GLOBAL CCS INSTITUTE

GLOBAL STATUS OF CCS: SPECIAL REPORT

UNDERSTANDING INDUSTRIAL CCS HUBS AND CLUSTERS

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Highlights

- Carbon capture and storage (CCS) is already in use across a variety of industrial applications, and has been for decades.
- A CCS hub and cluster network brings together multiple carbon dioxide (CO_2) emitters and/or multiple storage locations using shared transportation infrastructure.
- Areas where there is both a high concentration of CO_2 emitting industries and a nearby capacity to store emissions are considered prime sites for hub and cluster developments.
- Hub and cluster networks offer several distinct advantages for network participants, compared with ‘point-to-point’ projects. The hub and cluster approach reduces costs and risks for many potential CCS projects, and enables CO_2 capture from small volume industrial facilities.
- Strong policy support and cooperation between potential participants is needed for the development of CCS hubs and clusters, which is vital to decarbonising industrial processes and products while supporting the sustainable development of low-carbon industries.

Reducing emissions from industries such as iron and steel, cement, chemicals and refining is just as important as reductions in the power sector. Under the IEA’s 2DS, industrial applications account for 1.7 Gt per annum of CO2 emissions captured in 2040, or around 40 per cent of total emissions captured. **Global Status of CCS: 2015.**

1 Introduction

The technology components of carbon capture and storage (CCS) are already proven and in use across a variety of industries and applications. While this is most obviously the case in natural gas processing, CCS technologies have also been successfully implemented on projects including hydrogen production, fertiliser manufacture, and the production of synthetic natural gas. In the next two years, the range of industrial applications will grow further to include ethanol production and a steelworks.

In some instances, individual industrial facilities can capture millions of tonnes of carbon dioxide (CO_2) each year. CCS is already a valuable and proven solution for reducing emissions at this type of large-scale source. However, many industrial plants operate at much smaller scales, and as a result have lower overall emissions. While the combined level of emissions from a number of such smaller scale facilities can be significant, it may be uneconomic for any individual facility to consider application of the full CCS chain which includes capture, compression, transport and permanent storage of CO_2.

One solution to this problem is clustering, in which several industrial facilities share CCS infrastructure and knowledge, and thus reduce their costs compared with each facility attempting to individually reduce emissions. Clustering will create a network of smaller emitters, and centralise the parts of the CCS infrastructure that are shared by all of the individual contributors. This report provides an overview of the idea of clustering as applied to industrial CCS projects, and examines the conditions needed for its more widespread adoption.

2 Clusters, hubs and networks

Clusters

The concept of industry clusters is very well established in the fields of economic development and economic geography. An industry cluster is a geographic concentration of interconnected businesses, suppliers, and associated institutions in a particular field. Clusters can emerge for many different reasons, including proximity to raw materials, to transport options such as ports, to labour supply, and to markets.

For CCS, the idea of clusters takes advantage of the fact that around the world, many emissions-intensive facilities (both industrial and power) are located in tight geographical clusters. These clusters can be around energy supplies, power generation facilities, or ports.

This provides the opportunity for CO_2 emitters located in relatively close proximity to each other to join together to form a ‘capture cluster’, which is connected to a large-scale CO_2 storage site using strategically-sized (oversized) shared infrastructure.

In this context infrastructure is ‘oversized’ if it is too large for the requirements of a single user, but suited to the needs of multiple users.

The costs of a pipeline, possibly compression facilities, and associated activities such as community consultation, government approvals, negotiations with property owners

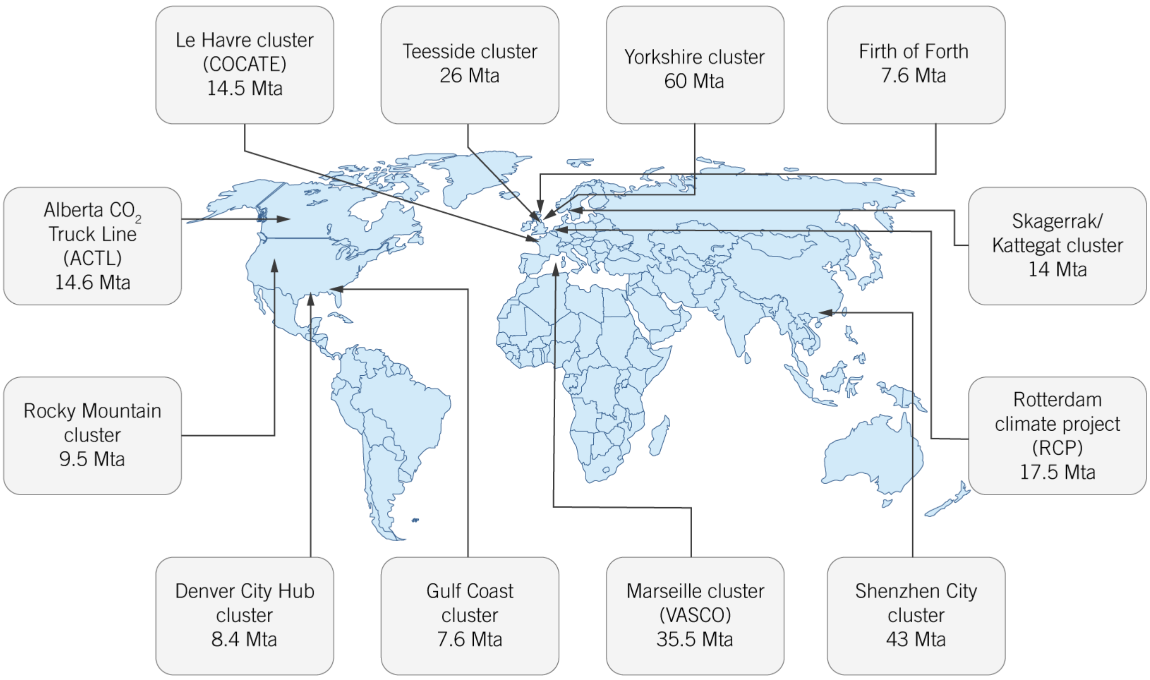
> There are many famous examples of industry clusters through history, from Staffordshire potteries in early industrialised England, through the Hollywood film industry in the 1930s and on to Silicon Valley’s information technology industry towards the end of the 20th century.
>
> For smaller firms, the advantages of locating in a cluster include accessing economies of scale usually only available to large firms, having ready access to a pool of skilled labour, being close to suppliers and/or customers, and being able to readily access information networks, both formal and informal.[1]

and so on, can be reduced on a per user basis if the costs are shared or only spent once rather than multiple times.

There can also be ‘storage clusters’, where CO_2 is distributed among a group of different, but reasonably proximate, geological storage locations and/or oil fields suitable for enhanced oil recovery (EOR).

Clusters of industrial emitters are also often co-located with power generation facilities that can represent large sources of emissions. The International Energy Agency Greenhouse Gas R&D Programme (IEAGHG) has identified at least 12 large-scale CO_2 clusters that are proposed or in progress around the world, ranging in size up to 60 million tonnes a year (Mta) of CO_2 captured. Europe’s Zero Emissions Platfom (ZEP) has also published detailed information about identified industrial clusters across the region. A selection of these identified clusters is illustrated below, in Figure 1.[1]

Figure 1 Major CCS clusters



Adapted from IEAGHG 2015a and ZEP 2014 data. Figure 1 identifies existing industrial clusters with estimated annual CO2 emissions. CCS infrastructure exists in some of the clusters identified in the figure. The figure is illustrative only.

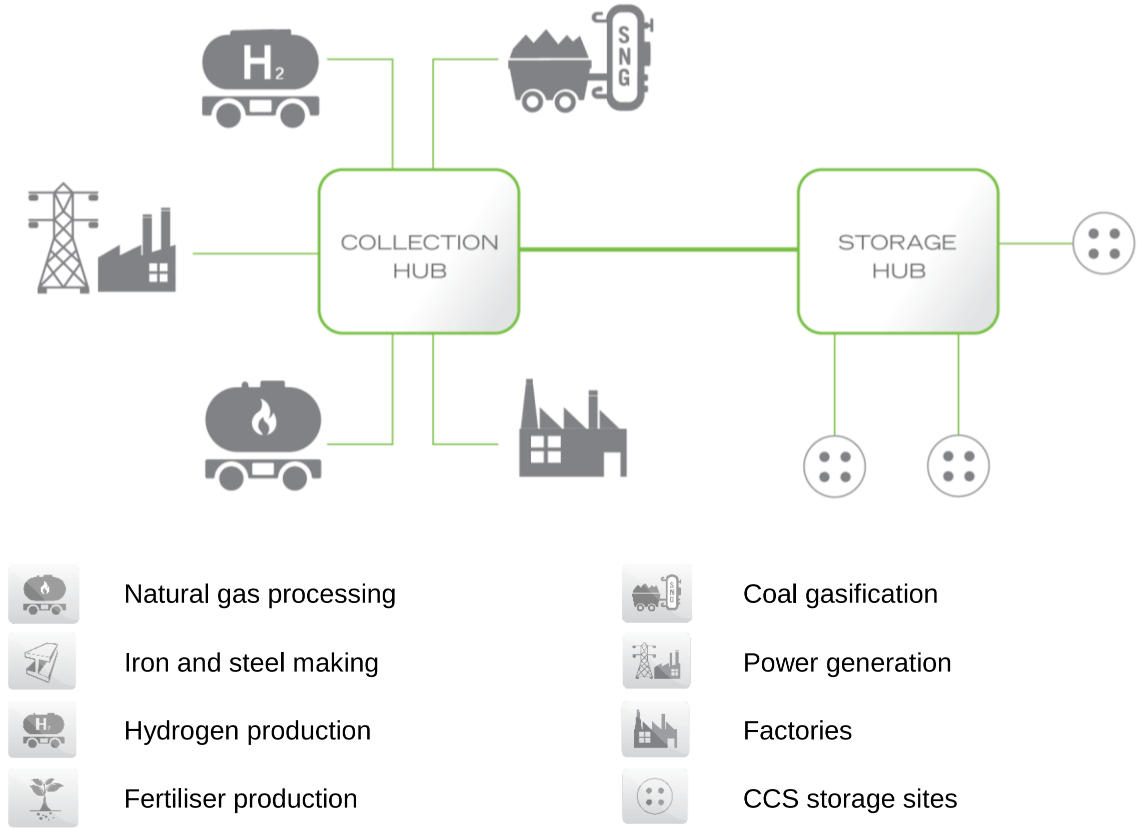
[1] (IEAGHG, 2015a)

Hubs

CCS hubs are the central collection or distribution points for CO_2. One hub would service the collection of CO_2 from a capture cluster or distribution of CO_2 to a storage cluster (Figure 2).

Hubs could be located at the capture end or the storage end of a multi-user pipeline (forming capture/collection or storage hubs), or both.

Figure 2 A CO_2 transport network, showing a capture cluster, capture/collection hub and storage hub



Collection hubs will form a connective element among a constellation of capture sources – giving rise to the term 'cluster'. Volumes of captured CO_2 will vary considerably depending on each individual emissions source within the cluster. Collection and storage hubs provide point-to-point transportation for compressed CO_2, thereby reducing the cost of transport infrastructure between the individual point-source emitters and individual points of injection into geological storage.

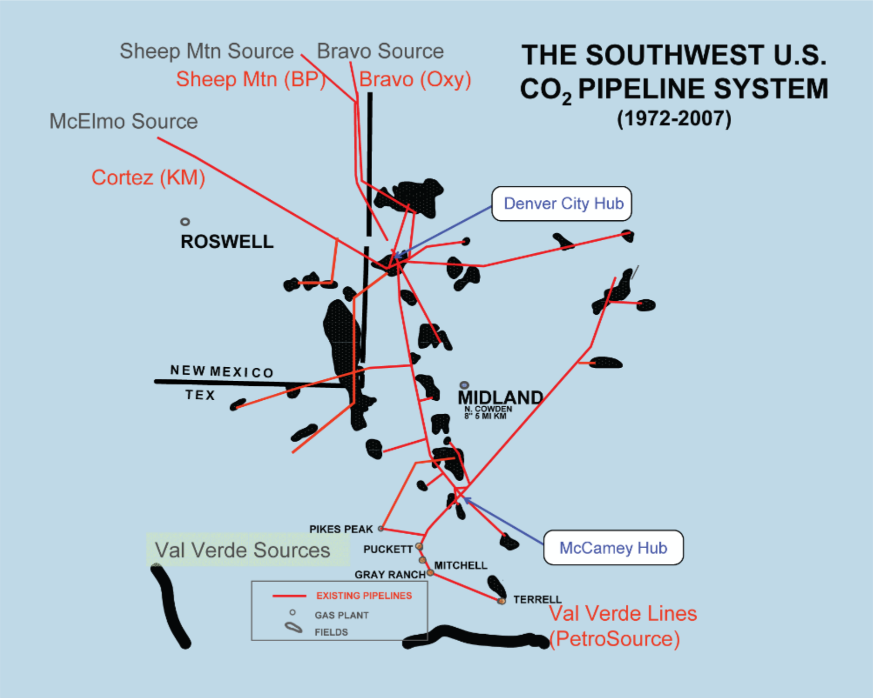
Hubs are very common in the natural gas distribution industry, where pipeline networks interconnect in order to bring together gas from many different production fields, or to distribute gas to dispersed markets.

In North America, for example, there are natural gas hubs that provide interconnections with up to 16 major pipelines,[2] and natural gas hubs are also widespread in Europe.[3]

[2] (Tobin, 2003)
[3] (Heather, 2015)

There are also existing hubs in the CO_2 pipeline distribution industry, most notably the Denver City and McCamey Hubs in Texas, US (Figure 3).[4] Much of the CO_2 transported through the US pipeline system is used in enhanced oil recovery (EOR) operations.

Figure 3 Hubs on the existing southwest US CO_2 pipeline system



Adapted from Melzer 2007.

Hub and Cluster Networks

A CCS hub and cluster network brings together many of the elements along the CCS value chain (CO_2 source, capture, transport, injection, storage) with multiple co-located (clustered) source capture facilities (of the same or different types) supplying CO_2 to a shared 'oversized' transport and storage system. As the network of emitters supplying CO_2 grows, the transport and storage infrastructure may increase to multiple transport pipelines, injection facilities, and storage formations (depending on local geological characteristics).

Multiple sources of CO_2 in a tight geographical location make planning infrastructure easier and less costly. Areas where there is both a high concentration of CO_2 emitting industries and a nearby capacity to store emissions are considered prime sites for hub and cluster developments.

Anchor Projects

An anchor project is a large emitter, usually in a single location, which provides a significant proportion of the CO_2 in a cluster of CO_2 capture projects. In practical terms, it would usually be a single large project that kick-starts the building of transport and storage infrastructure, and which would normally bear the fixed costs of the initial infrastructure, allowing cost effective deployment of CCS based on incremental capital and operational expenditure. The anchor project could be any source of CO_2 (power or industrial), so long as it can deal with the initial infrastructure cost, and is not commercially disadvantaged by the lower cost of deploying the second or subsequent load.

[4] (Melzer, 2007)

The cost efficiency of the infrastructure developed to service an anchor project can allow additional industrial CCS projects to be deployed. Without the anchor project, these projects may have difficulty passing the initial investment hurdles. With the appropriate commercial arrangements in place for the anchor load and infrastructure, later 'follow-on' projects only need raise investment to cover capture (if required) and the incremental capital and operational costs associated with connecting themselves to the network.

3 Strategic significance of CCS hubs and clusters

CCS clusters with their associated hubs are essential to secure the future of emissions intensive industries and encourage future investments in these economically important sectors. This will be especially important as CO_2 emission rights become increasingly constrained through mechanisms such as climate protection policies or the introduction of a price on carbon emissions.

Hub and cluster networks offer several distinct advantages for network participants, compared with single source to single sink projects. The hub and cluster approach reduces costs and risks for many potential CCS projects, removing the interdependency between the size of individual emitters, their investment decision, and the scale of the related storage/transport development.

The following section highlights five of the key benefits CCS hubs and clusters can provide, when tackling the challenge of reducing CO_2 emissions from industrial processes.

Reducing cost through the use of shared infrastructure

Industrial CCS clusters create an opportunity to reduce cost by allowing multiple parties to share expensive infrastructure. Strategically sized infrastructure built with additional or initially spare capacity allows the investment decision to be de-riske d for the emitter, creating space for more attractive capital structures and funding sources.

Shared infrastructure with sufficient, proved storage capacity also allows emitters to separate their investment decisions (in terms of both time and technology) from the development of the network. This is important to maximise deployment and exploitation of CCS and its benefits at scale.

The IEAGHG has concluded that development of cluster structures offers the potential for cost reduction through sharing of infrastructure and organisational costs with potentially significant additional value being generated from the confidence this gives multiple emissions sources of CO_2 to plan and implement CO_2 capture.[5]

Developing coordinated investment in shared CO_2 infrastructure will facilitate efficient commercial-scale demonstration and rapid deployment of CCS. Shared pipeline and/or shipping facilities capable of transporting CO_2 agglomerated from multiple capture sources to geological storage would be cost effective and are critical to realising the full value of initial CCS projects.

> The United Kingdom (UK) CCS Cost Reduction Task Force[1] found that CO_2 transport costs could be reduced by 50 per cent with the deployment of large, well-used pipelines, noting that even lower costs could be seen in the longer-run if even higher volumes of CO_2 from multiple large capture plants were feeding into an interconnected right-sized network.

[5] (IEAGHG, 2015a)

Enabling the capture of small volume sources

Many industrial processes, such as refining, gas processing, hydrogen and fertiliser production, separate CO_2 as part of their normal operations. Consequently, many facilities are currently venting relatively pure streams of CO_2 directly into the atmosphere. These sources can potentially be captured at low cost, and without additional investment in CO_2 capture equipment. However, compared to the typical emissions from a fossil fuel power station, volumes of emissions from industrial processes can be small, and it is often uneconomic to develop full-scale 'point-to-point' projects at this scale.

These processes offer positive opportunities for early CCS projects. As the Global Status of CCS: 2013 report noted:

'…the initial demand for additional CO2 transportation capacity is likely to occur in an incremental and geographically dispersed manner as new dedicated capture plants, storage, and EOR facilities are brought online. The incentives for CCS projects to be developed as part of a cluster, hub, or network linking proximate CO2 sources, through a hub, to clusters of sinks, either by ship or so-called 'back bone' pipelines - include economies of scale'.[6]

It is important to recognise that the multitude of smaller industrial facilities around the world contribute significant cumulative CO_2 emissions that are unavoidable as long as the facilities continue to operate.

Development of large-scale and strategically located infrastructure solutions will enable the lower cost and full-scale deployment of CCS in industrial clusters, reducing cost and risk to industrial and power emitters.

Reducing commercial risk for storage

The strategic investment decisions that governments and industry face for developing transport and storage infrastructure are complex due to a large number of uncertainties. Considerable investment and lead time may be necessary before a storage site can be characterised as 'bankable'. The appraisal of a deep geological storage site will typically take six to ten years of work ahead of any market demand.[7] In the early phases of CCS project development, storage availability is likely to be the most uncertain element, and may require significant allocation of resources.

In a typical point-to-point project, focused on the emissions of a single emitter and the time horizon of one industrial facility, a project developer would search for a right-sized storage site to appraise, only required to be capable of storing a known volume of CO_2. Important decision criteria for site selection would include: lowest overall cost; appropriate storage capacity; technical aspects of the storage site; credit risk of the emitter; and required upfront capital.

However, going directly (potentially solely) to such a storage site, assessed as 'best' and right-sized for a single project with dedicated pipeline, may not be the optimum strategy in order to store large volumes of CO_2 over the long term from multiple emitters. When the store reaches capacity, if no other adequate storage sites are located nearby, it would require developing another full stand-alone transport and storage infrastructure which could be costly and risky. For this reason there are distinct advantages to developing storage hubs and clusters, especially when considering that the scale of CCS deployment needed in the coming decades will require much larger volumes of future CO_2 storage. This implies additional criteria in the initial site selection process, including scoping of multiple potential storage sites in reasonable proximity to each other.

As the development of storage and transport infrastructure progresses, storage availability as a technical risk becomes increasingly more manageable by the storage developer, but at this stage commercial risks relating to CO_2 supply become important. In a traditional 'point-to-point'

[6] (Global CCS Institute, 2013)
[7] (Zero Emissions Platform, 2014)

development, all of the good work and investment of the storage developer can be undone by a partner emitter being unable to take a positive final investment decision or subsequently terminating capture operations. This CO_2 supply risk can be reduced if a storage provider is able to develop a portfolio of interlinked emitters that would ensure a continued supply regardless of the fate of individual industrial emitters.

By building in redundancy of supply, the development of a capture cluster linking a portfolio of emitters reduces risks related to the supply of CO_2 to a storage developer (or EOR customer) and allows the delinking of final investment decisions along the CCS chain.

Enabling CCS in regions without access to suitable local storage

Provision of independent CO_2 transport and storage capacity would encourage and accelerate interest and investment in CCS from other emitters. Subsequently, storage developments could receive CO_2 from other regional capture clusters which lack access to suitable CO_2 storage.

Enabling low carbon industrial production

In its 2014 study: *The economic benefits of carbon capture and storage in the UK*, the Trade Union Congress noted the role CCS could play in retaining existing industries and jobs.[8] The study notes that:

'…any of these sectors are facing difficult decisions regarding their continued existence in a carbon-constrained world, and without the development of supportive policies many of these industries are likely to close down in the UK and relocate to other countries', and concludes that 'the deployment of CCS in these industries is therefore vital to ensure the long-term continued existence of these important industries in the UK, safeguarding a significant number of jobs and generating value to the UK economy'.

While focused on the UK, these findings are equally applicable to many other countries.

In many industries, such as steel, cement and chemicals, CCS is the only available technology capable of breaking the link between production and emissions of greenhouse gases. Facilities able to 'plug in' their facilities to a CCS hub and cluster arrangement could effectively protect themselves and their investments against potential high future carbon prices, while regions which use CCS to establish themselves as 'low carbon industrial zones' could see significant advantages in the race to attract and maintain investment.

It is important to note that one of the key differences between industrial and power CCS is the need to maintain international market competitiveness, if 'carbon leakage' to other regions or countries is to be avoided. The products of the industrial sector can have a high exposure to global competition, making them highly sensitive to relative production costs. This aspect highlights a key area of interaction between climate policy and industrial policy.

In an increasingly carbon constrained world, the development of capture clusters will serve as a magnet to inward investment, increasing industry engagement and encouraging the development of further projects in each location, thereby accelerating the development of a broader CCS industry.

[8] (TUC, 2014)

4 Imperatives to enable development of CCS hub and cluster networks

Hub and cluster developments are a potential solution to accelerate CCS momentum in the coming years, make best use of existing infrastructure and strategically build new supporting infrastructure to drive down the costs of large-scale CCS deployment. However, like all CCS developments, their successful deployment will rely on a number of factors, especially those of a policy nature, to deliver a workable financial incentive to allow an acceptable business case.

Policy to create a financial incentive

Carbon prices, where they exist, are not currently sufficient to support the widespread deployment of CCS technology. In this early phase of CCS development, supportive public policy is essential to drive demonstration and deployment in both the industrial and power sectors.
Policy support for the proactive development of strategic CO_2 transport and storage infrastructure solutions is important to enable the low cost and full-scale deployment of CCS in industrial clusters. This support should also link to existing and future opportunities for cross-border cooperation.

While incentives for CCS in the power sector have been widely considered, this is not the case in industry. This needs urgent attention by policy makers, particularly since much of the CO_2 emissions in the industrial sector are a result of physical or chemical systems inherent to the manufacturing process. Such emissions cannot easily be reduced, if at all, and mean that fuel switching either has no effect on emissions or is not possible.

Investment in infrastructure

The IEAGHG review[9] of CCS hubs and clusters observed that while clustering will reduce costs, without government support these savings are currently insufficient to fill the cost-revenue gap. However, there is potentially large value in (shared) pre-investment in pipelines and storage in order to generate the confidence needed for investment decisions on capture facilities. This suggests a possible role for government in facilitating such pre-investment, which otherwise may not occur due to the dispersed nature of the benefits. The report also observed that the main risks for clusters are of a commercial rather than a technical nature. This is not to suggest a lack of technical challenges in hub and cluster development. Such technical challenges, however, have already been successfully addressed in North American CO_2 hubs and clusters, and also in the natural gas industry.

Provision of independent CO_2 transport and storage capacity as strategic infrastructure will encourage and accelerate interest and investment in CCS from other emitters. It will also be important to ensure that any future regional funding and support mechanisms recognise and are applicable to industrial as well as full chain power generation CCS projects.

Legal and regulatory issues

The Global CCS Institute's annual survey of projects has consistently highlighted a number of legal and regulatory issues that need to be fully addressed in order to facilitate CCS development. Several of these have particular relevance for hub and cluster developments, including:

[9] (IEAGHG, 2015a)

- The lack of CCS-specific laws or existing laws which are applicable across most parts of the CCS project cycle in many countries.
- A range of issues associated with financial security and longer-term liabilities for storage operations.
- Standards to account for cross-border movement of CO_2.

This latter point is especially important for regions such as Europe, where many countries with large point-source emitters lack domestic storage assets and would need to transport captured CO_2 across borders, for example to the North Sea. This also raises an important international regulatory aspect.

The London Protocol is a global marine treaty regulating the disposal of wastes and other matter at sea. The protocol was amended in 2009 to enable transboundary CCS activity, including to allow for the export of CO_2, subject to a number of conditions. The amendment needs 30 countries to ratify it in order to come into force. As of October 2015, only three countries had ratified the amendment to the convention, while a further four had ratification underway[10]. As a result, the transboundary shipment of CO_2 for offshore geological storage remains effectively prohibited.

Public engagement

Any industrial development must be pursued sensitively. Global research and project experience highlights that public perceptions and levels of public engagement with a project are a key non-technical risk factor for any CCS development. Hub and cluster developments are generally focused on highly industrialised areas, where pipeline corridors and industrial infrastructure form a familiar part of the landscape.

Well-planned, successful engagement within a CCS capture (and storage) cluster region has the potential to change the nature of discussions with stakeholders and local communities. CCS offers a technological solution to dramatically improve the sustainability of many of these highly industrialised areas – improving the environment, preserving employment and encouraging future inward investment.

Considerations for CCS project planning:

Building a shared pipeline increases the complexity and coordination required, and hence possibly the timeline required, versus a point-to-point project (if you want to go fast, go alone).

Often the longest period of time required in a CCS project is that necessary to (a) assess the storage field and (b) clear the transportation hurdles (for example, negotiating with property owners for rights of way).

While the cost of transport can be dramatically reduced by using a hub/cluster approach, 80 per cent of the cost of CCS (as currently deployed) remains with the capture element of it.

5 Conclusions & Recommendations

The development of CCS hubs and clusters, bringing together a number of different CO_2 emitters and/or different storage sites in an interlinked network, offers participants several advantages over ‘point-to-point’ CCS developments. Benefits include reduced costs, reduced risk, enabling more cost-effective capture from small volume sources, and maintaining investment and jobs in high-emitting industrial regions.

[10] (IEAGHG, 2015b)

Actions that should be considered by project proponents and governments in order to facilitate the development of CCS hub and cluster networks include:

- Policy support for the proactive development of strategic CO_2 transport and storage infrastructure solutions.
- Provision of incentives for the development of CCS in industrial sectors where opportunities for reducing CO_2 emissions is limited.
- Pre-investment in independent CO_2 transport and storage capacity as strategic infrastructure to encourage and accelerate interest and investment in CCS from other emitters.
- Examination of legal and regulatory barriers to development of CCS, including ratification of the London Protocol.
- Well-planned, early engagement with stakeholders and the community within a cluster region, recognising that such regions are often already highly industrialised.
- Scoping of multiple potential storage sites for projects where suitable conditions exist, rather than a focus on a single site.

A number of industrial regions have examined the potential to develop CCS hubs and clusters. At present, in most cases the incentives do not exist to enable such developments to proceed. Securing delivery of these initiatives is vital to decarbonising industrial processes and products while supporting the development of low-carbon industries based on existing skills. Urgent attention should be given to the development and widespread deployment of CCS hubs and clusters in high-emitting industrial regions around the world.

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7 Abbreviations and acronyms

CCS	carbon capture and storage
CO_2	carbon dioxide
EOR	enhanced oil recovery
GHG	greenhouse gas
IEA	International Energy Agency
IEAGHG	IEA Greenhouse Gas R&D Programme
Mt	million tonne/s
Mta	million tonnes a year
SCSS	Scottish Carbon Capture & Storage
TUC	Trade Union Congress
UK	United Kingdom