Dossier

This paper is a part of the hereunder thematic dossier published in OGST Journal, Vol. 69, No. 5, pp. 773-969 and available online here

Cet article fait partie du dossier thématique ci-dessous publié dans la revue OGST, Vol. 69, n°5, pp. 773-969 et téléchargeable ici

DOSSIER Edited by/Sous la direction de : **P.-L. Carrette**

PART 1

Post Combustion CO_2 Capture

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Oil & Gas Science and Technology – Rev. IFP Energies nouvelles, Vol. 69 (2014), No. 5, pp. 773-969

Oil & Gas Science and Technology – Rev. IFP Energies nouvelles, Vol. 69 (2014), No. 5, pp. 785-791

DOI: 10.2516/ogst/2013181

Dossier

Post Combustion CO_2 Capture
Captage de CO_2 en postcombustion

CO_2 Capture Rate Sensitivity *Versus* Purchase of CO_2 Quotas. Optimizing Investment Choice for Electricity Sector

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Résumé — Sensibilité du taux de captage de CO_2 au prix du quota européen. Usage du faible prix de quota européen de CO_2 comme effet de levier pour lancer le déploiement de la technologie de captage en postcombustion — La technologie de captage (associée au stockage) de CO_2, appliquée aux centrales thermiques, permet de réduire les émissions de CO_2 à l'atmosphère. Cet article démontre que dans le cas particulier de la phase de déploiement de la technologie de captage de CO_2 pendant laquelle le prix du CO_2 risque de rester faible, capturer moins de 90% des émissions totales de CO_2 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 CO_2, 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* — *CO_2 Capture Rate Sensitivity* Versus *Purchase of CO_2 Quotas. Optimizing Investment Choice for Electricity Sector — *Carbon capture technology (and associated storage), applied to power plants, reduces atmospheric CO_2 emissions. This article demonstrates that, in the particular case of the deployment phase of CO_2 capture technology during which CO_2 quota price may be low, capturing less than 90% of total CO_2 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 CO_2 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% CO_2 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 CO_2 projects. This environmental cost impacts the economic profitability of any CO_2 mitigation projects as any other economic cost parameter [1]. As soon as CO_2 cost becomes mandatory and not optional, as in an emissions trading scheme, CO_2 post-combustion capture projects become very sensitive to the CO_2 price through the associated capture rate. Under some conditions, developed hereafter and exclusively during the large deployment phase, a low CO_2 price is an advantage to reduce the overall CO_2 cost of power plants equipped with post-combustion technology. CO_2 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 markets[1] characterized by high uncertainty [3] and low CO_2 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 CO_2 market is characterized by poor reduction objectives, or is over flooded by free allowances, the CO_2 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, CO_2 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 CO_2 emitted [6]. After 2013, an operator will decide to invest in CO_2 capture technology only if he anticipates that his discounted total CO_2 capture cost during the lifetime of the project (CAPEX + OPEX + quotas purchase on remaining CO_2 emitted) is lower than his discounted total cost of purchasing quotas.
2. If the discounted total CO_2 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 CO_2 capture cost.
3. Total CO_2 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 CO_2 not captured (1- capture rate). The more the capture rate is low and the CO_2 price below capture cost, the more the total CO_2 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 CO_2 avoided.
5. To be in a low CO_2 price economic environment with low expectations to see CO_2 price increasing. European Union Emission Trading Scheme is structurally over allocated and CO_2 price forecasts on the EU-ETS do not exceed 24 €/tCO_2eq 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 CO_2 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 CO_2 at a capture rate below 90% does not mean operators are not concerned by CO_2 environment goal. In contrary, a low CO_2 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 CO_2 LEVERAGE EFFECT OR SWITCH PRICE

Total CO_2 capture cost of an operator is the sum of two parts: the capture cost (CAPEX + OPEX) and the cost of CO_2 quotas purchased (which depends on the percentage of CO_2 not captured and the CO_2 price). Actually, all depend on the structure of this total CO_2 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 "CO_2 switch price". This CO_2 switch price

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

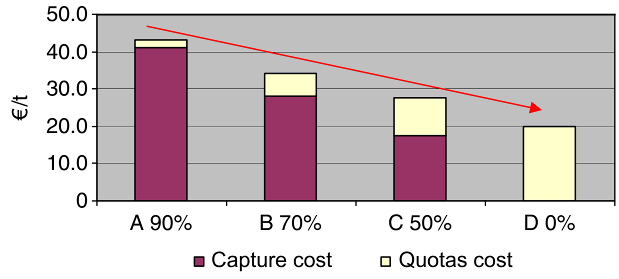

Figure 1

CO_2 price at 20 €/t - total CO_2 capture cost for different capture rates.

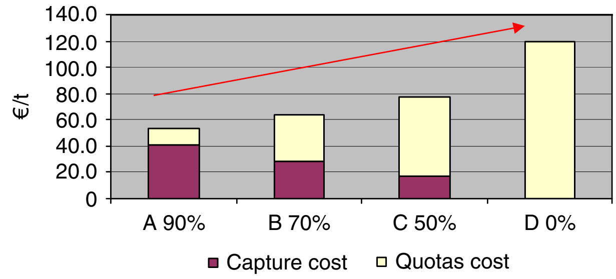

Figure 2

CO_2 price at 120 €/t - total CO_2 capture cost for different capture rates.

is function of two parameters: the capture cost and the CO_2 capture rate. This CO_2 switch price is equal to the CO_2 price under which an operator is more interested to buy quotas than to invest in carbon capture technology. This CO_2 switch price is the CO_2 price for which exchanging CO_2 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 CO_2 capture).

We assume capture cost technologies below 90% of CO_2 captured is less expensive than technologies capturing at 90%. Total CO_2 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 CO_2 capture cost when the quota price increases from 20 to 120 €/tCO_2 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 €/tCO_2, which is below the capture cost, the more the total CO_2 capture cost decreases. At 20 €/tCO_2 it is more interesting to capture at 70% (B) and buy the remaining 30% of allowances in the CO_2 market. In this example, 20 €/tCO_2, it is worth paying quotas than capturing (case D). With a relatively low CO_2 price it is more interesting to have low capture rate technologies.

2.2 Example 2

What happens with a high CO_2 price?

The same capture rate technologies associated to a CO_2 price equals to 120 €/t, the conclusion is completely reversed.

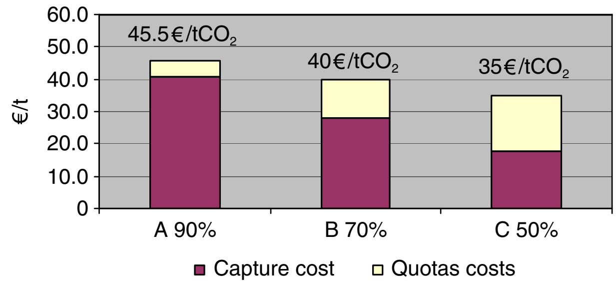

Figure 3

Breakdown capture and quotas costs and CO_2 switch price per capture rate technologies.

Figure 2 shows with a quota price of 120 €/tCO_2: technologies with reduced capture rate are not interesting compared to technology at 90% (A). Depending on the CO_2 price, CO_2 cost share becomes majority in the total CO_2 capture cost. Technologies with low capture rate are not worth with high CO_2 price.

Now, it's clear that for each capture technologies (A, B and C), there is a CO_2 price level that balances the CO_2 capture cost and the cost of purchased quotas. For this CO_2 price level, it is equal to capture or purchase quotas: we call this CO_2 price the "CO_2 switch price".

With technology A (90% capture rate) the CO_2 switch price making the cost of capture equal to the cost of purchased quotas is 45.5 €/tCO_2. In contrast with technology C (50% capture rate) competition with purchased quotas is at 35 €/tCO_2, a much lower CO_2 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%.

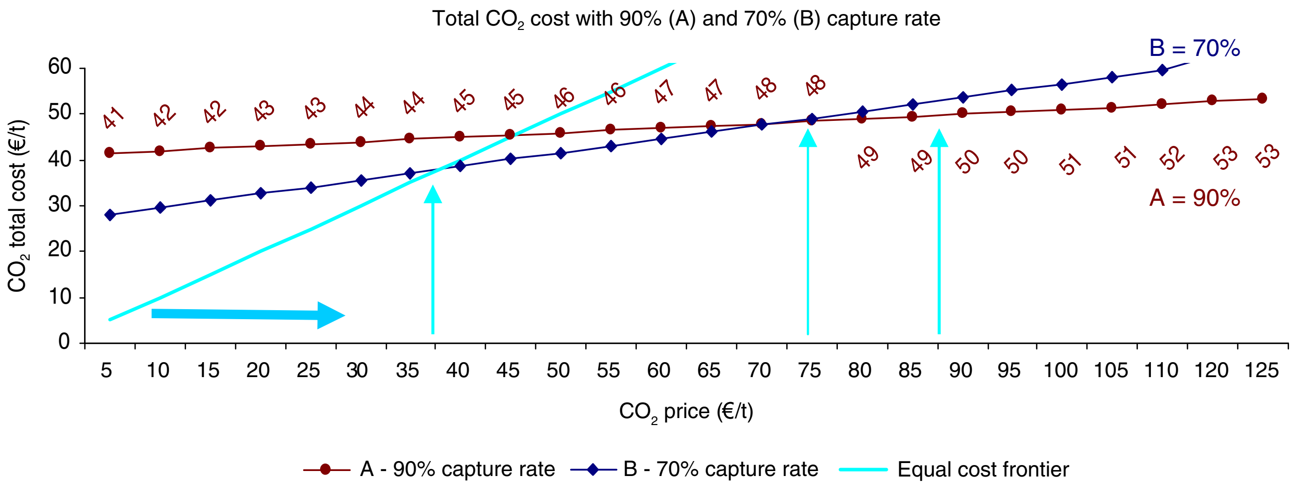

Figure 4

Total CO_2 capture cost with 90% (A) and 70% (B) capture rate.

When varying the CO_2 price (*Fig. 4*), what happens with the total CO_2 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 CO_2 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 €/tCO_2 and B from 40 €/tCO_2:

- at 15 €/tCO_2: total CO_2 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 €/tCO_2 than investing in capture. Left part of the equal cost frontier;
- above 40 €/tCO_2: it's better to capture CO_2 with the technology B rather than buy CO_2 quotas;
- similarly for technology A (90% capture rate) as the CO_2 price is less than 45 €/tCO_2 it is worth to buy quota rather than capturing CO_2.

Rule No. 2: it is important to compare the total CO_2 capture cost between technologies – here between technology A and B:

- from 72 €/t CO_2 total CO_2 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 €/tCO_2 the technology B is more interesting than technology A;
- looking only at the technology B (70%) around 40 €/tCO_2 capturing or buying allowances at time is equivalent. Above 40 €/tCO_2 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 CO_2 price is low (for example at 10 €/tCO_2) and another part during the deployed phase (Phase 2) supposing the CO_2 price increases then (at 100 €/tCO_2). In real life, a low CO_2 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 CO_2 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 dependents 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.

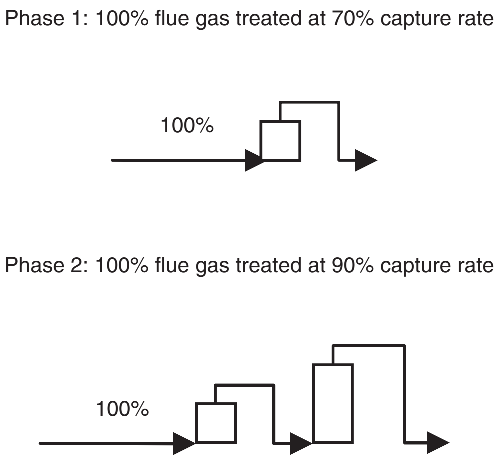

Figure 5

Option 1. Variation of the capture rate.

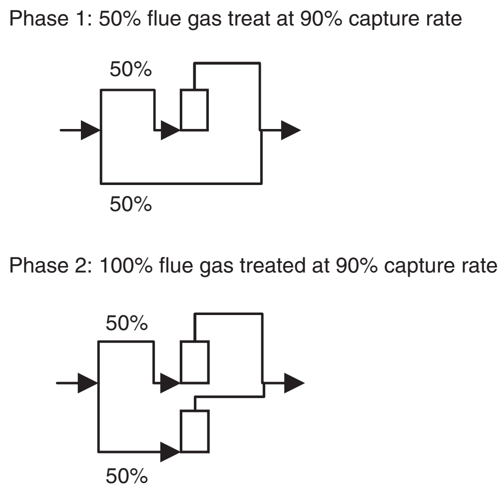

Figure 6

Variation of the flue gas treated.

TABLE 1

Total CO_2 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 CO_2 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). CO_2 price in Phase 1 is supposed to equals to 10 €/tCO_2 when in Phase 2 the CO_2 price equals to 100 €/tCO_2.

Total CO_2 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 CO_2 capture cost of the reference case (100% of the flue gas treated at 90% capture rate during Phase 1 and 2) is higher (46 €/tCO_2) than the two other options (40 €/tCO_2 for Option 1, and 38 €/tCO_2 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*).

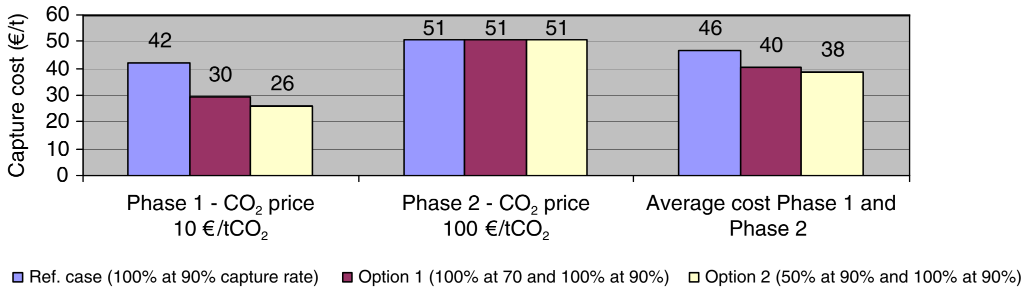

Figure 7

Total CO_2 capture cost per deployment options (without discounted costs).

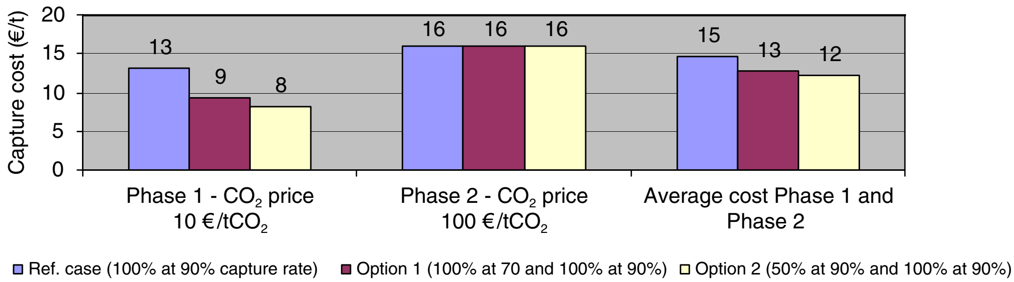

Figure 8

Actual total CO_2 capture cost per deployment options (8% discounted factor, Phase 1 = Phase 2 = 15 years).

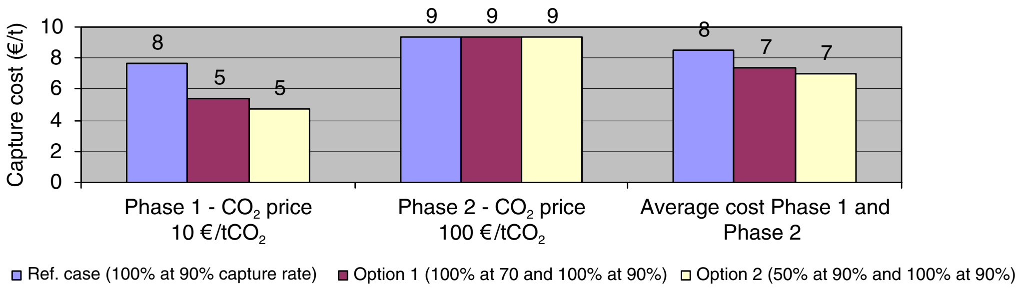

Figure 9

Actual total CO_2 capture cost per deployment options (12% discounted factor, Phase 1 = Phase 2 = 15 years).

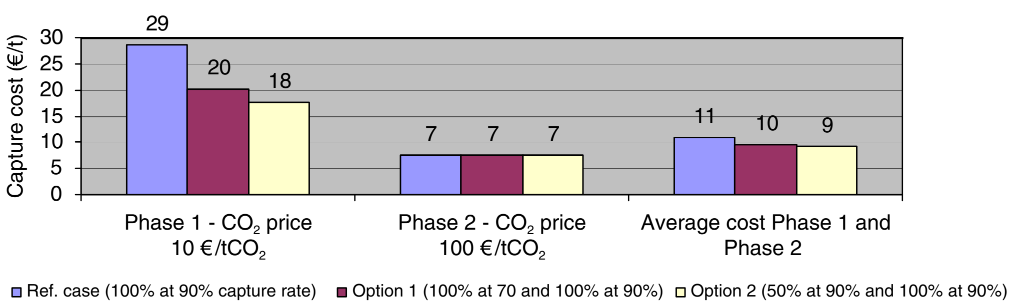

Figure 10

Actual total CO_2 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 CO_2 capture cost (CAPEX + OPEX + purchased quotas).

As long as the total CO_2 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 CO_2 capture cost. However, this total CO_2 capture cost depends on both the capture rate and the CO_2 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/tCO_2. With a lower total CO_2 capture cost at 70% these technologies are the first to compete with the CO_2 price on the market (*e.g.* technology B in *Fig. 4*). However these technologies are penalized when CO_2 price ascend and they become not profitable beyond the CO_2 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 CO_2 capture cost remains below the cost of purchasing quotas, may be a less risky in terms of investment. It is highly possible that the CO_2 price remains relatively low until at least 2020, all will depend on international negotiations on climate. Accordingly technologies with lower total CO_2 capture cost would be strategic to enter at the earliest the capture market which is strongly linked to the price of CO_2.

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Manuscript accepted in July 2013
Published online in November 2013