. Currently, most withdrawn water passes through open-cycle cooling units and is then treated and returned. Over the next decade, coal retirements and coal-to-gas conversions are expected to decrease withdrawals, but water management will remain important.

Most combined-cycle plants use closed-cycle cooling, and therefore consume less water, but overall plant water withdrawals and usage will continue to be siting and operational challenges as water availability issues grow. Water reuse is already a widespread practice, but scaling or biofouling difficulties in cooling towers and heat exchangers may arise. Further, over many reuse cycles, concentrations increase for constituents of concern, including sulfates, chlorides, selenium, ammonia, and suspended and dissolved solids.

Current and planned EPRI research addresses water withdrawal, consumption, and reuse to prepare for changes in water availability over time. Planned research will:

- Assess alternative cooling technologies, especially air-cooled condensers
- Develop technologies and leading practices for water reuse
- Test control methods and new materials for cooling towers, condensers, and heat exchangers (see Figure 2)
- Assess new materials and technologies to reduce evaporation and improve condensation and recapture
- Evaluate water use consequences of flexible operations in combined-cycle plants
- Design and assess processes for removing constituents of concern from blowdown water
- Evaluate alternative water sources, such as gray water and water produced from oil and gas operations

Figure 2. EPRI Water Testing and Conservation Center: Heat Exchanger Loop

FOR MORE INFORMATION

An in-depth EPRI report (3002022971) is available for those interested in more detail about the proposed research projects and the impacts of EPRI's past research in this area.

CONCLUSIONS

EPRI expertise spans the needed capabilities for this rapidly-shifting landscape (see Figure 3).

EPRI's role in the natural gas transition applies decades of research experience in coal-fired generation and draws on expertise from several research programs:

- Environmental controls programs (P232-233) support meeting emissions reduction targets by improving current technology while developing and demonstrating advanced technologies.
- Air quality and health programs (P234-236) characterize and quantify environmental and health consequences to inform regulators and stakeholders.
- Water management programs (P237-240) identify approaches to reducing water withdrawals, reusing water, and identifying alternative water sources for power plant operations.

Through this period of rapid energy transformation and technological development, EPRI is committed to performing objective, robust scientific research to inform utilities, the public, the regulatory community, and other stakeholders about the environmental aspects of natural gas generation.

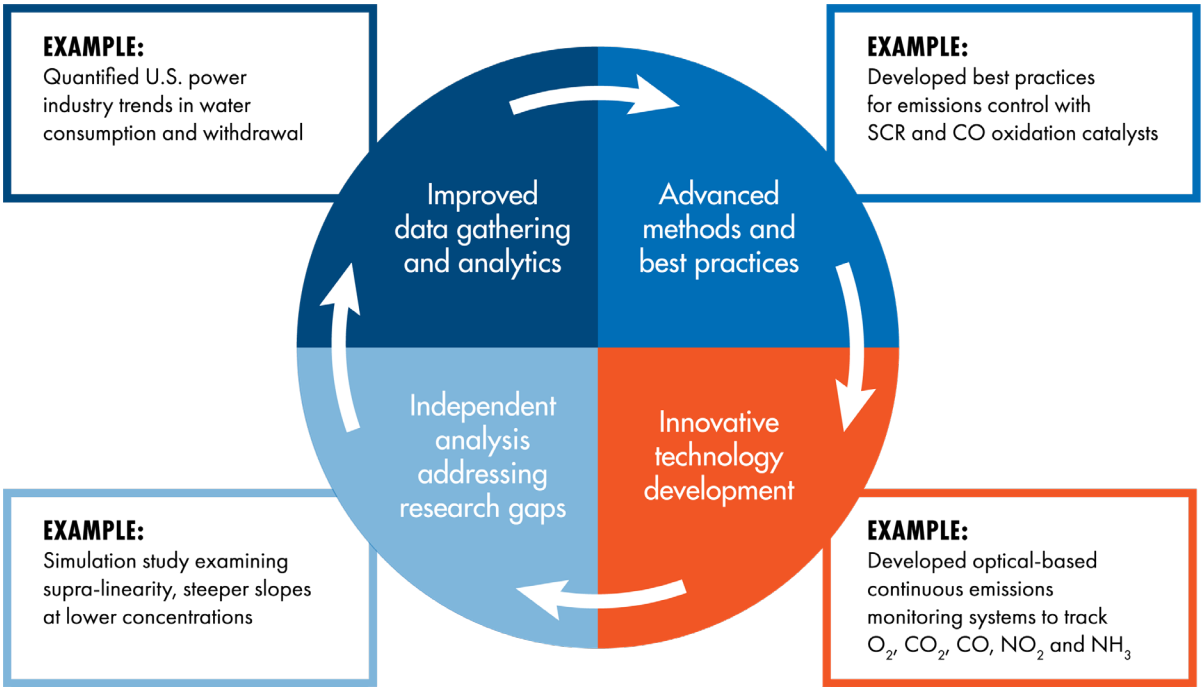


Figure 3. EPRI's research capabilities and examples applicable to environmental aspects of gas-fired generation

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