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WP6 Public Perception Assessment
Deliverable 6.2 Comprehensive description of sub-seabed storage
Lead beneficiary number: 2 - Plymouth Marine Laboratory

"The language of CCS"

Definitions, explanations

and some frequently asked questions

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Contents:

Preamble

Perception of a technology has some relationship with the words used to name or describe it. Terms can be so specialized that they alienate interest in the lay public or they may be unclear when they have a short history of usage in relation to a new technology, thus causing confusion. In other cases a specialist term can become familiar while at the same time losing its precise or original meaning. In addition, in a multidisciplinary field like CCS, even technical experts might have difficulty in understanding the "jargon" of their colleagues from different disciplines. The present work is aimed at supporting, both within and outside the scientific community, a process of sharing, discussion and clarification of terms that some of us use every day but of which others, particularly the general public, have no knowledge. This is related and supportive of the work being done in WP6 to study public perception of CO_2 geological storage, since all communications about it have to take into account that the "language of CCS" is mainly unknown to the general public. We hope that this work will be useful for all to better communicate and thus support a correct perception and understanding of what CO_2 geological storage really is.

The Process

This document is produced as an output of Work Package 6 of the project "**ECO2 - Sub-seabed CO2 storage: Impact on Marine Ecosystems".** This is a large scale integrating collaborative project funded by the European Commission (EC) FP7 work program topic OCEAN.2010.3 Sub-seabed carbon storage and the marine environment. (http://www.eco2-project.eu/)

This glossary represents an amalgamation of the original thoughts and work of many people and organisations. These have been brought together after an extensive search of the relevant CCS and related literature for glossary entries and definitions; accessing the growing number of partial and often very subject specific glossaries that already exist across the worldwide web (web addresses can be found at the end of the glossary). A consultation with ECO2 scientists, other members, and science advisory board members has elicited useful comments and suggestions, which have also been embraced into this document. Bringing together such a diverse range of opinion and attempting to gain agreement has proved challenging and surely illustrates the need for this glossary. It is recognised that despite this being the most exhaustive glossary on the subject of CCS in existence, it like the technology and science of CCS, is likely to need constant amendment to keep it current and useful.

Introduction

Every discipline requires its own lexicon to support clear communication and to minimise confusion, especially where complex concepts are being explained. Much of the resulting 'jargon' may, though not always, be common across related subjects, with the same words or phrases being used in quite different ways within differing subject contexts. This can lead to misunderstandings and be a barrier to effective communication. For instance the term 'generic', in a biological sense – pertaining to a Genus, is quite different to the same word in a pharmaceutical context – out of patent and produced by more than one company .

Within a topic area, such as CCS, which encompasses a multitude of scientific disciplines and additionally a broad audience of non-scientific stakeholders, the opportunities for confusion are amplified greatly. Environmental subjects, which are potentially contentious, can also attract interest from an essentially 'lay' public, who may have a passing acquaintance with some of the language but are not likely to have an in depth appreciation of the true or implied meanings of some words or phrases.

If clarity across disciplines or engagement with non-scientific audiences is an aim, then attention should be paid to the precision and consistency of the language that is being used, so as to avoid ambiguity of meaning. However, as the science and technology of CCS is still in development so is some of the terminology, not least because of the wide range of scientific, socio-economic, legal and policy areas that are involved.

CCS is a subject area where there is considerable overlap and confusion, even within the ranks of its proponents, as to the exact meaning of some words and definitions. It is the object of this work package Deliverable 6.2 to look at the CCS language, compile a glossary and suggest alternative, acceptable definitions where appropriate. For the purposes of this D6.2 the immediate intended audience are the consortium members themselves, thus encouraging consistency within the ECO_2 project. As a public document stakeholders should also find an agreed definition and glossary of terms useful and less confusing than the status quo. It is to be hoped that the wider CCS constituency might also embrace such a 'common language'. Following on from this a simplified version for wider public consumption is produced; this will be further developed to include diagrams and other illustrations to make definitions simple to understand by lay members of the public. Additionally the glossary has formed the basis for providing answers to frequently asked questions (FAQs), to further inform these FAQs questions asked by interviewees during public perception surveys have also been used. Both the simplified glossary and the FAQs will be placed on the ECO2

website where they can be accessed and scrutinised by a wider range of interested individuals and organisations; this should encourage further development and refinement.

Where there is confusion or overlap resulting in, sometimes, widely differing definitions for the same term attempts have been made to amalgamate the opinions into a single definition. Where this has proved impossible alternative definitions are included. But as the fundamental idea behind this glossary is to reach consistency in the use of terminology, there is a process of evolution to be followed and we welcome any further suggestions to be considered for inclusion in later editions of the glossary.

One area where differing definitions cannot be amalgamated is where legal terminology is already established. In the few cases where this occurs there is a distinction made between the 'scientific' and the legal definitions of the same word or phrase. Users should make it clear when using definitions whether they are doing so within a legal or scientific framework.

Access to documents

Access to the full glossary, the shortened 'lay public' version and the FAQs is available via the ECO2 project website - www.**eco2**-**project**.eu/

Some basic terminology

CCS – CARBON DIOXIDE CAPTURE AND STORAGE

Whilst the ECO_2 project is primarily concerned with the impact on marine ecosystems of an unintentional leak following the use of sub-seabed geological strata as a storage medium for large quantities of anthropogenically generated carbon dioxide (CO_2) it is worth discussing the Carbon dioxide Capture and Storage process of which it forms a part. Surprisingly, even the meaning of the term - abbreviated to CCS - is not universally agreed upon. There are variations which appear to be almost interchangeable, so heightening the opportunity for confused and disengaged public and stakeholder groups. This can only fuel the "If the scientists cannot agree amongst themselves, why should I believe them?" debate. It is fundamental that we introduce a high degree of clarity into how we communicate amongst ourselves and externally, the first stage is to agree exactly what CCS stands for.

Variations on a theme include: Carbon Capture and Storage; Carbon Capture and Sequestration; Carbon dioxide (CO_2) Capture and Storage; Carbon dioxide Capture and Sequestration. Indeed, whilst the ECO_2 project "*will establish a framework of best environmental practices to guide the management of offshore CO_2 injection and storage and as addendum to the EU directive on 'Geological Storage of CO_2' for the marine realm*", the opening lines of its 'Concept and Objectives' entry on the ECO2 website use the words CARBON and Carbon Dioxide thus: "*The ECO_2 project sets out to assess the risks associated with storage of CO_2 below the seabed. Carbon Capture and Storage (CCS) is regarded as a key technology for the reduction of CO_2 emissions from power plants and other industrial sources at the European and international level.*" It is not clear whether they refer to the same thing and so are being used interchangeably, or whether one is a subset of the other! This apparent confusion also appears within the FP7-OCEAN-2010 project call. Sequestration is also the term used by US DOE, another example of how accepted definitions differ across geographical boundaries.

In many documents Carbon Capture and Storage is used as a headline title but later in the same documents the term CO_2 storage is used – the implication being that it is the element carbon which is being captured and stored, and CO_2, as the gas, is only one aspect, or that the carbon miraculously transforms into CO_2 just prior to injection and storage! Similarly, in verbal communication the term 'carbon storage' is used commonly, both in interactions among scientists and in interactions between scientists and other groups. This is likely to be because it is the simplest and shortest form to use – laziness compromising accuracy!

Additionally the use of the word carbon leads to problems when translated into languages other than English, when it often becomes 'coal'.

C or CO_2?

Carbon (C) Is the chemical element of atomic number 6, a nonmetal that has two main forms (diamond and graphite). Carbon dioxide is a colourless odourless gas formed by a combination of carbon and oxygen, it occurs naturally but is also a by product of various human activities including some industrial processes and the burning of fossil fuels. CO_2 is a recognised greenhouse gas.

Carbon - Problems begin with the widely and traditionally used word CARBON, and objections (AUSTRALIA/CANADA) to its use include:

> Carbon implies a solid, either a lump of coal, the graphite in a pencil or a diamond. It is often thought of as the end product of combustion, is black and powdery.
>
> In a strictly chemical sense carbon is not collected or captured, nor is it injected into subsurface strata, $C0_2$ is. Trees will store carbon as part of their tissues – a more accurate use of the term carbon storage.
>
> Using the term carbon immediately requires the explanation that it is actually CO_2 that is being captured and stored. As far as analysts are concerned conversions have to be undertaken to convert to the same 'currency' or 'units' – CO_2 equivalents.

Carbon dioxide (CO_2) – Carbon Dioxide is beginning to be used as the 'C' in CCS and is often included within documents that are headed Carbon Capture and Storage. Apart from the traditional use of Carbon Capture and Storage, **Carbon Dioxide (or CO_2) Capture and Storage** is a more accurate and more logical description of what is actually happening.

> It is actually CO_2 that is being collected, transported and stored.
>
> CO_2 is widely recognised (in the press, media and public, as well as the scientific community) as being an important greenhouse gas, so there is an immediate link between problem and solution. It is not CARBON per se that is leading to global warming and its associated phenomena.
>
> In some countries, notably Australia and Canada, where CCS is at a more advanced or accepted stage, CO_2 is the favoured 'C', this approach appears to be gaining momentum as a refinement of the language.
>
> It is the terminology used by the IPCC and so immediately encourages consistency

It is suggested that Carbon dioxide (CO_2) Capture and Storage be used in future and that Carbon Capture and Storage be phased out as being less accurate.

CAPTURE

There appears to be no debate about the use of the word CAPTURE as the second 'C'. Capture of CO_2, by whatever means, describes exactly what is happening. The word REMOVAL does appear from time to time in descriptions of CCS, largely as an alternative word to allow for more flowing text and writing style. In a strict sense REMOVAL implies a once and for all and destructive process, which contradicts the idea of putting the CO_2 away in storage.

STORAGE,SEQUESTRATION or DISPOSAL?

Storage and sequestration are used in an interchangeable way, both describing the final part of the CCS process according to the accepted definitions. To be pedantic neither word is ideal. Storage implies something which is put away to be retrieved at a later date – this is not a stated intent at this stage of CO_2 adaptation/mitigation, although it might be in future if there is a commercial driver for large quantities of CO_2. However the use of the term 'storage' does have different legal implications to 'disposal' in terms of liability under EU legislation – that is, if you 'dispose' of something you take responsibility for anything that may ever happen to the material in the future, whereas this is seemingly not quite the same as 'storing' it and thereby retaining ownership of it. Disposal does occur occasionally, but is largely discouraged as it implies that CO_2 is garbage, and hence hazardous or directly polluting – it should be avoided. ('But see Carbon dioxide as a pollutant' in glossary) SEQUESTRATION, does appear to have its merits but there is room for much confusion with legal terminology, and elsewhere in chemistry. SEQUESTRATION also has an accepted link with more natural or biological processes – the planting of trees to offset CO_2 is an often used example of sequestration. Indeed the OECD defines carbon sequestration as: "a biochemical process by which atmospheric carbon is absorbed by living organisms, including trees, soil micro-organisms, and crops, and involving the storage of carbon in soils, with the potential to reduce atmospheric carbon dioxide levels." Sequestration might also be taken to involve an action on the part of the storage medium – so trees sequester carbon within their tissues, geological sequestration implies that the strata are doing the sequestering. But above all when talking to a non-scientific audience, STORAGE means putting something away, out of immediate reach, while sequester (with the same dictionary definition) means very little, if anything to most. This is not to say that SEQUESTRATION should always be avoided, more that it should be regarded as a specific sub-set of STORAGE.

The really important point is that both words are being used for the same meaning and within the same phrase expanded from CCS – this can cause confusion by lack of

consistency. It is therefore suggested that as STORAGE is already the term which is most used as the overall term, is increasingly being used and appears to be the most accepted term for this process across Europe, and avoids the confusion associated with other terms, it should be accepted 'S'.

Recommend: The process and activities which have become abbreviated to CCS should be collectively known as **Carbon dioxide (CO_2) Capture and Storage (CCS).** CO_2 sequestration by means of natural agents such as forests or phytoplankton enrichment or minerals should be regarded as a sub-set of storage**.**

CCS – WHAT IS IT?

Having established a consensus view on the process descriptor – **Carbon dioxide (or CO_2) Capture and Storage** - the next challenge is to define exactly what it means.

There are many definitions of CCS to be found in articles and reports, on websites and in the press and media, yet despite this plethora there seems to be little debate about the definition of CCS in a general sense. The variation is most likely generated by a desire to word things differently, to appeal to a particular audience level or to add greater detail, but more or less they are all follow the same principle.

Without inventing yet another form of words, just to be different, a succinct definition which has been provided by the Intergovernmental Panel on Climate Change ('IPCC Special Report on Carbon Dioxide Capture and Storage') provides a good, short definition of the overall process.

> ***"Carbon dioxide (CO_2) capture and storage (CCS) is a process consisting of the separation of CO_2 from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere."***

This general definition is perfectly acceptable at a high level but it encompasses a wide range of sub-processes including: geological storage of CO_2, deposition into the water column on the deep ocean floor and conversion into solid minerals. Whilst other elements of the entire CCS process and more specifically the storage aspects are included within the accompanying glossary (an ongoing collation and refinement) as far as ECO2 is concerned, it is geological storage and more specifically sub-seabed storage of CO_2 and its potential impacts that are the subject of this project delivery. Sub-seabed should be quite self-explanatory meaning below the bed of the sea. However it does not imply any particular depth or even whether the CO_2 is intended to be stored just beneath the unconsolidated sediment/water interface or within consolidated strata. A definition is provided, which if adhered to will provide consistency.

Comprehensive glossary of terms relevant to CO2 sub-seabed storage

Partial glossaries exist in a range of documents and on a large number of websites. These have been brought together into a single document for consideration as a 'standard' set of definitions for the language of CCS, particularly as it pertains to sub-seabed storage. Definitions of words and phrases differ depending upon the particular interest of the document or website. Where these are similar they have been amalgamated into a single definition intended to be the recommended definition, where there is a distinct subject 'angle' on a particular meaning, both definitions will be included. Additional entries to this list are welcomed in order to ensure it is as comprehensive and accurate as possible, and it is intended that updates will be made as new terminology is developed or definitions evolve.

Many of the definitions differ only in small detail, such as the arrangement of words, and are likely to be the result of 'borrowing' definitions from other sources. Likewise in this document an combination of definitions has been used to generate a preferred, clearer, definition, but where a suitable definition is used verbatim the source is acknowledged. However, many definitions are difficult or impossible to track to original source, thus omission of a credit is unintentional and the authors would be very pleased to receive corrections. (Contact author is Kelvin Boot (PML) kelota@pml.ac.uk)

A

Abatement - A reduction in the amount, degree or intensity of emissions like CO_2

Absorption - The process by which one substance, such as a solid or liquid, takes up another substance, such as a liquid or gas, through minute pores or spaces between its molecules. A paper towel takes up water, and water takes up carbon dioxide, by absorption.

Active project - A project under construction or in operation. An active project can be under construction (execute/execution stage) or in operation (operate/operational stage). In CCS terms an active project means from when the first CO_2 injection starts until CO_2 injection has ceased and the site is relinquished. Active projects are those that have a valid storage permit, even if responsibility passes to another agency or organisation such as the relevant state authority.

Adsorption - (in CCS) The process by which a material attracts carbon dioxide to its surface so it can be captured and/or stored

Amines - Derivatives of ammonia used as solvents in post combustion CO_2 capture process to absorb carbon dioxide from the flue gas stream. The amine is heated to release high purity CO_2 and the CO2-free amine is then reused. This technique can be used in power plants for cleaning of flue gas stream. (Power Plants)

Anthropogenic - This term describes effects, processes, objects, or materials (such as climate change gases) derived from human activities, as opposed to those occurring naturally and without human influence.

Anticline - Folded geological strata that is concave downwards (convex upwards)

Aquifer - The technical term for a geological structure whose rock is permeable, or porous enough to allow significant flow of fluids. Aquifers are bound by natural seals like cap-rock. Aquifers closer to the surface of the ground often contain freshwater suitable for human consumption, deeper aquifers are usually filled with salt water – these are called saline aquifers (however some suggest that the term saline formation might be a better substitute as it avoids any confusion with aquifers for water supply) – and maybe suitable for CO_2 storage.

Aquifuge - A rock which contains no interconnected openings or interstices and therefore neither stores nor transmits water (USGS).

Aquitard - A confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer; a leaky confining bed. It does not readily yield water to wells or springs, but may serve as a storage unit for ground water (USGS) (AGI, 1980).

Atmosphere - The layer of gases surrounding the earth; the gases are mainly nitrogen (78%) and oxygen (around 21%).

B

Basalt - A type of basic igneous rock which is typically erupted from a volcano. May have porosity and permeability in the fractures or cavities between blocks of solid rock.

Basel Convention - UN Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, which was adopted at Basel on 22 March 1989.

Basin - A geological region with strata dipping towards a common axis or centre, so forming a 'basin' shape.

Bathymetric - Pertaining to the depth of water above the seabed.

Benthic - Pertaining to conditions on the seafloor. Used as a descriptive term for the animals and plants that live on the seabed (the benthos). Benthic organisms, may be fixed to the substrate, may burrow through it or move across it.

Benthos – A collection of organisms living on a lake or sea bed.

Bio-Accelerated Sequestration - A concept of using microbial organisms (microscopic plants or animals) with CO_2, in geologic formations, to sequester the CO_2 and/or convert it to methane.

Bio-CCS – a large scale technology intended to combine sustainable biomass conversion with CO_2 Capture and Storage – eg in biofuels and bio-energy production. It is already being used in the USA.

Bioindicator – An organism or biological response that reveals the presence of pollutants or other impacting factors, by the occurrence of typical symptoms or measurable responses.

Biological indicators - Species which can be used by observers to determine how various conditions in an environment have changed over time.

Biomass-based CCS – CO_2 capture and storage in which the feedstock is Biomass.

Biomonitor – An organism that provides quantitative information on the quality of the environment around it.

Biosphere – That part of the Earth and its atmosphere which supports life or is capable of supporting living organisms.

Blowout – An uncontrolled eruption of oil or gas from wells during drilling or from abandoned wells subject to repressurisation . Like many other terms CCS has borrowed this from the hydrocarbon industry to describe an uncontrolled eruption of CO_2 from an injection, a monitoring or an abandoned well. .

Brine Water: Water with a salt concentration greater than 35 parts per thousand (3.5%). Sea water has a similar average concentration. Brines in underground formations can contain 20% salt or more.

Brine formation – see saline formation

Bulk CO_2 - Unprocessed gaseous CO_2, with a CO_2 content typically in excess of 95%

Buoyancy – The upward force acting on an object placed in a fluid – the force is equal to the weight of fluid displaced by the object. There is a tendency of a fluid or solid to float on or rise through a fluid of higher density.

C

$CaCO_3$ - Calcium carbonate

CaO - Calcium oxide

Capillary action – The movement of water in the interstices of a porous medium due to capillary forces (USGS, ASTM, 1990).

Cap-rock - Layer of rock that is very difficult to permeate, allowing it to act as an upper seal to prevent liquids and gases from flowing out of a formation or reservoir. Anhydrite, gypsum, limestone, sulphur, and clay rocks can form cap-rocks.

Capture - The removal of CO_2 resulting from fossil fuels' use.

Capture efficiency - The fraction of CO_2 separated from the gas stream of a source.

Carbon credit - A convertible and transferable instrument that allows an organization to benefit financially from an emission reduction. (CO_2 NetEast)

Carbon Dioxide (CO_2) - A colourless, odourless gas formed by carbon and oxygen to be found in the atmosphere and in the underground. It is derived from many sources: volcanic eruptions, rock alterations, decomposition of organic matter, combustion of fossil fuels, etc. It is also produced when animals (including humans) breathe. Carbon dioxide is essential to the photosynthesis process that sustains plant, upon which many animal species, in turn, rely. Although relatively non-hazardous, it can create lethal oxygen-deficient environments in high concentrations (especially in confined spaces). It is one of the greenhouse gases since over the last 200 years its concentration in the lower atmosphere has increased from 270 parts per million (PPM) to 380 ppm.

Carbon dioxide as a pollutant – There is some debate as to whether CO_2 should be regarded as a pollutant. One argument says that it should not be as it is a naturally occurring substance essential for life. However even useful substances in the wrong place and in excess can become polluting, for example iron is needed as a micro nutrient but becomes a pollutant at high concentrations.

Carbon dioxide Sequestration - The fixation? of carbon dioxide and other greenhouse gases by natural systems such as forests or phytoplankton, that would otherwise remain in the atmosphere. In natural systems plants and oceans sequester carbon for utilisation in life

processes such as growth of tissue. Carbon dioxide sequestration in CCS context is often regarded as synonymous with and replaced by the term carbon dioxide storage ie (The term "carbon sequestration" is used to describe both natural and deliberate processes by which CO_2 is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments (vegetation, soils, and sediments), and geologic formations. (USGS Fact sheet 2008-3097. Carbon Sequestration to Mitigate Climate Change. http://pubs.usgs.gov/fs/2008/3097/). For the purposes of this glossary sequestration is best reserved for natural systems, storage is regarded as a human activity following active capture for removal to prevent CO_2 entering the atmosphere.

CCR - Carbon capture ready. See CCSR

CCS – Abbreviation for Carbon capture and storage or Carbon dioxide Capture and Storage. The two terms are used interchangeably, for reasons of clarity and consistency Carbon dioxide Capture and Storage should be preferred.

CCSR - A CCSR facility is a large-scale industrial or power source of CO2 which could and is intended to be retrofitted with CCS technology when the necessary regulatory and economic drivers are in place. (www.globalccsinstitute.com)

CCUS - Carbon capture, use and storage (originated as a term in China) or (US DOE) carbon capture, storage and utilisation This term reflects a growing ambition to make use of CO_2, possibly even to profit from its capture. EOR is one example of CCUS, biochar another, where charcoal is produced and added to soils where its contained carbon is locked away, or re-used by growing plants.

Climate change - Defined by the United Nations Framework Convention on Climate Change (UNFCCC) as "change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

Closure of a storage site - means the definitive cessation of CO_2 injection into that storage site.

CO - Carbon monoxide

CO_2 - Carbon dioxide

CO_2 avoided - The difference between CO_2 captured, transmitted and/or stored, and the amount of CO_2 generated by a system without capture, net of the emissions not captured by a system with CO_2 capture.

CO_2 capture – The removal of CO_2 from a process stream or from the atmosphere to produce a highly pure stream of CO_2 amenable for conversion or storage. CO_2

capture systems are assessed on the purity of the captured CO_2, the percent of total CO_2 that is captured, and the capital cost and energy use per unit of CO_2 captured.

CO_2 equivalent - A measure used to compare emissions of different greenhouse gases based on their global warming potential. If CO_2 is given a value of 1; methane is 25 times more potent; and nitrous oxide 298 times more powerful than CO_2. Global warming potential is one, very important measure, but total amounts being emitted to the atmosphere are a very significant factor, which make CO_2 especially worrying.

CO_2 fixation – The immobilisation of CO_2 by its reaction with another material to produce a stable compound. (CO_2 NetEast).

CO_2 plume – the dispersing volume of carbon dioxide within the geological formation or other medium, such as seawater during a seep.

CO_2 reuse - A practical application of captured, concentrated CO_2 that adds value and which can partially offset the cost of CO_2 capture as a transitional measure to assist the accelerated uptake of CCS. (see also CCUS).

CO_2 stream – a flow of substances that results from CO_2 capture processes. This could be from a factory along pipework, for example.

CO2GeoNet – European Network of Excellence on the Geological Storage of CO_2 is an Association of 13 research institutes from 7 European countries, engaged for scientific advancement in the field of Co2 storage (http://www.co2geonet.com/).

Compressed - Put under pressure so that more gas will fit into the same volume; with carbon dioxide it is compressed until it is like a dense fluid.

CONCAWE - Conservation of Clean Air and Water in Europe .

Confining zone - A geological formation, group of formations, or part of a formation that is capable of limiting fluid movement above an injection zone (USGS)(40 CFR 146.3).

Connate pore fluids – Fluids that are captured in the pores of sedimentary rocks as they form.

Containment - Restriction of movement of a fluid (such as supercritical CO_2) to a specific place or space (like a storage aquifer or an oil or gas field in disuse).

Contaminants - Any non-CO_2 substance associated with the stored CO_2 and any associated leaks, including any impurities that might be associated with the injected CO_2 stream, and

any substances that might be released or formed as a result of sub-surface storage and/or leakage of CO_2.

Corrective measures - Any measures taken to correct significant irregularities or to close leakages in order to prevent or stop the release of CO_2 from the storage complex. (EC)

Critical point - The temperature and pressure point above which carbon dioxide gas and liquid phases cannot exist as separate phases.

D

Deep – In terms of local geology anything within the bedrock is considered deep while anything in the overlying unconsolidated sediments is considered shallow. IN CCS terms deep usually refers to depths greater then 800 metres.

Deep coal seam – a seam which is too deep to be mined economically. Often suitable for CO_2 injection/storage. CO_2 is adsorbed to the coal typically replacing methane. This methane can then be recovered.

Deep saline aquifer –An underground rock formation deep beneath the surface of the earth that is made up of permeable materials and containing highly saline fluids, and which may be suitable for storage of CO_2. The most suitable reservoirs are those at depths greater than 800m

Demonstration phase - Demonstration phase usually means that the technology is implemented in a pilot project or on a small scale, but not yet economically feasible at full scale. However, because of the nature of CO_2 storage projects it is deemed necessary to demonstrate efficacy on a larger scale to demonstrate costs and technologies realistically.

Depleted gas fields - Underground rock where most of the economically viable gas has already been extracted by traditional means from between the grains of rock.

Depleted oil fields - Underground rock where most of the economically viable oil has been already been extracted from between the grains of rock.

Depleted reservoir - A structure like an oil or gas reservoir where production has ceased or has significantly reduced from past exploitation.

Diagenesis - Processes that cause changes in sediment after it has been deposited and buried under another layer.

DOE - Department of Energy (United States).

Dry ice - Solid carbon dioxide.

E

EBTP – The European Biofuels Technology Platform. (www.biofuelstp.eu)

ECBMP(R) - Enhanced Coal Bed Methane Production (recovery), the use of CO_2 to enhance the recovery of the methane present in unminable coal beds through the preferential adsorption of CO_2 on coal.

ECO2 – FP7 research project that will establish a framework of best environmental practices to guide the management of offshore CO2 injection and storage and as addendum to the EU directive on "Geological Storage of CO2" for the marine realm. This includes the quantitative assessment of potential and actual impacts on marine ecosystems at a CO2 injection facility and the entire storage site. A comprehensive monitoring concept for storage sites will be developed comprising innovative techniques that are apt to detect different modes and levels of leakage including that of pre-cursors. Field studies at operated and prospective sites (Sleipner, Snøhvit) and natural CO2 seeps (North Sea, Mediterranean Sea) are completed by lab experiments and numerical simulations on different scales. An integral part of the project is to transfer this knowledge into a risk management concept and an economic valuing of the costs of leakage, monitoring, mitigation measures, and a clear communication framework. An understanding of the precautionary principle as primary tool for balancing the environmental risks will be built. (Abstract from www.eco2-project.eu)

Economic Potential - is the amount of greenhouse gas emissions reductions from a specific option that could be achieved cost-effectively, given prevailing circumstances (the price of CO_2 reductions and costs of other options). The estimated range of economic potential for CCS over the next century is roughly 200 to 2,000 $GtCO_2$.

Ecosystem - A dynamic community of plants, animals and microbes together with their physical environment; a natural system with interacting and interdependent relationships.

EGR – See Enhanced Gas recovery.

Emissions – For the purposes of the UInited Nations Framework Convention on Climate Change (UNFCCC) - "Emissions" means the release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time.

Enhanced coalbed methane production (ECBM) - When CO_2 is injected into coal beds, it displaces methane molecules that are attached to the surface of the coal. This methane that

is dislodged from the coal is then free to move about in the coal, and it can be pumped out of the bed. This methane extraction process is referred to as "Enhanced Coal Bed Methane" or "ECBM". (USGS)

Enhanced Gas Recovery - The incremental gas recovery from depleted conventional gas reservoirs. EGR is usually achieved by pumping another substance into the reservoir to 'push out' the remaining gas for economic use. CO_2 can be used for this purpose and provide the bonus of CO_2 storage. As gas is removed from natural gas reservoirs, the pressure of the reservoir decreases. As the pressure within the reservoir decreases, it becomes more difficult to recover more gas. By injecting CO_2 into the natural gas reservoir, the pressure of the reservoir is increased, and more gas can be recovered (USGS).

Enhanced Oil Recovery (EOR) - CO_2 can be injected into depleted oil reservoirs to enhance oil recovery from the reservoir. CO_2 will dissolve into the residual oil in place, which lowers the viscosity of the oil. The lower viscosity enables the oil to flow more easily, which makes it possible to extract more oil from reservoirs (USGS definitions). EOR is a generic term for techniques for increasing the amount of crude oil that can be extracted from an oil field. It is also known as improved oil recovery or tertiary recovery. Using EOR 30-60% more of the reservoir's original oil can be extracted compared to 20-40% using primary and secondary recovery. Fluids (such as steam of CO_2) injected into the reservoir 'push' the oil out.

Enhanced weathering – Enhanced weathering is the process by which carbon dioxide is sequestered from the atmosphere through the dissolution of silicate minerals on the land surface. (International Journal of Greenhouse Gas Control: The potential of enhanced weathering in the UK. July 2012).

Environmental Impact Assessment (EIA) -Environmental Impact Assessment (EIA) is a process of evaluating the likely environmental impacts of a proposed project or development, taking into account inter-related socio-economic, cultural and human-health impacts, both beneficial and adverse.

UNEP defines Environmental Impact Assessment (EIA) as a tool used to identify the environmental, social and economic impacts of a project prior to decision-making. It aims to predict environmental impacts at an early stage in project planning and design, find ways and means to reduce adverse impacts, shape projects to suit the local environment and present the predictions and options to decision-makers. By using EIA both environmental and economic benefits can be achieved, such as reduced cost and time of project implementation and design, avoided treatment/clean-up costs and impacts of laws and regulations. (Convention on Biological Diversity - http://www.cbd.int/impact/whatis.shtml)

Eliminatory criteria – a potential storage site that does not pass these criteria would not normally be considered for CO_2 storage. There are three categories:

> **critical** - failure to meet any of these would deem the site as being not suitable;
>
> **essential** – if one of these (seismicity, faulting and fracturing, size, hydrogeology) is not met but the others are there may be case for further consideration;
>
> **desirable** – there are 14 criteria in this section, none of these is eliminatory in itself, and a potential site that 'fails' to satisfy several of these may still be considered, but too many would result in further consideration is a likely requirement. (For further detail on the Eliminatory Criteria please see Bachu, S. Screening and selection criteria, and characterisation techniques for the geological sequestration of carbon dioxide (CO_2) in: Maroto-Valer, M. Mercedes; Developments and innovation in carbon dioxide ()CO_2) capture and storage technology. Woodhead Publishing Ltd., 2010.

EOR – See Enhanced Oil Recovery.

Escape - (of a gas, liquid, or heat) leak from a container, eg 'the CFCs have escaped into the atmosphere'; to break free from control. In a CCS context a leak would be an unintentional escape from geological storage.

EU Geocapacity – a European research project to assess the total geological storage capacity in Europe for anthropogenic CO_2 emissions.

EU SACS -European Union Saline Aquifer Carbon Dioxide Storage Programme.

Exploration - means the assessment of potential storage complexes for the purposes of geologically storing CO_2 by means of activities intruding into the subsurface such as drilling to obtain geological information about strata in the potential storage complex and, as appropriate, carrying out injection tests in order to characterise the storage site. (EC).

F

Fault – In geology a natural break in the rocks, with one side moves relative to the other. This movement may be lateral, vertical or a combination of both.

FEP - A Feature that represents a component of a storage system or an Event or Process relevant to its evolution. The term includes 'external' FEPs or EFEPs that are part of the global system but external to the storage system; the EFEPs may however act upon the

system to alter its evolution (e.g. seismic effects). Together, the FEPs of the system describe conceptual models that may be related to scenarios for system evolution.

Fixation - The immobilization of CO_2 by its reaction with another material to produce a stable compound.

Flood - The injection of a fluid into an underground reservoir.

Flue gas - Flue gas is gas that exits via a flue, which is a pipe or channel for gases from a fireplace, oven, furnace, boiler or steam generator. It often refers to the combustion exhaust gas produced at power plants. Its composition depends on what is being burned, but it usually consists of carbon dioxide (CO_2), water vapour and nitrogen (typically more than two thirds) derived from the combustion air as well as excess Oxygen (also derived from the combustion air). It further contains a small percentage of pollutants such as particulate matter, carbon monoxide, nitrogen oxides and sulphur oxides.

Fossil fuel - A general term for buried combustible geologic deposits of organic materials, formed from decayed plants and animals that have been converted to crude oil, coal, natural gas, or heavy oils by exposure to heat and pressure in the Earth's crust over hundreds of millions of years; they are hydrocarbons which produce CO_2 and other gases when burned.

Fracture – A break in rock along which no significant movement has occurred. (CO2 NET-East).

G

Geochemical trapping - The retention of injected CO_2 by geochemical reactions.

Geological formation: A geologic formation is a formally named rock stratum or geological unit. It is a rock unit that is distinctive enough in appearance that a geologic mapper can tell it apart from the surrounding rock layers and is the fundamental unit of lithostratigraphy (The scientific study and categorization of rock strata based on their lithology - color, texture, and composition). The concept of formally defined layers or strata is central to the geologic discipline of stratigraphy. Some geological formations are suitable for storing CO_2. Non-geologists may refer informally to outcroppings of rock or interesting geological features as geological formations, even though this is not technically correct.

Geological storage – see Storage, geological.

GHG (GreenHouse Gas) - Greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydroflurocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6). GHGs are responsible for maintaining the Earth at a habitable temperature, but rising

temperatures and ultimately global warming result from an imbalance leading to an increase in GHGs.

GESTCO - a European research project which determined the geological storage of CO_2 possibilities in 8 countries (Norway, Denmark, UK, Belgium, Netherlands, Germany, France and Greece)

Global Warming Potential (GWP) - A measure of the magnitude of the heat-trapping effect resulting from the addition of 1 kilogram of a gas to the atmosphere relative to that of 1 kilogram of carbon dioxide. GWP is a function of two factors (1) the instantaneous heat-absorbing ability of the gas, and (2) the length of time that emissions of the gas persist in the atmosphere, on average. See CO2 equivalent.

Greenfields - (in CO_2 storage) Geological formations where no hydrocarbon production has occurred within the potential storage area; (in CO_2 capture) New facilities where none previously existed

Greenhouse effect - A naturally occurring process that aids in heating the Earth's surface and atmosphere. It results from the fact that certain atmospheric gases, such as carbon dioxide, water vapour, and methane, are able to change the energy balance of the planet by absorbing longwave radiation emitted from the Earth's surface. Without the greenhouse effect life on this planet would probably not exist as the average temperature of the Earth would be a chilly -18° Celsius, rather than the present 15° Celsius.

Greenhouse gas – see GHG

H

Hazardous and non-hazardous waste - Potentially harmful and non-harmful substances that have

been released or discarded into the environment.

H_2 - Hydrogen

Host rock - In geology, the rock formation that contains a foreign material. In CCS a rock that receives stored CO_2.

Hydrodynamic trap - Hydrodynamic traps are quite rare. High water saturation of low-permeability sediments reduces hydrocarbon permeability to near zero, resulting in a water block and an accumulation of petroleum down the structural dip of a sedimentary bed below the water in the sedimentary formation. (Enciclopedia Britannica)

Hydrogeology - The branch of geology dealing with the waters below the earth's surface and with the geological aspects of surface waters (hydrogeological is the adjective)

I

IEA - International Energy Association

IEA GHG -International Energy Agency – Greenhouse Gas R&D Program. An international partnership that aims to evaluate technologies for reducing GHG emissions, disseminate the results of these studies, and identify targets for research, development and demonstration.

Impact – Measure of the consequences of one thing upon another

Impact assessment – A method of assessing the consequences of individual actions or projects. See Environmental Impact Assessment

Impermeable - A substance that cannot be penetrated. A rock or material that stops the movement of water or other liquids through it.

Injection of CO_2 into geologic reservoirs - CO_2 will be pumped into geologic formations from the surface, most likely as a dense, liquid-like fluid (also known as a "supercritical fluid") into either a coal bed, or a saline aquifer or hydrocarbon reservoir. If the CO_2 is injected into a depleted hydrocarbon reservoir, then additional petroleum or natural gas could be extracted (Enhanced Oil Recovery or Enhanced Gas Recovery). If the CO_2 is injected into a coal bed, then methane could be liberated and extracted (Enhanced Coal Bed Methane).(USGS definitions)

Injection well - Well used for injecting fluids into the subsurface. (USGS)

Injection zone - A geological "formation," group of formations, or part of a formation receiving fluids through a well (40 CFR Part 146.3).

IPAC-CO_2 - IPAC-CO2 Research Inc., the International Performance Assessment Centre for Geologic Storage of Carbon Dioxide, is an environmental non-government organization (ENGO) created to provide independent risk and performance assessments of CO2 storage projects.

IPCC - Intergovernmental Panel on Climate Change.

L

Lake Nyos – Lake Nyos, Cameroon, West Africa was the site of a limnic eruption in 1986, which released 80 million cubic metres of CO_2 from the lake, killing at least 1700 people. This event is often mistakenly cited as an example of the possible consequences of leakage from a CO_2 storage site. In reality the case of Lake Nyos is related to volcanic activity where CO_2 is produced continuously and thus the pressure in the reservoir increases continuously. In the case of a CO_2 storage site similar phenomena could not happen;, as is also demonstrated by natural gas reservoirs (CO_2, methane, etc) where such catastrophic phenomena have never occurred.

LCA - Life Cycle Assessment. (LCA) is a tool that can be used to assess the environmental impacts of a product, process or service from design to disposal i.e. across its entire lifecycle, a so called cradle to grave approach. The impacts on the environment may be beneficial or adverse. These impacts are sometimes referred to as the "environmental footprint" of a product or service. (RSC)

Leak - To permit the escape, entry, or passage of something through a breach or flaw. In CCS terms there is a sense of an accidental or unintentional escape of injected fluid from storage..

Leakage – Leakage in CCS terms is, for example in the CCS-Directive, “any release of CO_2 from the storage complex (Art.3 (5) CCS-directive)“ or “in respect of carbon storage, the escape of CO_2 from the storage formation (see below) in the water column and the atmosphere.” (The Risk Assessment and Management Framework for CO_2 Sequestration in Sub-seabed Geological Structures (FRAM) in the context of the London Protocol, p.31)

Limnic eruption – also referred to as ‘lake overturn’ is a rare natural disaster related to volcanic activity in which dissolved CO_2 suddenly erupts from deep lake water, suffocating any wildlife, livestock and humans it overwhelms. Lanslides, volcanic activity and explosions can trigger such ‘eruptions’.To date, only two occurrences have actually been observed: at Lakes Monuon and Nyos in Cameroon, West Africa.

Lithology - science of the nature and composition of rocks.

Lithosphere - The outer layer of the Earth, made of solid rock, which includes the crust and uppermost mantle up to 100 km thick.

Lithostatic pressure - the pressure or stress imposed on a layer of soil or rock by the weight of overlying material.

LOC - Loss of Containment is the release or escape of material, usually gas or liquid, contained inside plant equipment or piping such that it can enter the immediate

environment of the plant and potentially migrate outside of the plant boundaries (CRC NetBase.

London Convention - On the Prevention of Marine Pollution by Dumping of Wastes and Other Matter - adopted at London, Mexico City, Moscow and Washington in 1972.

M

MAOP - Maximum allowable operating pressure. The maximum pressure that a pipe or container can safely hold in normal operations.

Membranes - (in CCS) .Thin sheets of material that can separate carbon dioxide from other gases – acts like a sieve.

Mineralisation - Is a natural form of geologically storing CO_2 by the very slow reaction between CO_2 and naturally occurring minerals, such as magnesium silicate, to form the corresponding mineral carbonate.

Mineral trap - A geological formation that retains fluids through the reaction of the fluid - forming a stable mineral.

Measurement, Monitoring, and Verification (MM&V) - MM&V is defined as the capability to measure the amount of CO2 stored at a specific sequestration site, to monitor the site for leaks or other deterioration of storage integrity over time, and to verify that the CO_2 is stored and notharmful to the host ecosystem. MM&V capability will ensure safe permanent storage, reduce the risk associated with buying or selling credits for sequestered CO_2, and help satisfy regulators and local government officials who must approve large sequestration projects. MM&V will also provide valuable feedback for continual refinement of injection and management practices.

Migration - refers to movement of fluids (including injected CO_2) driven by pressure or density differential within the injection formation. This can involve movement both vertically and horizontally within the designated injection horizon. The fluids remain “trapped” by both the upper and lower bounding seal layers.

Mineral Carbonization (Mineral Carbonation) - A process in which CO_2 reacts with magnesium or calcium oxide to form mineral carbonates. The mineral carbonates are unreactive solids - highly permanent carbon storage. Challenges include slow reaction rates and the large tonnage of mineral-rich earth that must be mined for each unit of CO_2 sequestered.

Mineral trapping - see Trapping, Mineral.

MM&V (MMV) – see Measurement, Monitoring and Verification.

N

Natural analogue - A natural occurrence that mirrors in most essential elements an intended or actual human activity. In CCS terms natural occurring CO_2 or other gases (methane mainly) reservoirs from which much can be learned regarding trapping mechanisms, cover rock efficiency and eventually gas migration mechanisms to the surface where seepsexist. A subset of Natural Analogue are volcanic and geothermal areas where evident gas emanations (gas vents) occur. These areas are examples of unsuitable sites for CO_2 storage but are useful 'natural laboratories' for studying gas migration mechanisms, the effects of gas emanations on terrestrial and marine life and for testing monitoring tools.

Natural gas - Gas stored underground; it consists largely of methane, but can also contain other hydrocarbons, water, hydrogen sulphide and carbon dioxide. These other substances are separated before the methane is put into a pipeline or tanker.

Natural underground trap - A geological structure which retains fluids by natural processes.

NORSOK - Norsk Sokkels Konkuranseposisjon – Standards developed by the Norwegian Technology Centre.

O

Ocean Injection: A concept for ocean sequestration in which CO_2 is injected directly into the mid-or deep ocean waters, where it dissolves into the ocean water.(IPAC CO_2).

Ocean Sequestration: Storage of CO_2 in ocean waters. Oceans are an important part of the natural carbon cycle because they store, release, and absorb large quantities of CO_2 to and from the atmosphere. Research in this area is focused on learning more about the ocean carbon cycle, deep ocean ecosystems, and the safety and potential environmental impacts of CO_2 storage.(IPAC CO_2). See Ocean Storage. This is to be distinguished from sub-seabed storage where CO_2 is buried deep beneath the seabed in geological strata.

Ocean storage – A proposed method whereby CO_2 is injected into the deep ocean (greater than 1000m depth), where most of it would remain isolated from the atmosphere for centuries.

OECD - Organisation for Economic Cooperation and Development.

OSPAR - Convention for the Protection of the Marine Environment of the North-East Atlantic, which was adopted at Paris on September 22, 1992. (OSlo and PARis).

Overburden - Rocks and sediments above any particular stratum.

Overpressure - Pressure created in a reservoir that exceeds the pressure inherent, and normally expected, at the reservoir's depth. It is caused by the inability of **connate pore fluids** (see above) to escape as the surrounding mineral matrix compacts under pressure.

Oxyfuel combustion - The Oxyfuel combustion process eliminates nitrogen from the flue gas by combusting the fuel in a mixture of oxygen and recycled flue gases. After combustion, the flue gas is cleaned. The cleaned flue gas primarily consists of CO_2 and water vapour. By cooling the flue gas, the water vapour condenses thereby creating an almost pure CO_2 stream. The CO_2 can be compressed, dried and further purified before being transported to a storage site.

Oxy-fuel combustion capture - Burning a fuel in oxygen-rich gas. The oxygen is separated from the air, and it makes it easier to separate the carbon dioxide from the waste gases.

P

Permeability - Ability of porous and fractured material to allow fluids to flow across it. In CCS, it refers for instance to the ability of a porous rock, such as sandstone, which acts like a sponge to allow the injected CO_2 to fill the tiny spaces between grains of the rock (see pore spaces)

pH - Is a measure of hydrogen ion concentration; a measure of the acidity or alkalinity of a solution. (Chemistry Glossary: www.chemistry.about.com). pH 7 is neutral, a solution with pH less than 7 is said to be acidic; a pH greater than seven is basic or alkaline.

PHMSA - Pipelines and Hazardous Materials Safety Adminstration.

Pilot plant - The pilot plant is the necessary link between initial engineering and the demo plant. The purpose of the pilot plant is to validate the engineering work, to learn and better understand the technology and to demonstrate it.

Plume – in CCS the dispersing volume of CO_2 in the geological formation (Sitechar).

Pore space - Tiny space between the grains of a rock, usually occupied by a fluid of some sort, often water.

Porosity – percentage of the volume of a rock that is not occupied by mineral. The gaps are pores and may be filled with various fluids such as salt water, oil, methane, or CO_2.

Post-combustion capture - Separating carbon dioxide from other waste gases after a fuel is burnt.

Potential, Technical - Technical potential is the amount by which it is possible to reduce greenhouse gas emissions by implementing a technology or practice that already has been demonstrated.

Pre-combustion capture - Reacting the fuel to form a syngas made up of carbon dioxide, carbon monoxide and hydrogen; Carbon dioxide can be captured before the hydrogen is then burnt. It is also possible to convert the carbon monoxide to carbon dioxide and capture that as well, leaving only the hydrogen as a fuel to burn.

Probability – A risk rating is based on the probability of impact and the level of impact.

0 - 10% or Very unlikely to occur.

11 - 40% or Unlikely to occur.

41 - 60% or May occur about half of the time.

61 - 90% or Likely to occur.

91 - 100% or Very likely to occur.

(from Risk Management – Standard processes/definitions: probability of occurrence.(http://www.mitre.org/work/sepo/toolkits/risk/StandardProcess/definitions/occurence.html).

Projects – In terms of CCS, projects fall into the categories of: In Planning; Cancelled or Dormant; Pilot; Operational; and Finished. There are currently 8 operational sites worldwide, of which three (Sleipner, Snøhvit and K12-B are offshore, sub-seabed). Locations and more details of these can be found at http://www.sccs.org.uk/storage/globalsitesmap.html, where a useful interactive global map of all categories of projects can be accessed.

Province - An area with separate but similar geological formations.

R

REDOX - Reduction-oxidisation reaction.

Regional scale- A geological feature that crosses an entire basin. (see basin).

Reservoir - A subsurface body of rock with the porosity and permeability to store and transmit fluids.

Reservoir, hydrocarbon - A porous and/or fractured permeable underground formation containing an individual and separate natural accumulation of producible hydrocarbons

(crude oil and/or natural gas), which is contained by impermeable rock or water barriers and is characterized by a single natural pressure system.

Reservoir trap/seal - Hydrocarbons accumulation (oil and gas field) are found in geological traps below the earth surface. The fundamental characteristic of a trap is an upward convex form of porous and permeable reservoir rock that is sealed above by a denser, relatively impermeable cap rock (e.g., shale or evaporites). The trap may be of any shape, the critical factor being that it is a closed, inverted container. Deep reservoirs are, for the purposes of CO_2 sequestration, defined to be deeper than 1 kilometer. (USGS definitions).

Risk Management - entails the application of a structured process to identify and quantify the risks associated with a given process, to evaluate these,[…], to modify the process, to remove excess risks and to identify and implement appropriate monitoring and intervention strategies to manage the remaining risks" (IPCC Special Report, p.251)"

Risks due to leakage –

Global – a release that contributes significantly to climate change if some fraction leaks to the atmosphere.

Local – hazards of local significance such as may affect humans, ecosystems, groundwater. There are two types of scenario for local leaks: injection well failures or up abandoned wells, which could create a sudden and rapid release of CO_2; and leakage through undetected faults, fractures or leaking wells where the release is more gradual and diffuse, primarily affecting drinking water aquifers and ecosystems where CO_2 accumulates between the surface and the top of the water table. (IPCC)

S

Saline Formation- Underground rock where brackish water or brine occupies the tiny spaces between the grains of rock.

Saline groundwater - Groundwater in which a high quantity of salts is dissolved.

Saturated zone- Part of the subsurface that is totally saturated with groundwater.

Scenario - A plausible description of the future based on an internally consistent set of assumptions about key relationships and driving forces. Note that scenarios are neither

predictions nor forecasts. Scenarios can be quantitative (numerical), qualitative (textual) or a mixture of both.

Seabed- Borderline between the free water and the top of the bottom sediment.

Seal - An impermeable rock that forms a barrier above and around a reservoir such that fluids are held in the reservoir: a rock formation which it is very difficult for carbon dioxide and other subsurface fluids to move through under normal conditions.

Secondary recovery- Recovery of oil by artificial means, after natural production mechanisms like overpressure have ceased.

Sedimentary basin- Natural large-scale depression in the earth's surface that is filled with sediments.

Seep - To pass slowly through small openings or pores; to ooze. In CCS terms it is often reserved for a naturally occurring release of CO_2, from an underground source, such as might be seen in parts of Italy, and in the Mediterranean, for example.

Seepage - The fluid (or amount of fluid) discharged at a seep.

Selection criteria – favourable characteristics that would make a site preferable to another, all other considerations being equal. Failure to meet a selection criterion would not eliminate a site, it will only reduce its desirability or suitability.(see **eliminatory criteria**). Top level criteria would include: capacity, injectivity, confinement, risk minimisation and societal acceptance. *Maroto-Valoor (2010)*

Sequestration - To store something so that it is no longer available. Carbon sequestration involves the removal or storage of carbon dioxide so that it can't be released into the atmosphere. The term is often regarded as synonymous with **storage**, but has other confusing meanings and should be avoided in favour of **storage**. **Terrestrial sequestration** is the absorbtion and storage of CO_2 by vegetation and soils in terrestrial ecosystems.

Shale - Any of a group of fine-grained, laminated sedimentary rocks consisting of silt- and clay-sized particles. Shale is the most abundant of the sedimentary rocks, accounting for roughly 70 percent of this rock type in the crust of the Earth. Shales characteristically consist of at least 30 percent clay minerals and substantial amounts of quartz. These rocks have very low permeability.

Shallow - is a relative term that can mean different things depending on the context or on the method of study being used. For example, when applied to gas geochemistry it refers to the soil-atmosphere interface (for flux measurements) down to the top of the water table (typically 1-5m, for soil gas measurements). When applied to groundwater chemistry it can

refer to the more shallow (potable) aquifers where monitoring can occur, which could be from 10 to 50m depth. Instead when applied to geophysical methods, it could refer from the first 1-5 metres (for a technique like ground penetrating radar), to 10-100m (for methods like electrical resistivity or low-energy source active seismic). Finally another definition may refer to the local geology, whereby anything within the bedrock is considered deep while anything in the overlying unconsolidated sediments is considered shallow - this definition has the potential advantage of being linked to material characteristics (e.g. porosity) but is very site specific.

Sink - The natural uptake of CO_2 from the atmosphere, typically in soils, forests or the oceans. According to UNFCCC - "Sink" means any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere.

SiteChar - is a European research project about CO_2 storage site characterisation, which started in January 2011 and will last 3 years. Central to the Sitechar project is examining the technical, economic and societal requirements for a company to be allowed to store CO_2 underground.

Sleipner - At the Statoil Hydro-operated Sleipner fields on the Norwegian continental shelf, carbon dioxide from produced gas is captured and stored in a subsea aquifer. Emissions of more than 10 million tonnes of carbon dioxide to the atmosphere have been avoided since production started in 1996. This is more carbon dioxide than the total number of cars in Norway emit in two years. The Sleipner site is a study area within the ECO2 Project. http://www.statoil.com/en/TechnologyInnovation/NewEnergy/Co2Management/Pages/SleipnerVest.aspx

Soil carbon sequestration occurs through direct and indirect fixation of atmospheric CO_2. Direct soil carbon sequestration occurs by inorganic chemical reactions that convert CO_2 into soil inorganic carbon compounds such as calcium and magnesium carbonates. Direct plant carbon sequestration occurs as plants photosynthesize atmospheric CO_2 into plant biomass. Subsequently, some of this plant biomass is indirectly sequestered as soil organic carbon (SOC) during decomposition processes. Worldwide, SOC in the top 1 meter of soil comprises about 3/4 of the earth's terrestrial carbon.

Soil gas- Gas contained in the space between soil grains.

Solid hydrate - When an excess of CO_2 is present in relatively cold ocean water (below 8°C) a solid hydrate can form consisting of six or more water molecules that make a cage around one CO_2 molecule.

Solubility trapping - see trapping, solubility.

Solvent - (in CCS) A liquid that can soak up carbon dioxide.

Stable geological formation - A formation that has not recently been disturbed by tectonic movement.

Storage – (in CCS) a process for retaining captured CO_2 so that it does not reach the atmosphere.

Storage complex - means the storage site and surrounding geological domain which can have an effect on overall storage integrity and security; that is, secondary containment formations. (Art.3 (6) CCS-Directive)

Storage site - An underground rock formation that can store carbon dioxide; commonly this is deep sedimentary and porous rock, where there are tiny spaces between the rock grains for the carbon dioxide.

Stratigraphic trap- A sealed geological container capable of retaining fluids, formed by changes in rock type, structure or facies.

Structural trap- Geological structure capable of retaining hydrocarbons, sealed structurally by a fault or fold.

Structure - Geological feature produced by the deformation of the Earth's crust, such as a fold or a fault; a feature within a rock such as a fracture; or, more generally, the spatial arrangement of rocks.

Sub-seabed – In CCS terms, the consolidated geological strata beneath the seabed, Storage is usually at a considerable depth of thousands of metres within the strata beneath the bottom of the sea.

Supercritical - carbon dioxide (or any substance) is said to be in a supercritical state when its temperature and pressure are above its critical point. The critical point is the highest temperature and pressure at which it can exist as a gas and liquid in equilibrium. In its supercritical state, a substance shows properties of both liquids and gases, expanding to fill its container like a gas, but with the density of a liquid. The critical point for carbon dioxide occurs at a pressure of 73.8 bar (73 atm) and a temperature of 31.1°C.

T

Technical Potential – (in CCS) The amount by which it is possible to reduce greenhouse gas emissions by implementing a technology or practice that has reached the demonstration phase.

Transport, CO_2 -is the process of moving captured CO_2 through a pipeline, or by other means (eg ship) from its source to a suitable storage site.

Trap - A geological structure that physically retains fluids that are lighter than the background fluids, e.g. an inverted cup.

Trapping, Adsorbtion – CO_2 is preferentially adsorbed onto coal or organic-rich shales replacing gases such as methane. In these cases, CO_2 will remain trapped as along as pressures and temperatures remain stable. These processes would normally take place at shallower depths than CO_2 storage in hydrocarbon reservoirs IPCC.

Trapping, Dissolution – CO_2 disolves into surrounding salt water (EBTP/ZEP).

Trapping , Geochemical – where the CO_2 reacts with the in situ fluids and host rock. First dissolves in water (00's to 000's of years) becomes denser and sinks down into the formation. Next, chemical reactions between the dissolved CO_2 and rocks and minerals form ionic species, so that a fraction of the injected CO_2 is converted into solid carbonate minerals (millions of years) (IPCC).

Trapping, Mineral – CO_2 rich water sinks to the bottom of the reservoir and reacts to form minerals. (EBTP/ZEP).

Trapping, Physical - where upward migration is prevented by a cap rock, normally clay or shale, above the storage location IPCC

Trapping, Residual – CO_2 is trapped in rock pores and cannot move. (EBTP/ZEP).

Trapping, Solubility - the process in which CO_2 dissolves into formation waters. The extent of dissolution generally decreases with increasing temperature and salinity, and increases with increasing pressure. The process removes CO_2 as a separate buoyant phase.

Triple point - (of CO_2) the temperature & pressure where carbon dioxide exists as a gas, liquid and solid simultaneously.

U

UNCLOS - United Nations Convention on the Law of the Sea, which was adopted at Montego Bay on 10 December 1982.

Under-saturated - A solution that could contain more solute than is presently dissolved in it.

UNFCC - United Nations Framework Convention on Climate Change.

Unmineable coal bed - Extremely unlikely to be mined under current or foreseeable economic conditions. A coal bed that is unlikely to ever be mined – because it is too deep or too thin – may be potentially used for CO_2 storage. If subsequently mined, the stored CO_2 would be released. Enhanced Coal Bed Methane (ECBM) recovery could potentially increase methane production from coals while simultaneously storing CO_2. The produced methane would be used and not released to the atmosphere. (*IPCC Geological Storage).*

UN-IMO - United Nations International Maritime Organisation .

Utsira Formation - The Utsira Formation is a deep saline reservoir 800-1000 metres (2600-3300ft) below the sea floor, comprised of a 200-250 metre thick massive sandstone. It is estimated that the Utsira Formation is capable of storing 600 billion tons of CO_2. 3D seismic monitoring of the CO_2 injection into the Utsira Formation shows that there is no leakage of the CO_2 into other horizons. It is the receiving formation for CO_2 injection at Sleipner. http://sequestration.mit.edu/tools/projects/sleipner.html

V

Volatile organic - Any organic compound that participates in atmospheric photochemical compound (VOC) reactions; can be a nationally regulated air pollutant.

W

Water column – a notional column of water above the sediment and upwards to the surface of the sea, lake, river etc. Many aquatic phenomena: chemical, physical and biological are explained by mixing in the water column.

Well - A bored, drilled or driven shaft, or a dug hole, whose depth is greater than the largest surface dimension (USGS)(40 CFR 144.3 and 40 CFR 146.3).

Well injection - The subsurface emplacement of "fluids" through a bored, drilled, or driven "well", or through a dug well, where the depth of the dug well is greater than the largest surface dimension (USGS)

Z

ZEP – (The) Zero Emissions Technological Platform. www.zeroemissionsplatform.eu.

REFERENCES, further information:
Many of the definitions are taken from, or combined between those published in documents and on websites and other locations. A range of useful websites is included below – glossaries are found in some of these sites.

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(ASTM, 1980) American Society for Testing and Materials, 1980, Standard definitions of terms and symbols relating to soil and rock mechanics, in (D653-80) 1981 Annual Book of ASTM Standards, Part 19: Philadelphia, Pennsylvania, American Society for Testing Materials, p. 1402-1419.
(CFR, 1988) Code of Federal Regulations, 1988, Title 10—Energy: Nuclear Regulatory Commission (Parts 0-199), Department of Energy (Parts 700-999); Title 30—Mineral Resources-: Office of Surface Mining, Reclamation and Enforcement, Department of the Interior (Parts 700-999); Title 40—Protection of Environment: Environmental Protection Agency (Parts 1-799): Washington, D.C., U.S. Government Printing Office.
USGS United States Geological Survey – Glossary of Hydrologic Terms
IPCC Geological Storage Global – Annex II: Glossary, acronyms and abbreviations'

Useful web addresses:

Bellona - http://bellona.org/ccs/ccs-news-events/news/article/a-finnish-idea-carbon-capture-and-neutralization.html
Carbon Sequestration Leadership Forum - **http://www.cslforum.org/**
Convention on Biological Diversity - http://www.cbd.int/impact/whatis.shtml
CO_2 Australia - http://www.co2australia.com.au/
CO_2 Capture Project - http://www.co2captureproject.org/
CO2GeoNet brochure - http://www.co2geonet.com/NewsData.aspx?IdNews=44&ViewType=Old&IdType=18
CO2NetEast - http://co2neteast.energnet.com/
CCS Institute (Global CCS Institute) - http://www.globalccsinstitute.com/
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EBTP – The European Biofuels Technology Platform. www.biofuelstp.eu
ECO2 Project - http://www.eco2-project.eu/home.html
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IEA-GHG - www.ieaghg.org/
IPAC-CO2 - www.ipac-co2.com
IPCC - http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch7s7-3-7.html
North American Carbon Capture and Storage Association – http://naccsa.org/
OECD - http://www.oecd.org/
PowerPlantsCCS - http://www.powerplantccs.com/ccs/sto/conv/geo/geo.html
Quantifying and Monitoring Potential Ecosystem Impacts of Geological Carbon Storage (QICS) - http://www.bgs.ac.uk/qics/

(RSC) Royal Society of Chemistry - http://www.rsc.org/ScienceAndTechnology/Policy/EHSC/EHSCnotesonLifeCycleAssessment.asp
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USGS – Glossary of Hydrologic Terms: http://or.water.usgs.gov/projs_dir/willgw/glossary.html
USGS definitions – Geologic CO_2 Sequestration – Helpful definitions. http://energy.usgs.gov/HealthEnvironment/EnergyProductionUse/GeologicCO2Sequestration/Definitions.aspx
The Zero Emissions Platform (ZEP). www.zeroemissionsplatform.eu

Short glossary

The "language of CCS" has grown in a multidisciplinary environment and is moving its first steps in the wider world. We have tried to identify and explain the relevant terms and concepts in a way that might be useful for both the specialist and the layman. We hope that this work will help us all to better communicate and thus support a correct perception and understanding of what CO_2 geological storage really is.

This glossary represents an amalgamation of the original thoughts and work of many people and organisations. These have been brought together after an extensive search of the relevant CCS and related literature for glossary entries and definitions; accessing the growing number of partial and often very subject specific glossaries that already exist across the worldwide web (web addresses can be found at the end of the glossary). Further, consultations with ECO2 scientists, other members and science advisory board members, has elicited useful comments and suggestions, which have also been embraced into this document. Bringing together such a diverse range of opinion and attempting to gain agreement has proved challenging and surely illustrates the need for this glossary. It is recognised that despite this being the most exhaustive glossary on the subject of CCS in existence, it like the technology and science of CCS, is likely to need constant amendment to keep it current and useful.

A more comprehensive version including many other CCS related terms is available on the ECO2 website. This distilled glossary is intended as a first stop where most of the commonly used terms and phrases are included.

Absorption - The process by which one substance, such as a solid or liquid, takes up another substance, such as a liquid or gas, through minute pores or spaces between its molecules. A paper towel takes up water, and water takes up carbon dioxide, by absorption.

Adsorption - (in CCS) The process by which a material attracts carbon dioxide to its surface so it can be captured and/or stored.

Anthropogenic - This term describes effects, processes, objects, or materials (such as climate change gases) derived from human activities, as opposed to those occurring naturally and without human influence.

Aquifer - The technical term for a geological structure whose rock is permeable, or porous enough to allow significant flow of fluids. Aquifers are bound by natural seals like cap-rock. Aquifers closer to the surface of the ground often contain freshwater suitable for human

consumption, deeper aquifers are usually filled with salt water – these are called saline aquifers and maybe suitable for CO_2 storage.

Atmosphere - The layer of gases surrounding the earth; the gases are mainly nitrogen (78%) and oxygen (around 21%).

Basin - A geological region with strata dipping towards a common axis or centre, so forming a 'basin' shape.

Benthic - Pertaining to conditions on the seafloor. Used as a descriptive term for the animals and plants that live on the seabed (the benthos). Benthic organisms, may be fixed to the substrate, may burrow through it or move across it.

Cap-rock - Layer of rock that is very difficult to permeate, allowing it to act as an upper seal to prevent liquids and gases from flowing out of a formation or reservoir. Anhydrite, gypsum, limestone, sulphur, and clay rocks can form cap-rocks.

Capture - The removal of CO_2 resulting from fossil fuels after combustion.

Carbon Dioxide (CO_2) - A colourless, odourless gas formed by carbon and oxygen to be found in the atmosphere and in the underground. It is derived from many sources: volcanic eruptions, rock alterations, decomposition of organic matter, combustion of fossil fuels, etc. It is also produced when animals (including humans) breathe. Carbon dioxide is essential to the photosynthesis process that sustains plant, upon which many animal species, in turn, rely. Although relatively non-hazardous, it can create lethal oxygen-deficient environments in high concentrations (especially in confined spaces). It is one of the greenhouse gases since over the last 200 years its concentration in the lower atmosphere has increased from 270 parts per million (PPM) to 350 ppm.

Carbon dioxide Sequestration – The fixation of carbon dioxide and other greenhouse gases by natural systems such as forests or phytoplankton, that would otherwise remain in the atmosphere. In natural systems plants and oceans sequester carbon for utilisation in life processes such as growth of tissue. Carbon dioxide sequestration in CCS context is often regarded as synonymous with and replaced by the term carbon dioxide storage ie (The term "carbon sequestration" is used to describe both natural and deliberate processes by which CO_2 is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments (vegetation, soils, and sediments), and geologic formations. (USGS Fact sheet 2008-3097: Carbon Sequestration to Mitigate Climate Change. http://pubs.usgs.gov/fs/2008/3097/). For the purposes of this glossary sequestration is best reserved for natural systems, storage is regarded as a human activity following active capture for removal to prevent CO_2 entering the atmosphere.

Climate change - Defined by the United Nations Framework Convention on Climate Change (UNFCCC) as "change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

CO_2 equivalent - A measure used to compare emissions of different greenhouse gases based ontheir global warming potential. If CO_2 is given a value of 1; methane is 25 times more potent; and nitrous oxide 298 times more powerful than CO_2. Global warming potential is one, very important measure, but total amounts being emitted to the atmosphere are a very significant factor, which make CO_2 especially worrying.

Containment - Restriction of movement of a fluid (such as supercritical CO_2) to a specific place or space (like a storage aquifer or an oil or gas field in disuse).

Depleted reservoir - A structure like an oil or gas reservoir where production has ceased or has significantly reduced from past exploitation

ECO2 - The project will establish a framework of best environmental practices to guide the management of offshore CO2 injection and storage and as addendum to the EU directive on "Geological Storage of CO2" for the marine realm. This includes the quantitative assessment of potential and actual impacts on marine ecosystems at a CO2 injection facility and the entire storage site. A comprehensive monitoring concept for storage sites will be developed comprising innovative techniques that are apt to detect different modes and levels of leakage including that of pre-cursors. Field studies at operated and prospective sites (Sleipner, Snøhvit) and natural CO2 seeps (North Sea, Mediterranean Sea) are completed by lab experiments and numerical simulations on different scales. An integral part of the project is to transfer this knowledge into a risk management concept and an economic valuing of the costs of leakage, monitoring, mitigation measures, and a clear communication framework. An understanding of the precautionary principle as primary tool for balancing the environmental risks will be built. (Abstract from www.eco2-project.eu)

Ecosystem - A dynamic community of plants, animals and microbes together with their physical environment; a natural system with interacting and interdependent relationships.

Enhanced Gas Recovery - The incremental gas recovery from depleted conventional gas reservoirs This is usually achieved by pumping another substance into the reservoir to 'push out' the remaining gas for economic use. CO_2 can be used for this purpose and provide the bonus of CO_2 storage. As gas is removed from natural gas reservoirs, the pressure of the reservoir decreases. As the pressure within the reservoir decreases, it becomes more difficult to recover more gas. By injecting CO_2 into the natural gas reservoir, the pressure of the reservoir is increased, and more gas can be recovered (USGS).

Enhanced Oil Recovery (EOR) - CO_2 can be injected into depleted oil reservoirs to enhance oil recovery from the reservoir. CO_2 will dissolve into the residual oil in place, which lowers the viscosity of the oil. The lower viscosity enables the oil to flow more easily, which makes it possible to extract more oil from reservoirs (USGS definitions). EOR is a generic term for techniques for increasing the amount of crude oil that can be extracted from an oil field. It is also known as improved oil recovery or tertiary recovery. Using EOR 30-60% more of the reservoir's original oil can be extracted compared to 20-40% using primary and secondary recovery. Fluids (such as steam of CO_2) injected into the reservoir 'push' the oil out.

Flue gas - Flue gas is gas that exits via a flue, which is a pipe or channel for gases from a fireplace, oven, furnace, boiler or steam generator. It often refers to the combustion exhaust gas produced at power plants. Its composition depends on what is being burned, but it usually consists of carbon dioxide (CO_2), water vapour and nitrogen (typically more than two thirds) derived from the combustion air as well as excess Oxygen (also derived from the combustion air). It further contains a small percentage of pollutants such as particulate matter, carbon monoxide, nitrogen oxides and sulphur oxides.

Geological formation: A geologic formation is a formally named rock stratum or geological unit. It is a rock unit that is distinctive enough in appearance that a geologic mapper can tell it apart from the surrounding rock layers and is the fundamental unit of lithostratigraphy (The scientific study and categorization of rock strata based on their lithology - color, texture, and composition). The concept of formally defined layers or strata is central to the geologic discipline of stratigraphy. Some geological formations are suitable for storing CO_2. Non-geologists may refer informally to outcroppings of rock or interesting geological features as geological formations, even though this is not technically correct.

GHG (GreenHouse Gas) - Greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydroflurocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6). GHGs are responsible for maintaining the Earth at a habitable temperature, but rising temperatures and ultimately global warming result from an imbalance leading to an increase in GHGs.

Global Warming Potential (GWP) - A measure of the magnitude of the heat-trapping effect resulting from the addition of 1 kilogram of a gas to the atmosphere relative to that of 1 kilogram of carbon dioxide. GWP is a function of two factors (1) the instantaneous heat-absorbing ability of the gas, and (2) the length of time that emissions of the gas persist in the atmosphere, on average. See CO2 equivalent.

Host rock - In geology, the rock formation that contains a foreign material. In CCS a rock that receives stored CO_2.

Impermeable - A substance that cannot be penetrated. A rock or material that stops the movement of water or other liquids through it.

Injection of CO_2 into geologic reservoirs - CO_2 is pumped into geologic formations from the surface through a well, in the form of a dense, liquid-like fluid (also known as a "supercritical fluid") into either a coal bed, or a saline aquifer or hydrocarbon reservoir. If the CO_2 is injected into a depleted hydrocarbon reservoir, then additional petroleum or natural gas could be extracted (Enhanced Oil Recovery or Enhanced Gas Recovery). If the CO_2 is injected into a coal bed, then methane could be liberated and extracted (Enhanced Coal Bed Methane).(USGS definitions)

IPCC - Intergovernmental Panel on Climate Change.

Lake Nyos – Lake Nyos, Cameroon, West Africa was the site of a limnic eruption in 1986, which released 80 million cubic metres of CO_2 from the lake, killing at least 1700 people. This event is often mistakenly cited as an example of the possible consequences of leakage from a CO_2 storage site. In reality the case of Lake Nyos is related to volcanic activity where CO_2 is produced continuously and where the pressure in the reservoir increases continuously. In the case of a CO_2 storage site similar phenomena could not happen; as is also demonstrated by natural gas reservoirs (CO_2, methane, etc) where such catastrophic phenomena have never occurred.

Leak - To permit the escape, entry, or passage of something through a breach or flaw. In CCS terms there is a sense of an accidental or unintentional escape of injected fluid from storage.

Leakage – In respect of CCS, leakage is "any release of CO_2 from the storage complex (Art.3 (5) CCS-directive)" or "in respect of carbon storage, the escape of CO_2 from the storage formation (see below) in the water column and the atmosphere." (The Risk Assessment and Management Framework for CO_2 Sequestration in Sub-seabed Geological Structures (FRAM) in the context of the London Protocol, p.31)

Limnic eruption – also referred to as 'lake overturn' is a rare natural disaster related to volcanic activity in which dissolved CO_2 suddenly erupts from deep lake water, suffocating any wildlife, livestock and humans it overwhelms. Lanslides, volcanic activity and explosions can trigger such 'eruptions'. To date, only two occurrences have actually been observed: at Lakes Monuon and Nyos in Cameroon, West Africa.

Lithology - science of the nature and composition of rocks.

Ocean Sequestration: Storage of CO_2 in ocean waters. Oceans are an important part of the natural carbon cycle because they store, release, and absorb large quantities of CO_2 to and from the atmosphere. Research in this area is focused on learning more about the ocean

carbon cycle, deep ocean ecosystems, and the safety and potential environmental impacts of CO_2 storage.(IPAC CO_2). See Ocean Storage. This is to be distinguished from sub-seabed storage where CO_2 is buried deep beneath the seabed in geological strata.

Permeability - Ability of porous or fractured material to allow fluids to flow across it. In CCS, it refers for instance to the ability of a porous rock, such as sandstone, to act like a sponge absorbing the injected CO_2 in the tiny spaces between grains of the rock (see pore spaces).

pH - Is a measure of hydrogen ion concentration; a measure of the acidity or alkalinity of a solution. (Chemistry Glossary: www.chemistry.about.com). pH 7 is neutral, a solution with pH less than 7 is said to be acidic; a pH greater than seven is basic or alkaline.

Plume – in CCS the dispersing volume of CO_2 in the geological formation (Sitechar).

Pore space - Tiny space between the grains of a rock, usually occupied by a fluid of some sort, often water.

Porosity – percentage of the volume of a rock that is not occupied by mineral. The gaps are pores and may be filled with various fluids such as salt water, oil, methane, or CO_2.

Reservoir - A subsurface body of rock with the porosity and permeability to store and transmit fluids.

Saline Formation- Underground rock where brackish water or brine occupies the tiny spaces between the grains of rock.

Seabed- Borderline between the free water and the top of the bottom sediment.

Seal - An impermeable rock that forms a barrier above and around a reservoir such that fluids are held in the reservoir: a rock formation which it is very difficult for carbon dioxide and other subsurface fluids to move through under normal conditions.

Seep - To pass slowly through small openings or pores; to ooze. In CCS terms it is often reserved for a naturally occurring release of CO_2, from an underground source, such as might be seen in parts of Italy, and in the Mediterranean, for example.

Seepage - The fluid (or amount of fluid) discharged at a seep.

Sequestration - To store something so that it is no longer available. Carbon sequestration involves the removal or storage of carbon dioxide so that it can't be released into the atmosphere. The term is often regarded as synonymous with **storage**, but has other confusing meanings and should be avoided in favour of **storage**. **Terrestrial sequestration** is the absorbtion and storage of CO_2 by vegetation and soils in terrestrial ecosystems.

Storage – (in CCS) a process for retaining captured CO_2 so that it does not reach the atmosphere.

Storage site - An underground rock formation that can store carbon dioxide; commonly this is deep sedimentary and porous rock, where there are tiny spaces between the rock grains for the carbon dioxide.

Sub-seabed – In CCS terms, the consolidated geological strata beneath the seabed. Storage is usually at a considerable depth of thousands of metres within the strata beneath the bottom of the sea.

Trap - A geological structure that physically retains fluids that are lighter than the background fluids, e.g. an inverted cup.

UNFCC - United Nations Framework Convention on Climate Change.

Water column – a notional column of water above the sediment and upwards to the surface of the sea, lake, river etc. Many aquatic phenomena: chemical, physical and biological are explained by mixing in the water column.

Some frequently asked questions

Q: What is CCS?

A: CCS is **C**arbon dioxide **C**apture and **S**torage (sometimes called carbon capture and storage or carbon capture and sequestration). It is a series of technological processes that capture CO_2 from large scale industrial operations, transport it to a suitable site, inject it into a deep geological formation where it will be stored long-term.

Q: Why do we need to do it?

A: CCS has been identified as an effective mechanism for preventing large amounts of CO_2 entering the atmosphere, where it has led to dangerous global warming, and into the ocean where it is causing ocean acidification. It is one mitigation activity to reduce the amount of CO_2 entering the atmosphere, and is being actively investigated and trialled to determine its suitability and to perfect the technologies necessary for its implementation.

Q: How long does CO_2 stay in the reservoir?

A: Potential storage sites are carefully surveyed prior to any injection. Often they are depleted hydrocarbon reservoirs where the natural gas or oil has been removed or has almost all been removed. These sites have contained gas or oil for millions of years and so are likely to contain injected CO_2 for a similar time. The IPCC Special Report on CCS concluded that: 'observations...suggest that the fraction [of CO_2] retained in appropriately selected and managed geological reservoirs is very likely to exceed 99% over 100 years and likely to exceed 99% over 1000 years'.

Q: What are the risks for future generations?

A: Whilst it would be foolish to say all risks have been eliminated, the likelihood of any risks is considered to be almost negligible. Careful pre-injection surveys are carried out and post injection monitoring is in place to ensure that the injected CO_2 and its containing reservoir continue to perform as predicted. The geological formation selected for storage make it extremely unlikely that any massive release would take place. Even if a slow leak occurred there would be plenty of time to detect and deal with it.

Q: What are the guarantees for a site's stability?

A: Careful geological surveying establishes the relative chances of instability. Even some tectonically active areas, however, lend themselves to storage but always the key to success is careful investigation prior to any storage to ensure suitability of the site for retaining injected CO_2.

Q: Which tools are available for studying CO_2 storage? Are they reliable?

A: Many of the tools and techniques available for studying how CO_2 as a gas might behave in sub-seabed storage, or how the reservoir itself might perform to contain the CO_2, are available in research institutes and universities, including some that have been modified from existing industrial processes.. As such they have been perfected over many decades and are trusted by the industries

that rely upon them both practically and economically. Additionally there is a growing community of scientists covering a wide range of disciplines that are bringing further refinement to studies through their own specialisms.

Q: How will we know if there is a leak?

A: Before any CO_2 is stored in a chosen site a very detailed survey is undertaken to establish if there are any leakage pathways. Lessons learned from existing underground storage of natural gas and hydrogen (which has an excellent safety record in Europe) can be applied as can the very sophisticated monitoring techniques. Water and sediment sampling will detect any leakage. AUV (autonomous underwater vehicle)-based monitoring equipped with synthetic aperture sonar followed by ROV (remote operating vehicle)-based determination of gas bubble release and quantification of benthic fluxes across the seafloor at potential leakage sites and if required continuous records of emission rates over time by installation of HUBs; geological monitoring through sound, seismic, gravity, electromagnetic and density measurements can detect any changes within the 'store' itself.

Q: Haven't there been some incidents where CO_2 escaped from lakes and killed lots of people?

A: These are so-called limnic eruptions or lake overturning when CO_2 that had accumulated naturally at the bottom of lakes as a result of underlying volcanic activity was suddenly released by some disturbance. These events are extremely rare (there have only been two that have been witnessed) and are **nothing** to do with CCS; they are natural phenomena. Such a event could not happen as a result of CCS.

Q: If you are going to pump CO_2 underground won't that cause earthquakes?

A: Detailed surveys take place before sites are selected, these will identify any potential leakage pathways and the likelihood of any seismic activity. The amount of CO_2 that is stored in a reservoir takes into account the strength of the rock, so the volume stored will be related to that strength. So the pressure of the CO_2 will not cause any structural alterations within the geology of the site leading to seismic activity. In fact in Japan some CO_2 has been stored in seismically active areas and due to careful investigation before injection of CO_2 there has been no leakage, even after a natural 6.8 magnitude earthquake in the area.

Q: I read about a large crack being discovered on the seabed near a storage site, was this caused by CCS?

A: A fracture 3 km in length, up to 10 metres wide and 200 metres deep was discovered during surveys as part of the ECO2 project. The newly-discovered fracture is 25 km north of the Sleipner CO_2 storage site. Computer models and observations from monitoring surveys imply that the CO_2 stored in the Utsira Sand at Sleipner will never reach the fracture area. Furthermore, the available seismic data show that the fracture is vertically separated from the Utsira Sand by several thick, low permeability sedimentary seals. Such fractures, thought to be naturally occurring but formerly not detected, may be more common than previously thought. (further information at http://www.eco2-project.eu/newsarticles/items/north-sea-fracture-discovered.html)

Q: Why is sub-seabed storage the focus of the ECO_2 project, are there not plenty of sites on land that would be cheaper and easier to use?

A: The ECO_2 Project scientists, and colleagues in the social sciences and legal professions, have been asked to look specifically at the sub-seabed realm to determine best practices for all aspects of CO_2 storage in such locations. It is true that there are other potential sites on land which could be used for CO_2 geological storage, but these are currently, socially less acceptable and there are many

advantages to looking beneath the sea-bed first. Many of the largest natural gas and oil deposits (in Europe) occur in rocks beneath the seabed, as these become depleted they lend themselves as reservoirs for storing anthropogenic CO_2. Indeed much of the technology has been proven in the marine environment and is already in place. (further information at http://www.eco2-project.eu/home.html)

Q: In the unlikely event of a CO_2 escape from a sub-seabed store what might happen to the marine life, and how far might the CO_2 travel?

A: Much of what we know about the impacts of increased CO_2 in seawater has come from laboratory studies looking into the phenomenon of ocean acidification and how it might affect individual organisms, communities and ecosystems. In addition there are some natural analogues where (natural) CO_2 resulting from volcanic activity is seeping into the seabed. Both sets of observations show that many organisms, especially those that use calcium carbonate to build shells or skeletons, can be adversely affected by rises in CO_2 concentrations, with more affects at greater concentrations. Knowing this is part of the reason for the ECO_2 project which is aiming to ensure that best practice is developed and followed to avoid any such artificial leak. One unique experiment has mimicked a potential leak from a sub-seabed store (The QICS Project), at the time of writing the results from this experiment are still being evaluated, but see www.bgs.ac.uk/**qics**/

Q: Can we assess the maximum capacity of a potential CO_2 storage site?

A: Yes. Geological survey techniques have been perfected to establish the size and volume of oil and gas supplies. The same technology can be applied to measuring the carrying capacity (which can vary with depth and hence pressure) of any potential storage site, whether it be a depleted hydrocarbon reservoir, or previously untapped saline formation deep below the surface. The nature of the rock types present and the regional and local geological structure also determine how much CO_2 can be stored.

Q: What types of rock are best for storage of CO_2?

A: CO_2 is stored in the pore spaces between the grains, so rocks such as sandstone which are of a porous nature to allow for the passage of fluids make the best storage medium. But such storage rocks also need to be contained within a boundary of geological structures or impermeable rock types that prevent the flow of CO_2 into areas where it can escape or contaminate freshwater aquifers used for drinking water.

Q: Is CO_2 already being stored beneath the seabed?

A: Yes, in fact the main area of study for the ECO2 project is around the Sleipner (Norway) site beneath the North Sea. Other CCS sites using geological formations for storage are at Weyburn (Canada) and Salah (Algeria). The technology necessary for successful CCS has been developed over the last few decades, mainly as a spin-off from its usage in Enhanced Oil Recovery (see glossary).

Q: If the CO_2 is staying underground for millennia, who is responsible for it?
A: There are precedents for this in the oil and gas industry where the long-term liability is taken on by the relevant state. Indeed EU laws have already been formulated and are being implemented at a national level.

Q: What is the ECO_2 Project?
A: The ECO2 Project will establish a framework of best environmental practices to guide the management of offshore CO2 injection and storage and as addendum to the EU directive on "Geological Storage of CO2" for the marine realm. This includes the quantitative assessment of

potential and actual impacts on marine ecosystems at a CO2 injection facility and the entire storage site. (More detail at http://www.eco2-project.eu/home.html)

It is a multi-institution project drawing expertise from a wide range of disciplines within science, social science, the law and industry, from across the EU. (For further information on partners http://www.eco2-project.eu/consortium-members.html)

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