How does changing the penetration of renewables and flexibility measures affect the economics of CCS penetration?

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Abstract

We use real options analysis (ROA) to examine carbon capture and storage (CCS) under different future emissions reduction and renewable penetration scenarios. We consider different flexibility options and a range of trajectories for emissions and for other low-carbon technologies over time and explore what conditions will see the greatest penetration of CCS technologies and under what circumstances developers will decide to scale down or exercise their option to abandon if the project has not yet been completed.

Future development of intermittent generation will change the economics of both unabated fossil plant and plants with CCS. Since one major barrier to large-scale CCS deployment is its high upfront costs, particularly for CO_2 capture, CCS must demonstrate that it has the ability to flexibly operate under diverse economic settings. The economics of CCS profiles is inevitably imposed by other schemes such as future deployment of renewables and emissions reductions scenarios.

Advances in investment theory have allowed economists to analyze investment decisions under uncertainty, which is highly relevant for CCS, [1]. Doing any sort of uncertainty research on CCS is difficult due to the lack of project data, but analyzing stylized CCS projects can be helpful to explore deployment and operating decisions under uncertainty. Real options are valuable in analyzing such cases since the option characteristics are valuable in an investment environment characterized by the simultaneous existence of uncertainty, irreversibility of investment and some freedom on the timing of the investment.

The real option mostly considered in our analysis is the investment timing option, used to design a CCS project timeline. A second type is the operational flexibility option, which, at some extra cost, allows for scale up or scale down of a project, for stop and restart of operations or switching to other inputs or outputs in response to the market. A third type of option we distinguish is the option to abandon the project at salvage value, which is important for projects involving flexible multipurpose assets like CCS. Finally, there is the growth option that opens up new options upon exercise, which allow to see in what and how many ways CCS technologies can progress.

Past studies have focused on the operating flexibility of power plants equipped with CCS, which support various flexibility measures that could help improve the performance of a plant equipped with CCS, [2], [3]. In order to accommodate the increasing penetration of intermittent renewable electricity generation capacity, it is becoming more clear that decarbonized fossil-fired power plants will have to operate in a highly flexible fashion, [4], as power generation processes with CCS that are capable of operating at variable load will be needed to achieve deep reductions in emissions of carbon dioxide to the atmosphere, [5]. However, most past work on CCS flexibility does not account for the economic implications of such measures.

Expanding on site-specific studies accounting for ROA in CCS, which offered inconclusive results, [1] we conduct a comprehensive economic analysis in order to avoid the many pitfalls of presenting incomplete or inconsistent results of CCS cost assessments, [6], that often lead to a lesser understanding of economics necessary to present CCS as a viable and competitive technology.

For the case of the United Kingdom, National Grid has been publishing a series of Future Energy Scenarios reports, [7], since 2011. These reports outline four scenarios geared towards reducing the UK's greenhouse gas emissions including the Gone Green scenario and the Consumer Power scenario. Consumer Power is the scenario where low-carbon technologies are employed towards reaching the target, in contrast with the Gone Green scenario where the focus is overwhelmingly on the development of renewable energy sector.
The detailed nature of these scenarios offers a realistic platform for identifying future CCS deployment in the UK and can be adapted to study other jurisdictions in greater detail. We use these scenarios as the basis for our real options analysis.
In a scenario like Consumer Power we exercise the growth option that allows us to invest in a pilot project without having to commit to invest in the follow-up project. We can also exercise the operational flexibility option to expand or scale up since more funds are available for CCS advancement. When assessing the Gone Green scenario, we enact the scale down option for CCS to visualize a system with significantly lower penetration of CCS.
Finally, we present a strategic framework that showcases how CCS can complement conventional and renewable generation and aid in achieving emissions reductions targets. By obtaining and comparing scenarios from exercising different types of options on green incentives, the results enable us to develop a plan of action for optimal CCS growth with the incentive of reducing costs and without delaying the advancement of other green technologies aiming to mitigate climate change.

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