

CCS Defined
A glossary of terms
for
Carbon dioxide
Capture and Storage



Deliverable D7.3 of the STEMM-CCS project – 2016
(Updated October 2018)



INTRODUCTION:

This glossary – ‘CCS Defined’ - has been brought together from many sources, and following comments and advice from co-workers on the Strategies for Environmental Monitoring of Marine Carbon Capture and Storage, STEMM-CCS (654462), CO₂ Capture from Cement Production, CEMCAP (641185) and Low Emissions Intensity Lime and Cement, LEILAC (654465) Projects, which form a group under the EC H2020 Carbon Capture and Storage Programme.

‘CCS defined’ (deliverable D.73) comprises an update and broadening of a first attempt (Boot et al, 2013. The Language of CCS) to bring together a comprehensive set of definitions concerned with sub-seabed carbon dioxide capture and storage (CCS) produced as a deliverable of the FP7, ECO2 project (<http://www.eco2-project.eu/>). The ECO2 “Language of CCS’ was concerned primarily with aspects of sub-seabed storage, ‘CCS Defined’ includes other topics reflecting additional language required by the LEILAC and CEMCAP projects, especially elements of capture technologies, and is widened to include storage in general. It is, therefore, a more complete glossary which should prove useful beyond the immediate projects for which it is written. The aim of producing ‘CCS Defined’ is in the first instance to provide a common vocabulary intended to



minimise misunderstandings and confusion across the various scientific disciplines working with the

As with the previous publication, ‘CCS Defined’ has drawn upon a wide range of sources within the relevant literature and across numerous websites so this glossary is very much a compilation of many ideas. In particular the IPCC Special Report on Carbon Dioxide Capture and Storage has proved to be a firm foundation. A full listing of all sources and useful websites for further information is included at the end of this glossary. The author would like to acknowledge and thank all of those who compiled these sources.

As scientific disciplines develop the language evolves alongside. This glossary reflects the ‘state-of-the-art’ of CCS, but it is recognised that new definitions will appear and others will be modified during its lifetime. As such it can only be regarded as part of a continuum and perhaps should be considered as a draft document. The author welcomes further additions to grow the glossary and will consider suggested refinements of definitions. In an area as broad as CCS which relies upon a multitude of specialisms, there will be cases where a single word or phrase might have multiple accepted meanings, even between close scientific disciplines. Certainly the legal profession has to use very precise language and when applied to CCS it might appear to mean something very different to its scientific definition; where appropriate, alternative definitions are given.



The ECO2 “Language of CCS” outlined some basic principles and advised on the need for a consistent approach. Readers are referred to that document for further detail and justification of the use of certain terms over others. However it is worth mentioning some of these here. CCS, for example can be an abbreviation for: Carbon Capture and Sequestration, Carbon Capture and Storage; the recommended term should be Carbon dioxide Capture and Storage, which is increasingly being adopted globally. The justification is quite simple in that it is CO₂ that is being captured and stored not carbon alone which can translate into some European languages as ‘coal’. Storage is preferred over sequestration because the latter has a more precise meaning in biology (and many areas of GHG reduction) as taking something to be reused e.g. a tree removes CO₂ during photosynthesis to then build carbon into its tissues – the tree has sequestered the C of CO₂.



The Glossary:

As mentioned above there are many glossaries in existence, many of these are far from comprehensive, reflecting the interests of the source organization; perhaps the most complete is the IPCC glossary. Industry websites may go into a great deal of technical detail which is beyond the scope of this glossary, however links to some of these are given at the end for those that may require definitions of very specific, highly detailed terms. ‘CCS Defined’ brings together definitions from many of these sources, amalgamating them or altering them for more clarity. Because of this approach it is difficult and cumbersome to include all source acknowledgements with each entry and readers are directed to the full listing at the end of the document. It should be re-iterated that there will always be room for further refinement and additions, and constructive criticism is welcome. Readers are invited to forward comments to the glossary compiler Kelvin Boot at kelota.pml.ac.uk.



A

Abandoned well: In the oil and gas industry, a well that is plugged permanently due to reaching its economic viability or because of some technical reason. Once abandoned, any tubing will be removed and the wellbore filled with concrete.

Abatement: A reduction in the amount, degree or intensity of emissions like CO₂

Absorber tower: A tower or column where flue gas comes into contact with an amine-based chemical absorbent which bonds the flue gas and so removes it from the flue gas. See regeneration tower

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 CO₂ injection starts until CO₂ 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 molecules, such as carbon dioxide, to its surface so it can be captured and/or stored.

Advective transport: The transport of a substance by bulk movement of a fluid, such as groundwater, any properties of the substance are carried with it.

AIV: Autonomous Inspection Vehicle. Can carry an array of navigation tools and sensors for autonomous inspection with station and hovering capability.

Amines: Derivatives of ammonia used as solvents in the post combustion CO₂ capture process to absorb carbon dioxide from the flue gas stream. The amine is heated to release high purity CO₂ 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: Upward-folded geological strata that is arch-shaped with its oldest beds at its core, each half of the fold dips away from the crest

Aquifer: The technical term for a geological structure whose rock is permeable, or porous enough to allow containment or



significant through-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 CO₂ storage.

Aquifuge: A rock which contains no interconnected pore spaces 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).

Assessment unit: A geological unit with a high petroleum potential (IPCC)

ASV: Autonomous Surface Vehicle. Allows subsea to surface communication. Can also carry sensors.

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



ATR or Auto thermal Reforming: A process in which the heat for the reaction of CH_4 with steam is generated by a partial oxidation of CH_4 .

Attribution: The process of identifying the source of a CO_2 (or other, e.g. pH) anomaly

AUV: Autonomous Underwater Vehicle also called unmanned underwater vehicle. They are used for a wide range of underwater survey missions. In CCS they are a useful tool for carrying sensors to detect and monitor natural seeps or accidental leaks. (cf. ROV)

B

Basalt: A type of basic rock (rich in iron and magnesium; relatively poor in silica) of volcanic origin. Basalt may have porosity and permeability in the fractures or cavities between blocks of solid rock; it is a candidate rock for mineralization of CO_2 through reaction with calcium and magnesium.

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 natural large-scale depression or low lying area in the Earth's surface that allows for the collection of sediments. A crucial factor in the concept of basins is tectonic activity that creates the relief necessary for a thick



accumulation of sediments. Basins may not show a 'bowl' shape and those with origins back in geological time may not actually function as basins anymore.

Bathymetric: Pertaining to the depth of water above the seabed. Bathymetry measurements are used to determine the 'topography' of the seafloor.

Benthic: Relating 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.

Bentonitic rock: Rich in bentonite clays, often composed mostly of montmorillonite. Bentonites are good for sealing reservoirs due to their absorbent and swelling properties.

Bicarbonate: The anion formed by dissolving CO₂ in water HCO₃⁻

Bio-Accelerated Sequestration: A concept of using microbial organisms (microscopic plants or animals) with CO₂, in geologic formations, to sequester the CO₂ and/or convert it to methane.

Bio-CCS: A large scale technology intended to combine sustainable biomass conversion with CO₂ Capture and



Storage – e.g. in biofuels and bio-energy production. It is already being used in the USA.

Bioindicator/ Biological indicator: An organism or biological response that reveals the presence of pollutants or other impacting factors, by the occurrence of typical symptoms or measurable responses. Bioindicators can be used by observers to determine how various conditions in an environment have changed over time.

Biomass: In biology: the total quantity or weight of living organisms in a given area or volume. In energy terms: biological material derived from living or recently living organisms used as a fuel, especially in the generation of electricity.

Biomass-based CCS: CO₂ 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 repressurization. Like many other terms CCS has borrowed this from the hydrocarbon industry to describe an



uncontrolled eruption of CO₂ from an injection, a monitoring or an abandoned well.

Bowtie method: Risk management using the bowtie method. It provides a framework for a systematic risk assessment of events with the potential to affect storage performance. The bowtie represents the relationship between five key elements (threats, preventative and corrective barriers, top event, and consequences) that describe how a risk might arise and how safeguards can provide effective protection against the risk and its associated consequences.

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% or more salt.

Brine formation: (See saline formation).

Bulk CO₂: Unprocessed gaseous CO₂, with a CO₂ 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.

Business as usual: When things continue as they always have.



C

CaCO₃: Calcium carbonate

Calcination: In cement manufacturing calcination is carried out in furnaces or reactors, which heat limestone leading to its decomposition into calcium oxide (lime) and CO₂ as a by-product.

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 geological formation or reservoir. Anhydrite, gypsum, limestone, sulphur, and clay rocks can form cap-rocks.

Capture: The removal of CO₂ resulting from the use of fossil fuels.

Capture efficiency: The fraction of CO₂ separated from the gas stream of a source.

CarbFix/CarbFix2: CarbFix is a collaborative research project led by Reykjavik Energy, that aims at developing safe, simple and economical methods and technology for permanent CO₂ mineral storage in basalts. The CarbFix2 project aims to move the demonstrated CarbFix technology from the



demonstration phase to a general and economically viable complete CCS chain that can be used through Europe and throughout the world.

Carbonates: Rocks such as limestones or chalks, or minerals like calcite which are composed of an anion attached to a CO_3^{2-} cation (e.g. CaCO_3). Marble and dolomite are also examples.

Carbon credit: A convertible and transferable instrument that allows an organization to benefit financially from an emission reduction.

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 plants, 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, which largely



hinges on circumstance. 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. It is important to establish when CO₂ is a pollutant within legislative definitions.

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. CO₂ sequestration in CCS context is often regarded as synonymous with and replaced by the term CO₂ storage - i.e. the term “carbon sequestration” is used to describe both natural and deliberate processes by which CO₂ 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 CO₂ entering the atmosphere.



CDR: Carbon Dioxide Removal. The Paris Agreement explicitly includes the possibility of using CDR technologies to reach the agreed climate goals.

CCR: Carbon capture ready. See CCSR

CCS: Carbon Capture and Storage or Carbon dioxide Capture and Storage. The two terms are often used interchangeably. For reasons of clarity and consistency Carbon dioxide Capture and Storage should be preferred. Carbon dioxide Capture and Storage is the term used by IPCC which defines it as: “Carbon dioxide (CO₂) capture and storage (CCS) is a process consisting of the separation of CO₂ from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere.”

CCS - status of existing projects: Fifteen large-scale projects are operational with another seven under construction – between them they will have the capacity of 40 million tonnes per annum (Mtpa). Further details of these and expected projects can be found on the websites of the Global CCS Institute

(<https://www.globalccsinstitute.com/projects/large-scale-ccs-projects>) and the Massachusetts Institute of Technology (https://sequestration.mit.edu/tools/projects/map_projects.html).

CCS deployment: Uptake of CCS is far behind the levels necessary for the envisaged global emission reductions , as



CCS deployment faces a broad spectrum of barriers in both developed and developing countries, which may be: Legal and regulatory, Policy, Economic and financial, Technical, or a question of institutional and public acceptance.

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)

CCU: Carbon dioxide Capture and Use/Utilization. Carbon Capture and Utilisation consists of a range of technologies that use or convert captured CO₂ to make valuable fuels, feed, chemicals, building materials or other products. Some technologies require a purified (concentrated) CO₂ stream, whereas others can utilise the CO₂-rich exhaust gas. The market of these products however is not large enough to cover all man-made CO₂ emissions. Therefore, the cement and lime sectors consider CCS inevitable to reach the EU targets. (From LEILAC website)

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 CO₂, 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.



CEMCAP: CO₂ capture from cement production is a project funded by Horizon 2020 addressing CO₂ capture from cement production. Its primary objective is to prepare the ground for large-scale CO₂ capture in the European cement industry. CEMCAP will demonstrate CO₂ capture technologies for the cement industry in an industrially relevant environment (TRL 6). Existing pilot scale test rigs, adapted to replicate realistic cement plant operating conditions, will mainly be employed, and in addition a dedicated clinker cooler for oxyfuel cement plants will be designed and built. Cost-and energy-efficient retrofit of the capture technologies will be targeted, with focus on maintained product quality.

<http://www.sintef.no/cemcap>

Cement Industry emissions: CO₂ emissions from the cement industry constitute 5% (or 1.9 Gt annually) of global anthropogenic CO₂ emissions. CO₂ generation is an inherent part of the cement production process, due to the calcination of the most important raw material, limestone (CaCO₃ converted to CaO and CO₂), about 60 % of the CO₂ emissions from cement production are due to this conversion, whereas 40% come from the burning of fuels (which are to a large extent fossil) to provide heat for the clinker production. There are currently no feasible methods to produce clinker and thus cement without releasing CO₂ from CaCO₃. Furthermore, cement plants typically have a lifetime as long as 30-50 years. Thus, the only viable option to significantly reduce GHG emissions from the cement industry is CO₂



Capture and Storage (CCS), where CO₂ capture must be retrofitted to existing cement plants.

Chimney structures: Chimney-like structures, considered to have been caused by the passage of gases or fluids to the seabed surface. If situated above a potential CO₂ storage reservoir ‘chimneys’ may provide a possible route for a leak. Understanding how they formed, whether they are still active and what risk for leakage they present, is a key part of STEMM-CCS research and fieldwork

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”.

Clinker: In cement manufacture clinker occurs as lumps or nodules, usually 3-25 millimetres in diameter, produced when limestone and clay minerals are fused together at the kiln stage.

Clinker cooler: Part of the kiln equipment necessary for cement manufacture. Clinker leaves the kiln at 1200°C or more and must be cooled to: avoid wasting the heat; bring it to grinding temperature; preserve the high-temperature minerals that give cement its strength.



Closure of a storage site: The definitive cessation of CO₂ injection into that storage site.

CO: Carbon monoxide.

CO₂: Carbon dioxide.

CO₂ adsorption capacity: The measure of the capacity to adsorb CO₂ as a separation technology in CCS.

CO₂ avoided: The difference between CO₂ captured, transmitted and/or stored, and the amount of CO₂ generated by a system without capture, net of the emissions not captured by a system with CO₂ capture.

CO₂ capture: CO₂ capture is the removal of CO₂ from a process stream or from the atmosphere to produce a highly pure stream of CO₂ amenable for conversion or storage. CO₂ capture systems are assessed on the purity of the captured CO₂, the percentage of total CO₂ that is captured, and the capital cost and energy use per unit of CO₂ captured.

CO₂ compression: Following capture, the CO₂ needs to be compressed from near atmospheric pressure to a pressure between 1500 and 2200 psi for transport via pipeline or rail and road, prior to injection.

CO₂ equivalent: A measure used to compare emissions of different greenhouse gases based on their global warming potential. If CO₂ is given a value of 1; methane is 25 times



more potent; and nitrous oxide 298 times more powerful than CO₂. Global warming potential is one very important measure, but total amounts being emitted to the atmosphere are a very significant factor, which make CO₂ especially worrying.

CO₂ fixation: The immobilisation of CO₂ by its reaction with another material to produce a stable compound.

CO₂GeoNet: European Network of Excellence on the Geological Storage of CO₂ is an Association of 13 research institutes from 7 European countries, engaged for scientific advancement in the field of CO₂ storage.

CO₂ plume: The dispersing volume of carbon dioxide within the geological formation or other medium, such as seawater, during a seep.

CO₂ reuse: A practical application of captured, concentrated CO₂ that adds value and which can partially offset the cost of CO₂ capture as a transitional measure to assist the accelerated uptake of CCS. (see also CCUS).

CO₂ stream: A flow of substances that results from CO₂ capture processes. This could be from a factory along pipework, for example.

CO₂ transport: The process of moving captured CO₂ through a pipeline, or by other means (e.g. ship) from its source to a suitable storage site.



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. Concauwe was established in 1963 by a small group of leading oil companies to carry out research on environmental issues relevant to the oil industry. Its membership has broadened to include most oil companies operating 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.

Connate pore fluids: Fluids that are captured and remain within the pores of sedimentary rocks as they form.

Containment: Restriction of movement of a fluid (such as supercritical CO₂) to a specific place or space (like a storage aquifer or an oil or gas field in disuse).

Containment monitoring: Monitoring to ensure the security of a storage operation allowing timely intervention in case of unintended fluid migration, usually as part of a risk-based monitoring plan.

Contaminant: Any non-CO₂ substance associated with the stored CO₂ and any associated leaks, including any impurities that might be associated with the injected CO₂ stream, and



any substances that might be released or formed as a result of sub-surface storage and/or leakage of CO₂.

Contingency plan: Part of a monitoring plan, outlines additional monitoring required in case of suspected unintended CO₂ plume migration, usually based on leak path scenarios.

Corrective measures: Any measures taken to correct significant irregularities or to close leakages in order to prevent or stop the release of CO₂ 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

Decarbonisation: The removal of carbon. An economy can be decarbonized, meaning it has a minimal output of carbon in the form of GHGs (normally CO₂) to the environment. In 2015 the G7 industrial nations agreed to take steps to decarbonize the global economy by phasing out the use of fossil fuels.

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 than 800 metres below the surface (or the surface of the seabed).



Deep coal seam: A seam that is too deep to be mined economically. Deep coal seams may be suitable for CO₂ injection/storage. CO₂ 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 permeable and contain highly saline fluids, and which may be suitable for storage of CO₂. The most suitable CCS 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 CO₂ storage projects it is deemed necessary to demonstrate efficacy on a larger scale to demonstrate costs and technologies realistically.

Depleted oil/gas fields: Underground oil- or gas-bearing rock structure or formation where most of the economically viable oil/gas has already been extracted by traditional means 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: Process of post-depositional physical and chemical changes that transform unconsolidated sediment into a sedimentary rock.



Diffusive transport: the net movement of particles from high to low concentration

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 CO₂ to enhance the recovery of the methane present in unminable coal beds through the preferential adsorption of CO₂ on coal.

ECO2: FP7 research project that established 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 precursors. 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.

Economic Potential: The amount of greenhouse gas emissions reductions from a specific option that could be achieved cost-effectively, given prevailing circumstances (the price of CO₂ reductions and costs of other options). The estimated range of economic potential for CCS over the next century is roughly 200 to 2,000 GtCO₂.

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 United 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 CO₂ 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”.

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. CO₂ can be used for this purpose and provide the bonus of CO₂ 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 CO₂ into the natural gas reservoir, the pressure of the reservoir is increased, and more gas can be recovered (USGS).

Enhanced Oil Recovery (EOR): CO₂ can be injected into depleted oil reservoirs to enhance oil recovery from the reservoir. CO₂ 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 stream of CO₂) 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): A process of evaluating the likely environmental impacts (positive and negative) of a proposed project or development, taking into account inter-related socio-economic, cultural and human-health impacts, both beneficial and adverse. In CCS EIAs might be divided into Onshore and Offshore aspects.

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.



Eliminatory criteria: Criteria that are used to assess the suitability of a site for potential storage of CO₂. 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 a requirement for further consideration.

EOR: See Enhanced Oil Recovery.

Escape: (of a gas, liquid, or heat). Leak from a container, e.g. ‘the CFCs have escaped into the atmosphere’; to break free from control. In a CCS context a leak would be an unintentional escape of CO₂ from geological storage.

EU Geocapacity: A European research project to assess the total geological storage capacity in Europe for anthropogenic CO₂ emissions.

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



Evaporite: A naturally occurring mineral sediment resulting from evaporation and precipitation of contained minerals from an aqueous solution. Evaporates can be of marine or non-marine origin and included such minerals as: calcite, gypsum, halite and anhydrite. Evaporites can be important in CCS (and oil and gas) as cap rocks providing a seal for gases or fluids trapped beneath.

Exhaust gas: Gas removed from turbine or other fuel burning apparatus.

Exploration (in CCS): Means the assessment of potential storage complexes for the purposes of geologically storing CO₂. This might include 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. The terms site characterization or site assessment are often used for these activities. NB. in the oil and gas industry exploration has a very different meaning; exploration means exploring for oil and gas.

F

Fault: A naturally-occurring physical break in or across rock sequences, with strata on one side of the fault moving relative to the other. This movement may be lateral, vertical or a combination of both.



FEP: A **F**eature that represents a component of a storage system or an **E**vent or **P**rocess 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: In CCS, the immobilization of CO₂ 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 (CO₂), 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.

Flue gas carbon dioxide capture: CO₂ is taken out of the gases produced from coal combustion (flue gas).



Formation water: Naturally occurring water within the pores of rock formations

Fossil-based power generation: The generation of power from burning fossil fuels such as coal, natural gas or petroleum.

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 CO₂ and other gases when burned.

Fracture: A break in rock along which no significant movement has occurred (see fault where movement has occurred/could occur again. Fractures can occur at many scales; at microscopic scale, a network of interconnected fractures can create permeability in a rock unit.

Fugitive emission: A release of gas or vapour from anthropogenic activities such as the processing or transportation of gas or petroleum.

G

Gasification: A thermo-chemical process that converts carbon-containing materials, such as coal, petroleum coke (petcoke), biomass, waste, or other materials, with little or



no oxygen present and at high temperatures, into a synthesis gas (syngas).

Geochemical trapping: The retention of injected CO₂ by geochemical reactions.

Geological formation: A geological formation is a formally named rock stratum or geological unit. It is a rock unit that is distinctive enough in appearance that a geologist can tell it apart from the surrounding rock layers and is a fundamental unit of lithostratigraphy (the scientific study and categorization of rock strata based on their lithology - colour, 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 CO₂. 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: Injection of CO₂ into suitable deep rock formations where it can remain stored.

GESTCO: A European research project which determined the geological storage of CO₂ possibilities in 8 countries (Norway, Denmark, UK, Belgium, Netherlands, Germany, France and Greece)

GHG (Green House Gas): Greenhouse gases - carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O),



hydrofluorocarbons (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 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.

Greenfields: (in CO₂ storage) Geological formations where no hydrocarbon production has occurred within the potential storage area; (in CO₂ 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

H₂: Hydrogen

Habitats Regulations Assessment: HRA's are required under the EC Birds and Habitats Directives and the UK Habitats Regulations. This requirement is separate but related to EIA, equal in its significance to consenting requirements.

Hazardous and non-hazardous wastes: Potentially harmful and non-harmful substances that have been released or discarded into the environment. The incineration of some hazardous waste materials can result in emissions of CO₂.

Host rock: In geology, the rock formation that contains a foreign material (such as metal mineralisation, for example). In CCS a rock that receives stored CO₂.

Hydrate: An ice-like compound formed from the reaction of water with, for example, CO₂ and CH₄. Methane clathrate is a hydrate where large amounts of methane are trapped in a lattice of ice crystals. It is feared that as oceans warm as a result of climate change, the lattice will melt and release the methane.

Hydrodynamic trap: Hydrodynamic traps are rare. High water saturation of low-permeability sediments reduces hydrocarbon permeability to close to zero. The result is a



water block allowing for the accumulation of petroleum down the dip of a sedimentary bed below the water.

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.

Igneous rock: A rock formed from the cooling of molten magma, either from a volcano, or deep intrusion. As the magma cools it crystallizes and solidifies. Granite and basalt are examples.

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 CO₂ into geologic reservoirs): CO₂ 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 CO₂ 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 CO₂ 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). A well into which fluids are injected rather than extracted

Injection zone: A geological "formation," group of formations, or part of a formation receiving fluids through a well.

Injectivity: The rate at which a quantity of fluid can be injected into a well

***In-situ* mineralization:** The process of injecting carbon dioxide into a rock formation where it reacts with minerals to form silica and carbonates. It is also known as mineral trapping (qv).



International Seabed Authority: The ISA is an autonomous international organization established under the 1982 United Nations Convention on the Law of the Sea (UNCLOS), relating to the Implementation of Part XI of the United Nations Convention on the Law of the Sea. It was established to organize, regulate and control all mineral-related activities in the international seabed area beyond the limits of national jurisdiction, an area underlying most of the world's oceans.

IPAC-CO₂: 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 CO₂ 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 CO₂ storage site. In reality the case of Lake Nyos is related to volcanic activity where CO₂ is produced continuously and thus the pressure in the reservoir increases continuously. In the case of a CO₂ storage site similar phenomena could not happen, as is also



demonstrated by natural gas reservoirs (CO₂, 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. The word seep should be restricted to a natural escape, whereas a release is an intentional escape (however see leakage below), intended to aid in experimental, observational or monitoring studies.

Leakage: In CCS terms is, for example in the CCS-Directive, "any release of CO₂ from the storage complex (Art.3 (5) CCS-directive)" or "in respect of carbon storage, the escape of CO₂ from the storage formation in the water column and the atmosphere." (The Risk Assessment and Management Framework for CO₂ Sequestration in Sub-seabed Geological Structures (FRAM) in the context of the London Protocol, p.31)



LEILAC: Low Emissions Intensity Lime and cement is a Horizons 2020 project “developing, building and operating a pilot plant to demonstrate Direct Separation calcining technology applied to the lime and cement industries, allowing to capture over 95% of the process CO₂ emissions (which is 60 % of total CO₂ emissions) without significant energy or capital penalty.”

Limnic eruption: Also referred to as ‘lake overturn’ is a rare natural disaster related to volcanic activity in which dissolved CO₂ suddenly erupts from deep lake water, suffocating any wildlife, livestock and humans it overwhelms. Landslides, volcanic activity and explosions can trigger such ‘eruptions’. To date, only two occurrences have actually been observed: at Lake Monuon and Lake Nyos in Cameroon, West Africa.

Lithology: The science of the nature and composition or general physical characteristics 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, it is by implication accidental.

Local hazard: Hazard 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 CO₂; and leakage through undetected faults, fractures or leaking wells where the escape is more gradual and diffuse, potentially affecting drinking water aquifers and ecosystems where CO₂ accumulates between the surface and the top of the water table.

London Convention: The 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: -The **M**aximum **A**llowable **O**perating **P**ressure is 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 acting like a sieve.

Migration: In CCS, the movement of fluids in reservoir rocks.



Mineralisation: Is a natural form of geologically storing CO₂ by the very slow reaction between CO₂ and naturally occurring minerals, such as magnesium silicate, to form the corresponding mineral carbonate.

Mineral carbonation: The reaction of carbon dioxide with magnesium and calcium-containing silicate minerals to form geologically stable, environmentally benign carbonate minerals (calcite and magnesite), allowing for the storage of CO₂ in a stable, inert and solid form. **Mineral trap:** A geological formation that retains fluids through the reaction of mineral components with a fluid, forming a stable mineral.

Measurement, Monitoring, and Verification (MMV): The primary purpose of an MMV plan is to evaluate and demonstrate the performance of the storage site, complying with all relevant regulations. Besides monitoring for conformance and containment, MMV provides data for emission accounting and to support transfer of long-term liabilities after closure of the storage site. Conformance monitoring is designed to compare the forecast and actual behaviour of CO₂ in the storage site in order to demonstrate that the long-term forecasts are valid. Containment monitoring is designed to demonstrate containment and to detect any significant irregularities, migration and leakages of CO₂ outside the storage reservoir in order to trigger timely corrective measures to protect the environment.



Migration: Refers to movement of fluids (including injected CO₂) 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 CO₂ 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 CO₂ sequestered.

Mineral trapping: see Trapping, Mineral.

Mitigation: The process of making impacts of failure (in a CCS context) less severe.

MM&V (MMV): See Measurement, Monitoring and Verification.

N

Natura 2000: Is a network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types which are protected in their own right. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive and the Habitats Directive.



Natural analogue: A natural occurrence that mirrors in most essential elements an intended or actual human activity. In CCS terms natural occurring CO₂ 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 seeps exist. A subset of Natural Analogues is volcanic and geothermal areas where evident gas emanations (gas vents) occur. These areas are examples of unsuitable sites for CO₂ 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 formed through natural processes; it consists largely of methane, but can also contain other hydrocarbons, water, nitrogen, 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.

Negative CO₂ emissions: The opposite of 'emissions'; a process that results in permanent removal of CO₂ from Earth's atmosphere through removal technologies which might include: bioenergy with CCS, biochar, 'blue carbon' habitat restoration and enhanced weathering.



NORSOK: Norsk Søkkel Konkuranseposisjon – Standards developed by the Norwegian Technology Centre.

O

Observation well: A well installed to permit the observation of subsurface conditions. Also called a monitoring well.

Ocean Injection: A concept for ocean sequestration in which CO₂ is injected directly into the mid-or deep ocean waters, where it dissolves into the ocean water).

Ocean Sequestration: Storage of CO₂ in ocean waters. Oceans are an important part of the natural carbon cycle because they store, release, and absorb large quantities of CO₂ 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 CO₂ storage. (IPAC CO₂). See Ocean Storage. This is to be distinguished from sub-seabed storage where CO₂ is buried deep beneath the seabed in geological strata.

Ocean storage: A proposed method whereby CO₂ 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: 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 lying above any particular stratum or feature.

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 natural pore fluids to escape as the surrounding mineral/sediment 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 CO₂ and water vapour. By cooling the flue gas, the water vapour condenses thereby creating an almost pure CO₂ stream. The CO₂ can be compressed, dried and further purified before being transported to a storage site.

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, to act like a sponge to allow the injected CO₂ to fill the tiny,



interconnected 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: The Pipelines and Hazardous Materials Safety Administration (US Dept. of Transport) has a remit “to protect people and the environment by advancing the safe transportation of energy and other hazardous materials that are essential to our daily lives”.

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 CO₂ in the geological formation. May also refer to a dispersing volume in seawater following an unintentional escape. (SiteChar).

Pockmark: a round depression in the seafloor, created by rapid fluid ascent. Pockmarks may be associated with chimney structures; Scanner Pockmark as an example



Pore space: Microscopic space between the individual 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 pore spaces and may be filled with various fluids such as salt water, oil, methane, or CO₂.

Post-combustion capture: Separating carbon dioxide from other waste gases after a fossil 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 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: The likelihood of a given event occurring and the level or intensity of its impact. Risk rating is based on probability. One example of a probability/risk rating is from Risk Rating Management: 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.

Produced water: In the hydrocarbon industries, water that is brought to the surface with oil and gas as a byproduct.

Province: An area with separate but similar geological formations.

Q

QICS project: A scientific research project funded by the Natural Environment Research Council of the UK, with support from the Scottish Government. Its purpose was to improve understanding of the sensitivities of the UK marine environment to a potential leak from a carbon capture and storage (CCS) system.

R

REDOX: Reduction-oxidisation reaction.

Regeneration tower: Where the CO₂-rich amine is heated to separate out the CO₂ and the amine using low pressure steam.

Regenerative Calcium Cycle (RGC): Another name for the calcium looping process which is used to separate CO₂ from other gases coming from other power generation or an industrial plant. It is suggested as being less toxic and more



efficient than current post-combustion technologies such as amine scrubbing.

Regional Carbon Sequestration Partnerships (RCSP): A network of seven RCSPs in the US to help develop the technology, infrastructure, and regulations to implement large-scale CO₂ in different regions and geologic formations.

Regional scale: In geology a feature that crosses an entire basin.

Release: An intentionally driven escape of gas or fluid from storage. In the STEMM-CCS Project for example, CO₂ will be released to test the ability of sensors and other equipment to detect and monitor for leaks that, though unlikely, may occur at storage sites in the future.

Remediation: The process of correcting any source of failure or remedying any damage caused. In CCS this might mean a failure of reservoir integrity.

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

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). Reservoirs are contained by impermeable rock or water barriers and each is characterized by a single natural pressure system.



Reservoir trap/seal: Hydrocarbon accumulations (oil and gas fields) 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 CO₂ sequestration, defined to be deeper than 1 kilometre.

Retrofit: A modification of existing equipment to upgrade and incorporate changes after the initial installation. In CCS this might be retrofitting a power station for CO₂ capture, or retrofitting an oil platform for CO₂ injection.

Risk Management: The application of a structured process to identify and quantify the risks associated with a given process or activity, 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.

Risk-based monitoring: Monitoring tasks are identified through a systematic risk evaluation based on the collective expert judgment and validated by independent experts. The scope and frequency of monitoring tasks depends on the outcome of this risk assessment. Project safeguards (mitigation strategies) are implemented to reduce storage risks to as low as reasonably practicable.



ROV: ROVs are **R**emotely **O**perated **V**ehicles, underwater robots that can carry out many tasks, often at great depth; they are unoccupied and highly manoeuvrable. These differ from AUVs in that they are tethered to a mother vessel and are remotely operated by a crew aboard the mother vessel.

S

Saline Formation: geological strata 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.

Seafloor: The interface between seawater and sediment (i.e., effectively the surface) whilst seabed implies inclusion of the upper portion of unconsolidated 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.

Seep: To pass slowly through small openings or pores; to ooze. In CCS terms it is often reserved for a naturally occurring escape of CO₂, from an underground source, such as might be seen in parts of terrestrial Italy, and in the Mediterranean Sea, for example.

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

Selection criteria: The 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-Valloor (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 carbon storage, but has other confusing meanings and should be avoided in favour of storage. Terrestrial sequestration is



the **absorbtion** and storage of CO₂ by vegetation and soils in terrestrial ecosystems. In biology sequestration includes both capture and storage – a further complication to be avoided.

Shale: A fine-grained, laminated sedimentary rocks consisting of silt- and clay-sized particles. Shale is the most abundant, accounting for around 70% of the sedimentary rocks in the crust of the Earth. Shales characteristically consist of at least 30% clay minerals and substantial amounts of quartz. These rocks have very low permeability. Shale is the most common trap rock.

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.



Shallow gas: A natural gas that has accumulated at a shallow depth, typically between 440m and 1000m below the surface. Shallow gas is often found in unconsolidated Tertiary sediments and is difficult to control during the drilling process and drilling engineers usually try to avoid it.

Sink: The natural uptake of CO₂ 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: A European research project about CO₂ storage site characterisation, which started in January 2011 and lasted 3 years, the Sitechar project is examining the technical, economic and societal requirements for a company to be allowed to store CO₂ underground.

Site characterization/site assessment: See Exploration

Soil carbon sequestration: Occurs through direct and indirect fixation of atmospheric CO₂. Direct soil carbon sequestration occurs by inorganic chemical reactions that convert CO₂ into soil inorganic carbon compounds such as calcium and magnesium carbonates. Direct plant carbon sequestration occurs as plants photosynthesize atmospheric CO₂ 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 CO₂ 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 CO₂ molecule. (see methane hydrates and clathrates).

Solubility trapping: See trapping, solubility.

Solvent: In CCS, a liquid that can soak up carbon dioxide.

Source: In CCS, any process, mechanism or activity which releases GHGs to the atmosphere.

Special Protection Area (SPA): A designation under the European Union Directive on the Conservation of Wild Birds. Under the Directive, Member States of the European Union (EU) have a duty to safeguard the habitats of migratory birds and certain particularly threatened birds.

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

STEPWISE: (Sorption-Enhanced Water Gas Shift (SEWGS) Technology Platform for cost effective CO₂ reduction the in



the Iron and Steel Industry) – “Scaling-up of the Sorption-Enhanced Water-Gas Shift technology for the capture of CO₂ from blast furnace gas, with a higher carbon capture rate, higher energy efficiency and lower cost in comparison to conventional technologies as goals.” STEPWISE is an H2020 project, <http://www.stepwise.eu/>

Storage: In CCS a process for retaining captured CO₂ so that it does not reach the atmosphere.

Storage complex: 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 to accommodate 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: 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.

Syncline: Folded strata where the each half of the fold dips towards the trough of the fold. The youngest rocks occur at the core of the fold

Syngas: An abbreviation for synthesis gas, a mixture of CO, CO₂ and H. It is produced by gasification of carbon containing fuel by reaction with steam or oxygen.

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.

Tertiary recovery: Oil is generated first by pressure release or depletion, secondly by oil driven out using water injection. The third way, which may use injected CO₂ or other chemicals, is tertiary recovery.

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

Trapping, Adsorption: CO₂ is preferentially adsorbed onto coal or organic-rich shales replacing gases such as methane. In these cases, CO₂ will remain trapped as long as pressures and temperatures remain stable. These processes would normally take place at shallower depths than CO₂ storage in hydrocarbon reservoirs.

Trapping, Dissolution: CO₂ dissolves into surrounding salt water.

Trapping, Geochemical: Where the CO₂ 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 CO₂ and rocks and minerals form ionic species, so that a fraction of the injected CO₂ is converted into solid carbonate minerals (millions of years).



Trapping, Mineral: CO₂ rich water sinks to the bottom of the reservoir and reacts to form minerals.

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

Trapping, Residual: CO₂ is trapped in rock pores and cannot move.

Trapping, Solubility: The process in which CO₂ dissolves into formation waters. The extent of dissolution generally decreases with increasing temperature and salinity, and increases with increasing pressure. The process removes CO₂ as a separate buoyant phase.

Trap rocks: Rocks, such as shale, which act as walls or ceilings to prevent the movement of gases or fluids; they have been described as the 'lid on the jar'.

Triple point of CO₂: 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.

Underground injection control (UIC): The US Environmental protection Agency in 2010 introduced the UIC Program for



Carbon Dioxide (CO₂) Geologic Sequestration Wells Final Rule (Class VI Rule). Within this regulation Class VI wells are used to inject CO₂ into deep rock formations for geological storage. The regulation addresses the unique nature of CO₂ injection including: relative buoyancy of the gas, its subsurface mobility, its corrosivity in the presence of water and the large injection volumes anticipated. The well requirements are designed to protect underground sources of drinking water and so mostly relevant for land-based injection; they include addressing the entire 'life' of the well from Siting through construction, operation, testing and monitoring to closure.

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

UNFCCC: 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 CO₂ storage. If subsequently mined, the stored CO₂ would be released. Enhanced Coal Bed Methane (ECBM) recovery could potentially increase methane production from coals while simultaneously storing CO₂. The produced methane would be used and not released to the atmosphere.



UN-IMO: United Nations International Maritime Organisation

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.



Further Information:

Many of the definitions in this glossary are taken from existing listings, in most cases definitions are combined or modified to provide better clarity. It has proven difficult to source each definition within the body of the text and thus a complete list of reference sources including useful websites is included here. I would like to thank all of those responsible for those sites and publications whose work has been used to compile this glossary. (KB. September 2016)

References consulted:

American Geological Institute (AGI), 1980, Glossary of geology: Falls Church, Virginia, American Geological Institute

American Society of Civil Engineers (ASCE), 1985, Manual 40 - Ground water management.

American Society for Testing and Materials (ASTM), 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.

Boot, K; Vercelli, S; Mabon, L; Shackley, S; Lombardi, S. 2013. The language of CCS: Definitions and explanations. (<http://www.eco2-project.eu/glossary.html>).



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.

Cohen Y, Rothman DH. 2015. Mechanisms for mechanical trapping of geologically sequestered carbon dioxide. Proc. R. Soc. A 471: 20140853.

IPCC Special Report on Carbon Dioxide Capture and Storage. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [Metz, B., O. Davidson, H. C. de Coninck, M. Loos, and L. A. Meyer (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 442 pp.- https://www.ipcc.ch/pdf/special-reports/srccs/srccs_wholereport.pdf

Leung, Dennis Y.C., Giorgio Caramanna, M. Mercedes Maroto-Valer (2014) An overview of current status of carbon dioxide capture and storage technologies. Renewable and Sustainable Energy Reviews 39 (2014) 426–443.

Maroto-Valer, M. Mercedes; Developments and innovation in carbon dioxide (CO₂) capture and storage technology. Volumes 1&2 Woodhead Publishing Ltd., 2010.



USGS United States Geological Survey – Glossary of Hydrologic Terms

ZEP (2013). Carbon Capture and Storage in EU Energy-Intensive Industries.

<http://www.zeroemissionsplatform.eu/library/publication/22-ccsotherind.html>

Useful web addresses:

Most of these websites contain glossaries from which definitions for the STEMM-CCS Glossary – CCS Defined - have been drawn. Original definitions and alternatives can be found within their pages.

Bellona - <http://bellona.org/ccs/ccs-news-events/news/article/a-finnish-idea-carbon-capture-and-neutralization.html>

British Geological Survey (BGS) - <http://www.bgs.ac.uk/discoveringGeology/climateChange/CCS/home.html?src=topNav>

Capture Ready – CaptureReady.com

Carbon Brief - <https://www.carbonbrief.org/explainer-10-ways-negative-emissions-could-slow-climate-change>

Carbon Sequestration Leadership Forum - <http://www.cslforum.org/>



CEMCAP - <http://www.sintef.no/cemcap>

Convention on Biological Diversity -
<http://www.cbd.int/impact/whatis.shtml>

CO2 Australia - <http://www.co2australia.com.au/>

CO2 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/>

The Carbon Capture and Storage Association (CCSA) -
<http://www.ccsassociation.org/what-is-ccs/capture/pre-combustion-capture/>

Global Carbon Capture and Storage Institute (Global CCS Institute) - <http://www.globalccsinstitute.com/>

CRCNetBase - <http://www.crcnetbase.com/>

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

ECO2 Project - <http://www.eco2-project.eu/home.html>

US Environmental Protection Agency (EPA) -
<https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data>



UD Department of Energy carbon sequestration -
www.fossil.energy.gov/programs/sequestration/index.html

Gasification and Syngas Technologies Council -
<http://www.gasification-syngas.org/resources/glossary/>

GreenFacts - www.greenfacts.org

International Association of Drilling Contractors (IADC)
Lexicon Project- <http://www.iadclexicon.org/>

International Energy Authority – Greenhouse Gas R&D
Programme (IEA-GHG) - www.ieaghg.org/

International Performance Assessment Centre for the
geologic storage of Carbon Dioxide (IPAC-CO₂). - www.ipac-co2.com

Intergovernmental Panel on Climate Change (IPCC) -
http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch7_s7-3-7.html

Low Emissions Intensity and cement (LEILAC) -
<http://www.project-leilac.eu/>

Massachusetts Institute of Technology -
<https://sequestration.mit.edu/index.html>

Nordic CCS Competence Centre -
<https://data.geus.dk/nordiccs/terminology.xhtml>



North American Carbon Capture and Storage Association –
<http://naccsa.org/>

Organisation for Economic Co-operation and Development
(OECD) - <http://www.oecd.org/>

Petropedia Dictionary -
<https://www.petropedia.com/definition/4365/abandoned-well>

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/>

Risk Management – Standard processes/definitions:
probability of occurrence.
<http://www.mitre.org/work/sepo/toolkits/risk/StandardProcesses/definitions/occurrence.html>

Royal Society of Chemistry (RSC) -
<http://www.rsc.org/ScienceAndTechnology/Policy/EHSC/EHSNotesonLifeCycleAssessment.asp>

Shell Global -
<http://www.shell.com/sustainability/environment/climate-change/carbon-capture-and-storage-projects.html>

STEPWISE - <http://www.stepwise.eu/>



Strategies for Environmental Monitoring of Marine Carbon Capture and Storage (STEMM-CCS) - <http://www.stemm-ccs.eu/>

United Nations Framework Convention for Climate Change (UNFCCC) – http://unfccc.int/essential_background/convention/status_of_ratification/items/2631.php

United Nations International maritime Organization (UN-IMO) – www.imo.org

US Geological Survey (USGS) - <http://energy.usgs.gov/EnvironmentalAspects/EnvironmentalAspectsOfEnergyProductionandUse/GeologicCO2Sequestration.aspx>

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