# *THE POTENTIAL ROLE OF NATURAL GAS POWER PLANTS WITH CARBON CAPTURE AND STORAGE AS A BRIDGE TO A LOW-CARBON FUTURE*

Samaneh Babaee, ORISE Postdoctoral Fellow at U.S. Environmental Protection Agency (EPA), 9192641744, sbabaee@ncsu.edu
Daniel H. Loughlin, Research Scientist at U.S. Environmental Protection Agency (EPA), 9195413928, loughlin.dan@epa.gov

## Overview

The $CO_2$ intensity of electricity produced by state-of-the-art natural gas combined-cycle turbines (NGCC) is approximately one-third that of the U.S. fleet of existing coal plants. Compared to new nuclear plants and coal plants with integrated carbon capture, NGCC has a lower investment cost, shorter construction time, and new plants can more easily be sited. NGCC can also be fitted with carbon capture equipment either during construction or as a retrofit. As a result, NGCC is seen as a potential bridge to a low-$CO_2$ future, which would increasingly rely on technologies such as wind, solar, advanced nuclear, and carbon capture as those technologies mature [Cole et al. (2016), Nichols and Victor (2015), and C2ES (2013)]. A logical approach may be to displace coal with new NGCC in the near-term, building NGCC near geological storage sites. Later the NGCC could be retrofit with $CO_2$ capture (NGCC-CCS) when the regulatory or economic drivers are in place [IEA (2007)]. There are, however, technical challenges to widespread deployment of NGCC-CCS. First, fugitive methane emissions associated with natural gas production, transmission, and distribution processes could offset some of the climate benefits of using natural gas [McJeon et al. (2014)]. Second, applying carbon capture retrofit technologies to NGCC results in cost and energy penalties [Teir et al. (2010)], both of which affect its competitiveness. Third, the lower carbon content of natural gas may yield difficulties in capturing $CO_2$ economically [Rubin et al. (2012)]. Fourth, stringent GHG reduction targets may make natural gas plants less attractive in the long-term, even with carbon capture since these plants would still have some $CO_2$ emissions [Cole et al. (2016)]. Answers to the following questions are necessary to understand more fully the potential role of NGCC-CCS: How is NGCC-CCS competiveness affected by technology assumptions (e.g., NGCC cost and efficiency; $CO_2$ capture cost and capture rate), fuel prices (e.g., for natural gas and competing fuels), technological developments in competing technologies (e.g., in wind, solar, and advanced nuclear power), lifetime extensions of existing electricity production capacity (e.g., nuclear plants), the stringency of $CO_2$ reduction targets, and whether these targets account for upstream methane leakage? Furthermore, is NGCC-CCS more competitive as a low-$CO_2$ bridge technology in some parts of the country than others?

## Methodology

The modeling framework used for this analysis consists of two components: 1) The MARKet ALlocation (MARKAL) energy system model, which is a technology rich, energy-economy optimization framework [Loulou et al. (2004)], and, 2) the EPA U.S. nine-region MARKAL database (EPAUS9r), which is an input dataset developed by the EPA's Energy and Climate Assessment Team (ECAT) to aid in future energy, technology, and policy assessment in the U.S. at the regional scale [Lenox et al. (2013)]. With this framework we examine the regional deployment of NGCC-CCS and associated energy and emissions impacts in the U.S. by 2050. We perform sensitivity runs to explore conditions in which NGCC-CCS competes with other technologies in response to a 50% system-wide $CO_2$ reduction by 2050 relative to 2005. Parameters examined in the sensitivity runs include natural gas price, CCS cost, $CO_2$ capture rate, efficiency penalty associated with CCS, and $CO_2$ storage cost. Each parameter is evaluated parametrically, including high, default, and low values. We also examine competitiveness under a 50% system-wide green-house gas (GHG) reduction target, which allows consideration of methane leakages. As there is uncertainty and variability in real-world leakage rates, multiple rates are examined.

## Results

The three factors that lead to the greatest amount of NGCC-CCS deployment are: low natural gas prices, a high $CO_2$ capture rate, and low efficiency penalty for CCS. High natural gas prices, high investment cost, and low $CO_2$ capture rate all led to the low deployment. NGCC-CCS deployment was relatively insensitive to $CO_2$ storage costs. When the $CO_2$ reduction target was replaced with a GHG target, NGCC-CCS deployment fell. This decrease was very small at a leakage rate of 0.25%, but resulted in nearly 2/3rds less deployment at a leakage rate of 4%.

## Conclusions and next steps

Parametric sensitivity analysis of NGCC-CCS parameters suggests that the technology could play an integral part in GHG mitigation strategies in the U.S. NGCC-CCS appeared in all sensitivity runs that were conducted. Furthermore, while NGCC-CCS deployment decreased if methane leakage is considered, the technology still played a role in mitigation for the highest leakage rates. We intend to expand this study in several ways. For example, we plan to: examine sensitivity to characterizations of competing technologies, such as solar, wind and nuclear power; explore alternative $CO_2$ and GHG reduction targets; examine regional deployment patterns; and explore the effects of changing multiple parameters simultaneously.

## References

Nicholas and Victor (2015) Examining the relationship between shale gas production and carbon capture and storage under $CO_2$ taxes based on the social cost of carbon. Energy Strategy Reviews, 7:39-54.

Cole et al. (2016) Considering the Role of Natural Gas in the Deep Decarbonization of the U.S. Electricity Sector. NREL, JISEA report.

Center for climate and energy solutions (C2ES) 2013. Leveraging Natural Gas to Reduce Greenhouse Gas Emissions.

International energy Agency (IEA) Greenhouse Gas R&D Programme (IEA GHG), $CO_2$ capture ready plants, 2007/4, May 2007.

McJeon et al. (2014) Limited impact on decadal-scale climate change from increased use of natural gas. Nature 514(7523): 482-485.

Tier et al. (2010) Potential for carbon capture and storage (CCS) in the Nordic region. VTT Technical Research Centre of Finland.

Rubin et al. (2012) The outlook for improved carbon capture technology. Progress in Energy and Combustion Science, 38: 630-671.

Loulou et al. (2004) Documentation for the MARKAL Family of Models. http://www.iea-etsap.org/web/Markal.asp

Lenox et al. (2013) EPA U.S. nine-region MARKAL database. http://nepis.epa.gov/Adobe/PDF/P100I4RX.pdf