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Carbon prices and CCS investment: A comparative study between the European Union and China

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HIGHLIGHTS

- I develop a method to objectively update and compare CCS costs in the EU and China.
- To represent investment choices, intra and inter CO_2 switching prices are required.
- EU CCS plants are profitable for a CO_2 price higher than 115 €/t (offshore storage).
- Chinese CCS plants are profitable beyond 45 €/tCO_2 (35 €/tCO_2 with onshore storage).
- With 2030 projections, CCS (coal) plants are profitable in China but not in the EU.

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ABSTRACT

Carbon Capture and Storage is considered as a key option for climate change mitigation; policy makers and investors need to know when CCS becomes economically attractive. Integrating CCS in a power plant adds significant costs which can be offset by a sufficient CO_2 price. However, most markets have failed: currently, the weak carbon price threatens CCS deployment in the European Union (EU). In China, a carbon regulation is appearing and CCS encounters a rising interest. This study investigates two questions: how much is the extra-cost of a CCS plant in the EU in comparison with China? Second, what is the CO_2 price beyond which CCS plants become more profitable than reference plants in the EU and in China? To address these issues, I conducted a literature review on public studies about CCS costs. To objectively assess the profitability of CCS plants, I constructed a net present value model to calculate the Levelised Cost of Electricity and the breakeven CO_2 price. CCS plants become the most profitable plant type beyond 115 €/tCO_2 in the EU *vs.* 45 €/tCO_2 in China (offshore transport and storage costs). I advise on the optimal plant type choice depending on the CO_2 price in both countries.

1. Introduction

Scientists and international organisations, such as the IPCC (2005, 2014), the International Energy Agency IEA (2013)), and the Global CCS Institute (2011, 2014), identify Carbon Capture and Storage[1] as the only current mitigation technology that would allow industrial sectors to meet deep emission reduction targets. Thus, most energy scenarios with ambitious climatic goals use CCS techniques. For example, the IEA (2013) has developed a 2 °C scenario (COP 15) in which CCS accounts for up to 14% of the total emission reductions globally through 2050. About half of the total volume of the captured carbon comes from the power sector and the other half from the industry (cement, iron, steel, etc.).

Thus, when applied to the power sector, CCS has the potential to significantly reduce GHG emissions: in 2009, power generation contributed to 40%[2] of total CO_2 atmospheric emissions (IEA,

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[1] CCS is a suite of techniques designed to capture the CO_2 contained in flue gases from large point sources (fossil fuel plants, blast furnaces, cemeteries, etc.) before it is emitted to the atmosphere, transport it (e.g., pipelines) and then to inject it into a suitable storage facility (e.g., depleted oil and gas fields, deep saline aquifers) (Bernstein et al., 2006).

[2] Around two thirds of the world's electricity was generated from fossil fuels, with 40% from coal and 21% from natural gas; the use of coal and gas to generate electricity is still rising (IEA, 2012a).

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2012a). Thus, the focus is on the power sector, where abandoning CCS as a mitigation option would increase the investment requested by 40%, *i.e*., an additional cost of USD 2 trillion over 40 years (Best and Levina, 2012). Indeed, even though CCS remains costly and has not yet been demonstrated at large scale, CCS can still be "competitive on a levelised cost of electricity basis with solar, wind…" (IEA, 2012c).

Therefore, given the potential environmental effects of economic growth, CCS is an important option for decarbonising the power sector (Grimston et al., 2001) in both developed and developing countries whose energy demands are still growing and are highly reliant on fossil fuels.

The EU and China were chosen to compare CCS costs for several reasons: (1) in contrast to China, a CCS slowdown can be observed in the EU (see below). (2) Both have introduced[3] or planned[4] to introduce carbon price regimes, and carbon regulation plays a key role in CCS profitability and deployment (Giovanni and Richards, 2010). Indeed, the use of CCS can emerge endogenously as a cost-effective response to carbon restriction. If the carbon price is high enough, decision makers/investors face the choice to either invest in a CCS power plant to reduce their carbon burden or to not install CCS and pay for emitted CO_2, thereby implying a CO_2 cost pass-through to electricity prices. This CO_2 cost pass-through to electricity prices exists in the EU (Jouvet and Solier, 2013) but is currently impossible in China because of regulated electricity prices. Nonetheless, reforms are currently undergoing to partially deregulate gas prices (IEA, 2012b), and thus the reform of electricity regulations is perfectly conceivable in China. (3) The EU is a developed region, whereas China is a developing country. Power plant costs significantly vary by country, and the contrast is especially striking between the emerging economies of East Asia, including China, and the mature markets of North America and Europe. At least four explanations for this cost difference can be put forward: lower labour costs in China[5], economies of scale from building multiple power plants with standardised designs in China, lower raw materials/commodities prices (national abundance and state-set prices significantly lower than free-market prices) and fewer constraining regulations in China. Thus, with the goal of minimising the cost of the ecological transition, the case of CCS in China may be significant. If it is, then some transfers (monetary/R&D…) or policy agreements between the EU and China to support and incentivise CCS deployment must occur.

In the late 2000s, the EU viewed CCS playing a critical role in meeting its climate targets, well known as the "20–20–20", in the Climate and Energy Package Framework (2009).[6] Following the European Council's (2007) decision to support up to 12 large-scale demonstration projects by 2015, the EU has committed to support CCS from a financial and regulatory point of view. The CCS Directive was adopted to provide a legal and common framework (transposition deadline set at June 2011). In addition, CO_2 transport pipelines were included in the European legislation related to trans-european energy infrastructures in 2011. To establish a demonstration support framework, CCS has become an integral part of the EU R&D programme; in the frame of the European Industrial Initiative (EII), CCS is part of the Strategic Energy Technology (SET) Plan. Two funding instruments have also been created: the European Energy Programme for Recovery (EEPR) and the NER300.[7] However, the current weak EUA price has slowed the development of CCS demonstration projects and threatens CCS deployment. As a result, the European Union could lose its leadership[8] in the CCS field while other countries like China currently invest in CCS.

Indeed, China has committed to reduce its carbon intensity by 40% to 45% from 2005 levels by 2020 (Wu et al., 2013). However, the coal share of the Chinese electricity mix was 78% in 2010 and is projected to be 60% in 2020 (IEA, 2012a). Thus, CCS has a large potential market in China, and the inclusion of CCS in China's 12th Five-Year Plan reflects a strong commitment. China now has 11 Large Scale Integrated Projects (LSIPs) planned compared to five in 2010, ranking second only to the United States in terms of total number of LSIPs (GCCSI, 2014).[9]

As power plant costs strongly differ between China and the EU, one can expect CCS costs to vary between China and the EU. Two questions thus arise: how much is the extra cost of a CCS plant in the EU in comparison with China? Second, what is the CO_2 price beyond which CCS power plants become more profitable than power plants without CCS in the EU and in China? However, if, within a particular country, there is a large gap between the CO_2 price triggering CCS investments and the forecasted CO_2 market price, then this country could support CCS deployment in a lower cost country to minimise the cost of the ecological transition. Such support may include monetary/technology transfers, R&D agreements (MOU), or other elements.

To address these issues, I conducted a literature review on public studies about CCS costs in the EU and China. This paper summarises the results of the most recent public studies about the current CCS costs for fossil power plants and gives an updated comparison of coal and gas power plants with and without CCS. To objectively assess the profitability of CCS power plants, two metrics are calculated: the Levelised Cost of Electricity (LCoE) and the CO_2 switching price (the CO_2 price beyond which a CCS power plant becomes more profitable than another power plant type). Thus, I constructed a net present value model to calculate the breakeven CO_2 price. While technical and economic studies on CO_2 capture from power generation are numerous in OECD countries, particularly in the EU, they are scarce in China (Wu et al., 2013). However, very few of the studies in China or in OECD countries assess the CO_2 switching price for coal and gas plants, with and without CCS. This study fills this gap by providing an objective CCS cost comparison in the EU and in China and by examining the implications for European and Chinese power plant investors/policy makers.

Section 2 briefly describes the state of art in CCS techniques in the power sector and then describes the methodology used to objectively characterise the economic factors of CCS power plants. Section 3 presents the main results. Section 4 uses sensitivity analysis and a 2030 CCS cost projection to discuss implications for investors on the optimal power plant type choice depending on the CO_2 market price and to suggest an optimal timing for CCS investments in the EU and China. The final section concludes.

[3] The European Parliament has recently adopted the back-loading proposal, which could be seen as the first step to further structural measures to revitalise the EU-ETS.

[4] Different designs of the carbon market are currently tested in five cities, and 7 cities are scheduled.

[5] Notably required for project/construction management, infrastructure and power plant construction.

[6] A 20% reduction in GHG emissions from 1990 levels, a rise in the share of EU energy consumption produced from renewable resources to 20% and a 20% improvement in the EU's energy efficiency.

[7] New Entrance Reserve (NER) dedicated to subsidy innovative renewable energy technologies and CCS. In 2008, the EU agreed to set aside 300 million of Emission Unit Allowances (EUA) from the NER under the European Union-Emission Trading System (EU-ETS) Directive. No CCS projects were selected in the first call for proposals of NER300; one project has been submitted in the second call, for which Awards are envisaged by mid-2014.

[8] For instance, Alstom has been involved in these pilots: Lacq (France), Le Havre (France), the Technology Center Mongstad (TCM) (Norway), which is the world's largest facility for testing CO_2 capture, or the White Rose project (United Kingdom).

[9] The 19 American LSIPs are generally in more advanced stages (7 evaluate, 8 define, 4 execute, 2 operate) than the Chinese LSIPs (9 evaluate, 2 identify).