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Carbon Capture and Storage in the European Emissions Trading Scheme

by

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Carbon Capture and Storage in the European Emissions Trading Scheme

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Abstract: Carbon Capture and Storage (CCS) is a new combination of technologies that may become available to firms that emit CO_2 under the European Union's emissions trading scheme (EU ETS). An example is an electricity producer that captures its CO_2 and transports it to a depleted gas field where it is permanently stored. In the short term, CCS is more expensive than either buying emission rights on the market or reducing emissions within the firm itself. Therefore, the EU provides for substantial subsidies of several billions of euros to installations under the EU ETS that apply CCS. Although it is to be applauded that the EU has avoided several uneconomical alternatives, our analysis shows that these subsidies are inefficient. First, the EU ETS was created to let emitters choose the least-cost option to comply with their emission targets. Policymakers should not undermine this market by picking winners: the CO_2 price should and can determine when CCS becomes attractive. Second, we question the design of the CCS subsidies. For instance, emission rights will be taken from the new entrants reserve to fund CCS projects, which creates a barrier to entry, and allowance auction revenues will be given to CCS users, whereas it is more efficient to use that money for reducing distortionary taxes (such as taxes on labour). Nevertheless, we find it economically reassuring that the EU restricts the subsidies both in scope and in time, which significantly limits the associated inefficiency.

Key words: carbon capture and storage; emissions trading; European Union; incentives; subsidies; auctioning.

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1. Introduction

Under the Kyoto Protocol, the European Union (EU) aims to reduce carbon dioxide (CO_2) and other greenhouse gas emissions by 8% in 2012 below 1990 levels. Although an international climate deal for the period after 2012 is still absent, the EU already decided to reduce greenhouse gas emissions by at least 20% in 2020 (or 30% if other developing countries make comparable reductions). There are several ways to achieve those reductions, for instance by improving energy-efficiency or by using more renewable energy.

To achieve the reductions in a cost-effective way, big emitters in the EU, such as power plants or industries making steel, paper or glass, are allowed to trade emissions under the Emissions Trading Scheme (ETS). This market has been up and running since 2005, based on Directive 2003/87/EC (COM, 2003) that regulates its design until 2012. We will simply refer to it as the 'ETS Directive'.

Soon after the start of the ETS, carbon capture and storage (CCS) emerged on the political agenda as an additional option to prevent greenhouse gases from being emitted. CCS is a new combination of technologies that aims to capture, transport and permanently store CO_2, for instance in a depleted gas or oil field. To facilitate CCS, Directive 2009/31/EC was adopted (COM, 2009a), which we will call the 'CCS Directive'. Moreover, the ETS Directive was amended into Directive 2009/29/EC (COM, 2009b), abbreviated by us as the 'amended ETS Directive', which regulates the design of this market after 2012. A crucial design element is that the latter Directive incentivizes CCS by counting stored CO_2 as an emission redcuction under the ETS.

The EU ETS is a 'cap-and-trade' scheme that allocates emission caps to emitters in the form of tradable emission rights, called 'allowances'. Until 2012, most allowances are given away free of charge based on the historical emissions of the emitters, which is called 'grandfathering'. Article 10 of the ETS Directive specifies that for the period 2005-2007 at least 95% of the allowances should be handed out free of charge and at least 90% for the period 2008-2012. For the period 2013-2020, the amended ETS Directive provides for full auctioning of allowances to the power sector, while the other sectors go from 20% auctioning of the allowances in 2013 to

70% auctioning in 2020 and 100% auctioning in 2027.[1] Carbon leakage sectors, which are exposed to international competition and could therefore relocate to countries without an emission cap, will receive allowances free of charge until 2020.[2]

The CCS Directive provides a legal basis for CCS as an additional mitigation option for emitters under the EU ETS. Moreover, the amended ETS Directive separately adds the capture, transport and storage of greenhouse gases to the (Annex I) list of activities covered by the EU ETS. These Directives provide a legal framework, which is essential to facilitate investments in CCS. According to various policymakers and industry representatives, CCS is a necessary tool to ensure compliance with the increasingly stringent emission targets of the EU (e.g. COM, 2008a: 2; ZEP, 2007: 2).

Next to letting stored emissions count as emission reductions under the EU ETS, the EU has decided to provide additional subsidies for CCS. First, the amended ETS Directive states that Member States intend to use at least 50% of the revenues from auctioning allowances for climate measures, including CCS. Second, this Directive determines that 300 million allowances will be taken from the new entrants reserve of the EU ETS, after which they will be auctioned to fund 12 CCS demonstration projects. If the allowance price is € 10, for instance, those revenues will be (€ 10 x 300 =) € 3 billion. Third, the European Economic Recovery Plan (EERP, 2009) provides for an additional € 1200 million of subsidies for CCS to stimulate economic growth.

The central question of this paper is: how should the CCS option be incentivized under the EU ETS from an economic point of view? This question triggers a number of more specific, related questions. For instance, does the storage of a tonne of CO_2 always free up allowances? Is it necessary to subsidize CCS, now that we have a market price for CO_2? And if additional incentives are required, are they necessary for capture, for transport, for storage or for all of those elements in the CCS chain? And what is more efficient: to use auction revenues for CCS or to use

[1] Although transitional free allocation is possible for electricity producers in Eastern European Member States until 2020, the auctioning rate must be at least 30% in 2013 and will be progressively increased to 100% no later than 2020. This means that after 2020, the auctioning rate for the power industry will be 100% everywhere in the EU.

[2] The European Commission should identify the carbon leakage sectors by 31 December 2009. One possible candidate for free allocation is considered to be the aluminium industry (e.g. Smale et al., 2006). Although free allocation is based on grandfathering until 2012, it will be based on product benchmarks of the 10% most efficient installations in a sector after 2012. It falls beyond the scope of this paper to elaborate on this subtle yet economically relevant difference.

allowances from the new entrants reserve for CCS? By answering those and other questions we want to find out whether the current design of the EU ETS provides economically efficient incentives to stimulate investment in and use of the CCS technologies.

This paper is structured as follows. Sections 2 and 3 present a theoretical framework to find out how CCS works as one of the emission reduction options in an emissions trading scheme. Section 4 is devoted to the analysis of the efficiency of various alternatives to incentivize CCS, including the use of allowance auction revenues under the EU ETS. In section 5 the economic insights obtained are used to evaluate the main characteristics of the current set of incentives for carbon storage under the CCS Directive and the amended ETS Directive. Section 6 draws conclusions.

2. Make, Buy or Store

Before analyzing the design of the CCS and EU ETS Directives, we apply economic theory to see how CCS fits in an emissions trading scheme. Generally, in a market economy, firms compare the costs and benefits of manufacturing a product against purchasing it, which is referred to as 'make or buy'. Specifically, in a carbon market, emitters will compare the costs and benefits of at least three options to reduce their greenhouse gas emissions, which we refer to as 'make, buy or store'.

The first option is to *make* the emission reductions within the firm itself, for instance by installing climate-friendly technologies. The second option is to *buy* the emission reductions, in the form of allowances, from another emitter that succeeds in keeping the emissions below its emission cap. The third option is to *store* the emissions underground, so that they are not released into the atmosphere, by capturing, transporting and permanently storing the pollution in a geological formation, referred to as carbon capture and storage (CCS). In principle, one could say that emitters also have a fourth option, that is to *pay the fine* for non-compliance when CO_2 is released above their emission cap.

Economic theory holds that the emitter will choose the least-cost alternative. To make clear how CCS works in an emissions trading scheme, we have developed a simple numerical example. Suppose that the costs per tonne of CO_2 for the

aforementioned alternatives are as follows: make (€ 30), buy (€ 20), store (€ 40) and pay the fine (€ 100), as portrayed in Table 1.

Table 1: Hypothetical example of compliance costs (€ / tonne CO_2)

Alternative	*Description*	*Costs*
Make	Reduce emissions within the firm	€ 30
Buy	Trade emissions with another firm	€ 20
Store	Put the emissions underground	€ 40
Fine	Pay the fine for non-compliance	€ 100

Before we explain why the cost estimates of Table 1 are not unrealistic, we want to emphasize that the costs of these options are not fixed as they may change over time. First, the costs of reducing emissions within the firm itself are expected to decrease over time, since cheaper abatement technologies will be developed. Second, the cost of buying emission rights from other firms is expected to increase as governments are presumed to implement increasingly stringent emission reduction targets. Third, the costs of CCS are expected to decrease, since in particular the costs of capturing CO_2, which is more costly than transport and storage (e.g. McKinsey & Company, 2008), will decrease as more demonstration projects and cheaper techniques are being developed. Finally, even the fine for non-compliance could be adjusted upwards if governments would be confronted with the situation that allowance prices soar, so that the fine does not sufficiently enforce compliance with the emission caps. If the cost estimates of our hypothetical example are correct, the emitter will choose to buy allowances from another emitter, because this is cheaper than all other options, including CCS.

But how realistic are the aforementioned figures? First, the costs of making the emission reductions within the firm, for instance by improving the energy-efficiency of a power plant, are somewhere around € 30 per tonne of CO_2. Although precise data are hardly available (e.g. IPCC, 2001: 578), we do know that, for instance, in order to force switching from coal to gas in a power plant, it requires an allowance price of € 35 per tonne of CO_2 (Lewis and Curien, 2008). So reducing emissions within the firm should cost somewhat less.

Second, the costs of buying allowances are around € 20 per tonne of CO_2. The prices negotiated in forward sale contracts over 2007 for allowances to be delivered in 2008 ranged between € 12 and € 25 per tonne of CO_2 (Point Carbon, 2008: 7). At mid-2008 the allowance price was about € 25, but at mid-2009 it had decreased to about € 15, largely because of the global economic crisis. McKinsey & Company (2008: 43) expects an allowance price of about € 35 in 2015. In a survey held by *Point Carbon* (2008: 31), climate specialists (both scientists, businessmen and policymakers) expect an allowance price of € 25 to € 35 in 2010 and of € 35 to € 50 in 2020. Obviously, the development of the market price will depend on various factors, including the stringency of future emission caps as well as future oil and gas prices. For example, if oil-linked gas prices would go up, electricity producers may switch to coal, which requires additional allowances and would thus result in higher allowance prices.[3]

Third, although different estimates exist, the costs of CCS are roughly in the area of € 40 per tonne of CO_2. The IPCC Special Report on CCS mentions wide cost ranges of € 20 to € 60 ($ 30 to $ 90) (IPCC, 2005: 11). The IPCC concludes that the costs of CCS are at least somewhere between € 15 to € 20 ($ 25 to $ 30) (IPCC, 2005: 341). Capros et al. (2007: 4) calculate that the costs of CCS are at least higher than € 22. According to Ecofys (2007: 44), the cost range for CCS is between € 30 and € 40, depending on whether it is a stand-alone project (one emitter, short pipeline, single storage site) or a more expensive network project (several emitters, pipeline network, multiple storage sites). In a more recent study, McKinsey & Company (2008: 6) assumes a cost range for CCS between € 60 and € 90 in 2015 (demonstration phase), between € 35 and € 50 in 2020 (early commercial phase) and between € 30 and € 45 in 2030 (mature commercial phase).

For the period 2013-2020, the third phase of the EU ETS, CCS will be unprofitable if the European Commission is correct to expect an allowance price of

[3] Emitters under the EU ETS also have another, related option to cover their CO_2 emissions: they can buy reduction entitlements by carrying out abatement projects under the Kyoto Protocol, either in Eastern Europe via Joint Implementation (JI) or in developing countries via the Clean Development Mechanism (CDM). Although the transaction costs of buying those entitlements are relatively high, for instance because an emission baseline has to be constructed and approved to determine the reductions by estimating future emissions at the project location if the project had not taken place, the price of JI and CDM 'credits' is typically lower than the allowance price, because countries outside the EU usually have cheaper abatement options. At the end of 2007, CDM credits were traded on average around € 17 and JI credits between € 6 to € 10 (Point Carbon, 2008: 19). Until 2012, Member States are only allowed to import 10 to 20 % of those CDM credits in the EU ETS (e.g. COM, 2006: 10), but after 2012 this import limit will be widened to as high as 50% (COM, 2009b: 78).

around € 30 and costs of CCS somewhere between € 50 to € 60 (as reported in a document of the Dutch government, see: BuZa, 2008: 4). Also McKinsey & Company (2008) note an economic gap for CCS in this period, of about € 25 to € 55 per tonne of CO_2. However, they also expect the costs of CCS to drop by around 50% between 2010 and 2030 (McKinsey & Company, 2008: 32-33). After 2020, the European Commission also expects that the costs for CCS will have decreased, so that this technology may compete with emissions trading assuming an allowance price of around € 35 (COM, 2008b: 5-6). CCS may even become competitive much earlier if McKinsey & Company (2008) is right to expect an allowance price of around € 35 even before 2020, or if the Deutsche Bank (Lewis and Curien, 2008) is right to expect an allowance price of as high as € 65 in 2020. This makes clear that it all depends on the relative prices, as well as price and cost developments, of mainly energy-efficiency measures (*make*), allowances (*buy*) and CCS (*store*).

Fourth, and finally, there is still the option of not complying with the emission caps and pay the fine. Article 16 of the ETS Directive not only determines that the emitter has to pay a fine for excess emissions of € 100 per tonne of CO_2, but also that he has to surrender an amount of allowances equal to those excess emissions when surrendering allowances in the next year. Moreover, the amended ETS Directive establishes an inflation correction of the fine after 2012 by requiring an increase of the excess emissions penalty in accordance with the European index of consumer prices.

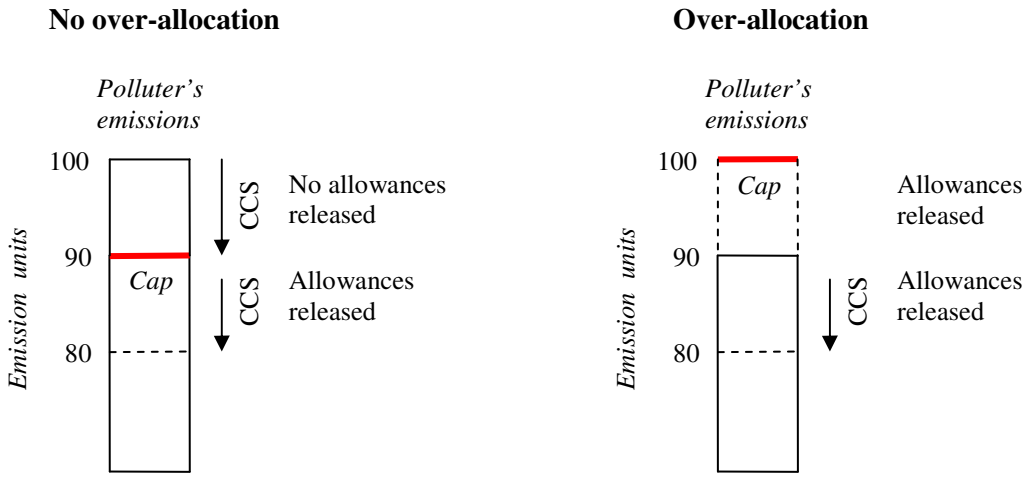
For the near future, it is thus safe to conclude that our hypothetical, somewhat stylistic example of costs in Table 1 will not be that far from reality, if not so much in absolute terms, then at least in relative terms. It makes clear that CCS will be more expensive than emissions trading in the short to mid term. But as we move closer to 2020 and beyond, allowance prices will probably increase and the costs of CCS are likely to decrease, making CCS a competitive alternative for emissions trading in the longer term. For the next years, however, CCS will be more expensive than the other two alternatives of ‘make or buy’.

3. When Storing Emissions Frees Up Allowances

The amended ETS Directive states: ‘The main long-term incentive for the capture and storage of CO_2 (…) is that allowances will not need to be surrendered for CO_2

emissions which are permanently stored (…)' (COM, 2009b: 66). When it comes to analyzing the incentives for CCS, however, it is important to realize that this does not mean that CCS automatically frees up allowances under the EU ETS. Some seem to believe or use wordings which could suggest that underground storage of CO_2 leads to less emissions in the atmosphere and thus automatically implies that allowances are released which then can be sold on the carbon market (e.g. EZ, 2009: 7).[4] However, this is not necessarily the case. First, it depends on whether an emitter in the EU ETS only uses CCS to reduce his emissions to the level of his emission cap, or whether he uses CCS to reduce emissions even further, that is, below the cap. Only in the latter case does CCS free up allowances. Second, it depends on whether an emitter faces stringent emission caps, which is likely in the EU ETS after 2008, or whether allowances have been over-allocated, which has been the situation in the EU ETS before 2008, so that the cap does not force a company to reduce emissions. Again, only in the latter case, CCS frees up allowances. We will explain this below in more detail on the basis of Figure 1.

Figure 1: When CCS frees up allowances (with and without over-allocation)



[4] For instance, in a policy memorandum to the Dutch parliament, the Ministry of Economic Affairs states: '(…) CO_2-reductie als gevolg van CCS [zal] meetellen in het Europese emissiehandelssysteem (ETS). Daardoor zullen bedrijven die CCS toepassen hun emissierechten kunnen verkopen' (EZ, 2009: 7). English translation: '(…) CO_2-reduction by means of CCS [will] count in the European emissions trading scheme (ETS). As a result of this, firms which apply CCS can sell their emission rights. For firms, this leads to a substantial cost reduction for CCS'.

Suppose that an emitter has to reduce its pollution from 100 to 90 emission units, as portrayed on the left-hand side of Figure 1. He currently emits 100 units, but he faces a stringent cap that allows him to emit only 90 emission units. In other words: he has received (or bought) allowances equal to 90 emission units. This means that he has to reduce his emissions, or cover his surplus emissions, with 10 units (in, say, one year time). If he uses CCS to put these 10 emission units underground, no allowances will be released. He simply complies with the cap. In this example, it is assumed that he uses CCS to make that reduction, which is rational only in the case that CCS would be cheaper than buying allowances to cover the deficit. If he brings emissions down to those 90 units by using CCS, he has no allowances to sell.

This changes when he wants to reduce emissions even further than is implied by his cap to, say, 80 units. Suppose he uses CCS to do that. Because he has a right to emit up to 90 units, he will then have 10 allowances to sell. So in the case that an emitter uses CCS to reduce emissions below the cap, allowances are released. It is only rational for an emitter to do this, if the costs of CCS per ton of CO_2 are lower than the allowance price.

The picture is different in the case of an over-allocation of allowances. Over-allocation means that too many allowances have been allocated to emitters, giving them more (instead of less) allowances than they need to cover their emissions. Such a situation is portrayed on the right-hand side of Figure 1. If a polluter emits 90 emission units but receives allowances equal to 100 units, he can sell allowances equal to 10 units without having to reduce emissions by means of CCS or some other abatement option. Reduction measures are only needed when he wants to bring emissions below his actual pollution level of 90 to, say, 80 units. In that case an amount of allowances equal to 10 units falls free. He can do that via CCS, but again this is only rational if the cost of CCS is lower than the allowance price. However, if allowances are over-allocated for the EU ETS as a whole, then there will be no demand for these additional allowances resulting in an allowance price of zero (although a positive price may still emerge if buyers are interested in allowances to bank them for a next commitment period). This means that in the case of over-allocation it is unprofitable to use CCS since the associated costs will be higher than the (almost zero) allowance price.

Several authors have calculated that over-allocation occurred in the first phase (2005-2007) of the EU ETS (e.g. Ellerman and Buchner, 2006; Clò, 2007; Woerdman

et al., 2008). Overall CO_2 emissions released in 2005 by the regulated sectors were about 4% lower than the number of allowances distributed to them. This was caused both by the desire of politicians to start with a modest ETS that facilitated learning and by the successful lobbying of energy-intensive industries who all preferred to be 'long' (as sellers) rather than 'short' (as buyers) on the carbon market. The unfortunate result was that the allowance price dropped to below € 1 during 2007 (namely € 0.03), which also decreased public confidence in the scheme. Fortunately, over-allocation for the EU ETS as a whole is less likely to occur in the future. We expect this to be the case not only because EU Member States have strengthened their emission caps for the period 2008-2012, but also because the EU has set even more ambitious emission reduction goals for the period 2012-2020 (COM, 2007). According to the amended ETS Directive, calculated from the mid-point of the period 2008-2012, the Community-wide quantity of allowances should decrease by 1.74% each year (COM, 2009b: 64).

This not only suggests that the left-hand side of Figure 1 (i.e. the situation of no over-allocation) is probably more relevant in the future than its right-hand side (i.e. the situation of over-allocation), but this exposition also clearly underlines the perhaps obvious observation that over-allocation is not an incentive to stimulate the use of CCS. Only stringent caps stimulate CCS, since these increase the allowance price. This would make CCS more attractive as an emission reduction option. Once again: if the cap is strict enough, CCS does not result in freeing up allowances *above* the cap, but prevents that an emitter needs to buy additional allowances. CCS does release allowances when emissions are reduced *below* the cap. It is of course an important incentive for CCS that the EU ETS considers stored CO_2 as not emitted, but one should not think that CCS always frees up allowances under the EU ETS.

4. Providing Efficient Incentives

The discussion about the incentives for CCS under the EU ETS brings up the question which alternatives to stimulate CCS are economically efficient and which are not. From a theoretical point of view, which we can use as a benchmark to analyze the actual incentives decided upon by the EU, there are at least four (sets of) options discussed in the literature to stimulate CCS after 2012:

- impose a carbon tax instead of using cap-and-trade;
- provide double credits to companies who use CCS (indirect subsidy);
- close the cost gap between CCS and the allowance price (direct subsidy);
- make CCS obligatory.

From an economic perspective, it is crucial to make a distinction between effectiveness and efficiency. Basically, effective means that a certain goal is achieved, whereas efficient means that this goal is achieved at lowest costs. The options sketched above are all more or less effective in stimulating the use of CCS. However, from an economic point of view, the key question is whether each of these CCS incentives is efficient or not. This evaluation follows below.

4.1 Levying a carbon tax

Some authors have proposed to replace the cap-and-trade scheme in the EU by a uniform carbon tax to stimulate CCS. It is argued that a carbon tax would provide a stable price signal which facilitates CCS investments more than the inherently uncertain allowance price (e.g. Jepma, 2006, 2005). Of course, both are economic instruments that attach a price to CO_2 emissions. Moreover, it is correct that a tax gives price certainty, whereas cap-and-trade entails price uncertainty. However, the EU ETS is economically superior to a carbon tax, as we will explain below, so that replacing the first with the latter is actually not a good idea.

It is important to realize, also from an economic point of view, that cap-and-trade provides environmental certainty as a result of the emission ceilings, at least regarding the emitters covered by the scheme (and provided that monitoring and enforcement are effective), as well as an efficient investment incentive for CO_2 reduction techniques. A carbon tax would suffer from environmental uncertainty and would create an inefficient investment incentive. The reason for this is that information is always incomplete on the abatement costs of emitters and on the intensity that energy consumers react to energy price changes (called ‘demand elasticity’). The implication is that the European Commission would become involved in a trial-and-error process of (re)adjusting the carbon tax rate trying to reach the overall EU emission target. This inherent environmental uncertainty under a carbon

tax is an important economic disadvantage, because the ultimate goal of climate policy is to reach an emission target in order to limit the damage from greenhouse gases at a certain emission level. Furthermore, with information on abatement costs incomplete, the actual setting of a carbon tax level would result in inefficient investment in reduction techniques. If the level is set too high, too much investment in reduction techniques, including CCS, would be provoked; if the level is set too low, too little would be invested. Ideally, the cap-and-trade system provides for the economically correct incentives for such investments via the market price of the allowances.

A political economy perspective does not really change that picture. Both cap-and-trade and a carbon tax suffer from lobbying by industry representatives. The EU ETS has seen and will see lobbying by energy-intensive industries in order to receive as much as (preferably free) allowances as possible. A carbon tax would face similar problems (of what economists call 'rent-seeking'). Economic growth tends to increase the consumption of fossil fuels and would thus require a steady upward adjustment of the carbon tax. Resistance from the industry is to be expected every time the tax increase is necessary to attain the emission target.

If the carbon tax rate is set in such a way that it makes CCS attractive, it has the important side-effect that it would almost be a political prescription to CCS as the dominant way for achieving the emission target. As such the system would lock-in the CCS technology for energy producers, while other techniques might be more efficient compared to CCS. This would hinder the invention or further development of other, cheaper technologies.

What remains in an emissions trading scheme is the uncertain allowance price. However, we should not forget that companies are used to dealing with all kinds of uncertainties related to their inputs, such as the oil price. The allowance price is now added to that list. As long as the regulatory framework is stable and predictable, the EU ETS gives the correct price signal to determine when CCS becomes profitable and when investment in that technology is economically efficient. The EU has also decreased price uncertainty by making a transparent commitment in the amended ETS Directive to an increasingly stringent emission cap, which will decline by 1.74% each year.

4.2 Assigning double credits

Some have proposed an indirect subsidy by assigning some form of double crediting to firms using CCS (e.g. ZEP, 2007). An electricity company, for instance, would then receive additional emission rights when it employs CCS. This means that the company not only gets (or buys) allowances to cover its emissions, but also receives additional allowances free of charge for its investment in CCS. This is the first option mentioned in the EU Flagship Programme by the industry-lead European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP, 2007: 3). We will explain below why this is a bad idea from an economic point of view in general and, in particular, why some variants are worse than others.

The worst variant would be if all electricity companies using CCS would get allowances by creating an additional pool of allowances on top of the number of emission rights already awarded. This would effectively increase the emission cap for the power companies and energy-intensive industries in the ETS. This would be a form of over-allocation which is environmentally ineffective, as we have already explained in the previous section, since more allowances are given than what would have been allocated in the absence of CCS. Giving more allowances would also be inefficient, as well as inconsistent, in stimulating CCS. It would mean that companies can raise emissions (because they receive more allowances) in order to reduce emissions (by means of CCS). If allowances are over-allocated to the ETS sectors, there is no incentive to invest in and use CCS, because emissions do not have to be reduced. The firm could use CCS to reduce emissions beyond the emission cap, but that is only attractive if the associated costs are lower than the allowance price. And the problem in a situation of over-allocation is that the allowance price will probably be lower than the costs of CCS, making it unlikely that CCS becomes profitable.

Over-allocation of allowances to the ETS sector as a whole means that this sector has to reduce less. The implication is that the non-ETS sectors, which mainly include agriculture, households and transport, will have to reduce more if a Member State still wants to comply with its emission target. This is problematic from an economic point of view because the literature shows that, on average, marginal abatement costs are higher for the non-ETS sectors than for the ETS sectors (e.g. Criqui and Kitous, 2003; Böhringer et al., 2005; Peterson, 2006). The implication is that total social costs will be higher than without over-allocation. Moreover, the government needs to intensify its environmental policies in order to lower the

emissions for the non-ETS sectors, some of which may well be ineffective and inefficient (like subsidies or trading schemes based on performance standards) (e.g. Woerdman, 2005).

A less inferior alternative is to give additional, free allowances to companies which employ CCS by taking these allowances out of the existing emission space. This means that no additional allowances are created for the ETS sector as a whole, but that they are taken from companies within the ETS sector that do not use CCS. These allowances are then allocated free of charge to companies that do invest in and use CCS. If companies are not compensated for allowances that are taken from them, this would redistribute the (value of the) allowances within the ETS sectors. However, it also implies that non-CCS companies face a higher total payment for their CO_2 emissions than companies that do invest in CCS. This effectively increases the costs for emitting CO_2 for the non-CCS companies. Depending on the market price of the allowances, the extra costs for these non-CCS companies may become so high that investment in CCS becomes necessary. This redistribution scheme may thus imply a near-obligatory investment for companies in CCS. However, if the companies are aware of this, all of them will invest in and use CCS. No allowances will then be redistributed and all companies will then again face the same allowance price. If this price is lower than the costs of CCS, then it is not profitable to use this technology. Companies have then invested inefficiently in CCS, diverting resources from CO_2 reduction methods that are cheaper than CCS.

Another alternative is to take allowances from the new entrants reserve in the EU ETS and to support CCS users, either by giving allowances free of charge or by awarding the revenues from auctioning them. In that case the allowances are not taken from existing firms under the emissions trading scheme, but from firms that want to enter this scheme in the future. Although this would avoid the redistribution effect among existing firms, it would result in redistribution from future firms to existing firms. In other words, it would lead to unequal treatment of existing firms versus newcomers. This is especially relevant in the transitional period in which allowances are still allocated free of charge to a certain extent. It effectively creates a barrier to entry as new firms are confronted with a higher initial investment cost than existing CCS firms.

Our exposition makes clear that an indirect subsidy in the form of double crediting is not the instrument to make CCS economically attractive. Double crediting

distorts the price signal coming from the allowance market and it distorts investment decisions. It also gives companies the incentive to lobby for additional allowances or subsidies to cover the additional costs of CCS. This might even lead to over-allocation, which would further reduce the incentive to use CCS. The idea of taking allowances from the new entrants reserve results in a barrier to entry for new firms, which may hinder competition and innovation.

4.3 Closing the cost gap

Some authors have proposed a direct subsidy by closing the cost gap between producing electricity with and without CCS (e.g. ZEP, 2007: 3). As long as the costs of CCS (are expected to) remain higher than the allowance price, which can be referred to as a 'cost gap', investments in CCS will not come about. The cost gap can be closed by giving subsidies, for instance in the form of state aid. Variants include investment subsidies that fund early demonstration projects, feed-in subsidies that provide a fixed fee per unit of CCS-based electricity, or even a CO_2 price guarantee (Groenenberg and De Coninck, 2008, 2007).

One of the ways in which the cost gap can be overcome is to subsidize CCS by using the revenues that are generated from auctioning the allowances after 2012. Currently, most allowances are given away free of charge, but for the period beyond 2012 the EU will make auctioning the rule rather than the exception (COM, 2009b: 64). It is well-known from the economic literature that auctioning is an efficient instrument to allocate the allowances (assuming perfect competition). Auctioning forces emitters to pay for the damage they cause by emitting greenhouse gases, or as economists say, it prices the marginal CO_2 unit (e.g. Cramton and Kerr, 1998). Although auctioning itself is thus efficient, using the revenues from auctioning, for instance to stimulate CCS, is an entirely different matter.

There are at least five economic arguments *against* subsidizing CCS, which we will elaborate upon below, namely:

- the allowance price should determine the attractiveness of CCS;
- allowance auction revenues should be used to reduce distortionary taxes;
- any subsidy, also for CCS, generates an excess burden for society;
- emitters have an incentive to lobby for too much CCS subsidies;

- carbon capture investments can be recouped via patents.

The first argument against subsidizing CCS is that the allowance price in the EU ETS should determine the attractiveness of CCS. From an efficiency point of view, closing the cost gap via subsidies, also those coming from auction revenues, is generally a bad idea, because they interfere with the market mechanism created under the EU ETS. Subsidization distorts market pricing and might result in an underinvestment in cheaper reduction methods. Companies have emission caps in this market and they are free to search for the cheapest options, including the transfer of allowances, to comply with those caps. Getting an expensive abatement option like CCS subsidized is obviously attractive for those firms, but not for society as a whole. It makes climate policy more expensive, while the idea of emissions trading was, on the contrary, to make it cheaper.

The second argument against subsidizing CCS, by using the revenues from auctioning allowances to stimulate CCS, is that those revenues can be better spent on lowering distortionary taxes in the industry. Using auction revenues to lower labour taxes for the industry, for instance, would generate a so-called 'double dividend' (Goulder, 1995). Auctioning attaches a price to CO_2 emissions (the first 'dividend') and the revenues are used to reduce distortionary taxes (the second 'dividend'). Labour taxes, for instance, are economically distortionary, because they distort the market price of labour. With such taxes, labour becomes more expensive and thus the demand for labour will be less than without taxes. Unfortunately, it is unlikely that the amount of funds generated via the auctioning of allowances will be enough to lower taxes on labour in a substantial way. Nevertheless, lowering distortionary taxes is still more efficient than giving money to an expensive abatement technology such as CCS, in a situation where the allowance price, in the end, should determine this technology's commercial viability.

In this context, it is interesting to know that auctioning itself, which is the primary allowance allocation mechanism after 2012, does not incentivize CCS more than grandfathering would. Free allowances also entail costs for firms, namely the opportunity costs of the emission rights when they are used for covering the emissions

(Woerdman, 2005).[5] Both under auctioning and under grandfathering, CO_2 is priced, and this price crucially depends on the stringency of the emission caps.

The third argument against subsidizing CCS is that any subsidy, also for CCS, implies a welfare loss. Economists call this the excess burden, or deadweight loss, of a subsidy (e.g. Varian, 2003). To explain the theoretical argument, suppose that the subsidy pushes down the market price of the CCS option from € 40 to € 15 per tonne of CO_2. Some companies will then use CCS even though the benefit to them is less than the real cost of € 40. This unneeded expense creates a deadweight loss to society. The CCS subsidy is inefficient because resources are diverted from CO_2 reduction methods that are cheaper than CCS (*store*), which could include – if we use the hypothetical example developed before – the reduction of emissions within the firm itself at € 30 (*make*), and the purchase of allowances at € 20 (*buy*). In other words: such a subsidy results in overuse of CCS and underuse of 'make or buy'.

The fourth argument against subsidizing CCS is that emitters have an incentive to lobby for too much CCS subsidies. Based on the public choice literature, we can expect that companies always have an economic incentive to try to get more CCS subsidies from the government, a type of socially suboptimal behavior which economists call 'rent-seeking'. If we use our hypothetical example once more, CCS is attractive to companies if its price is pushed down below € 20 per tonne of CO_2, say to € 15, but why not lobby for a subsidy that reduces its price to € 10 or even to (below) € 5? Such opportunistic behavior, worsening the already existing welfare loss, is possible in the likely situation that the government has incomplete information on the relative prices of the different emission reduction options for firms.

The fifth argument against subsidizing CCS is that in particular carbon capture investments, also in demonstration projects, can be recouped via patents. The exclusive right granted to a patentee is the right to prevent others from using, making or selling the patented invention without permission. Various patents already exist for carbon capture techniques (e.g. Glessner and Young, 2008: 29). A few patents exist

[5] Instead of using the allowances, the firm could have sold those emission rights. These costs are part of the cost price and thus have to be incorporated in the product price. An electricity producer, for instance, will not sell his allowances only if he can earn the revenue forgone via the electricity price. If the entrepreneur were not allowed to pass on the opportunity costs of the grandfathered allowances, he would incur an economic loss.

for carbon storage techniques in the ocean.[6] Patents are also expected for novel techniques that reduce compression costs for transporting CO_2, in particular where long pipelines are involved. The fact that patents primarily exist for capturing techniques is economically relevant since, according to McKinsey & Company (2008), the costs of capturing carbon (in a range of € 25 to € 32) is higher than the costs of its transport (€ 4 to € 6) or storage (€ 4 to € 12). The implication of the existence and possibility of CCS patents is that third parties cannot freely exploit those technologies. Some argue that cap-and-trade schemes, such as the EU ETS, suffer from an '(…) innovation market failure (…) as they do not provide the incentives needed to compensate innovators for inducing technological change (…)' (Groenenberg and De Coninck, 2008: 655). However, there might be no innovation market failure here. The inventors of a particular capture, transport or storage technique can cover their research and development costs by requiring third parties to pay when they want to make use of the invention. Subsidization is not necessary if it is possible to obtain a patent right for the invention.

Nevertheless, subsidies for CCS demonstration projects may help in two respects. First, it might force technological innovation needed to get CCS started, as private investors are still weary of the risks. As a positive side-effect, it also gives the (additional) signal that the government is truly committed to CCS. Second, it might be easier to disseminate CCS in the industry with this technology in the public sphere. However, the adverse effect is that the industry players will not do the research themselves anymore as they loose the possibility to file a patent for it. Subsidies could therefore discourage further technological development and cost reduction of CCS (Groenenberg and De Coninck, 2008: 659).

4.4 Imposing an obligation

Finally, some have proposed to make CCS mandatory, in particular in the electricity sector (e.g. Henningsen, 2008: 27, 30). This would be a legal obligation rather than an economic 'incentive', because companies would not be free to choose the (cheapest) abatement option. It would obviously stimulate CCS, but it comes at a cost for emitters. Instead of giving companies the opportunity to choose the least-cost option

[6] Although such patents exist, ocean storage (in the water column or on the sub-seabed) is forbidden in the EU under the current CCS Directive.

to comply with their emission caps, which is the essence of emissions trading, they would be forced to choose CCS which is still a higher-cost option, at least in the short term. Mandatory CCS, even when combined with a subsidy (as explained before), is thus inefficient. It basically neglects the market mechanism created under the EU ETS and makes compliance unnecessarily expensive.

A variant of an obligation, discussed in an ECN report by Groenenberg and De Coninck (2007), is a performance standard that requires a minimum percentage of CCS-produced electricity (say, 20 or 50%). They call this a 'portfolio standard with tradable certificates'. A trading component might lower the costs of such an obligation for the companies involved. Such a flexibility element would be an advantage for the firms involved, but a partial obligation is still an obligation. It creates a technology bias in the EU ETS by making CCS partially compulsory, which increases compliance costs. Moreover, a portfolio standard is a complex, additional trading mechanism alongside the EU ETS, which increases transaction costs in the scheme. The bottom line is that a portfolio standard partially reduces the freedom for firms in the EU ETS to choose the abatement option they want.

A full or partial obligation to use CCS to some extent puts the carbon market aside. The crux of the EU ETS is to let emitters determine the means of how to comply with the emission targets. However, mandatory CCS implies a market intervention that transforms one of the means into a goal. This is undesirable, because the goal of climate policy is to meet an emission reduction target, not to reach a certain level of CCS activities per se. Market failures could in principle justify mandatory measures, but with these interventions, market failures are actually created in the EU ETS.

4.5 Evaluating the options

In the subsections above we have outlined several theoretical options to incentivize CCS. We conclude that all four (sets of) options are more or less inefficient. Although it is difficult to rank the alternatives based on the economic analysis in this paper, making CCS obligatory and closing the cost gap between CCS and the allowance price are probably the most inefficient options to stimulate an abatement technology in a recently created emissions trading market. But also providing double credits to companies that use CCS (in particular when over-allocating allowances) as well as

imposing a carbon tax instead of using cap-and-trade are economically unattractive, for reasons already discussed above.

Of course, 'legally enabling' CCS by acknowledging it as a reduction alternative is important, because companies then have as much options as possible to make the most efficient abatement choice. However, 'economically enabling' CCS is unnecessary, because the EU has created an emissions trading market in which the allowance price is the incentive that should determine whether or not CCS becomes attractive. If one finds this incentive for CCS too weak, policymakers should not so much 'pick winners' by creating additional incentives for this particular set of technologies (e.g. Krozer and Nentjes, 2006), but rather strengthen the primary incentive by lowering the emission cap under the EU ETS. This will increase the allowance price and, eventually, close the cost gap for CCS. The EU ETS is clearly the most efficient incentive for CCS.

5. Economic Analysis of the Incentives for Carbon Capture and Storage

In this section, the theoretical insights obtained above are used to evaluate the main characteristics of the CCS Directive (COM, 2009a), against the background of the amended ETS Directive (COM, 2009b). The actual choices are judged on their economic merits in light of the aforementioned possibilities to incentivize CCS. We will show that the policy on CCS in the EU is not always based on first-best alternatives, but we will also argue that the EU has certainly done much to circumvent the worst inefficiencies in its subsidies for CCS.

5.1 Evaluating the incentives

The amended ETS Directive incentivizes CCS, under Article 12 (paragraph 3a), by counting carbon storage as reduced emissions under the EU ETS (COM, 2009b: 78). This is efficient, because legally enabling CCS expands the set of abatement options for firms under the EU ETS. It simply means that when CCS becomes cheaper than all other options, companies are allowed to use it. The Impact Assessment of the European Commission uses an economic model (PRIMES) which confirms that long-term climate policy is cheaper with CCS than without it (COM, 2008c: 4). However,

the EU has also decided to economically enable CCS by providing additional subsidies. How inefficient are they?

First, the amended ETS Directive states, under Article 10 (paragraphs 3 and 3e), that Member States intend to use at least 50% of the revenues from auctioning allowances for climate measures, including CCS (COM, 2009b: 71-72). This Directive writes 'should' and not 'shall', which means that the 50% spending goal is not compulsory. Therefore, Member States have full freedom in choosing how to use the revenues generated from auctioning allowances. If all Member States adhere to their intention to spend part of those revenues on CCS, this direct subsidy would have to be characterized as second-best. First-best would be, as we have argued in the previous section, to lower distortionary (labour) taxes in the industry, thereby generating a 'double dividend' (Goulder, 1995).

Second, the amended ETS Directive determines, under Article 10a (paragraph 8), that 300 million allowances will be taken from the new entrants reserve of the EU ETS, after which they will be auctioned to use the revenues for funding 12 CCS demonstration projects before 2015 (COM, 2009b: 74).[7] If the allowance price is € 10, for instance, those revenues will be (€ 10 x 300 =) € 3 billion. Fortunately, the Directive neither creates over-allocation by handing out additional allowances for CCS users, nor takes allowances from existing firms. However, the measure does create a barrier to entry in the carbon market.

On the one hand, we must acknowledge that the scope of this indirect subsidy, and thus its inefficiency, is limited. The revenues will not be given to all CCS users, but only to 12 CCS demonstration projects, before the end of 2015. Moreover, no such project shall receive support that exceeds 15% of the 300 million allowances available, which implies a maximum of 45 million allowances for each project. If the allowance price is € 10, for instance, the support will be no more than (€ 10 x 45 =) € 450 million. This also restricts rent-seeking by the ETS sectors. On the other hand, we should not be blind to the fact that the subsidy creates an inefficiency. The allowance price and not a subsidy should determine the attractiveness of CCS, whereas any subsidy, also for CCS, generates an excess burden for society. Although the total

[7] The new entrants reserve is 5% of the total emission cap in the EU from 2013 to 2020 (COM, 2009b: 73). It can be calculated, based on COM (2008d: 6), that this reserve is 738,7 million tonnes of CO_2. The 300 million allowances for CCS thus means that almost half of the new entrants reserve goes to CCS.

number of allowances is not increased, it is still somewhat perverse that additional emission rights are sold to finance emission reductions.

Third, the European Economic Recovery Plan (EERP, 2009) provides for an additional € 1200 million of subsidies for CCS to stimulate economic growth. Obviously, the subsidy creates employment and may speed up technological development, but these funds may also be used for other projects with even stronger macro-economic benefits. However, such a macro-economic analysis is not the focus of our paper. Furthermore, *ceteris paribus*, the global economic crisis leads to fewer emissions and lower allowance prices, which not only means that it becomes easier to meet the emission caps, but also that the cost gap between CCS and the allowance price becomes larger. This aggravates the inefficiency of the subsidy. Nevertheless, we do appreciate that the money will not be spent unconditionally. Funding is only possible in 2009 and 2010 and the knowledge generated by the demonstration plant must be made available to the wider industry (EERP, 209: 2, 8, 11). This at least makes the technology developed in these projects available to the industry, but it also lowers the incentive for firms to do the research themselves as they cannot obtain a patent anymore.

Next to the three direct and indirect subsidies discussed above (auction revenues for CCS, allowances from the new entrants reserve for CCS, and economic recovery support for CCS), there is also a fourth measure to stimulate CCS. The CCS Directive requires, under Article 33, that combustion plants with an output of more than 300 megawatts should be capture-ready (COM, 2009a: 119, 128, 129). This weak variant of making CCS mandatory implies that suitable space for capture and compression equipment is made available on the installation site. However, the requirement only applies when making this space available is 'economically feasible', the CCS Directive states. This seems to ensure that the requirement does no economic harm, but it cannot be excluded that the competent authority comes to a different conclusion than the operator of the power plant about the economic feasibility of its capture-readiness. In that situation, which could materialize in case of uncertainty or incomplete information, an unnecessary increase in costs could arise.

Although a capture-ready requirement is mild compared to mandatory CCS, we should not forget that being capture-ready also comes at an additional cost for power producers. An obligation to be capture-ready is necessary, according to the European Commission, to avoid the lock-in of newly built coal-fired power plants

without CCS (COM, 2008b: 5). Although this seems sensible, as these costs will not be freely incurred by any producer, it also 'locks-in' CCS which more or less presupposes that CCS is the solution for coal-fired plants to the climate problem. The obligation should not hold if any other abatement technology is or will be available that is cheaper than CCS.

5.2 Balancing pros and cons

Economically positive about the CCS Directive, among other things, is that CCS is seen as an additional 'means of reducing climate change' under the EU ETS (COM, 2009a: 114) and that 'the relative prices of carbon and CCS' matter (COM, 2009a: 118). This suggests that the EU correctly sees the ETS as the centre piece of its climate policy and regards CCS as an additional option to reduce emissions. The intention of the European Commission was, indeed, to make CCS legally possible and avoid legal uncertainty on the position of CCS (COM, 2008a: 2, 7). This is sensible from an economic point of view, not only because long-term climate policy is cheaper with CCS than without it, but also because legal certainty basically lowers transaction costs for emitters under the EU ETS.

It is also important to observe what is *not* in the CCS Directive. Several inefficient measures, some of which were advocated by the industry lobby or by the environmental movement, were avoided. The European Commission refused to replace the EU ETS with a carbon tax, to create over-allocation by providing double credits to companies who use CCS, or to make CCS obligatory. Extra allowances will be available for CCS users, but they are taken from the new entrants reserve instead of taking them from existing users or creating them on top of the existing stock of allowances. This is the least inefficient choice, although it still means that the price signal from the EU ETS becomes distorted and that a barrier to entry is erected for newcomers.

The biggest economic problem is the choice made by the EU to close the cost gap between CCS and the allowance price. Part of the auction revenues will go to CCS, allowances will be taken from the new entrants reserve for CCS, economic recovery support will be given to CCS, and large power plants will need to be capture-ready. It is inefficient to subsidize this particular set of technologies in an emissions trading market where the allowance price should determine the

(un)attractiveness of CCS. Moreover, there is a risk that market participants will argue that, regardless of the phase of development, subsidies cannot yet be stopped, because the technology is still not fully proven. There is still another risk. Newbery et al. (2009) warn that 12 CCS demonstration projects involves only a small number of plants, which will limit the cost reductions from learning-by-doing, and they expect that the EU will only realize 3 to 4 of such projects by 2015 because of the investment uncertainties involved. The subsidies could thus be ineffective, which may lead to claims for even stronger financial support of CCS.

It is a difficult question how much public money should be invested in CCS demonstration projects and for how many years. Sorrell and Sijm (2003: 430) note that there is a lack of consensus on such issues in the economic literature. Nevertheless, the United Nations published a report in which they warn against subsidies in the energy sector, for instance because they may place a heavy burden on government finances and because they may impede the development of more environmentally benign energy technologies (UNEP, 2008: 30). Where CCS is concerned, *The Economist* (2009: 17-18) comes to even more outspoken conclusions: 'The world is investing too much cash (…) in carbon capture and storage. (…) Politicians should indeed encourage investment in clean technologies, but direct subsidies are not the way to do it. A carbon price or tax, which raises the cost of emitting carbon dioxide while leaving it up to the private sector to pick technologies, is the better approach'. Although we agree with the core message, we think that *The Economist* exaggerates when it even compares subsidizing CCS to 'burning cash'. The amended ETS Directive and the CCS Directive clearly describe the subsidies and, which is crucial, limit them both in scope and in time.

The EU ETS is the most efficient incentive for CCS. If the counterargument would be that the EU ETS does not give a solid price signal, we should keep three things in mind. First, the EU deliberately chose for emissions trading at the start of the new millenium, also because the industry lobbied against a carbon tax and in favour of free allowances, and price uncertainty is inherent to this market. A carbon tax with price certainty might replace that market, but such a tax also has serious problems in reaching the emission targets because it has no caps. Moreover, the EU decided to reduce the emission cap by a predictable 1.74% each year. Companies should thus not use the argument that allowance prices are uncertain to claim additional money for CCS. Second, the EU ETS is a mature market covering more than 10.000 installations

in 27 Member States, making market power unlikely. Furthermore, carbon capture investments can be recouped via patents. Therefore, companies should not use the argument that the ETS market is imperfect to claim additional money for CCS. Third, the allowance price dropped to almost zero in the past, but that was in the learning phase from 2005 to 2007 in which politicians set lenient caps to spare the industry. The second phase from 2008 tot 2012 and the third phase from 2013 to 2020 correspond with the first and second commitment period of the Kyoto Protocol respectively and have much stricter emission caps. Consequently, companies should not use the argument that the allowance price was too low in the learning phase to claim additional money for CCS.

5.3 Considering leakage

A final element that needs to be considered under the EU ETS are the provisions for leakage in the CCS chain.[8] Does leakage of emissions from the transport pipeline or from the storage complex mean that allowances have to handed over to the authorities? The anwer is yes. The original ETS Directive 2003/87/EC (COM, 2003), under Article 4, requires the operator of an installation to have an emission permit. If the operator emits more than what he is entitled to based on his allocated allowances, he is allowed to buy additional allowances on the market to comply with his emission cap, according to Article 12 (paragraph 1). The same permit requirement and trading possibility apply to CCS now that the amended ETS Directive has separately added the capture, transport and storage of greenhouse gases to the (Annex I) list of activities covered by the EU ETS.

If CO_2 leaks from a transport pipeline or from a storage complex, the responsible operator has the possibility to buy allowances to cover those emissions. If he does not do that, corrective measures need to be taken, following Article 16 (paragraph 3) of the original ETS Directive. In that case, the operator has to pay a penalty for excess emissions of € 100 per tonne of CO_2, which will, after 2012,

[8] Some authors associate 'leakage' with 'carbon leakage': the possibility that greenhouse gas emissions rise when energy-intensive companies which are exposed to international competition relocate to countries without an emission cap. Therefore, those authors prefer to speak about 'seepage' when CO_2 is released from the transport pipeline or from the storage site in the CCS chain (e.g. Groenenberg and De Coninck, 2008: 656). The CCS Directive, however, refers to 'leakage', so that we will not use the term seepage in this paper.

increase with the level of inflation (COM, 2009b: 79). In addition, which is at least as important, he must surrender an amount of allowances in the next year equal to those excess emissions.[9]

The bottom-line is clear: not just the emitter, say, a power producer, but also the transport and storage operator(s) must cover any emissions resulting from leakage in their part of the CCS chain with allowances. From a cost internalization perspective, this is desirable. Bode and Dietrich (2008) explain that the market for emission reduction options is distorted if the risk of leakage would be excluded from a CCS investment. CCS would then gain an advantage over other abatement alternatives and society would bear the costs in case of leakage. This external cost should therefore be carried by the polluters.

According to the amended ETS Directive, under Article 10a (paragraph 3), no free allowances shall be given to electricity generators, CO_2 capture installations, pipelines for CO_2 transport or CO_2 storage sites (COM, 2009b: 73). This means that allowances need to be bought at an auction, or on the market, to cover any leakage during the transport or storage of CO_2. So when CO_2 escapes from a transport pipeline, the transport operator (and not, say, the power producer) has to cover this with allowances, which he has to buy.

Before CO_2 is stored, and before a storage permit is granted, the CCS Directive requires the potential operator to proof, under Article 19 (paragraph 1), that adequate provisions can be established by way of financial security to meet all obligations, including those regarding leakage. Member States should decide upon the details as to how this should be done. One such a system is to set up a security trust fund that is filled via premiums per tonne of CO_2 paid by companies that use the storage facility. At least 20 years after the CO_2 has been stored, and when the operator wants to transfer responsibility to the State, he must also make an additional financial contribution to the competent authority, according to Article 20 (paragraph 1) of the CCS Directive, so that costs can be covered by this authority, for instance in case of leakage. The operator must at least cover the monitoring costs that the competent authority has to make for 30 years. Obviously, both provisions will increase the total costs of CCS per tonne of CO_2.

[9] According to the CCS Directive, Article 16, the competent authority may even demand extra and different corrective measures, or take those measures itself and recover the costs from the operator.

6. Conclusion

The ultimate goal of domestic, European and international climate policy is to reduce greenhouse gas emissions. CCS is one of the options to reach that goal. Compared to trading allowances under the EU ETS, CCS is still relatively expensive, but that is likely to change in a few years time. Learning will bring down the costs of CCS and more stringent emission targets will push allowance prices upwards. Long-term climate policy is cheaper with CCS than without it.

These apparently simple observations have two important implications. First, it means that the allowance price is the incentive that should determine whether or not CCS becomes attractive. Second, it means that the ultimate goal of climate policy is *not* to stimulate CCS. That may sound obvious, but some turn goals and means upside down by arguing that CCS needs strong financial support from the government because we will not reach the climate target without it. That is economically wrong because it undermines the market concept of the EU ETS. This market uses emission caps to reach the emission targets and allows emissions trading to reach them at lowest costs. When CCS stays more expensive than either trading allowances or using other emission reduction options for many more years, we should not waste public money to finance the reduction obligations of CO_2-emitting companies.

It is to be applauded that the EU has avoided several inefficient options to stimulate CCS, including mandatory CCS or over-allocation by providing double credits to companies that use CCS. However, it is to be criticized that the EU has chosen to partly close the cost gap between CCS and the allowance price. Part of the auction revenues will go to CCS, allowances will be taken from the new entrants reserve for CCS, economic recovery support will be given to CCS, and large power plants need to be capture-ready. It is inefficient to subsidize this particular set of technologies in an emissions trading market where the allowance price should and can determine the (un)attractiveness of CCS. Also for demonstration projects the subsidies are economically questionable, because the possibility of patenting CO_2 capture and transport technologies undermines the innovation market failure argument. Nevertheless, it is economically reassuring that the EU restricts the subsidies both in scope and in time, which significantly limits the associated inefficiency.

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