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Carbon Capture and Storage (CCS) and its Impacts on Climate Change and Global Warming

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Abstract

From the beginning of the Industrial Revolution time period, the gas exterior from burning of fossil fuels and extensive clearing of forests has contributed to a increase in the atmospheric concentration of carbon dioxide and recently it has been estimated that, if greenhouse gas emissions continue at the present rate, Earth's surface temperature could exceed historical values as early as possible, with almost harmful effects on ecosystems, biodiversity and the living conditions of people all over the world. Therefore Global climate is maybe the most challenging environmental problem the world will be facing in future. To decrease the growth of greenhouse gases and its consequences, a set of CO2-limiting policies will be needed. Carbon capture and storage (CCS) technology is one of the most important technologies around the world that is considered as one of the options for reducing CO2 gas and decreasing the global warming although, some aspects of using this technology, especially those of regulatory issues on this aspects should be more considered by States all around the world. In this article we will consider the impacts of applying CCS on the reduction of air pollution and global warming and also survey the Side effects of this technology in the context of international environmental law.

Keywords: CCS; Climate change; Global warming; Environment; Fossil fuels; International Environment Law

Introduction

The Earth's atmosphere is being changed at an unprecedented rate, primarily by humanity's ever-expanding energy consumption, and these changes represent a major threat to global health and security. Sound policies must be quickly developed and implemented to provide for the protection of the planet's atmosphere [1].

As the scientists report, Global warming is defined as an increase in the average temperature of the Earth's atmosphere, especially an increase great enough to cause changes in the global climate conditions. The term global warming is synonymous with Enhanced greenhouse effect, implying an increase in the amount of greenhouse gases in the earth's atmosphere, leading to entrapment of more and more solar radiations, and thus increasing the overall temperature of the earth. The heating situation of the earth in itself causes the life of humanity to be in danger. Our world is characterized by fast moving geopolitical and natural changes and the scenarios drawn by climate change specialists are alarming. If we want to avoid dangerous climate change and its ample consequences for creatures all over the world, it is necessary to take actions right now.

There is now scientific consensus that human activities, and in particular the way we transform and use fossil fuel energy, are responsible for increased CO_2 concentrations in the atmosphere and climate change.[1] It's good to mention that the global temperatures are higher than they have ever been during the past years, and the amounts of CO_2 gas in the atmosphere have excessed all previous records of reports. The important discovery from examining different periods throughout Earth's history is that notable results amplify any warming at the first levels[2] [2]. This is why climate has changed so dramatically in the past. Positive feedbacks take any temperature changes and amplify them. These feedbacks are why our climate is so sensitive to greenhouse gases, all of which CO_2 gas is the most important driver of climate change[3] [3]. On this way carbon capture and storage (CCS) is expected to play a key role in climate change mitigation strategies. CCS could be reduced from power stations using fossil fuel, such as coal, and it has been noted that no new power plants should be built without CCS facilities around. Carbon dioxide (CO_2) capture and storage (CCS) is a process including the segregation of CO_2 gas from industrial and energy sources, transport to a storage position and long-term isolation. It's good to point that increase in the amount of carbon dioxide will cause loss to the future generations because of its harmful effects accordingly. In this paper we would examine the impacts of CCS technology as one of the newest processes in order to minimize the global warming effect and the future of this technology and the way which it works. At the beginning of this paper it should be mentioned that thus paper includes some new and up to date information on the relation between technology of CCS and human common heritage as a worldwide concept that is new in itself.

Global Warming and Environmental Side Effects

Global warming

Increasing global temperature would result in the increasing the sea levels and will change the amount and pattern of environment,

[1] CO_2 capture and storage projects, Directorate-General for Research Directorate Energy, p. 6, 2007

[2] Denman KL, Brasseur G, Chidthaisong A, Ciais P, Cox PM, et al. (2007) Couplings Between Changes in the Climate System and Biogeochemistry. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, USA.

[3] Durwood Zaelke and James Cameron, "Global Warming and Climate Change- an Overview of the International Legal Process", AM. U.J. Int'l L. & Pol'y 5: 249.

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including an expanse of the desert regions. Some other effects include increases in the intensity of extreme weather conditions, changes in agricultural productions, glacier retreat, species extinctions and increases in the ranges of disease.

The greenhouse gases that cause climate change includes as the following: Carbon Dioxide, Methane and Nitrous Oxide are among the most noticeable gases. Carbon dioxide emissions therefore are the most important cause of global warming. CO_2 is created by burning fuels like oil, natural gas, diesel, petrol, organic-petrol, and ethanol.

Coal is the most carbon intensive fossil fuel. For every ton of coal burned, approximately 2.5 tons of CO_2 are produced.[4] Of all the different types of fossil fuels, coal produces the most carbon dioxide. Because of this and its high rate of use, coal is the largest fossil fuel source of carbon dioxide emissions. Coal represents one-third of fossil fuels' share of world total primary energy supply but is responsible for 43% of carbon dioxide emissions from fossil fuel use.[5]

Consequently increasing amounts of man-made greenhouse gases lead to an increase in the temperature on Earth. This temperature increase causes other effects, one of them being the increase of the amount of water vapor in the atmosphere. Although human activities don't directly add significant amounts of water vapor to the atmosphere, warmer air can contain more vapors. Because water vapor is a greenhouse gas, global warming will be again increased by the amounts of water vapor (Figure 1).

This is called a positive feedback or positive result. In other words:

- The current global warming is caused by man-made greenhouse gases (mainly CO_2, NOx and Methane).
- Global warming leads to a higher temperature on Earth.
- Because of the higher temperature, the air does contain more water vapor.

[4] Defra UK (2014) The 2014 Government greenhouse gas conversion factors for company reporting. London: U.K. Department for Environment, Food & Rural Affairs.

[5] http://whatsyourimpact.org/greenhouse-gases/carbon-dioxide-emissions (visited 2016/06/20)

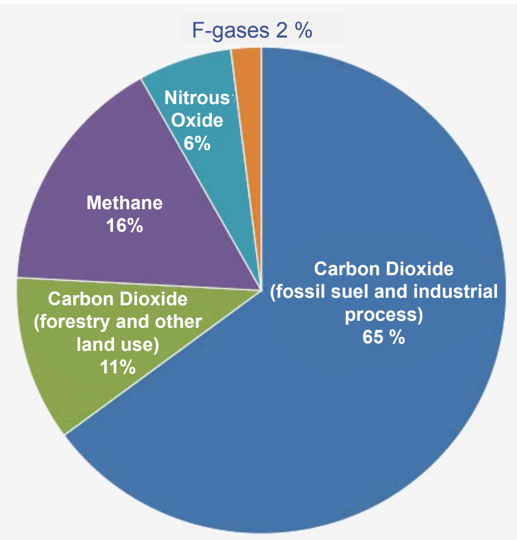

Figure 1a: Overview of greenhouse gases and sources of emissions. (Note: IPCC (2014) based on global emissions from 2010. Details about the sources included in these estimates can be found in the Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change).

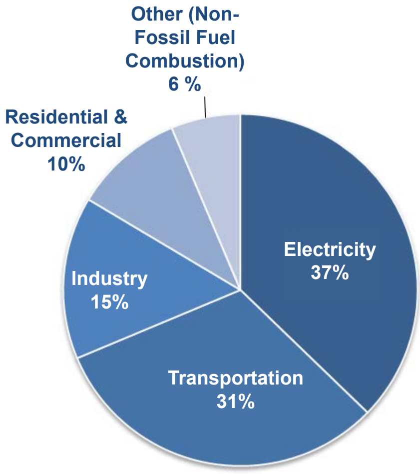

Figure 1b: U.S. Carbon dioxide emissions. (Note: All emission estimates from the Inventory of U.S. Green-house gas emissions and sinks: 1990-2014).

- This additional water vapor (a greenhouse gas) does again increase the effect of global warming (a positive feedback or secondary effect).

Global warming refers back to the recent increase in global average temperature near Earth's surface. It is caused almost by increasing concentrations of greenhouse gases in the atmosphere. Therefore increases in global temperatures have been accompanied by changes in weather conditions. Many places have been affected with changes in rainfall, resulting in more floods or droughts, as well as more severe heat waves. As such we could mention that Climate change refers back to any significant change in the measures of climate lasting for an increased times of year. In other words, climate change includes major changes in temperature or wind patterns that occur over several decades or longer and consequently climate change is expected to bring about major changes in freshwater availability, the productive capacity of soils, and patterns of human settlement. Accordingly climate change is intimately linked to human health either directly or indirectly. However, considerable uncertainties exist with regard to the extent and geographical distribution of these changes. Here undoubtedly it's good to note first that the agreed view on climate change and greenhouse gases is based on various lines of evidences. There includes basic physics, many different kinds of observations of both past and present climate conditions, and models that project future climate conditions.[6]

In the next part of this paper we'll discuss about the undesirable effects of climate changes and also global warming in the framework of environment international law.

The harmful effects of global warming for environment

The living conditions and desirable ways of creature lives depends upon the healthy and suitable environment and any manipulations and harmful attacks to the nature could lead to the undesirable conditions in living and accordingly would cause damages to the environment.

These damages to the environment are the direct causes of not suitable usages from energies available around us. This could lead

[6] IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

to the global warming and results in the climate changes. One of the most notable causes of this effect in the process of global warming is the excessive amounts of carbon dioxide in the atmosphere. Human activities are significantly increasing its concentration amounts in the atmosphere; consequently leading to Earth's global warming. Therefore there are both natural and human sources of carbon dioxide emissions in the atmosphere. Natural sources include decomposition, ocean release and respiration.

Human sources come from activities like cement production, deforestation as well as the burning of fossil fuels like coal, oil and natural gas. Due to human activities, the atmospheric concentration of carbon dioxide has been rising extensively since the Industrial Revolution and has now reached dangerous levels not seen in the last 3 million years. Human sources of carbon dioxide emissions are much smaller than natural emissions but they have upset the natural balance that existed for many thousands of years before the influence of humans. This is because natural sinks remove around the same quantity of carbon dioxide from the atmosphere than are produced by natural sources [4]. This had kept carbon dioxide levels balanced and in a safe range.

But human sources of emissions have upset the natural balance by adding extra carbon dioxide to the atmosphere without removing any. With reviewing the sources of CO_2 (as in the diagram) we would know that since the Industrial Revolution, human sources of carbon dioxide emissions have been growing. Human activities such as the burning of oil, coal and gas, as well as deforestation are the primary cause of the increased carbon dioxide concentrations in the atmosphere (Figure 2).

The important and also largest human source of carbon dioxide emissions is from the combustion of fossil fuels. This produces 87% of human carbon dioxide emissions. Burning these fuels releases energy which is most commonly turned into heat, electricity or power for transportation. Some examples of where they are used are in power plants, cars, planes and industrial facilities. Coal is the most carbon intensive fossil fuel. For every ton of coal burned, approximately 2.5 tons of CO_2 are produced.[7] Because of its high rate of use, coal is the largest fossil fuel source of carbon dioxide emissions. Anything involving fossil fuels has a carbon dioxide emission attached. Therefore burning these fuels releases energy but carbon dioxide also gets produced as a byproduct. This is because almost all the carbon that is stored in fossil fuels gets transformed to carbon dioxide during this process. It's important to note that the three main economic sectors that use fossil fuels are: electricity/heat, industry and transportation.[8]

It's better to understand that Carbon Dioxide should not be confused with carbon monoxide or CO, another odorless byproduct of combustion that is highly toxic to humans and animals. Carbon monoxide – not carbon dioxide or CO_2 – is the reason buildings must be properly ventilated, to prevent fireplace or furnace emissions from killing inhabitants. Volcanoes and deep sea vents also release notable amounts of CO_2. Indeed, they were the original sources of the CO_2 that helped launch life on earth. The periodic shifts in ocean current patterns in the southern tropical Pacific, known as El Niño and La Niña, also affect carbon dioxide levels. As scientific aspects, El Niño warms the sea waters and causes them to exhale huge amounts of CO_2 into the atmosphere; La Niña events cool waters and cause them to absorb more CO_2, which spurs the growth of oceanic algae.

[7] Defra UK (2014) The 2014 Government Greenhouse Gas Conversion Factors for Company Reporting. London: U.K. Department for Environment, Food & Rural Affairs.

[8] International Energy Agency CO_2 Emissions from Fuel Combustion (2012) Paris: Organization for Economic Co-operation and Development.

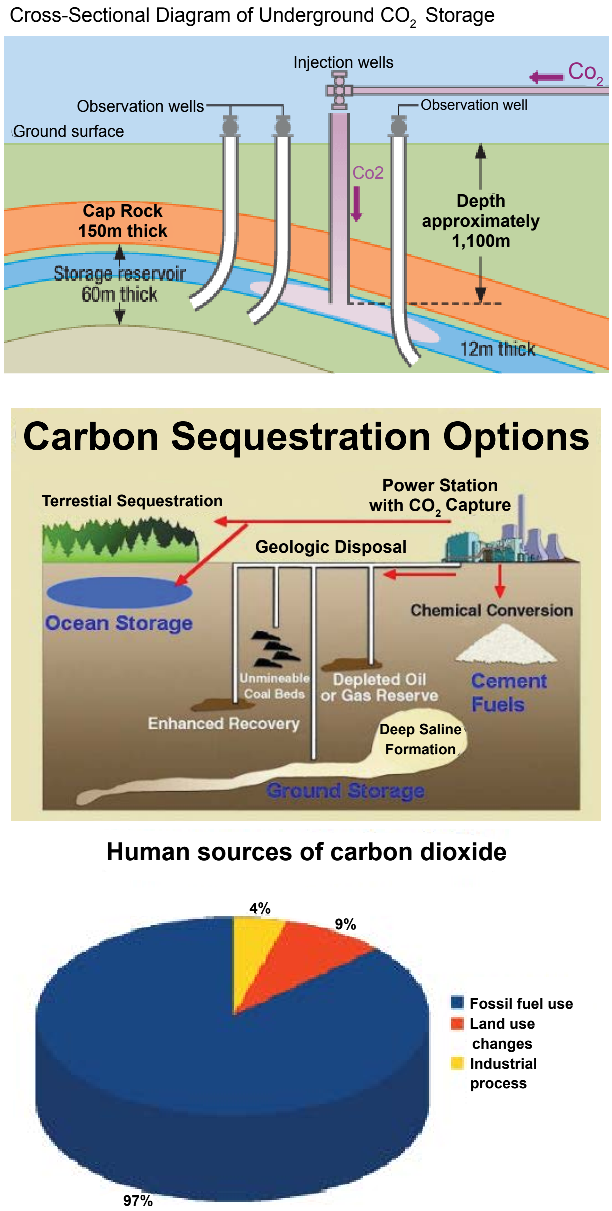

Figure 2: Carbon Dioxide Capture and Storage (CCS), a process for capturing and storing carbon dioxide (CO_2).

As a result the increase in atmospheric CO_2 concentration is known to be caused by human activities because the character of CO_2 in the atmosphere, in particular the ratio of its heavy to light carbon atoms, has changed in a way that can be related to addition of fossil fuel carbon. Moreover, the ratio of oxygen to nitrogen in the atmosphere has declined as CO_2 has increased; this is as expected because oxygen is depleted when fossil fuels are burned. A heavy form of carbon, the carbon-13 isotope, is less abundant in vegetation and in fossil fuels that were formed from past vegetation, and is more abundant in carbon in the oceans and in volcanic emissions. The relative amount of the carbon-13 isotope in the atmosphere has been declining, showing

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that the added carbon comes from fossil fuels and vegetation. Carbon also has a bare radioactive isotope, carbon-14, which is present in atmospheric CO_2 but absent in fossil fuels. Prior to atmospheric testing of nuclear weapons, decreases in the relative amount of carbon-14 showed that fossil fuel carbon was being added to the atmosphere[9].

Over the long run, the ability to remove CO_2 from the air should be viewed as an essential tool in our kit for managing carbon-climate risks. We therefore need, at the minimum, a serious long term exploratory research effort to develop air capture along with other direct methods for removing CO_2 from the atmosphere.

The harmful effects of CO_2 for future generations

Many present efforts to guard and maintain human progress, to meet human needs, and to realize human ambitions are simply unsustainable - in both the rich and poor nations. They draw too heavily, too quickly, on already overdrawn environmental resource accounts (especially those un renewable) to be affordable far into the future without bankrupting those accounts. As Brundtland declared in her report on Sustainable development[10] (1987) we borrow environmental capital from future generations with no intention or prospect of repaying. They may damn us for our spendthrift ways, but they can never collect on our debt to them. We act as we do because we can get away with it: future generations do not vote; they have no political or financial power; they cannot challenge our decisions.

National and international law is being rapidly outdistanced by the accelerating pace and expanding scale of impacts on the ecological basis of development. Governments now need to fill major gaps in existing national and international law related to the environment, to find ways to recognize and protect the rights of present and future generations to an environment adequate for their health and well-being, to prepare under UN auspices a universal Declaration on environmental protection and sustainable development and a subsequent Convention, and to strengthen procedures for avoiding or resolving disputes on environment and resource management issues.

So while many believe that Our moral duties can extend only to existing people, Since future generations do not presently exist and therefore it is not possible to have any moral obligations toward them, there are many reasons to think this objection is mistaken. For one thing, it would also rule out any moral claims or responsibilities toward those in the past since past people do not presently exist anymore than future people do! Yet, it certainly seems that we can have moral concerns involving people in the past and in future. This is while today it has been to some extent accepted that we have moral and legal obligations toward future generations to provide a safe and secure world for them.[11] Global warming in result of burning of fossil fuel and reducing CO_2 gas, could harm both existing and future generations by some negative impacts on climate change and atmosphere stability.

Diagram below makes clear that with an increase in CO_2 concentration in the atmosphere, there are more CO_2 greenhouse molecules in the tropopause, they will radiate into space from a higher level (from Ze to Ze + ΔZe). Because of the adiabatic lapse rate, it will be colder there, so they will radiate (a lot!) less energy to space. This disturbs the equilibrium, so in order to restore that, the earth surface has to heat up (from Ts to Ts + ΔTs), so the adiabatic lapse rate (ALR) will move upwards and warm the tropopause, until the radiation into space is the same as before the CO_2 increase. In the drawings this theory is always illustrated with beautifully straight lines.[12] (Figure 3).

[9] IPCC (2007) Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M and Miller HL (eds.)] Cambridge University Press, Cambridge, United Kingdom and New York, USA.

[10] Report of the World Commission on Environment and Development: Our Common Future.

[11] Moral Obligations toward the Future

Some Possible Solutions

Now that the harmful effects of global warming on environment have been elucidated, we should also make clear and propose the possible solutions for facing with this notable challenge. In order to make choices that reduce greenhouse gas pollution amount, and preparing for the changes we can reduce risks from climate change.

There are several things we can do to deal with global warming. One answer is to stop making CO_2. We can do this by switching from oil, coal and gas to renewable energy. Next solution is to plant more trees. Trees absorb CO_2 and produce oxygen, which is not a greenhouse gas. Another idea is to use less energy and recycle more products. If we use less energy and be more environmentally friendly, the earth's temperature may not rise too much.[13] Obviously, the solutions are directed towards controlling the release of these harmful gases:

- One of the ways for this problem is reducing the usages of fossil fuels but unfortunately there is no way and the humanity should use one of the fuel sources available.
- Second way is using the alternative energy and clean energy sources and that's not cheaper though.
- And the middle way proposed is using CCS technology that simultaneously with CO_2 release, it will be captured and stored undergrounds and of course this is relatively middle way.

As I noticed for clarification in order to solve this danger, we have to reduce the consumption of energy and use the alternative energy

[12] http://www.climatetheory.net/ (visited 2016/06/26)

[13] T J, Rochelle (2016) Global Warming (Problem -Solution model essay).

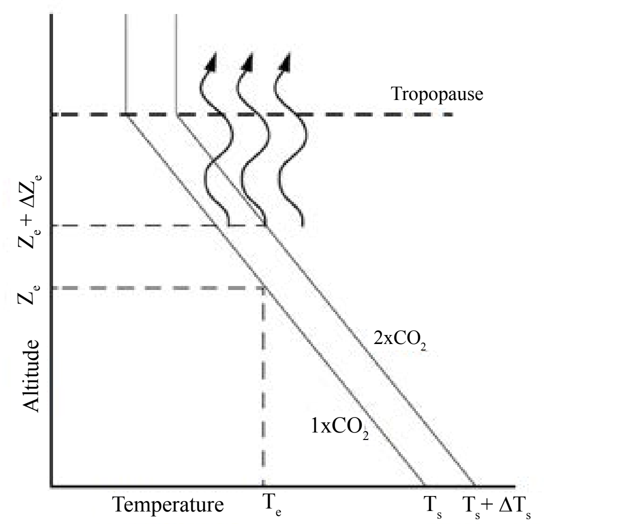

Figure 3: Schematic illustration of the change in emission level (Ze) associated with an increase in stn-face temperature (T_s) due to a doubling of CO_2 assuming a fixed atmospheric lapse rate. (Note that the effective emission temperature (T_e) remains unchanged).

resources. If we calculate the present energy price, alternative energy must be more expensive than fossil fuels. However if we consider the negative price which is caused by global warming, this result might be different.[14]

It's better to mention that we can avoid the most severe results by implementing available clean energy and efficiency solutions at the local, state, and national levels. Many of these solutions provide immediate additional benefits including consumer savings on energy costs and cleaner air and water. We must begin enacting these available solutions today to impede the worst effects of global warming. We must get together to tackle the problem of global warming by managing the surroundings around our own houses.[15]

We need to find place to plant trees in the jungle. We should begin first with our own house. Gardens are necessary if we have to survive but we also need to device some other methods to cover the surface of buildings as is possible. Management of jungles has to be our top priority. Recycling of the trees in the jungles with cutting dry trees is very important because dry trees cause fire that not only destroy green trees but also cause release of harmful gases. Management of jungles is an issue that governments have to take care while each one of us can take care of surroundings around all of us. We also ought to reduce the consumption of electricity. As solar energy and wind energy is still too expensive to be used at mass scale.

Accordingly for this problem most of the states have proposed the underlined ways that some of them have been mentioned earlier and I'm taking into account them again in order to elucidate more:

- Renewable Electricity Standard: Great Lakes states in the world currently have standards and have significant economic and environmental benefits consequently.
- Increased Clean Energy Funding: The fund should be supported by a kilowatt hour charge on consumer bills to provide a guaranteed pool of public money for energy management programs.
- State Residential Energy Efficiency Building Code: The legislature should approve legislation to adopt such a code, which would yield consumer energy savings and help cut global warming emissions.
- Incentives for Cleaner Burning Fossil Fuel Generation: persuading the use of heat and power in a combination that produce both heat and electricity for a facility or surrounding community.
- Energy Efficient Lighting[16]

At last, making small changes now in the way we live means avoiding huge changes in the future. Scientists, governments and individuals must work together to overcome this serious threat.

Carbon Dioxide Capture and Storage (CCS)

The raison detre for carbon capture and storage (or sequestration) (CCS)[17] is to make the world use the limited conditions of having no or less carbon dioxide. Good points and benefits include economic competitiveness, energy security and a non-disruptive transition to low-carbon energy systems. We could consider CCS in the process of mitigation actions for greenhouse gas concentrations. As we noted large point sources of CO_2 include large fossil fuel or biomass energy facilities, major CO_2-emitting industries, natural gas production, synthetic fuel plants and fossil fuel-based hydrogen production plants. Potential technical storage methods are: geological storage (in geological formations, such as oil and gas fields, unminable coal beds and deep saline formations[18]), ocean storage (direct release into the ocean water column or onto the deep seafloor) and industrial fixation of CO_2 into inorganic carbonates.

For CO_2 capture, the challenge is to separate CO or CO_2 from synthetic fuels derived from fossil fuels, or to separate CO_2 from the flue gas. This is respectively pre- and post-combustion capture. There are also alternative ways, like for instance having the combustion in almost pure oxygen (oxy-fuel combustion), which produces a stream of highly concentrated CO_2, but requires the separation of oxygen from the air.[19]

Large-scale CCS usages would need the creation of a regime to manage risks and supporting policies to facilitate technology investment. Within this frame, regulatory, legal, and public understanding considerations emerge as crucial factors that could either accelerate or inhibit CCS usages. Policy makers worldwide need to work towards a system of regulation and risk governance for CCS that is globally consistent nationally coordinated, and which adequately manages local risks. This policy shortly reviews regulatory issues post-capture, particularly the transport and geological storage of CO_2. It identifies key areas where relevant stakeholders should coordinate in international arena and proposes a model for development of national deployment and regulation, which includes jurisdictional specificities.

For practical implementation and working, CCS will need to be regulated as an industrial process, with regulations entered to each project stage: capture, transportation, site selection and permitting, site operations, site closure, and long-term stewardship. Despite the fact that all the elements of this industrial process exist, they are not yet developed to scale nor are they integrated. The structure of the future CCS industry deployment can take a number of possible forms in terms of the relationships between CO_2 producers, CO_2 pipeline operators, and geological storage site operators. This concise policy does not cover regulatory issues related to capture but it is worth noting this important point that, while the long-term potential for CCS is in capturing CO_2 at fossil-fired electric power plants, significant short-term potential lies in other industrial processes that already generate a concentrated CO_2 stream, such as natural gas or hydrogen production. Regulation of transport and geological storage must be designed to manage CO_2 from both electric utilities and from these other industries. A thorough CCS regulatory framework must balance competing needs and interests of local, national and international publics, CO_2 generators, CO_2 pipeline operators, geological storage site developers, financial institutions supporting the project, government agencies of safety and environmental requirements, and national and international agencies managing various climate regimes. The potential contribution of this technology will be influenced by factors such as the cost relative to other options, the time that CO_2 will remain stored, the means of transport to storage sites, environmental concerns, and the acceptability of this approach. The CCS process requires additional fuel and associated CO_2 emissions compared with a similar plant without capture.

[14] Solutions Of The Problem Of Global Warming

[15] http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/ucssolutionilfinal.pdf

[16] http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/ucssolutionilfinal.pdf
(accessed 2016/4/14)

[17] A note: CCS is a new technology, and issues of terminology are still in flux. Some practitioners use the phrase Carbon Capture and Sequestration while others prefer Carbon Capture and Storage. The EU, the IPCC, and the UNFCCC have adopted Carbon Capture and Storage.

[18] Saline formations are sedimentary rocks saturated with formation waters containing high concentrations of dissolved salts. They are widespread and contain enormous quantities of water that are unsuitable for agriculture or human consumption. Because the use of geothermal energy is likely to increase, potential geothermal areas may not be suitable for CO_2 storage.

[19] CO_2 capture and storage projects, Directorate-General for Research Directorate Energy, p. 6, 2007

Many factors will need to be taken into account in any comparison of mitigation options, not least that is making the comparison and for what purpose. In addition, there are broader issues, especially questions of comparison with other mitigation measures. Answering such questions will depend on many factors, including the potential of each option to deliver emission reductions, the national resources available, the accessibility of each technology for the country, national commitments to reduce emissions, the availability of finance, public acceptance, likely infrastructural changes, environmental side-effects and so on.

CO_2 from capture to storage

Capturing CO_2 typically involves separating it from a gas stream. Useful and suitable techniques were developed 60 years ago in connection with the production of town gas; these involved scrubbing the gas stream with a chemical solvent. Accordingly they were adapted for related purposes, such as capturing CO_2 from the flue gas streams of coal- or gas-burning plant for the carbonation of drinks and brine, and for enhancing oil recovery. It's important to mention that there are three main technology options for CO_2 capture in the generation of electricity and heat: post-combustion capture through chemical absorption, pre-combustion capture, and oxy- fuelling. The captured carbon dioxide must be compressed for transport and storage.

In the post-combustion process CO_2 is captured typically through the use of solvents and subsequent solvent regeneration, sometimes in combination with membrane separation. The basic technology has been used on an industrial scale for decades, but the challenge is to recover the CO_2 with a minimum energy penalty and at an acceptable cost. Pre-combustion capture processes can also be used in coal- or natural gas-based plant. The fuel is reacted first with oxygen and/or steam and then further processed in a shift reactor to produce a mixture of hydrogen and CO_2. The CO_2 is captured from a high-pressure gas mixture.

The oxy-combustion process includes the removal of nitrogen from the air in the oxidant stream using an air separation unit or, potentially in the future, membranes. At this time after the process of capturing the next stage takes place. This phase is transportation of carbon dioxide to the storage fields. Except when the emission source is located directly over the storage site, the CO_2 needs to be transported. Pipelines have been used for this purpose in the USA since the 1970s. CO_2 could also be transported in liquid form in ships similar to those transporting liquefied petroleum gas (LPG). For both pipeline and marine transportation systems of CO_2, costs depend on the distance and the quantity transported. For pipelines, costs are higher when crossing water bodies, heavily congested areas, or mountains. Compressed CO_2 can be injected into formations under the Earth's surface using many of the same methods. The three major types of geological storage are oil and gas reservoirs, deep saline formations, and un-minable coal beds. CO_2 could be physically trapped under a well-sealed rock layer or in the pore spaces within the rock. It can also be chemically trapped by dissolving in water and reacting with the surrounding rocks. The risk of leakage from these reservoirs is rather nothing in importance. Storage in geological formations is the cheapest and most environmentally acceptable storage option for CO_2. It's good to note that Oceans can store CO_2 because it is soluble in water. When the concentration of CO_2 increases in the atmosphere, more CO_2 is taken up by the oceans. Captured CO_2 can potentially be injected directly into deep oceans and most of it could remain there for centuries. CO_2 injection, however, can harm marine organisms near the injection point. It is furthermore expected that injecting large amounts would gradually affect the whole ocean.

Accordingly we could mention that storage of CO_2 in oceans isn't a good option for considering in this process. By chemical reactions with some naturally occurring minerals, CO_2 is converted into a solid form through a process called mineral carbonation and stored virtually permanently. This is a process which occurs naturally, although slowly. These chemical reactions can be accelerated and used industrially to store CO_2 in minerals artificially. However, the large amount of energy and mined minerals needed makes this option less cost effective. It is technically possible to use captured CO_2 in industries manufacturing products such as fertilizers. The overall effect on CO_2 emissions, however, would be very small, because most of these products rapidly release their CO_2 content back into the atmosphere. So we could describe three main mechanisms for CO_2 storage as followings:

- Physical trapping by immobilizing CO_2 in a gaseous or supercritical phase in geological formations. This can take two main forms: static trapping in structural traps and residual-gas trapping in a porous structure.
- Chemical trapping in formation fluids (water/hydrocarbon) either by dissolution or by ionic trapping. Once dissolved, the CO_2 can react chemically with minerals in the formation (mineral trapping) or adsorb on the mineral surface (adsorption trapping).
- Hydrodynamic trapping through the upward migration of CO_2 at extremely low velocities leading to its trapping in intermediate layers. Migration to the surface would take millions of years. Large quantities of CO_2 could be stored using this mechanism.[20]

Financial, legal and regulatory issues

A number of non-technical challenges need to be overcome if the full potential of CCS is to be achieved. These include:

- Financing near-term demonstration projects.
- Setting a long-term, sufficiently high and stable price for CO_2.
- Establishing legal and regulatory frameworks.
- Educating the public to foster awareness and acceptance.

These critical non-technical issues are discussed in this part of the paper.

Financing: In the newest fiscal and regulatory environment, commercial fossil-fuel power and industrial plants are unlikely to capture and store their CO_2 emissions, as CCS reduces efficiency, adds costs, and lowers energy output. Even in the European Union (EU), which has carbon constraints in, the benefits of reducing carbon emissions are not sufficient to outweigh the costs of CCS. These barriers can be partially overcome by government support in the form of tax credits and other related incentives. The wider penetration of CCS will require such support at all stages of project development.

Experience from early CCS projects will guide subsequent future commercial deployment and foster the learning needed to facilitate CCS for the power generation and industrial sectors. There are a variety of promising early opportunities for CCS, including expanding existing CO_2 capture in natural gas processing, or in ammonia or hydrogen manufacturing where the CO_2 is already separated, and developing EOR activities where there are financially attractive storage options.[21] CO_2-EOR offers a specially promising opportunity for early projects that are supported commercially by the values of additional recovered

[20] IPCC (Intergovernmental Panel on Climate Change) (2005) "Transport of CO_2", Chapter 4 of Special Report on Carbon Dioxide Capture and Storage, Cambridge University Press, Cambridge.

[21] Karstad O (2007) "CCS Business Models", IPIECA Workshop, Oslo.

oil. Large volumes of CO_2 are lately being captured and used for EOR in the United States, the Middle East and other regions and also it's vital to mention that with the right carbon pricing signals, the EOR market could provide more important early demand for CO_2. Consequently it's good to note that the most of CCS demonstration projects will need to be implemented and acted in the electricity generation sector. There is limited worldwide experience of carbon capture from coal-fired power plants, and also no experience of an integrated CCS project at a coal-fired power plant. There has been much debate and discussion about the minimum project size needed for meaningful demonstration of the relevant technologies.

Legal and regulatory issues: The expansion of CCS will present a number of legal and regulatory issues. The most important of these include: developing regulations for CO_2 transport; establishing jurisdiction among international, national, government actors; establishing ownership of storage-site resources and legal means for acquiring the rights to develop and use such resources, including access rights; developing clear guidelines for site selection, permitting, monitoring and verifying CO_2 retention; clarifying liabilities in a long run and financial responsibility for CO_2 storage operations; and, in the case of offshore CO_2 storage, complying with appropriate international marine environment protection instruments.

The safe and effective transportation of CO_2 requires the management of local environmental and safety risks and the mitigation of the potential impacts of CO_2 leakages on the global environment. There are different options for transporting CO_2 from capture sites to storage locations, including pipelines and pressurized road and sea tankers. Given the large volumes of CO_2 that are likely to need to be injected, pipelines offer the most cost-effective means of transport. As a result, most governments are focusing in the near-term on pipeline regulations.[22]. If other, non-pipeline transport mechanisms are used; they will require convenient regulatory frameworks to minimize safety and environmental risks levels. The most difficult issues in CO_2 pipeline regulations relate to funding, pipeline siting, and pipeline access.

Important point is that any regulatory and liability framework for CO_2 storage sites needs to define the roles and financial responsibilities of industry and government after site closure and permanent decommissioning. The level of risk associated CO_2 storage project will evolve as the project progresses along its life cycle.

Environmental Negative Effects of Using CCS

CCS is a means of separating out carbon dioxide when burning fossil fuels, and then dumping it - underground, or else at or under the sea bed.[23] CCS provides the greatest potential to reduce the greenhouse gases emitted by our stationary energy sector.[24] [5].

CCS technologies require approximately 15% to 25% more energy depending on the particular type of technology used, so plants with CCS need more fuel than conventional plants. This in turn can lead to increased 'direct emissions' occurring from facilities where CCS is installed, and increased 'indirect emissions' caused by the extraction and transport of the additional fuel.[25] The impact of carbon capture and storage (CCS) on environment is an important issue in discussing whether this technology should be part of choices for facing with increasing greenhouse gas emissions, both nationally and internationally. On the other hand, CCS has the long term potential to make a substantial positive impact on the amount of CO_2 emitted into the atmosphere by the stationary energy sector.

The most substantial risk associated with CCS is the leakage of CO_2 from storage sites. While there is some experience with geological storage of CO_2 and natural gas for periods of approximately 10-20 years, long term storage over many hundreds or thousands of years has not been proven [6]. The IPCC Special Report on CCS suggests that the environmental risks associated with CO_2 capture and storage are low. As the IPCC stated well-selected geological formations are likely to retain over 99% of their storage over a period of 1,000 years.

Overall, the risks of CO_2 storage are comparable to the risks in similar existing industrial operations such as underground natural-gas storage and [EOR][26] [7].

Here it's good to mention that "Migration of CO_2 into neighbor geologic formations" is one of the related risks according to the projects of CCS that its probability of occurrence is very high and the direct and indirect consequences of that are as follows:

Lateral and/or descendent diffusion of CO_2 from the storage complex into neighbor formations (the caprock - top sealing rock layer is, by definition, impermeable to CO_2). CO_2 reactive processes with minerals of neighbor geologic formations (secondary trap mechanisms occurring at long-term storage).[27]

The environmental impact is highly dependent on the characteristics of underground geological formation for the purposes of lasting storage of the CO_2, partly because of overpressure issues of the reservoir and lithology adjacent to the storage reservoir. CO_2 stored in saline aquifers is absorbed and dissolved in the saline water, and also, eventually, part of the injected amount may have reacted with other dissolved minerals in the aquifer.

An eventual leakage from underground is a slow process that may last for decades or even centuries, depending on the diffusion capacity of the CO_2 through the geologic formations above the reservoir layer, until the CO_2 finally reach the surface. Although deep saline aquifers are considered to represent a huge potential for CO_2 storage and are geographically available all over the world, but in countries where hydrocarbons reservoirs are non-existent abandoned or unmineable coal seams represent a better potential location for lasting storage of CO_2. The safety of CO_2 sequestration depends on geological, both chemical and physical, trapping mechanisms for CO_2, which are different for saline aquifers and for coal. CO_2 naturally occurs in coal seams, associated with other gases Coal adsorbs CO_2 preferably to other gases, while in saline aquifers the injected CO_2 will not be adsorbed and will compete for underground space with brine, most probably causing its displacement accordingly. Because of this, overpressure of the storage reservoir is most likely to occur sooner in aquifers than in coal seams.

CCS and Its Future

Only geological storage of CO_2 is going to be considered to be environmentally acceptable in the world. Ocean storage above the

[22] MCMPR (Ministerial Council on Mineral and Petroleum Resources) (2005) Principles for engagement with communities and stakeholders, Melbourne

[23] http://www.greenpeace.org.uk/blog/climate/the-problem-with-carbon-capture-and-storage -ccs-20080103 (last visited 2016/06/20)

[24] Lacis AA, Schmidt GA, Rind D, Ruedy RA (2010) "Atmospheric CO_2: Principal Control Knob Governing Earth's Temperature. Science" 330: 356-359.

[25] http://www.eea.europa.eu/highlights/carbon-capture-and-storage-could

[26] United Nations Environmental Programme (UNEP) (2006) Can carbon dioxide storage help cut greenhouse emissions? A Simplified guide to the IPCC's 'Special report on carbon dioxide capture and storage'. p: 15.

[27] http://conferences.iaia.org/2012/pdf/uploadpapers/Final%20papers%20review%20process/Oliveira,%20Gisela.%20%20Environmental%20Impact%20Assessment%20of%20Carbon%20Capture%20and%20Sequestration.Pdf

seabed, for instance, is not considered acceptable. Several geological settings are envisaged as potential storage sites, oil and gas reservoirs, in exploitation or depleted, non-mineable coal seems, and deep saline aquifers. In all cases, the CO_2 should be under a hydrostatic pressure of more than 70 bars (that is deeper than 700 meters on-shore) to make sure that it is stored as a supercritical fluid, and not as a gas. From a storage potential point of view, estimates – also obtained in Framework Program research contracts – are that deep saline aquifers have the potential to hold more than all of the CO_2 which would be produced if we used all of the oil, gas and coal. These geological formations are – like coal reserves – quite evenly spread across the world. The challenge is therefore to make sure that the injection of CO_2 in these strata is a safe process, from the immediate health and safety issues associated with the injection process, to the CO_2 storage permanence required to effectively address climate change. From this point of view, CO_2 injection and storage, like any other engineering activity, will require a proper legislative and regulatory framework, norms and standards, good practice, and common sense. Mother Nature, which has stored oil, gas, water and CO_2 for million years, indicates that this should be feasible. Safety is also directly linked to the long term liability issue. The timescales required to effectively combat climate change are incompatible with the operations of a private company, so that liability transfer to the public authorities must take place sometime after the end of the injection. This can happen only if proper site certification, monitoring and verification methods are in place. Given appropriate emission reduction incentives, CCS offers a viable and competitive route to mitigate CO_2 emissions. CO_2 capture leads to an increase in capital and operating expenses, combined with a decrease in plant energy efficiency. With the recent development of a more robust methodology for storage capacity estimates, governments urgently need to conduct detailed evaluations of their national CO_2 storage capacity, working in partnership with bordering nations who share the same storage space.

The Role of Seabed Authority in Managing the Problem

UNCLOS (United Nations Convention on the Law of the Sea) is applicable to sub-seabed storage because its jurisdiction includes seabed and subsoil. UNCLOS specifies that the sovereignty of a coastal state over its territorial sea and contiguous zone extends to the “seabed” and “subsoil”. According to article 56, Within its EEZ, a coastal state is provided sovereign rights for the purpose of exploring and exploiting, conserving and managing the natural resources of the “seabed and its subsoil”. Within its continental shelf (the seabed and subsoil of the submarine areas extending beyond the territorial sea), and according to article 77 a state has sovereign rights for exploring and exploiting natural resources. Thus, the geologic formations that would be used for carbon dioxide storage fall within the jurisdiction of UNCLOS.

Accordingly “Dumping” as defined in article 1 by UNCLOS in this regard means the “deliberate disposal of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea”. However UNCLOS does not define the term “wastes or other matter”. Then it seems that any storage mechanism for carbon dioxide that was not a man-made structure at sea, such as a pipeline that transported the carbon dioxide from land directly to the sub-seabed point of injection, would not be “dumping” under UNCLOS.

Therefore Carbon dioxide storage using a vessel, platform, or man-made structure at sea would be defined as “dumping” under UNCLOS, but is not necessarily prohibited. Even if a carbon dioxide storage mechanism was used that fell under the UNCLOS definition of “dumping” (in the case the storage mechanism included a vessel, platform, or manmade structure, and assuming arguendo that carbon dioxide was determined to fall under the UNCLOS definition of “waste”), the dumping is not necessarily prohibited by UNCLOS. Rather, in article 210, UNCLOS requires that states adopt laws and regulations to prevent, reduce and control pollution of the marine environment by dumping. These laws and regulations are expected to be based on rules, standards and recommended practices and procedures established by “competent international organizations;” and the London Convention, would be the appropriate source of international law in this case. Thus UNCLOS does not necessarily prohibit dumping of wastes or other matter, but rather would defer to the London Convention’s interpretation of pollution by dumping.

Conclusion

Global warming is the result of increase in the earth’s average surface temperature due to greenhouse gases like carbon dioxide and methane.[28] It is constantly resulting in extreme high temperature of the surface, reduction of snow cover, and rise in the water level and the increasing human activities are significantly contributing to the cause of global warming. The foremost activity among them is the burning of the fossil fuels by the industries, which forms the huge amount of the carbon dioxide and the Nitric acid into the air. In this way the environment is dealing with some of the very serious problems, which are having its considerable effect on the climate too. One of the main causes of global warming is increase in the amount of carbon dioxide in the atmosphere.

CO_2 is a naturally occurring atmospheric gas that is considered safe at levels below 0.5%. In addition to potential indoor exposure, high concentrations of CO_2 can collect outdoors. Outdoor exposure can occur where CO_2 is venting from below ground sources such as mining operations, natural gas production, and magmatic emissions.[29] It’s good to note here that we should first recognize the sources of carbon dioxide in the environment that as the diagram shows: 87 percent of all human-produced carbon dioxide emissions come from the burning of fossil fuels like coal, natural gas and oil. The remainder results from the clearing of forests and other land use changes (9%), as well as some industrial processes such as cement manufacturing (4%)[30].

So it has become really important to reduce the process of warming as soon as possible by the way of reducing this hazardous gas in the atmosphere. Capturing carbon dioxide emissions (CCS) from power plants and storing it underground is seen as a crucial technology to reduce the global warming impact of fossil fuels such as coal and gas, on which the world will continue to rely for decades. According to International Energy Agency demand, CCS will need to lead somehow one fifth of emissions reductions, across both power and industrial sectors, so CCS plays an important role as part of an economically sustainable way to meet climate mitigation goals within the 2050 timeframe, that at the same time ensuring global and regional energy security. Finally it seems that CCS is currently one of the best available technologies to drastically reduce greenhouse gas emissions from certain industrial processes and it is a key technology option to decarbonize the power sector especially in countries with a high share of fossil fuels in electricity production. That’s so necessary to install this equipment of CCS project because the main concern of the international society is to resolve and impede the harmful effects of greenhouse gases accordingly. However we should

28 http://www.conserve-energy-future.com/various-global-warming-facts.php

29 Health Risk Evaluation for Carbon Dioxide (CO_2) http://www.blm.gov/style/medialib/blm/wy/information/NEPA/cfodocs/howell.Par.2800.File.dat/25apxC.pdf

30 Le Quéré C, Jain AK, Raupach MR, Schwinger J, Sitch S, et al. (2012) "The global carbon budget 1959-2011" Earth System Science Data Discussions 5: 1107-1157.

not ignore the possible negative sides of this case. The future practice of States, specially developed states, in using CCS could help international community to provide a more proper Judgment about this technology and its advantages. Clearly we can mention to the role of sea bed authority in the way of reducing the amounts of carbon dioxide and decreasing global warming effects. We can dedicate the implied role of this authority related to this matter because there are no clear proofs for supporting this idea but with perusing the UNCLOS articles carefully we can make conclusions to the related roles of sea bed authority in decreasing the effects of global warming and its harmful consequences.

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