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Assessing the Option Value of Retrofitting a 200MW Power Plant to Oxyfuel CO_2 Capture

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Abstract

An advantage of oxyfuel capture technology is the flexibility of capable of retrofitting existing conventional coal-fired power plants. This analysis investigates the option value of retrofitting a 200MW coal-fired power plant to Oxyfuel CO_2 capture power plant. The initial retrofit option value is the theoretical financial value for pre-investment (Oxyfuel CO_2 Capture Ready) to keep the oxyfuel CO_2 capture retrofit option open. The study assumes carbon price (either carbon tax or carbon allowance market) is the only driver for oxyfuel CO_2 capture retrofit decision and there are no other operational or investment options in the decision making process.

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Keywords: Oxyfuel, CCS, Option Value, China

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1. Introduction

Oxyfuel CO_2 capture is one of the three major CO_2 capture technology pathways. Past studies have confirmed oxyfuel capture could be a competitive technology in CO_2 capture (Jordal et al, 2005; Bouillon et al, 2009; Hadjipaschalis et al, 2009). The oxy-fuel CO_2 capture system have a number of niche advantages, for example, much easier separation of CO_2, no solvent required, smaller physical size, and the potential to retrofit existing plants (though the boilers may be required to be reconstructed). Oxyfuel could play an important role in Chinese CCUS industry.

Developing a large-scale oxyfuel CO_2 capture power plant has a high marginal cost (e.g. 70% higher) compared to a conventional power plant, but currently there is neither a premium tariff scheme nor a carbon support scheme to bridge the financial gap in China. Retrofitting existing coal-fired power plants in China to Oxyfuel CO_2 capture is an important technical option to achieve a deep cut of carbon emissions in China.

The economics of retrofitting flexibility in a coal-fired power plant is a real option problem (Liang et al, 2009), because a deterministic net present value may fail to capture the option value of retrofitting involved in the sequential decision-making at each year. Therefore, building on previous studies on the economics of CO_2 capture ready and retrofit cost assessment, the paper applies a real option approach (ROA) to value of the retrofitting option in a 200MW coal-fired power plant.

2. Methodology

We take the perspective of a project investor to investigate the value and the exercising strategy of retrofitting option in the coal-fired power plant. Uncertainties are drivers of the option value. We build a stochastic cost cash flow model and use option value at each time-step (i.e. year) as the criterion to justify the decision of retrofitting. The ROA decision-making framework is a complex model with Bermuda style claims (i.e. options could be exercised the end of each year from now to any expiry date), therefore it requires a backward looking algorithm to find the optimal exercise boundary. We will use a least square regression method with Monte-Carlo simulation to estimate the option value.

In each operating year, there are options to retrofit an unabated coal-fired power plant with post-combustion CO2 capture technology. The retrofit decisions would be driven by a number of factors: electricity price (PE_t), carbon price (PA_t), the expected benefit of retrofit in the present value at year t ($E(B_{R,t})$), the retrofit cost at year t ($K_{R,t}$), and r is the risk free discount factor (at 3% in this case).
Assuming the retrofit will take one year, the value of retrofit option at year t (V_t), could be evaluated by the following Bellman equation:

$$V_t(PE_t, PA_t) = max\left\{E(B_{R,t}) - K_{R,t}, \frac{1}{1+r}E(V_{t+1}(PE_{t+1}, PA_{t+1}))\right\} \quad (1)$$

At year t , the remaining retrofit option value is V_t , assuming the plant's life time is N, the terminate value $V_N = 0$. The initial retrofit option value of an unabated coal-fired could be estimated as V_0
i.e. the value of making a plant retrofitable at year 0 is equal to the value of retrofit option $V_{0,c}$

The expected benefit of retrofit ($E(B_{R,t})$ is equal to the financial impact of retrofit affected by electricity output penalty cost, transportation and storage cost and the CO_2 allowance benefit. $Q_{i,R}$ is the net output capacity after retrofit at year i, Q_0 is the initial plant capacity (i.e. 188.7MW), u is annual utilisation hours (assumed to be constant at 5000). The emission factor after retrofit is $H_{i,R}$, the emission factor before retrofit is H_0. GC is the total amount of CO_2 captured at year i, CS is the cost for storage and transportation at year i. d is the commercial discount factor (assumed to be 8%) while T is the total lifetime of the power plant (i.e. 20).

$$E(B_{R,t}) = \sum_{i=t+1}^{T} \frac{[(Q_{i,R}-Q_0)\cdot u\cdot E(PE_i)+(H_{i,R}-H_0)\cdot Q_{i,R}\cdot u\cdot E(PA_i)-GC_i\cdot CS_i]}{(1+d)^{i-t}} \quad (2)$$

The investment decision of CCR depends on the retrofit option value difference between with CCR and without CCR scenarios at year 0 (V_0) and the required investment for CCS ready (I_{ccr}) to make a plant retorfitable . That is,

$$\text{Invest, if } V_0 \geq I_{ccr} \quad (3)$$

Notablely, some power plants may be retrofitable in absence of CCR investment. In that case, only very minor design modification may be required.

A real option analysis was conducted based on findings in ADB TA8133 Oxyfuel study (WP2.1 and WP2.2), as shown in Table 1 below. The electricity output penalty with CO2 capture is 72.7MW. The wholesale electricity tariff is assumed at CNY 400 in 2015 (following a GBM-MR process, with a 1% drift factor, a 20% mean reverting ratio).

Table 1 Main technical indicators of 200MW power plant

Item	Quantity		
	Unit	Air Condition	Oxygen Condition
Gross Capacity	MW	200	200
Construction duration	year	2	2
Operation duration	year	20	20
Plant Reference price	RMB/kw	4349	4349
Cost for coal (with VAT)	RMB/t	800	800
Annual Operation hours	h	5000	5000
Desulfurization efficiency (without desulfurization equipment)	%	-	40
Desulfurization efficiency (plus desulfurization equipment)	%	95	95
Denitrification efficiency (without denitrification equipment)	%	-	40
Denitrification efficiency (with denitrification equipment)	%	80	80
Denitration equipment cost	RMB/kw	185.7	185.7
Desulfurization equipment cost	RMB/kw	121.65	121.65
Desulfurization power consumption	%	1.5	0.5
Denitration power consumption	MW	0.217	0.07
Loan proportion	%	80	80
Repayment term of local loan	year	15	15
Long-term interest rate of local loan	%	6.55	6.55
Limestone price (including taxes)	RMB/t	100	100
gypsum price (including taxes)	RMB/t	50	50
The denitration price (including	RMB/t	4000	-

taxes)			
ASU unit Price	MRMB	-	120
ASU power consumption	MW	-	59.64
CPU investment coefficient	%	-	0.025
CPU power consumption	MW	-	17.56
Boiler efficiency	%	92.5	~95
Electricity used for power plant	%	5.64	-
Concentration of CO2 emissions	%	~14.6	≥80
Coal consumption	g/KWh	319.3	-
water price	RMB/t	0.5	0.5
Sewage treatment price	RMB /t	1.6	1.6
Sewage discharge	t/h	120	120
O&M rate of desulfurization system （including fixing）	%	1.5	1.5
Fixed assets formation rate	%	95	95
ratio of remaining value	%	5	5
depreciation life	year	15	15
Repair rate	%	2	2
Intangible and deferred assets proportion	%	5	5
Time of Depreciation and amortization	year	5	5
SO2 、 NOx Pollutants equivalent charge standard		0.5￥/0.95kg	0.5￥/0.95kg
The CO2 capture efficiency	%	-	90
Unit Capacity (backup member 10%)	person	100	112
Annual Salary/person	RMB	50000	50000
Welfare	%	60	60
Cost for materials	RMB /MWh	6	6
Other expense ratio	RMB /MWh	12	12
Gypsum Purity	%	90	90
Gypsum market prices	RMB /t	50	50
Income tax	%	25	25

3. Preliminary Results

When the carbon price is assumed to be CNY 150 / tonne CO2 (following a GBM-MR process,with a 6% drift factor, a 10% mean reverting ratio) in 2015 and the transportation cost is assumed to be CNY60 / tonne CO2 captured, the simulated retrofit option value is CNY 119 million (payoff illustrated in Figure 1). Because the coal input is the same after retrofitting to capture, therefore the coal price has no impact on this decision. In other word, if the carbon and electricity price and technical assumptions are valid, it is commercially viable to invest up to 119 million Yuan to ensure the base power plant to be retrofittable for oxyfuel CO_2 capture. There is approximately 40% of financially viable probability in retrofit, primarily distributed across 2019 to 2030 (Figure 2 and Figure 3). The study implies a significant financial value for making a new coal-fired power in Oxyfuel capture readiness status.

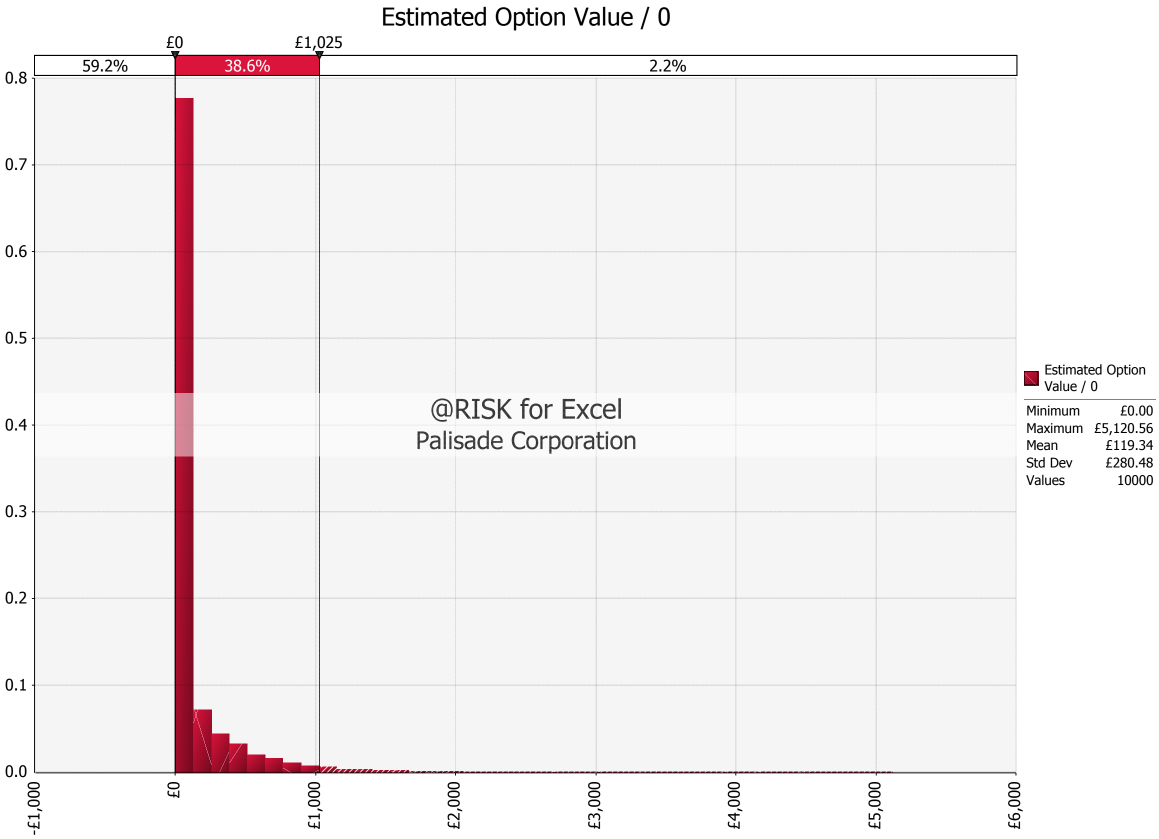

Figure 1 Estimated Payoff Distribution of Retrofit Option (10,000 trials)

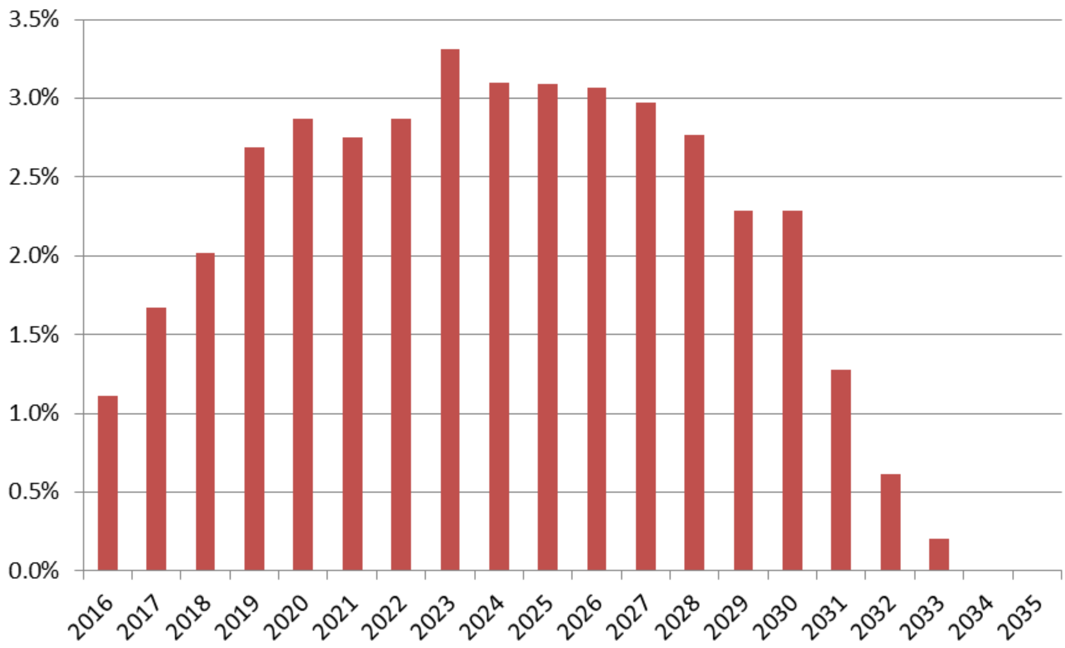

Figure 2 Simulated probability distribution of retrofit decision in the 200MW oxyfuel project's lifetime (2016 – 2035) (10,000 trials)

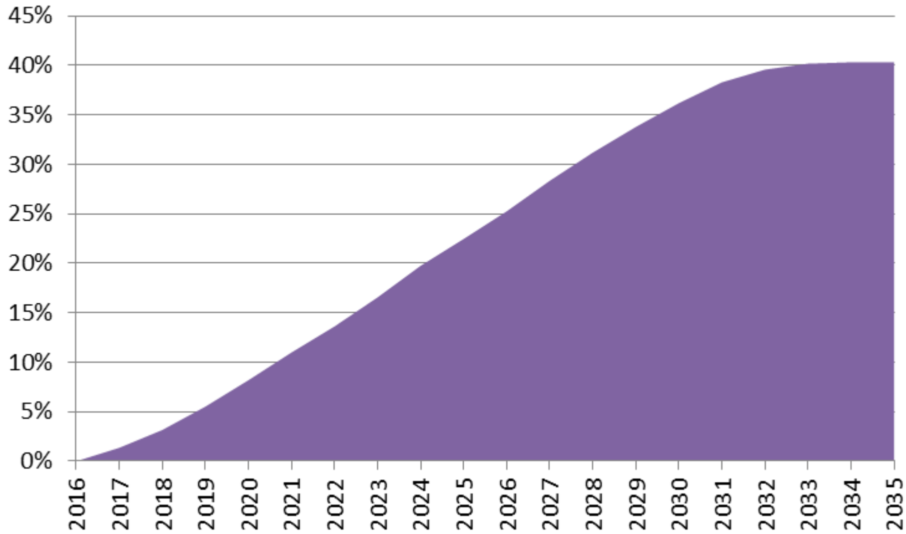

Figure 3 Simulated Cumulative Retrofit Probability in in the 200MW oxyfuel project's lifetime (2016 – 2035) (10,000 trials)

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