CCS in the Baltic Sea Region – Bastor 2

Work Package 4 – Legal & Fiscal Aspects

Elforsk report 14:48

Nils Rydberg and David Langlet

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Preface

David Langlet was commissioned by Elforsk to analyse legal and fiscal aspects of CCS in the Baltic Sea region. The study was carried out jointly with Nils Rydberg who brought expertise on the CCS value chain and its actors. This report is part of the project Bastor2 (Baltic Storage of CO_2), with the overriding objective to assess the opportunities and conditions for CO_2 sequestration in the Baltic Sea Area. The project, which runs from June 2012 through September 2014, was financed by the Swedish Energy Agency, the Global CCS Institute and a number of Swedish industrial and energy companies.[1]

[1] The companies were SSAB, Jernkontoret, Svenska Petroleum Exploration, Cementa, Nordkalk, SMA Mineral, Minfo, Vattenfall, Fortum and Preem.

Summary

There is currently considerable interest in the capture and storage of carbon dioxide (CO_2) within Swedish basic industry. The purpose of the Baltic Storage of CO_2 ('Bastor 2') project is to increase awareness of the potential for geological storage of CO_2 in the Baltic Sea and to identify barriers to carbon capture and storage (CCS) implementation. This report, the main outcome of Work Package 4 (WP4) on legal and fiscal aspects of the Bastor 2 project, provides an analysis of the current and suggested legal framework that could regulate CCS activities in Sweden and the wider Baltic Sea region. The evolution of a well-functioning legal framework for regional CCS operations is expected to be time consuming, with the early identification of potential hurdles critical to all stakeholders.

It is within this context that the report aims to give an accessible account of the legal framework and how it is likely to affect various actors along the CCS value chain. This includes the identification of legal obstacles and gaps as well as analysing the incentives and disincentives that are created by the law in its current form. While using Sweden as its focal point, the report inevitably has its main focus on the EU CCS Directive (Directive 2009/31/EC) and related pieces of (European Union) EU law.

The report utilises a 'decision tree' structure to describe the key interlinked business processes which form the CCS value chain, thereby enabling the identification of ambiguities or gaps in the regulatory system. It then highlights the multiple factors that determine the effect of decisions made along the chain.

In addition to providing an increased understanding of the legal framework and its defining impact on the CCS value chain, the report sets out a number of recommendations. These recommendations are primarily intended as input to the discussions regarding the imminent review of the CCS Directive. Among these are that a clearer definition of 'captured CO_2' ought to be developed and that more consideration should be given to potential market failures and the role of competition authorities in the buildup of CCS infrastructure. In particular, the rules on third party access to pipelines and storage sites were found to be quite vague at the EU level and thereby create room for problematic discrepancies between the Member States.

It was found that the EU Natural Gas Directive could provide a valuable point of reference for transport and storage issues. The responsibility for any transboundary CCS installations or structures is also under-regulated thereby causing significant uncertainties that ought to be addressed by means of relevant guidelines. As to the potential for storing CO_2 captured in the EU outside of the union, something which may be relevant in a regional Baltic context since parts of the Baltic Sea is under Russian jurisdiction, this is found to be impossible without significant amendments to applicable EU law.

It is also concluded that further efforts should be made to enable transport of captured CO_2 by ship, something which currently is highly problematic due to the details of the EU emissions trading system (EU ETS), and that the inclusion of biogenic emissions under the EU ETS may also benefit the deployment of CCS in the Baltic Sea region.

Sammanfattning

Det finns idag ett betydande intresse för avskiljning och lagring av koldioxid (CO_2) inom den svenska basindustrin. Projektet Baltic Storage of CO_2 (”Bastor 2”) syftar till att öka medvetenheten om potentialen för geologisk lagring av CO_2 i Östersjön och att identifiera hinder för genomförandet av CCS. Denna rapport – det främsta resultatet av arbetspaket 4 inom Bastor 2 om juridiska och fiskala aspekter – innefattar en analys av nuvarande och föreslagna regelverk som skulle vara tillämpliga på CCS-verksamheter i Sverige och i Östersjöregionen. Utvecklingen av ett väl fungerande regelverk för regionala CCS-projekt bedöms vara tidskrävande varför tidig identifiering av potentiella hinder är avgörande för alla intressenter.

Mot denna bakgrund är rapportens huvudsakliga syfte att ge en tillgänglig redogörelse för den rättsliga ramen för CCS och hur den sannolikt kommer att påverka olika aktörer längs CCS-värdekedjan. Det omfattar kartläggning av rättsliga hinder och eventuella luckor i regelverket så väl som analyser av de positiva och negativa incitament som skapas av regelsystemet i dess nuvarande form. Även om rapporten tar Sverige som sin utgångspunkt ligger tyngdpunkten i analysen med nödvändighet på EU:s CCS-direktiv (direktiv 2009/31/EG) och relaterad EU-lagstiftning.

Rapporten använder en beslutsträdsstruktur för att beskriva de viktigaste länkade affärsprocesserna i värdekedjan för CCS. Det gör det möjligt att identifiera oklarheter eller luckor i regelsystemet och lyfta fram de många faktorer som avgör vilken effekt som kan väntas av olika beslut längs kedjan.

Utöver att ge en ökad förståelse för den rättsliga ramen och dess avgörande betydelse för CCS-värdekedjan ger rapporten ett antal rekommendationer, främst avsedda som underlag för diskussioner om den förestående översynen av CCS-direktivet. Bland dessa är att en tydligare definition av ”infångad CO_2” bör utvecklas och att större hänsyn bör tas till eventuella marknadsmisslyckanden och den roll som konkurrensmyndigheterna kan spela i uppbyggnaden av CCS-infrastruktur. Särskilt bestämmelserna om tredjeparts-tillträde till rörledningar och lagringsplatser befinns vara ganska vaga på EU-nivå och därmed skapa utrymme för problematiska skillnader mellan medlemsstaterna. I detta sammanhang kan EU:s naturgasdirektiv utgöra en värdefull referenspunkt. Vidare är ansvaret för eventuella gränsöverskridande CCS-installationer eller –strukturer underreglerat vilket orsakar betydande osäkerheter. Det borde föranleda åtgärder t.ex. i form av utvecklande av relevanta riktlinjer. Analysen visar också att lagring utanför EU av CO_2 som infångats inom unionen, något som kan vara relevant i ett regionalt Östersjösammanhang eftersom delar av Östersjön är under rysk jurisdiktion, är omöjligt utan betydande ändringar av EU-rätten. Ytterligare slutsatser är att ansträngningar bör göras för att möjliggöra transport av infångad CO_2 med fartyg, något som för närvarande är mycket problematiskt på grund av detaljerna i EU:s utsläppshandelssystem (EU ETS), samt att inkluderande av biogena utsläpp inom ramen för EU ETS skulle kunna gynna utbyggnaden av CCS i Östersjöregionen.

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List of abbreviations and symbols

ANSI	American National Standards Institute
ASU	Air-Separation Unit
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CCUS	Carbon Capture Utilisation and Storage
CEER	Council of European Energy Regulators
CMU	Carbon Mineralisation Utilisation
CO_2	Carbon dioxide
ECBM	Enhanced Coal Bed Methane
EanaEZ	Exclusive Economic Zone
EFTA	European Free Trade Association
EGR	Enhanced Gas Recovery
EGS	Enhanced Geothermal System
EHR	Enhanced Hydrocarbon Recovery
EIA	Environmental Impact Assessment
EOR	Enhanced Oil Recovery
ESG	Enhanced Shale Gas
EU	European Union
EU Court	Court of Justice of the European Union
EU ETS	European Union Emission Trading System
IEA	International Energy Agency
IED	Industrial Emissions Directive
ILC	International Law Commission
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
O_2	Oxygen
OECD	Organisation for Economic Cooperation and Development
PPP	Public-Private Partnership
SPIRE	Sustainable Process Industry through Resource and Energy Efficiency
TEU	Treaty on European Union
TFEU	Treaty on the Functioning of the European Union
TPA	Third Party Access
UNCLOS	United Nations Convention on the Law of the Sea

1 Introduction

1.1 General remarks

There is currently considerable interest in the capture and storage of carbon dioxide (CO_2) within Swedish basic industry. The interest comes mainly from large companies in the cement, metallurgy and refining industry, but also from parts of the energy industry. Interest in carbon capture and storage (CCS) from industries, such as the cellulose industry, that use large volumes of biofuels, is likely to grow if sufficient incentives come into existence. Currently capture of CO_2 from biofuels is not recognised under the EU's emission trading system (EU ETS)[2] meaning that there is no price on such emissions and thus no economic gain from reducing them.

The purpose of the Baltic Storage of CO_2 ('Bastor 2') project is to increase awareness of the potential for geological storage of CO_2 in the Baltic Sea and to identify barriers to CCS implementation. Thereby, the project will provide insight for both the authorities and the industry for strategic decisions about carbon capture and other measures to reduce greenhouse gas emissions in an environmentally responsible manner.

In the longer term, the project will also lay the groundwork for possible future commercial development of transport and storage of CO_2 as part of efforts to facilitate the deployment of CCS in the region in cooperation with other countries. The vision is the development of common cross border infrastructure for transport and storage of CO_2 in the Baltic Sea region. The evolution of a well-functioning legal framework for regional CCS operations is expected to be time consuming for which reason the early identification of potential hurdles is critical to all stakeholders.

This report – the main outcome of Work Package 4 (WP4) on legal and fiscal aspects of the Bastor 2 project – provides an analysis of the current and suggested legal framework that would regulate CCS activities in Sweden and the wider Baltic Sea region. Using Sweden as a focal point, the report includes a significant focus on the EU CCS Directive (Directive 2009/31/EC) and related pieces of EU law and their implementation by relevant EU Member States. The report's core aim is to give an accessible account of the legal framework and how it is likely to affect various actors along the CCS value chain. This includes the identification of legal obstacles and gaps as well as analysing the incentives and disincentives that are created by the law in its current form. Key to doing this is to understand the dynamics of the CCS value chain from capture to storage and enable the applicable rules to be viewed in relation to this dynamics. The analysis also includes legal aspects of the classification and potential commercial use of captured CO_2 as well as issues pertaining to third party access to common transport and storage infrastructure with a focus on what (dis)incentives are created through existing rules (or the lack thereof) in this area. Since regional, and thus transboundary, CCS solutions are likely to be needed to make CCS feasible in the region the legal and fiscal impediments to transboundary movements of CO_2, above as well as below ground, are another important element of the analysis. In this regard particular attention is given to the implications of the EU-Russian border in the Baltic Sea. Another consequence of the regional nature of the envisioned CCS infrastructure is that the extent to which the regulatory framework is harmonised between the countries in the region becomes an important issue which is dealt with as part of the assessment of regulatory obstacles to CCS deployment.

In addition to increased understanding of the legal framework and its defining impact on the CCS value chain the report deliverables include a number of recommendations, primarily intended as input to the discussions regarding the imminent revision of the CCS Directive.

1.2 Report structure

Immediately following this first, introductory Chapter is a chapter on Methodology explaining the research approach, focusing on issues where business activities interface with the legal environment.

The third Chapter, Legal premises, accounts for the status of implementation of the CCS Directive in the legal orders of the Member States concerned. It also describes the relationship between EU law and the

[2] The EU ETS is based on Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community (as amended) but also comprises several other legal acts dealing with specific issues such as monitoring, verification and reporting of CO_2 emissions.

legal orders of the respective Member States and tries to define the regulatory autonomy that remains for the individual States in relation to the CCS Directive and related legal acts, thereby establishing to what extent EU law harmonises the regulation of CCS activities

Chapter four, The CCS value chain, wraps the concerns and observations that constitute the core of the assessment. It introduces the CCS value chain and describes initially the approach taken to it, including the decision tree in the shape of flow charts that is used to describe the value chain and visualise the context in which the specific issues addressed are imbedded. It then goes on to analyse the different parts of this chain, including capture, transport and storage.

The fifth Chapter, Transboundary Issues, deals with some issues brought up by the transboundary nature of the envisioned CCS chain in the region. This includes the preconditions under EU law and international law for exporting captured CO_2 for storage outside of the EU, as well as the legal implications of transboundary migration of CO_2 once it has been injected into a storage site.

The final Chapter summarises the conclusions and recommendations made in the report and also sets out some recommended considerations for the planned revision of the CCS Directive.

The report also contains an appendix in which some important terms are defined and elaborated.

2 Methodology

The present report deals with the CCS value chain and a number of associated questions. Geographically it is limited to the States bordering the Baltic Sea and has the Swedish legislation as its main focal point. Nonetheless several issues are by necessity dealt with at EU and international levels, eg because they are regulated by means of EU- or international law, for which reason the conclusions are relevant also beyond the Baltic Sea region. The conclusions rest on analyses of applicable law, and reviews of pertinent academic literature and various reports – including those generated within other parts of the Bastor 2 project. In addition, interviews have been were carried out with key persons at some pertinent authorities and one company. Data on the respective EU Member States' implementation of the EU CCS Directive is, except for the case of Sweden, derived from official EU (or other) publications.

As demonstrated by (Jakobsen, et al., 2008), the principles of value chain construction provide a useful methodology for CO_2 chain analysis that is capable of taking account of variable perspectives and needs at required levels of detail.[3] Following these principles this report utilises a decision tree structure to describe the key interlinked business processes which form the CCS value chain.

A value chain can be defined in many ways, eg as: 'a sequence of activities required to make a product or provide a service' (Schmitz, 2005, p. 4), as 'internal activities a firm engages in when transforming inputs into outputs' (Insight, 2013) or as intended 'to separate the business system into a series of value-generating activities' (Business Knowledge Center, NetMBA, 2002-2010). However, definitions of decision trees all tend to draw on *Competitive Advantage* by Michael Porter (1985). For our present purposes the most useful and informative definition is that a decision tree is '[a] schematic tree-shaped diagram used to determine a course of action. Each branch of the decision tree represents a possible decision or occurrence. The tree structure shows how one choice leads to the next, and the use of branches indicates that each option is mutually exclusive. A decision tree can be used to clarify and find an answer to a complex problem. The structure allows users to take a problem with multiple possible solutions and displays it in a simple, easy-to-understand format that shows the relationship between different events or decisions. The furthest branches on the tree represent possible end results.' (Investopedia, 2014)

In this report the decision tree is in the shape of a flowchart and embeds the overall structure of the CCS value chain. This approach facilitates dealing with the multidimensional problems which the CCS value chain raises. The report aims to provide a perspective on the complexity of the legal environment that defines the economic preconditions for CCS operations. It also provides a proactive view to incipient problems along the value chain. The technique can also be used to describe material flow that may correspond to the pertaining management and control measures of the physical CO_2 flow associated with CCS.

The value chain as a decision tree allows analyses of multiple variables or effects and an advantage of the chosen approach is that the reader can observe processes in either direction along the CCS value chain. It also has the capacity to expose relationships that are beyond simple one-cause-one-effect routes. It may further enhance the ability to identify ambiguities or gaps in the regulatory system and highlight the multiple factors that determine the effect of decisions made along the chain. (de Ville, 2006, p. 8) The assessment focuses not solely on the nodes[4] but also on the connecting transition intervals.

CCS can be seen as a construct of interlinked node systems. Generally CCS is a wide concept involving several types of CO_2 sources with several alternative ending points which entail different levels of sequestration permanence. However, the EU CCS Directive, ie the main piece of legislation on CCS operations affecting most States around the Baltic Sea, has a much narrower approach by applying only to certain methods of sequestration and having a restricted territorial scope. When viewed in connection with the EU emissions trading system (EU ETS) there are also significant restrictions of the means of transport that may be employed in a CCS chain for it to be fully recognised under EU law. The present report builds on but also to some extent problematises this narrower understanding of CCS.

[3] The methodology includes the whole CO_2 chain; CO_2 source, CO_2 capture, transport and storage in aquifers or in oil reservoirs for enhanced oil recovery which form a sequential construct of value-generating activities.

[4] A labeled point in a tree diagram at which subordinate lines branch off.

In the EU regulatory framework the core notion of captured CO_2 has a rather clear endpoint, ie the storage, but the legislation lacks in clarity as to the exact point when CO_2 is to be regarded as captured. Whereas the EU ETS deals with the operation of the cap and trade system and defines who is covered by it the CCS Directive regulates storage and indirectly to some extent capture of CO_2 and transport as processes. None, however, is very clear on the exact entry of captured CO_2 in the system. When the CCS legislation steps in, captured CO_2 already exists. One of the objectives of the report is therefore to assist in finding and defining the starting point of the captured CO_2 as relevant for the CCS value chain. Similarly, identification of the divergence points in cases where captured CO_2 ceases to be regarded as captured in the light of the EU ETS and the CCS Directive are highlighted in the report. It is also an important task to make the distinction clear between those potential operators along the CCS value chain who are covered by the EU ETS/CCS regime and those who are not and the implications of this.

The motive for drawing the comprehensive picture with the help of a CCS value chain is that it facilitates the linking of the legal regime defined by the EU ETS and the CCS Directive to business perspectives. After all, as the initiative of CCS deployment is in the hands of enterprises the assessment approach will be based on this premise. However, the picture in the form of a decision tree, the CCS value chain as illustrated in the Figure 2, will provide a robust platform for standardised reviewing by any party concerned.

The comprehensive picture drawn introduces risks or uncertainties to viable business operations within the limits of the report's objectives. It incorporates the regulatory framework and satisfies the business perspectives providing a context where the complexities of the CCS topics are projected. The principle of a CCS value chain univocally connects to the EU ETS and CCS Directive. The initial generic system boundary is a CO_2 emitting plant covered by the EU ETS Directive to which then a system with CCS is added. The flows of inputs and outputs considered in the system are those needed to produce a unit of end user product.

The incorporation of the production input factors – fuel, labor, raw material and capital – and output – the end-user product – is intentional as it defines the system boundary in a systematic manner as codified in the International Standard ISO 14044 (2006) on life cycle analysis (LCA). (American National Standards Institute, ANSI, 2014)[5] The idea is to provide as the first step a 'business as usual' base line that can be extended with further development towards CO_2 capture or complete CCS deployment. The first is illustrated in Figure 1 and the extension, including the base line, is illustrated in Figure 2. The chosen approach allows us to define the base line CO_2 output in relation to end user product output with related quantifiable business activity in comparison to the same system extended with CO_2 capture. This allows robust and systematic evaluation of the implications of different CCS application options in an environment where substitution or switching of energy carriers, other industrial processes or end user products is a reality.

[5] ISO 14044:2006 specifies requirements and provides guidelines for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, relationship between the LCA phases, and conditions for use of value choices and optional elements. ISO 14044:2006 covers life cycle assessment (LCA) studies and life cycle inventory (LCI) studies.

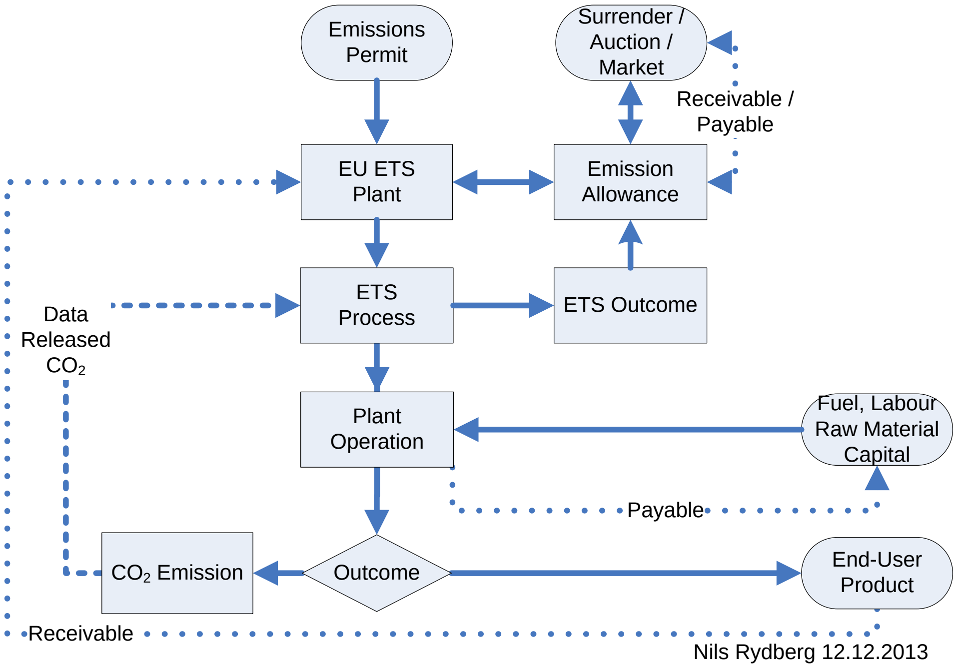


Figure 1

The CCS value chain links directly to EU ETS and CCS related key business processes but does not prejudge the type of industries – which may be paper and pulp, cement, metallurgy, refining and energy industry – involved. In the text the CO_2 emitters are collectively referred to as 'CCS plant' or 'point source'. The CCS value chain is robust, due to diversifying the characteristics of the CO_2 exhaust streams as defined later in the text, against the possibilities to greenfield[6] or retrofitting investment on CCS or to selective CO_2 capture from multiple CO_2 emission streams. This enables purpose oriented use of the CCS value chain analysis to a) a non-incremental or b) an incremental CCS chain analysis. The first

(a) can be used to assess a new plant or retrofitting capture total CO_2 exhaust stream(s); the second (b) to consider a given CO_2 exhaust stream capture investment against pragmatic business decision making. (Jakobsen, et al., 2008, p. 442)

[6] A type of venture where finances are employed to create a new physical facility for a business in a location where no existing facilities are currently present.
See further: http://www.businessdictionary.com/definition/greenfield-investment.html#ixzz35AjiYD2T

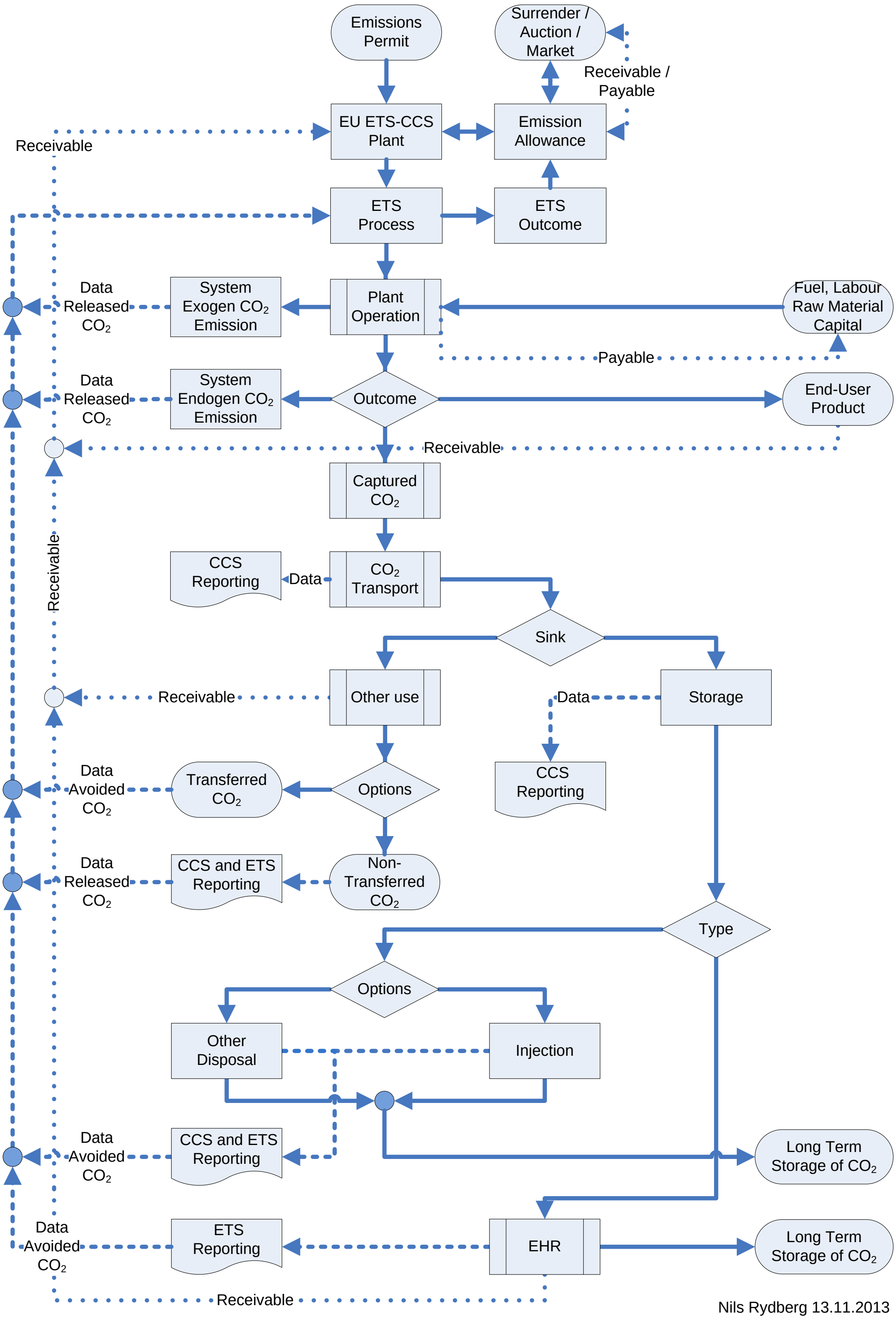


Figure 2

The CCS value chain builds up from five logical components: legal regime, source, capture, transport and sink. The first logical component, the ‘legal regime’, includes the EU ETS processes. The related six nodes revolve around the CO_2 emission issues which can be observed in Figures 1 and 2. With these annually reviewed processes a plant guarantees its operational existence. Due to the characteristics of the demand-supply chain[7] it is reasonable to amalgamate the 'source' and the 'capture' into one component 'Plant Operation' which in turn is then zoomed. Thereby the interface to 'captured CO_2' can be exposed. The third logical component, 'transport', is a system of chained logistics solutions which involve several operators, factors and territories. Due to the multiple variations and the complexity of far reaching related issues transport is depicted on the top level with branching options and as a node in a sub-process. The fourth logical component, 'sink', is dispersed to the ends of each transport route with attendant consequences for the outcome of the ETS process. In other words, the effects of the optional sinks are described as ending nodes and there are always two ending nodes no matter what route 'captured CO_2' may take. Thus the CCS value chain follows all the known possible routes that captured CO_2 may take to the very end of the chain. It incorporates the end-user product as well as the relevant EU ETS and CCS related money and information streams.

The presumption of the system is based on the idea that one or more actors, which do not necessarily have to be solely CO_2 emitters, are considering investing in CCS. The assessment draws on the outcome of work package 2 (WP2) of the Bastor study, ie the results of the geological analysis. However, the regulatory perspective pursued in this report is mostly focused on the capture and storage phases of CCS although some significant issues regarding what constitutes legally viable storage sites are also addressed. Storage as part of so called enhanced oil recovery (EOR) is also addressed as an alternative to storage in not previously used geological formations.

Issues relating to technology and infrastructure are addressed only to the extent that has been deemed necessary to enable the regulatory and value chain analyses. Some topics that could be of relevance, including financial instruments relating to CO_2 storage operations and industrial mineralisation as an alternative sequestration option are not addressed in the report due to time constraints and the way that the objectives of the Bastor 2 project have been defined.

The time line of the CCS value chain can be perceived as one EU ETS emission allowance cycle, twelve months in other words. However, the time perspective plays no role in the assessment. The CCS value chain is a never-ending loop where the number of loops is not restricted as such but by the means of ETS processes that imbed different types of emitter specific legal regulations. The details of the ETS process are, however, intentionally excluded from the analysis since their examination would not add value to the assessment. Concerning the EU ETS scheme the assessment deals purely with CO_2 related issues.

[7] Demand-supply chain is based on a customer's order which the seller receives and which triggers the related processes that in the end outputs an end-user product. The processes' workloads affect the whole business input (production factors) and output (emissions and end-user product) performance.

3 Legal premises

3.1 Implementation of the CCS Directive in the Member States concerned

There is a far-reaching obligation incumbent on EU Member States to ensure that the various elements of EU law become effective. According to Article 4 (3) of the Treaty on European Union (TEU) the Member States shall take any appropriate measure to ensure fulfillment of the obligations arising out of the Treaties or resulting from the acts of the institutions of the Union. The latter includes directives such as the one on CCS ('the CCS Directive'). The Member States are also generally obligated to facilitate the achievement of the Union's tasks and to refrain from any measure which could jeopardise the attainment of the Union's objectives. These requirements have been elaborated by the Court of Justice of the European Union ('the EU Court') which, inter alia, has established that when an activity, such as the geological storage of CO_2, requires a permit under EU law the Member States are obliged not only to set up a permitting system but also to make sure that the system is actually applied and complied with, in particular by conducting appropriate checks and ensuring that operations carried out without a permit are actually brought to an end and punished (Case C-494/01, para. 117).

At the current stage however, when very few CCS activities above experimental scales are yet in place within the Union, the issue of the Member States' compliance with the EU's CCS legislation is mostly formal and primarily concerns the correct and timely transposition (ie implementation) of the CCS Directive in the respective national legal orders of the Member States. Directives are not as such applicable in the Member States – save for the fact that specific provision may acquire so called *direct effect* under certain conditions[8] – but must be implemented in national law in order to become effective. They are binding as to the result to be achieved rather than with respect to the particular forms for achieving that result (Art. 288 of the Treaty on the Functioning of the European Union, hereafter 'TFEU'). Thereby they leave considerable leeway for the individual Member States to achieve the results by means that are appropriate within the context of their own legal and administrative structures. However, the implementation must take an appropriate legal form. Mere administrative practices, which may be changed by the authorities concerned, are not regarded as constituting proper fulfillment of a Member State's obligations (Case C-381/92, para. 7).

The EU Commission is tasked with overseeing the application of EU law under the control of the EU Court (Art. 17 TEU) and to that end the Member States are required to report to the Commission on their transposition of directives. In the specific context of the CCS Directive, the Member States were required to bring into force the laws, regulations and administrative provisions necessary to comply with the Directive by 25 June 2011 (CCS Directive, Art. 39(1)). They are also required to submit to the Commission every three years a report on the implementation of the Directive. The first such report was due to be sent to the Commission by the end of June 2011 (CCS Directive, Art. 27).

In actual fact these first reports were delivered to the Commission between July 2011 and April 2013 and fed into the Commission's first report on the implementation of the CCS Directive published in February 2014 (Commission 2014).

Based on these communications the Commission decides from case to case whether it needs to take action against a particular Member State in order to ensure compliance with the Directive. If the Commission is not satisfied with the information that has been provided by a Member State the first step is for it to enter into informal consultations and request further information. Subsequently, and if needed, it may issue a so-called *reasoned opinion* in which it describes the non-compliance of the Member State and sets out a deadline after which it may bring the Member State to the EU Court unless it has received a satisfactory explanation before that date (Art. 258 TFEU).

It is not at all uncommon for the Commission to initiate so-called infringement procedures against Member States for missing the deadline for transposing a directive. However, the CCS Directive seems to have been particularly challenging.

By the deadline in June 2011 only a few Member States had reported either full or partial transposition and the Commission sent letters of formal notice to 26 Member States. The obstacles to transposition encountered by Member States have involved eg widespread public opposition to CCS and problems

[8] On this notion and its implications see eg **Invalid source specified.**, Chap. 8, or (in Swedish) **Invalid source specified.**.

related to complex division of powers between regions and central government affecting the ability to put the required rules and regulations in place (Armeni 2012).

By October 2013 all Member States had notified transposition measures and the Commission closed 19 of the 26 infringement cases by November 2013. Although the vast majority of Member States had completed transposition of the Directive a handful, including Sweden, had at that time not yet notified complete transposing measures (Commission 2014, p. 2-3).

Since then, however, Sweden has adopted a government ordinance on geological storage of carbon dioxide (Förordning (2014:21) om geologisk lagring av koldioxid) and communicated its transposition measures. The national legislative measures communicated by the Member State to the Commission in relation to the transposition of the CCS Directive are public and available online.[9]

Against this background it may be concluded that the Baltic Sea coastal States that are also EU Member States, ie all except Russia, have by now taken measures to implement the CCS Directive.

It is important to note that although Member States need to implement the CCS Directive they are not actually required to allow the activity with which the Directive is primarily concerned, ie geological storage of CO_2. If a Member State does not allow for such storage there is no need to establish a procedure for assessing applications for storage permits. Therefore, the action a Member State must take to correctly transpose the CCS Directive varies depending on whether it opts for allowing geological storage under its jurisdiction or not.

In this context it should be noted that whereas most Member States allow geological storage of CO_2 Finland and Estonia have opted for not allowing such storage (Commission 2014, p. 3.). Finland has prohibited all geological storage of CO_2 – except storage of volumes below 100.000 tonnes for research purposes or for development and testing of new products and processes – within its territory or below the seabed in its exclusive economic zone.[10] Sweden on the other hand recently, in connection with the adoption of its Ordinance on geological storage of carbon dioxide, lifted a previous ban on storage in the seabed. Storage operations are now in principle allowed in the Swedish economic zone and also in areas beyond one nautical mile seaward of the baseline in Sweden's territorial waters provided that the area is not part of a real estate (§10 of the Ordinance).

With respect to the Baltic area it should also be noted that Germany has restricted the annual quantity of CO_2 that may be stored to 4 Mt CO_2 as a national total and 1.3 Mt of CO_2 per storage site (Commission 2014, p. 3.).

3.2 Harmonisation and the right of Member States to adopt stricter rules

The extent to which the CCS Directive and other EU legislation pertaining to CCS operations harmonise the legal conditions and thus prevent individual Member States from adopting rules that differ from the ones the EU has agreed is an important issue. Not least since CCS operations may have such strong transboundary elements and thus be subject to the jurisdiction of two or more Member States. There are many dimensions to the issue of harmonisation.

From an environmental and health perspective harmonisation may be desirable since it guarantees – at least formally – that no Member State undercuts another in terms of the level of protection, either in order to gain some competitive advantage for its domestic industry, or as a consequence of a generally more lax approach to environmental and health concerns. However, if a Member State is not satisfied with the level of protection achieved by EU law harmonisation may prevent it from rectifying this by supplementing EU law with its own more stringent standards. Complete harmonisation also largely rules out 'regulatory experimentation' by individual Member States which may be a potent driver for the development of more effective and efficient regulatory approaches that may eventually be picked up at the EU level.

From the perspective of market actors harmonisation is generally desirable, at least for those engaged in transboundary operations or otherwise with an interest in operating in more than one national jurisdiction within the EU. A fixed set of rules spares such actors the cost and hassle of understanding and

[9] See http://ec.europa.eu/cyprus/news/20131120_november_infringements_package_en.htm; visited 26 February 2014.

[10] Laki hiilidioksidin talteenottamisesta ja varastoinnista / Lag om avskiljning och lagring av koldioxid, 416/2012, § 3. This prohibition should be seen against the fact that all deep rocks in Finland, including offshore locations within Finnish waters, are expected to be crystalline basement rock and not suitable for CO_2 storage.

adapting to differing national rules and also typically facilitates transboundary operations by subjecting all the actors concerned to the same 'regulatory playing field'.

The situation with respect to CCS is that the CCS Directive, as well as most of the other important pieces of EU law that affects CCS operations (inter alia the directives on industrial emissions (IED), waste, environmental impact assessment (EIA) and environmental liability), are based on the EU's environmental policy (Art. 192 TFEU) and only establish minimum harmonisation. According to Article 193 TFEU '*protective measures adopted pursuant to Article 192 shall not prevent any Member State from maintaining or introducing more stringent protective measures.*'

From the point of view of environmental protection this is obviously laudable since it combines the setting of a common minimum level below which no Member State is allowed to go with a right for individual States to pursue more protective policies according to their own needs and priorities. At the same time, it may impose additional burdens on operators and make the establishment of common standards for transboundary operations harder.

However, this right of the individual Member States does not constitute a *charte blanche* for them to freely devise their own requirements for CCS operations. Firstly, any national measure that deviates from the EU standard must constitute a 'more stringent protective measure'. What this means has, at least partly, been clarified by the EU Court. First the measure must pursue the same objective as the Directive. The Court has also found that measures that 'follow the same policy of protecting the environment as the Directive does' but impose requirements stricter than those of the Directive constitute more stringent protective measures (Case C-6/03, para. 41). To pass the test national measure should thus not be of a distinctly different nature than those prescribed by an environmental Directive or operate according to a different logic. Inasmuch as such a national regulation imposes requirements stricter than those of that Directive, it constitutes a more stringent protective measure.

Additionally, any national measure must be compatible with the EU Treaties and therefore also with other pieces of EU law since these are based on the treaties (Art. 193 TFEU). Member States are also required to notify any more stringent national measures to the EU Commission thereby enabling it to assess whether they are in fact compatible with the Treaties. A full account of what it means for a measure to be consistent with the EU Treaties cannot be provided here.[11] A core requirement is, however, that such measures should not constitute an arbitrary restriction to trade, eg by being unjustifiedly discriminatory or impose unproportional restrictions on trade by going beyond what is necessary to achieve its protective purpose. In summary, and despite this list of requirements, Member States enjoy a fairly wide leeway for supplementing EU regulation of CCS operations with more stringent national standards as long as those standards pursue a genuinely environmental or health objective and are well drafted.

There may, however, be elements in an environmental directive which Member States are not allowed to deviate from even if the national provision may be deemed to constitute a more stringent protective measure. The EU Court has found that environmental directives may have additional objectives besides protecting the environment, such as the smooth functioning of the internal market, the achievement of which must not be frustrated (Case C-64/09, para. 35). But this should primarily apply to administrative procedures and similar measures and in the case law this has only been applied in relation to a Directive that very explicitly promotes other objectives besides environmental protection.

Although the right to take additional protective measures is not without limits,[12] it is sufficiently wide to cause divergent national rules, and the mere uncertainty that follows from this right, and the time required to challenge the legality of any national measure seen by the affected operator as not justifiable under EU law is in itself a significant obstacle to the initiation of CCS projects involving Member States with differing standards.

Furthermore, the mere fact that most pieces of EU legislation affecting CCS operations take the form of directives, rather than regulations, gives the Member States relatively free hands to choose the means by which they implement the EU requirements.

[11] See instead eg Barnard 2013 or (in Swedish) Langlet & Mahmoudi.2011.

[12] For an extensive analysis of the room for Member States to adopt more stringent measures see **Invalid source specified.**.

4 The CCS value chain

4.1 Generic System Boundary

Figure 1 depicts the generic system boundary, building up from two components: legal regime and plant operation as a CO_2 emission source, of a plant covered by the EU ETS Directive.

The legal regime around the EU ETS plant comprises the emission permit, ETS process, ETS outcome, emission allowance management and allowance surrender/auction/market. The emission permit process as the starting point is a precondition for an EU ETS plant. The plant operation inputs fuel, labor, raw material and capital; outputs the end-user product and CO_2 emissions. The on-going ETS process receives emitted CO_2 data and outputs the ETS outcome with which emission allowance management interacts by surrendering or purchasing in auctions or on the market or selling them on the market.

Figure 1 defines the 'business as usual' base line for business activity that is dynamic, where substitution or switching of energy carriers, industrial processes or end user products is a reality. The base line as such is not constant. It is rather a variable set of different values with varying spreads relating to longer periods of time. In the base line CO_2 output varies in proportion to end user product output and is affected by quantifiable business activities. In case one has the intention to extend the same system with CO_2 capture or full scale CCS deployment an evaluation should rest on solid enough ground.

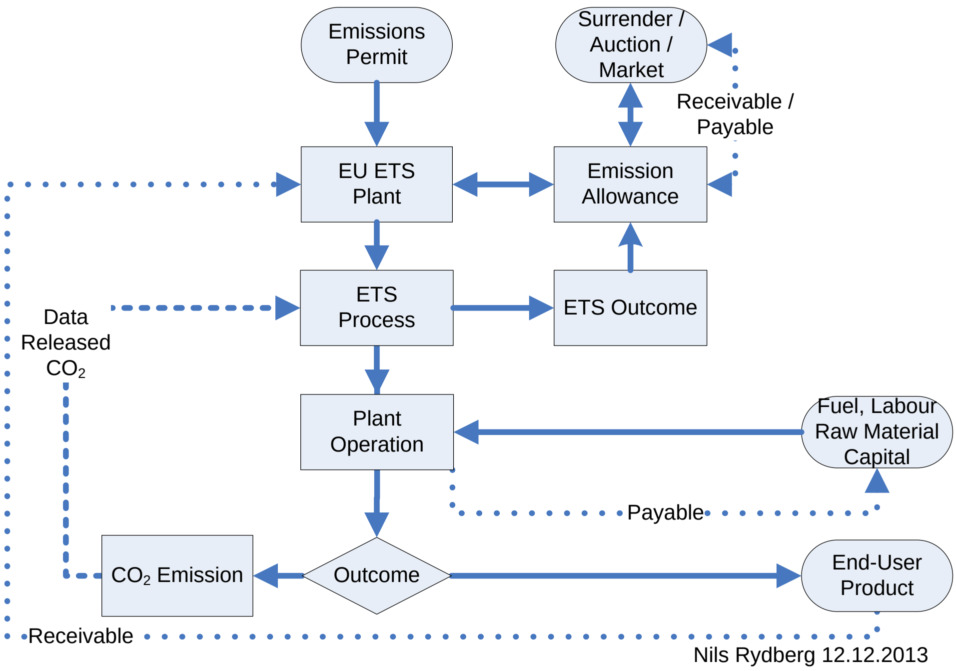


Figure 1: The generic system boundary at the time of writing.

4.2 Value Chain

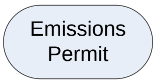
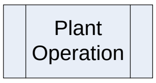
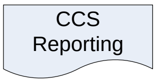
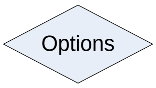
Assuming that a decision has been made to extend the above described system with CO_2 capture, examining neighboring or similar systems or even benchmarks provides an insufficient basis. The influence of prevailing identified risks and uncertainties can be highlighted by the use of the CCS value chain and evaluated against the expected performance that CCS extension should yield as a minimum in order to be feasible to any of the parties who will participate in the endeavor.

Based on the above understanding which the CCS value chain provides insight can be drawn regarding not only the plant oriented perspectives but also those institutions, like free market and competitive markets; factors and operators that play a core role in the deployment or operational phase of a CO_2 capture system. The CCS value chain extends the generic system boundaries. In this context the logical component 'legal regime' is the same but the 'source' has a profound meaning compared to the base line; it is simultaneously a CO_2 emission source and a CO_2 capturer. Therefore it is reasonable to amalgamate these two into one component to 'Plant Operation', as is done in Figure 2, which in turn is then zoomed. Thereby the interface to 'captured CO_2', which is explained and defined in the following chapter, can be exposed. The reason is, as mentioned above, that the legislation lacks in clarity as to the exact point when CO_2 is to be regarded as captured. The starting point of the captured CO_2 is a watershed between legal regimes. This will be demonstrated in the following chapter by a case. The captured CO_2 starting point is a piece of information that aids in designing the network of operators and their roles in the development of a feasible market design that may appear optimal for the participants. The authorities are also benefitting since it assists in regulatory design as well as in permit processes.

As mentioned earlier the entity 'transport', is a system of chained logistics solutions which involve several operators, factors and territories. A complex legal environment twines around this theme. With the help of the CCS value chain regulatory and market design issues can find their relevant places. The analytical notion 'transport' also exposes the consequences of disturbance or ruptures to the notion of 'captured CO_2' as defined in the legal regime. This includes the identification of the divergence points in cases where captured CO_2 ceases to be regarded as captured in the light of the EU ETS and the CCS Directive. Each CO_2 transit option leads to a physical end which represents the logical component 'sink'. Each of the ends has a link to the ETS process in the legal regime as described in the previous chapter.

The titles of sub-chapters and sections are, with some adjustments, based on the flow chart boxes with double sided lines. The CCS value chain flow chart nodes are linked to each other with lines. Table 1 lists the used symbols.

Table 1:

Symbol *	Description
	*Start node*: A process or material flow starts from this point. *End node*: A process or material flow ends at this point.
	*Node:* Business process that is referred in the text.
	*Node:* Business process with reference to equally named chapter and eventual sub-system figure.
	*Connecting Node:* A node that relates to ETS, CCS or both reporting processes.
	*Connection point:* A point that connects streams relating to CO_2.
	*Connection point:* A point that connects monetary streams.
	*Branching process:* A point where two or three possible alternatives diverge. It describes the choice which is to be taken in the preceding process or even earlier.
	*One way connection:* Connection through CO_2 related – physical or logical – flow.
	*Two way connection:* Interacting connection between two nodes through CO_2 related – physical or logical – flow.
	Data flow: The arrow head shows the flow direction.
	*Money flow:* The arrow head shows the flow direction.

* The symbol contains the name of the process.

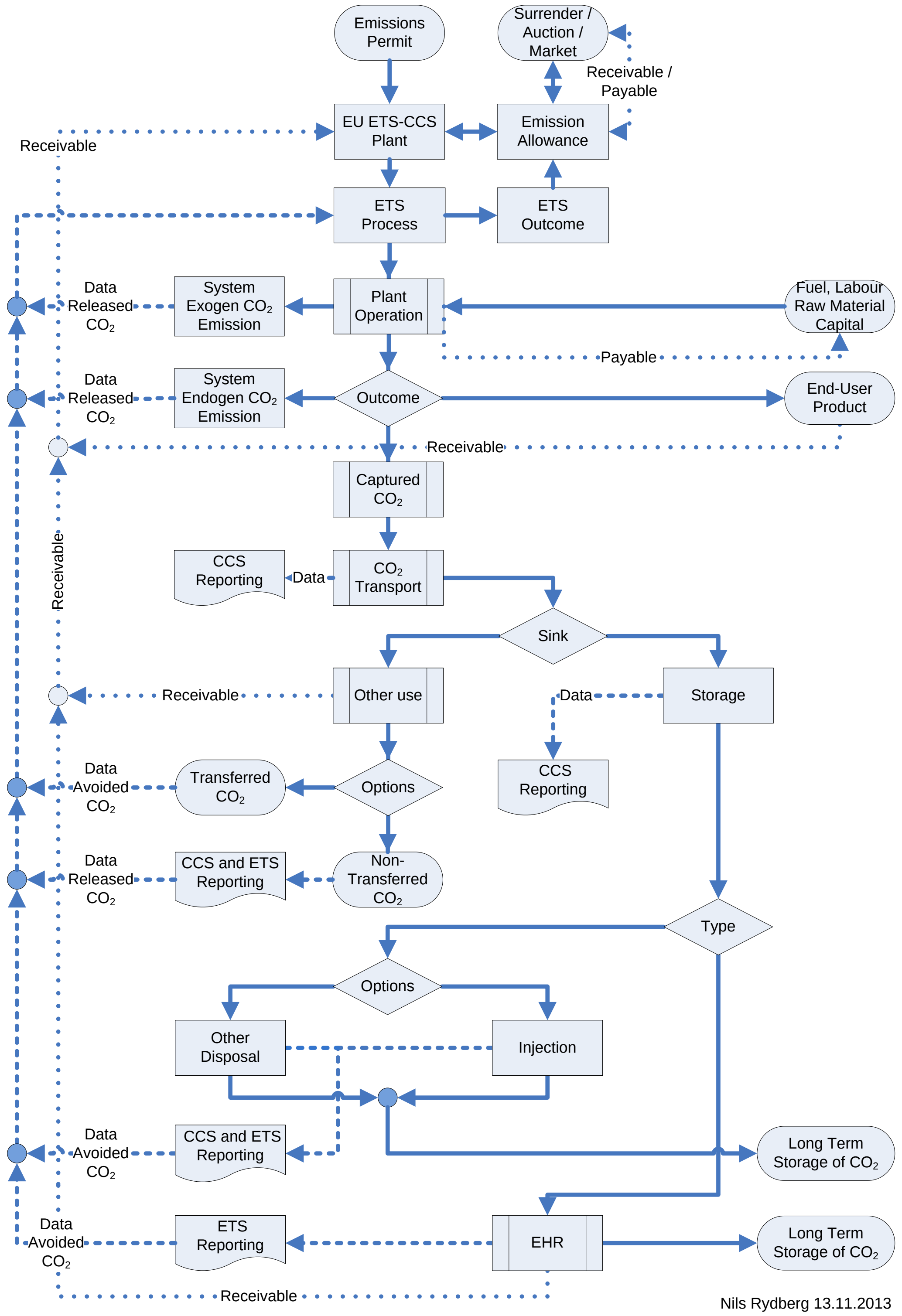


Figure 2: The CCS value chain.

Whereas the logical component 'legal regime' stays the same through the CCS value chain the component 'plant operation' is added with CO_2 capture. The generic system boundary is then extended with the logical components 'transport' and 'sink'. The main money and data flows are depicted. Although not explicitly set out in the picture, the end-user product may contain CO_2 as the law concerns purely the emissions.

4.2.1 Plant operation

Figure 2 describes the complete value chain and shows how CCS application brings a paradigm change to emission valuation. The CCS value chain introduces two new terms, 'System Exogen CO_2 Emissions' and 'System Endogen CO_2 Emissions' applicable within the generic system boundaries, which are rationalised as follows. The word 'system' refers to CO_2 capture irrespective of the applied technology.

In 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Sánchez, et al., 2006) fugitive emissions are categorised and defined to include all intentional and unintentional emissions from the extraction, processing, storage and transport of fuel to the point of final use.(Ibid. p. 16) They may (excluding venting and flaring) stem from the gas wellhead through to the inlet of gas processing plants, or, where processing is not required, to the tie-in points on gas transmission systems. This includes fugitive emissions related to well servicing, gas gathering, processing and associated waste water and acid gas disposal activities (Ibid. p. 18) whereas accidental emissions are mentioned under certain categories (Ibid. oil and natural gas 1 B 2, other 1 B 2 a iii6, and transport of CO_2 1 C 1) Venting is categorised and defined as associated gas and waste gas/vapor streams at oil facilities.(Ibid, p. 16). It is evident from the definitions that do not link to the business dynamics or reflect its behavior as the new terms do. Also, the non-integrated CO_2 emission streams and emissions that are not related to the capture technology are 'system exogenous CO_2 emissions'. System Exogenous Emissions will remain for the following reasons: a) in oil refineries it is unfeasible to integrate numerous non-main CO_2 emission streams, b) in power plants, not only depending on the applied capture technology, there may be a need to bypass the capture unit for market pricing and electric trunk line stabilisation capacity reasons, c) in steel mills bizarre situations may develop: take as an example an oxygen blast furnace, which in comparison with some other technologies provides economic flexibility and process optimisation at the cost of higher electricity demand thereby simultaneously lowering the breakeven point. Depending on the electricity pricing structure; ie emission allowance price penetration and prevailing substitution regime, electricity cost may reach the point where CO_2 capture ceases to be feasible. (Teir, et al., 2013, pp. 23-25) Intentional capture bypassing is expected and such emissions can thus be regarded as System Exogenous Emissions. In other words, the term contains the emissions which will be emitted any way forming the base line to CO_2 emissions which need to be covered by emission allowances. The remaining CO_2 stream, which constitutes the major volume, is conveyed to the capture system.

'System endogenous CO_2 emissions' occurring within the CO_2 capture system are management independent and related to the capture technology. The term does not rule out the occurrences of unintentional, intentional and accidental emissions which may be 'fugitive' or 'vented'. In addition, the term includes the capabilities of the applied technology to separate and capture the CO_2 stream directed for capture. In practice, 100% capture will not be achieved due to the characteristics of the different technologies. The extent of capture will depend on the integration degree and the performance capability which differ from one methodology to another. The preconditions for applying CCS in different industries may be illustrated by the following: a) in steel and iron mills applicable technologies are capable of extracting about 25 - 75% of the total emissions (Ibid. p.23), b) in gas fired power plants extraction efficiency is 79 - 90%; c) in oil refineries it is beneficial to concentrate only on the main CO_2 streams (Ibid. pp. 21-22) and d) before the capture facility is in full operation after a cold-start there is a technology dependent time lapse. Taken together i) the applied integration, ii) the applied technology specific features, iii) requisite venting and iv) other unintentional leakages that may occur along the operation and CO_2 capture pathway determine the minimum level of 'system endogen CO_2 emissions'. The remaining CO_2 stream, the major volume, is captured.

The term 'avoided CO_2 emissions' refers to the outcome of the entire CCS process.[13] It can be detected after the full cycle of the CCS chain since on the route to the sink there may occur any type of emissions and leakages, including leaks from the permanent storage. The IPCC Special Report on CCS visualises the terms 'CO_2 avoided' and 'CO_2 captured'.[14] The term 'system exogenous CO_2 emissions' means an increase in the volume of emitted CO_2 and the term 'system endogenous CO_2 emissions' a decrease in the volume of captured CO_2. Thus together they sum up to a lesser volume of avoided CO_2. As noted earlier the new terms assist in predicating particularly the spreads concerned in relation to business dynamics.

[13] The amount of CO_2 avoided is the difference between the emissions of the reference plant and the emissions of the power plant with CCS. **Invalid source specified.**

[14] Ibid. Figure SPM.2 on page 16

4.2.2 Captured CO_2

4.2.2.1 Starting point of the captured CO_2

Although it is common practice in CCS literature to use the denominator ‘captured CO_2’ (total amount of CO_2 transported away from the CCS plant) the point or instance where CO_2 starts to be ‘captured CO_2’ is not explicitly determined in law. The purpose of this chapter is to assist in finding and defining the starting point of the captured CO_2 as relevant for the CCS value chain.

The question is: ‘Where does isolated CO_2 turn into captured CO_2 in the meaning of the ETS, CCS Directive and other relevant legislation?’ The rationale of determining the upstream boundaries for captured CO_2 is to:

- articulate explicitly the end of the CO_2 production process;
- subject captured CO_2 to the ETS and CCS regimes and their objectives;
- identify and manage the obligations of the plant operator;
- identify the responsibilities and objectives of the plant management systems.

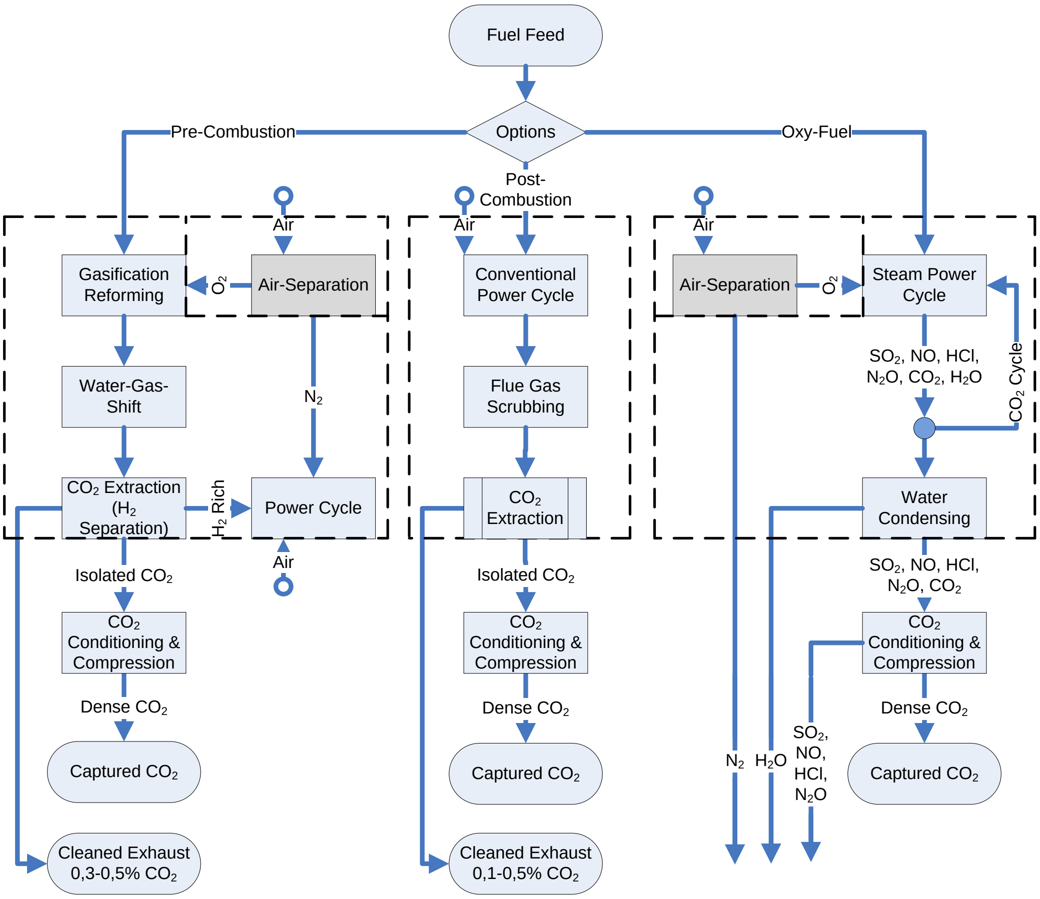
From a technological perspective CO_2 production processes are highly heterogeneous as can be seen in Figure 3. The identification of the starting point enables the definition of the upstream boundaries for captured CO_2. Although Figure 3 seems to provide an easy answer, in reality finding a CO_2-tight interface may be complicated.

Produced CO_2 may be captured by means of two main processes, combustion and industrial mineralisation. Combustion comprises three technology concepts: pre-combustion, post-combustion, and oxy-fuel combustion; introduced in Figure 3. Industrial mineralisation, currently not part of the CCS regime, finds its application in ‘Other Use’ and ‘Other Disposal’ in Figure 2. The latter and industrial mineralisation are not further dealt with in this report.

CO_2 separation is a complicated and most challenging process, the characteristics of which may differ significantly between different applications. Figure 3 shows the CO_2 route up to conditioning. After going through all the conditioning phases CO_2 is expected to conform to the CCS and ETS regimes.

According to the CCS Directive, the EU ETS, and other relevant legislation, CO_2 that has been captured is defined as ‘captured CO_2’ when it is an output from the final conditioning and compression process.

Where physically this takes place is another question and thus needs further examination. It is highly important that the regulatory framework treats the different CCS applications equally through the whole value chain so as to avoid incentivising technically and economically sub-optimal outcomes.



The charts: Modified from VTT Technology 125, pp. 27, 29 and 3

Nils Rydberg 12.12.2013

Figure 3: Plant operation. Abreast the capture processes showing their similarities and differences. The dotted lines mark the CO_2 capture islands. Depending on the function and ownership the Air-Separation Unit, ASU, may be either included in or excluded from the capture island.[15]

4.2.2.2 Case

The CCS Directive defines 'CO_2 stream' as *'a flow of substances that results from CO_2 capture processes'* (CCS Directive, Art. 3, para. 13). However, the Directive can be seen as flexible or vague since it does not define 'capture process.' There is no other regulation of the 'capture process' since it is a voluntary undertaking, so far. Nor are the terms 'produced' and 'captured CO_2', used in relation to the regulation of third-party access, defined. One may of course question whether it is at all meaningful to invest energy in the analysis of concepts and definitions, considering the limited attention given by the EU legislator to such issues. The following case – although of small concern – which aims to highlight some of the problems that may arise in the application of Commission Regulation 601/2012 on greenhouse gas monitoring and reporting Annex IV, should make the case for giving due attention to definitions and the associated system boundaries.

It is worth noting that from the point where CO_2 is 'captured CO_2' it may fall under two parallel paths: a) the chemical identity of CO_2 will remain through the whole CCS value chain. In the CO_2 production there are procedures to which it can be clearly referred,[16] b) after being turned into 'captured CO_2' the CO_2 has non-chemical properties that may change along the CCS value chain and which are determined by the legislation applicable at any given time. Upstream from the point at which the CO_2 is defined as captured, ie where it is not yet under the CCS regime, it is still subject to the requirements of occupational health and safety and environmental legislation.

[15] For interest, see Appendix I: Transportation of carbon dioxide (CO_2) in the dense phase
[16] In combustion the reference point is the extraction process.

Assume that there is a plant that houses three individual operators. The first is an ETS plant operator whose core business is eg electricity or steel production. The second is the operator of the capture process.[17] These are distinct legal persons. The third legal person is a transporter who with sub-contractors takes over the captured CO_2 for further distribution. The three parties are obligated to be under the greenhouse gas emission allowance trading scheme. Something unwanted happens. As a result the absorber column of the pre-combustion or precipitation reactor leaks its complete contents on a flat surface. The capture process is set to rest. The run-off substance properties are water like or thin slurry and are hazardous for occupational health and safety. Solute, usually amines, or slurry contains trapped CO_2. From this position it cannot escape to the atmosphere. The run-off is collected but cannot be redirected back to the further process steps. It will be collected and transported to a plant incinerating hazardous waste. No ground or water contamination or human injuries has been registered. What are the overall consequences in light of the CCS and ETS regimes?
The incident does not concern the ETS plant operator. The plant operator knows the CO_2 contents of the inputted energy carrier and is thus able to report hourly energy carrier use. He is also able to comply with the commitment to surrender allowances covering the CO_2 emitted to the atmosphere during the period under which the capture operation is out of operation as a consequence of the accident. However, he is not liable to surrender allowances that relate to the run-off.
The capture process operator is obligated to surrender a number of allowances equal to the total greenhouse gases released into the atmosphere from all installation sources but not that related to the run-off CO_2 since it is not emitted into the atmosphere. Instead the run-off as a whole falls into the waste regime causing a mismatch between input and output in the indirect carbon concentration measurement records or in carbon mass balance or records (Commission Regulation 601/2012, Art. 43 paras 3b and 5a). The CO_2 volume in the run-off can be expected to fit into the measurement uncertainty margins set out in Regulation 601/2012 Annex II but may considerably reduce the free uncertainty margin left. Estimating CO_2 content must be made case by case since it depends on how much CO_2 an individual absorber can absorb before its saturation point is reached. Nevertheless, at the moment there are no clear answers how this cap should be treated.

4.2.2.3 Purity of captured CO_2

The present section introduces the complexity of CO_2 stream purity with an emphasis on cross border situations. This is done against a background of a regulatory context which comprises several regulatory regimes, including the CCS Directive and the EU ETS, which may or may not apply to the CO_2 stream depending on the circumstances. Due to the many aspects of the regulation of captured CO_2 this discussion is divided between this Chapter and the Chapter ‘Transport’.

Under Article 12 of the CCS Directive a CO_2 stream – ie the flow of substances that results from CO_2 capture processes - must consist ‘overwhelmingly’ of CO_2.[18] This rather vague obligation is somewhat elaborated by the statement that concentrations of all incidental substances from the source, capture or injection process as well as of any trace substances that may have been added to assist in monitoring must meet certain requirements. The fundamental requirement is that such substances may not adversely affect the integrity of the storage site or the relevant transport infrastructure or pose a significant risk to the environment or human health. They must also not breach the requirements of applicable EU legislation, such as the Industrial Emissions Directive (Directive 2010/75/EU). Only streams that have been analysed as to their composition, and for which a risk assessment has been carried out, may be injected.

Although not binding the preamble (introduction) to the CCS Directive provides some insights into the rationale for the substantive requirements. According to recital 27 ‘*[i]t is necessary to impose on the composition of the CO_2 stream constraints that are consistent with the primary purpose of geological storage, which is to isolate CO_2 emissions from the atmosphere, and that are based on the risks that contamination may pose to the safety and security of the transport and storage network and to the environment and human health.*’

[17] Commission Regulation 601/2012, para. 21: ‘*CO_2 capture shall be performed either by a dedicated installation receiving CO_2 by transfer from one or more other installations, or by the same installation carrying out the activities producing the captured CO_2 under the same greenhouse gas emissions permit. All parts of the installation related to CO_2 capture, intermediate storage, transfer to a CO_2 transport network or to a site for geological storage of CO_2 greenhouse gas emissions shall be included in the greenhouse gas emissions permit and accounted for in the associated monitoring plan.*’

[18] The term “overwhelmingly’ was first used in the London Protocol; Article 4(2) of Annex I to the amended London Protocol. The term “significant risk’ refers to articles 3(2)(f)(iv) and 3(3)(d) of respectively Annexes II and III of the OSPAR Convention.

Hence it is clear that the sole purpose of the purity requirement is to uphold the safety of the transport and storage operations.

All the operators dealing with CO_2 along the CCS value chain will have to grapple with these ambiguously expressed requirements on purity which do not always seem to argue in favour of the same purity level. Core elements of Article 12 are: a) ‘overwhelmingly’, b) ‘incidental associated substances’ and c) ‘significant risk’. Whereas ‘*significant risk*’ is subject to a definition in the Directive,[19] both ‘*overwhelmingly*’ and ‘*significant*’ remain rather unclear. Nowhere is it specified when incidental associated substances or tracers adversely affect the integrity of storage and transport infrastructure. In practice, however, the substances added for identification, monitoring and tracing the stream and the plume do not give rise to risk problems.[20] The vagueness of the Directive may eventually result in the question being addressed by the EU Court if Guidance Documents 1 and 2 to the Directive are not convincing enough.

In practice, purity considerations will be addressed on a case-by-case basis and can hardly be subject to generally agreed limit-values. Each technology application, as applied by different ETS plats, comes with its own characteristics regarding impurities in the CO2 stream. The technically and legally viable purity in each case is a result of the following factors: 1) production type, 2) incineration type, 3) extraction technology and methodology, 4) type of transport infrastructure (non-corrosiveness, ice formation), 5) contamination risks, 6) public/political concerns, and 7) chemical properties of the storage complex. Guidance Documents 1 and 2 to the CCS Directive are of limited assistance. There are non-binding values[21] for CO_2 stream purity but the competent authority will have to determine an acceptable CO_2 stream composition in each case.[22]

The Member States are, with certain restrictions and if it can be justified by environmental and health considerations, allowed to apply stricter standards than what is articulated in the Directive (see the Chapter ‘Harmonisation’). If the implementation of the national law exceeds the Directive’s standards the law is said to be ‘gold plated’. The Swedish Ordinance (2014:21) on geological storage of carbon dioxide could possibly be regarded as being gold plated.[23] It requires the CO_2 stream to be ‘composed exclusively of carbon dioxide’ whereas the Directive states that it ‘shall consist overwhelmingly of carbon dioxide’.

Sweden is expected to export captured CO_2. However, the fact that the requirements of an exporting State are gold plated does not imply that the importing State must also tighten its legislation. It is thus fully conceivable that additional substances may be added after the CO_2 stream has left the jurisdiction of the exporting State, even though those substances would not meet the legal requirements in that State. Nonetheless, gold plated purity requirements will likely increase costs along the CCS value chain and either raise the threshold for application or cause trade restrictions.

The competent authority assessing applications for CCS deployment will have to tackle several complex questions. In cross boarder situations the relevant authorities from each country, with their different organisational structures, should work together to establish a cooperation structure with cluster like features that is transparent to the actors concerned.

In addition to what has been described above, purity has also technical features. Ambitious purity levels must not be an end in itself. *‘For safety reasons as well as for technical and economic grounds it is deemed important not to exaggerate the purity levels – especially in terms of free water (neither towards the lower end nor towards the upper end). Equipment, eg pipeline design specifications should be consistent with the tolerable concentrations of impurities, particularly water content, hydrogen sulfide (H2S), oxygen, hydrocarbons.’* (Teir, et al., 2010, p. 50). Purity level design balances several factors. CO_2 in super critical form is optimal for pipeline transportation but is difficult to reach because of impurities, especially of H_2. *‘Lowering both the impurity levels in the transported CO_2 and the velocity of the flow inside the pipeline lowers both the pressure loss and the energy demand of pressurisation, and thus*

[19] ‘Significant risk’ is defined as ‘a combination of a probability of occurrence of damage and a magnitude of damage that cannot be disregarded without calling into question the purpose of this Directive for the storage site concerned’; Art. 3 point 18.

[20] Naturally occurring chemical constituents include stable isotopes of O, H, C, S, and N, noble gases (He, Ne, Ar, Kr, Xe) and their isotopes, and radioactive isotopes (eg, tritium, ^{14}C, ^{36}Cl, ^{125}I, ^{129}I, ^{131}I). Manmade trace substances eg perflurocarbon (PFC) and sulphur hexafluoride (SF6) are effective markers and powerful greenhouse gases. Prevention of spills and leakages must be secured.

[21] See Guidance Document 2, gases Table 2 and 3; water Table 5.

[22] Ibid Figure 4

[23] The Swedish CCS Ordinance (Förordning (2014:21) om geologisk lagring av koldioxid) requires the CO_2 stream to be “composed exclusively of carbon dioxide’ whereas the Directive states that it “shall consist overwhelmingly of carbon dioxide ‘. However, the Swedish Ordinance allows for exceptions to the general rule which add up to the same substantive scope for impurities as that allowed for under the Directive. However, a significant signal is being sent, which may affect the application in individual cases, by the general rule under Swedish law being a stream consisting *exclusively* of CO_2.

could present one way to decrease the capital and operational costs.'. (Teir, et al., 2010, p. 159) In liquid form CO_2 has its highest density. However, dry ice formation must be avoided, thus volatile gases such as Argon or Nitrogen must be scrubbed.(Ibid. p.35) This means that the transportation mode is an important factor when defining the desirable purity level.

Oxygen (O_2) constitutes a peculiar problem. Notwithstanding its crucial role in the oxidising process it can appear in flue gases and travel to the captured CO_2 stage causing potential corrosion hazards to pipeline infrastructure and overheating risks in EOR. A comprehensive understanding of the O_2 problem is still lacking. Defining the allowed levels is case dependent. The wording of the Swedish CCS Ordinance introduces some uncertainty as to whether it will in practice result in stricter purity requirements compared to the Directive. In some cases such more stringent standards could be hard to achieve in practice or may entail excessive costs.

The conditioning and compression process is designed to yield such a CO_2 stream purity that facilitates transportation along the value chain and in the final stage permits geological storing. The receivers along the value chain are to accept the stream in motion and the storage operator to inject what is received; for the initial dispatcher purity is key to having the CO_2 accepted for transport and subsequently storage. The conditioning is the very step where CO_2 properties are analysed. At that point the owner also earmarks the CO_2 stream. Earmarking includes two measures: bookkeeping and adding tracing component(s) to the captured CO_2.

4.2.2.4 Some words about monitoring

The operators along the CO_2 value chain are obligated to monitor the stream of captured CO_2. Although monitoring falls outside the scope of this analysis it is important to have a quick look at sampling along the value chain ending at the injection point. Here the topic, limited to purity, will be approached from an administrative perspective.

For the competent authority purity may be a highly challenging issue. Guidance Document 2 to the CCS Directive[24] highlights the problem. The approach of the document is limited to that of the CCS Directive. It does not provide assistance on jurisdictional, economic and competition issues.

The insight concerning capture technologies is thin. However, those technologies and methods that are already available have too small a capacity compared to what a full-scale CCS deployment would require. For representative sampling this causes problems. However, compositional sampling by the means of gas chromatography is applicable. The problem stems from the case dependent purity levels. Guidance Document 2 (p. 101) phrases the problem as follows:

> *'Resolution can be translated into the question 'what is the smallest amount of CO_2 that can be detected by the method'. Resolution generally depends on the instrument specifications, but also on the local environmental circumstances. This question might be stated more exactly based on what is being measured.'*

Referring to (Järvinen, 2013) the substances originating from an amine based extraction cannot be sampled with conventional methods. In addition, these substances can be sampled only offline using non-standard methods. This creates a great challenge to each of the operators along the value chain as each operator must carry out an analysis of the total composition of mobile captured CO_2. The data retrieved from the analysis are to be reported in the bookkeeping of delivered and received captured CO_2. In a worst-case scenario a strict interpretation would entail a park of non-interlinked laboratories along the CCS value chain. Operator specific analysis generates high costs and may reflect to cross boarder activities and related transactions of any kind. This could be avoided by such an agreement between all parties that Guidance Document 2 recommends. In case of agreement the most favourable place for sampling could be the conditioning and compression unit. However, as Guidance Document 2 indicates, the agreement would be applicable only for short distance pipelines. The term 'short distance' remains undefined. Noteworthy is that the CCS Directive does not take a stand on where the injection site sampling must take place. As the Directive does not consider consolidated CO_2 streams the agreement procedure perhaps needs political acceptance.

Sampling raises the following questions that need to be studied further:

1 Why are purity agreements for long pipelines not supported?

[24] Guidance Document 2, **Invalid source specified.**

2 As it is most obvious that there is a time lapse between the sampling input and output of a CO_2 stream in motion and reaction time for corrective action, what sort of management measures are expected to take place concerning the stream that passes through that time window? Must the infrastructure design take this type of risk into account?

3 What is to happen if at the injection site the CO_2 stream is found to exceed the set purity level?

4 Must the injection site be designed to host a sampling station?

5 Must the above sampling station have an online feed-back loop to the process control?

4.3 Transport

The CCS Directive was designed and is expected to be implemented in a situation with very modest transportation infrastructure for captured CO_2 yet in existence in Europe. The Directive's main idea is to enable the market actors to find a Pareto optimal transportation solution. The existing pipeline system for natural gas differs considerably from that which will be necessary for transporting captured CO_2. Firstly, in captured CO_2 transportation the stream is reversed; almost pure CO_2 will be injected into seabed sediments. Secondly, transportation of captured CO_2 is a business-to-business market without whole sale and distribution activities, involving consumer entities, which characterise the natural gas market. Thirdly, natural gas transportation distinguishes between 'pipeline' and 'linepack'[25] whereas the latter is unknown to the CCS Directive but is in fact essential to captured CO_2 transportation. Despite these differences the Natural Gas Directive 2009/73/EC could in some ways serve as a template to support the regulation of transport of captured CO_2. This follows from the fact that several activities and actors are the same or similar in the two transport cases. Particularly instructive for the management of CO_2 transport may be the rules pertaining to line pack and unbundling, as well as the distinction between upstream and downstream pipelines in the Natural Gas Directive.

The pipeline network is not only a tubular highway for transportation, it is also defined by the way of usage; what type of ancillary services it can and is allowed to provide. Thus the line pack topic is discussed here. However, the following topics are not included in the discussion: line pack balancing, business exit (bankruptcy), mergers (divestment) and the permanent storage tariffs as the injection rate may turn out to develop to a bottle neck. The next section characterises the network construction; the following one introduces the concept of the line pack. The list of the related actors and activities involved are commented in the Chapter 'Some conclusions and considerations for the planned revision of the CCS Directive'.

4.3.1 Pipeline infrastructure

Unlike the Natural Gas Directive the CCS Directive does not recognise the pipeline division into up- and downstream pipeline parts. The upstream pipeline, described in Figure 3, comprises equipment, facilities or systems located in the production train before the no-return valve at the end of the conditioning and compression unit. The concession legislation[26] may provide logical division between upstream and downstream pipelines which supports the concepts of isolated CO_2 and captured CO_2. It should be observed that the upstream pipeline is, as defined earlier, excluded from the CCS regime, since the CO_2 is not yet regarded a captured, but is included in the ETS regime in the sense that emissions must be covered by allowances. The reason for this is set out below in the subsection on 'Market design'. The conditioning and compression unit controls downstream fluid flow rate and system pressure. From the point of no-return-valve the pipeline is recognised as a downstream pipeline.

The downstream pipeline in Figure 4 receives captured CO_2 from the conditioning and compression unit or another pipeline at a specific connection point. Two or more downstream pipelines together form a gathering system. (Schlumberger, 2014b)[27] The gathering system is a flowline network, small-diameter pipelines, containing optional process facilities that transport and control the flow of captured CO_2 from two or more emission point sources to a main storage facility, liquefying facility or shipping point. There are two types of gathering systems, radial and trunk line. The radial type brings all the flowlines to a

[25] See also Appendix I: Line pack
[26] Like the Swedish: Lag (1978:160) om vissa rörledningar, Koncessionplikt, 1§
[27] EHR will be discussed further in Chapter Enhanced Hydrocarbon Recovery below.

central header, while the trunk-line type uses several remote headers to collect captured CO_2. The latter may be suitable in the Baltic Sea environment. The gathering system is also called the collecting system, gathering facility, or hub. A hub is a location where pipelines intersect and flows are transferred, a center of logistics and services that provides storage and value-added services such as a commercial storage tank terminal at the sea front. The hub connects to a wide-diameter main transmission/trunk line, a long-distance pipeline to transport captured CO_2 from the on-shore area to a permanent storage site or to enhanced hydrocarbon recovery (EHR) use[28]. A hub can be located at the exporting end only, at the importing end only or at both ends. In case of liquefied CO_2 the exporting end must be a liquefying facility and at the importing end a de-liquefying facility before captured CO_2 can be directed to injection.

Figures 4 and 5 reveal how the phase of transported captured CO_2 affects the infrastructure design. Figure 5 describes the transboundary transportation options. It is evident that different captured CO_2 phases cannot be joined which means that a pipeline can transport only one phase of the three. This surely entails limitations but also incentives to industry to apply opt-in procedures for other transportation means as well as for logistics co-operation and cluster building.

[28] U.S. Energy Information Administration, based on data through 2007/2008 with selected updates.

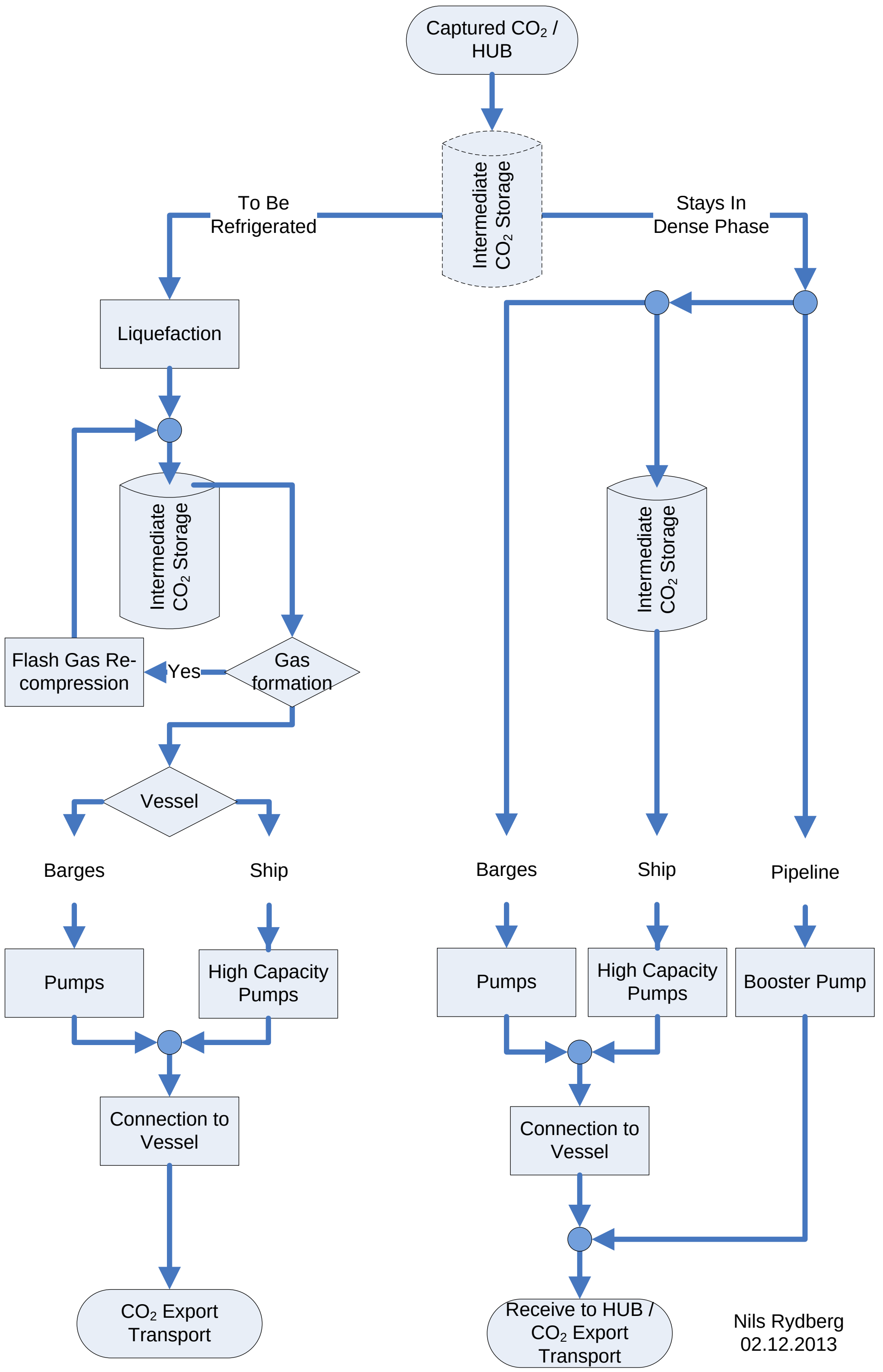


Figure 4: The captured CO_2 starting point that can be located at the CCS plant or elsewhere. The same chart applies also to a HUB but then the captured CO_2 starting point may reside at a distance from the HUB. The flow chart depicts the and downstream pipelines with different captured CO_2 phases within the national boarder lines from the starting point of the captured CO_2 either at the ETS plant site or from the plant site to an on-shore hub at the seafront. Different captured CO_2 phases effect the choice of suitable transportation options.

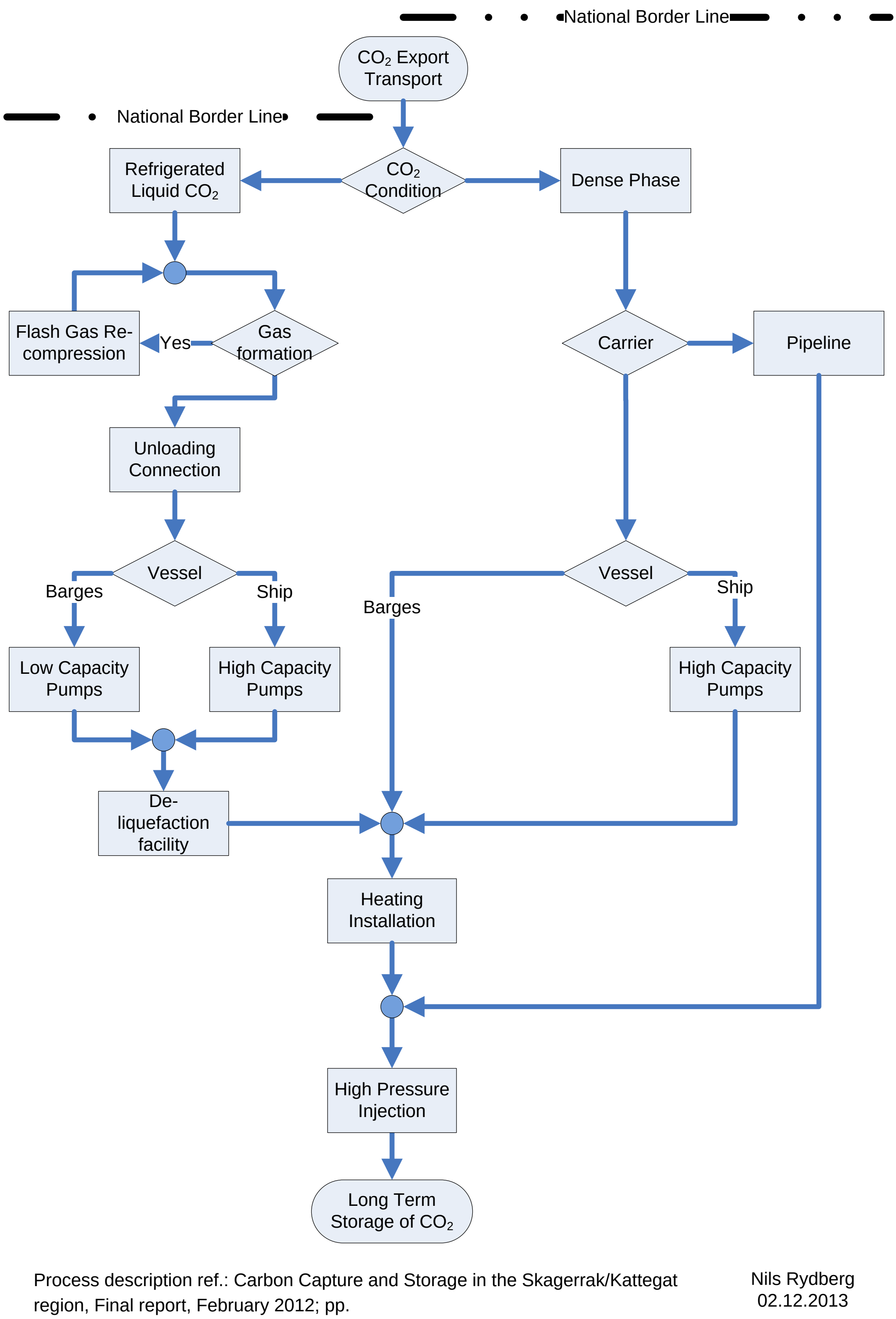


Figure 5: Captured CO_2 can be transported to the permanent storage either within or over national borders. However, transportation in liquid phase is efficient but also requires heavy investments.

4.3.2 Market design

Pipeline and storage planning involves land use and technical planning. They both together realise carefully elaborated market designs. Market design covers the nature of the CCS deploying industries and their markets, and aims to equip market actors with instruments that promote market neutrality. The task of the Natural Gas Directive is to regulate the natural gas markets. The Natural Gas Directive was designed to match existing infrastructure with existing markets, actors and monopoly dismantling aims. The Directive's main instrument is control of infrastructure ownership and the role of the actors involved. The captured CO_2 pipeline system has a different starting point compared to the existing natural gas pipeline systems. As there are no markets yet the task is to develop them. The aim of the CCS Directive is not only to control the technical properties and the technical use of the infrastructure. In fact, its primary mission is to assist in developing a functioning market with controlled implications. Unfortunately the CCS Directive is poorly equipped for this task. The market design should take foothold on competition regulation as can be observed from the following.

Capacity planning interfaces with transportation and storage space demands. Quality requirements interface with infrastructure demands, as well as environmental and health considerations. The competent authority is to examine and approve the plans sent by the ETS plant. In fact, pipeline and storage plans concern not only technical performance for transporting captured CO_2 from one point to another and storing it. They also concern possible ancillary services. The transport system, including the permanent storage site, is expected to serve without market distortions.

Market distortion can appear in several ways. CCS pipeline solutions are at risk to become bilateral oligopolistic markets. A bilateral oligopoly is a situation where there is a single or few buyer(s) and seller(s) of a given product in a market. The level of concentration in the sale or purchase of the product, say around a single pipeline, results in a mutual inter-dependence between the seller(s) and buyer(s). Two or more companies representing the same industry may cause a risk of developing a cartel that is typical to oligopolistic markets. There is also a risk that one of the companies exercise market power over the other. Furthermore, too high transparency is an unwanted situation, although, the Nordic power market[29] requires short term market notifications from the delivering power plants. An insider risk is also present while an insider can observe how his/her plant reacts to the other companies' behavior and their fault situations. A pipeline solution the way the CCS Directive sees it is purely theoretical while the third party access (TPA)[30] regulation is a reality that entails market distortion risks. Thus it is well justified to advocate the participation of the competition authority in the early planning stages of any pipeline solution so as to forestall market distortions.

It is evident that the pipeline network will in many cases be long and pass by several ETS plants, thereby making it attractive for them to make use of their TPA rights. If the plants are non-competitors or construct vertical or horizontal market structures without ownership bundling the initial pipeline routing and capacity sizing cause less threats to market distortion. It is nonetheless possible that a long route will affect competing ETS plant(s) and enable them to file a TPA request. If access is technically possible and there is no valid refusal argument the competent authority has to provide for TPA (see further 'Third Party Access' below). The CCS Directive does not recognise market distortion as an argument for refusal. This type of potential can have an effect on pipeline routing or it can lead to total alienation of CCS deployment (Holwerda, 2011), Nevertheless, in the context of if the planning process the land use and the capacity sizing may take the market distortion into account resulting in purpose-building and strategic behavior.[31] Purpose-building may appear in two ways; either capacity is matched precisely for use of the first runner or extra capacity for TPA is imbedded. If extra capacity is planned to cut the cost risk associated with TPA then the market distortion will be mitigated.

VTT report 2556 shows that CCS emitters along the Swedish and Finnish costal lines form clusters.[32] Each emitter cluster contains competing ETS plants which gives relevance to the above described risks. In this type of environment CCS deployment can come to a complete halt if a competing plant downwards the pipeline route disputes the plans of the one upwards the route. Generally, clusters are re-

[29] The Nordic power market today covers Norway, Denmark, Sweden, Finland, Estonia, Latvia and Lithuania.
[30] CCS Directive, Article 21:
1. Member States shall take the necessary measures to ensure that potential users are able to obtain access to transport networks and to storage sites for the purposes of geological storage of the produced and captured CO_2 […]. 2. The access shall […] be provided in a transparent and non-discriminatory manner determined by the Member State. The Member State shall apply the objectives of fair and open access […].
[31] See Appendix I: Strategic behavior
[32] Appendix B4; Clusters of facilities with CO_2 emissions >0,1 Mt CO_2/a in 2007 – both fossil and biogenic CO_2 emissions visible; (Teir, et al., 2010)

garded to be efficient but it contains a severe pitfall. The competitors become far too transparent to each other which from a competition point of view is unwanted in concentrated markets like energy, pulp and paper and steel industries. In case an emitter cluster will be developed it ought to happen under the control of the competition authorities in order to prevent competition distortions.

The CCS Directive does not clearly define the term ‘pipeline’. Also, it does not address upstream networks, eg feeding lines at the plant site between the CO_2 extraction processes and the conditioning & compression unit (as described in Figure 3.).[33] The relevance of TPA in this context will be illustrated with two examples:

An ETS plant erects a conditioning and compression unit on a plot that the operator has bought for this purpose. The plot is located near the plant itself.

Two ETS plants deploy extracting methods which result in isolated CO_2 streams the composition of which is similar enough for common treatment. The plants are located close enough for a common conditioning and compression unit to be erected.

In both cases the feed line sizing is matched to the production processes. Later a third plant expresses its interest in accessing the feed line(s) by filing a request. The problems that an upstream TPA generates are not only of interest to the competition regulation but also related to the plants’ production processes. In case of upstream pipeline TPA, there are process control matters and competition issues which cause significant problems. Firstly, one plant must adjust its production processes to match with flow stream from the other plant. Secondly, the transparency issue is evident. Both effects must be avoided. Generally, the question is also the extent to which a third party can exercise his rights. The Natural Gas Directive’s access regulation allows upstream TPA but one should note that natural gas extraction conditions differ from the industrial production processes where CO_2 will be ‘extracted’. If the CCS value chain definition, as earlier introduced, is overlooked while TPA is projected to complete pipeline sections then a TPA process may prove agonising and will jeopardise production process controls and cause market distortions. The TPA issue is further discussed in the Chapter ‘Third party access’ below.

4.3.3 Line pack

As the CCS Directive is obscure concerning the term ‘capacity’ it is essential to shed some light on it.

A pipeline has a dual function; transmission and intermediate storage of the transported gas. ‘Packing the line’ increases the amount of gas in the system by adding gas and/or increasing pressure and ‘drafting the line’ decreases the amount of gas in the system by decreasing gas and/or decreasing pressure. It is a service that any gas pipeline provides by its very nature. Here two concepts must be distinguished: ‘line pack’ is the total amount of gas present in a pipeline section, whereas ‘line-pack flexibility’ is the amount of gas that can be managed flexibly by controlling the operation-pressure levels between a minimum and a maximum level. The line pack properties originate from the tube diameter, the pressure resistance of the tube and the performance of the compressor. So, the pipeline capacity utilisation is a trade-off between the transmission and the flexibility functions. There are two distinct principles to utilise pipeline capacity: Entry-exit defines capacity rights as the right to enter gas at one or more entry nodes and withdraw at one or more exit nodes without any specification of the physical path. This provides geographical flexibility to shippers, ie the ETS plant or the one who is the extraction process operator. Point-to-point, on the other hand, defines capacity rights as the right to use a path between two defined points. Hence, geographical flexibility is absent.

The basic principle of storage is that one can only withdraw what has been fed before. Earlier in the chapter ‘Plant operation’ the task of the conditioning and compression unit to produce steady-state gas flow was described. However, that is the ideal. In practice the gas flow is often in non-steady-state flow which advocates line pack. One task of line packs is to absorb the flow variation and a second is to balance between the demands of supply, ie the ETS plant end, and withdrawal, ie the injection end. To allow the withdrawal of captured CO_2 before the feed-in has reached the withdrawal point the line-pack buffer has to be used to satisfy demand. This buffer needs to be created and kept in storage within the physical boundaries of the pipeline. Therefore, part of the capacity cannot be allocated to transport service which means that the pipeline concept with which the CCS Directive seems to be concerned is an ideal rather than an actual situation.

[33] Further in the next Chapter below on Swedish Pipeline Law

Feed-in and withdrawals have varying time patterns. Therefore, line-pack flexibility operates like a buffer that is filled first, and emptied at a later time which means that the buffer is relative to time. At any point in time, the available buffer is the difference between certain line-pack at that time and the minimum safe level of line-pack. Operational flexibility in gas-transport results from the ability to store gas in the pipeline whilst gas transport is still guaranteed within the line-pack flexibility. (Keyaerts, 2012, p. 53)

The network operator is expected to co-operate with the storage site operator. The co-operation guarantees the transportation function and controlled withdrawal for injection. At the same time, however, the network operator and the ETS plant are not expected to co-operate as there should be unobstructed feed-in access. The pipeline operation should not erect hurdles to the plant's production processes. In other words, the pipeline capacity is expected to meet the feed-in demands. Whoever the pipeline network operator may be, he runs a natural monopoly. Nevertheless, he can decide how much captured CO_2 to transport and how much captured CO_2 to line pack taking into account the technical limits.

Line pack generates two consequences: risk for market distortion and tariffs. The market distortion may result from the network operation that is in the hands of one of the competing ETS plants. TPA is regulated by the CCS Directive but the line pack is not.

4.3.4 Third Party Access

Pipelines connecting to a CO_2 storage site have been deemed to be so called natural monopolies. (Vedder, 2009, p. 279) In order to address the problems associated with infrastructure monopolies the CCS Directive includes rules on TPA to transport networks and storage sites. However, the relevant provisions are not very precise and leave Member States considerable discretion when implementing and elaborating the requirements in national law. (Eilertsen, 2010, p. 139)

The EU Commission initially contemplated a more elaborate approach imposing specific rules for achieving equal access to relevant infrastructure, including unbundling provisions, modeled on existing EU law pertaining to the common market for electricity and natural gas. However, it was deemed that far-reaching regulation of third-party access would not be a proportional measure at such an early stage in the development of CCS technology, not least since the Commission found it likely that there in practice will be separate operators for the combustion and capture phase, on the one hand, and transport and storage on the other. (Commission staff working document, 2008)

It is hence up to the individual Member States to regulate the manner in which TPA is to be arranged in accordance with Article 21 of the CCS Directive.

While the decision to accept, or deny, access to the transportation network or a storage site ultimately resides in the hands of the operator, the decision has to be justified. In case of denial, the operator must base the decision on a duly substantiated lack of capacity or of connection. The operator should be required under national law to make any enhancements to the relevant infrastructure that would be economic, or for which the potential customer is willing to pay. However, no such obligation applies in respect of enhancements that would negatively impact on the environmental security of the transport system or the storage site.

The Member States are obligated to implement dispute settlement arrangements, and are required to consult each other in order to ensure a consistent application of the TPA rules in respect of transport networks or storage sites that fall under the jurisdiction of more than one Member State.

The CCS Directive appears to build on an assumption of a straight passage of CO_2 from an emission point source to the end storage. As illustrated eg by the discussion on so-called line pack (see 'Line pack' above) this is a simplification. The Directive does not concern itself with issues relating to ownership of captured CO_2 streams, neither when in transit nor after injection into a geological formation. Although not necessarily in the Directive, such issues -or rather rights and obligations pertaining to particular volumes of captured and transported CO_2 – ought to be clarified in order to avoid confused incentives. It could also lower the negotiation costs among the parties concerned along the CO_2 value chain. Yet the current lack of clear rules does not prevent the actors concerned from dealing with these issues by means of agreements.

As regards ownership of CCS infrastructure a mixture of public and private investment and ownership is quite possible. From the TPA point of view the ownership structure may be important depending on the motives for establishing the pipeline and/or storage infrastructure. Pure environmental reasons will not motivate private capital to invest in the construction and operation of CO_2 transportation and storage infrastructure. For such capital the main mission is to yield revenue that satisfies the profit expectations. If nothing else, every commercial undertaking needs to yield at least a zero result on order to stay in business.

A State is free to invest in infrastructure and own it but must avoid subsidising business operations or else it will have to navigate the EU rules on state aid.[34] In this context an ETS plant may not need to get involved with investing in infrastructure. However, if for a certain industry, like energy generation, CO_2 capture becomes a prerequisite for market entry or market existence, pipeline and storage ownership is likely to become of interest to the ETS plant. In such a case the ETS plant has an incentive to own and thereby control the infrastructure to make sure that it serves the plant operator's interests.

It is not only companies but also Member States that could have an interest in shielding transport and/or storage capacity from foreign actors. Although the CCS Directive urges the Member States to establish transboundary co-operation there is no guarantee that States will not be reluctant to enter into *bona fide* negotiations and cooperation. If a Member State so chooses it has a number of regulatory and supervisory instruments that it can deploy in order to make it hard for foreign operators to gain access to infrastructure and storage space within its territory. A pertinent question in this regard is to what extent a receiving State can influence and even veto the construction of sub-sea pipelines necessary for gaining access to an already existing CO_2 installation, eg a storage site? In order to forestall the erection of hurdles to infrastructure access the CCS Directive tries to establish a level playing field by applying the 'essential facilities doctrine'[35]. Thus the terms for access and refusal are defined. Presuming that ownership arrangement is not a refusal instrument, and provided that the natural monopoly doctrine is accepted, there are three ways to arrange the TPA for the emission point source companies or other transporters: a) negotiation between the parties over all the access conditions totally without competent authority involvement,[36] b) competent authority intervention in case the parties do not reach an agreement,[37] or c) regulated negotiation; access based on pre-published tariffs and conditions that the competent authority has approved beforehand.[38] Although fair access may to some extent be guaranteed by these arrangements in the relationship between private actors there are no similar mechanisms applicable as between Member States.

An essential question in respect to any TPA action is which physical point or section is proposed for accessing the infrastructure, and which risk for triggering refusal that it entails? Accessing an existing hub is for example much less likely to trigger a valid reason for rejection than accessing another point on a pipeline. With certain provisos Article 20 of the Natural Gas Directive may provide relevant guidance.

The Swedish Pipeline Law (Lag (1978:160) om vissa rörledningar) defines the pipeline types and their length that are excluded from TPA. In addition, the Council of European Energy Regulators, CEER, has published recommendations on implementation of TPA to pipelines (line pack) and storages. (Council of European Energy Regulators, 2003) The document may be instructive also in the CCS context.

As noted above, under the CCS Directive a Member State can determine the detailed modalities for access to both transportation networks and permanent storage sites. The Directive lists certain criteria that are to be taken into account – including storage and transport capacity that can reasonably be made available – but these create little predictability as to how the rules will play out in practice. Important is that access must be provided in a transparent and non-discriminatory manner. Concerning the costs and burdens which may result from TPA, Article 21 of the CCS Directive stipulates that:

> *2. … access … shall be provided in a transparent and non-discriminatory manner determined by the Member State. The Member State shall apply the objectives of fair and open access, taking into account:*
>
> *….*
>
> *(d) the need to respect the duly substantiated reasonable needs of the owner or operator of the storage site or of the transport network and the interests of all other users of the storage or the network or relevant processing or handling facilities who may be affected.*

[34] On state aid in relation to CCS infrastructure see (Vedder, 2009).
[35] See Appendix I: Essential Facilities Doctrine
[36] The Dutch model does not know third party access. Pipelines belong to the mining jurisdiction; thus a dispute is a court matter.
[37] This is being applied in Finland
[38] This is used in the energy sector (gas pipeline network and storages and electricity grids) and in the telecommunications sector.

There can be three types of tariffs, ie payment to the pipeline owner. The first is take-or-pay, which is a type of contract whereby the network operator has an obligation to either take the captured CO_2 transport feed-in supplied or pay a specified amount as a kind of punishment when not able to accept the feed-in supplied. For the network operator this creates an incentive to accept captured CO_2. The second type of tariff is pure volume based pricing. This type favours only the shipper and de-motivates the pipeline network owner/operator. The third tariff type contains two non-interacting components: volume of transported captured CO_2 and line pack segment as a function of time. These types of contracts are not common. However, the Russian electricity wholesale market has applied it since 2011. (Erkkilä, et al., 2009) The advantage of this type is that the total capacity, including line pack, is planned to digest peak loads. The capacity tariff grants unobstructed supply of feed-in and unobstructed withdrawal for injection. Both the tariffs ought to be designed with care. An inefficient pipeline flexibility tariff can result in misallocation of resources in the flexibility market, which subsequently raises a need for regulation to develop other flexibility, like storage, which generates unnecessary costs. The Swedish Pipeline Law is not very specific on the compensation merely requiring the concession holder to transport CO_2 for others *on reasonable terms*. The Finnish CCS Law is somewhat more specific by requiring reasonable compensation including return on capital.[39]

The way TPA is designed in the CCS Directive does not incentivise CCS infrastructure and may even lead to systematic access refusals. The main reasons are the vagueness of the rules and the attendant uncertainty about how they will play out in real cases as well as the omission to properly address the complexities of CO_2 transport, including line pack and issues pertaining to ownership of the CO_2. To some extent these problems can be dealt with through negotiations and agreements between the actors concerned. However, the more CO_2 streams that are added to a network the more complex will it be to deal with such issues and the less willing to negotiate are the parties likely to be.

With respect to EHR applications the problems may be somewhat alleviated by the fact that the captured CO_2 is sold to the EHR operator, a transaction that will clarify the legal relationship between the parties. However, in cases of incremental storage during EOR operations (scenario two in the Chapter on EOR) and incremental storage following termination of EOR operations (scenario three in the Chapter on EOR) TPA is likely to be even more complex than for pure CCS operations. In these cases the pipeline infrastructure will be used either simultaneously or consecutively for transport of CO_2 that is covered by the CCS Directive, including its rules on TPA, and for transport of CO_2 that falls outside the CCS regime. Since at least incremental storage following termination of EOR operations seems to be a viable route for CCS deployment it may turn out to be a problem that the legislation appears not to have considered these mixed forms of pipeline use. Furthermore, an EHR oriented market design could facilitate vertical market structuring that may lead to other types of competition related problems (Commission Decision 2006). Finally it must be noted that also when CO_2 is transported beyond the CCS Directive the environmental and human safety factors remain the same.

Considering the wide spectrum of ways in which the Member States have applied the TPA rules of the Natural Gas Directive it is obvious that there is a wide range of possibilities for applying TPA to CCS operations.[40] Each Member State can choose its own implementation method.

Previous Chapters have shown that a pipeline system is a venturesome exercise. A radial gathering system may entail less market distortion risks, especially when each line ends in a hub that is simultaneously a sea port. Ship transport may serve to minimise the risk for market distortion as well as avoid bundling of ownership and activities. A ship solution provides more flexibility compared to pipelines and gives a low threshold for business entries and exits. In other words, it does not result in business stagnation or erosion in the worst case and gives flexibility for creative destruction.

The Section 'Market design' in the Chapter on 'Enhanced Hydrocarbon Recovery' below deals further with certain aspects of TPA.

4.3.5 Ship transport

Transport of captured CO_2 by ship may be the most cost-effective solution under certain conditions and also provide the flexibility that can be highly desirable during a ramp up phase of a regional CCS infra-

[39] Lag om avskiljning och lagring av koldioxid 416/2012, § 7

[40] According to Roggenkamp: Netherlands: no tariffs on new storages; tariffs on old storages. Denmark: negotiation plus competent authority takes part to the tariff design process. Great Britain: the main commercial conditions must be publicly available. The system includes several exceptions. France: negotiation without no in advance published conditions and tariffs. Italy: mixture of regulation and negotiation relevant to storage type.

structure. (Mathisen, 2012, p. 66) In fact, the Swedish Government has described ship transport of CO_2 as a likely prerequisite, at least initially, for making CCS commercially interesting (Government Bill 2011/12:125 p. 97).

Safety issues pertaining to CO_2 transport by ship are covered by international agreements and some EU rules. (Raine, 2008, p. 358) These should not constitute a major obstacle since there are previous experiences of transporting CO_2 by ship in the region, although at a much smaller scale than a regional CCS operation using ships would entail. Such transport also features important similarities with familiar transport systems for natural gas. From a legal perspective analogies with the regulation of natural gas can therefore be informative.

However, there are other legal challenges confronting any CCS transport system involving ships. They relate to the fact that transport of CO_2 by ship is not covered by the EU ETS. This follows from ship transport not being mentioned in Annex I of the ETS Directive which sets out the categories of activities to which the Directive applies. In line with this the Commission Regulation on monitoring and reporting of greenhouse gas emissions pursuant to the ETS Directive defines 'CO_2 transport' as 'the transport of CO_2 by pipelines for geological storage in a storage site permitted under Directive 2009/31/EC' without any mentioning of transport by ship (Commission Regulation 601/2012, Art. 3(1), point 52). From this follows that emissions from ship transport need neither be monitored nor covered by allowances. Put differently, the EU ETS does not impose any obligations on the use of ships to transport CO_2.

More importantly, this also means that captured CO_2 that is transported by ship does not benefit from the exemption from the obligation to surrender emission allowances which applies to 'emissions verified as captured and transported for permanent storage to a facility for which a permit is in force in accordance with [the CCS Directive]' (ETS Directive, Art. 12(3a).) It is namely very unlikely that CO_2 transported by ship could count as 'verified'. (Langlet & Olsen-Lundh, 2012, p. 81)

It has been pointed out that Article 49 of the Commission Regulation on monitoring and reporting (Regulation (EU) No 601/2012) introduces a certain ambiguity. (Macrory, et al., 2013, p. 18) It holds that the operator of an installation covered by the EU ETS shall subtract from the emissions of the installation CO_2 which is not emitted but transferred out of the installation to any of the following:

> *'(a) a capture installation for the purpose of transport and long-term geological storage in a storage site permitted under Directive 2009/31/EC;*
>
> *(b) a transport network with the purpose of long-term geological storage in a storage site permitted under Directive 2009/31/EC;*
>
> *(c) a storage site permitted under Directive 2009/31/EC for the purpose of long-term geological storage.'*

This could be taken to imply that transferral to a storage site, irrespective of the means employed, would as such enable the operator to subtract the transferred CO_2. However, this does not overcome the problem of breaking the chain of monitoring and verification. It would thus conflict with the logic of the scheme as a whole and the intention of the monitoring system as defined eg in Recital 13 of the Preamble of the Regulation.

Point 21 on determination of greenhouse gas emissions from CO_2 capture activities in Annex IV to the Regulation is informative about the logic of the monitoring system. It holds that '[a]ll parts of the installation related to CO_2 capture, intermediate storage, transfer to a CO_2 transport network or to a site for geological storage of CO_2 greenhouse gas emissions shall be included in the greenhouse gas emissions permit and accounted for in the associated monitoring plan. 'Monitoring all parts' associated with capture, including transfer to a storage site is hardly reconcilable with allowing transfer to occur by a means of transport that is not covered by the EU system for monitoring[41] and is also not itself included in the EU ETS.

Article 24 of the ETS Directive provides a mechanism for unilaterally including (a) installations as well as (b) activities and greenhouse gases not covered by the trading scheme (ie not listed in Annex I). This opt in clause could enable shipping to be integrated in the ETS on a case-by-case basis. The relevant option would then be (b), since shipping is an activity rather than an installation.[42]

[41] On non-EU guidelines on monitoring and reporting for the transportation of CO by ship see (Hemmer & Kassis, 2012, p. 11).
42 An "installation' is defined as a stationary technical unit in the ETS Directive, art. 3 e.

Any such opt in will need to be approved by the EU Commission and may entail amendments of 'non-essential elements' of the ETS Directive by supplementing it. This indicates that amendments are allowed to some extent but the leeway seems to be quite narrow. (Langlet & Olsen-Lundh, 2012, p. 81) When assessing a proposed opt in the Commission will be required to consider inter alia potential distortions of competition, the environmental integrity of the ETS scheme and the reliability of the planned monitoring and reporting system (ETS Directive, Art. 24 (1)).

It must also be recognised that the ETS Directive primarily covers stationary activities whereas ship transport comes with a number of additional challenges associated with the fact that ships may move between Member States and also beyond the geographical jurisdiction of any Member State.[43]

Although presenting a number of challenges, opting in ship transport in relation to individual CCS projects may be a viable option. (Hemmer & Kassis, 2012, p. 25) However, dealing with the issue on a case by case basis is hardly a satisfactory long-term solution. (Macrory, et al., 2013, p. 20) The solution could be something similar to the Aviation Directive (Directive 2008/101/EC) through which another kind of moving emission source, namely airplanes, has been included in the EU ETS. Obviously, consideration would have to be given to the particularities of ships, including the rules on jurisdiction in the United Nations Convention on the Law of the Sea (UNCLOS). This is most probably best done at the EU level by means of harmonised measures. (Langlet & Olsen-Lundh, 2012, p. 82)

Since regional CCS networks, like the one(s) envisioned for the Baltic Sea area, may be particularly reliant on the flexibility provided by ship transport it seems that an amendment of the ETS Directive and related EU legal acts to cover CO_2 transported by ship is an issue that representatives from the region may be well advised to push at the EU level. In fact, the Swedish Government has concluded that Sweden ought to pursue the inclusion of ship transports under the EU ETS. Until such inclusion has been achieved the Government foresees that inclusion of ship transport could be applied for in relation to specific CCS projects (Government Bill 2011/12:125 p. 97).

4.4 Sink

The terms CCS (Carbon Capture and Storage), CCUS (Carbon Capture Utilisation and Storage), and CCU (Carbon Capture and Utilisation), refer to different concepts. The first two – CCS and CCUS – tend to be climate policy strategies. CCU seems to be a vision of converting CO_2 to viable products without policy support.[44] The task of CCU is to develop new materials and energy feedstock from captured CO_2. CCS has gained political approval, especially in the EU. The emphasis is on advocating CO_2 capture technologies which entail energy penalty, while omitting political support for CO_2 recycling and material engineering applications. CCUS, on other hand, underlines 'utilisation', it advocates sustainable use of natural resources and is favoured by the United States and China. The diverse polices are not contradictory. CCUS can rather be viewed as offering wider perspectives, a result of concept evolution. Although CCU lacks policy measures, it contains many near-future potentials and is beneficial for investors. (Carus, 07.10.2013 – 09.10.2013) CCU is about monetising CO_2 streams.

The Chinese National Development and Reform Commission has set out the following '*Aim, benefit and working principle'* relating to CCUS:[45]

> *'Carbon capture, utilisation and storage (CCUS) technology has the potential to achieve a large–scale reduction in greenhouse gas emissions. CCUS will be an effective measure to control greenhouse gas emissions in China, given that the Chinese energy system is dominated by coal, and will contribute to decarbonising coal, oil and other energy intensive sectors. CCUS will promote the transition and upgrade of high emission industries such as electricity and coal-to-chemicals while, at the same time, encouraging the development of other associated industries. It has significant value to Chinese medium- and long-term plans to combat climate change and promote the development of low–carbon technologies.'*

The 12th five-year program phases in carbon capture technology and sets the primary working tasks to 'promote multiple mechanisms to utilise captured CO_2 to improve the economic performance of pilot and

43 On the complications of regulating monitoring and verification for ship transport see further Langlet & Olsen-Lundh, p. 82.

44 *CCU in the Green Economy Report*, downloadable on: http://co2chem.co.uk/carbon-capture-and-utilisation-in-the-green-economy; and *Carbon Dioxide – raw material of the future*, available on: http://co2-chemistry.eu/

45 "Notice of National Development and Reform Commission (NDRC) on Promoting Carbon Capture, Utilisation and Storage Pilot and Demonstration," 2013. English translation can be found at: http://www.globalccsinstitute.com/publications/notice-national-development-and-reform-commission-ndrc-promoting-carbon-capture

demonstration projects'. The emphasis is evidently on EHR. The goal is to develop a large-scale CCUS industry by removing technical and economic barriers.

The outlooks for CCUS and CCS seem to differ. The CCUS helps to alleviate climate change by first harnessing different sink-like solutions and then addresses climate change with permanent storages while CCS tries to address climate change in one go. (Heping, et al., 2013, p. 8) The CCUS approach contains investor-motivating factors, while CCS has fewer of them. The European Commission seems to have adapted CCS through the CCS Directive with no other policy concerns regarding CCUS or CCU. This, however, does not exclude CCU from utilisation opportunities.

The Chapter 'Other use' will discuss CCU, while the Chapter on 'EHR' deepens the discussion about CCUS.

4.4.1 Other use

Carbon Capture and Utilisation is largely excluded from EU climate policy measures. The EU's focus and support have been directed almost exclusively towards CCS. The exception to this CCS focus has been a few projects that are part of the bio-based programs.[46] This focus is due to change in 2016 with SPIRE (Sustainable Process Industry through Resource and Energy Efficiency), a contractual Public-Private Partnership (PPP) dedicated to developing the enabling technologies and solutions along the value chain, required to reach long term sustainability for Europe.[47] The rate at which CO_2 may establish itself as a feedstock depends largely on the political framework conditions, the support measures available to develop it further and the incentives for commercial implementation. Thus, national R&D programs can be a meaningful support in the creation of CCU technologies.

CCU is a commercially based undertaking. Hence, the nature and volume of the market is obviously important. Based on 2009-2012 records, the commercial annual market for CO_2 was some 20 million tons (excluding the use in EHR, large chemical manufacturing and several niche applications). About 40% of the global total CO_2 sales occur within the United States followed by Japan and the EU. In the world markets, about 70% of the refined CO_2 product is sold to food and beverage manufacturing operations for chilling, freezing, gas modified atmospheric packaging, and beverage carbonation. The remaining 30% is utilised in a wide selection of industrial uses, including pH reduction uses, agricultural applications, metallurgical and mining uses, welding gas usage, solvent use, dry ice applications, gas well stimulation, and chemical feedstock use. (Rushing, 2010)

From a climate perspective these volumes are rather negligible and are made even more so by the fact that many of the uses don't keep the CO_2 away from the atmosphere more than very briefly. However, as more applications are developed they will gradually increase the volumes demanded and could make the commercial market for CO_2 a driver for development and deployment of CO_2 capture technologies.[48] VTT Technology report 125 provides a comprehensive review of potential CO_2 applications. (Teir, et al., 2013, pp. 51-55)

There are new technologies and methodologies being developed to re-purpose and monetise CO_2 emission streams. The leading development occurs in the United States followed by the EU. However, the development in China should not to be overlooked. The current scientific and engineering focus concerning CO_2 is related to how it can be used or converted as a fuel or chemical feedstock. CO_2 utilisation may store energy by the means of methane and liquid fuels. CO_2 utilisation may also include making chemicals and plastics. Many demonstration facilities showcasing these approaches (including the first commercial plants) are already up and running. The technological pathways, not dealt in this report, include electrolysis, catalytic processes, bacteria and direct use and industrial mineralisation.[49]

Storage and transport of CO_2 for other use than CCS does not require any kind of CCS related permits or allowance procedures. However, this also means that if CO_2 captured at a plant included in the EU ETS is directed towards other uses it is regarded as emitted under the ETS. This follows from it not being 'verified as captured and transported for permanent storage to a facility for which a permit is in force in accordance with [the CCS Directive]' (ETS Directive, Art. 12(3a).) This means that if captured

[46] http://bio-based.eu/news/co2-ready-go-fuel-chemical-feedstock/.

[47] What is SPIRE, http://www.spire2030.eu/spire-vision/what-is-spire (25 March 2014).

[48] An example is provided by Linde, a world-leading gases and engineering company producing refined CO_2, which in 2012 reported that they will build a plant for the purification and liquefaction of carbon dioxide in Salamanca, Spain. The plant will be able to process around 70,000 tons of CO_2 per year. The plant will be supplied with raw CO_2 from Abengoa Bioenergy's bioethanol production plant on the same site. **Invalid source specified.**

[49] *CCU in the Green Economy Report*, downloadable on: http://co2chem.co.uk/carbon-capture-and-utilisation-in-the-green-economy and 2nd Conference on Carbon Dioxide as a Feedstock for Chemistry and Polymers, Essen, 7-9 Oct 2013

CO_2 is considered a raw material and not transported to permanent storage it falls outside the CCS regime but stays within the ETS in the sense that it will have to be covered by emission allowances. This obviously provides a disincentive for other uses.

When the issues related to purity, as dealt with above, have been successfully addressed the emissions from fossil-burning power stations and industries such as steel, cement, and pulp and paper can be utilised at accelerating speed along with the advancement of technological assimilation. This applies for CCS as well as CCU. Actually, they both contain considerable synergy potentials in the field of technology assimilation that can be accomplished with the help of renewable energy sources, like power from wind and sun. As long as the ETS allowance price stays at a very low level the sales price for CO_2 will define whether investments in CO_2 capture technology can be a financially sound first step on the way towards full CCS deployment.

4.4.2 Enhanced Hydrocarbon Recovery

Although the most discussed form of CO_2 utilisation Enhanced Hydrocarbon Recovery (EHR) is clearly not the only use to which captured CO_2 can be put in significant volumes. EHR in itself also covers a number of distinct uses with different characteristics. Carbon Geological Utilisation and Storage, CGUS, is a subset of the CCUS. CGUS refers to processes utilising underground minerals to mineralise CO_2 or to enhance the recovery of oil and gas. Subsets to CGUS, which are used in the literature, are:

1. Carbon Mineralisation Utilisation, CMU
2. Enhanced Geothermal System, EGS
3. Enhanced Coal Bed Methane, ECBM
4. Enhanced Shale Gas, ESG
5. Enhanced Gas Recovery, EGR, and
6. Enhanced Oil Recovery, EOR

Points 3-6 are collectively referred to as Enhanced Hydrocarbon Recovery, EHR.

This Chapter will concentrate on characteristics of EOR and the EOR market design.

4.4.2.1 Legally relevant characteristics of EOR

The CCS Directive does not explicitly cover EOR. Whereas none of the substantive provisions of the Directive mention EOR recital 20 of the preamble (introduction) holds that ‘EHR is not in itself included in the scope of this Directive.’ The preamble is not legally binding, and can therefore not formally exclude EOR from the applicability of the Directive, but is intended to provide insights into the reasoning behind the Directive’s substantive provisions. The phrase ‘not in itself’ supports an interpretation which allows the Directive to be applied to storage of CO_2 undertaken in association with EOR operations, if not the actual EOR operations themselves.

The term ‘storage’ is not clearly defined in the CCS Directive.[50] However, according to an insightful analysis by Macrory et al. the preferable interpretation of the concept of storage in the Directive is that it is ‘not intended to encompass the injection and storage of CO_2, which is the inevitable or ordinary result of EOR.’ (Macrory et al., 2013, p. 14) If it did, it would mean that all EOR operations would qualify as storage sites under the CCS Directive and be subject to the Directive’s requirements regarding eg site characteristics and financial security. It is, however, fully conceivable that ‘ordinary’ EOR operations could be accompanied or followed by injection of CO_2 that would in principle qualify for being covered by the CCS Directive and the ETS. The following sections will take a closer look at different EOR scenarios and how they relate to the CCS regime and the ETS.

(Marston, 2013, pp. 106-108), introduces four EOR scenarios:

[50] Article 3.1 does define “geological storage of CO_2’ but since “storage’ occurs without further explanation also the definition, which is “injection accompanied by storage of CO_2 streams in underground geological formations’, this says little about what is required for CO_2 to be considered as being stored in such formations.

1. Incidental storage of CO_2 during EOR operations,
2. Incremental storage during EOR operations,
3. Incremental storage following termination of EOR operations,
4. Storage during buffering or balancing operations.

The first scenario, that what commonly is understood by EOR and illustrated in Figure 6, refers to the CO_2 that inevitably accumulates in the strata during the injection of CO_2 as part of an EOR operation.

For a correct legal analysis it is important to understand how EOR works. Based on Marston's scenarios, the EOR operation differs considerably from CO_2 injection as part of a permanent storage operation. Although oil deposits reside in geological formations and CO_2 is injected into such formations for enhancement of oil production the CO_2 injected as part of a normal EOR operation will not remain stored there other than in an incidental manner.

Firstly, EOR uses CO_2 but also other hydrocarbon displacements (EOR substances), such as water, steam, polymers, sodium hydroxide, propane, butane and other miscible gases depending on various economic, production and geo-formation factors. (Sino Australia Oil & Gas Pty Limited, 2013) (Shell Global Solutions International B.V., 2012) (Schlumberger, 2014a) The consecutive use of different substances is referred to as ‘chemical shifting’.

The EOR substances, apart from steam, are generally injected in a bore hole at some distance from the point where oil extraction takes place. The substances are injected in varying intervals causing front like impulses whereas CO_2 injection into a permanent storage will occur more or less at a steady flow rate without flooding substances. First the EOR substances, like CO_2 are injected and will mix with surrounding hydrocarbons. Thereafter water is injected to flush mobile hydrocarbons towards the extraction point. This procedure is referred to as ‘water-gas cycling’. As all the substances advance slowly in the strata the process takes from two to several years. Therefore there is a considerable time lapse before any remaining CO_2 works through for recovery[51], (Marston, 2013, p. 16)

[51] See references above.

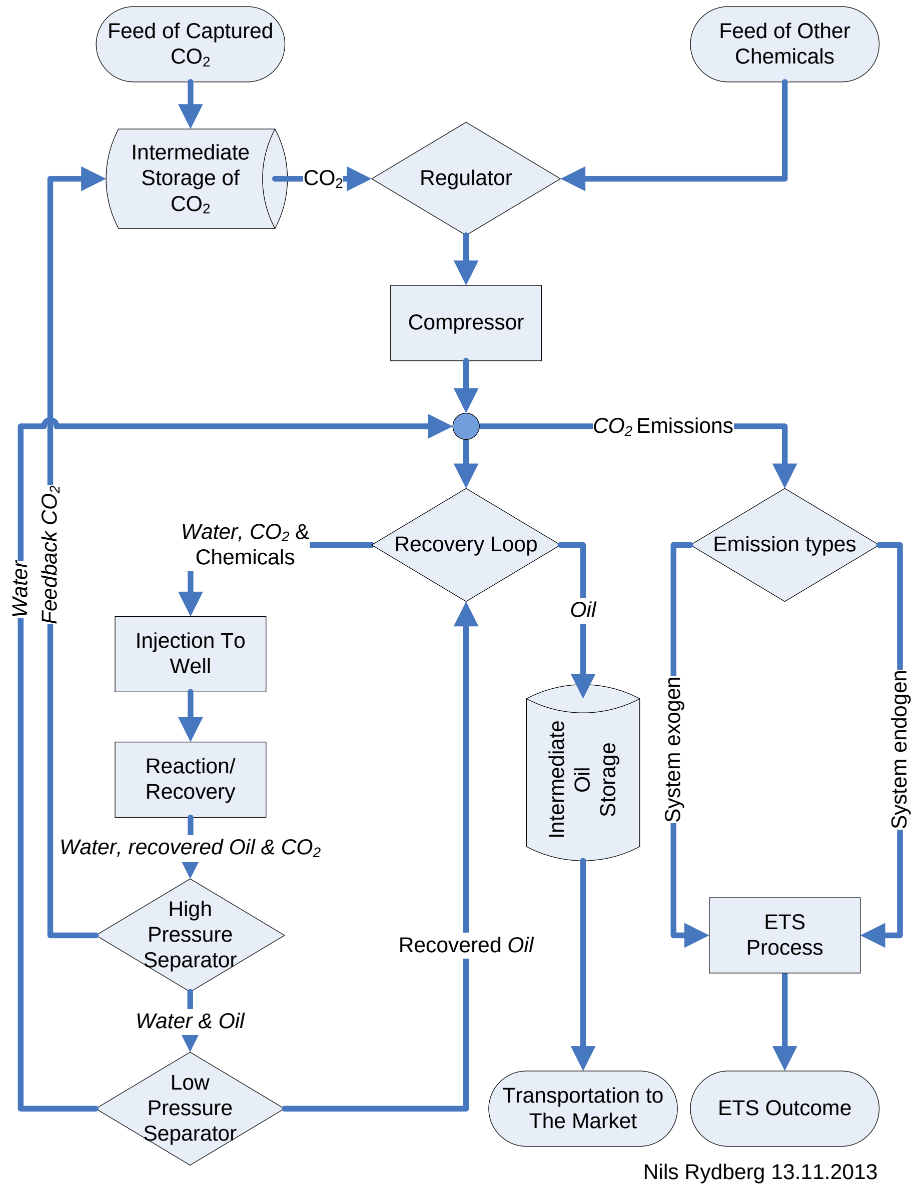


Figure 6: The EOR system. Illustration of the CO_2 based enhanced oil recovery mechanism, the EOR-loop. The EOR system is analogical to the generic system boundary as in Figure 1.

The CO_2 is subject to recovery and is in constant circulation by means of separation, as illustrated in Figure 6. EOR operators recycle as much CO_2 as possible for further injection, but typically between 30% -50% remains, which may stay in the strata following initial injection. As soon as a deposit is depleted, in technical or economical terms, exploitation will cease which means an end to the use of CO_2. (Macrory, et al., 2013, p. 8)

Even though a significant volume of CO_2 may remain in the geological formation once the EOR operation ceases, the operation as such is thus not concerned with storage of CO_2. Ordinary EOR takes place only as long it is considered feasible depending on the age of the oil well or oil field and not all deposits are suitable for CO_2 based EOR.

It is hence logical and in accordance with the overall structure and purpose of the CCS Directive that incidental storage of CO_2 during EOR operations does not fall within the framework of the CCS Directive and may hence not generate any benefits under the EU ETS since the two directives are functionally linked.

Since sending captured CO_2 for use as part of an EOR operation will not alleviate the operator of an ETS plant of the obligation to surrender allowances the only incentive for doing so will be the price that the ETS operator is willing to pay for the CO_2. This obviously depends on the value of the additional oil that may be extracted and the cost of using alternative boosters, ie other substances than CO_2.

For ordinary EOR operations to become attractive from a climate policy perspective they would have to be included in the ETS regime and also covered by the CCS Directive. Although there is, as described under 'Ship transport' above, a mechanism in Article 24 of the ETS Directive which allows additional activities and installations to be unilaterally included in the ETS any such opt in must be approved by the EU Commission and may only entail amendments of '*non-essential elements*' of the ETS Directive. It is unlikely that the amendments needed to fit ordinary EOR operations into the ETS regime could qualify as amendments of non-essential elements.

In addition to problems with the concept of storage in the CCS Directive, and thereby indirectly in the ETS regime, the treatment of EOR operations as permanent storage would cause immense, if not insurmountable problems in drawing a line between what resides in the deposit for recycling and what which is to be regarded as stored. Issues regarding purity of the CO_2 stream and monitoring would also generate severe conflicts that will be hard to deal with within the CCS regime.

The inclusion of ordinary EOR operations in the ETS would hence only be possible if the Directive was significantly amended by the EU legislator to accommodate the particular characteristics of EOR and the challenges that it brings in relation to the concept of permanent storage.

In scenario two (where the EOR-loop in Figure 6 is applicable) the amount of captured CO_2 that is injected exceeds the CO_2 volume optimal for oil extraction. In other words, the EOR operation is optimised to inject additional captured CO_2 in the EOR-loop. Intermediate and buffer storages, if any, are in this case of minimal importance. Constant receipt of captured CO_2 can be agreed and guaranteed.

In this scenario the EOR operator will inevitably charge a service fee for receiving and injecting captured CO_2 since there exists no other incentive for injecting CO_2 additional to that required for the EOR operation. If the injection of such additional CO_2 is not recognised as geological storage in the meaning of the CCS Directive and alleviates the ETS operator supplying the CO_2 from the obligation to surrender emission allowances this kind of storage will not occur since no one will then have an economic interest in it.

Macrory et al. argue for scenario two operations being covered by the CCS and thus able to alleviate the operator an ETS site from the obligation to surrender allowances. (Macrory et al. 2013, p. 17) However, much the same problems relating to monitoring and to the composition of the injected CO_2 stream as arise under scenario one will also affect scenario two as well as any other EOR technology where CO_2 is recycled. This would make inclusion of scenario two operations in the ETS hard to accomplish.

Referring to Figure 6, the problems will appear the moment the second injection cycle is about to start as the recycled CO_2 would not meet the CCS purity requirements due to prevailing EOR substances listed earlier in this chapter. However, a narrow reading of the purity requirements in the CCS Directive could allow for recycled CO_2 to be injected. However, water-gas cycling and chemical shifting is most likely not consistent with the CCS regulation.

The third scenario, ie incremental storage following termination of EOR operations, refers to CO_2 that can be injected permanently into a depleted hydrocarbon site, where the ultimate use of the site for CCS storage is planned from the beginning of the EOR project. Once the EOR operation has ended issues of monitoring and purity of the injected substances are no longer a major problem since all incoming captured CO_2 is of anthropogenic origin and should comply with the CCS Directive. The fact that the formation into which the CO_2 is injected is already partly filled with various EOR substances does also not pose a problem since there will be no more recycling of CO_2 once the ETS operation has been terminated. This is the kind of EOR-related operation that would most easily fit within the CCS and ETS regulatory frameworks. Figure 6 does not apply to this scenario since there is no recycling of injected CO_2.

Once injection of CO_2 is found to fall under the CCS Directive the operation will also benefit from the exemption from the waste definition which applies to CO_2 captured and transported for the purpose of geological storage according to applicable EU law.[52] With respect to EOR operations that do not fall

[52] The exclusion of CO_2 captured and transported for the purpose of geological storage from the waste definition is somewhat technical. Article 36 of the CCS Directive amended the definition of waste in the then Waste Framework Directive (Directive 2006/12/EC, art. 2(1)(a)) so as to exclude '…carbon dioxide captured and transported for the purposes of geological storage and geologically stored in accordance with [the CCS] Directive…'. Directive 2006/12/EC was subsequently repealed by a new Waste Framework Directive, Directive 2008/98/EC. However, according to art. 41 of the

under the CCS Directive the potential waste classification of the CO_2 injected is likely to be a problem. However, since such operations are unlikely to be motivated by climate considerations or acknowledged within the ETS this issue will not be further discussed here (see instead Macrory et al. 2013, pp. 20-23).

The fourth scenario refers to intermediate subsea storage and could encompass stacked storage in non-hydrocarbon bearing saline formations where excess CO_2 is stored for use when CO_2 supplies fall below the quantity needed for EOR purposes, as in Figure 6. This scenario establishes a potential risk to leave unknown volumes of CO_2 after EOR applications end. In other words, there could be two deposits containing CO_2, the oil well/field and the intermediate storage that perhaps does not comply with permanent storage requirements. The problems associated with the first scenario have strong bearing also on the fourth scenario making inclusion of such operations in the ETS hard to achieve. This means that for the EOR operator, or any other party, there are no further incentives to proceed with CO_2 injection after oil exploitation ends.

4.4.2.2 EOR market design

In the EU, unlike in the United States, captured CO_2 intended for EOR application can, due to climate change policy measures, be seen to generate two different commodities[53] on the monopsony market. Monopsony is a market similar to a monopoly except that a large buyer, not seller, has sole control or controls a large proportion of the market and sets the prices. A synonym is a buyer's monopoly.

Competitive markets will form under certain conditions, including[54]:

1. The profit motive. Free markets form when the profit motive can be satisfied.
2. The principle of diminishability. Stocks of pure private goods will diminish as the good is purchased.
3. The principle of rivalry. Consumers must compete with each other to get the benefit provided by the good or service.
4. The principle of excludability. For markets to form it is essential that consumers can be excluded from gaining the benefit that comes from consumption.
5. The principle of rejectability. It is also necessary that consumers can reject goods if they do not want or need them.

The entity '*customer*' is theoretical, thus it is generalised to apply equally to private persons as well as businesses – an approach that competition regulation has adopted. Conclusions drawn from the literature[55], author's experience and definitions as in Appendix I, in the EU the EOR market will hardly become competitive, thereby causing a market failure, due to the fact that:

1. Pipeline networks will be not be built only for demonstration purposes,
2. Existing pipeline networks do not compete with pipelines transporting CO_2,
3. Oil exploration companies may have incentives to promote EOR operations but not to develop markets and related transportation infrastructures,
4. CO_2 supply to EOR operations will be based on bilateral agreements,
5. Information of diminishing storage space will be not available,
6. TPA may be excluded due to the characteristics of EOR operations,

new Waste Framework Directive references to the old Waste Framework Directive shall be read as references to Directive 2008/98/EC. For this reason the amendment made by art 36 of the CCS Directive still apply, despite the fact that consolidated versions of Directive 2008/98/EC do not mention any exception for CO_2 captured and transported for the purposes of geological storage.

[53] See Appendix I: Commodity

[54] See Appendix I: Competitive markets / Market Failure

[55] **Invalid source specified.Invalid source specified.Invalid source specified.Invalid source specified.Invalid source specified.Invalid source specified.**

7. CO_2 demand is based only on EOR operators optimised needs,
8. Considerable time lags exist,
9. The number of contracting EOR–ETS parties will be limited due to the possible buffer/intermediate storage capacity, and
10. The property rights are not sufficiently defined.

Concerning a normal commodity, the price is subject to supply and demand. Consumption decreases when the price increases and vice versa. For an EOR operator, CO_2 is almost a normal commodity as the operator balances costs and production factors by chemical shifting. The incentive to buy or use extra amounts of CO_2 depends on the prevailing extraction factors and expected oil price development. The operator's decision hinges on short and medium range time perspectives. Within the medium range as a rule of a thumb it takes about two years before the injected CO_2 starts to show results. The fact that an 'ordinary' CO_2 based EOR operation falls outside the CCS legislation results in cost alleviation, since it means that the various requirements of the CCS Directives do not have to be met.

Pursuant to the principle of diminishability normal commodity prices increase as resources are depleted. This may apply to a permanent storage for CO_2 as defined by the CCS Directive but not to an EOR application. From the point of view of an ETS plant, an EOR application is not a normal commodity, and does not fit any market theory category. This is due to total lack of information. For an EOR operator capacity information is highly confidential, thus the operator does not share it. This is a prevailing rule in the oil extraction industry. Even the oil producing countries do not publish their remaining oil and gas reservoir capacities. Due to constant CO_2 cycles, oil recovery exposes increasing volumes of CO_2 that gradually reduces the need for refills from ETS plants. At some point the EOR operation reaches a saturation point, with a vague link to reservoir capacity. The site has become self-sufficient with CO_2 production. Due to lack of information the saturation point comes as a surprise to the ETS plant as there is no price signal.

CO_2 supplied to an EOR operation could have a price/cost ceiling.[56] From the point of view of the ETS operator the business case is based on the difference between the cost of CCS and the price of ETS allowances.

The EOR operator knows the ETS price and is able to set his price equal or slightly below it as long it remains below the operators production costs. If the production costs are well below the ETS price he will take advantage of the existing price difference. This design also may apply to situation where the competent authority has set the tariff in case of TPA. The ETS plant has to take the price as he has no other options.

The ETS relies on a rising price of constantly decreasing allowance volumes. CCS, on the other hand, relies on reducing CCS technology costs. This business case omits the fact that once an ETS plant has made the CCS investment it has to live with it over a very long period – or in a worst case conduct a write-off that jeopardises positive profit development.

In Europe, unlike the US, compensation for supplied CO_2 will not be granted unless the EOR operation has an incentive. A tax regime, like in Norway, could provide a suitable driver within the range of concession policy.

If the EOR operation, however a monopsony, with its above described special characteristics will be accepted as a natural monopoly then it falls within the competition regulation. Due to prevailing market failures[57] the competition authority should gain the status of competent authority also when EOR operation will be connected to ETS cases.

[56] See Appendix I: Price ceiling
[57] See Appendix I: Competitive markets / Market Failure

5 Transboundary issues

5.1 Export of captured CO_2 in the light of EU law

One of the fundamental features of the European Union is that the Member States make up a common market referred to as the 'internal market'. As defined in Article 26 of the TFEU the internal market comprises an area without internal frontiers in which the free movement of goods, persons, services and capital is ensured in accordance with the provisions of the Treaties. Closely linked to the ambition of maintaining the internal market is the fact that the EU constitutes a customs union covering all trade in goods. It involves the prohibition between Member States of customs duties on imports and exports and of all charges having equivalent effect, and the adoption of a common customs tariff in their relations with third countries, ie non-EU Member States (TFEU, Art. 28).[58] In practice this means that goods crossing a border between Member States should, with respect to tariffs and related charges, be treated like goods circulating within a single Member State. Goods moving to or from any third country are subject to a common policy adopted by the union rather than by the Member States individually.

With respect to captured CO_2 intended for geological storage in accordance with the CCS Directive this means that no customs duties or charges having equivalent effect may be imposed as a consequence of the CO_2 being transported between EU Member States.

CO_2 captured and transported for the purpose of geological storage according to applicable EU law has been excluded from the general EU legislation on waste.[59] However, even if a certain volume of exported CO_2 were to be classified as waste that would not affect the way it is treated with respect to customs duties. For, as the EU Court has made clear, waste is indeed goods, although of a particular or *sui generis* nature, under EU law (Case C-2/90, para. 28). It is thus subject to the prohibition on customs duties on imports and exports and charges having equivalent effect.

With respect to any potential shipment of captured CO_2 outside of the EU, notably to Russia, the situation would be different. The rate of the import duty currently applied to CO_2 when imported to Russia is 5 per cent of the customs value.[60] The customs territory of the Russian Federation includes installations and structures situated in the Russian exclusive economic zone (EEZ) or located on its continental shelf and subject to the jurisdiction of the Russian Federation in accordance with Russian federal law.[61] It is hence not likely that shipments of CO_2 to an injection point within the Russian EEZ would be exempted from import duty on the basis that it doesn't reach Russian territory.

A second important issue to be considered in relation to any such export of CO_2 outside of the EU is that the CO_2 would no longer be 'verified as captured and transported for permanent storage to a facility for which a permit is in force in accordance with Directive2009/31/EC'since no such permit can be issued for a storage site outside of the EU (Directive 2003/87/EC, Art. 12(3a)). Capturing CO_2 with the intention of exporting it to eg Russia would thus not exempt the operator of the facility generating the CO_2 from the obligation to surrender emission allowances, ie the operator would not benefit from the incentives for CCS under the EU ETS.

However, with respect to prospective export to Russia, or any other non-EU Member State, there is a third, even more significant, obstacle. As noted above, the CCS Directive amended the EU framework directive on waste so that '…carbon dioxide captured and transported for the purposes of geological storage and geologically stored in accordance with [the CCS] Directive…' is excluded from the general definition of waste under EU law (CCS Directive, art 36). But since the amended waste definition only

[58] That customs duties on imports and exports and charges having equivalent effect are prohibited between the Member States is specified in art. 30 TFEU.

[59] The exclusion of CO_2 captured and transported for the purpose of geological storage from the waste definition is somewhat technical. Article 36 of the CCS Directive amended the definition of waste in the then Waste Framework Directive (Directive 2006/12/EC, art. 2(1)(a)) so as to exclude '…carbon dioxide captured and transported for the purposes of geological storage and geologically stored in accordance with [the CCS] Directive…'. Directive 2006/12/EC was subsequently repealed by a new Waste Framework Directive, Directive 2008/98/EC. However, according to art. 41 of the new Waste Framework Directive references to the old Waste Framework Directive shall be read as references to Directive 2008/98/EC. For this reason the amendment made by art 36 of the CCS Directive still apply, despite the fact that consolidated versions of Directive 2008/98/EC do not mention any exception for CO2 captured and transported for the purposes of geological storage.

[60] Customs tariff of the Russian Federation (Approved by Russian Federation Government Regulation N 830, dated November 30th, 2001), Section VI, Products of Chemical Industry and of Related Branches, Group 28, Code 2811 21 000 0. Retrieved from <http://www.russian-customs.org/legislation/tariff/index.html> (19 March 2014).

[61] The Customs Code of The Russian Federation, Part I, Chapter 1 (Adopted by the State Duma of the Russian Federation on 25 April 2003), art. 2(2). Retrieved from < http://www.russian-customs-code.com/> (19 March 2014).

applies with respect to CO_2 managed in accordance with the CCS Directive and that Directive only applies within the territories and marine jurisdictional zones of the EU Member States, CO_2 transported for storage beyond these areas will be considered waste under EU law. Export of captured CO_2 beyond the EU is therefore governed by Regulation 1013/2006 on shipments of waste. It distinguishes between shipments of waste for disposal and shipments for recovery purposes. Except for export to EFTA countries which are also Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal ('Basel Convention') all export of waste for disposal is prohibited (Regulation 1013/2006, art. 34.). Not least in the light of the case law of the EU Court of Justice, which has made it clear that EU waste law is to be interpreted in such a way as to prevent the erosion of its protective aim (see eg Joined Cases C-241/12 and C-242/12), it should be clear that geological 'storage' with no intention of ever retrieving the CO_2 qualifies as disposal. Like the Waste Framework Directive the Regulation on shipments of waste excludes 'shipments of CO_2 for the purposes of geological storage in accordance with [the CCS Directive]' from its scope. But also in this case the exception is of little relevance for export from the EU since storage 'in accordance with' the CCS Directive cannot occur where that Directive is not applicable, ie outside the EU. This means that export of captured CO_2 intended for storage in a third county is prohibited with the exception of shipments to Iceland, Lichtenstein, Norway and Switzerland, ie the EFTA States, which are all also parties to the Basel Convention. The current state of the waste legislation thus in effect rules out projects involving injection of CO_2 from EU Member States in the Russian part of the Baltic Sea.

CCS projects involving non-EU Member States could be facilitated eg by an amendment of EU waste law suspending the waste definition eg in relation to CO_2 intended for export to a third State with which an agreement on the modalities for the operation of joint CCS projects has been entered into. However, there would have to be guarantees that any such agreement preserved the protective aim of the CCS Directive. A less far-reaching option, which would probably better accord with the environmental concerns underlying EU law on waste export, would be to subject CO_2 intended for storage outside the EU to the same procedure as currently applies to export of waste for disposal to EFTA countries.[62] At least this would seem a reasonable solution with regard to export to other industrialised States. In such cases there would be less concern for those States being used as 'dumping grounds' for CO_2 from the EU or for technological or governance problems affecting the handling of the CO_2 compared to if export was allowed also to developing States. Export to developing States would also for practical reasons hardly be an option with regard to CO_2 origination in the Baltic Sea region. An amendment of the waste law framework along these lines could eg enable utilisation of any storage sites straddling the EU border and where at least some injection was to take place outside the EU. Obviously, any such amendment would require careful consideration of its environmental, legal and practical implications before it was decided. And it would not solve the problem that export outside the EU will mean that the CO_2 has to be covered by emission allowances under the EU ETS regardless of it being geologically stored.

5.2 Export of captured CO_2 for sub-seabed storage and international law

Exporting captured CO_2 for storage in sub-seabed geological formations, the form of storage of most interest in the context of the Bastor project, is prohibited for the Parties to the 1996 London Dumping Protocol[63]. This is a significant problem in regard to regional CCS solutions in the Nordic or Baltic Sea regions since Denmark, Norway and Sweden (but not Finland) as well as Germany and Estonia are all parties to the Protocol.

Dumping at sea has since the early 1970s been regulated under the London Dumping Convention[64] which was the first instrument to address marine pollution by dumping at the global level. A core feature of the Convention is a list of waste and other matter that may not be dumped. Eventually, however, the Convention came to be regarded by many as outdated, eg due to its insufficient basis in science and the fact that is does not give effect to the polluter pays principle (Sielen, 2009, p. 299). This prompted the negotiation of what is formally a protocol to the Convention but which in effect replaces the Convention for those Parties that ratify the new instrument, ie the 1996 Protocol.

[62] Regarding that procedure see Regulation (EC) No 1013/2006, art. 35.
[63] The full official name is 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, adopted 7 November 1996.
[64] The full official name is Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, adopted 13 November 1972.

The Protocol, which entered into force in 2006, differs from the Convention in a number of significant ways. Most important is perhaps that the previous ‘permitted-unless-prohibited’ approach to dumping is replaced by a general prohibition on dumping of any material or substance of any kind with specific exceptions set out in an Annex (Art. 4.1.1 and Annex 1). Of particular relevance to CCS operations is that ‘dumping’ covers any deliberate disposal into the sea of material or substances from vessels, aircraft, platforms or other man-made structures at sea as well as any storage of material or substance in the seabed and the subsoil thereof from vessels, aircraft, platforms or other man-made structures at sea (Art. 4.1 and 4.3). It is hence clear that geological storage of CO_2 in the sub-seabed qualifies as dumping.

In order to enable sub-seabed storage the Parties to the Protocol in 2006 adopted an amendment whereby CO_2 sequestration in sub-seabed geological formations was added to the Protocol’s Annex 1, ie among the substances that may be considered for dumping subject to a permit (Resolution LP.1(1)). The amendment entered into force in early 2007. The same year the Parties also adopted ‘Specific Guidelines for Assessment of Carbon Dioxide Streams for Disposal into Sub-seabed Geological Formations’.

However, the Protocol contains an Article 6 according to which ‘Contracting Parties shall not allow the export of wastes or other matter to other countries for dumping or incineration at sea.’ This provision gave rise to some discussion as to its significance for transboundary movements of CO_2. The dominant view that crystallised was that Article 6 prohibits the export of CO_2 streams from the jurisdiction of Party to any other country (IMO 2008a, para. 1). After much debate an amendment to Article 6 was put to a vote at the Meeting of the Parties in 2009. It was adopted as Resolution LP.3 (4) with 15 Parties voting in favour, one Party, China, voting against, and six Parties abstaining (IMO 2009, para. 5.14). China issued a statement saying that the issue of CO_2 sequestration in transboundary sub-seabed geological formations ‘has many complicated legal and technical implications, the deep and thorough study and discussion of which still need to be carried out by all countries’ and making clear that it was ‘not in favour of adoption of the proposed amendment to Article 6 in a hasty manner.’ (IMO 2009, para. 5.18) The statement also expresses concern that the export of CO_2 might open a door for export of other wastes in contradiction with the objective of the London Protocol.

The adopted amendment allows for export of CO_2 streams for disposal provided that an agreement or arrangement has been entered into by the States concerned. Such an agreement or arrangement must include ‘confirmation and allocation of permitting responsibilities between the exporting and receiving countries, consistent with the provisions of [the] Protocol and other applicable international law’ (London Protocol, Article 6 (2) as amended). In the case of export to non-Parties to the Protocol, the agreement or arrangement must contain provisions at a minimum equivalent to those of the Protocol, including those relating to the issuance of permits and permit conditions for complying with the provisions of the Protocol’s Annex 2, to ensure that the agreement or arrangement does not derogate from the obligations of Parties under the Protocol to protect and preserve the marine environment.

Unlike amendments to annexes an amendment to the Protocol as such requires acceptance by two-thirds of the Parties for it to enter into force and then only bind those Parties that have accepted it (Art. 21.3). Almost five years after the adoption of the amendment only Norway and Great Britain had submitted such an acceptance (McCoy, 2014, p. 76). As of 31 May 2014 the Protocol had 45 Parties. According to the International Energy Agency (IEA) a significant number of the Parties take a limited interest in CCS and also among those that do engage with CCS policy issues not all are interested in offshore CO_2 storage or CO_2 export for such storage. It is thus likely that ratification of the Article 6 amendment is given a low priority by many Parties (IEA 2011, p. 12). The chances of the amendment entering into force within the foreseeable future are thus slim. This has given rise to a discussion on whether there are measures other than the acceptance and formal entering in to force of the amendment that may enable Parties to export CO_2 for sub-seabed geological storage without breaching their obligations under the Protocol.

The IEA, which sees CCS as a critical component in a portfolio of low-carbon energy technologies, has published a ‘working paper’ that explores different options in this regard (IEA 2011). The document sets out six different options, namely: 1. The adoption by the Parties of an interpretative resolution; 2. An agreement to apply the amendment provisionally; 3. The conclusion of a subsequent agreement; 4. Modification of the operation of relevant aspects of the Protocol as between two or more contracting parties; 5. Suspension of the operation of relevant aspects of the Protocol as between two or more Parties; and 6. Conducting CCS through non-Parties. The reasoning provided for the different options is at times rather meagre. It is clear, however, that some of the options warrant more serious consideration than others.

Exporting CO_2 to or with non-Parties to the Protocol is not a viable option. There is nothing in the wording of Article 6 ('…shall not allow the export of wastes or other matter to other countries…') to suggest that the prohibition would not apply to export to non-Parties. That such export is covered by the prohibition has also been confirmed by many of the Parties (IMO 2008b, para. 5.14).

The option adoption by the Parties of an interpretative resolution is also of limited practical interest. Several of the Parties have rejected that an interpretative declaration would be an adequate basis for regulating CO_2 sequestration in sub-seabed geological formations (IMO 2006, para. 3.6). The fact that the Parties have initiated a formal amendment procedure also confirms that they perceive Article 6 to prohibit export for sub-seabed storage. There can hence be little doubt that the Parties consider a prohibition to be in force. Assuming that an attempt would nonetheless be made to have an interpretative resolution adopted, that would require consensus among the Parties (ILC 2014, para. 102). Considering that China actually voted against the adoption of the amendment in the first place, although expressing its support for facilitating export for sub-seabed storage in principle, and a number of other Parties laid down their votes, that may be very hard to attain. But if consensus could nonetheless be mustered for an interpretative resolution there appears to be no formal obstacles to using this method for enabling CO_2 export.

5.2.1 A subsequent agreement

The IEA's third option, the conclusion of a subsequent agreement, is perhaps the most promising one. It has the advantage of not requiring unanimity among the Parties.

According to the relevant rules on the application of successive treaties relating to the same subject matter a new agreement between some of the Parties to the London Protocol could change the legal obligations between these, eg by allowing export of CO_2 for sub-seabed storage between such Parties. In relation to the Parties to the London Protocol that were not Parties to such a subsequent agreement the Protocol would apply as before (Vienna Convention, Art. 30.4)

A major issue here, which is not analysed in the IEA report, is the nature of the obligation owned towards those States that remain Parties only to the Protocol. The IEA report seems to be premise on the assumption that the London Protocol only aims to protect, and thus only establishes obligations relating to the right of individual Parties not to have substances intended for dumping exported to them (IEA 2011, p. 18). However, the movement of the water of the sea and its inhabitants makes pollution of the sea, eg by dumping, a concern for more than just the State in whose maritime zone the dumping occurs. As regards the EEZ that argument is further strengthened by the rights enjoyed there by other Sates than the coastal State. It cannot therefore be assumed that the obligations set out in the Protocol are only intended to protect the interests of the State in whose waters any particular act of dumping would occur.

But prohibiting export for dumping is not the same as prohibiting dumping as such. It could be that the intention with this obligation is only to protect the State to which the export may be destined. There is, however, little to suggest that this is the case. The overall intention of the Parties when concluding the Protocol, as inferred from its first preambular paragraph, is to protect the marine environment and to promote the sustainable use and conservation of marine resources, without mentioning the rights or interests of particular States. And there is no mentioning of any other intention behind the export ban in Article 6 which constitutes a general export ban, without any distinction between eg Parties and non-Parties or between developed and developing States as may be expected if it was the interests of particularly vulnerable States that were to be protected by the ban. It is thus hard to sustain an argument that the export ban, as opposed to the ban on dumping as such, would be an obligation that is owned only in respect to each State to which export may take place.

However, Article 6 only allows for export to other Parties to the Protocol or, in the case of non-Parties requires that export occur only in accordance with an agreement or arrangement containing provisions at a minimum equivalent to those contained in the Protocol. If this is respected the actual risk of the export of CO_2 for dumping resulting in environmental harm that would not otherwise have occurred is limited. As a matter of fact export may very well enable captured CO_2 to be managed more safely and efficiently if the export is prompted by better storage sites and/or higher technical capacity in the State of import compared to that of export. In this way an argument can still be made that the rights of the non-Parties to a subsequent agreement would not suffer in any material sense as a consequence of export for dumping taking place under responsible and well regulated conditions. The argument would be most persuasive in situations where export occurs to States with high levels of technological and regulatory capacity. In order to avoid additional risks due to insufficient technical or regulatory structures as well as the risk of enabling developing countries being used as 'CO_2 dumping grounds' any subsequent agreement should thus be limited to allowing for export to industrialised countries, eg defined as members of the OECD. Such a limitation would be immaterial in a Baltic Sea context since the States that for geographical and practical reasons could qualify as importers of CO_2 are all OECD Member States.

5.2.2 Further related options

Of the other options presented in the IEA documents most run up against the same problem, and thus also possible opening, as a subsequent agreement. The provisional application of the amendment should also avoid the requirement for unanimity since a decision to apply a treaty (on an amendment thereto) provisionally can be made unilaterally as well as by two or more Parties (ILC 2013, para. 22.) But the Parties that don't apply the modification provisionally will still be able to claim that export is contrary to the obligation set out in Article 6 although it can be questioned, in line with the above argument, that their rights would actually be infringed in any material way. More or less the same goes for the option of modifying the operation of relevant aspects of the Protocol (ie Article 6) as between two or more Parties. Also the fifth option, suspension of the operation of relevant aspects of the London Protocol as between two or more contracting parties, is affected by much the same problems as the previous two. In addition it would, as noted in the IEA paper, signal that the Parties are prepared to set aside the multilaterally agreed obligations in order to pursue their own agenda (IEA 2011, p. 20). That would perhaps make it the least palatable option.

To summarise, enabling export of captured CO_2 is not a problem if consensus can be achieved for eg an interpretative resolution making it clear that construing Article 6 of the Protocol as not prohibiting export of captured CO_2 for geological storage, at least not when storage is to occur in another Party to the Protocol, is consistent with the will of the Parties. However, in light of the developments at the Meetings of the Parties so far this seems rather unlikely to happen. There are also measures which do not require consensus that could be resorted to. They would not make the legality of export a foregone conclusion but would at least enable a good argument to be made that the interests of the Parties who did not join such action, eg the adoption of a subsequent agreement or the provisional application of the amendment to Article 6, had not been injured in any substantive way.

5.3 Transboundary migration of injected CO_2

Under the CCS Directive no site for the geological storage of CO_2 may be operated without a permit issued by the competent authority in the Member State under whose jurisdiction the site is located (CCS Directive, art. 6(1)). A precondition for issuing such a permit is that the planned injection does not involve a storage site with a storage complex extending beyond the territory of any EU Member State, including the exclusive economic zones and continental shelves of such States (CCS Directive, art. 2(3)).[65]

The Directive does not define the storage complex with more precision than referring to it as 'the storage site and surrounding geological domain which can have an effect on overall storage integrity and security', also referred to as 'secondary containment formations' (CCS Directive, Art. 3, point 6). This obviously opens for varying readings. What is to be considered as the storage complex is also likely to vary depending on the nature of any particular storage site that is being considered. This should provide the Member States and the competent national authorities with some leeway to apply their own judgment in defining the relevant storage complex as long as they stay within the bounds of established geological science and geological terminology.

[65] The definitions of exclusive economic zone and continental shelve of the United Nations Convention on the Law of the Sea (UNCLOS) apply. In Swedish law the Directive's requirement has been implemented almost verbatim ('… lagring får dock inte ske …. i lagringskomplex som sträcker sig utanför en stat inom Europeiska unionens territorium eller utanför den ekonomiska zonen till en sådan stat.'). Förordning (2014:21) om geologisk lagring av koldioxid § 10.

The Directive doesn't provide any reasons for disallowing the use of storage sites with a storage complex extending beyond EU territory but the fact that the EU, or more accurately the concerned Member States, have very limited rights to carry out monitoring operations and take so-called corrective measures in order to prevent leakages or other irregularities beyond their respective territories and maritime zones,[66] is likely to have been an important factor. Correctly accounting for any such leakage under the international climate regime is also likely to be challenging.

Interestingly, the CCS Directive doesn't allow for the use of such storage sites even if it were to be undertaken in accordance with an agreement with the concerned non-EU Member State. In relation to the Baltic Sea this means that any storage site where the secondary containment formations are partly found beneath the Russian part of the continental shelf must be ruled out for storage purposes.

However, the fact that the storage complex may not extend beyond the outer borders of the EU is not the same as prohibiting the use of a storage site on the mere ground that there is a risk that part of the stored volume of CO_2 over long periods of time may spread outside those borders. It is namely not required by the Directive that there be no risk (if such a thing is ever scientifically possible to establish) of stored CO_2 eventually escaping the storage complex. The storage complex can thus not be equated with the whole geological area in which stored CO_2 could eventually end up.

If stored CO_2 escapes from the storage complex that constitutes leakage as defined by the Directive (CCS Directive, Art. 2, point 5). Interestingly, under the EU ETS it is only stored CO_2 that escapes to the air or the water column – but not CO_2 which escapes the designated storage complex but stays underground – that is to be categorised as an emission from the storage site and thus to be covered by emission allowances (Commission Regulation 601/2012, Annex IV, point 23). However, for the present analysis it is the wider definition of leakage in the CCS Directive, and the way that notion of leakage is used, that are relevant.

A geological formation may only be selected as a storage site, and thus a storage permit issued for that site, if under the proposed conditions of use there is no *significant* risk of leakage (CCS Directive, Art. 4(4)).[67] The notion of 'significant risk' is defined in the Directive but that definition is strikingly nebulous. For the purpose of the CCS Directive a significant risk is 'a combination of a probability of occurrence of damage and a magnitude of damage that cannot be disregarded without calling into question the purpose of th[e] Directive for the storage site concerned'. Interestingly the purpose of the Directive which may not be called into question is not set out explicitly. However, the Directive 'establishes a legal framework for the environmentally safe geological storage of carbon dioxide (CO_2) to contribute to the fight against climate change' (CCS Directive, Art. 1(1)). The purpose of 'environmentally safe geological storage of CO_2' is held to be 'permanent containment of CO_2 in such a way as to prevent and, where this is not possible, eliminate as far as possible negative effects and any risk to the environment and human health' (CCS Directive, art. 1(2)). Hence, the purpose of the Directive may be assumed to be at least that. Accordingly, a 'significant risk' should be at least a combination of a probability of occurrence of damage and a magnitude of damage that cannot be disregarded without calling into question the ability of permanent containment of CO_2 (at a specific site) to prevent and, where this is not possible, eliminate as far as possible negative effects and any risk to the environment and human health. Reasonably, it is a tall order to establish, for example, when a risk calls into question the ability to eliminate as far as possible negative effects and any risk which may not be prevented. Not least since the definition appears to be based on circular reasoning. This leaves the Member States with some discretion to define under what circumstances a storage site may be used even if eventual leakage of the stored CO_2 outside the storage complex and potentially outside the territory of any Member State cannot be ruled out.

However, the scientific estimates of the geological conditions that prevail in the southern Baltic Sea indicate limited movement of injected CO_2 and find it unlikely that any significant migration would occur for several thousand years. For this reason the remaining risk for such movements are unlikely to constitute any real problem for permitting in relation to actual storage sites as long as it is not a site where the actual storage complex stretches beyond the EU's outer boarders.

[66] As an example any drilling in the continental shelf requires prior consent by the coastal state. Any measure that involves drilling would thus be at the discretion of the non-EU Member State.

[67] This has been implemented verbatim in the Swedish Ordinance on geological storage ('En geologisk formation får användas för lagring av koldioxid endast om 1. det inte finns någon betydande risk för läckage av koldioxid från lagringsplatsen…'. Förordning om geologisk lagring av koldioxid (2014:21) § 9).

The above does not affect the right to make use of storage complexes that straddle the territories of two or more EU Member States. The utilisation of such complexes is foreseen by the CCS Directive which requires the Member States concerned in such cases to jointly meet the requirements of the Directive and of other relevant EU law (CCS Directive, Art. 24). The Directive does not, however, make it clear how the responsibilities are to be allocated between the Member States concerned.

As far as international law is concerned the Parties to the London Protocol have confirmed that trans-boundary movement of CO_2 after injection (ie migration) is not export for dumping and therefore not affected by Article 6 of the Protocol (IMO 2009, Annex 5).

6 Conclusions and considerations for the planned revision of the CCS Directive

The following issues of significance for deployment of CCS in the Baltic region may benefit from consideration in the context of a revision of the CCS Directive.

6.1 Defining the starting point of 'captured CO_2'

As elaborated in the sections 'CCS Value Chain', 'Starting point of the captured CO_2' and 'Pipeline infrastructure', the point at which CO_2 comes to be regarded as 'captured CO_2' is not clearly defined in the legislation despite 'captured CO_2' being a core term. This may cause problems in the negotiation of transport contracts and with respect to TPA related issues. It also has implications for the market design. A clear definition taking cluster development into account may lower the threshold for CCS deployment.

6.2 EOR market development potentials

The section 'EOR market design' as a whole showed the severity of the potential problems which may jeopardise the development of competitive markets for the EOR application. As the issues dealt with play a central role in market failure mitigation they should be elaborated in co-operation between market actors and legislators in order to create optimal preconditions for EOR. That could enable EOR to act as an initial step towards the full deployment of CCS.

6.3 Prohibition on the utilisation of 'extra-EU' storage complexes

As elaborated in the section 'Transboundary migration of injected CO_2' the CCS Directive prohibits the utilisation of any storage site with a storage complex extending beyond the territory of any EU Member State, including the exclusive economic zones and continental shelves of such States. Although the geological assessment indicates that significant migration of CO_2 geologically stored below the southern Baltic Sea is unlikely the prohibition would nonetheless preclude the use of any potential storage facility with a storage complex extending into the Russian continental shelf. This could be a problem if one or more suitable storage sites were to have this characteristic. A possible remedy could be to supplement the CCS Directive with the possibility of using storage sites with storage complexes extending beyond the EU if they were used in accordance with an agreement with the non-EU State or States concerned. Such a solution could potentially also prove valuable in the Mediterranean region.

6.4 Responsibility for transboundary structures

The CCS Directive as well as the ETS Directive contains very little information on how storage sites with storage complexes that straddle the territories of two or more EU Member States are to be regulated and managed. With respect to pipelines that cross boundaries between Member States there is even less guidance. This may result in unnecessary uncertainty among potential operators of such facilities as well as within national authorities. Even if revision of the Directives may not be called for, guidelines or some other kind of recommendations may be desirable in this area.

6.5 Export of captured CO_2 for sub-seabed storage

Exporting CO_2 for sub-seabed storage is prohibited for parties to the 1996 London Dumping Protocol, including Sweden. Although an amendment to the Protocol has been decided it is unlikely to enter into force in the foreseeable future. Export of captured CO_2 could be enabled if consensus can be achieved for eg an interpretative resolution making it clear that construing Article 6 of the Protocol as not prohibiting export of captured CO_2 for geological storage is consistent with the will of the Parties. However, that seems rather unlikely to happen. There are also measures which do not require consensus that could be resorted to. They would not make the legality of export a foregone conclusion but would at least enable a good argument to be made that the interests of the Parties who did not join such action, eg the adoption of a subsequent agreement or the provisional application of the amendment to Article 6, had not been injured in any substantive way.

6.6 Transport of captured CO_2 by ship

As elaborated in the section 'Ship transport' transport of captured CO_2 by ship, which may provide the flexibility needed during ramp up of a regional CCS infrastructure, is currently not covered by the EU ETS regime. This means that any CO_2 transported by ship is likely to be treated as emitted thereby effectively making ship transport a non-viable option. Although the ETS Directive provides a mechanism for unilaterally including activities not covered by the trading scheme (ie not listed in Annex I), which may enable ship transport to be included in the ETS on a case-by-case basis, this is an untested option and hardly a satisfactory long-term solution. The problem is most probably best dealt with at the EU level by means of harmonised measures. It would therefore be beneficial for the planned revision of the CCS Directive to consider integrating ship transport into the trading system as a supplementary option to pipelines. These are currently the only recognised means of transport for captured CO_2. The Aviation Directive, through which airplanes have been included in the EU ETS, could provide a valuable template for dealing with moving emissions sources. Obviously, consideration would have to be given to the particular characteristics of ships and the rules on jurisdiction under the Law of the Sea Convention.

6.7 Biogenic CCS

Particularly with respect to Sweden and Finland the possibility of including CO_2 from biomass could contribute to the financial viability and also the climate impact of a regional CCS structure.[68] Currently there are no financial incentives for capturing biogenic CO_2 since such emissions are not covered by the EU ETS. There may thus be good reasons from a regional perspective to push for an expansion of the ambit of the trading scheme to also cover biogenic CO_2. In fact, the explicit position of the Swedish Government is that CCS applied to bioenergy production should receive equal treatment as CCS applied to coal fired power generation (Government Bill 2011/12:125 p. 28). However, any such discussion must be sensitive to the fact that biomass plays a limited role in the energy systems of many European countries and that use of biomass for energy generation is often perceived as competing with food production over eg land and water resources.

6.8 Third party access

It would be beneficial to create additional predictability regarding the interpretation and application of TPA rules, both within individual Member States and in transboundary settings. This could be done in the context of a revision of the CCS Directive but also to a significant extent by action at Member State level. An important step would be to develop rules or at least guidelines that consider the complexities of actual pipeline operations, including line pack and the different incentives created by different infrastructure solutions. It would likely also be very beneficial if competition authorities were formally involved in the planning and operation of CCS infrastructure from an early date.

6.9 Market actors and activities

Although the CCS value chain differs fundamentally from that for natural gas (Insight Economics Pty Ltd, 2011), the Natural Gas Directive provides a valuable point of reference in the way it regulates the roles of the market actors and constructs the principles for owning/operation of structures including TPA concerns. The current Natural Gas Directive unbundles ownership of transmission system operators, requires the establishment of operator's cooperation in Europe, as well as increases the powers of the national authorities.

The following list draws on the Natural Gas Directive. It suggests some minor amendments through which the provisions could become suitable for the regulation of CCS operations. The numbers in brackets and text following in italics are from Article 2 of the Directive dealing with definitions.

(1) 'natural gas undertaking' means a natural or legal person carrying out at least one of the following functions: production, transmission, distribution, supply, purchase or storage of natural gas, including

[68] On biogenic emission in the Nordic region see eg Teir, S. and others, 'Potential for carbon capture and storage (CCS) in the Nordic Region', VTT Tiedotteita – Research Notes 2556, 2010, p. 23.

LNG, which is responsible for the commercial, technical and/or maintenance tasks related to those functions, but shall not include final customers

Instead of '*natural gas*' 'CCS' should be used. '*production*' covers the ETS plant or the legal person owning/operating the capture processes including the conditioning and compression unit. '*purchase*' comes in question in case of EHR deployment. This leads to the fact that energy industry ends up under the control of three different strongly regulated market regimes; energy, ETS and CCS. In case captured CO_2 is aimed to 'Other use' it is questionable if the term is applicable in CCS deployment. Instead of '*LNG*' '*liquefying*' should be used.

(4) 'transmission system operator' means a natural or legal person who carries out the function of transmission and is responsible for operating, ensuring the maintenance of, and, if necessary, developing the transmission system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the transport of gas;

For CCS deployment this can be applied as it is.

(6) 'distribution system operator' means a natural or legal person who carries out the function of distribution and is responsible for operating, ensuring the maintenance of, and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of gas;

For CCS deployment this could be applied especially in the emitter cluster environment where the local or regional streams are collected.

(8) 'supply undertaking' means any natural or legal person who carries out the function of supply;

In case captured CO_2 is aimed for 'Other use' it may perhaps be applied. Otherwise it will not be applicable as in CCS the material stream is reversed.

(9) 'storage facility' means a facility used for the stocking of natural gas and owned and/or operated by a natural gas undertaking, including the part of LNG facilities used for storage but excluding the portion used for production operations, and excluding facilities reserved exclusively for transmission system operators in carrying out their functions;

Instead of '*LNG*' 'liquefying' should be used. Otherwise for CCS deployment this can be applied as it is.

(10) 'storage system operator' means a natural or legal person who carries out the function of storage and is responsible for operating a storage facility;

For CCS deployment this can be applied as it is covering operations of both on-shore and permanent storing.

(12) 'LNG system operator' means a natural or legal person who carries out the function of liquefaction of natural gas, or the importation, offloading, and re-gasification of LNG and is responsible for operating a LNG facility;

Instead of '*LNG*' '*liquefying*' should be used. Instead of '*natural gas*' '*CO_2*' should be used. Otherwise this can be applied as it is for CCS deployment.

(13) 'system' means any transmission networks, distribution networks, LNG facilities and/or storage facilities owned and/or operated by a natural gas undertaking, including linepack and its facilities supplying ancillary services and those of related undertakings necessary for providing access to transmission, distribution and LNG;

Instead of '*LNG*' '*liquefying*' should be used. Instead of '*natural gas*' '*CO_2*' should be used. Otherwise this can be applied as it is for CCS deployment.

(19) 'integrated natural gas undertaking' means a vertically or horizontally integrated undertaking;

Instead of '*natural gas*' '*CO_2*' should be used. Otherwise this can be applied as it is for CCS deployment.

(20) 'vertically integrated undertaking' means a natural gas undertaking or a group of natural gas undertakings where the same person or the same persons are entitled, directly or indirectly, to exercise control, and where the undertaking or group of undertakings perform at least one of the functions of transmission, distribution, LNG or storage, and at least one of the functions of production or supply of natural gas;

Instead of '*natural gas*' '*CO_2*' should be used. Instead of '*LNG*' '*liquefying*' should be used. In case captured CO_2 is aimed for 'Other use' or EHR the term 'supply' may be applied. Otherwise this can be applied as it is for CCS deployment.

(21) 'horizontally integrated undertaking' means an undertaking performing at least one of the functions of production, transmission, distribution, supply or storage of natural gas, and a non-gas activity;

In case captured CO_2 is aimed for 'Other use' or for EHR term '*supply*' may be applied. Otherwise this can be applied as it is for CCS deployment.

(22) 'related undertaking' means an affiliated undertaking, within the meaning of Article 41 of Seventh Council Directive 83/349/EEC of 13 June 1983 based on the Article 44(2)(g)[69] *of the Treaty on consolidated accounts*[70] *and/or an associated undertaking, within the meaning of Article 33(1) of that Directive, and/or an undertaking which belong to the same shareholders;*

For CCS deployment this can be applied as it is.

(23) 'system user' means a natural or legal person supplying to, or being supplied by, the system;

For CCS deployment this can be applied as it is.

[69] The title of Directive 83/349/EEC has been adjusted to take account of the renumbering of the Articles of the Treaty establishing the European Community in accordance with Article 12 of the Treaty of Amsterdam; the original reference was to Article 54(3)(g).

[70] OJ L 193, 18.7.1983, p. 1.

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8 Appendix I - Glossary

8.1 Ancillary services

See Linepack

8.2 Capture technology

Citation: In its 2005 special report on CCS, the IPCC characterised the pre-combustion and post-combustion processes as commercially mature, but only for select applications. For example, in natural-gas processing pre-combustion technology is used to remove CO_2 from the mined product in order to meet market regulations; however, the same capture technology is considered immature when applied to power generation and to the iron, steel, and cement industries.

On the other hand, oxy-fuel technology is considered to be in the development phase 3. In practice, the former two capture systems are used in the majority of existing large-scale CCS projects, while there are only a few proposed demonstration projects that use oxy-fuel combustion. CO_2 capture is generally the most expensive of the three stages in the CCS production process, and cost is the main barrier to further technological development. Outside the natural-gas sector, there is currently insufficient financial incentive to shoulder these financial and energy costs.

Source: M. Doelle and E. Lukaweski / Carbon capture and storage in the CDM; pp. 50-51:

8.3 Commodity

A commodity is a physical substance, such as grains, metals, EOR chemicals, CO_2, and EU ETS allowances, which is interchangeable with another product of the same type. If one commodity can replace another they are substitutes to each other. When commodities cannot replace each other they form separate markets, one for each commodity. For an ETS plant a CCS operation may be seen to substitute for emission allowances (or more precisely, a sub-seabed storage space that may be used for storing CO_2 substitutes for the allowances that would otherwise have been needed to cover the emission of that volume of CO_2); for an EOR operator CO_2 can substitute for other booster chemicals. Since CO_2 will be used to boost oil extraction the ETS plant and the EOR operator meet on different markets with different interests but with common objectives. A successful contract between the parties realises a win-win situation. However, since the EOR-operator has several substitution options and is the only actor on the monopsony market he has the negotiation power over the ETS plant and is able to set the price that the ETS plant has to take or leave.Competitive markets / Market Failure

A competitive market is one in which a large numbers of producers compete with each other to satisfy the wants and needs of a large number of consumers. In a competitive market no single producer, or group of producers, and no single consumer, or group of consumers, can dictate how the market operates. Nor can they individually determine the price of goods and services, and how much will be exchanged. Competitive markets will form under certain conditions. When some of the listed conditions are absent, it is likely that market failure will exist.

8.3.1 The formation of competitive markets

For markets to form a number of necessary conditions must be met, including:

1. The profit motive. Free markets form when the profit motive can be satisfied.
2. The principle of diminishability. Stocks of pure private goods will diminish as the good is purchased.
3. The principle of rivalry. Consumers must compete with each other to get the benefit provided by the good or service.
4. The principle of excludability. For markets to form it is essential that consumers can be excluded from gaining the benefit that comes from consumption.
5. The principle of rejectability. It is also necessary that consumers can reject goods if they do not want or need them.

The necessary conditions for market formation and success:

8.3.2 The profit motive

Free markets form when the possibility of profits provides an incentive for firms to enter the market. Basic economic theory states that profits are earned when firms gain a revenue which exceeds the costs of production. However, more advanced micro-economic theory offers two definitions of profit - normal and super-normal. When revenue exceeds costs supernormal profit is earned, and when revenue equals costs (breakeven) the firm makes normal profits.

8.3.3 Diminishability of private goods

A further condition for market formation is that stocks of goods will diminish as the good is purchased. For example, the purchase of a laptop computer by one consumer means there is one less available for other consumers. This is referred to as the principle of diminishability. Eventually, stocks will diminish to zero and as this happens, price will be driven up. Higher prices create an incentive for the producer to increase production.

8.3.4 Rivalry

In addition, free markets will only form when consumers are forced to compete with obtain the benefit of the good or service. For example, to be guaranteed a good seat at a restaurant, or at a music venue, consumers need to book in advance, or get there early - there is clearly a need to be competitive to secure the benefit of the good. This is called the principle of rivalry, and is clearly closely related to the principle of diminishability. Indeed, many consider it to be just another way to explain the need for consumers to compete when stocks diminish.

8.3.5 Excludability

For markets to form it is essential that consumers can be excluded from gaining the benefit that comes from consumption. A storekeeper can stop consumers gaining the benefit of a product if they are unable or unwilling to pay. For example, a market for music can only be formed if the musicians perform in a venue where access is denied to those without a ticket, or where the songs can be recorded and sold through shops, via downloads, or through other media. This is called the principle of *excludability*. If consumers cannot be excluded they may become *free-riders* and, as will be seen later, the possibility of free riders can prevent the formation of fully fledged market.

8.3.6 Rejectability

It is also necessary that consumers can reject goods if they do not want or need them. For example, a supermarket employee could not place an unwanted product into a shopper’s basket and expect the shopper to pay for it at the checkout. This is called the principle of *rejectability*.

8.3.7 Ability to charge

When the conditions of diminishability, rivalry, excludability and rejectability are present it is possible for a market to form and for the seller to charge the buyer a price and for the buyer to accept or reject that price. It is also possible for the buyer to make a bid for a good or service, and for it to be accepted or rejected by the seller.

8.3.8 No information failure

For markets to work effectively there can be no significant information failure affecting the decisions of consumers and producers. It is assumed that the consumer of a private good or service knows what they are getting - they are able to estimate accurately the *net benefit* they are likely to derive. Net benefit is the private benefit to a consumer in terms of satisfaction, or utility, less the private cost associated with buying the product. It equates to the concept of consumer surplus. Free markets do not work effectively when significant gaps in knowledge exist when either the producer or consumer can exploit.

8.3.9 No time lags

For markets to form and work effectively there will be no significant time lags between the purchase of the private product and the net benefit derived by the consumer. For example, if a consumer buys a newspaper with their morning coffee they can read it immediately. Who would bother to purchase a newspaper if they could not read it for several days? Of course, where mail order or online deliveries are concerned, a short time lag is acceptable.

8.3.10 No externalities

Markets are said to work at their best when there are no effects on parties not involved in the market transaction. This means that during the production of the good, and during its consumption and disposal after use, there is no positive or negative impact on other citizens. A positive impact is called a positive externality or external benefit, and a negative impact is called a negative externality or external cost. For example, a positive externality associated with a cafe would be the benefit to a nearby newsagent of customers purchasing their newspaper to read with their morning coffee. An example of a negative externality is the litter created outside the cafe when consumers throw away their used coffee cups into the street. When such externalities exist, free markets may not form or, more likely, may not work efficiently.

However, even when negative externalities exist, such as waste or potential damage to the environment, markets may form to eliminate the waste or prevent damage to the environment.

8.3.11 Property rights

For markets to form and operate successfully, consumers and producers must have property rights. Property rights mean that they have the right to own private property and protect it from theft or damage, or from other people's waste, and from the pollution of others. If property rights cannot be established, the good is not a pure private good.

8.3.12 Incentives for entrepreneurs

The combined effects of the above characteristics means that markets will form because entrepreneurs will be willing to take risks associated with producing and supplying pure private goods. This is because consumers would be prepared to pay for the good, and producers can charge consumers at the point of consumption, from which they can earn revenue and make a profit.

Read more:
http://www.economicsonline.co.uk/Competitive_markets/Competitive_markets.html#The_profit_motive

8.4 Market failure

Situation where resources cannot be efficiently allocated due to the breakdown of price mechanism caused by factors such as establishment of monopolies. See also market inefficiency.

Read more: http://www.businessdictionary.com/definition/market-failure.html#ixzz35ph7MD56

8.5 Price mechanism

System of interdependence between supply of a good or service and its price. It generally sends the price up when supply is below demand, and down when supply exceeds demand. Price mechanism also restricts supply when suppliers leave the market due to low prevailing prices, and increases it when more suppliers enter the market due to high obtainable prices. Also called price system.

Read more: http://www.businessdictionary.com/definition/price-mechanism.html#ixzz35phLvgvu

8.6 Essential facilities doctrine

An essential facilities doctrine specifies when the owner(s) of an 'essential' or 'bottleneck' facility must provide access to that facility, at a reasonable price. For example, it might specify when a railroad must be made available on reasonable terms to a rival rail company or an electricity transmission grid to a rival electricity generator.

Topics covered include the access regime, interoperability (that different systems, products, and services work together transparently), standards, the importance of market definition in defining an essential facility, single versus joint ownership of an essential facility, legitimate reasons to deny access and possible remedies.

There is an important distinction among public, private but regulated, and private unregulated facilities because mandatory access can diminish private incentives to invest and to innovate.

Read more: http://www.oecd.org/competition/abuse/1920021.pdf

8.7 Line pack

The storage of gas by compression in gas transmission and distribution systems, but not including facilities reserved for transmission system operators carrying out their functions.

Is regarded as 'ancillary services' which means all services necessary for access to and the operation of transmission networks, distribution networks, LNG facilities, and/or storage facilities, including load balancing, blending and injection of inert gases, but not including facilities reserved exclusively for transmission system operators carrying out their functions. Tariffs are based on Line pack readings per each Gas Day.

Line pack is determined by calculating the volume of gas within the pipelines using a network model and instantaneous measurements. The model contains a database of pipeline diameters and lengths, updated as required to accommodate changes to the network.

The pipeline network is divided into pipeline sections and the volume of gas within each section is determined by multiplication of the pipe free volume by the ratio of the gas density at actual conditions to the gas density at standard temperature and pressure. The actual gas density is computed from a standard equation of state applying pressure, temperature and specific gravity data. The pressure is derived from telemetered measurements at the beginning and end of the pipeline section, and an average network gas temperature is applied. The specific gravity is determined from telemetered measurements at entry and exit points according to a fixed mapping arrangement. The network model then summates the calculated volume of gas for each pipeline section to compute total Line pack.

The Opening Line pack for a Gas Day, which is equivalent to the Closing Line pack for the preceding Gas Day, will be the volume calculated by the network model as close to the start of the Gas Day as possible.

Read more: http://www2.nationalgrid.com/uk/industry-information/gas-transmission-system-operations/balancing/nts-linepack/

8.8 Price ceiling

The maximum price a seller is allowed to charge for a product or service. Price ceilings are usually set by law and limit the seller pricing system to ensure fair and reasonable business practices.

Many economists question their effectiveness for several reasons. For example, price ceilings will have no effect if the equilibrium price (that will not exist on EOR market) of the good is below the ceiling. If the ceiling is set below the equilibrium level, however, then there is a deadweight loss created. Deadweight loss is not defined here.

Read more: http://www.investopedia.com/terms/p/price-ceiling.asp Visited 2014-03-18

Price ceiling may cause another type of problem if the price is set above the equilibrium level: ceiling price may be interpreted as maximum price which causes loss to the consumer.

8.9 Regulated Conduct Defense

The regulated conduct defense allows antitrust immunity where conduct is required by federal or state regulation. The regulated conduct defense is important to ensure that the state can exercise its sovereign power to apply regulation that it deems justified for economic and/or social reasons even though the regulation may conflict with competition policy. The defense is also important to ensure firms do not face multiple and inconsistent legal demands, in particular from regulations and competition law.

Nevertheless, the regulated conduct defense also bears important risks including high potential costs for society. Indeed, the defense may preserve unduly anti-competitive regulation entailing welfare cost not necessary for achieving the regulatory objective. The defense may also lead to competition law exemptions of only weakly regulated conduct. The roundtable identified circumstances when the regulated conduct defense is most appropriate and when it is least appropriate.

Read more: http://www.oecd.org/daf/competition/mergers/48606639.pdf Visited 2014-02-28

8.10 Strategic behavior

Strategic behavior is the general term for actions taken by firms which are intended to influence the market environment in which they compete. Strategic behavior includes actions to influence rivals to act cooperatively so as to raise joint profits, as well as non-cooperative actions to raise the firm's profits at the expense of rivals.

Various types of collusion are examples of cooperative strategic behavior. Examples of non-cooperative strategic behavior include pre-emption of facilities, price and non-price predation and creation of artificial barriers to entry. Strategic behavior is more likely to occur in industries with small numbers of buyers and sellers.

Read more: https://stats.oecd.org/glossary/detail.asp?ID=3314 Visited 2014-02-28

8.11 Swedish Ordinance (2014:21) on geological storage of carbon dioxide (Förordning om geologisk lagring av koldioxid)

Note: translation by the authors; not official version.

4 § In this ordinance a carbon dioxide stream is defined as:

a stream of substances that originate from carbon dioxide capture process, […]

39 § The carbon dioxide stream that is injected into the storage site shall be composed exclusively of carbon dioxide. The carbon dioxide stream may however contain traces of other substances than carbon dioxide originating from the source of the carbon dioxide emissions, the capture of the injection process, as well as trace elements added in conjunction with monitoring and control of carbon dioxide movements within the storage complex. The concentrations of such substances shall not exceed levels that would

1. have negative effects on the storage site or the safety and operation of the infrastructure used for the transport of carbon dioxide,

2. pose a significant risk to human health or the environment;

3. be contrary to the requirements of other legislation.

40 § The operator must not allow the injection of a carbon dioxide stream into the storage site without having

1. analysed the composition of the carbon dioxide stream and the presence in it of corrosive substances and other substances that are significant for the risk assessment under sections 21-25, and

2. performed a risk assessment of the carbon dioxide stream concerning the levels of substances other that carbon dioxide referred to in section 39 and the conditions regarding the composition of the carbon dioxide stream in the permit.

8.12 Transportation of carbon dioxide (CO_2) in the dense phase

Citation: When a pure compound, in gaseous or liquid state, is heated and compressed above the critical temperature and pressure, it becomes a dense, highly compressible fluid that demonstrates properties of both liquid and gas. For a pure compound, above critical pressure and critical temperature, the system is oftentimes referred to as a ‘dense fluid’ or ‘super critical fluid’ to distinguish it from normal vapor and liquid. Dense phase is a fourth (Solid, Liquid, Gas, Dense) phase that cannot be described by the senses. The word ‘fluid’ refers to anything that will flow and applies equally well to gas and liquid. Pure compounds in the dense phase or supercritical fluid state normally have better dissolving ability than do the same substances in the liquid state. *The dense phase has a viscosity similar to that of a gas, but a density closer to that of a liquid.* Because of its unique properties, dense phase has become attractive for transportation of CO_2 and natural gas, enhanced oil recovery, food processing and pharmaceutical processing products.

The low viscosity of dense phase, super critical carbon dioxide (compared with familiar liquid solvents), makes it attractive for enhanced oil recovery (EOR) since it can penetrate through porous media (reservoir formation). As carbon dioxide dissolves in oil, it reduces viscosity and oil-water interfacial tension, swells the oil and can provide highly efficient displacement if miscibility is achieved. Additionally, substances disperse throughout the dense phase rapidly, due to high diffusion coefficients. Carbon dioxide is of particular interest in dense-fluid technology because it is inexpensive, non-flammable, non-toxic, and odorless. Pipelines have been built to transport CO_2 and natural gas in the dense phase region due to its higher density, and this also provides the added benefit of no liquids formation in the pipeline.

M. Doelle and E. Lukaweski / Carbon capture and storage in the CDM; pp. 50-51:

Read more: http://www.jmcampbell.com/tip-of-the-month/2012/01/transportation-of-co2-in-dense-phase/ Visited: 2013-12-11