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

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Abstract

In recent years, investment into carbon capture and storage (CCS) technologies has been seemingly sidelined to encourage larger renewable energy generation investment. High initial CCS costs have to compete with decreasing renewable costs and in some scenarios the role of CCS is completely overtaken by renewable energy. However, not recognising the value of a wider variety of low-carbon options in an energy system and committing to a single low-carbon technology can lead to a reduction in flexibility and further down the line even a lock out from successfully adapting the system to new advancements in smart technologies. On the path to a greener British energy system, gas power plants are considered as the transitional technology given the intermittent nature of most renewable generation. CCS can play a crucial role in mitigating the polluting effects of conventional generation. This paper employs real options analysis (ROA) to explore various cost and flexibility states, accounting for various penetrations of CCS and renewables working in cohesion.

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Keywords: CCS; flexibility; renewable energy; real options analysis; gas CCGT

1. Introduction

Carbon capture and storage (CCS) technologies have been adapting to apparently accepting market needs, however, a breakthrough carbon capture or storage technology has yet to be witnessed. CCS has frequently been criticised for being too large and not flexible enough to be worth investing in, due to the high initial costs, given the

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ever changing demand needs in a world where new renewable technology development is constantly reaching new milestones. On the other hand, it could be argued CCS has not been given a fair trial given its recent cuts in funding in developed nations like the United Kingdom (UK), [1], and the unwillingness to follow through with projects promised to be already finished in the near future, [2]. As successful CCS demonstration projects carried out from start to finish have been relatively rare, [3], it is unjust to perform assessments about the restrictions or the potential CCS truly has.

A technology the size of a CCS complex should not be compared to smaller green developments, yet we still witness energy professionals trying to present similar arguments for a single wind turbine as they do for a whole plant equipped with carbon capture. Because the pressure and expectations for CCS development are so much higher, CCS requires more time and thus appropriate financial backing to justify its promises. Instead of being a limitation, the size and wide range of CCS components are its advantage. When investing in CCS there is an opportunity to pick among various technologies adapted to fit to different power plants for optimised performance. Unlike renewable technology, CCS is intended as a long-term investment, not meant to be replaced immediately when a newer version becomes available.

Since CCS is so unique in its deployment, commonly used methods to compute its profitability are seldom not sufficient to address every component of the CCS structure. In this paper we use real options valuation to demonstrate how various flexibility measures can provide more security in future carbon investments. Resource allocation in investment is historically mostly done with net present value (NPV) calculations. However, NPV calculations assume a decision needs to be made immediately and there is no possibility to alter the decision once it has been made. Yet, in most cases the business climate can change a lot during the life-time of the project. This is even more apparent in the world of energy and environmental science, where we are provided with new information regarding our changing world every day. More than that, it is incredibly applicable to projects like CCS, where the average life-span of a project is 40 to 50 years. Applying real options to various CCS flexibility mechanisms is very relevant since not enough security is provided for CCS projects to make more determinative conclusions to solely rely on NPV calculations.

In the past, real options have rarely been used in calculations regarding CCS profitability, and even less frequently when it comes to CCS flexibility. Additionally, they have not been used to look at CCS as a part of a bigger picture we are trying to present here – CCS as a component of a future, greener energy generation mix. Previous CCS studies using real options, [4], have neglected the impact incoming technologies have on CCS performance, which does not allow for an accurate representation of CCS or any other technology.
The multi-layered nature of real options allows to apply different scenarios to each specific flexibility feature, which is crucial in getting CCS recognised as a cluster of multiple technologies instead of a large and unmanageable whole. It is a unique approach, which enables CCS to be assessed from three different viewpoints: by each single component, on its own as a whole, and as an agent in the larger energy scheme. By breaking CCS flexibility into smaller components more insight is given into what needs to happen to improve a single component, while still maintaining a complete grasp of the aggregate energy picture.

Given the ability to consider what would happen to a CCS project if the option was delayed or expanded, real options analysis is well-fitted for CCS as it is far less committal than just a NPV calculation. Time frames allow CCS investors to react accordingly to what is happening in the energy generation domain. Having more options in terms of project funding, puts investors in a more secure environment, where they are more likely to participate, since they are in a position in which the funds can be distributed differently if deemed necessary. Real options theory permits to approximate investments today to allow for greater choices and responses to different scenarios in the future and to make power plant planning more responsive to price movements.

With the use of different investment scenarios, this paper aims to demonstrate the benefits of employing real options instead of more traditional investment calculations in order to accurately portray the scale at which flexibility measures can aid in developing a more realistic approach of successful CCS implementation.

1.1. Types of real options

There are four different types of real options. Firstly, the investment timing option, which is helpful when designing a CCS project timeline and allows one to determine at what point in time it is best to take a certain business decision in the project's lifespan. Second is the operational flexibility option, which, at some extra cost, allows for scaling up or scaling down of a project, for stopping and restarting the operations, or even switching to other inputs or outputs in response to market behaviour. 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 additional possibilities upon it being carried into action, which then demonstrates the different pathways of potential CCS progress.

1.2. National Grid's Future Energy Scenarios 2016

Since 2011, National Grid (NG) has released its predictions for the development of the British energy platform, in the form of the Future Energy Scenarios, [5]. The analysis performed in this paper is based on these predictions and follows the Gone Green scenario, as it is the only scenario that reaches the emissions targets set for the UK. In Gone Green, policy interventions are a driving force behind realising a renewable, low carbon world. Funding is available to support innovation in green technologies such as renewable generation and low carbon heating systems.

The focus of this paper is on combined cycle gas turbines (CCGT) CCS due to the fact that all British coal-fired power plants should be shut down by 2025. Gas capacity is supposed to increase and be used as the transitional technology due to its high flexibility, current low gas prices, and the fact gas-fired power plants pollute half as much as coal-fired power plants. CCS is crucial for British green development, and without a national CCS infrastructure the cost of reaching climate change targets will double from a minimum of around £30 billion per year, [6].

2. Model

The work was based on the fundamental ideas of ROA applied to CCS. Three different states accounting for CCS and renewable energy penetration between the years of 2029 and 2040 were studied. This timespan was chosen based on NG's prediction for CCS to enter the British energy system in 2029 and run until 2040. The end goal is to decrease whole system costs, increase system flexibility, abate greenhouse gas emissions, and demonstrate the best balance of CCS and renewable energy co-operation. The year 2034 was chosen as the mid-point as there is no increase in CCS capacity between the years 2039 and 2040 so the capital costs did not change.

2.1. Option to abandon

In the first state we entertain the possibility of exercising the option to abandon by halting CCS progress halfway through the intended duration in 2034. The initial CCS capacity in 2029 is 900 MW and grows to 5995 MW by 2034. The total capital cost for that capacity is almost £7.5 billion using a CCGT CCS capital cost estimate, [6]. If CCS was allowed to reach its intended capacity, 5175 MW of additional capacity would have to be built, resulting in a capital cost of almost £6.5 billion during the second period. Thus, almost £6.5 billion is saved by choosing not to invest in CCS beyond June 2034. The total capital cost then equates to almost £14 billion at the end of 2040.

However, if a more expensive renewable technology, such as offshore wind, is chosen instead to compensate for the abandoned CCS capacity, 5175 MW of offshore wind would have to be built. This would result in a capital cost of almost £16 billion based on the cost predictions, [7], ensuing in the capital cost being almost £10 billion more than choosing to invest in CCS for the entire duration of the predictions.

2.2. Option to expand

The second state employs the option to expand CCS past what NG suggests in their Gone Green scenario at the expense of the most expensive renewable technology. The focus is on solar photovoltaic (PV), onshore, and offshore wind. However, NG also predicts that marine energy, wave and tidal combined, is set to grow from the current 48 MW to 5216 MW in 2040. Given the lack of commercial harvesting and the infant state of marine technology we chose not to include it as one of the renewable technologies that could be partially replaced by CCS despite its large predicted growth and likely even larger costs associated with it, as it is difficult to base these predictions in capacity expansion and their impact on any historical evidence.

The current PV capacity is 10,799 MW, [8], projected to reach 33,939 MW in 2034 and 36,833 MW in 2040. Onshore wind capacity was almost 9 GW in September 2016, should be 18,895 MW in 2034, and reach 19,598 MW in 2040. Offshore wind capacity is currently smaller than onshore wind capacity due to larger capital costs, and stood at 5 GW in September 2016. As costs continue to fall it is expected to grow to 28,982 MW in 2030, and then remain at that capacity until 2040. For this reason, offshore wind was not considered. It is currently more expensive than onshore wind, PV, and CCS, and is supposed to remain more expensive than CCS. In addition to the decreased level of flexibility, in terms of cost there is little justification for opting for offshore wind instead of CCS.

If we cut the combined growth of 3524 MW from solar PV and onshore wind between 2034 and 2039, it could be invested in CCS expansion, and more than 3.5 GW of CCS would be additionally available to capture gas emissions, meaning that the same amount of gas capacity could be operating instead of the onshore wind and solar PV, yet more emissions would be caught. This would increase operational flexibility and aid with intermittency issues posed by renewable resources without an increase in emissions. A larger capacity of gas power plants could operate at baseload, negating the need for building 3.5 GW of additional capacity of some other energy generating technology. By not installing 3.5 GW of onshore wind and solar PV capacity, £6.61 billion could be saved, following the cost evaluations for onshore wind, [7], and solar PV, [9]. Installing the same amount of CCS capacity would cost £4.37 billion, saving £2.24 billion.

However, to maintain the same generating capacity, and to compensate for the 3.5 GW of capacity lost, there is potential to build additional CCGT power plants. This would mean the same amount of emissions would get caught as in the original scenario, except now there would be more CCS and gas in the system, instead of onshore wind and solar PV, allowing for a more reliable and flexible baseload capacity. Taking into account estimations for capital costs, [10], 3524 MW of gas would cost £2.36 billion. Adding that to the cost of CCS already installed in the system, the final cost would be £6.73 billions, which is £119.8 million more than what the system would save from installing 3.5 GW less onshore and PV capacity, however, this decreases reliance on storage, provides greater energy security, and increases the flexibility of baseload capacity.

2.3. Option to delay

Postponing a CCS rollout until 2034 is attractive in terms of decreasing costs in addition to CCS already being more flexible than renewables. As CCS becomes cheaper so does onshore wind, meaning CCS would have to be of lower or similar cost to be competitive. Building 5995 MW of onshore wind between 2029 and 2034 would cost £11.3 billion, so CCS would have to cost less than that for a delay not to be sensible in terms of affordability.

A delay makes sense in terms of expenditure reduction, however, choosing to do so while continuing to rely on gas just trivialises green targets. To ensure meeting them reliance on wind would go up, emphasising intermittency issues. Unless large scale energy storage becomes affordable prior to CCS, a delay in CCS rollout is not favourable.

3. Results

Calculations were performed for three generation technologies, operating for a single month, each year from 2029 to 2040, with 12 peak hours. Following the equation below, call values in Figure 1 were calculated comparing CCGT, CCGT equipped with CCS, and onshore wind.

The value of a simple call, *c*, is expressed in a closed-form solution by Black and Scholes as it follows:

$$c = S * N(d_1) - e^{-r(T-t)} E * N(d_2)$$

$$d_1 = \frac{\ln\left(\frac{S}{E}\right) + (r + \frac{\sigma^2}{2})(T-t)}{\sigma\sqrt{T-t}}$$

$$d_2 = d_1 - \sigma\sqrt{T - t}$$

where S, is the current market price of the asset, E, is the price of the exercise, r, is the riskless rate of interest, σ, is the volatility of the underlying asset, $T - t$, is the time to maturity, time to expiry, and $N(*)$, is the cumulative normal distribution.

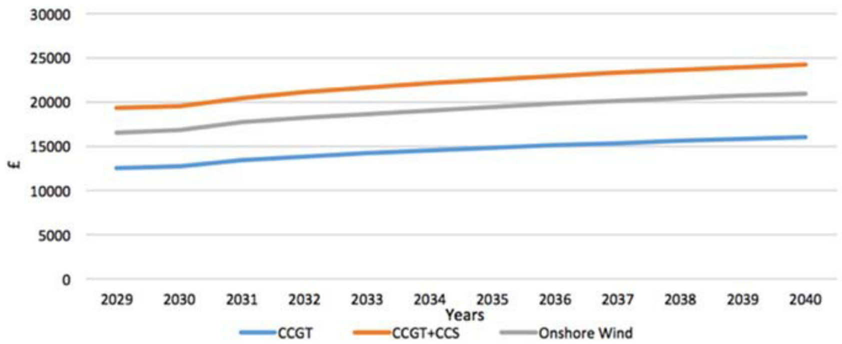

Figure 1. Call Values for Different Generation Technologies Between 2029 and 2040

Since the call values are higher for CCGT with CCS than those of just CCGT or onshore wind, the payoff is also higher, making CCS the most attractive for investment.

4. Conclusion

The future energy mix will consist of a plethora of technologies responding to energy system fluctuations. Recent policy decisions to decrease the role of CCS could cause big increases in cost, [6]. If the transitional technology will be gas, measures have to be taken to ensure emission reduction is still the primary priority, while maintaining a security of supply. Different calculations in future scenarios presented in this paper all demonstrate CCS as an attractive technology to invest in. Although currently more expensive than onshore wind and PV, CCS offers a solution to such constrains and should be given a fair trial to see what impact it would have on the energy system.

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