CATO-2 Deliverable WP 4.1-D05
Permitting cross border networks in relation to monitoring, verification and accounting under EU-ETS

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1 Executive Summary

This deliverable discusses the permitting of cross border CO_2 transport networks in relation to monitoring, verification and accounting under EU-ETS. The legal perspective on permitting and technical requirements for permits are investigated in relation to developing future cross border CO_2 transport networks. An analysis on possible barriers for the development of cross border CO_2 transport networks is made, as well as recommendations for implementation and improvements on the existing legislative framework.

The Commission Decision as regards to the inclusion of monitoring and reporting guidelines for greenhouse gas emissions from the capture, transport and geological storage of carbon dioxide (EU, 2010) is a background for this deliverable. The exact implementation of these rules is of great importance for permit holders, as it can ease requirements for monitoring.

The report starts with a discussion of background information. It consists of summaries of analyses on the Commission Decision from other deliverables of work-package 4.1 of CATO-2, a description of a legal framework for existing cross border pipeline networks, and a description of how access to such networks can be arranged. The main conclusions following from the background information are that the Commission Decision contains barriers towards the construction of cross border CO_2 transport networks, and that implementation of permits can be complex.

The background information is used to create a case for a cross border CO_2 transport network based on the CO_2EuroPipe project. In this case two scenarios are sketched that describe the network for two different proposed permitting situations: In one situation the network is split up in smaller networks and in the other situation it is a single entity. In the case the streams and network losses that occur in the two permitting situations are shown. An identification is made with regard to where monitoring has to occur and how biomass can be accounted for.

In the chapters that follow on the case conclusions and recommendations are made. One is that the network can best be regarded as a single network, crossing several borders. This has many advantages from the perspective of the physical monitoring at the CO_2 transfer points of the capture installations and storage sites. From a legal point of view however, there are several complexities to overcome, in terms of possible conflicting jurisdiction and conflicting regulation. These possible barriers can be resolved by closing bilateral or multilateral agreements between the countries that are involved.

Table of Content

2 Introduction

2.1 Scope and objectives

This deliverable discusses the permitting of cross border CO_2 transport through pipelines with the goal of storing CO_2 from large sources in (off-shore) sinks. CO_2 transport is discussed in relation to the European Emission Trading System (EU ETS) and specific legislation on carbon, capture and storage (CCS). To do this the legal perspective on permitting and technical requirements for permits are investigated in relation to developing future cross border CO_2 transport networks. What aspects play a role in requirements for permits, whether they are straightforward or contain barriers, and recommendations on their implementation and possible improvement are the outcomes of this deliverable.

The ‘Monitoring and reporting guidelines’ which amends the EU ETS Directive for the inclusion of CCS is a background document for this report. The precise implementation of these rules is of great importance for permit holders, as it can ease requirements for the monitoring. Next to these requirements regarding monitoring there is the legal framework for existing cross border pipeline networks. This is important when a permit structure is created, as well as how access to a network can be arranged. Relevant information regarding this subject is an important background for this deliverable.

The combination of multiple capture plants, cross border transport and multiple storage sites raises questions on how to implement the measurement system, permitting and verification. The way in which these issues are resolved can have an impact on the implementation of monitoring of a large scale CCS infrastructure throughout Europe. Therefore a scenario in the form of a case is made in which this is explored.

Working with the background information and the situations which are explored in the case the research questions which are listed in the paragraph below can be answered.

2.2 Research questions

The purpose of this report is to facilitate the measurement of the CO_2 stream within cross border networks. In order to reach this objective, the following question will be addressed in this report:

- What monitoring requirements are to be met by a cross border CO_2 transport network, can they be met and how could accounting best be designed (in a 'measuring code')?

Of the monitoring requirements several aspects will be addressed, such as the required uncertainty, the locations of the metering points, the overlap between EU-ETS and the CCS Directive and the measurement of other components in the CO_2 stream.

- Which authorities have the jurisdiction to regulate the cross border network and how can possible conflicting jurisdiction be overcome?

The legal framework for cross border CCS will be described, as well as the jurisdiction issues that might arise with regard to the regulatory aspects of pipeline networks (siting and construction, environmental and safety demands, use of the infrastructure).

2.3 Reading guide

The report is structured to first provide background information on the topics which are discussed. After that a scenario in the form of a case is made. Drawing on the background information and the general part of this deliverable then follows. The chapters discuss the following topics:

- Chapter 3 provides background information
- Chapter 4 provides an elaboration of a possible network as a case example
- Chapter 5 deals with the permitting of a cross border network
- Chapter 6 deals with the monitoring aspects of a cross border network
- Chapter 7 proposes an outline for a possible 'measuring code'
- Chapter 8 contains conclusions and recommendations

3 Background information on the MRG & CCS directive

This chapter summarizes background information which is relevant for this deliverable. Most of the content of this chapter on monitoring is discussed in depth in CATO-2 Deliverable WP 4.1-D4.1.03 (CATO2, 2010b). This background information serves as a basis for the analysis made in this report.

- The background concerning the monitoring of cross border transport networks consists of:
  - A description of the EU Monitoring Reporting Guidelines
  - A short analysis of methods which can be used to monitor CO_2 in a transport network
  - A short comparison of monitoring and reporting guidelines and rules for storage sites
  - A discussion on the advantage and disadvantages of having one network operator who is solely responsible for monitoring on a network, which is the starting point for the case discussed in chapter 4
- Regarding the background from a legal perspective the following is described in this chapter:
  - Legal obstacles to cross border pipeline networks
  - Issues regarding jurisdiction in cross border networks
  - The aspects that will be regulated in a pipeline network (location, use)

3.1 EU Monitoring and Reporting Guidelines and CCS

For implementation of monitoring within the Scheme for Greenhouse Gas Emission Trading the Monitoring and Reporting Guidelines (MRG) for greenhouse gas emissions were published (EU, 2004), with a revision accepted (EU, 2007a) which took effect from 1 January 2008. The MRG defines how an operator of an installation will carry out the monitoring and reporting of CO_2-emissions for an installation. This MRG requires a “monitoring plan” which is part of or connected to the permit of an installation. Once approved, monitoring of greenhouse gas emissions has to be in accordance to the approved “monitoring methodology”.

On 8 June 2010 the last version (CCS MRG), Commission Decision amending Decision 2007/589/EC (EU, 2010), entered into force. It amends Directive 2003/87/EC (EU, 2003), so as to include the capture, transport and geological storage of carbon dioxide within the emission trading Community scheme from the year 2013 onwards. CCS will be included in the EU ETS from Phase 3 (2013-2020) onwards. Under current proposals, CO_2 captured, transported and permanently stored will not be considered as emitted. However, any CO_2 leakage will have to be accounted for which requires accurate monitoring and reporting. To show how the MRG and CCS MRG are interconnected and what they mean in practice for the required uncertainty of the monitoring an example CCS chain is made which is shown in Figure 1 taken from CATO-2 Deliverable WP 4.1-D4.1.03 (CATO2, 2010b, p19). This chain includes all steps from generation, capture, transport and storage.

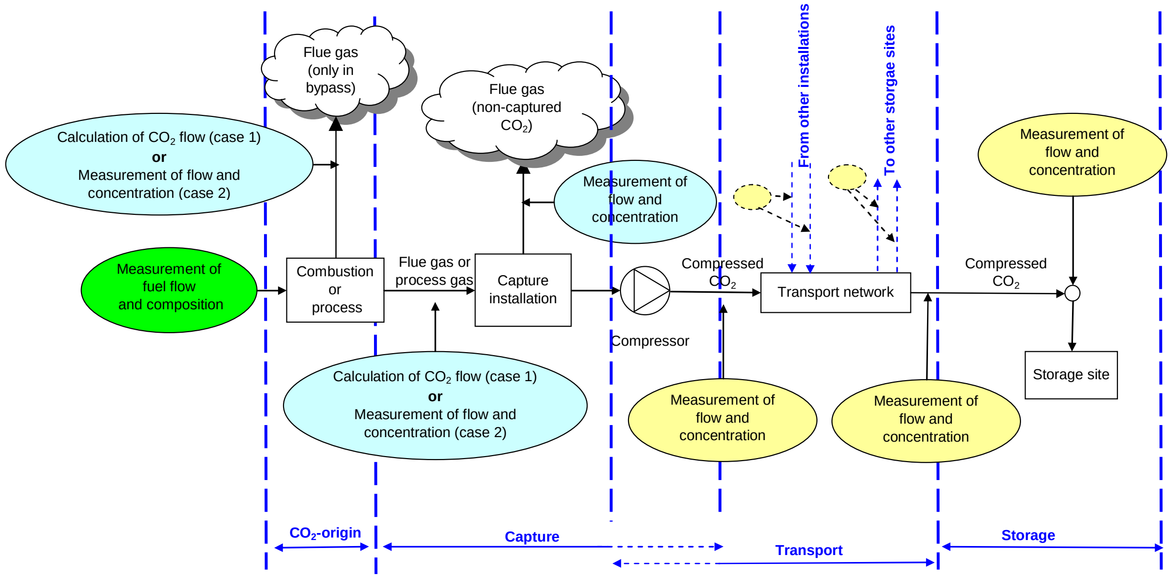

Figure 1 Overview of the monitoring over the CCS Chain

3.2 Monitoring of transport under the CCS MRG

There are two methods available according to the CCS MRG to determine the emissions of a transport network:

- Method A: The emissions of the transport network are determined using a mass balance
- Method B: Emissions shall be calculated taking into account the potential CO_2 emissions from all emission relevant processes at the installation as well as the amount of CO_2 captured and transferred to the transport facility

The total emission of a network can be measured by the difference between input and output. The input is CO_2 from sources and output is CO_2 transferred to storage sites. This approach, method A in the MRG, subtracts two large quantities which are measured with relatively small uncertainty, resulting in high uncertainty over the small amount (hundreds of percents). This is not acceptable and makes method B the alternative, which involves measurement of all emissions from the transport network to determine emission factors which are necessary for calculation. Using method B requires annual comparison with method A, which is an irrelevant procedure with such high uncertainty in method A. In practice the network emissions will have to be calculated using method B only.

In Europe the use of Continuous Emission Measurement Systems (CEMS) for monitoring CO_2 emission in flue gas is rare because calculation by measuring fuel input is a more straightforward option. With CCS however that calculation method is often not feasible and the CCS MRG, an amendment on the existing MRG, assume a large role for CEMS: It is expected that at all transfer points the composition of the CO_2 stream needs to be measured continuously to determine the amount of CO_2 transferred for CCS purposes (CATO2, 2010b, p8).

The obligation to use EN14181 for the CEMS system when measuring flue gas makes the implementation of CEMS even more complex. All requirements for CEMS under EN14181 are based on hourly values and requirements of the MRG based on the annual load. For a CEMS measurement in a transport network with almost pure CO_2-streams at high pressures the standard EN14181 could be considered not relevant, however it is required by the MRG (EU, 2007a, § 7.1). With these limitations, the envisioned approach to determine the total amount of CO2 transferred for CCS purposes would thus be using method A with CEMS.

3.3 Overlap of the CCS MRG with the CCS directive

There are overlaps between the CCS MRG and the CCS directive which governs how CO_2 should be stored in a CCS storage site: Parts of the information required by them are similar. If such information is available for the CCS MRG it can be used for the CCS directive. Also the following overlaps between the MRG CCS and the CCS storage directive are identified (CATO2, 2010b, p 43):

- **Window of concentration:** If the concentrations which are fed into the network are known the concentrations at the storage site can be calculated. If the maximum concentration of components can be safeguarded, it can be prevented that at any moment the concentrations do not fulfil the criteria of the storage site and transport network.

- **Monitoring for acceptance:** Acceptance of the CO_2 stream for the storage site can be checked to the acceptance criteria on a continuous basis by using information on streams available in the network. If the composition of incoming streams, total quantities, and mixing conditions in the network are known the output streams can be calculated.

- **Reporting to the authorities:** The total quantity of CO_2 to be injected and stored, the composition of streams and injection rates can be provided by the network. Monitoring of leakage and fugitive emissions is the responsibility of the storage site permit holder. The need for measurement of pressure and temperature is dependent on the type of metering system. Chemical analysis can come from the input and calculations of the network monitoring system. For checks the injected material can be analysed by discrete sampling and off-line analysis.

- **EU-ETS monitoring in the storage monitoring plan:** The Storage directive requires that the monitoring for EU-ETS is incorporated in the monitoring plan. In the supply of information the network operator can also play a major role. In many cases the monitoring and reporting effort for EU-ETS at the storage site would be minimal.

3.4 Legal framework for cross border networks

With the development of cross border CO_2 networks several legal complexities might arise because international law is involved. A first aspect that should be researched is whether or not international law allows for cross border CO_2 transport. When pipelines are used for transport, a number of issues will be regulated. These issues relate to the construction and siting of pipelines, the safety of pipelines and the use of pipelines (Havercroft, 2011, p 108). In onshore situations the national regulation applies. When the network goes offshore, the situation is more complicated as conflicting jurisdiction might occur for each of these aspects. This section first discusses the international legal framework for cross border transport. Secondly, the different permits and jurisdiction will be discussed taking into account the possible complexities of offshore storage.

3.4.1 Aspects of regulation for cross border CO_2 transport networks

The CCS Directive assumes that cross border transport will occur. It does this because not all European countries have the possibility to store CO_2. However, in international law, cross border transport of CO_2 for storage is not yet possible. Art 6 of the London Protocol currently prohibits cross border transport of CO_2. Although the contracting parties have agreed to enable cross border transport by amending the protocol in 2009; this amendment was not yet ratified and probably won't be in the near future (IEA 2011) so cross border CO_2 transport is not yet allowed from a legal perspective. There are several ways in which this obstacle can be overcome, based on international law. Either by providing for a resolution for interpretation of the protocol for the period that the amendment is not ratified yet, or by bilateral or multilateral agreement.[1]

The issues that need to be regulated with pipelines in general can be divided in three categories. The first category is the siting and construction. In order to locate and build the pipeline, several permits are required (building permits, environmental permits). These permits have to do with the physical location and will be decided upon by decentralized authorities. A second aspect of regulating pipelines is the environmental and safety standards that have to be met in using the pipeline. There will be regulation in pipeline integrity, monitoring and remediation plans. With regard to CCS, especially the monitoring for emissions is of importance. Up to this moment installations falling under EU-ETS have only operated within countries, falling under the national cap of emissions. Also no transfer of CO_2 under EU-ETS law across borders has occurred up to this moment. If there would be one permit for the entire network, this would mean that emissions would count in only one of the participating countries in the network. When it comes to define the state that would be responsible for the allowances in case of leakage, there are four options (Havercroft, 2011, p 128) of which no regime has yet been chosen:

- The state on whose territory or Exclusive Economic Zone (EEZ) it occurs
- The state in which the pipeline owner resides
- The state in which the CO_2 was captured
- The state in which the CO_2 will be stored

[1] Several other options are available, but are not discussed here, for more information, see the IEA working paper.

Another aspect that will be regulated is the use of the pipeline. In essence this concerns the question who will be able to use the pipeline, and whether or not this party can refuse access to third parties. Regulation on the access regime deals with grounds for refusal of access and conditions and tariffs. These conditions also might relate to the CO_2 stream criteria. The CCS Directive requires fair and open access, and provides states with the possibility to make more stringent demands for CO_2 stream purity criteria. In section 3.5.2, where the network operators' role is discussed, the access regime possibilities will also be addressed.

3.4.2 Jurisdiction on a cross border CO_2 transport network

Now that the aspects of regulation are clear, the main question is which state has jurisdiction in regulating these aspects in case of a cross border network. On-shore, states have the sovereign rights to regulate the pipelines. The siting and construction, environmental and safety demands and the use of the pipeline will be regulated on a national level. Observing past experiences with cross border pipelines, the relevant jurisdiction issues are dealt with in bilateral or multilateral treaties. Off-shore, the situation is more complex as depending on the location of the pipeline or storage site, jurisdiction is determined. If the pipeline is located in the high seas, there is general freedom to lay pipelines, and the state in which the company has a registered seat has jurisdiction. If the pipeline is in the territorial waters of a state, the laws of that state apply. Art 56, 77 and 87c of the UNCLOS state that the coastal state has functional jurisdiction further out of the coast if an EEZ has been established and limited rights on the continental shelf. Functional jurisdiction means that one has the right to exploit and regulate the use of the infrastructure. Should the pipeline land on the coast of another country, or even pass through another country's water, that state has the right to regulate environmental protection and safety. So, both states have jurisdiction over environmental and safety standards, from the perspective that a coastal state has the responsibility to protect the environment. Furthermore, as the pipeline will enter another states territorial waters, the law of that state applies, which in essence means that states will have to approve of the siting and construction.

States are entitled to decide which environmental and safety laws apply off-shore in the EEZ and limited on the continental shelf (Havercroft, 2011, p 116). In the regulation of off-shore pipelines for gas transport, the type of pipeline determines the jurisdiction over the pipeline. There are interconnectors, pipelines between two states, and coast to field pipelines. In case of a coast to field pipeline, there is functional jurisdiction over the pipeline of the state in which the field is located. The jurisdiction issues are dealt with in bilateral or multilateral treaties. The development is that the coastal states become more and more important in the different treaties (Roggenkamp, 1999, p 656). When it comes to interconnection pipelines, there is conflicting jurisdiction with regard to siting and construction and environmental and safety demands. If an interconnection crosses the jurisdiction of a third state, that state only influences the siting and environmental and safety demands. Only the state responsible for the storage location, has functional jurisdiction and might regulate access in territorial waters, but still has conflicting jurisdiction when it comes to environmental and safety demands and siting and construction on the continental shelf/EEZ. All of these issues are dealt with in bilateral and multilateral treaties.

3.5 The network as the spider in the web

In this section the advantages and disadvantages of a network operating as a 'spider in the web' are discussed. This means that the network plays a central role in monitoring and access to its infrastructure. First the monitoring aspects are discussed, then the aspects for third party access. Regarding access a single operator with a common carriage network for transport is assumed to be present.

3.5.1 Role of a network operator for monitoring

The CCS MRG do not state who has to perform the measurements at transfer points (CATO2, 2010b). Summarized: It is sufficient that one party performs measurements and makes them available to the capture installation and the transport network. The network operator can be the organization who performs the monitoring at the capture and storage site. This would be a similar situation to the natural gas transport network in the Netherlands. Monitoring of natural gas has to meet the requirements of a so called measuring code. Advantages of this approach are:

- Measurement takes place with predefined and guaranteed quality.
- Quality assurance and control of measurement equipment at installations is not necessarily the responsibility of the permit holder.
- From input and distribution in the network output concentrations can be calculated.
- Information streams can be supplied to all installations at the transfer points
- The network organization is a neutral organization with no interest in deliberately measuring too low or high values.

Advantages for a transport network to play an important role in monitoring at transfer points are:

- Fulfillment of the required uncertainty
- Continuous availability of measurement data
- Quality assurance of metering systems
- Safeguarding and control of the composition of the CO_2-streams
- Neutrality of the organization

3.5.2 Role of a network operator with regard to access to the network

The network operator can control the access to the pipeline. External parties want to feed in CO_2 or have concessions for storing CO_2 in off-shore aquifers or empty gas fields. It is envisioned that these parties are already active in off-shore oil and gas exploration or are newcomers who see CO_2 storage as a good business case.

The issue of third party access is common in the oil- and gas industry and electricity industry. The relevant question is: Who gets access to the network and under which conditions? For regulators this translates to the question: How do we make sure that there is sufficient open access? There are several forms in which regulators have dealt with the issue of TPA. Regulators can either regulate the access with regulated TPA (rTPA) or leave it up to the market parties themselves with negotiated TPA (nTPA). Within the category of nTPA two forms can be distinguished: A more stringent form and a more simple form (Havercroft, 2011, p 118). The conditions for access see to the quality of the CO_2 stream, the tariffs for access and the conditions for refusal of access.

In essence rTPA is the situation in which access is allowed, based on published tariffs. These tariffs apply to all customers objectively and without discrimination. Access can only be denied on limited grounds, such as lack of capacity. This regime is currently applied in transmission and distribution pipelines. In contrast nTPA is the situation in which network operators are obliged to provide indicative tariffs and conditions before negotiations can start. During the early phases of liberalization nTPA was used frequently in the energy market.

Next to rTPA and nTPA there is also simple TPA (sTPA) which is the situation where the regulator has not regulated anything but has declared there is open access: That parties should negotiate access and if there is a complaint about the access, there is recourse to a complaint handling institution. This institute will judge the issue between the party wanting access and the operator. In sTPA information about tariffs and conditions is not published in advance. Currently, sTPA is used in upstream pipelines which are used for oil- and gas production.

For CCS the question is which regime is applicable based on the CCS Directive and national legislation. The CCS Directive addresses the possible access to pipelines and storage facilities in art 20 and 21. Article 20 states that access shall be provided in a transparent and non-discriminatory manner, applying the objective of fair and open access and shall take into account available capacity, domestic requirements, technical specifications and the interests of the owner and users of the infrastructure. Operators may refuse access (with reasons) if there is no available capacity. States must ensure that in those cases the operator is required to enhance the network if it is economic to do so and has no negative impact of environmental security. Furthermore, states are required to have a dispute settling mechanism in place. states have the competence to regulate this aspect in more detail.

The CCS Directive does not prescribe a specific TPA regime, although the wording of the article is similar to the essential facilities doctrine as stated in art 34 Gas Directive. This article describes the regime for sTPA as applicable to upstream pipelines. It can be argued that CO_2 pipelines can be seen as reversed upstream pipelines (Havercroft, 2011, p 121), which would entail a sTPA regime for CO_2 pipelines. The CCS Directive leaves it up to countries to regulate the access into more detail. In case of cross border transport, it therefore is possible that several different regimes are applied. In the UK for example, in the development of a CO_2 transport network, a more regulated form of TPA is considered (De Hauteclocqeu, 2011).

- Arguments in favour of more regulation are:
  - Pipelines exhibit characteristics of natural monopolies, in which case there is limited competition that could induce operators to perform activities efficient. Via regulation of access conditions regulatory authorities can separately introduce efficiency incentives (thereby 'mimicking' competition)
  - It is an emerging infrastructure market characterized by considerable uncertainties, so not regulating it would probably lead to underinvestment.
- Arguments in favour of not regulating access or doing so minimally (Havercroft, 2011, p 122):
  - The number of interested parties is low, so there is room to negotiate access, and suffice with a complaint handling institution in case of abuse of market power.
  - Regulating access in a very strict form (rTPA) to ensure competitiveness seems out of place. Especially since the CCS Directive does not have an objective to create a competitive market for CO_2.

The consequence of the possibility of different regimes might be that a network operator in one country is able to negotiate freely with other users, where in another county it has to provide for tariff information in advance, and where in a third country government has appointed a regulator that sets or approves tariffs and conditions in advance.

Conclusions on chapter 3:

This chapter serves as a background for the chapter which describes the case and the chapters following that chapter. In this report several aspects of permitting, monitoring and legal aspects have been discussed. The following stands out:

- CO_2 flow has to be monitored, but the use of mass balances gives high uncertainties on the amount of loss from the network because of the high flow in pipelines. The network emission losses thus have to be calculated separately instead
- Monitoring of the CO_2 flow is required to determine the amount of CO_2 transferred for CCS purposes
- Because the streams which are being supplied to a network cannot be assumed to be constant continuous emission measurement systems (CEMS) will have to be used
- In case of cross border networks, permitting will be complicated due to the fact that there might be issues with jurisdiction. More than one country might be competent to regulate the use of the pipeline, the environmental and safety standards and the siting and construction
- For siting, construction, environmental and safety demands this might mean that different demands must be met in different states, but by the same operator. In case of leakage, it is not yet clear to which state the emission allowances need to be surrendered
- For the use of the pipeline, the access regimes might differ per state. This can increase the complexity for parties operating pipelines in multiple countries

4 Cross border CO_2 transfer based on CO2EuroPipe scenario

In this section a case for a cross border network is described. This case serves to illustrate what the implications of the requirements following from the MRG, the CCS MRG and other legislation are on the subject of monitoring CO_2 transport networks. From chapter 5 onwards the various aspects of the case are discussed to form general conclusions and recommendations on permitting, monitoring, etc.

4.1 Case description

This case is based on a cross border CO_2 network which is presented in the CO_2EuroPipe report on transport infrastructure for large-scale CCS in Europe (CO2EUROPIPE). In the CO_2EuroPipe report several network scenarios are explored.

In the scenarios of the CO_2EuroPipe project the geographical distribution and timing of CO_2 supply and storage availability is sketched for 2020, 2030 and 2050. From these scenarios the so called 'off-shore only' scenario for 2020 is used as the basis of this case. A section of the network presented in this scenario is used in an adapted form for this case. In this network future capture installations are located on land and storage occurs in storage sites at sea.

The basis for the scenarios presented in the CO_2EuroPipe project is current emission levels, which are used to estimate future captured volumes. Data on CO_2 emission sources and available sinks is provided by the database compiled by the recently concluded EU FP6 project Geocapacity. Sources include large CO2 point sources like power plants and industry. The CO_2EuroPipe project references to the PRIMES scenario from the CCS Impact Assessment published in 2008. The cross border network presented in the case runs from France, trough Belgium, the Netherlands and up to Great Britain.

4.2 Network layout

In Figure 2 a map is shown of the case network where the different streams that occur in the network are illustrated. As can be seen 1.5 Mt of CO_2 is transported from France into the Netherlands. From the Netherlands the CO_2 is then transferred to sea in two streams of 1.35Mt and 7.7Mt respectively. The 9.05Mt total flowing to the sea also contains biomass. From this stream 1.05 Mt is transferred to a British CO_2 storage site which also receives CO_2 from Britain. The case makes an alteration to the scenario presented in the CO2Europipe report: The difference with the CO_2EuroPipe report is that in the scenario presented there no transfer to the UK is mentioned (in the CO_2EuroPipe report the 1.05Mt goes to a Dutch gas field/aquifer in the North-Sea instead of being transferred to Britain). This is done to create a cross border off-shore situation in the case. The amounts mentioned in Figure 2 and Table 1 come from Appendix A of the CO_2EuroPipe report. Here the amounts that source clusters produce in 2020 are mentioned. Figure 3, which comes directly from the CO_2EuroPipe report, contains the amounts mentioned in Table E-2 '*Transport routes, lengths and CO_2 flow rates for the offshore-only scenario*' of the CO_2EuroPipe report. These amounts are rounded of in most cases. Because of this the amounts mentioned for the sources are used to avoid inconsistencies.

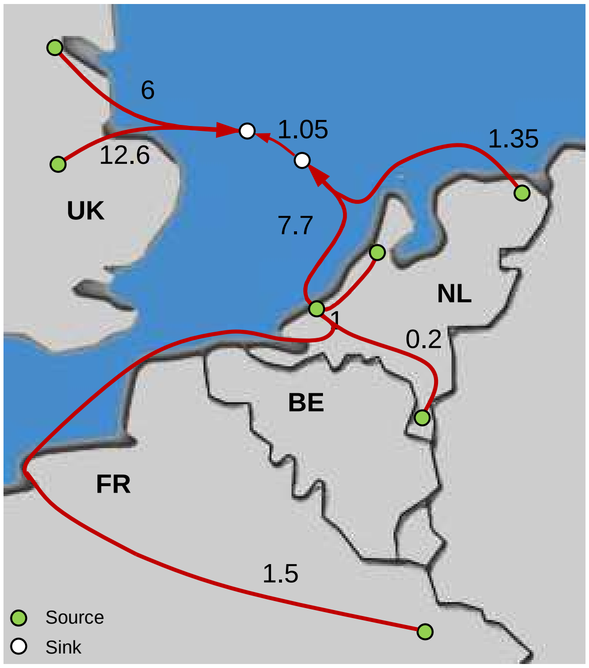

Figure 2 Simplified representation of the network

Figure 3 shows a more detailed representation of the network, as it is represented in the CO_2EuroPipe case. The area which is outlined marks the part of the scenario of which the network consists.

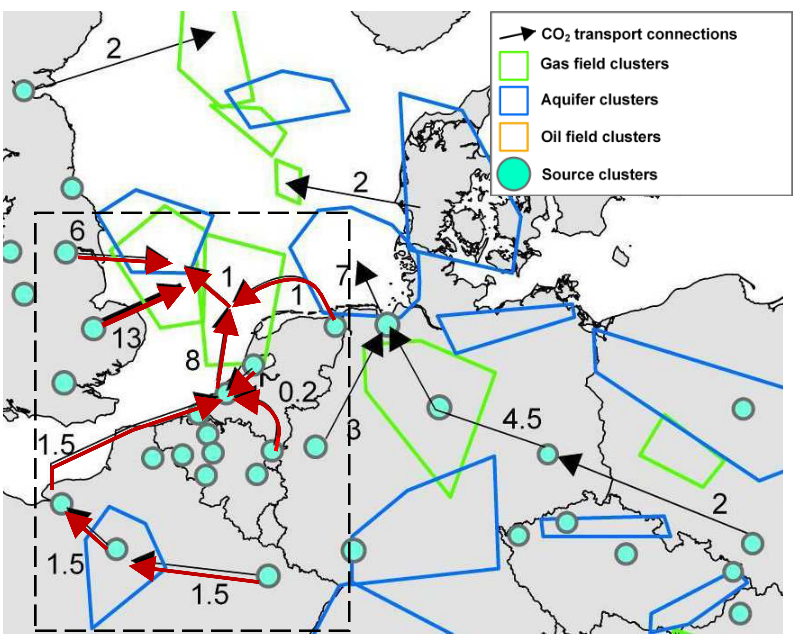

Figure 3 CO_2 transport in Europe in 2020, CO_2EuroPipe off-shore scenario, the case described is pictured within the dashed area

The flows are summarized in Table 1:

France		Belgium		Netherlands		Netherlands Sea		UK Sea		UK
Source	→	Transfer FR→NL	→	Sources	→	Sink (Gas field)	→	Sink (Aquifer/Gas)	←	Sources
1.5Mt	**1.5 Mt**	1.5Mt	**1.5 Mt**	5Mt 1Mt 1.35Mt 0.2Mt	**9.05 Mt**	8Mt	**1.05 Mt**	19.65Mt	**18.6 Mt**	12,6Mt 6Mt

Table 1 Capacities from and to the Netherlands

The cross border and on-shore to off-shore transfer points are listed in bold in Table 1 and show the yearly transferred amounts in 2020 which are illustrated in Figure 2.

4.3 Permitting of the case network

What approach can be used for the permitting and supervision of the cross border network by the competent authorities involved. Which authorities are involved and how will the processes be practically designed? The answer to these questions is that in the case two situations are possible, each with their own benefits and drawbacks (Conan, 2011, p 226).

1. The network is defined as a single network which is co-owned by regulated or government network operators in the countries mentioned in the case. Thus multiple owners control the network which operates under a single permit. The permit will be registered in the Netherlands because it functions as a hub within the case network.
2. The network is defined as consisting of multiple smaller networks which are located within countries on-shore borders. Off-shore transport networks are co-owned by regulated or government network operators of countries in whose territory the network is located. These smaller networks each have their own permit.

The competent authorities in the countries which are part of the network will have to cooperate in both of the permitting situations.

4.4 Streams in the network

This section creates an overview of the streams which run through the network. This overview builds on section 4.2 where the network layout is described. This section explains what kind of accounting is necessary and where monitoring has to be performed. The goal of this section is also to investigate the impact of the requirement to measure CO_2 from biomass separately. This is done by making a breakdown of the streams of the network so that the impact of biomass becomes visible. Its role is discussed in the next subsection.

The tables shown in subsections 4.4.2 and 4.4.3 describe the streams flowing through the case network. These tables list the streams flowing through the network from up to down and are similar to Table 1 in section 4.2 where the streams are described from left to right. The tables in subsections 4.4.2 and 4.4.3 respectively describe the two permitting situations as described in section 4.3.

The tables incorporate the points where monitoring has to occur. Transferred amounts and composition (concentration) for normal CO_2 and biomass CO_2 are shown. The tables also incorporate emission losses within the network. These losses represent the network losses calculated with emission factors, or method B (section 3.2). They are the losses belong to the stream running trough the monitoring point and the next monitoring point in the network (with the exception of the small stream running from NL to the UK). The numbers are generic values and are not related to the size of the stream. In certain cases the network losses are not listed in the same table. This is because the monitoring are then placed within the border of another country or i.e. an on-shore area instead of an off-shore area. With Belgium this is the case, as CO_2 is only transferred trough Belgium the inflow can be monitored by France and the outflow by the Netherlands.

Water content is described and this shows what happens when a technical substance, something that can do damage to the network infrastructure, enters the network. The maximum allowed concentration is 500 ppm (safety limit of H_2O in CO_2 as discussed in subsection 6.1).

4.4.1 The role of biomass in the case network

Biomass plays a special role in CO_2 transport. It is not yet eligible for ETS emission rights and thus does not reduce emissions when CCS is performed. However it is CO_2 and has the same physical properties as fossil CO_2. The differentiation between fossil and biomass CO_2 can be made by isotope ratio analysis. It can be assumed that if a known amount of biomass CO_2 is present in a network it will play a role in system losses in the same way as fossil CO_2. As reporting of emissions happens on a yearly basis it does not matter if more or less biomass CO_2 is present in the network as a fraction of the total CO_2 amount as long as network losses are considered constant throughout the year. In the following subsection biomass is incorporated. It is shown that if the amount of biomass which is emitted at sources and network losses are known, the amount of biomass CO_2 elsewhere in the network can be calculated.

The biomass mentioned in the tables is only produced at one source in the Netherlands. In the case, biomass flows from the source to the off-shore storage location in the Netherlands and the UK. It illustrates the impact biomass streams can have on the accounting of the CO_2 gas flows. It could be considered if, due to the complexity biomass creates in the network; it should be taken into account at all in the accounting of CO_2 transported for CCS purposes under EU-ETS.

4.4.2 Breakdown for the single network situation

In the tables below the streams are shown which occur in the network in the situation where the cross border network is a single entity with one permit.

In this table emissions in France are shown including network losses. Monitoring occurs at the source 1 to determine feed into the network. This is an entry point in the network so network losses are shown.

France			Fossil feed Mt	Composition %	Biomass feed Mt	Emission Kt	H_2O ppm
	Source 1		1.5	98%		0	
	Monitoring at Source 1						
	Network	Combustion				-5	250
	in France	Fugitive				-1	
		Vented				-2.5	
		Leakage				-1.5	

Transfer ⇩ 1.49 Mt

Here transfer occurs from France to the NL trough Belgium off-shore area. No monitoring occurs as the network is a single entity in this permitting situation. There are no network losses shown here because there are no monitoring points.

Belgium		Fossil Mt	Compos. %	Biomass Mt	Emission Kt	H_2O ppm
	Transfer FR --> NL	1.49	98%			250

Transfer ⇩ 1.49 Mt

These are the emissions in the Netherlands. There are three sources: Source 2, 3 and 4 form a network and feed in from the Rotterdam area. Source 5 feeds in directly to off-shore from the Delfzijl area. Note that biomass is produced at Source 4 and is incorporated in the overview. Monitoring occurs at the sources. Network losses belonging to source 2 and 3 are shown.

NL			Fossil Mt	Compos. %	Biomass Mt	Emission Kt	H_2O ppm
	Source 2		1	99%			
	Monitoring at Source 2						
	Network	Combustion				-5	300
	from	Fugitive				-1	
	source2	Vented				-2.5	
		Leakage				-1.5	
	Source 3		0.2	97%			150
	Monitoring at Source 3						
	Network	Combustion				-5	150
	from	Fugitive				-1	
	source2	Vented				-2.5	
		Leakage				-1.5	
	Source 4		4	95%	**1**		400
	Monitoring at Source 4						
	Source 5		1.35	98%			450
	Monitoring at Source 5						

Transfer ⇩ 9.02 Mt

Here the streams which occur in Netherlands territory off-shore are shown. Two network losses are taken into account, one coming from the network from the Rotterdam area including biomass and one coming from the network from the Delfzijl area. Biomass is stored in large part in Sink1 but a fraction goes to the UK. Monitoring occurs at the sink and the network losses of source 2-4 and 5 are shown because these two streams go off-shore.

NL Sea			Fossil Mt	Compos. %	Biomass Mt	Emission Kt	H_2O ppm
	Network from source 2-4	Combustion	6.67	96%	1	-5	346
		Fugitive				-1	
		Vented				-2.5	
		Leakage				-1.5	
	Network from source 5	Combustion	1.35	98%		-5	450
		Fugitive				-1	
		Vented				-2.5	
		Leakage				-1.5	
	Sink 1 (NL Off-shore) Monitoring at Sink 1		7.07	96%	**0.882**		365

Transfer ⇩ **1.05 Mt**

Here the streams in UK off-shore territory are shown. Streams come from the NL off-shore network and the UK off-shore network receiving streams from the UK. The biomass which is received from the NL network is shown and is included in network losses. Monitoring is being performed at the sink. No monitoring occurs between NL → UK but network losses are mentioned because this stream consists of CO_2 coming from the Netherlands minus the CO_2 which goes into Sink1. The losses of the sources in the UK are mentioned here as well.

UK Sea			Fossil Mt	Compos. %	Biomass Mt	Emission Kt	H_2O ppm
	Network between NL --> UK	Combustion	0.934	96%		-5	365
		Fugitive				-1	
		Vented				-2.5	
		Leakage				-1.5	
	Sink 2 (UK Off-Shore) Monitoring at Sink 2		19.5	97%	**0.115**		271
	Network from source 6	Combustion	12.6	97%		-5	300
		Fugitive				-1	
		Vented				-2.5	
		Leakage				-1.5	
	Network from source 7	Combustion	6	98%		-5	250
		Fugitive				-1	
		Vented				-2.5	
		Leakage				-1.5	

Transfer ⇧ **18.6 Mt**

Here sources in the UK on-shore are shown. They are located near the coast and in this scenario feed directly to the off-shore network so no network losses are shown. Monitoring occurs at the sources. The table above shows the network losses.

UK		Fossil Mt	Compos. %	Biomass Mt	Emission Kt	H_2O ppm
	Source 6 Monitoring at Source 6	12.6	97%			300
	Source 7 Monitoring at Source 7	6	98%			250

4.4.3 Breakdown for the multiple network situation

In the tables below the streams are shown which occur in the network in the situation where the cross border network consists of multiple smaller networks.

In this table emissions in France are shown including network losses. Monitoring occurs at the border due to the permitting situation and is shown. Monitoring occurs at the source and at the border because of the permit situation. This is an entry point so network losses are shown.

France		Fossil feed Mt	Composition %	Biomass feed Mt	Emission Kt	H_2O Ppm
	Source 1	1.5	98%		0	
	Monitoring at Source 1					
	Network Combustion				-5	250
	in France Fugitive				-1	
	Vented				-2.5	
	Leakage				-1.5	
	Monitoring border FR_BE					

Transfer 1.49 Mt

Here the streams in Belgium are shown. Because permitting occurs separately in each country network losses in Belgium have to be accounted for. Network losses are listed separately for this section as monitoring occurs at the French and NL border. Network losses are shown because monitoring is performed at the French border.

Belgium		Fossil Mt	Compos. %	Biomass Mt	Emission Kt	H_2O Ppm
	Feed from France	1.49	98%			
	Network Combustion				-5	250
	in Belgium Fugitive				-1	
	Vented				-2.5	
	Leakage				-1.5	

Transfer 1.48 Mt

Here the streams in the on-shore network in the Netherlands are shown. Monitoring occurs at the sources but also for the feed from Belgium due to the permitting situation. Biomass is included just as with the example for the single permit situation. As can Be seen monitoring occurs for the streams coming from Belgium because of permits.

NL			Fossil Mt	Compos. %	Biomass Mt	Emission kt	H_2O ppm
	Monitoring border BE_NL						
	Feed from France		1.48	98%			
	Network	Combustion				-5	
	in Belgium	Fugitive				-1	
		Vented				-2.5	
		Leakage				-1.5	
	Source 2		1	99%			
	Monitoring at Source 2						
	Network	Combustion				-5	300
	from	Fugitive				-1	
	source2	Vented				-2.5	
		Leakage				-1.5	
	Source 3		0.2	97%			150
	Monitoring at Source 3						
	Network	Combustion				-5	150
	from	Fugitive				-1	
	source2	Vented				-2.5	
		Leakage				-1.5	
	Source 4		4	95%	**1**		400
	Monitoring at Source 4						
	Source 5		1.35	98%			450
	Monitoring at Source 5						

Transfer ⇩ **9.02 Mt**

Streams in the Netherlands off-shore network. Biomass is included. Monitoring occurs at sources and the interface with the off-shore network because of the permit situation. CO_2 enters the network here so networks losses are shown.

NL Sea			Fossil Mt	Compos. %	Biomass Mt	Emission kt	H2O ppm
	Monitoring NL Net. Src 2-4						
	Network	Combustion	6.67	96%	1	-5	346
	from	Fugitive				-1	
	source 2-4	Vented				-2.5	
		Leakage				-1.5	
	Monitoring NL Net. Src. 5						
	Network	Combustion	1.35	98%		-5	450
	from	Fugitive				-1	
	source 5	Vented				-2.5	
		Leakage				-1.5	
	Sink 1 (NL Off-shore)		7.07	97%	**0.882**		365
	Monitoring at Sink 1						

Transfer ⇩ **1.04 Mt**

Here the streams in the UK off-shore network are shown. Monitoring of the streams coming from the NL off-shore network has to be performed because of the permitting. The biomass coming from the NL off-shore network is shown. The network losses are shown for the streams coming from the UK and for the small stream coming from NL.

UK Sea			Fossil Mt	Compos. %	Biomass Mt	Emission Kt	H_2O ppm
	Network	Combustion				-5	
	from NL	Fugitive				-1	
		Vented				-2.5	
		Leakage				-1.5	
	Sink 2 (UK Off-Shore)		19.5	97%	**0.115**		271
	Monitoring at Sink 2						
	Network	Combustion	12.6	97%		-5	300
	from	Fugitive				-1	
	source 6	Vented				-2.5	
		Leakage				-1.5	
	Network	Combustion	6	98%		-5	250
	from	Fugitive				-1	
	source 7	Vented				-2.5	
		Leakage				-1.5	

Transfer ⇧ **18.58 Mt**

Streams on-shore in the UK flowing to off-shore. Monitoring is performed at the sources and at the transfer points to the off-shore network. Network losses are shown for the losses which occur between transfer points.

UK			Fossil Mt	Compos. %	Biomass Mt	Emission Kt	H_2O ppm
	Source 6		12.6	97%			
	Monitoring at Source 6						300
	Network	Combustion				-5	
	from	Fugitive				-1	
	source 6	Vented				-2.5	
		Leakage				-1.5	
	Monitoring UK Net. Src 6						
	Source 7		6	98%			
	Monitoring at Source 7						250
	Network	Combustion				-5	
	from	Fugitive				-1	
	source 7	Vented				-2.5	
		Leakage				-1.5	
	Monitoring UK Net. Src 7						

4.5 Best implementation of monitoring at cross border transfer points?

How is monitoring at cross border transfer points best implemented to assure quality of the measurements and availability of data? As discussed in section 4.3 there are two permitting situations. In the scenario where the entire network is one entity there only has to be monitoring at sources and at storage locations. If the network is split up into multiple networks for each country monitoring has to be implemented at borders and at the transfer points between on- and off-shore as well. Section 4.4 makes clear that the number of times monitoring has to be performed is significantly higher when multiple permits are used: Fourteen times as compared to nine times if the network is a single entity. What is also learned is that the networks structure is important. If the incoming and outgoing streams are known in a network were CO_2 from a source has only one path to reach a sink the amounts at transfer points are known. And if the sinks lie at one point within the network and networks loss emission factors are constant it can be determined how much biomass flows to them, based on the fraction of biomass which goes into the network at sources. When sinks are located at different points in the network this cannot be done. This is because when variations in output of sources occur it cannot be determined based on annual data how much biomass CO_2 flowed to which part of the network during the year.

4.5.1 Proposed cross border monitoring

Cross border monitoring can be complex. In Figure 4 a gas meter indicated as ‘M’. It is illustrated that there are several possible locations of the metering position relative to country border. This is because it will be difficult to always position monitoring stations exactly at the border, be it for practical reasons alone. Therefore the permitting has to incorporate these different possible positions where the border can be located.

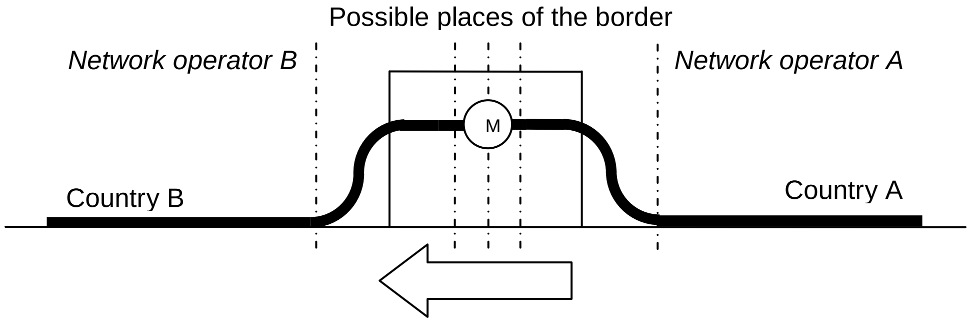

Figure 4 Illustration of cross border monitoring with possible locations relative to the border shown

4.5.3 Proposed monitoring between on- and off-shore

A CO_2 transport network can branch out into the sea. This happens in the case, with CO_2 streams both running into the sea and coming to the shore. Monitoring at these places is relevant when the network is divided into multiple networks. It has to be taken into account for the permit that in the EEZ of a coastal state that country has jurisdiction and that on the high seas the jurisdiction can be assigned as mentioned in subsection 3.4.2.

4.5.4 Proposed on-shore monitoring

In Figure 5 an illustration of proposed on-shore monitoring at a source/incoming stream is shown. It is assumed that sources will feed in at transport pressure. In the figure there is a gas meter indicated as ‘M’: As can be seen the network operator measures the amount of incoming CO_2 in the proposed setup.

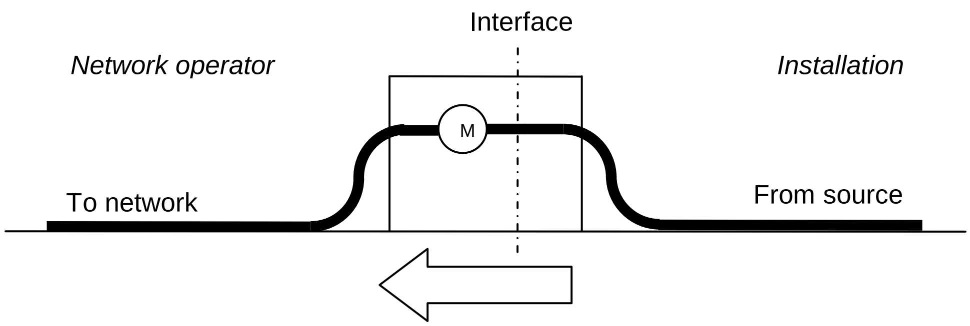

Figure 5 Illustration of the proposed set-up on land at the source

4.5.5 Proposed off-shore monitoring set-up (sinks)

Gas is typically delivered under transport pressure to a decompression station or pressure regulator: Feeding into the sinks normally occurs at lower pressures to adjust for column pressure build-up in a well and low initial pressure of empty gas fields. The envisioned location for monitoring is at a decompression station at an off-shore platform. In Figure 6 this is illustrated with a gas meter indicated as 'M' and decompression equipment is shown as an expanding shape. After the meter the connection up to the wellhead is considered to be part of the storage site.

The storage site can be an aquifer for example or an empty gas field. The storage directive asks for 'monitoring' at the wellhead' and unlike the ETS directive it does not specify an allowed uncertainty, only that the monitoring has to be 'real-time' (CATO2, 2010b, p 44).

The meter at the off-shore platform monitors the total amount of gas transferred. There may be multiple storage locations being connected to a platform and the connection from the off-shore decompression platform to the wellheads is considered part of the storage sites. Assignment of streams to individual storage sites can be based on monitoring at wellheads or modelling of the streams. Requirements regarding uncertainty are less strict there as they originate from the storage directive and not the MRG.

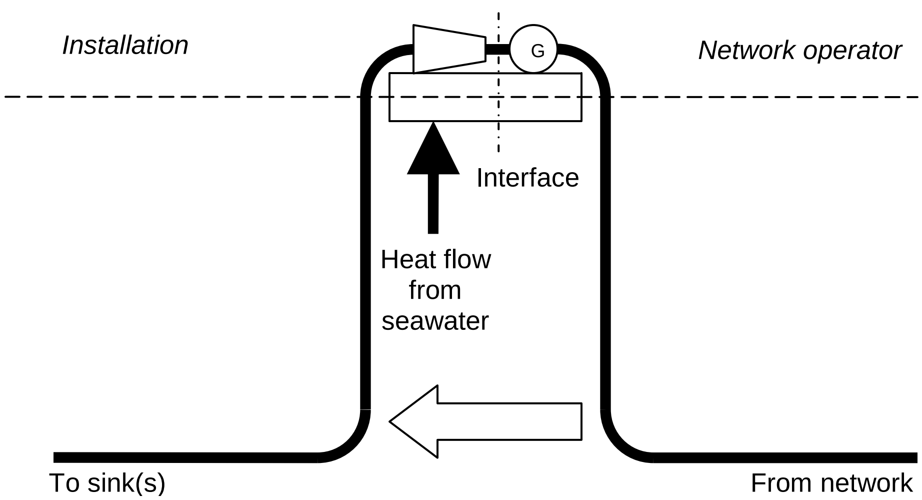

Figure 6 Example of the off-shore metering layout

Conclusions on the case:

A cross border CO_2 transport network is a complex installation because is located in multiple countries. Two situations are compared, one where the network consists of a single entity which is co-owned and falls under a single permit. The other situation divides the network in multiple smaller networks which each have their own permit. The following can be concluded from the case:

- When the amount of biomass fed into the network is known the amounts transported in the can be calculated in the case network. Emissions from network losses can also be calculated when network losses are assumed to be constant: In this situation the biomass network loss emissions are equivalent to the biomass fraction which is transported
- Splitting up the network results in as higher amount of points that have to be monitored
- If more than one sink is present in the network, monitoring also has to be done at the exit otherwise the amounts flowing through the network cannot be calculated
- With regard to measuring at borders, when monitoring has to occur, it can be the case that the monitoring equipment is not located exactly at the border. This is something which has to be arranged in the permit
- If the network is divided into multiple networks, monitoring is best performed at the interface from on-shore to off-shore with the off-shore part of the network falling under one permit. This is as to avoid complex situations where monitoring has to be performed in the middle of the sea because of a border-crossing.
- Off-shore monitoring is complex and the permit of the network is best limited to a point on an off-shore platform. There will be piping running from such a platform to the wellhead of sinks. If this piping is considered to part of the storage sites monitoring for entry op the storage site can be performed on the platform and can be provided by the network operator.

5 Approach for permitting cross border networks under EU-ETS

This chapter discusses what approach can best be used for the permitting and supervision of the cross border networks. Two types of permitting were discussed in the case treating it as a single entity for the permit or dividing the network into multiple entities. The advantages and disadvantages of these approaches are discussed here. Also the role of the authorities involved is discussed, as well as how the accompanying processes could be practically designed.

First the legal aspects of the permitting situations which could be used for the cross border network are discussed. This is followed by a section which discusses how access can be arranged for permitting in the single- or multiple network situations. Finally the advantages and disadvantages of having single- or multiple permits are discussed, concluding that a single permit is the best option.

5.1 Legal aspects of permitting cross border CO_2 networks

As analyzed in the case there can be two permit situations. The two situations are reviewed in this section from a legal perspective and further in this chapter an analysis on the implications of these situations is performed. For the case where CO_2 is eventually stored off-shore the legal framework is described in section 3.4. Assuming the network would need only one permit, based on the reasoning in that section, the state under whose jurisdiction the field falls would have functional jurisdiction (to regulate the use of the pipeline) over the pipelines towards that field. The storage permit will contain the monitoring requirements for compliance with the CCS Directive and the EU-ETS. Another option is to use the same mechanism that is used for aviation, the only other situation in which cross border emissions are dealt with under ETS. Art 18 (b) of the ETS Directive states that one administrative authority is appointed, either the state in which the aviation organization has received its aviation permit, or the state in which is assumed that the most emissions take place. For our case the first option would mean that the state in which the network operator has received its storage permit or the state in which most emissions are expected will also be responsible for the ETS permit and the allowances. The other option does not seem reasonable, as it is hard to predict where leakage occurs, and not all states in which leakage occur have the same amount of jurisdiction over environmental and safety demands. Furthermore, as a network might contain multiple capture locations, for parts of the network, it is not clear 'whose' CO_2 has leaked, so to address the capture state also does not seem reasonable. It seems most reasonable to choose either the storage state or the state in which the network operator is registered as the state that would be competent to issue the permit.

In the situation in which the network would be viewed as consisting of several networks, for each of the networks an ETS permit has to be acquired. In this case, for four countries and four authorities would be involved. Although the CCS directive prescribes that the competent authorities for CCS in Europe have the obligation to work together (art 24 CCS Directive), such an obligation is not found in the ETS Directive: This is because it provides for central administration and the European Commission organizes an information exchange (art 20 and 21 ETS Directive). This means that the network operator has to deal with four different authorities, and perhaps four different sets of regulation with regard to measuring and reporting procedures.

As the ETS Directive is fairly detailed in prescribing the procedure and administration of the emissions, we see that it is still possible for states to prescribe specific measuring techniques. For the network operator, this is complicated and costly. With regard to verification, the ETS Directive requires independent and competent verification parties and has issued minimal demands for accreditation of the verification parties. As these demands might be interpreted differently in the different states, it is possible that the quality of measurement and verification in the different permits is different.

Conclusions on the legal aspects of permitting cross border CO_2 transport networks:

Although cross border CCS, especially off-shore, is not yet legally allowed, the different states that are relevant in the case might agree to a cross border network. In this agreement, jurisdictional issues should be regulated, as there will be conflicting jurisdiction within the network.

If there is one permit for the entire network, the question would be where to issue this permit and where to account for the allowances, Several options are available:

- To choose for the state responsible for the storage location
- To choose for the state in which the network operator has received its CCS permit
- To choose for the state in which the most emissions are expected
- To choose for the state in which the CO_2 is captured

Advantages would be that there will be one metering code applicable and one relevant authority.

In case of different networks, different permits will be required, with possible different measuring demand, differently qualified and accredited verification parties and different competent authorities, which do not need to work together.

5.2 Access to the network with single- or multiple permits

States are allowed to regulate TPA as long as there is fair and open access. The possible different access regimes differ around the question who determines the tariffs and conditions under which access has to be granted. Summarizing subsection 3.4.2, in rTPA a regulator determines the tariffs and conditions. In nTPA the network operator publishes indicative conditions in advance and in sTPA everything is negotiated between the operator and the organization wanting access.

In case of a single network, with a single network operator, therefore we cannot assume that the operator will have to deal with one possible TPA regime. It is possible that the network operator of the single network will have to deal with the TPA regimes of all four countries that are present in the case. Each of these countries might choose its own TPA regime, which might vary from rTPA to sTPA. The operator thus might be facing regulation in advance, determining the tariffs and conditions, or might face court intervention of complaint handling afterwards, if negotiations fail. In case of multiple networks, divided at the border, the natural borders of the network are the same as the borders of the possibly different TPA regimes of states. As in the CCS Directive is mentioned, the competent authorities are obliged to cooperate. So, in case of unreasonable demands for the network operators, there at least is a mechanism in place that addresses this issue.

Conclusions on access to the network in single- or multiple permit situations:

With regard to TPA, several regimes are possible, and as the CCS Directive does not prescribe a specific regime, states are allowed to choose a regime. As there are both reasons to regulate the access and to not regulate access, it is possible that different regimes exist throughout Europe. Furthermore, TPA will not be regulated in the CCS permit, but in the surrounding state regulation. In case of a single permit for the network, the operator still has to deal with these national demands. However, competent authorities are obliged to cooperate based on the CCS Directive.

5.3 Implications of a single compared with multiple permits

Having a single permit means that all the network emissions are reported in one country. This may seem to be a disadvantage however if an agreement is made that it is possible to assign these emissions to countries where these emissions actually took place this can be resolved. Also, since measurement at borders is unnecessary from a technical point of view and costly it seems to outweigh the disadvantages.

Summarizing, the implications of having a single permit for the entire network are that:

- The permit has to hold up in all relevant countries
- The permit holder has to have a registered basis where network emissions can be verified
- Accounting of emissions for all countries will be more complicated
- There will be fewer monitoring obligations

If the network consists of multiple smaller networks monitoring will have to occur at country borders to determine how much CO_2 is transported for CCS purposes. For an off-shore network monitoring of streams from one country to another has to occur off-shore at the border between countries and/or at the point where countries territorial waters ends. This is unpractical and costly and raises questions about the status and ownership of the network in international waters. Because of this a preferred solution is to make off-shore networks co-owned by the network operators of the countries in whose national waters the network is located. This removes the advantage of splitting a larger network into smaller networks located within countries. There is again the need to have a permit which is valid in multiple countries. The difference is that this permit only has to be valid in the respective countries and not for all the countries in the network.

Consequences thus are when a larger network consists of multiple smaller networks:

- There will be more permits for the same network
- There will be extra monitoring points
- The situation will be more complex in case of off-shore

This comparison, along with the aspects which were already mentioned in the case make clear what the differences between the two monitoring situations are. Considering the advantages and disadvantages of both approaches it seems that having a network in multiple countries which operates under one EU-ETS permit is the preferable situation. Especially with off-shore situations dividing the network into smaller networks does not reduce complexity from that perspective. And off-course, the increased number of monitoring points, approximately 1.5 times as many, adds to the cost of monitoring and may also increase emission from the network if i.e. extra flanges are required.

Conclusions on single compared to multiple permits:

What approach is best for permitting and supervision of a cross border network? The simplest approach for permitting is to have a single permit for a network which runs through multiple countries. The key advantage is that no monitoring is required between borders and transfer point between on- and off-shore. The disadvantage is that there has to be a method to allocate the network emissions to the respective countries through where the network operates.

6 Other requirements; i.e. waste, hazardous

This chapter is about what other monitoring requirements need to be fulfilled. This can be conditions such as minimum CO_2 concentration, waste, hazardous and other components, in relation to permitting the cross border network. First a summary is made of the streams which can typically occur in CO_2 streams which are the result of a power production capturing process.

6.1 Other components in the streams

Apart from CO_2 there can be various other substances within the pipelines such as nitrogen or water. Also the concept of ‘Overwhelmingly CO_2’ is used meaning that the stream consists for the largest part of CO_2. In CATO-2 Deliverable WP 4.1-D4.1.01 (CATO2, 2010a) it is discussed what kind of concentrations of substances can be expected in paragraph 4.4 ‘*Concentrations applying capture technologies*’. Also discussed in this deliverable are recommendations for allowable substance in a network in paragraph 4.5. ‘*Transport, Storage and HSE requirements*’. The information in these paragraphs has been summarized in Table 2 where indications of concentrations are compared with recommended concentrations.

Table 2 Comparison of indicated concentrations with recommended concentrations

Unit		Post-combustion Capture		Pre-combustion Capture		Oxyfuel		Recommendation
		Process	Cleaned	Process	Cleaned	Process	Cleaned	
vol%	CO2	98.6	99.5	95.0	99.9	89.4	99.2	95.50%
Ppm	H20 water	1400-14000	<1400	1400	<1400	1400	<1400	500ppm
vol%	Argon	0.020		0.050		0.600-5.700	0.045	4 vol%
vol%	N2	0.02		0.03		0.60-5.00	0.30	4 vol%
vol%	O2	0.003		<0.003	?	0.60-5.00	0.30	4 vol%
Ppm	O2	30		<30	?	6000-50000	3000	100-1000ppm
vol%	H2			1.7- 5.00	0.10			4 vol%
ppm	SO2	10				47- 760	57	100ppm (SOx)
ppm	NOx	20	20	<20	<20	2000	20	100ppm
ppm	H2S			1- 100				200ppm
vol%	CH4			0.035				2 vol%

The following problems can be identified for cleaned processes. Processes that are not cleaned are unsuited in any case for feeding in due to water content and are thus not further discussed.

- H_2O can be above the recommended value (solubility limit H_2O in CO_2) in all types of processes so monitoring has to be performed.
- O_2 content for an oxyfuel process where drying and cleaning has been performed is higher than the recommendation for EOR injection.

O_2 content in a pre-combustion process is stated as unknown in but will be small or not present because this is a reduced combustion environment. As can be seen the requirement that the stream consists of 'overwhelmingly CO_2' can be met easily as was also concluded in CATO-2 Deliverable WP 4.1-D4.1.01 (CATO2, 2010a).

Conclusions on other substances than CO_2 in the streams:

If streams are being generated by a combustion process several types of components can typically occur in them, other than CO_2. If drying of the CO_2 stream is not performed water content is almost always a problem, risking corrosion of pipelines. If the stream is cleaned, O_2 could possibly to be a problem with a specific combustion process if injection in EOR wells is envisioned. Calculations can also be used to guard concentrations of these substances at storage locations.

6.2 Hazardous substances, applicable legislation

Hazardous substances can be present in CO_2 streams. They can occur for example as a co-product of CO_2 capture processes. These substances can be subject to specific legislation regarding hazardous substances. Two possible sets of regulation are relevant with regard to the hazardous substances that might be incorporated in the CO_2 stream:

- The regulation in hazardous substances: REACH (EU, 2006b), Regulation on classification, labelling and packaging of substances and mixtures: CLP (EU, 2008)
- The regulation on hazardous wastes as agreed upon in the Basel Convention (implemented in the EU in the Basel Regulation on shipments of waste (EU, 2006b)
- The regulation on accidents involving hazardous substances (EU, 1996)

This section will analyse whether or not these rules are applicable to the possible hazardous substances in the CO_2 stream.

6.2.1 REACH and the CLP regulation

A first source of regulation is the regulation in hazardous substances in general. This regulation can be found in the REACH regulation and the CLP regulation. It deals with the Registration, Evaluation, Authorisation and Restriction of Chemical substances and the Classification, Labeling and Packaging of these substances. Both of these regulations do not apply to the presence of dangerous substances in the CO_2 stream, as they are not a specific substance in itself, but can be regarded as not isolated intermediates, which are excluded in the art 2 (1c) in both regulations.

6.2.2 Basel Convention

Another source of regulation dealing with large amounts of possible dangerous substances is the Basel Convention. All of the individual states and the EU as a whole are members to the Basel Convention.[2] In the EU, the Basel Convention is implemented in the Basel regulation on shipments of waste. In general, the regulations for shipments of wastes destined for disposal, as is the case with storage, are stricter than for waste meant for recovery. Based on the purpose of the waste, different procedures for notifying cross border transport are to be followed. A first question to be answered is how to qualify storage. According to the definition of disposal (art 2 (4) Basel Regulation, art 1 (1e), Annex IIA (d3) Waste Directive), storage is qualified as disposal. Therefore, storage of (hazardous) of all kinds of wastes accompanying the CO_2 stream is subject to the procedure of prior written notification and consent of the Basel Regulation.

Of this regulation, title II (articles 3-32) seems to apply to the case: shipments of waste between states. In essence, the regulation states that if waste is transported, a specific procedure (prior written notification and consent) must be followed. The Basel Regulation distinguishes between a green list (subject to a general information requirement), an amber list (subject to a prior informed consent procedure) and a list of wastes that may not be exported. In the sense of the regulation, export means to a non OECD country, which is not applicable in the case. Even the hazardous wastes thus might be transported throughout the EU, using the prescribed procedure of notification and consent. This procedure is described in art 4 Basel Regulation. In summary it

[2] Only in the situation in which the EU implementation of the Basel Convention is not in accordance with the Convention, this individual Membership is relevant.

says that the notification of the transport has to be submitted to the authority of dispatch, which will check for completeness, and then will be forwarded to the authority of destination (any transits in between also). The authorities have 30 days to consent, with or without conditions, or to raise objections (grounds for which are limited). In the Basel regulation, no substances, but activities leading to waste consisting of substances is regulated.

Although the Basel regulation seems to apply to the situation of cross border CCS, it can be questioned whether or not CCS is excluded from the Basel regulation. The CCS Directive (art 35 CCS Directive), states 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 Waste Directive. Because of the wording of this article that only refers to carbon dioxide, and not to the CO_2 stream, it might be concluded that the other components of the CO_2 stream (not carbon dioxide) might be qualified as waste. Especially since the CCS Directive does not regulate carbon dioxide, but CO_2 streams (art 12 CCS Directive). However, the explicit intention to exclude CCS from the Waste Directive in the CCS Directive, and the intention of the Waste Directive not to regulate substances that have already been regulated elsewhere, indicates that the complete CO_2 stream is excluded from the application of the Waste Directive and other regulations based on the definition of waste from the Waste Directive (such as the Basel Regulation). It would have been more precise though, if the CCS Directive consequently used the term CO_2 stream.

6.2.3 Seveso II Directive

A final possible set of regulation applicable to cross border CCS might be the Seveso II Directive. In short, the Seveso II Directive regulates the control of major-accident hazards involving dangerous substances. It introduces requirements relating to safety management systems, emergency plans and land-use planning, and tightened provisions on inspection and public information. As of now, the Seveso II Directive is not designed to apply to CCS, mostly due to the fact that CCS was not an option when the Seveso II directive was designed. When analyzing the articles of the Seveso II Directive, it becomes clear that the directive does not apply to transport of dangerous substances through pipelines, so it is not applicable to CO_2 transport (art 4 (d) Seveso II Directive). Furthermore, the Seveso II does not apply to mining activities for minerals, both onshore and offshore (art 4 (e,f) Seveso II Directive). However, as CO_2 is not a mineral, this does not exclude CCS. When the injection installation can be qualified as an installation or establishment as defined in art 3 of the Seveso II Directive, the directive might be applicable to CCS (all things necessary for the operation of the installation).[3] [4] When the CCS injection facility is defined as an installation under the Seveso II Directive, this does not necessarily mean that the Directive applies to CCS. In order for it to apply to CCS, certain thresholds for substances need to

[3] 1. ‘establishment’ shall mean the whole area under the control of an operator where dangerous substances are present in one or more installations, including common or related infrastructures or activities; 2. ‘installation’ shall mean a technical unit within an establishment in which dangerous substances are produced, used, handled or stored. It shall include all the equipment, structures, pipe work, machinery, tools, private railway sidings, docks, unloading quays serving the installation, jetties, warehouses or similar structures, floating or otherwise, necessary for the operation of the installation;

[4] As the situation has not occurred yet, it is not clear whether or not this is so. However, for the purpose of the Seveso Directive, in general a rather broad definition is used, in which handling and storage underground are likely to be counted as part of the establishment/installation.

be present in the installation. Substances that might be present in the CO_2 stream and fall under the Seveso II Directive are hydrogen and oxygen, which would have to be present in the amount of respectively 5 /50 and 20/2.000 tones (notification and prevention/safety report). In order for these substances to be present, the whole field should be part of the 'installation'.

As of now, carbon dioxide is not recognized as dangerous substance under the Seveso II Directive. However, in the proposal for the Seveso III Directive, CCS as an activity to be regulated is mentioned, especially by environmental organizations. In the proposal, carbon dioxide is not included. The European Environmental Bureau advises to include carbon dioxide (threshold 20/10.000 tones), as well as pipeline transport and offshore installations (EEB, 2010, p 5, 7). Industry, on the other hand, calls upon members of the European Parliament to vote against inclusion of CO_2 in the Seveso III Directive (amendment 280). The proposal is still awaiting the European Parliaments first reading.

Conclusions on hazardous substances:

Aside from the question whether monitoring occurs at countries borders and at transfer points from on-shore to off-shore or not it has to be performed at CO_2 sources and at CO_2 sinks. For source installations it is advised that monitoring of waste streams and hazardous components is done by setting requirements for third party sources, as these installations have the incentive of not wanting such substances in their own installations.

The CO_2 stream is regulated; the hazardous substances that might be part of the CO_2 stream are not regulated as such. Furthermore, as CO_2 streams are not to be regarded as waste, the other components of that stream are also not likely to be regarded as waste. Therefore, the stringent regime of the Basel regulation does not seem to apply. It is possible that the Seveso II directive applies, if the substances oxygen and hydrogen are present in large amounts. This would mean that the remediation and safety plans have to be adapted to the demands of the Seveso II Directive.

7 Bringing all findings together in an measuring code of CO_2

The composition of CO_2 streams is investigated in CATO-2 deliverable 4.1.1. Individual states want to know if and how much hazardous substances cross their border. In many cases this is also a requirement of law. Mutual recognition and common standards for CO_2 monitoring will streamline the process of permitting and verification of cross border CO_2 streams. This chapter provides a limited framework of the most important aspects of the (cross border) CO_2 monitoring.

7.1 Data collection

Data collection is an important issue with transport networks, especially when dealing with remote locations such as off-shore storage sites. It can be divided into data collection and data transmission. Data collection is about which values have to be recorded and on what timescale. Data transmission aspects are about what has to be monitored continuously. Off-shore a real-time measurement of pressure and flow will be necessary for system control. Other parameters such as concentration will not require real-time monitoring.

Attention is given to the off-shore situation. One of the conditions set by the EU storage directive is that there has to be continuous monitoring at the wellhead. This implies that there also has to be a data-connection. Therefore there has to be suitable space on the off-shore platform to install data sending equipment for storage site owners. In-case the network operator decides to create a data connection to the platform it is advisable to offer access to this connection for the storage site owners.

7.2 Aspects which have to be part of a measuring code

Based on the topics which have been discussed in this deliverable thus far a summary for requirements in a measuring code has been made. These requirements are shown in . In the upper part of the relevant monitoring aspects are listed and what requirements they are determined by. In the lower part of the transfer points are listed and what their requirements are. has been compiled based on the topics which are discussed in this deliverable. The types of transfer points which are present in the case network are shown and the description of the monitoring aspects flow and concentration comes directly from the MRG. H_2O can be a problem (subsection 6.1) and it is required that specific hazardous substances do not enter the network (subsection 6.2) so these monitoring aspects are described as well.

Table 3 Monitoring requirements in the network, (*, **) see monitoring aspect flow rationale

Monitoring aspects:	**Flow**	**CO_2 concentration (%)**	**H2O**	**Hazardous**
Requirements:	-Averaging period -Monitoring period -Monitoring uncertainty -Specific information -Monitor for biomass?	-Monitoring period -Monitoring uncertainty -Specific information -Monitor for biomass?	-Measuring period -Technical requirement -Monitoring period -Regulation	-Averaging period -Monitor for what? -Specific information
Transfer points:				
Network source	-Hourly (EN14181 for CEMS) -Related to MRG uncert. req. -MRG requirement <1.77%* -Point where monitoring and other measuring can be done -Yes, to determine fraction	-Related to MRG uncert. req. -MRG requirement <1.77%* -Monitoring at source always has to be performed -Yes, to determine fraction	-Network requirements -H_2O solubility in CO_2 -None (source measures) -'Overwhelmingly CO_2'	-Network requirements -HSE requirements -Network has to make no (disallowed amounts of) substances are fed in
Cross border	-Related to MRG uncert. req. -Related to MRG uncert. req. -MRG requirement <1.77%* -Only relevant with permits for each country -No, can be calculated (**)	-Related to MRG uncert. req. -MRG requirement <1.77%* -Not necessary when no mixing occurs , network operates under one permit -No, can be calculated (**)	-None (source measures) -None (source measures) -None (source measures) -None (source measures)	-Not necessary -HSE requirements -The network should guarantee no disallowed substances (i.e. by modeling)
On- <-- --> Off-shore	-Related to MRG uncert. req. -Related to MRG uncert. req. -MRG requirement <1.77%* -Only relevant with permits for each country -No, can be calculated (**)	-Related to MRG uncert. req. -MRG requirement <1.77%* -Not necessary when no mixing occurs , network operates under one permit -No, can be calculated (**)	-None (source measures) -None (source measures) -None (source measures) -'Overwhelmingly CO_2'	-Not necessary -HSE requirements -The network should guarantee no disallowed substances (i.e. by modeling)
Network sink	-Hourly (EN14181 for CEMS) -Related to MRG uncert. req. -MRG requirement <1.77%* -Point where monitoring and other measuring can be done -No, can be calculated (**)	-Related to MRG uncert. req. -MRG requirement <1.77%* -Not necessary when no mixing occurs in network after previous monitoring -No, can be calculated (**)	-None (source measures) -None (source measures) -None (source measures) -None (source measures)	-Not necessary -HSE requirements -The network should guarantee no disallowed substances (i.e. by modeling)

In a lot of information is shown. The rationale for the monitoring aspects is as follows:

- Monitoring aspect: Flow
    - In the MRG flow is used together with CO_2 concentration to determine the amount of transferred CO_2. Annual uncertainty has to be <2.5% for transferred CO_2, and the uncertainty of flow and CO_2 concentration are thus related. If they would have the same uncertainty the requirement would thus be <1.77% (*, see description of monitoring aspects flow and concentration). This uncertainty includes both random and systematic uncertainty.
    - The monitoring period is related to the required monitoring uncertainty; more measurements on an annual base create a lower uncertainty. The averaging period at least has to be hourly which is a requirement of the EN14181 standard for CEMS measurements.
    - From the perspective of network requirements it should be known what the streams flowing into the network and flowing out of the network are. The averaging period should be such as required for operation of the network
    - From an MRG perspective measurement of flow should be done at each point where a network begins and ends. In the case where the entire network operates under a single permit this will be at the source and at the storage site. If the network operates under multiple permits monitoring also has to be performed at borders and between on-shore and off-shore networks.
    - The case makes clear that with networks where CO_2 streams are one-way and the network converges to a central downstream point where CO_2 sinks are located, the amount of biomass which is transferred trough a network at other points can be calculated if the biomass fraction in streams are when they are fed into the network. In networks which are more complex monitoring points may have to be introduced to determine the biomass fraction (**, see description of monitoring aspects flow and concentration)
- Monitoring aspect: CO_2 concentration
    - The requirement to monitor CO_2 concentration follows from the MRG. Therefore the situation for monitoring is the same as with the monitoring aspect flow. Uncertainty requirements are related and the monitoring period is the same.
    - The averaging period can be the same as the monitoring period. If no mixing occurs between transfer points meaning that the network is a single pipeline the concentration is known from previous monitoring no new measuring is necessary.
    - As with the monitoring aspect flow, only if the network operates under multiple permits monitoring for CO_2 concentration has to be performed between borders and between on-shore and off-shore.
    - The same as with flow, if the biomass fraction is known at the source it can be calculated at other points in the network (**)

- Monitoring aspects: H_2O
    - H_2O can have a negative impact on the network infrastructure with CO_2 from capturing processes. The criterion is H_2O solubility in CO_2.
    - If monitoring is performed upon network entry at the source H_2O monitoring is not necessary at other transfer points in the network
- Hazardous substances
    - Hazardous substances are subject to specific legislation. Sometimes these substances are banned from being transported across borders or to be stored in storage locations as discussed in subsection 6.2. Therefore the best approach is to monitor for substances upon entry.
    - To guarantee that no disallowed amount is present in the network possible chemical processes when mixing of streams occurs should be taken into account.

Remarks on Table 3:

- Pressure plays a role in network control; it is however not mentioned here as it is not an aspect of the MRG and is also not related to entrance criteria on the network other than technical specifications. For the storage site pressure plays a role, but this is something which is controlled by i.e. a decompression station and is not related to the network operating pressure.
- The rationale behind the measurement of hazardous substances is that it is often subject to specific legislation which disallows or only leaves room for small amounts of these substances. It is therefore important that (the) network operator(s) can guarantee that amounts of such substances do not exceed allowed limits. Monitoring at the network source and modelling i.e. chemical processes should be able to guarantee this.

This deliverable discusses the monitoring requirements for a cross border network. It is relevant however to investigate requirements at storage site as well. This is because there is a large overlap between the storage directive and the requirements for monitoring on the network. A number of monitoring requirements which follow from the storage directive are already provided by monitoring within the network. Table 4 shows monitoring aspects, requirements and their specifics at transfer points in the same manner as Table 3. The monitoring aspects for the reservoir are not shown in Table 4.

Table 4 Monitoring requirements at the storage location

Monitoring aspects:	CO2 volumetric flow	Chemical analysis	Pressure & Temperature	Fugitive Emissions
Requirements:	-Specific information:	-Specific information	-Averaging period -Specific information	-Monitoring method -Monitoring uncertainty -Specific information
Transfer points:				
Injection wellhead	-CO_2 volumetric flow deter-mines mass flow which is provided by the network. With multiple wellheads allocation has to be done	-The chemical composition can be determined by data from the network on CO_2 concentration, waste and hazardous/tech. Substances	-Storage site related to CO_2 flow -Required to determine CO_2 mass <-> volumetric flow	-Emission factors -MRG requirement <7.5% -With downstream transfer only uncertainty should be met

Remark on Table4: The parameters which have to be monitored by the storage directive can in a large part be derived from data from which is being monitored on the network. The only parameters which cannot be derived are temperature and pressure in the reservoir.

8 Conclusions and recommendations

8.1 General conclusions

In this report the measurement requirements for a possible cross border network have been researched. To summarize the answers to the research questions:

- With concern to the first research question "*What monitoring requirements are to be met by a cross border CO_2 transport network, can they be met and how could accounting best be designed (in a 'measuring code')?*"
  - The relevant monitoring requirements were identified and elaborated
  - A proposal for aspects which can be part of measuring code has been made
  - Monitoring requirements are met most easily if a single permit is used for a network
  - When biomass is monitored at the sources its concentration can be calculated in the network
  - Monitoring at the exit is necessary if more than one sink is present
  - Waste substances are likely to be in the allowed window with normal operation
  - Seveso II might pose a problem with regard to waste and hazardous substances
- With concern to the second research question "*Which authorities have the jurisdiction to regulate the cross border network and how can conflicting jurisdiction be overcome?*"
  - Complexities with implementation remain in both permit scenarios
  - A measuring code can be part of the access regime
  - Cross border networks are not yet legally allowed (London Protocol), but this can be overcome with bilateral or multilateral treaties
  - Multiple permits imply countries will apply their own rules. For the operator this means conditions can differ per country even though there is a European ETS system
  - What regime is applicable with a single network and one permit is not yet established. Options are a permit in state of the registered seat or in the state responsible for the storage site

8.2 Recommendations

This report has made a number of conclusions on aspects which are currently related to the monitoring of cross border networks, and their permits. There are topics which were not researched into depth in this deliverable. Proposed topics for further research are:

- The effect of Nitramines and Nitrosamines as a waste product of combustion and capture processes
- Specific legislation on EU countries on hazardous substances, not all state law is accessible or transparent so it was not researched in this deliverable
- Further development of a measuring code, involving more technical details on measuring equipment
- Research into how existing EU legislations such as the MRG and CCS MRG can be improved to better encompass the expected monitoring aspects of cross border networks

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