REVIEW OF GHG ACCOUNTING RULES FOR CCS

Report: 2016/TR3

May 2016

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. The IEA fosters co-operation amongst its 28 member countries and the European Commission, and with the other countries, in order to increase energy security by improved efficiency of energy use, development of alternative energy sources and research, development and demonstration on matters of energy supply and use. This is achieved through a series of collaborative activities, organised under more than 40 Implementing Agreements. These agreements cover more than 200 individual items of research, development and demonstration. IEAGHG is one of these Implementing Agreements.

DISCLAIMER

COPYRIGHT

ACKNOWLEDGEMENTS AND CITATIONS

This report describes research commissioned by IEAGHG. This report was prepared by:

- Carbon Counts Company (UK) Ltd

The principal researchers were:

- Greg Cook
- Paul Zakkour

To ensure the quality and technical integrity of the research undertaken by IEAGHG each study is managed by an appointed IEAGHG manager.

The IEAGHG manager for this report was:

Tim Dixon

Acknowledgements are given to Anhar Karimjee of US DOE for input on US aspects.

The report should be cited in literature as follows:

'IEAGHG, "Review of GHG Accounting Rules for CCS", 2016/TR3, May 2016.'

Further information or copies of the report can be obtained by contacting IEAGHG at:

IEAGHG, Pure Offices, Cheltenham Office Park,
Hatherley Lane, Cheltenham,
GLOS., GL51 6SH, UK
Tel: +44(0) 1242 802911
E-mail: mail@ieaghg.org
Internet: www.ieaghg.org

IEA Greenhouse Gas R&D Programme

Review of GHG accounting rules for CCS

(IEA/CON/16/239)

FINAL REPORT

Carbon Counts Company (UK) Ltd

27 May 2016

Prepared by:
Greg Cook and Paul Zakkour
Our Ref: 076

CONTENTS

ACRONYMS AND ABBREVIATIONS

1996 GLs	Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories
2006 GLs	2006 IPCC Guidelines for National Greenhouse Gas Inventories
AAU	Assigned Amount Unit (the trading and compliance unit of the Kyoto Protocol, equal to 1 tCO_2e)
AB32	California Global Warming Solutions Act, 2006
ACR	American Carbon Registry
AM	Approved methodology (for the CDM)
API	American Petroleum Compendium
A/R	Afforestation and reforestation
Bio-CCS	Biomass energy with carbon capture and storage
CAR	Climate Action Reserve
CARB	California Air Resources Board
CCS	Carbon dioxide capture and storage
CCS M&Ps	Modalities and procedures for CCS in the CDM
CCU	Carbon dioxide capture and utilisation
CDM	Clean Development Mechanism
CDM M&Ps	Modalities and procedures for the CDM
CER	Certified Emission Reduction (units issued under CDM, equal to 1 tCO_2-equivalent)
CEM	Continuous emissions monitoring
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent (based on global warming potentials of non-CO_2 GHGs)
COP	Conference of the Parties
CRF	Common reporting format (for national GHG inventories)
C-stock	Carbon stock
EHR	Enhanced hydrocarbon recovery
EOR	Enhanced oil recovery
EPA	US Environmental Protection Agency
EPA	Environmental Protection Agency (US)
ERU	Emission Reduction Unit (trading unit under JI, equal to 1 tCO_2e)
ETS	Emission trading scheme
EU	European Union
EU ETS	European Union GHG Emissions Trading Scheme
EU MRR	EU ETS Monitoring and Reporting Regulation (No. 601/2012)
EUA	European Union Allowance (the trading unit of the EU ETS, equal to 1 tCO_2e)
FQD	EU Fuel Quality Directive (2009/30/EC)
GHG	Greenhouse Gas
GHGRP	Mandatory Greenhouse Gas Reporting Program (US Regulation 40 CFR 98)
IGCC	Integrated gasification combined cycle
iLUC	Indirect land use change (changes in use of other land as a consequence of bioenergy production, principally displacement effects)
iNDC	Intended nationally determined contribution
IPCC	Intergovernmental Panel on Climate Change

ISO	International Organization for Standardization
JI	Joint implementation (under the Kyoto Protocol)
LULUCF	Land use, land use change, and forestry
LNG	Liquefied natural gas
MRV	Monitoring, reporting and verification
MWh	Megawatt-hour
NDC	Nationally determined contribution
NG	Natural gas
NGER	National Greenhouse and Energy Reporting Act
PDD	Project design document (under the CDM)
PF-SC	Pulverised fuel-supercritical
QELRO	Quantified emission limitation and reduction obligation
RED	EU Renewable Energy Directive (2009/28/EC)
t	Metric tonne
UIC	Underground injection control
UNFCCC	UN Framework Convention on Climate Change
USA	United States of America
USC	Ultra-supercritical

PREFACE

This report was prepared by *Carbon Counts Company (UK) Ltd* ("Carbon Counts") under contract to the IEA Greenhouse Gas R&D Programme ("IEAGHG"). The lead authors were Greg Cook and Paul Zakkour.

The project team would like to thank Tim Dixon of the IEAGHG for his oversight and inputs during the development of the report.

EXECUTIVE SUMMARY

A range of greenhouse gas (GHG) monitoring and accounting protocols and guidelines currently exist for carbon capture and storage (CCS) activities, and various activities continue in this area. Such guidelines exist at the project-, entity-, state-, country- and international-level. In addition, work is ongoing with efforts to develop common accounting approaches, such as the ISO standard under development by TC265. Furthermore, discussions are ongoing at the international level regarding the development of appropriate monitoring, reporting and verification (MRV) rules in respect of carbon crediting mechanisms which may emerge following the Paris Agreement reached at the 21st Conference of Parties (COP21) to the UN Framework Convention on Climate Change (UNFCCC). These will have important implications for the treatment of CCS as a key mitigation technology over coming years.

In these contexts, this report aims to provide a comparative review of how current GHG accounting rules apply to CCS activities worldwide. These include international, regional and national approaches employed under policies and measures such as mandatory GHG emissions reporting, carbon taxes and emission trading schemes (ETS). Based on the review, the report identifies issues, gaps and potential barriers emerging from the review and possible measures that could be taken to support CCS deployment.

The report identifies several specific issues for CCS and CCU (carbon capture and utilisation) in respect of GHG accounting and MRV rules. Firstly, three key requirements are found to be fundamental to all CCS projects:

1. **Recognising captured CO_2 for storage as "not emitted"**. MRV rules need to allow for captured CO_2 to be deducted from the relevant inventory (e.g. sector; installation).
2. **Including transport and storage within the scheme accounting rules**. MRV rules need to be developed also for monitoring of transport and storage, and these need to dovetail across the project chain.
3. **A mechanism to address permanence**. Appropriate accounting and MRV rules must provide assurances that the injected CO_2 remains in the intended geological formation and isolated from the atmosphere over the long-term, and quantify any leaks that occur.

Secondly, some specific considerations arise for the following 'special cases':

1. **Recognition of negative emissions from bio-CCS**. GHG accounting schemes and associated MRV rules need to adequately evaluate, attribute and reward any *negative emissions* associated with bio-CCS activities.
2. **Accounting for CO_2-EOR**. The potential 'leakage' of emissions outside a scheme boundary associated with incremental oil production can be addressed through suitable MRV rules, taking into account the relevant accounting framework.
3. **Accounting for CO_2 utilisation**. The different mitigation pathways associated with CO_2 utilisation technologies must be evaluated and suitable MRV rules developed if they are to be recognised and supported within GHG accounting schemes.

The review of GHG accounting and MRV rules in place worldwide finds that the three key 'fundamental' requirements are addressed within existing rules. All of the schemes reviewed

allow for recognising captured CO_2 to be recognised as "not emitted". In nearly all cases, this is dependent upon monitoring of CO_2 storage sites to provide assurances over the *permanence* of emission reductions achieved through CCS. Similarly, all of the schemes reviewed allow for inclusion of transport and storage within the scheme accounting rules, thereby allowing for attribution of emissions and reduction across the CCS or CCU project chain. *Permanence* is addressed within different GHG accounting rules in place worldwide primarily through the use of risk-based management approaches. At the international level, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 GLs) sets detailed, site-specific monitoring requirements for injection and storage, including aspects such as site characterisation, non-permanence risk assessment, and quantification of any leaks, relying on detailed monitoring of the sites to allow countries to continue reporting the stored CO_2 as not emitted in their national inventory. This approach is mirrored in regional cap-and-trade and GHG reporting schemes and associated GHG accounting rules. The Modalities and Procedures (M&Ps) for CCS in the CDM set out a risk-based approach to managing permanence, following similar lines to that under the 2006 GLs and as employed in the EU, US and Australia.

The review therefore finds that existing GHG accounting rules are broadly able to account for emissions and emissions reductions associated with 'standard' CCS projects. Some specific gaps, challenges and issues arise however when considering 'special cases' for CCS and CCU projects, as well as potential approaches to addressing them.

1 INTRODUCTION

1.1 Purpose of this report

A range of greenhouse gas (GHG) monitoring and accounting protocols and guidelines currently exist for carbon capture and storage (CCS) activities, and various activities continue in this area. Such guidelines exist at the project-, entity-, state-, country- and international-level. In addition, work is ongoing with efforts to develop common accounting approaches, such as the ISO standard under development by TC265 which builds upon earlier work such as the *Greenhouse Gas Accounting Framework for Carbon Capture and Storage Projects* (C2ES, 2012) and other publications. Furthermore, discussions are ongoing at the international level regarding the development of appropriate monitoring, reporting and verification (MRV) rules in respect of carbon crediting mechanisms which may emerge following the Paris Agreement reached at the 21st Conference of Parties (COP21) to the UN Framework Convention on Climate Change (UNFCCC). These will have important implications for the treatment of CCS as a key mitigation technology over coming years.

In these contexts, this report aims to provide a comparative review of how current rules for compiling and reporting inventories of GHG emissions and removals, and for MRV of GHG emissions and removals (hereafter collectively termed "GHG accounting rules") apply to CCS activities worldwide. These include international, regional and national approaches employed under policies and measures such as mandatory GHG emissions reporting, carbon taxes and emission trading schemes (ETS). The report will identify any significant differences between accounting protocols for CCS, the reasons for differences, and any issues that might arise from their differences. It will identify issues, gaps and potential barriers emerging from the review and possible measures that could be taken to support CCS deployment.

1.2 Report structure

The report is structured as follows:

- **Chapter 2** summarises the key principles of GHG accounting and describes the range of issues and factors relevant to GHG accounting, and how they apply to CCS;
- **Chapter 3** presents an assessment of what accounting rules need to contain to support CCS, and a comparative analysis is made of how these issues and factors are addressed across different GHG accounting/MRV rules worldwide; and
- **Chapter 4** sets out the main conclusions from the study and identifies potential gaps and areas of inconsistency between different GHG accounting/MRV rules.

2 GHG ACCOUNTING AND CCS

Emissions accounting is a term that refers to rules and methodologies employed to compile a GHG emissions inventory for a fixed period of time, typically one calendar year.

Various approaches to emissions accounting can be adopted. Generally, *production-based accounting* approaches are used in climate change policy, where the anthropogenic emissions of GHGs are estimated for e.g. a country, based on the amount of GHG emissions produced within e.g. its national borders, irrespective of exports and imports. Alternatives include *consumption-based accounting*, where a GHG inventory is compiled based on the emissions embedded in products consumed within e.g. a national economy, including imports and exports, or hybridised approaches involving *life-cycle emission accounting*, where the full range of emissions associated with a product or activity are estimated, including manufacture, transport, construction and end-of-life.[1]

In addition, GHG accounting can also involve estimating the removal of GHGs from the atmosphere by sinks. This is typically accomplished on the basis of measuring annual stock changes in the carbon stored in various pools on managed lands (i.e. altered by human activities), such as agricultural land, forestry and wetlands.

The focus of this report is on production-based emissions accounting as generally applied in GHG policy frameworks.

2.1 Purpose of emissions accounting

GHG emissions accounting and the resultant GHG emissions inventories can be developed for a wide range of purposes and at different scales, including:

- global scale (total world GHG emissions, covering sources of anthropogenic GHG emissions to atmosphere and removals by GHG sinks)
- a country (a national GHG inventory of sources and removals by sinks)
- a sector (e.g. power, iron & steel, cement, transport, managed forestry, agriculture)
- an installation or facility (e.g. a factory or power plant)
- a corporation or organisation (a corporate GHG inventory. These may cover multiple installations, sectors and countries)
- a policy (e.g. domestic energy efficiency labelling; targets for low carbon power generation)
- a programme (e.g. roll-out of solar water heater or efficient cooking stoves)
- a project (e.g. related to a specific infrastructural development or GHG mitigation activity)
- a product (e.g. product life-cycle emissions accounting for e.g. a food item or as applied in e.g. low carbon fuel standards)

[1] Life-cycle emissions accounting is usually used to generate, *ex ante*, an estimate of the GHG emission impacts of a proposed scheme or project. It can form part of a projects regulatory approvals. It is also applied in product-based accounting, and may be used in some regulatory schemes on an *ex post* basis, such as low carbon fuel standards.

- an event of activity (e.g. a "carbon footprint" of a flight, rail or car journey, or all emissions associated with e.g. a conference)
- an individual (a personal "carbon footprint")

In each case, different approaches, tools and methods are typically used to take account of different features of the inventory being compiled, and a large and growing body of guidance exists which provide methods for their development.

As with any accounting framework, GHG accounting is underpinned by several important principles that provide assurances over the quality of the inventory being compiled. These include transparency, completeness, consistency, comparability and accuracy.[1] Furthermore, any scheme which provides incentives to reduce emissions, such as carbon credits or tax exemptions, also needs to ensure that the emission reductions rewarded are *real*, *measurable*, *verifiable*, *permanent, additional* and avoid *double-counting* i.e. not measuring the same emission reduction twice. This is essential to maintain the environmental integrity of the scheme by ensuring that the level of incentive given is commensurate with the true level of emission reductions made, and that different emission reduction technologies can be recognised on a common basis.

Within the context of climate change mitigation commitments or 'contributions', these principles and requirements are paramount – as they also determine the extent to which emissions reductions made by countries, and various actions to reduce emission by sub-national entities, are appropriately incentivised and accounted for (see Box 2.1).

There are several key elements to consider when designing a GHG accounting framework and preparing an emissions inventory:

- First, inherent to preparing an emissions inventory at a given scale is the need to draw *boundaries* around what is being counted i.e. delineating the area and defining the scope of the inventory;
- Second, as a consequence of boundary setting, there may be potential for emissions *leakage* to occur. *Leakage* relates to changes in GHG emissions that can occur as a result of a given project, policy, programme or activity, but occurring outside of its specific boundaries (note that this is distinct from physical leakage of CO_2 from a storage site, which for clarity is here referred to as *non-permanence*)
- Third, there is the possibility for stored CO_2 to leak back to the atmosphere at some future point in time, long after the emission reduction has occurred – this is a *permanence* problem.
- Fourth, a reference case or *baseline* is often employed against which achievements towards meeting a particular outcome can be measured;
- Lastly, there is a need for the *monitoring and reporting* of emissions in order to collect the data necessary for undertaking GHG accounting and compiling the emissions inventory (often just referred to as "MRV");

[1] Further information on these principles can be found in e.g. 2006 IPCC Guidelines, Volume 1, Chapter 1 (Section 1.4).

Each of these components is described further below, and the relevance for CCS is briefly discussed.

Box 2.1 Linking national inventories and national climate policies

National GHG inventories are generally compiled by countries as part of their obligations under the UN Framework Convention on Climate Change (UNFCCC). A GHG inventory is a record of all emissions of anthropogenic GHGs from various source sectors in the country, removals by carbon sinks, and changes in carbon stocks arising as a result of land use changes taking place in its territory. It is applied for a given calendar year. It is typically presented on a sectoral basis, compiled in accordance with guidelines established by the Intergovernmental Panel on Climate Change (IPCC).

For countries bound by emission limitation targets under the Kyoto Protocol, the annual national GHG inventory provides the basis for compliance with these targets. For countries now making emission reduction pledges in the form of Nationally Determined Contributions (NDCs), the national GHG inventory will be critical for the "MRV" of progress being made in pursuit of agreed contributions.

Where the burden of meeting reduction targets is inevitably passed on to various parts of the economy (corporations, individuals etc.) – for example through the application of policies such as emissions trading schemes like the EU ETS (where private sector participants are expected to make the reductions) – the GHG accounting rules (or "monitoring and reporting rules") for that scheme should be consistent with the international rules to ensure that the efforts made by participants can be recognised in the national GHG inventory, and therefore compliant with MRV rules under the UNFCCC.

For this reason, GHG accounting rules at a national and international level are closely linked; if the rules are not compatible, actions taken by private entities under national polices and measures cannot be recognised in the national GHG inventory. And conversely, if actions are recognised at the country level but not passed on to the private entities, the incentive or obligation to take action is not appropriately passed on. Consequently, governments need to be mindful of this requirement when designing policies for low carbon technology deployment.

2.2 Boundaries

When considering different scales of GHG accounting – be it country, organisation, installation or product – a critical aspect to consider is the inventory *scope* and *boundary*. The boundary determines the GHGs and emission sources and/or removals by sinks to be included within the inventory, which will vary according to the purpose, scope and rules under which the GHG inventory is going to be used. Typically, in scoping the boundaries a distinction can be made between:

- Direct emissions ("scope 1"), which are those arising from within the boundaries of a specific activity. This is the same as the production-based accounting method described previously; and,
- Indirect emissions ("scope 2" and "scope 3" emissions), which are those occurring outside of the boundary but potentially attributable to the activity (e.g. emissions from power generation associated with bought-in electricity). To an extent, this is more akin to consumption-based accounting.

Different boundaries will apply for different scales and different purposes of GHG accounting.

A country's national GHG inventory, for example, should include all emissions sources and removals occurring within its national territory i.e. be economy-wide covering all relevant sectors. In this case, distinctions between *direct* and *indirect* emission sources do not generally apply as all sources will be *direct emissions* as they will fall within the country's territory, and emissions associated with imported products are excluded for the purpose of production-based accounting. In the case of imported electricity, any associated emissions will be attributed to the country where the power was generated rather than used.

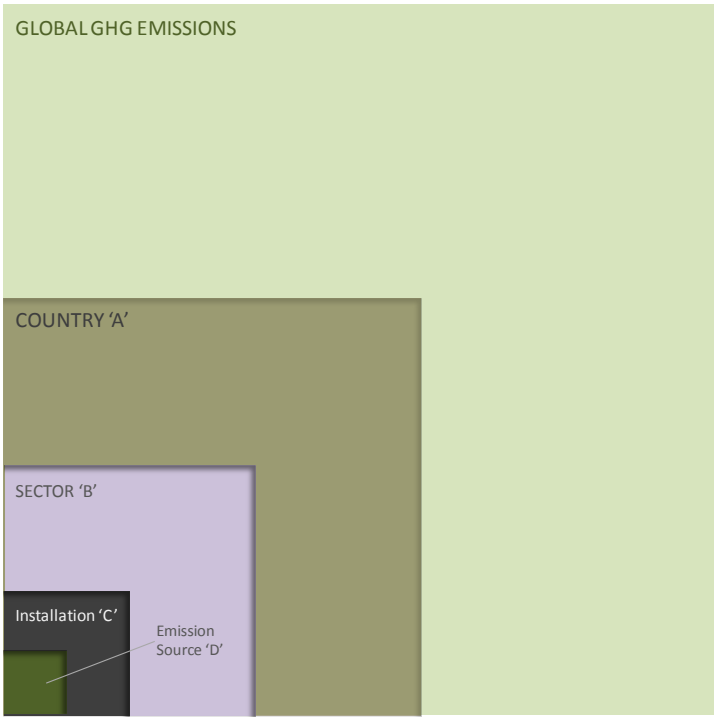
Other GHG accounting schemes, for example those used for emissions trading schemes (ETS), cover only sub-sectors of the economy, and the regulatory regime usually applies only to *direct emissions* from qualifying activities included in the scheme; *indirect emissions* (i.e. scopes 2 and/or 3) are generally not included.[1] Conversely, for project-based accounting, careful consideration of the boundaries is often necessary in order to accurately determine the net effects of implementing a specific project in one place and potential effects on emissions elsewhere. This is primarily because either: (i) the project-based scheme operates alongside other sectoral schemes, and there is a need to avoid double-counting; or (ii) it operates in a country with weak or no controls on GHG emissions, and therefore presents the risk of leakage (see below).

As such, whilst boundaries seek to impose defined borders or limits upon a GHG accounting approach, in reality certain interventions and circumstances may give rise to direct and indirect emissions effects (both positive and negative) which do not fully align with such definitions. These limitations notwithstanding, in principle at least, GHG accounting and inventory compilation undertaken across all levels (installation, project, product, corporate, national) should dovetail together to create a universally compatible and comparable approach, with global emissions corresponding to the sum of all emissions from all countries in the world, country emissions corresponding to the sum of all sector emissions in the country, each sector total being equal to the sum of all installations emissions, and so on. This relationship is depicted in the simple graphic below (Figure 2.1).

Data collected through monitoring can in theory, therefore, be used to fulfil various different objectives (e.g. installation GHG emissions inventory; national GHG inventory; corporate GHG emissions inventory). In reality, however, existing accounting approaches are not fully linked and aligned; data measurement coverage and quality may vary considerably whilst the existence of multiple boundaries developed for different purposes and at different levels may give rise to gaps and overlaps. The need for boundaries, from a regulatory perspective, inherently gives rise to an imperfect system.

[1] This is because they are inherently linked e.g. if an industrial facility that uses grid electricity were to account for indirect emissions, they would end up being double counted if power plants are also covered under the same scheme. Under the European Union's ETS, boundaries are defined by the operator, but must include all relevant GHG emissions from all sources belonging to qualifying activities carried out at the installation. Indirect emissions

Figure 2.1 Relationship between emissions accounting at varying scales



Source: Carbon Counts

2.2.1 CCS and accounting boundaries

In the case of CCS, GHG accounting boundaries can be an issue, primarily because of the nature of the technology: CCS differs from other low carbon technologies in that CO_2 formation is not eliminated, but rather its emission to atmosphere is avoided by injecting the CO_2 into geological reservoirs. As such, the technology involves a carbon "stock transfer" in which the CO_2 that would have been emitted to the atmospheric carbon pool is actually transferred to the geological carbon pool for an indefinite period of time. This creates accounting challenges, both geographically and temporally.

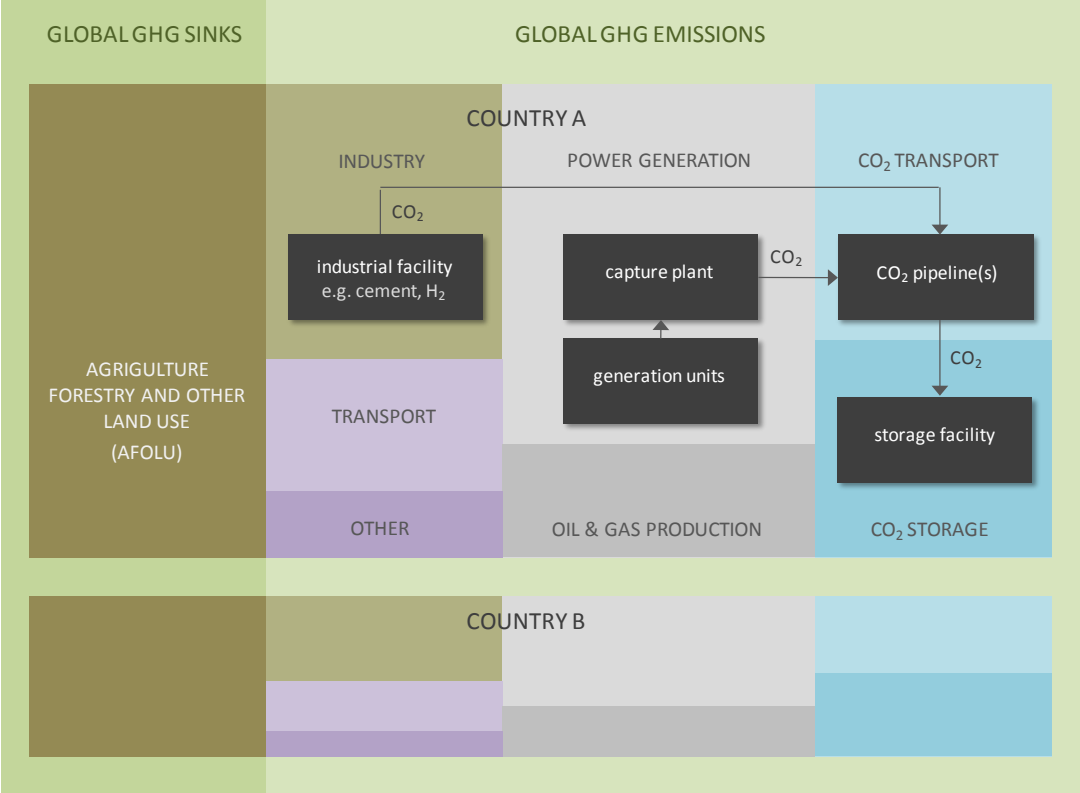
The capture, transport and storage of the CO_2 means that typically it will be transferred between different types of installations, operators and owners, and could potentially be emitted somewhere else outside of a scheme's accounting boundaries – this would affect the schemes environmental integrity, essentially a type of *leakage* problem. This includes the potential for the CO_2 to be transferred across sub-national and international borders. The nature of these movements in respect of the different scales of GHG emissions accounting is outlined graphically below (Figure 2.2). The diagram shows that in a fairly simple CCS project located in one country, the CO_2 is transferred across different sectors to its ultimate point of storage.

To address the issue, it is necessary to build a 'chain of custody'[1] for the CO_2 across the different sectors involved by including transport and storage as sectors/installations within GHG regulatory scheme, and establishing MRV rules applicable them (see Section 2.6.1). Under such

[1] This term emerged mainly in the context of the European Union CCS Directive; however, other terms are used in other jurisdictions worldwide referring to the need to ensure responsibility for CO_2 accounting across the entire project chain.

an approach, the scheme boundaries are extended to include these potential emission sources, an obligation created to measure any emissions that might occur.

Figure 2.2 Cross-sector relationship in CCS projects



Source: Carbon Counts

Other indirect and secondary effects can also create challenges, which can give rise to other types of *leakage* (see Section 2.3).

Temporal challenges arise as a result of the possibility for CO_2 to leak back to the atmosphere at some future point in time, long after the emission reduction has occurred and, for example, an incentive paid for avoiding emissions – this is a *permanence* problem (see Section 2.4).

2.3 Leakage

As most regulatory schemes controlling GHG emissions operate at either sub-national or at project levels, the MRV rules inevitably set boundaries regarding the emissions sources and activities that need to be measured and calculated when compiling the relevant GHG inventory. As such, there is the scope for some secondary effects to go unrecorded in the GHG inventory – as the emissions occur outside of the installation/activity boundary, but occur as a result of the activity. An example might be the effect of incentivising biomass through an ETS or carbon credit scheme, which may actually limit its availability to previous users leading them to use other more emission intensive sources of energy (e.g. kerosene) and/or lead to the conversion of previous unmanaged lands to managed forest lands for the intensive cultivation of biomass; these scenarios could lead to net changes in emissions outside of the boundary of the scheme under consideration. This compromises the environmental integrity of the scheme, an effect that is known as *leakage.*

It is important to note, however, that under a fully linked GHG regulatory system with comprehensive coverage and use of common and comparable methods, such leakage effects should not arise – as second order effects would be addressed elsewhere in the system and measured, and potentially regulated, accordingly. But since there is not an internationally-agreed set of rules for controlling GHG emissions from all sectors and removals by sinks, and the MRV framework is variable and patchily implemented, leakage can occur. It has been a particular concern for project-based schemes that take place in developing countries (e.g. under the CDM), because these jurisdictions typically have limited controls in place on GHG emissions across their economy, and therefore the scope for leakage to occur is high.

2.3.1 CCS and Leakage

In the case of CCS, there are several situations where leakage could occur. As mentioned before, the geographical and legal nature of CCS "chains" means that leakage could occur once the captured CO_2 is transferred out of the capture facility, as the transport and storage facilities not included within the installations boundary. This issue has largely been addressed, as described above (Section 2.2.1).

Furthermore, other types of leakage effects can arise from CCS projects, both positive and negative. This occurs for certain 'special' CCS project types that involve more than just capture of fossil fuel emissions and their storage in geological reservoirs (see Section 2.6.1).[1]

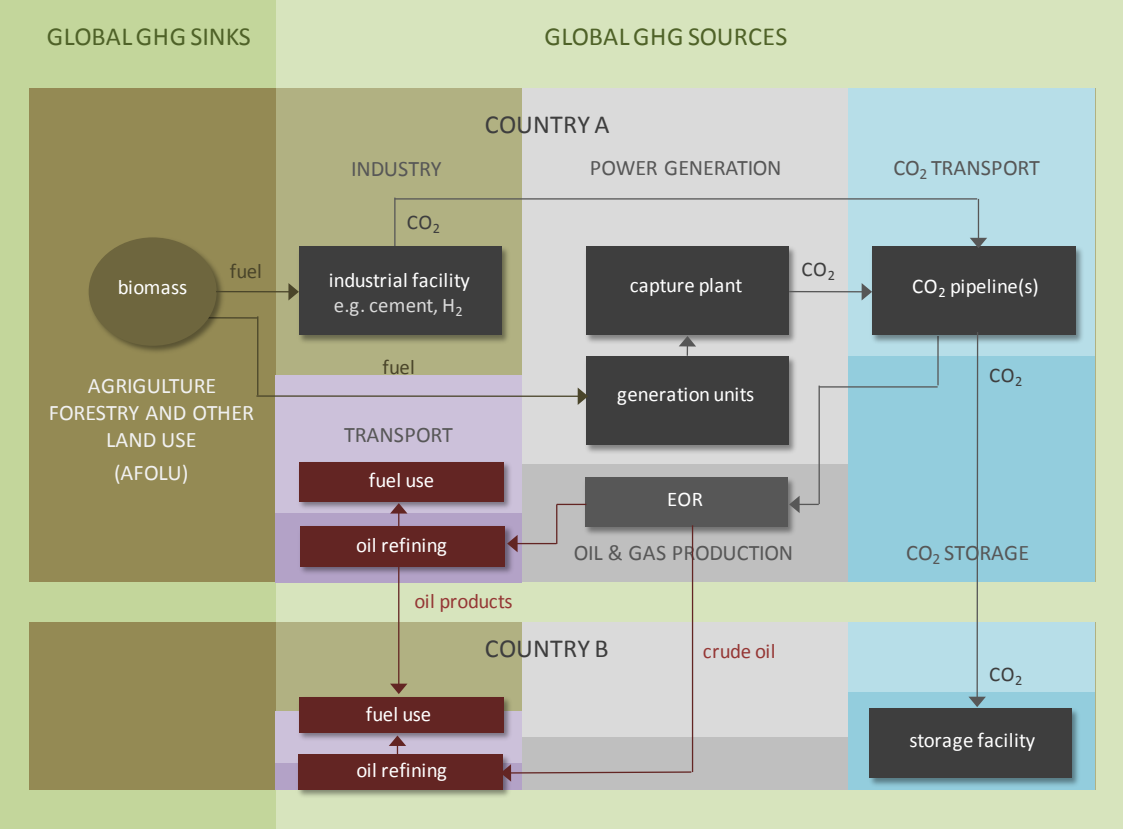
One such situation relates to the emissions arising from the combustion of fossil fuels incrementally produced through CO_2 enhanced hydrocarbon recovery (EHR). In such circumstances, production of fuels may be supported in part through the receipt of a GHG incentive payment for the amount of CO_2 stored. However, simultaneously the activity may be increasing fossil fuel supply and thereby driving further emissions outside of the activity boundary, which compromises the environmental integrity of scheme providing the rewards unless this effect is accounted for. This cross-sector effect is depicted graphically below (Figure 2.3). On the other hand, such circumstances could arguably equally drive negative leakage effects as the incrementally produced oil might substitute more emission intensive sources of oil. This is a complex issue to consider and has yet to be resolved in any GHG accounting scheme.

Negative leakage can also be considered to be occurring in the case where bioenergy production is combined with CCS. This is because the upstream effect of the atmospheric removal and sequestration of CO_2 in the biomass typically falls outside of the schemes boundary. As such, in the situation where a "double sequestration" effect occurs by, firstly, removing the CO_2 from the atmosphere during plant growth, and secondly, transferring that CO_2 to the geological carbon pool through CCS, only the latter typically gets accounted for in the scheme. This means the negative emission effect typically gets lost.

These 'special' CCS cases do create some particular challenges for MRV of CCS activities, as described further below (Section 2.6.1).

[1] Leakage is inherently a negative concept, as it derives from concerns over perverse outcomes of certain policy actions. Negative leakage is the opposite, involving circumstances where the net effect of the activity reduces overall emissions across all affected activities. For example, the negative emission effect of biomass energy with CCS could outweigh any indirect land use effects.

Figure 2.3 CCS and leakage (special cases)



Source: Carbon Counts

2.4 Permanence

A temporal disconnect between when an emission reduction takes place and the scope for it to be reversed at some point in the future poses a problem of *permanence*. The issue is generally confined to CO_2 removal sink enhancement activities, such as reforestation, where e.g. the trees could die, and CCS and CO_2 utilisation (CCU) activities where the formation of CO_2 still occurs although it is not emitted atmosphere – at least not straight away.

Non-permanence can negate at least part of the environmental benefits achieved by sink enhancements, CCS and CCU activities, compromising the effectiveness of policies and measures designed to incentivise them and undermine the environmental integrity of any emission reduction units awarded to a sink enhancement, CCS or CCU project under an emission trading scheme or CO_2 tax. For this reason, a key part of any GHG accounting rules applicable to CCS and CCU is the management of permanence risk (see below).

2.4.1 CCS and permanence

When CCS is applied as a climate mitigation technology concerns over permanence arise vis-à-vis the possibility that the injected CO_2 could leak from the subsurface back to the atmosphere at some future point in time. To address this matter, three essential elements have generally been employed in a regulatory approach which provides a framework to manage non-permanence risk:

1. To assure project integrity and to reduce the likelihood of impermanence arising, a range of upfront conditions on, *inter alia*, site selection and characterisation must be applied; this is because a key part of achieving permanent storage is the selection of a high quality geologically storage site in the first place;
2. Rules and regulatory oversight of storage site operation and closure is needed to ensure that it is effectively managed so as to reduce the risk of CO_2 leaks occurring due to poor practice. A key part of this oversight is the imposition of robust MRV requirements (see Section 2.6 below);
3. Short-, medium- and long-term responsibility for the stored CO_2 must be allocated, with the responsible party accepting liability to remediate any damage caused by seepage, including the replacement of an equivalent amount of units to any quantities of CO_2 determined to have occurred.

This combination of requirements can provide assurances that permanence may be achieved for many 100's if not 1000's of years. Such assurances serve to maintain the environmental integrity of polices and measures designed to support CCS and also for emissions trading schemes into which CCS-derived units are sold. A consequence is that inclusion of CCS within GHG accounting approaches is necessarily underpinned by regulatory approaches to control site development, operation and closure and to allocate liability across the project life-cycle.

Different approaches have been taken to manage non-permanence risk in CO_2 removal activities (Box 2.2.). These considerations add a further potential layer of complexity to bio-CCS activities.

Box 2.2 Permanence and land use measures

Carbon is stored in biological form in biomass and soils, such as in forests and grasslands, and can be enhanced through land use measures such as afforestation and/or reforestation.

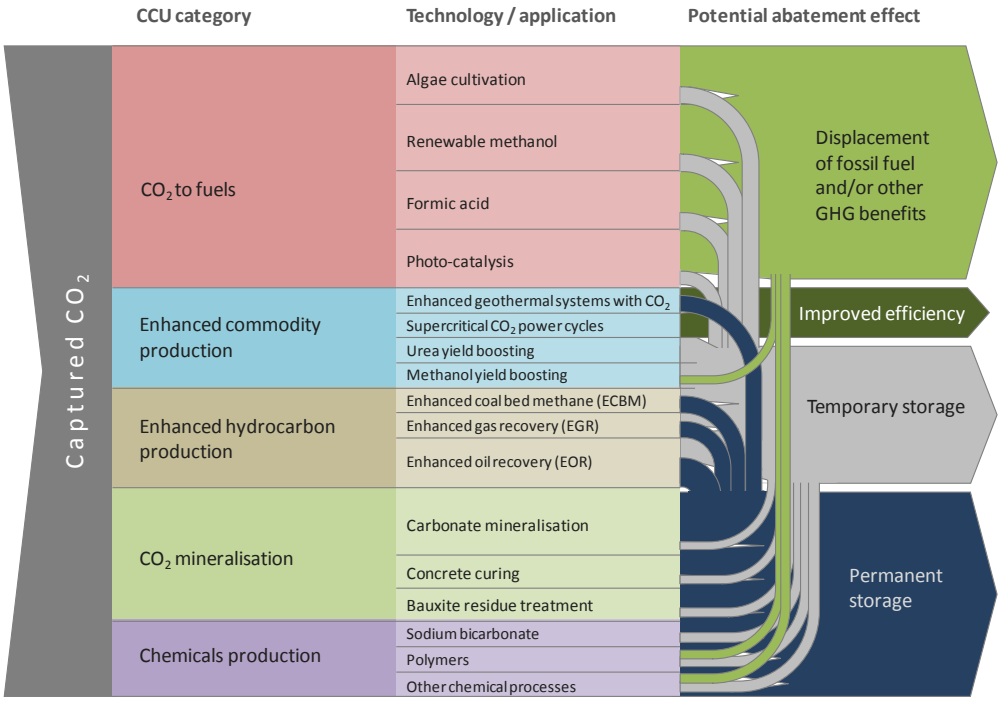
Concerns over permanence arise in this context because of the reversibility of such activities either through human activity, natural disturbances and/or climatic events and climate change. In order to address concerns over non-permanence, approaches such as temporary crediting have been applied to afforestation/reforestation (A/R) under the CDM, and the evolution of complex GHG reporting rules for the LULUCF (land use, land use change, and forestry) sector in national inventories.

Approaches using risk management frameworks (as applied for CCS) have generally not been favoured by policy-makers. Options include the use of forest management standards.

As well as non-permanence risks associated with geological storage, certain types of CO_2 utilisation activities can also lead concerns over non-permanence, because the CO_2 can often only be stored for a short period of time before being emitted elsewhere. The diagram below provides a useful overview of the different mitigation pathways that may be associated with different CO_2 utilisation technologies, showing how the application of technologies may or may not result in permanent storage of CO_2 from the atmosphere (Figure 2.4). As shown, different CO_2 utilization technologies and emission reduction pathways can give rise to different levels of permanence. For example, some CO_2-utilizing fuels and products release (the utilized) CO_2 upon combustion and product degradation; other options are designed to store CO_2 over very long periods of time. For the latter options, which include CCS, the permanence of the captured and

stored CO_2 must however be addressed through the relevant GHG accounting rules and/or incentive scheme.

Figure 2.4 Illustrative emission reduction pathways for CCU technologies



Source: EC, 2013.

2.5 Reference case (or baseline)

In most situations, a GHG inventory is compiled to track progress in emissions over time and to measure performance against a given reference level, be it historical emissions or an alternative scenario involving a different technology choice (i.e. the counterfactual). Under these circumstances, a reference case – usually referred to as a base-year or a baseline – is employed, against which to measure achievements in pursuit of the given emission reduction outcome or objective, be it a politically or scientifically-based, and set in absolute (e.g. a "cap") or relative terms (e.g. an intensity target). The nature of the target and reference case can vary widely depending on the scheme and objective in question, including:

- A global atmospheric CO_2 concentration target, and therefore implicitly an emission reduction and removals (sink enhancement) target at a global scale (i.e. the shared global ambition, such as under UNFCCC and Paris Agreement);
- National emission reduction target (e.g. a particular country's 'contribution' to the shared ambition pledged in an NDC; this may be absolute in terms of a cap or relative e.g. based on emissions per unit of gross domestic product compared to an agreed base-year);
- Sectoral targets (e.g. a collective industry target, or under regulatory schemes that apply to particular sectors such as an emission mandate, carbon tax or under an ETS. For the latter, these are typically set as a cap derived from the country's national emission reduction target and the relative share to be contributed by the covered sectors)

- Project- based approach (an emissions level i.e. “baseline”) estimated for a counterfactual scenario that could occur in the absence of the project)
- Programmatic approach (again, typically a counterfactual baseline scenario)
- Product-based approach (e.g. an improvement in emissions intensity over time)

As such, different GHG reduction schemes often use very different reference cases against which effectiveness is to be measured, and different ways of deriving that target. Some examples include:

- **A base-year** e.g. the 1990 base-year used under the Kyoto Protocol for most Parties involved the setting of a cap, or “assigned amount”, as a percentage change from 1990 emission levels. Other base-years are now being used in various intended NDCs (e.g. the USA has adopted a 2005 base-year for its intended NDC (iNDC) emission reduction pledge).
- **A total cap** e.g. as in the EU ETS, where the total number of EU Allowances available in the market is determined in the Allocation Plan for each trading period or “phase”, based on the level of emission reductions to be made by sectors and activities included in the scheme in relation to the EU’s total emission reduction commitments
- **A baseline** e.g. as in project-based crediting mechanisms, in which the baseline is usually estimated based on the most realistic and credible alternative to the technology pathway chosen for the project. This can involve a dynamic baseline that needs to be monitored and updated over time, *ex post*.
- **A year-on-year percentage improvement** e.g. as may be adopted in a corporate target

In respect of selecting a base-year, there are no particular firm rules, and as has been seen under the recent iNDC process in the lead up to the Paris Agreement, a range of base-years have been selected by different countries, with some choosing to continue with a 1990 base-year, and others selecting 2000 or 2005.

In terms of cap-setting, the approach depends on the type of target adopted under the scheme, with a cap only being applicable where an absolute target is adopted rather than an intensity-based (relative) one.

In respect of establishing a baseline, two main approaches exist by which it can be determined at a project-level:

1. A *standards-based* approach – where the emissions intensity of providing the same service using a different technology is used to calculate the baseline emissions (e.g. on a tCO_2/MWh generated basis, for grid-connected power projects); or,
2. A *project-specific* approach – where the emissions of the same plant absent the intervention (i.e. a “no action” scenario). It is likely to be most applicable in projects involving retrofits, where historical emissions exist and could serve as a baseline.

Either approach may be taken for CCS projects, as described further below.

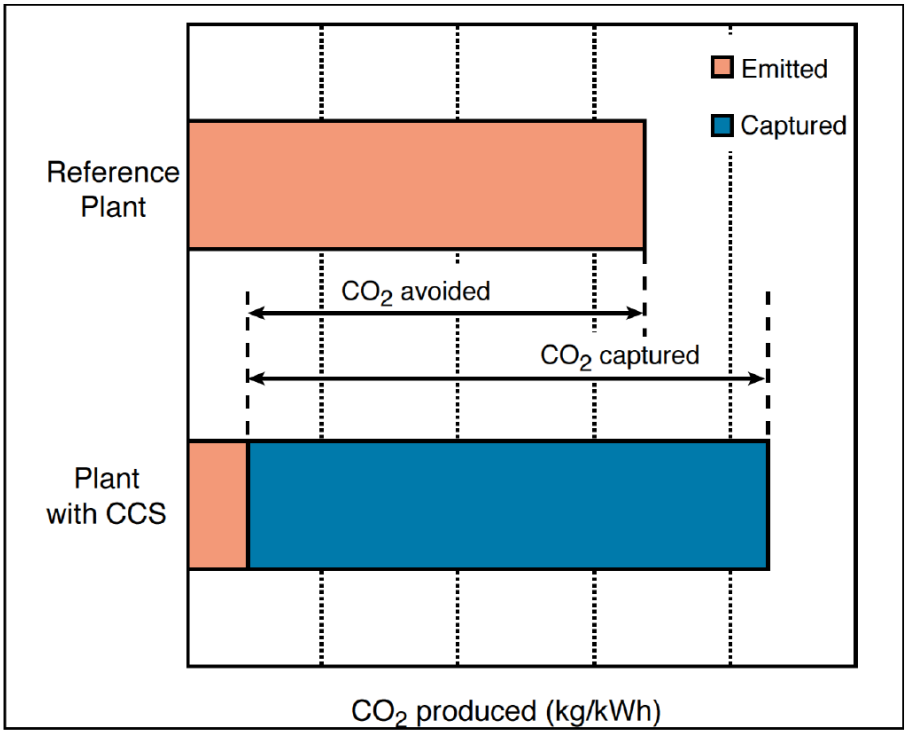
2.5.1 CCS and reference cases

Where CCS may be used as part of a portfolio of mitigation options employed to reach an improvement against a base-year, there are no particular CCS-specific issues associated with determining a reference case (e.g. where CCS makes a contribution towards a country making reductions against a base-year). This is the same when considering CCS at a sectoral level, or under a cap within an emissions trading scheme. This is because the reference case is set independent of the technology under consideration.

Complications arise, however, at a project level since the baseline is usually set by the counterfactual scenario, which is a matter of technology choice that is not always straightforward to determine. In such cases, the reference case is the alternative technology option determined according to prevailing local conditions and economic considerations, rather than independent of these factors such as under a portfolio approach.

The baseline case for a CCS project is often assumed to be the CO_2 emissions avoided compared to an equivalent plant not employing CCS, taking into account the energy penalty involved in CO_2 capture, treatment and compression. This relationship is highlighted below (Figure 2.5).

Figure 2.5 Reference case for estimating CCS performance



Source: IPCC, 2005

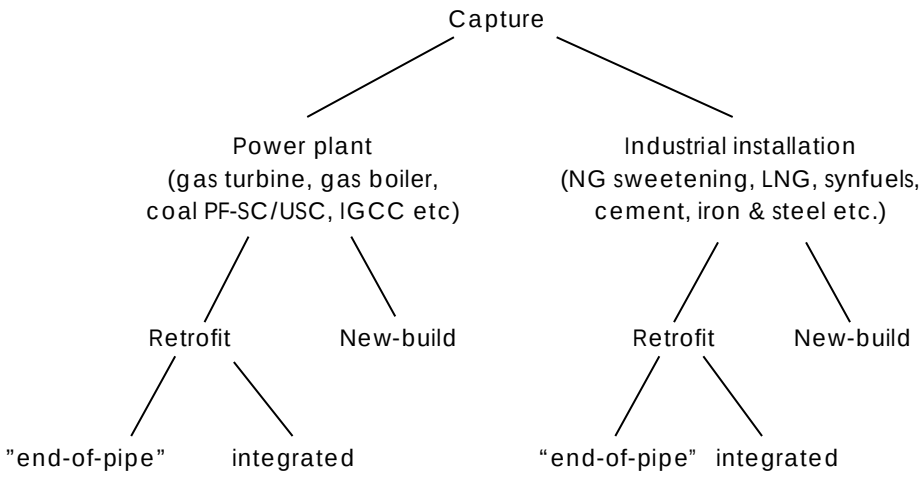
However, this type of *project-specific* approach may be contentious insomuch as the counterfactual alternative technology option might not necessarily be the same plant without CCS, but rather an alternative low carbon technology capable of providing the same service e.g. use of a renewable energy source for power generation. In such cases, it may be more appropriate to take a *standards-based* approach. To some extent, the choice may be determined by whether the CCS project is a new-build (greenfield) or retrofit of an existing facility. In the

case of the latter, the existence of historical emissions may point towards the use of a *project-specific approach*, whilst the former may involve assessing competing counterfactual options, and the taking of a *standards-based* approach. Other complications may also arise, however, in the case of retrofits with respect to the energy penalty and the potential need to install auxiliary power to maintain the same level of output prior to installation of the CO_2 capture units.

In the case of the CDM, although no approved methodologies yet exist for the technology, it is extremely likely that the baseline would involve using a *standards-based* approach for new-build projects, especially grid-connected power plants employing CCS. In the CDM, the baseline standard (i.e. tCO_2/MWh generated) is determined according to the characteristics of the grid to which the power plant is connected. This approach is used today for grid-connected renewable power generation sources, typically adopting an approach known as the "combined margin".[1] This usually results in a baseline that is lower than the simple reference plant as outlined above (Figure 2.5), and may be used under a *project-specific* baseline approach. It results in a lower estimate of the emission reductions achieved by the project compared to the simple reference plant approach. Adopting the CCS project typology below (Figure 2.6), the IEA Greenhouse Gas Programme has considered more than twenty different baseline scenarios for a range of potential CCS project types (IEAGHG, 2007). Further information on baseline setting can also be found in the *GHG Protocol for Project Accounting* (WBCSD/WRI, 2004).

Other project-based schemes may adopt other approaches, such as in Alberta, where a *project-specific* approach is applied to determine baseline emissions (see below).

Figure 2.6 Framework typology for CCS projects



Source: *Zakkour et al, 2011.*

[1] The combined margin, as applied in ACM0002 "Grid-connected electricity generation from renewable sources", involves a combination of the operating margin (the emissions from power plants that might be displaced by the new power plant) and the build margin (the emissions of the power plants that would have been built instead of the project activity).

2.6 Measurement, reporting and verification

MRV forms the cornerstone of any GHG accounting framework. It involves the collection of data – typically activity data[1] – that provides the basis for developing an inventory of GHG emissions for the entity under consideration. It is vital that MRV is carried out in a consistent and transparent way in order that emissions inventories can be effectively compared over both time (when considering year-on-year improvements) and space (when comparing between entities and jurisdictions). Typically it is the MRV rules that underpin any scheme designed to regulate and/or incentivise emission reductions, such as an ETS, carbon tax or carbon credit scheme. Such MRV rules vary according to different schemes under consideration and the different scales to which the scheme applies. The various rules in existence today include:

- **International MRV rules**. Under the UNFCCC, all Parties must publish national inventories on GHG emissions and removals by sinks using comparable methodologies; the Intergovernmental Panel on Climate Change (IPCC) provides guidelines on compiling national GHG inventories, the most recent edition being the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (2006 GLs; IPCC, 2006), although not all Parties are obliged to use the most recent version, and may instead employ the 1996 Guidelines (IPCC, 1996). The approach taken is economy-wide and includes MRV approaches for a range of anthropogenic emissions of GHG gases by different sources and removals by GHG sinks such as forests and other types of land use. The methods and reporting requirements are organised on a sectoral basis.
- **Regional, national and sub-national MRV rules**. These cover policy measures in place to measure and/or control GHG emissions in various jurisdictions around the world, such as cap-and-trade based ETSs and other carbon pricing instruments, and their associated GHG accounting rules. Key amongst these are the *EU ETS Monitoring and Reporting Regulation* (EU MRR),[2] *AB32 Mandatory Greenhouse Gas Reporting Rule* (applied in California's emissions trading scheme),[3] Australia's *National Greenhouse and Energy Reporting Act*, *2008* (NGER), and the US EPA *Greenhouse Gas Reporting Program* (GHGRP)[4]. These schemes are typically focussed on sectors of the economy with the highest point source emissions, such as power and industry, and are regulated at the installation- or facility-level.
- **Project-based scheme MRV rules**. Project-based GHG offset schemes are underpinned by methodologies which set out the GHG accounting rules in terms of how the baseline is derived and calculated, and how MRV is carried in support of estimating project emissions, baseline emissions and in some cases, leakage emissions. The main existing scheme in this context is the *Kyoto Protocol's clean development mechanism (CDM)*, although regional schemes exist in California (the *American Carbon Registry* and *Climate*

[1] Activity data is a proxy measure of emissions, such as levels of coal, natural gas or petroleum consumption or levels of livestock growing that can provide a basis for estimating the related GHG emissions. The IPCC define it as "data on the magnitude of human activity resulting in emissions or removals taking place during a given period of time". In some cases, certain GHG emissions may be directly measured using a continuous emissions monitoring (CEM) system placed on e.g. an exhaust stack.
[2] Commission Regulation (EU) No 601/2012 of 21 June 2012 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and Council.
[3] California Govt, Mandatory Reporting of Greenhouse Gas Emissions (title 17, CCR §95100-95157).
[4] US EPA, Final Rule on Mandatory Reporting of Greenhouse Gases (Title 40, CFR Part 98).

Action Reserve), Alberta (*Alberta-based Offset Credit*) and Australia (*Carbon Farming Initiative*), as well as voluntary schemes such as the *Gold Standard* and the *Verified Carbon Standard* (VCS).

- **Product-based MRV rules**. This primarily relates to low carbon fuel standard schemes that set portfolio standards on the GHG intensity of fuels sold and used in certain markets. These include California's *Low Carbon Fuel Standard* (LCFS) and the *EU Renewable Energy Directive* and *Fuel Quality Directive* (FQD). These policy instruments adopt a portfolio standards/mandates approach on operators to limit the GHG emissions associated with the supply of energy products – namely liquid transport fuels – into markets. They have their own rules of calculating the "well-to-wheel" emissions intensity of different fuels, including biofuels.

As noted above in relation to boundaries, the methods used should in theory be fully interlinked and compatible, but in practice some variations exist which can create complications in terms of the inter-comparability of systems and the treatment of different technologies within different schemes.

2.6.1 CCS and MRV

For CCS, these variations – coupled with varying scheme boundaries – do create some issues for recognising and fully accounting for the net level of emission reductions that may be achievable by the technology. Issues that can potentially arise include:

- Not recognising CCS as a mitigation technology e.g. due to the absence of approved MRV rules for the technology;
- Not covering all sources of emissions associated with a CCS chain e.g. if the CO_2 is used for enhanced oil recovery, and the breakthrough emissions associated with oil production fall outside the scheme – this is type of leakage, as described above;
- Not counting negative emissions from bioenergy with CCS e.g. where the scheme excludes installations combusting biomass.

Variations may also exist in the methodologies and approaches applied to measure emissions from certain parts of the CCS chain, especially for transport and storage. Such variations, if considered to be sufficiently material – so as to affect the environmental integrity of the technology – may also affect the capacity of schemes to link and exchange fungible units within a regional or international carbon market. These variations are further considered below.

In addition, certain 'special' CCS cases where described previously in the context of leakage (as illustrated in Figure 2.3). The issues highlighted there pose certain challenges for MRV including:

1. **Negative emissions from combining biomass with CCS**. When applying CCS to biomass emissions sources (e.g. as a fuel used for combustion), the carbon released is not emitted to the atmosphere (and potentially from there reabsorbed for shorter-term storage in biomass) but is instead transferred into the geological carbon pool for long-term, or permanent, isolation from the atmosphere. Therefore, rather than leading to a zero net change in atmospheric CO_2 concentrations, bio-CCS actually leads to a net removal of CO_2 from the atmosphere, and hence, all other things being equal, the net

change in the atmospheric C-stock becomes negative.[1] *Negative emissions* technologies such as bio-CCS are distinct in this way from other technologies that can reduce emissions. Whilst the importance of such mitigation options are widely accepted, some carbon schemes face challenges in recognising, attributing and rewarding negative emissions (see Section 3).

2. **Incremental oil production (CO_2-EOR)**. Whilst most of the GHG accounting issues presented by CCS (including permanence) apply also to CO_2-EOR operations, there are additional issues presented by CO_2-EOR compared to 'pure' geological storage projects. Additional on-site emissions from sources associated with oil production may present a source of leakage outside the scheme boundary, as well as emissions arising from transport, refining and end-use of the incrementally-produced crude oil.[2] Figure 2.3 shows just some of the potential routes by which leakage outside the boundary of one accounting scheme could occur; which may occur within the sector of the same country (Country A) e.g. transport or else in a different country (Country B) via the export of crude and/or refined oil products.

Furthermore, issues for the MRV of CCS can arise where trans-national CCS projects occur. Figure 2.3 shows how the geographical boundary of a CCS project or activity may take place in one or more country. In such cases, differences may arise in respect of accounting rules applying to different schemes (under which the CCS activity is incentivised). This factor is potentially compounded in light of the various issues and challenges described above i.e. relating to ensuring an effective chain of custody across the project chain; accounting for negative emissions from bio-CCS; and accounting for leakage arising from CO_2-EOR. In addition, the international transfer of CO_2 between different countries creates the potential for certain emissions sources to fall outside the scope of GHG reporting requirements.

2.7 Summary of GHG schemes and accounting rules

Table 2.1 summarises GHG schemes worldwide according to each of the key elements described in this section.

[1] As plants grow, they absorb (or "remove") CO_2 from the atmosphere, which is typically re-released back to the atmosphere upon combustion or biological degradation of the harvested biomass. Using CCS to capture and store the CO_2 from such sources can remove carbon from the short-term biological cycle and lock it up for long periods of time in the geological carbon pool, leading to a net reduction in atmospheric CO_2.

[2] This is a topic that has proved contentious: some argue that CO_2-EOR can never reduce emissions because it produces additional oil, whilst others assert that it is a relevant emission reduction technology. Core to this discussion is whether the incrementally-produced crude oil *substitutes* other sources of crude oil supply, thereby resulting in a minor or negative net change in emissions, or whether it *adds* to supply, thereby creating new sources of emissions. There is also a temporal dimension to the debate, relating to long-term elasticity of demand for oil, and the risk of path dependency on fossil fuels and carbon "lock-in".

Table 2.1 Summary of GHG schemes and accounting rules

<table>
<tr><th>Scheme</th><th>Purpose</th><th>Boundaries</th><th>Reference case</th><th>MRV Rules</th><th>Leakage</th></tr>
<tr><td>UN Framework Convention on Climate Change (UNFCCC)</td><td>“Stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”
Parties track national GHG emissions and removals by sinks in pursuit of the objective.</td><td rowspan="3">Parties must compile inventories for all anthropogenic GHG emissions occurring within their national territorial limits.
Organised by sector:
• Energy
• Industrial Processes and Product Use
• Agriculture, forestry and land use
• Waste
Variations exist in terms of both requirements for removals by sinks and quality (i.e. differing tiers)</td><td>Not applicable - no measurable target for preventing dangerous climate change</td><td rowspan="3">The Intergovernmental Panel on Climate Change (IPCC) is mandated by the COP to develop appropriate national GHG inventory compilation guidelines. Currently three are applicable:
• Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (1996 GLs)
• IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2000 GPG)
• IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry (2003 GPG LULUCF)
In the future Annex I Parties will need to use the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 GLs).
Annex I Parties report inventories annually. Biennial update reports (BURs) required by most non-Annex I Parties. Allowed to use earlier versions of IPCC Guidelines.</td><td rowspan="3">Not really relevant, since all emissions from all countries should be reported and counted under the scheme(s).
Exception is ‘bunker fuels’ used in international aviation and international maritime transport. Not accounted for by Parties and therefore fall outside of scheme boundaries.</td></tr>
<tr><td>Kyoto Protocol to UNFCCC (KP; to 2020)</td><td>Sets quantified emission limitation or reduction obligations (QELROs) for Annex B Parties in pursuit of the UNFCCC objective.
Non-Annex B Parties may develop and sell offsets to Annex B Parties under CDM</td><td>Emission limitation / reduction against 1990 base-year for most Parties and most GHGs (some exceptions exit)</td></tr>
<tr><td>Paris Agreement to UNFCCC (PA; from 2020)</td><td>“Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels”
All Parties to adopt increasingly stringent nationally determined contributions (NDC) over time in pursuit of UNFCCC objective.</td><td>Parties proposed different types of reduction targets (absolute and intensity) using differing base years in intended NDCs (iNDCs).</td></tr>
<tr><td>Clean development mechanism (CDM) under Kyoto Protocol</td><td>Project based mechanism, to allow Annex B Parties to KP to offset QELRO target through acquisition of Certified Emission Reductions (CERs), from CDM projects in developing countries.</td><td>Project-specific. Based on Approved Methodology (AM)</td><td>Project-specific baseline established in AM. May be ex ante or ex post, and project- or standards-based</td><td>The CDM modalities and procedures (CDM M&Ps) contains the rule(s).
AMs are developed according to the M&Ps, setting out the project-type specific GHG accounting rules, the basis for calculating the CERs generated.</td><td>As projects occur in non-Annex B Parties with limited economy-wide GHG controls, issues of can arise for certain project types. Must be accounted for in accordance with AM.</td></tr>
</table>

Scheme	Purpose	Boundaries	Reference case	MRV Rules	Leakage
Joint implementation (JI) under Kyoto Protocol	**Project based mechanism**, under which Annex B Parties to Kyoto Protocol may acquire Emission Reduction Units (ERUs). Now redundant	Depends on "track" taken. Track 2 same as CDM	Depends on "track" taken. Track 2 same as CDM	Based on two possible approaches according to the Party's inventory quality/system: a streamlined "Track 1" using GHG Inventory, or "Track 2" procedure similar to CDM	As for CDM for Track 2 JI
EU GHG emissions trading scheme (EU ETS)	**GHG cap-and-trade scheme** aimed at reducing GHG emissions across the EU-27 plus 4 non-EU countries, from large GHG emitting installations.	Physical boundary of **qualifying installations**, **aeroplanes and ships**	"Cap" for each phase set according to EU-wide emission reduction target. This translates to a 21% reduction against **2005 base year**	Regulation No. 601/2012 on monitoring and reporting (the "MRR"; most recent for Phase III)	Generally not an issue since other policies and measures in place across EU Member States to control GHG emission across all sectors
EU Renewable Energy Directive (EU RED) and the EU Fuel Quality Directive (EU FQD)	**Product-based** portfolio standard for fuel suppliers, based on reaching a target of 10% renewable transport fuel use in the EU by 2020.	**Life-cycle GHG intensity** of fuel and energy supplied emission inventory ("well-to-wheel").	10% improvement in GHG intensity of fuels supplied by 2020 compared to **2010 base year** (range of other sub-targets included)	The GHG intensity of fuels calculated in accordance to methodologies set out in Article 19 of the RED and/or Article 7 of the FQD (2009/30/EC). Life-cycle analysis and use of emissions factors	Life-cycle approach should prevent leakage. Concerns raised about indirect land-use (iLUC) effects
US EPA GHG Reporting Program (GHGRP) – 40 CFR Part 98	To collect accurate and timely GHG data to inform future policy decisions.	Physical boundary of **facilities emitting > 25 ktCO2-e/yr** (for most sources)	Not applicable – only requires reporting. Caps or reduction targets are covered under separate rules.	The GHGRP has a wide number of subparts which set out the accounting rules applicable to different GHG emitting facilities, suppliers of GHGs, and facilities injecting CO_2 for EOR and/or long-time storage.	Not applicable – no targets, so no leakage possible (n.b. CCS is a compliance option under the Clean Power Plan and New Source rules).
California Emission Trading Scheme	**GHG cap-and-trade scheme** in the US State of California. Allows use of offsets from projects developed under CARB-approved offset programmes, including ACR and CARB.[1]	Physical boundary of **facilities emitting > 25 $ktCO_2$-e/yr and fuel distributors.**	Support California's commitment to reduce GHG emissions to **1990 base year** levels by 2020	The AB32 Mandatory Greenhouse Gas Reporting Rule	Generally not an issue since other policies and measures are in place across California to control GHG emission across all sectors

[1] Note that work is currently ongoing by the CARB to develop accounting rules for CCS under the California ETS and Low Carbon Fuel Standard programs.

Scheme	Purpose	Boundaries	Reference case	MRV Rules	Leakage
Canada GHG Reporting Program (Canada GHGRP)	To help Canada assess its overall environmental performance.	Physical boundary of **facilities emitting > 50 $ktCO_2$-e/yr**	Not applicable – only requires reporting. No caps or reduction targets.	*Technical Guidance on Reporting Greenhouse Gas Emissions* largely endorses use of IPCC methods	Not applicable – no targets, so no leakage possible
Alberta Specified Gas Emitters Regulation	To reduce emissions intensity of facilities that emit more than 100,000 tonnes GHG/yr. Allows use of *Alberta-based offset credits* to meet compliance.	Physical boundary of **facilities emitting > 100 $ktCO_2$-e/yr**	Currently 15% improvement in intensity against average of 2003, 2004 and 2005 emissions intensity. Increases to 20% in 2017.	Monitoring must be undertaken following industry or UNFCCC guidelines	Generally not an issue
Australia National Greenhouse and Energy Reporting Act (NGER)	The NGER imposes mandatory GHG and energy monitoring and reporting obligations for businesses.	All businesses must measure and report emissions where the certain thresholds are exceeded	Not applicable – only requires reporting. No caps or reduction targets.	Various MRV requirements established in the *National Greenhouse and Energy Reporting Regulations*, 2008; and the *National Greenhouse and Energy Reporting (Measurement) Determination*, 2008	Not applicable – no targets, so no leakage possible

3 REVIEW OF ACCOUNTING RULES FOR CCS

This section reviews and compares the different GHG accounting rules as they apply to CCS. A brief review is made of the specific requirements for CCS technology support in respect of GHG accounting; the comparative review is then made according to these identified requirements.

CCS needs to be incentivised through climate policies and measures undertaken by governments, and at the international level, in support of meeting climate change targets and international commitments under the UNFCCC. CCS is recognised as an eligible mitigation technology within most schemes worldwide, including at the UNFCCC level, each of which has its own specific purpose and accounting rules (see above). In order to review and compare how these apply to CCS, there is a need to cleanly define the specific requirements. Based on the range of issues and factors outlined in Section 2, the following key requirements are identified for CCS:

1. **Recognising captured CO_2 as "not emitted"**. The general principle underpinning CCS support is recognition of captured and stored CO_2 as "not emitted" to atmosphere, so as to be counted towards an emissions reduction goal against a reference case/baseline (see Section 2.5). MRV rules therefore need to allow for captured CO_2 to be deducted from the relevant inventory (e.g. sector; installation).
2. **Including transport and storage within the scheme accounting rules**. CCS requires building a chain of custody for the CO_2 across the different sectors/installations involved at each stage of the project chain. MRV rules therefore need to be developed also for monitoring of transport and storage, and these need to dovetail across the project chain.
3. **A mechanism to address permanence**. Appropriate accounting and MRV rules must provide assurances that the injected CO_2 remains in the intended geological formation and isolated from the atmosphere over the long-term, and quantify any leaks that occur.
4. **Specific considerations for CCS 'special cases'**. These include:
    a. *Recognition of negative emissions from bio-CCS*. GHG accounting schemes and associated MRV rules should adequately recognise, attribute and reward the *negative emissions* associated with bio-CCS activities.
    b. *Accounting for CO_2-EOR*. The potential 'leakage' of emissions outside a scheme boundary associated with incremental oil production could be addressed through suitable MRV rules (these include additional *site-level* emissions e.g. from break-through, as well as *life-cycle* emissions arising from e.g. transport, refining and the end-use of oil products).
    c. *Accounting for CO_2 utilisation.* The different mitigation pathways associated with CO_2 utilisation technologies should be addressed by suitable MRV rules if they are to be recognised and supported within GHG accounting schemes (both in respect of the CO_2 captured and stored, and also any fossil fuel displacement effects).

The extent to which these requirements are currently addressed within existing GHG accounting and MRV rules in place worldwide are summarised in Table 3.1. The assessment highlights those areas where: (a) the requirement is adequately addressed; b) there is a clear gap/issue; and (c) there are areas of uncertainty, or where only minor issues exist.

Table 3.1 CCS requirements and GHG accounting and MRV rules worldwide

Accounting/ MRV rules		All CCS projects			Special cases		
		Recognising captured CO_2 as "not emitted"	**Inclusion of transport and storage**	**Permanence mechanism**	**Negative emissions from bio-CCS**	**CO_2-EOR**	**CO_2 utilisation**
Economy-wide	2006 IPCC Guidelines	CO_2 reported as "not emitted" and deducted from the relevant source category (Energy; Industrial Processes and Product Use) subject to Vol 2.5. provisions	Vol 2.5 sets out detailed MRV requirements for CO_2 transport and storage	Vol 2.5 provides detailed, site-specific monitoring requirements, including site characterisation, leakage risk assessment, and quantification of any leaks	Included. Negative emissions can be recorded in the national GHG inventory.	MRV of all emissions from CO_2-EOR site-level operations must be included in the national GHG inventory; mid-and downstream sources covered elsewhere.	Captured CO_2 can be deducted, subject to the relevant sector where CO_2 is re-emitted having appropriate guidance
Sector-based	EU Monitoring and Reporting Regulation (MRR)	Captured "fossil carbon" is deducted from source installation inventory and accounted as "not emitted" (if transferred to a storage site licensed under the EU CCS Directive)	CO_2 pipelines and CO_2 storage sites included as qualifying installations under the EU ETS	Reported under EU CCS Directive, which sets out detailed requirements for *inter alia* site characterisation and selection, risk assessment and monitoring	Not possible. Only transferred fossil CO_2 can be deducted from an installation's GHG inventory; 100% biomass installations not included within EU ETS	Site-level emissions reported by qualifying installations within oil and gas sector. Potential for leakage outside of the EU ETS boundary (other sectors and/or countries).	Possible inclusion, subject to MRV rules being developed and approved under EU comitology process.
	US EPA GHG Reporting Program (GHGRP)	CO_2 capture is reported under subpart PP (Carbon Dioxide Suppliers) and the EPA acknowledges there are emissive and non-emissive uses of CO_2.	CO_2 pipelines are not covered. CO_2 storage sites, including those associated with compliance under the Clean Power Plan, are subject to subpart RR requirements which requires MRV of amounts of CO_2 geologically sequestered.	CO_2 injection and storage is regulated by the EPA's Underground Injection Control (UIC) program. UIC Class VI is tailored to CO_2 storage and includes detailed provisions for MRV of CO_2 storage sites. UIC Class II is focused on enhanced oil and gas recovery.	Emissions associated with biomass are only reported when a facility triggers the 25ktCO_2 reporting threshold by burning other fuels; 100% biomass installations are therefore not included	EOR operators may report under subpart UU (*Injection of Carbon Dioxide*) or subpart RR (*Geologic Sequestration of Carbon Dioxide*). However, to qualify for support for purposes of long-term storage (CCS), all operators (Class II and VI) must report under RR; RR requires reporting of site-level emissions (under subparts C+W). Downstream leakage potential.	Possible inclusion, subject to MRV rules being developed.
	Canada GHG Reporting Program (Canada GHGRP)	MRV as per IPCC Guidelines	MRV as per IPCC Guidelines	As per IPCC Guidelines	Included, as per IPCC guidance (see above)	CO_2-EOR site level operational emissions monitored and reported following IPCC Guidelines (see above). Downstream leakage potential.	MRV requirements would be subject to development of IPCC guidance (see above)

Accounting/ MRV rules		All CCS projects			Special cases		
		Recognising captured CO_2 as "not emitted"	**Inclusion of transport and storage**	**Permanence mechanism**	**Negative emissions from bio-CCS**	**CO_2-EOR**	**CO_2 utilisation**
	Australia National Greenhouse and Energy Reporting Act (NGER)	Allows for CO_2 that is captured for permanent storage to be deducted from a regulated entity's emissions inventory	Government has developed guidance for MRV of storage site emissions based on the API Compendium, with effect from July 2015.	Government has developed guidance for MRV of storage site emissions based on the API Compendium, with effect from July 2015.	Possible to account for negative emissions.	Government has developed MRV guidance covering CO_2-EOR site emissions based on the API Compendium, with effect from July 2015. Downstream (transport) leakage potential.	Possible inclusion, subject to MRV rules being developed.
Project-based	Kyoto Protocol clean development mechanism (CDM)	CCS eligible as emission reduction technology subject to *CCS Modalities and Procedures*; CO_2 "not emitted" depends upon baseline within Approved Methodology.	All parts of the CCS chain would need to be included within the boundary of the CDM activity.	The *CCS Modalities and Procedures* set out a risk-based approach to managing permanence, following similar lines to that under the 2006 GLs	Possible to account for negative emissions, subject to a new methodology being developed and approved.	Any CO_2-EOR CDM methodology would require monitoring to include all emissions from CO_2-EOR site level operations. Mid- and downstream sources should also be identified as 'leakage emissions'.	CDM methodology developed for CO_2 utilisation would require monitoring methodology based on IPCC rules
	Alberta-based Offset Credits scheme	Under the scheme's approved Protocols for CCS and EOR, emissions reductions arising from the capture and storage of CO_2 are recognised against a counter-factual emissions baseline.[1]	Under both Protocols, all parts of the CCS (or CO_2-EOR) chain are included within the boundary of the project activity.	Risk-based approach to managing permanence based on an approved MRV plan.	Possible, as scheme is based on accounting against baseline emissions using emission factors (as per CDM).	The EOR Protocol (based on gas processing only) includes MRV of site-level emissions. Mid- and downstream emissions not considered because "No Leakage" is an eligibility criterion for projects.	Possible inclusion, subject to new Protocol being developed and approved under the scheme.
	American Carbon Registry (ACR)	Recently approved methodology for CCS (April 2015) describes rules to account to emissions reductions against a counter-factual emissions baseline.	All parts of the project chain are included within the boundary of the project activity.	Risk-based approach to managing permanence based on an approved MRV plan; proponents may also make use of liability insurance and reserve accounts.	Possible to account for negative emissions, subject to a new methodology being developed and approved.	Operators required to monitor and report all site-level GHG emission sources; also required to take into account "leakage emissions" although exact methods are not specified.	Possible inclusion subject to development of new methodology (currently applies to CO_2-EOR projects only).

[1] *Note that as part of the support package provided for the QUEST project, the Alberta scheme awards, for a limited time only and under various conditions, bonus credits for CCS projects. This arrangement provides an additional incentive to CCS however, rather than any underlying change to the accounting methodology.*

Accounting/ MRV rules		All CCS projects			Special cases		
		Recognising captured CO_2 as "not emitted"	**Inclusion of transport and storage**	**Permanence mechanism**	**Negative emissions from bio-CCS**	**CO_2-EOR**	**CO_2 utilisation**
Product-based	EU Renewable Energy Directive and Fuel Quality Directive	Captured and stored CO_2 subtracted from the GHG intensity calculation (guidance outlined in Section C of Annex IV of RED and Annex V of the FQD)	Captured and stored CO_2 subtracted from the GHG intensity calculation (guidance outlined in Section C of Annex IV of RED and Annex V of the FQD)	Does not provide guidance on how permanence should be taken into account for such activities; however this is addressed within IPCC 2006 GLs	Possible to account for negative emissions, as GHG intensity is calculated at a portfolio level	All emissions sources accounted for in theory; requires entities importing crude oil and refined products into the EU to take account of upstream and midstream emissions arising in their production.	Where applicable (e.g. CO_2-utilising fuels), downstream emissions would be subject to European national inventory (and/or scheme) rules (see above).

Note: GREEN indicated where the requirement is adequately addressed; RED where there is a clear gap/issue; and YELLOW where there are currently areas of uncertainty, or where only minor issues exist.

4 KEY FINDINGS

This section presents the key findings of the report. Following a summary of the key GHG accounting issues and requirements identified for CCS, differences between accounting protocols for CCS worldwide are summarised. Key issues, gaps and potential barriers emerging from the review are identified along with possible measures that could be taken to address them and support CCS deployment.

4.1 GHG accounting issues and requirements for CCS

GHG accounting rules have been developed for a wide range of purposes and at different scales. These include the development of national GHG inventories compiled by countries as part of their obligations under the UNFCCC, as well as regional and national approaches employed under policies and measures such as mandatory GHG emissions reporting, carbon taxes and ETS. The report identifies specific issues arising for CCS and CCU projects according to each of the key elements involved in the design of a GHG accounting framework and emissions inventory:

- **Boundaries**. GHG accounting boundaries can be an issue for CCS and CCU, primarily because of the nature of the technology which involves a carbon "stock transfer" in which the CO_2 that would have been emitted to the atmospheric carbon pool is actually transferred to the geological carbon pool for an indefinite period of time. This creates accounting challenges, both geographically and temporally. Geographical challenges arise as a result of CO_2 being transferred between different types of installations, operators and owners across the project CCS chain, potentially resulting in CO_2 be emitted somewhere else outside of a scheme's accounting boundaries (see *leakage* below). Temporal challenges arise as a result of the possibility for CO_2 to leak back to the atmosphere at some future point in time (see *permanence* below).
- **Leakage**. There are several situations where leakage could occur in the case of CCS and CCU. The geographical and legal nature of CCS "chains" means that leakage could occur once the captured CO_2 is transferred out of the capture facility, as the transport and storage facilities not included within the installations boundary. Other types of leakage effects can arise, both positive and negative, for certain 'special' CCS project types that involve more than just capture of fossil fuel emissions and their storage in geological reservoirs. These involve emissions arising from the combustion of fossil fuels incrementally produced through CO_2 enhanced hydrocarbon recovery (EHR) and the potential for negative leakage to occur in the case where bioenergy production is combined with CCS.
- **Permanence**. A temporal disconnect between when an emission reduction takes place and the scope for it to be reversed at some point in the future poses a problem of *permanence*. This is an issue for CCS, and in particular for certain types of CCU, in which there is the potential for CO_2 to return to the atmosphere at some future point in time. *Non-permanence* can negate at least part of the environmental benefits achieved by CCS and CCU, compromising the effectiveness of policies and measures designed to incentivise the technology.

- **Reference case**. The use of a reference case or baseline against which emissions reduction achievements can be measured do not typically present issues for CCS at an economy-wide or sectoral level. Complications may arise, however, at a project level since the baseline is usually set by the counterfactual scenario, and this can be difficult to determine, given the wide range of potential CCS project types (different sectors, retrofit versus new-builds etc). A *project-specific* approach may be appropriate where the counterfactual is the same plant without CCS. In other cases it may be more appropriate to take a *standards-based* approach (e.g. where the counterfactual plant is an alternative low carbon technology capable of providing the same service).
- **Measurement, reporting and verification**. MRV forms the cornerstone of any GHG accounting framework and typically underpins any scheme designed to regulate and/or incentivise emission reductions. Variations exist between MRV rules applied at different levels and for different purposes, which makes it important to understand and apply the right set of rules based on the needs of a certain program and/or to tailor them accordingly.

In these contexts, the report identifies several specific issues for CCS and CCU in respect of GHG accounting and MRV rules. Firstly, three key requirements are found to be fundamental to all CCS projects:

4. **Recognising captured CO_2 for storage as "not emitted"**. MRV rules need to allow for captured CO_2 to be deducted from the relevant inventory (e.g. sector; installation).
5. **Including transport and storage within the scheme accounting rules**. MRV rules need to be developed also for monitoring of transport and storage, and these need to dovetail across the project chain.
6. **A mechanism to address permanence**. Appropriate accounting and MRV rules must provide assurances that the injected CO_2 remains in the intended geological formation and isolated from the atmosphere over the long-term, and quantify any leaks that occur.

Secondly, some specific considerations arise for the following 'special cases':

- **Recognition of negative emissions from bio-CCS**. GHG accounting schemes and associated MRV rules need to adequately evaluate, attribute and reward any *negative emissions* associated with bio-CCS activities.
- **Accounting for CO_2-EOR**. The potential 'leakage' of emissions outside a scheme boundary associated with incremental oil production can be addressed through suitable MRV rules, taking into account the relevant accounting framework.
- **Accounting for CO_2 utilisation**. The different mitigation pathways associated with CO_2 utilisation technologies must be evaluated and suitable MRV rules developed if they are to be recognised and supported within GHG accounting schemes.

4.2 Key gaps, issues, and challenges, and options to address them

A review of GHG accounting and MRV rules in place worldwide finds that the three key 'fundamental' requirements outlined above for CCS are addressed within existing rules.

All of the schemes reviewed allow for **recognising captured CO_2 to be recognised as "not emitted"**. In nearly all cases, this is dependent upon monitoring of CO_2 storage sites to provide assurances over the *permanence* of emission reductions achieved through CCS. Under international GHG accounting rules, which include guidance on GHG accounting for CCS in national GHG inventories in the 2006 GLs, a country's national GHG inventory may only report captured and stored CO_2 as "not emitted" in the relevant source category (e.g. the energy sector) where IPCC guidance for monitoring CO_2 storage sites is followed. The approach in the 2006 GLs is broadly mirrored in regional cap-and-trade and GHG reporting schemes and associated GHG accounting rules. In the EU ETS, for example, under *Article 49* of the EU MRR, captured "fossil carbon" may be deducted from an installations GHG inventory, and therefore be accounted for as "not emitted" by the source installation, only where it is *transferred* to a storage site regulated under the EU CCS Directive. Similarly, under the US GHGRP, regulated entities may report amounts of CO_2 transferred offsite in accordance with *subpart PP* ("Carbon Dioxide Suppliers"), which requires such entities to report the amount of CO_2 transferred offsite and the end use application for which the CO_2 was transferred, including for long-term storage, where known. The Clean Power Plan and New Source Performance Standards for power plants require facilities using CCS for compliance purposes to send CO_2 to a facility reporting under *subpart RR* (and under *subpart RR* facilities must report volumes of CO_2 received). Project-based schemes such as the CDM and JI also allow for the recognition of CCS as an emission reduction technology subject to rules and guidance set out in the CCS M&Ps.

Similarly, all of the schemes reviewed allow for **inclusion of transport and storage within the scheme accounting rules**, thereby allowing for attribution of emissions and reduction across the CCS or CCU project chain. Under national GHG inventory guidelines and in the regional reporting and GHG cap-and-trade schemes reviewed, the emission reductions achieved through CCS are recognised and attributed at the point of CO_2 generation. In the case of national GHG inventories, the amount captured and stored is deducted from the relevant source category in the inventory. Under the EU ETS and Australian NGER, the facility/installation where the CO_2 was generated is absolved of its liability for the CO_2 generated where the CO_2 is transferred offsite. In all cases, emissions occurring during transport, injection and storage would be attributed to the transport or storage installation. In project based schemes, the entire chain of capture transport and storage would need to be included within the boundary of the project activity, resulting in the net emission reductions across the entire chain being recognised.

Permanence is addressed within different GHG accounting rules in place worldwide primarily through the use of risk-based management approaches. At the international level, the IPCC 2006 GLs (Volume 2, Chapter 5) sets detailed, site-specific monitoring requirements for injection and storage, including aspects such as site characterisation, non-permanence risk assessment, and quantification of any leaks, relying on detailed monitoring of the sites to allow countries to continue reporting the stored CO_2 as not emitted in their national inventory. This approach is mirrored in regional cap-and-trade and GHG reporting schemes and associated GHG accounting rules. The EU CCS Directive sets down detailed requirements for, *inter alia*, site characterisation and selection, risk assessment and monitoring, allowing permanence to be managed following similar approaches to the 2006 GLs; under the US GHGRP, "geological sequestration" can only be reported by the injection facility where *subpart RR* rules are applied ("Geological Sequestration

of Carbon Dioxide"). The CCS M&Ps set out a risk-based approach to managing permanence, following similar lines to that under the 2006 GLs and as employed in the EU, US and Australia.

The review therefore finds that existing GHG accounting rules are broadly able to account for emissions and emissions reductions associated with 'standard' CCS projects. Some specific gaps, challenges and issues arise however when considering 'special cases' for CCS and CCU projects, as summarised below, along with options to address them.

4.2.1 Recognition of negative emissions from bio-CCS.

At an international level, the 2006 GLs generally allow for negative emissions from bio-CCS to be recorded and recognised in national GHG inventories. Some sector-based reporting schemes including the Canada GHGRP and Australian NGER can also allow for negative emissions to be recognised within the ambit of their respective GHG accounting rules; similarly, project-based and product-based schemes can potentially allow for negative emissions accounting (subject in the former case to the development of appropriate methodologies, which raises some additional issues). These scheme/rules allow for negative emissions accounting either because the scheme's compliance operates at a *portfolio level*, allowing negative emissions to be "netted back" against positive emissions elsewhere in the portfolio (e.g. against other emissions in a county; or other emissions in a fuel suppliers portfolio); or by allowing "credits" to be generated.

Regional cap-and-trade schemes GHG accounting rules do not however recognise and attribute negative emissions should they arise. Under the EU ETS, only the mass of "fossil carbon" transferred for geological storage may be deducted from an installation's GHG inventory, which prevents negative emissions from bio-CCS being recognised. Further, installations exclusively using biomass are exempted from the scheme, implicitly excluding recognition of such activities. This is also an issue within the US GHGRP, under which biomass installations are not included unless the reporting threshold is triggered by fossil fuel combustion. Several options to address these shortfalls have been described in detail (Zakkour et al, 2014). Notwithstanding these barriers and options to address them, any amendment to the EU ETS rules would need to be accompanied by an approach to *reward* negative emissions. Presently, whilst the scheme's architecture potentially allows for *pooling* (i.e. "netting-back" at a portfolio level) and *domestic offsets* (i.e. crediting), these elements of the legislation are largely defunct. Also, mechanisms to allocate EUAs to an installation that accounts for and reports negative emissions do not exist. Options to address these aspects include net-back accounting and/or issuing "credits" for the negative emissions.[15]

The discrepancy between international and some sector-specific GHG accounting rules such as low carbon fuel standards (which do recognise negative emissions), and regional cap-and-trade schemes (which do not to recognise negative emission technologies), suggests that whilst national governments may accrue the benefits of negative emission technologies under e.g. the UNFCCC, there is only limited means to incentivise the private sector to undertake such activities (e.g. the application of CCS at a biofuels refinery could qualify, whilst CCS at biomass fired power plant would not have any rewards) (ibid). Further, the differential treatment of transfers of fossil CO_2 and biogenic CO_2 under regional cap-and-trade scheme GHG accounting rules such as the EU ETS means that an incentive is provided for fossil-CCS but not bio-CCS. This distortion

[15] These options are described in detail in Zakkour et al, 2014

should be removed to encourage biomass users to consider applying CCS. In most cases this will require a new type of mechanism to reward such activities e.g. net-back accounting or crediting approaches (ibid).

4.2.2 Accounting for CO_2-EOR

CO_2-EOR operations can give rise to two potential sources of leakage outside a given GHG accounting boundary: (1) additional on-site emissions from sources associated with oil production and (2) mid- and down-stream emissions arising from transport, refining and end-use of the incrementally-produced crude oil. From a climate policy perspective, the central concern is that such emissions could take place in jurisdictions without GHG controls in place. The risk of emissions leakage occurring is variable because of the variations in the type and stringency of GHG controls in place in different parts of the world (Zakkour and Cook, 2016). In this context there is a need to understand whether the existing GHG accounting rules operating at different levels worldwide effectively determine a true, credible and realistic estimate of the net emissions attributable to a CO_2-EOR operation.

At an international level, there are no significant issues: under the 2006 GLs, monitoring and estimation of all emissions from CO_2-EOR site-level operations would need to be included in a country's national GHG inventory using methods under the various source categories.[16] Similarly, activities involving the transporting, refining and end use of incrementally produced oil should also generally be included in a country's national GHG inventory irrespective of the process or sector in which it is used, and compiled in accordance with various volumes of the 2006 GLs. As a result, the various relevant chapters provide guidance for an inventory compiler at a national level as to how to produce full estimates of all GHG emissions from CO_2-EOR activities – both site-level and downstream.

Potential leakage issues can occur however when considering accounting rules across both regional and national-level sector-based schemes, and project-based schemes. Under the EU ETS for example, the scheme boundaries are defined by the physical limits of the qualifying installation. Therefore, all mid- and downstream emissions associated with incrementally produced oil from a CO_2-EOR operation could potentially lead to emissions leakage, as they fall outside of this boundary (noting that the possibility of emissions leakage is dependent on the market/jurisdiction into which the crude oil or product is sold). Regarding imported fuels, the EU RED and the related EU FQD amendments require entities importing crude oil and refined products into the EU to take account of upstream and midstream emissions arising in their production. These regulations act as an anti-leakage border adjustment measure by requiring operators to account for emissions from operations in the fuel cycle value-chain occurring outside of the EU (ibid).

The US GHGRP sets out differential requirements for operators of CO_2-EOR operations, based on applying either *subpart RR* (*Geologic Sequestration of Carbon Dioxide)* or *subpart UU* (*Injection of Carbon Dioxide)* of the rule. All operators undertaking CO_2 injection for the purposes of long-term storage must apply *subpart RR* in order for recognition of CO_2 stored in order to qualify for

[16] These include on site fuel use (Volume 2, Chapter 2: Energy); flaring, venting and other fugitive emissions (Volume 2, Chapter 4: Fugitive Emissions); and emissions of CO_2 leaking from the geological storage site (Volume 2, Chapter 5: Carbon Dioxide Transport, Injection and Storage).

recognition under the Clean Power Plan and any other form of CCS support e.g. tax incentives. Operators reporting under *subpart RR* are required to report all site level emissions – from fuel combustion (under *subpart C*) and other site level emissions (under *subpart W*). Operators of CO_2-EOR sites reporting under *subpart UU* must report only the amounts of CO_2 received, and are exempted from any other emission reporting requirements such as those under *subpart RR.* In terms of mid- and downstream emissions, petroleum refineries and other large industrial facilities are required to report under the GHGRP. However, there is in theory potential for mid- and downstream emissions leakage to occur from transport emissions.

In Australia, the Government has developed MRV guidance under the NGER covering CO_2-EOR site emissions based on the API Compendium, with effect from July 2015. However, there is potential for mid- and downstream emissions leakage to occur.

While several project-based schemes explicitly address the problem of leakage, there are uncertainties regarding their specific application, the methods used and subsequently their comparability with other accounting rules. Any CDM methodology developed for CO_2-EOR for example would be required to include a monitoring methodology to measure and calculate project emissions for all emissions from CO_2-EOR site level operations covering bought-in electricity, onsite electricity generation and vented and fugitive emissions etc. Since CDM projects take place exclusively in developing countries with limited economy-wide policies and measures to control emissions, emissions leakage has been a major concern for CDM policy-makers. The question of whether mid- and downstream emissions arising from incrementally produced oil should be accounted for is dependent on the terms “measurable” and “attributable” used in the definition of leakage in the CDM. The Alberta-based Offset Credits scheme contains one protocol applicable for EOR (based on gas processing); whilst this includes MRV of site-level emissions and requires ‘no leakage’ to be a project criteria it does not provide guidance on accounting for emissions leakage from mid- and downstream emissions. Similarly, under the ACR, while operators are required to take into account “leakage emissions”, exact methods are not specified.

Developing appropriate rules to account for potential leakage effects attributable to CO_2-EOR operations can be challenging, in part because linking mid- and downstream emissions to incremental oil production is a contentious and complex topic, and in part because of the various methodological challenges involved. Independent of the options to account for such emissions, a key question concerns *whether and when to account for emissions leakage*, a consideration based upon *inter alia* the scale and materiality of potential leakage risk. With respect to approaches to account for emissions leakage, Zakkour and Cook (2016) consider that in those cases where the supply from CO_2-EOR can be assumed to be *additional* to existing supply the most appropriate approach would be to develop a product-specific emissions factor that reflects emissions from mid- and downstream activities associated with the incrementally produced crude oil from CO_2-EOR. This factor can be used to “net-back” these emissions to the activity producing the crude oil from CO_2-EOR. Where there is a substitution element, they describe a first-pass methodology similar to approaches adopted under in the CDM for grid connected renewable energy projects, where a combined margin approach is used. They note however that this is proposed only to foster further debate on the matter (ibid).

4.2.3 Accounting for CO_2 utilisation

Certain types of CO_2 utilisation activities can also provide opportunities for GHG mitigation but careful consideration is required, because the CO_2 can often only be stored for a short period of time before being emitted elsewhere. The review finds that this issue can likely be accommodated within most GHG accounting rules worldwide, subject to implementation and clarification. For example, under IPCC guidance, captured CO_2 can be deducted from national inventory categories, subject to its being accounted for elsewhere within the relevant sector where CO_2 is re-emitted (e.g. transport; agriculture).[17] In practise, the national inventory compiler may decide whether or not to account for CO_2 utilisation activities on a case by case basis, according to the availability of sector-specific guidance, and as such this appears to represent an area of uncertainty in need of testing and/or further clarification.

Similarly, the GHG accounting rules associated with several sector-based scheme worldwide do not preclude CO_2 utilisation. For example they could be included and recognised within the EU ETS, subject to associated MRV rules being developed and approved under EU comitology process. Other schemes would likely need appropriate methodologies to be approved, with reference to IPCC guidance. The inclusion of CO_2 utilisation technologies within project-based schemes would similarly require the development of appropriate accounting methodologies. In all cases, it is noted that adequate accounting for abatement effects arising from CO_2 utilisation pose various methodological challenges when considering the extremely wide range of technology and emissions reduction pathways involved, and the uncertainties involved.

[17] Vol. 2 Chapter 2; page 2.37

5 REFERENCES

ACR, 2010. *American Carbon Registry Standard*. Version 2.1. October 2010.

AESRD, 2013. *Technical Guidance for Offset Project Developers*. Version 4.0. February 2013. Calgary, Alberta. *Alberta Environment and Sustainable Resource Development*.

C2ES, 2012. Greenhouse Gas Accounting Framework for Carbon Capture and Storage Projects. Centre for Climate and Energy Solutions. Arlington, February 2012.

Commonwealth of Australia, 2014. *National Greenhouse and Energy Reporting (Measurement) Amendment Determination 2014 Departmental Commentary.* May 2014, Canberra.

EC, 2013. *Implications of the Reuse of Captured CO_2 for European Climate Action Policies*. Report to DG Climate Action by Ecofys and Carbon Counts.

IEAGHG, 2007. *Carbon Dioxide Capture and Storage in the Clean Development Mechanism*. IEA Greenhouse Gas R&D Programme, Report 2007/TR2. Cheltenham, April 2007.

IPCC, 2005. *Special Report on Carbon Dioxide Capture and Storage.* Metz, B, Davidson, O., de Coninck, H. C., Loos, M., and Meyer, L. A. (eds.), 2005. Prepared by Working Group III of the Intergovernmental Panel on Climate Change Cambridge and New York: Cambridge University Press.

IPCC, 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Eggleston H.S., Buendia L., Miwa, K., Ngara, T. and Tanabe, K. (eds.). IGES, Japan.

UNFCCC, 2005. *Modalities and procedures for a clean development mechanism as defined in Article 12 of the Kyoto Protocol*. Decision 3/CMP.1. Montreal, 2005.

UNFCCC, 2011. *Modalities and procedures for carbon dioxide capture and storage in geological formations as clean development mechanism project activities*. Decision 10/CMP.7. Durban, 2011.

US EPA, 2013. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011*. Annex 2 (Methodology for estimating CO_2 emissions from fossil fuel combustion), P. A-68, Table A-38 and Table A-45. U.S. Environmental Protection Agency, Washington, DC. U.S. EPA #430-R-13-001 (PDF) (429 pp, 10.6 MB).

US EPA, 2014. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012*. US Environmental Protection Agency, April 15. Washington D.C.

WBCSD/WRI, 2004. *The GHG Protocol for Project Accounting*. Available at: http://www.ghgprotocol.org/standards/project-protocol

Zakkour, P. D, Cook, G., Carter, A., Streck, C. and Chagas, T., 2011. *Assessment of climate finance sources to accelerate carbon capture and storage deployment in developing countries*. A report by Carbon Counts and Climate Focus for the World Bank. 16th June 2011. Washington D.C.

Zakkour, PD. Cook, G. and French-Brooks, J., 2014. *Biomass and CCS – guidance for accounting for negative emissions*. Report 2014/05, July 2014, IEA Greenhouse Gas R&D Programme, Cheltenham, UK.

Zakkour, PD. And Cook, G., 2016. *Quantifying and monitoring emissions reductions from CO_2-EOR*. Report 2016/06, July 2016, IEA Greenhouse Gas R&D Programme, Cheltenham, UK.

Carbon Counts Company (UK) Ltd.

web: www.carbon-counts.com

email: enquiries@carbon-counts.com