The impact of CCS readiness on the evolution of China’s electric power sector

RT Dahowski¹ CL Davidson¹ HC McJeon² S Yu² LE Clarke² MA Wise² B Liu² GP Kyle² N Wei³

¹Pacific Northwest National Laboratory, Richland, WA USA
²Joint Global Change Research Institute, College Park, MD USA
³Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, Wuhan China

Abstract

With one of the most rapidly growing economies in the world, the continuing development and expansion of China’s electric generation infrastructure is of global interest as society grapples with how best to address atmospheric greenhouse gas levels. Of particular interest is how China might meet environmental quality and related emissions goals while also using its enormous domestic coal resources and coal-dominant electric generation and industrial infrastructure. CO₂ capture and geologic storage (CCS) is widely discussed in the research and policy communities as an important technology for enabling the transition to low-carbon energy systems. China understands the importance of CCS technologies for lowering their carbon emissions and in a recently released CCS Roadmap (ADB 2015) outlines and recommends specific actions and activities towards a phased CCS demonstration and deployment approach covering periods to 2020, 2030, and beyond. Yet, constraints including the timing, availability and costs to access CO₂ storage resources in China could significantly impact the degree to which CCS may be utilized effectively within the portfolio of low carbon options. This study examines the impact on China’s electric power sector of variations in timing of CCS deployment readiness.

GCAM-CHINA is a new extension of the Global Climate Assessment Model (GCAM)¹ providing enhanced detail for China at the level of each province, autonomous region, and municipality. It allows modelling of multi-sectoral energy supply and demand, coupled with air pollutant and greenhouse gas emissions, within a consistent global modelling framework allowing the impacts of global energy and climate mitigation scenarios to be evaluated at regional levels within China. The level of detail in the electric, transportation, buildings and agricultural sectors facilitates the evaluation of impacts on the deployment of various technologies over time in response to energy, resource, and economic signals. The impact on the deployment of conventional technologies can be compared against those of low-carbon technologies such nuclear, hydro, renewables, and energy efficiency measures. Building on previous work presented by Edmonds et al. (1997), Kim et al. (2006), Dahowski et al. (2008, 2012) and Wei et al. (2014), the authors have incorporated province-specific CCS supply curves into GCAM-CHINA to allow for a more detailed and nuanced evaluation of the impact of CCS technology deployment potential within the mix of available low-carbon energy options.

¹ GCAM is a dynamic-recursive model that projects global energy use, land use, and resulting emissions through the end of the century. See http://www.globalchange.umd.edu/models/gcam/
In this study, GCAM-CHINA is exercised to examine the impact of CCS availability on the projected evolution of China’s electric power sector. After Fawcett et al. (2015), the climate change mitigation scenario selected for this analysis is based upon the Intended Nationally Determined Contributions (INDCs), per national-level COP-21 commitments, for carbon reductions through 2030. Beyond 2030, Fawcett et al. implement a 5% per year emissions reduction, continuing through the end of the analysis period in 2100. This allows an examination of scenario-specific evolution of China’s generation portfolio over the coming century, under three variations in CCS availability: CCS is fully available for commercial-scale deployment by 2025; CCS is available by 2050; and CCS is unavailable for use in meeting the modelled mitigation targets. These three cases are compared against a no-policy case (Figure 1).

![Graphs showing China's electric generation mix through 2100 under the four scenarios discussed above](image)

Preliminary results suggest that, should large-scale CCS deployment be delayed in China by 25 years, the per-ton cost of climate change mitigation is projected to be roughly $350/tC by 2050, relative to $325/tC in the case in which CCS is available to deploy by 2025, reflecting an 8% increase. Once CCS is available for commercial use, mitigation costs for the two cases converge, equilibrating by 2080. However, should CCS be entirely unavailable to deploy in China, the cost spread between the two cases (2025 and no-CCS case) widens to roughly double by 2080 ($670/tC and $1370/tC respectively), and triple by 2100 ($1000/tC and $2900/tC respectively).

Under all variants, the modelled mitigation scenario dramatically reduces the role of coal in China’s electric generation mix, as it is increasingly displaced by nuclear, renewables, biomass, and when available, CCS. These technologies and associated generation infrastructure are relatively more expensive on a per-kW capital basis, which drives the relative mitigation cost increases where CCS availability is constrained.
Figure 2 shows the impact of the modelled policy on China’s generation mix, relative to a no-policy case, under the 2025 CCS and no-CCS cases considered in this paper. As discussed above, in all cases, emissions reductions from China’s power sector are met almost entirely by displacing non-CCS coal power, and to a much lesser extent, other fossil fuels and biomass. Under full availability (top panel), CCS-paired fossil and biomass accounts for roughly 30% of the displaced conventional generation in 2050 (and comprises 9% of total generation at that time). Nuclear, wind and solar make up 21%, 13% and 6% of the generation mix, respectively, and 36%, 23%, and 10% of the displaced conventional and primarily coal-fired generation capacity from the no policy case. However, when CCS is unavailable for use in China, all three of the non-CCS low-carbon technologies must grow to meet demand. Without CCS, nuclear capacity increases to a 26% share of total generation in 2050, with wind and solar rising to 17% and 7%, respectively, and markedly higher than under the no policy scenario.

Early results suggest that, while delays in availability of CCS in China may have short-term impacts on the overall per-ton cost of meeting the policy target evaluated here, and thus will increase the overall cost of doing so, the impact of not having CCS available after the middle of the century could result in a substantial tripling of mitigation costs by the end of the century, relative to a case in which CCS is available to deploy. Impacts on the generation mix for regions of China will also be examined.