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Effect of Carbon Price Floor on Levelised Cost of Gas-Fired Generation Technology in the UK

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Abstract

The UK government implements carbon price floor to provide long-term incentive to invest in low-carbon technology, thus, fossil-fuel power plants have to face increasing carbon price. This report addresses the effect of carbon price floor on levelised cost of gas-fired generation technology through the levelised cost of electricity (LCOE) approach with the estimation of carbon price floor. Finally, the comparison of levelised cost of electricity for all generation technology in the UK will be shown and discussed.

Keywords

Carbon Price, Levelised Cost, Gas-Fired Power Plant

1. Introduction

Greenhouse gases (GHG) emitted by human activity are changing global climate with severe effect on our planet. In 1997, the third Conference of Parties (COP 3) adopted the Kyoto Protocol which binding developed countries to reduce the global temperature increment below 2 degrees Celsius [1]. In 2005, the European Union Emission Trading System (EU ETS), the first emissions trading system in the world, was launched as the most efficient tool to fight Global warming issue [2]. The European Union Emission Trading System control GHG emissions through "cap and trade" system which caps the total volume of GHG emission from installation. If participants require releasing more GHG emission, they trade emission allowances in the system [3]. The participant of EU ETS includes industrial plants, power stations, aviation and other organizations, and they get emission allowances in two ways using free location, and auction. However, in the third Phase of EU ETS (From 2013 to 2020), power generators have to auction their allowance at trading platform, and according to the relevant EU legislation, at least half of auctioning revenues and all of the revenue from aviation sec-

tor should be used to combat climate change in Europe and other countries [2].

On 1 April 2013, UK government announced and implemented the carbon price floor (CPF) policy to provide a long-term incentive to invest in low-carbon power generation by putting a minimum price on the emission of electricity generation [4]. The CPF as the UK's top-up carbon tax, applied to power stations and designed to supplement inadequate prices on EU market [5]. CPF consists of EU ETS carbon price and Carbon Price Support (CPS) levy on fuel, and the CPS rate is set for the taxable commodities which used in electricity generation in Great Britain [6] [7].

This report will calculate the levelised costs of electricity (LCOE) under the effect of carbon price floor, which is based on International Energy Agency (IEA) resource [8]. The study on electricity generating costs has been proven to be an important tool for policy makers, academics, and the interested public when discussing the economics of power generation and carbon price floor.

2. Methodology

The LCOE methodology reflects generic technology risks, not specific project risks in specific markets [8]. There is a gap between the LCOE and financial costs for owner-operators in real electricity markets facing specific uncertainties. For the same reason, LCOE is closer to the real cost of investment in electricity production in regulated monopoly electricity markets with regulated prices rather than to the real costs of generators in competitive markets with variable price.

The LCOE is a useful tool for comparing the unit costs of different electricity generation technologies over their operating life. The assumption of carbon price as a key parameter will impact on the final results in LCOE calculation especially for coal-fired and gas-fired power plant. Therefore, this report will use floating carbon price floor to replace fixed carbon price to estimate the change of levelised cost on fossil-fuel power plant caused by CPF.

2.1. Levelised Costs of Electricity Equation

The levelised costs formula which is used to calculate lifetime average levelised cost includes methodological conventions and key assumptions to guarantee the comparability of generating technologies. With annual discounting, the LCOE calculation begins with equation (1) expressing the equality between the present value of the sum of discounted revenues and the present value of the sum of discounted costs. In other words, on the left-hand side is the discounted sum of benefits and on the right-hand side is the discounted sum of costs. Equation (2) is the formula used to calculate average lifetime levelised costs on the basis of the costs for investment, operation and maintenance, fuel, carbon emissions and decommissioning and dismantling. The discount rate r refers to the interest rate used in cash flow analysis to determine the present value of the future cash flow, because the revenue today has more value to the investor than revenue tomorrow. And, the discount rates would be higher when investor facing substantially greater financial, technological or price risks.

$$\sum P_{MWh} \times MWh \times (1+r)^{-t} = \sum [(Capital_t + O\&M_t + Fuel_t + Carbon_t + D_t) \times (1+r)^{-t}] \quad (1)$$

$$LCOE = P_{MWh} = \frac{\sum [(Capital_t + O\&M_t + Fuel_t + Carbon_t + D_t) \times (1+r)^{-t}]}{\sum MWh(1+r)^{-t}} \quad (2)$$

P_{MWh} = The constant lifetime remuneration to the supplier for electricity;
MWh = The amount of electricity produced in MWh, assumed constant;
$(1+r)^{-t}$ = The discount factor for year t;
$Capital_t$ = Total capital construction costs in year t;
$O\&M_t$ = Operation and maintenance costs in year t;
$Fuel_t$ = Furl costs in year t;
D_t = Decommissioning and waste management costs in year t.

The assumption on specific key parameters, such as discount rates, lifetimes or fuel and carbon prices, need harmonisation because they have a decisive impact on final results. According to the Projected Costs of Generating Electricity 2015 by International Energy Agency, the key parameter assumption shows as **Table 1**.

2.2. Estimation of Carbon Price Floor

In 2013, the UK government set carbon price floor to rise gradually to £30/tCO_2 in 2020 and £74/tCO_2 in 2030, however, it was frozen at £18/tCO_2 from 2016/17 to 2019/20 in order to support business competitiveness and to restrain increases in household energy bills, since the large and increasing gap between the carbon price in the UK and abroad [9]-[12]. According to the UK government documents, **Figure 1** shows the estimation of carbon price floor from 2015 to 2044 in US dollars.

Table 1. The assumption of key parameter in LCOE.

Lifetime	**years**
Wind and solar plants	25
Natural gas-fired CCGTs	30
Coal-fired power and geothermal plants	40
Nuclear power plants	60
Hydropower	80

Carbon price	30 USD/ tonne of CO_2
Capacity factor for CCGT OCGT and nuclear plant	85%

Fuel prices	**USD**
Hard coal	101/tonne
Natural gas	11.1/MMBtu
Front end of nuclear fuel cycle	7/MWh
Back end of nuclear fuel cycle	2.33/MWh
Capacity factor for CCGT OCGT and nuclear plant 85%	85%

3. Results and Discussions, Conclusion

Table 2 and **Table 3** represent the levelised cost of electricity with and without the effect of carbon price floor in the UK. Under the carbon price floor policy, the carbon cost of CCGT and OCGT has been increased from 9.43 and 14.22 USD/MWh to 18.27 and 27.64 USD/MWh, and levelised cost reach 112.38 and 150.91 USD/MWh respectively. **Figure 2** and **Figure 3** illustrate the levelised cost of all technologies with different carbon price and reveals the contribution of carbon cost on power plant.

Table 2. The levelised cost for all technology in the UK (USD/MWh).

Technology	Construction	O&M	Fuel cost	Carbon cost	LCOE
CCGT	12.02	6.63	75.51	9.43	103.59
OCGT	6.14	3.02	113.85	14.22	137.23
Nuclear	68.51	20.93	11.31	0	100.75
Solar-large	130.7	37.06	0	0	167.76
Wind onshore	87.73	36.24	0	0	123.97
Wind offshore	106.19	52.06	0	0	158.25
Wind offshore	113.08	61.15	0	0	174.23
Large hydro	133.89	41.02	0	0	174.91
Biomass	11.6	21.1	134.68	0	167.38
Geothermal	79.89	37.09	0.44	0	117.42

Table 3. The levelised cost for all technology in the UK under CPF policy (USD/MWh).

Technology	Construction	O&M	Fuel cost	Carbon cost	LCOE
CCGT	12.02	6.63	75.64	18.27	112.38
OCGT	6.14	3.02	114.16	27.64	150.91
Nuclear	68.51	20.93	11.31	0	100.75
Solar-large	130.7	37.06	0	0	167.76
Wind onshore	87.73	36.24	0	0	123.97
Wind offshore	106.19	52.06	0	0	158.25
Wind offshore	113.08	61.15	0	0	174.23
Large hydro	133.89	41.02	0	0	174.91
Biomass	11.6	21.1	134.68	0	167.38
Geothermal	79.89	37.09	0.44	0	117.42

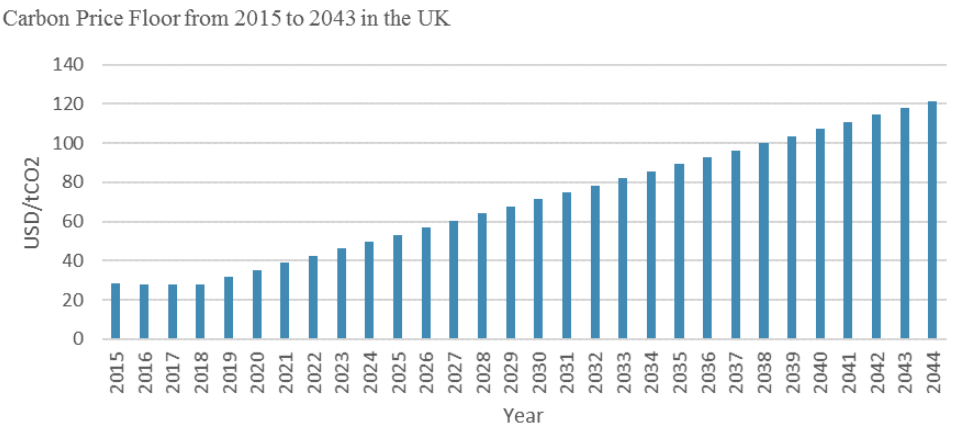

Figure 1. Estimation of carbon price floor from 215 to 2043 in the UK.

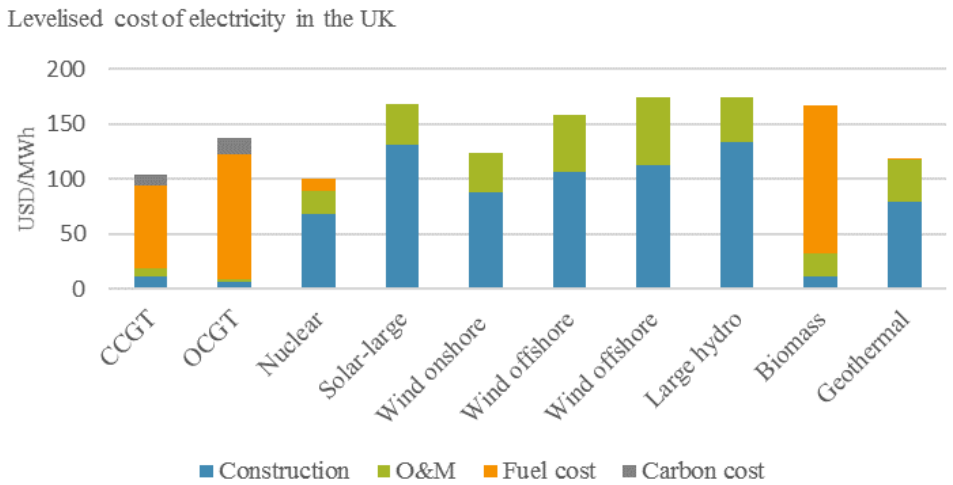

Figure 2. The levelised cost of electricity for all technology in the UK.

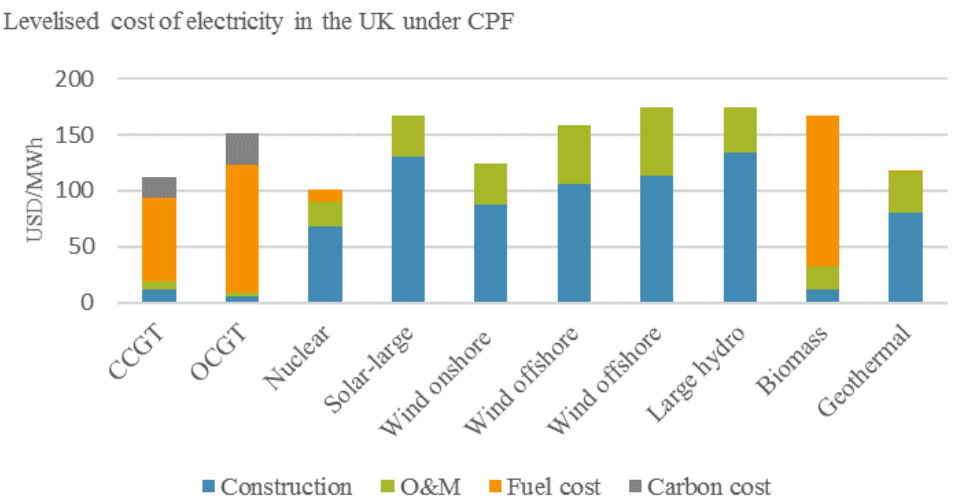

Figure 3. The levelised cost of electricity for all technology in the UK under CPF.

There are some important points need to be mentioned and clarified. First, this report does not take account system costs even though system cost is a major issue for variable renewable energy, such as wind and solar. Second, the discount rate in LCOE calculation is 7%, which can be considered as the rate available to an investor with a low risk of default in a stable environment. Finally, the value of money is reported here is not harmonized, the price of carbon price floor in 2014 price and the costs of LCOE calculation in 2013 price.

4. Conclusion

The carbon price floor policy increases the carbon cost of power plant which based on fossil-fuel technology to make low-carbon power generation technology more competitive, and furthermore, it provides a long-term stable policy environment on reducing greenhouses gases emissions to lower low-carbon technology risk and capital cost. This report represents the effect of carbon price floor on levelised cost of electricity for all generation technology in the UK, through comparing the levelised cost under carbon price floor with that of with fixed carbon price.

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