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CO₂ Capture Rate Sensitivity Versus Purchase of CO₂ Quotas. Optimizing Investment Choice for Electricity Sector

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Résumé — Sensibilité du taux de captage de CO₂ au prix du quota européen. Usage du faible prix de quota européen de CO₂ comme effet de levier pour lancer le déploiement de la technologie de captage en postcombustion — La technologie de captage (associée au stockage) de CO₂, appliquée aux centrales thermiques, permet de réduire les émissions de CO₂ à l'atmosphère. Cet article démontre que dans le cas particulier de la phase de déploiement de la technologie de captage de CO₂ pendant laquelle le prix du CO₂ risque de rester faible, capturer moins de 90% des émissions totales de CO₂ des centrales thermiques peut être une solution économiquement intéressante. En effet pour un électricien, la technologie de captage est intéressante si, seulement si, le coût marginal actualisé de captage est inférieur au coût marginal actualisé d'achat de quota sur l'ensemble de son site industriel. Pour un niveau faible du quota de CO₂, il vaut mieux disposer de flexibilité et pouvoir réduire le taux de captage global du site, soit en arrêtant le captage sur un ou plusieurs trains de combustion si le site en détient plusieurs, soit en adoptant un taux de captage inférieur à 90%.

Abstract — CO₂ Capture Rate Sensitivity Versus Purchase of CO₂ Quotas. Optimizing Investment Choice for Electricity Sector — Carbon capture technology (and associated storage), applied to power plants, reduces atmospheric CO₂ emissions. This article demonstrates that, in the particular case of the deployment phase of CO₂ capture technology during which CO₂ quota price may be low, capturing less than 90% of total CO₂ emissions from power plants can be economically attractive. Indeed, for an electric power company capture technology is interesting, only if the discounted marginal cost of capture is lower than the discounted marginal cost of purchased quotas. When CO₂ price is low, it is interesting to have flexibility and reduce the overall capture rate of the site, by stopping the capture system of one of the combustion trains if the site has multiple ones, or by adopting less than 90% CO₂ capture rate.

INTRODUCTION

The cost of purchasing quotas (on the EU-ETS (European Union Emission Trading Scheme)) or carbon credits (from CDM projects) is an additional parameter which has to be included in the economic evaluation of CO₂ projects. This environmental cost impacts the economic profitability of any CO₂ mitigation projects as any other economic cost parameter [1]. As soon as CO₂ cost becomes mandatory and not optional, as in an emissions trading scheme, CO₂ post-combustion capture projects become very sensitive to the CO₂ price through the associated capture rate. Under some conditions, developed hereafter and exclusively during the large deployment phase, a low CO₂ price is an advantage to reduce the overall CO₂ cost of power plants equipped with post-combustion technology. CO₂ price is of course on the long term the main condition to stabilize the Capture Carbon Storage (CCS) technology [2].

The aim of this article is to point out that, at the large CCS deployment stage, in the current European carbon markets¹ characterized by high uncertainty [3] and low CO₂ price, post-combustion capture technology with a lower capture rate than technologies capturing at 90% and an associated lower investment cost, can be a winner strategy option.

As long as the CO₂ market is characterized by poor reduction objectives, or is over flooded by free allowances, the CO₂ price signal is weak and does not justify today any capture projects at 90% capture rate [4]. This is what is observed on the EU-ETS market during the phase 2 (2008-2012). In contrast, CO₂ capture rate below 90%, applied on the overall power plant emissions could launch capture technology deployment. Quite all capture studies nowadays are working with 90% capture rate with post-combustion technology [5], but there is no technical justification or economical one. On the contrary for the deployment phase!

1 SIX MAIN CONDITIONS REQUIRED TO BE IN BENEFICIAL CONTEXT

1. In the EU-ETS market, the choice between utilizing quotas or investing in capture technology arises for an electric power company from the very first ton of CO₂ emitted [6]. After 2013, an operator will decide to invest in CO₂ capture technology only if he anticipates that his discounted total CO₂ capture cost during the lifetime of the project (CAPEX + OPEX +

- quotas purchase on remaining CO₂ emitted) is lower than his discounted total cost of purchasing quotas.
2. If the discounted total CO₂ capture cost is lower than the discounted total cost of purchasing quotas then the cheapest technology of capture (ranked on marginal costs) is the first technology deployed by operators. Between two capture technologies an operator will choose the technology with the cheapest discounted total CO₂ capture cost.
3. Total CO₂ capture cost of a power plant, equipped with post-combustion technology, has two parts: one part linked to capture investments and another part related to the purchase of quotas for the CO₂ not captured (1- capture rate). The more the capture rate is low and the CO₂ price below capture cost, the more the total CO₂ capture cost (CAPEX + OPEX + purchase quotas) is reduced compared to technology with 90% of capture rate. There is substitution of one part of the capture cost by the purchasing quotas cost.
4. Post-combustion technology with lower capture rate and lower investment cost than those capturing at 90% exists and reduces the cost of the CO₂ avoided.
5. To be in a low CO₂ price economic environment with low expectations to see CO₂ price increasing. European Union Emission Trading Scheme is structurally over allocated and CO₂ price forecasts on the EU-ETS do not exceed 24 €/tCO₂eq for 2020. On Kyoto market [2008-2012] as surplus AAU (Assigned Amount Unit) observed, stress is also virtually nil. After 2020, all will depend on international negotiations but no expectations to see the CO₂ price rising suddenly.
6. Nowadays, in the context of limited funds available, banks limit their financial risk and prefer investing in higher secure projects.

Capturing CO₂ at a capture rate below 90% does not mean operators are not concerned by CO₂ environment goal. In contrary, a low CO₂ price on the carbon market is the signal of a low policy environmental goal which consequently can't justify high mitigation climate change investments [7].

2 CO₂ LEVERAGE EFFECT OR SWITCH PRICE

Total CO₂ capture cost of an operator is the sum of two parts: the capture cost (CAPEX + OPEX) and the cost of CO₂ quotas purchased (which depends on the percentage of CO₂ not captured and the CO₂ price). Actually, all depend on the structure of this total CO₂ capture cost *i.e.* on the share of the capture cost compared to the share of quotas cost.

An operator can identify for a given technology, what is his "CO₂ switch price". This CO₂ switch price

¹ European allowance (EUA) and Kyoto carbon credits (CERs and ERUs).

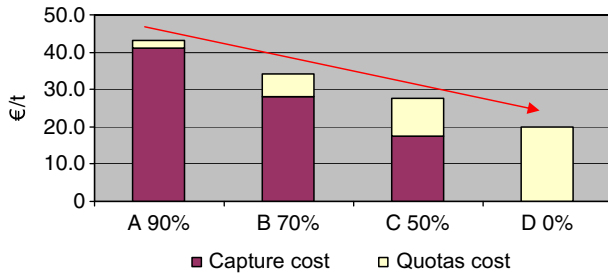


Figure 1
CO₂ price at 20 €/t - total CO₂ capture cost for different capture rates.

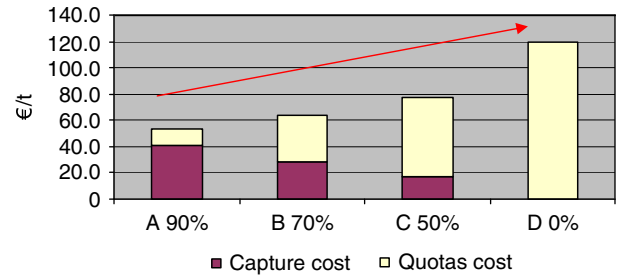


Figure 2
CO₂ price at 120 €/t - total CO₂ capture cost for different capture rates.

is function of two parameters: the capture cost and the CO₂ capture rate. This CO₂ switch price is equal to the CO₂ price under which an operator is more interested to buy quotas than to invest in carbon capture technology. This CO₂ switch price is the CO₂ price for which exchanging CO₂ captured cost by purchasing allowances is cost equivalent.

2.1 Example 1

In Figure 1, we have four decreasing capture rate technologies (A = 90% carbon capture rate, B = 70%, C = 50%, and D without any CO₂ capture).

We assume capture cost technologies below 90% of CO₂ captured is less expensive than technologies capturing at 90%. Total CO₂ capture cost per technology, is the sum of the cost of capture (dark part) and the cost of purchasing quotas (clear part).

What happens on the total CO₂ capture cost when the quota price increases from 20 to 120 €/tCO₂ for technologies with different capture rate?

Figure 1 shows, when capture rate decreases, how capture cost is substituted by the cost of purchased quotas. The more we substitute capture cost (at 70% or 50% capture rate), with the cost of allowances at 20 €/tCO₂, which is below the capture cost, the more the total CO₂ capture cost decreases. At 20 €/tCO₂ it is more interesting to capture at 70% (B) and buy the remaining 30% of allowances in the CO₂ market. In this example, 20 €/tCO₂, it is worth paying quotas than capturing (case D). With a relatively low CO₂ price it is more interesting to have low capture rate technologies.

2.2 Example 2

What happens with a high CO₂ price?

The same capture rate technologies associated to a CO₂ price equals to 120 €/t, the conclusion is completely reversed.

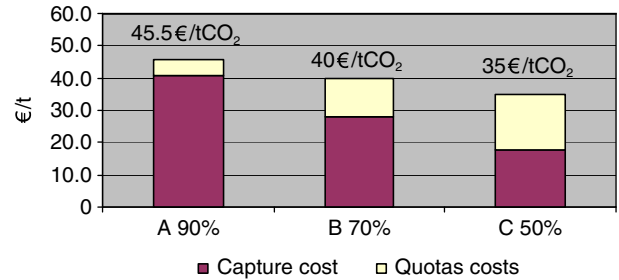


Figure 3
Breakdown capture and quotas costs and CO₂ switch price per capture rate technologies.

Figure 2 shows with a quota price of 120 €/tCO₂: technologies with reduced capture rate are not interesting compared to technology at 90% (A). Depending on the CO₂ price, CO₂ cost share becomes majority in the total CO₂ capture cost. Technologies with low capture rate are not worth with high CO₂ price.

Now, it's clear that for each capture technologies (A, B and C), there is a CO₂ price level that balances the CO₂ capture cost and the cost of purchased quotas. For this CO₂ price level, it is equal to capture or purchase quotas: we call this CO₂ price the "CO₂ switch price".

With technology A (90% capture rate) the CO₂ switch price making the cost of capture equal to the cost of purchased quotas is 45.5 €/tCO₂. In contrast with technology C (50% capture rate) competition with purchased quotas is at 35 €/tCO₂, a much lower CO₂ switch price (Fig. 3).

3 THE GENERAL RULE

Considering two different technologies: A and B. Capture rate of A equals to 90%, and capture rate of B is 70%.

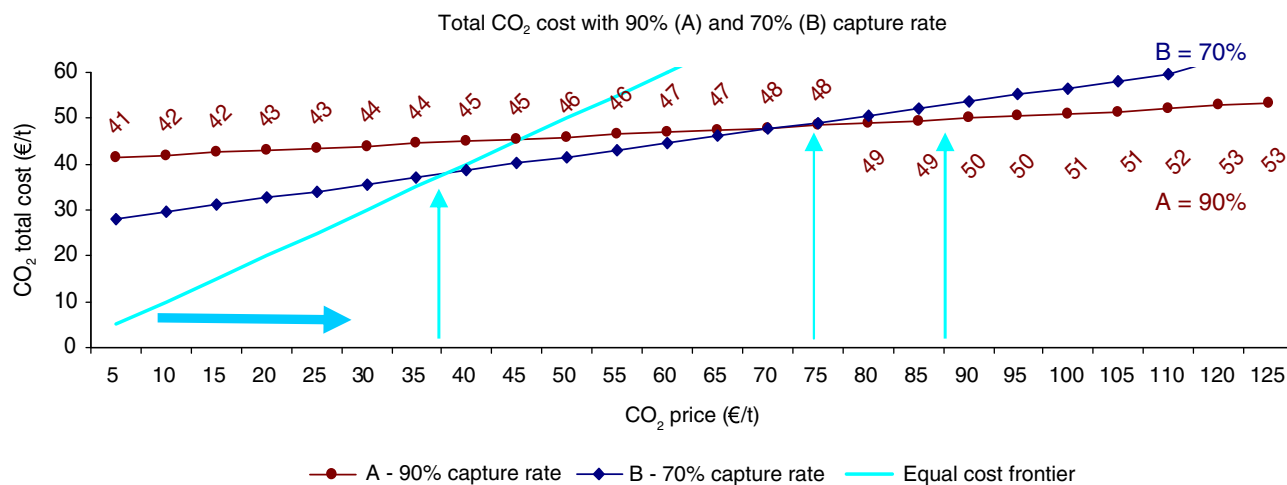


Figure 4

Total CO₂ capture cost with 90% (A) and 70% (B) capture rate.

When varying the CO₂ price (Fig. 4), what happens with the total CO₂ capture cost (CAPEX + OPEX + quotas purchase) for technology A (90%) and compared to technology B (70%)?

Rule No. 1: an electric power company should invest in capture technology only if the discounted total CO₂ capture cost of this technology is cheapest than the discounted cost of purchasing quotas (at the right of the blue line of equivalence between investing in the capture or paying the quotas – Fig. 4). This is the case for technology A from 45 €/tCO₂ and B from 40 €/tCO₂:

- at 15 €/tCO₂: total CO₂ capture cost of B is 31.1 € while that of A is 42.5 €. For both technologies it is better to buy quota at 15 €/tCO₂ than investing in capture. Left part of the equal cost frontier;
- above 40 €/tCO₂: it's better to capture CO₂ with the technology B rather than buy CO₂ quotas;
- similarly for technology A (90% capture rate) as the CO₂ price is less than 45 €/tCO₂ it is worth to buy quota rather than capturing CO₂.

Rule No. 2: it is important to compare the total CO₂ capture cost between technologies – here between technology A and B:

- from 72 €/t CO₂ total CO₂ capture cost curves of A and B intersect and it is more interesting to have the technology A (90%) than technology B (70%). In contrast, between 45.5 and 72 €/tCO₂ the technology B is more interesting than technology A;
- looking only at the technology B (70%) around 40 €/tCO₂ capturing or buying allowances at time is equivalent. Above 40 €/tCO₂ the opposite is true.

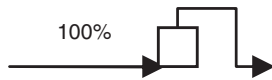
4 IN SITE APPLICATION

In that context of high capture investment costs [8], an operator could decide to invest in capture technology in two step times: one part of the investment during the deployment phase (Phase 1) when the CO₂ price is low (for example at 10 €/tCO₂) and another part during the deployed phase (Phase 2) supposing the CO₂ price increases then (at 100 €/tCO₂). In real life, a low CO₂ price always preclude any high investment cost.

At the end of the large deployment phase (Phase 2): 100% of power plant's flue gas is treated at 90% capture rate, but in the deployment phase (Phase 1) two options of investment are possible *a priori*:

- Option 1: the operator varies the capture rate applied to all the flue gas of the power plant between the deployment and the deployed phase (Fig. 5). The operator treats 100% of the flue gas of the power plant at a reduced capture rate of 70% in Phase 1, then in Phase 2 when the CO₂ price is higher, he switches to 90% of capture rate. Investing in Phase 2 on a second capture to improve the capture rate of the plant (to 90%) is interesting if the capture cost depends on the capture rate – which is the case of hydrates capture technology;
- Option 2: only 50% of the power plant flue gas are treated at 90% capture rate in Phase 1 (Fig. 6). For example one train of two is equipped with capture technology. In Phase 2, additional investment on the second train of the power plan could treat 100% of the flue gas with 90% capture rate.

Phase 1: 100% flue gas treated at 70% capture rate



Phase 2: 100% flue gas treated at 90% capture rate

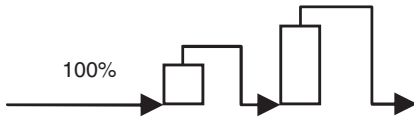
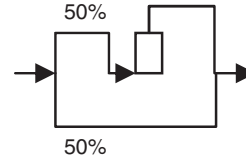


Figure 5

Option 1. Variation of the capture rate.

Phase 1: 50% flue gas treat at 90% capture rate



Phase 2: 100% flue gas treated at 90% capture rate

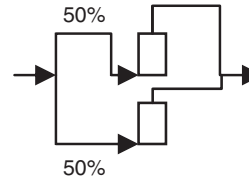


Figure 6

Variation of the flue gas treated.

TABLE 1
Total CO₂ capture cost for different investment phase of capture

Total capture cost (€/tCO ₂)	Reference case		Option 1		Option 2	
	% fumes	Capture rate	% fumes	Capture rate	% fumes	Capture rate
Phase 1 - CO ₂ price 10 €/tCO ₂	100	90	100	70	50	90
CO ₂ price (€/t) = 10		42		30		26
	% fumes	Capture rate	% fumes	Capture rate	% fumes	Capture rate
Phase 2 - CO ₂ price 100 €/tCO ₂	100	90	100	90	100	90
CO ₂ price (€/t) = 100		51		51		51
Average cost Phase 1 & Phase 2		46		40		38

We can calculate the total CO₂ capture cost for the reference case (100% of the flue gas treated with 90% capture rate in Phase 1 and Phase 2), for the Option 1 and for the Option 2 (options described above). CO₂ price in Phase 1 is supposed to equals to 10 €/tCO₂ when in Phase 2 the CO₂ price equals to 100 €/tCO₂.

Total CO₂ capture costs are calculated in Table 1 and illustrated Figure 7 for these three main options of capture deployment. We suppose first, the length time period of Phase 1 is equal to the length time period of Phase 2, *i.e.* in the example 15 years.

The average total CO₂ capture cost of the reference case (100% of the flue gas treated at 90% capture rate during Phase 1 and 2) is higher (46 €/tCO₂) than the two other options (40 €/tCO₂ for Option 1, and 38 €/tCO₂ for Option 2), taking into account a reduce

capture rate (Option 1) or a reduced treatment of the flue gas (Option 2).

It's noteworthy that an actualisation rate will reduce in the same amplitude the actual total capture cost of these three options without modifying the ranking between them (Fig. 8-10). However, the relative lengths of the Phases 1 and 2 have an impact on the total capture costs discounted per phases. With a short Phase 1 (for example 5 years) and a much longer Phase 2 (of 25 years), the total discounted capture cost in Phase 2 is lower (Fig. 10) than the one calculated with equal length phases of 15 years (Fig. 8).

The calculated global discounted capture cost (Phases 1 and 2) shows the same ranking of the technologies as the one calculated (a) without discount rate and (b) with a discount rate (8%) and equal lengths Phases (Fig. 8).

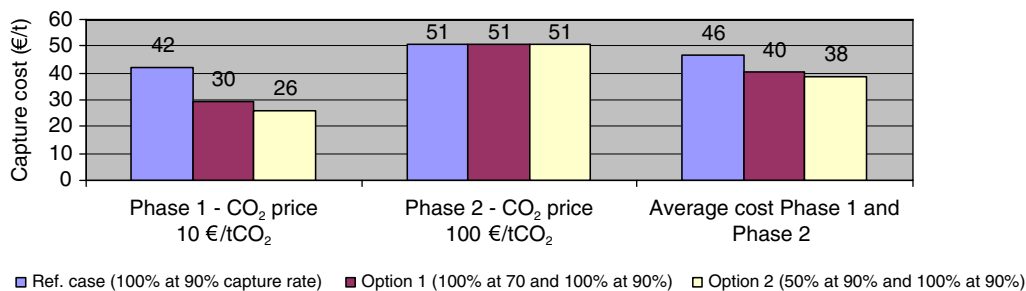


Figure 7

Total CO₂ capture cost per deployment options (without discounted costs).

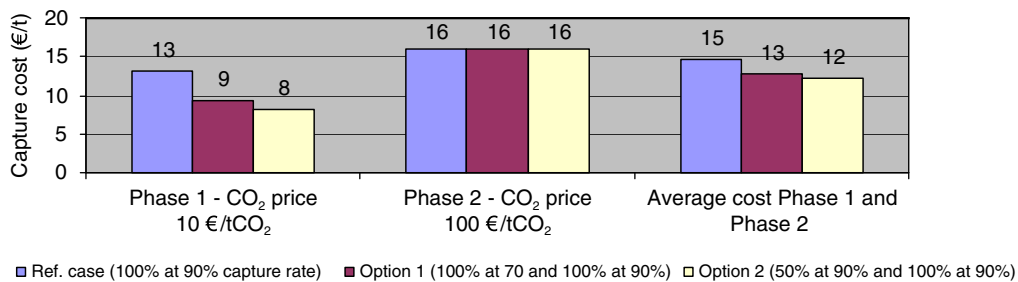


Figure 8

Actual total CO₂ capture cost per deployment options (8% discounted factor, Phase 1 = Phase 2 = 15 years).

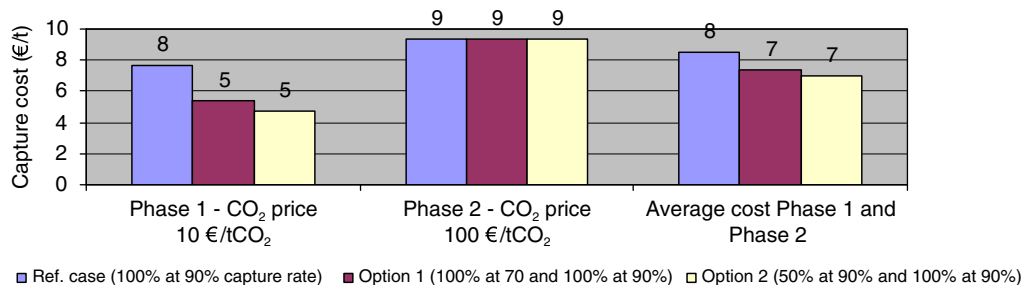


Figure 9

Actual total CO₂ capture cost per deployment options (12% discounted factor, Phase 1 = Phase 2 = 15 years).

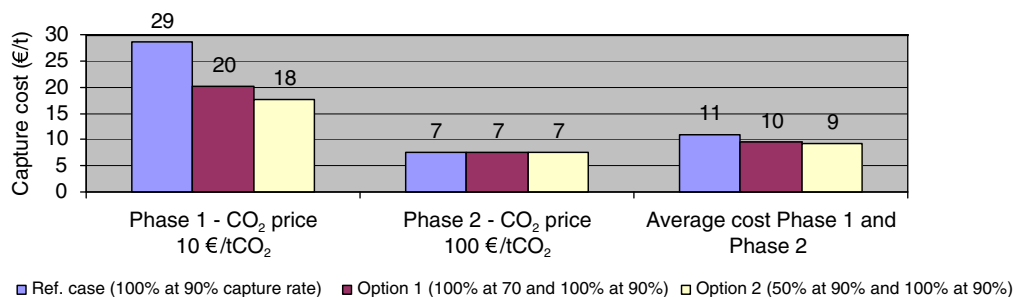


Figure 10

Actual total CO₂ capture cost per deployment options (8% discounted factor, Phase 1 = 5 years, Phase 2 = 25 years).

CONCLUSION

Capture technologies are deployed on large scale according to their discounted purchased quotas cost and their discounted total CO₂ capture cost (CAPEX + OPEX + purchased quotas).

As long as the total CO₂ capture cost is still higher than the purchased quotas cost without capture, no technology will be selected by investors. The first selected (and ranked) technologies on the market will be those below the purchased quotas cost and with the lowest total CO₂ capture cost. However, this total CO₂ capture cost depends on both the capture rate and the CO₂ price on the market.

For a given technology, reducing its capture rate is only profitable if the increase in purchasing quotas cost does not invalidate the decrease in CAPEX/tCO₂. With a lower total CO₂ capture cost at 70% these technologies are the first to compete with the CO₂ price on the market (e.g. technology B in Fig. 4). However these technologies are penalized when CO₂ price ascend and they become not profitable beyond the CO₂ switch price. If you have a way to increase the capture rate or consider a second capture unit to complete the first, this scenario has the merit of spreading investment.

In other words, in the early phase of large CCS deployment, technologies with less than 90% capture rate, as their total CO₂ capture cost remains below the cost of purchasing quotas, may be a less risky in terms of investment. It is highly possible that the CO₂ price remains relatively low until at least 2020, all will depend on international negotiations on climate. Accordingly technologies with lower total CO₂ capture cost would

be strategic to enter at the earliest the capture market which is strongly linked to the price of CO₂.

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