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**CARBON CAPTURE AND STORAGE  
LEGAL AND REGULATORY FRAMEWORK IN DEVELOPING COUNTRIES:  
PROPOSALS FOR BRAZIL**

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LEGAL AND REGULATORY FRAMEWORK IN DEVELOPING COUNTRIES:  
PROPOSALS FOR BRAZIL**

Dissertation submitted in partial satisfaction of the requirements for the degree of Doctor of Philosophy in Science at the Institute of Energy and Environment of the University of Sao Paulo (IEE/USP).

Ph.D. Adviser: Prof. Dr. José Goldemberg

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AUTORIZO A REPRODUÇÃO E DIVULGAÇÃO TOTAL OU PARCIAL DESTE TRABALHO, POR QUALQUER MEIO CONVENCIONAL OU ELETRÔNICO, PARA FINS DE ESTUDO E PESQUISA, DESDE QUE CITADA A FONTE.

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*For my grandparents Vovô Dondi, Vovó Maria, Vovô Ângelo (in memoriam) and Vovó Orídia,  
for having given me the loveliest father, mother (and brother).*

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## RESUMO

ROMEIRO-CONTURBIA, Viviane Roberto da Silva. **Marco legal e regulatório da captura e armazenamento de carbono em países em desenvolvimento: propostas para o Brasil.** 2014. Tese (Doutorado) – Programa de Pós Graduação em Energia, Universidade de São Paulo, São Paulo, 2014.

O principal objetivo desta tese foi propor recomendações sobre como a captura e armazenamento de carbono (CAC) deve ser regulada no Brasil de acordo com a política ambiental do país, e quais seriam os principais aspectos que um marco legal e regulatório sobre CAC no Brasil deverá abranger. Dados primários foram obtidos através de entrevista contextualizadas com especialistas nacionais e internacionais, e a pesquisa foi complementada com um estudo de caso comparativo para investigar avanços legais e regulatórios de CAC em determinados países em desenvolvimento (Brasil, China, México e África do Sul). A principal contribuição desta tese é uma proposta concreta de um marco regulatório de CAC que eventualmente poderia servir de base para uma resolução do Conselho Nacional do Meio Ambiente (CONAMA). As principais questões abordadas foram: (i) a indicação de uma autoridade reguladora competente para projetos CAC; (ii) a definição dos direitos de propriedade e de posse do CO<sub>2</sub> no subsolo, e (iii) a designação dos requisitos de licenciamento ambiental para projetos de CAC no Brasil. Critérios para a responsabilidade em longo-prazo não foram incluídas na resolução proposta, uma vez que tal questão ainda é muito controversa no Brasil atualmente, conforme ressaltaram alguns entrevistados. Dessa forma, seria importante fortalecer capacitação institucional em questões regulatórias sobre CAC para incentivar autoridades governamentais a obterem um entendimento comum sobre como as responsabilidades poderiam ser simultaneamente coordenadas. Em última instância, a análise e as propostas desta tese pretendem contribuir para os estudos legais e regulatórios sobre CAC como um esforço para assegurar a proteção eficaz ao meio ambiente e à sociedade.

**Palavras-chaves:** Mudança do clima; captura e armazenamento de carbono; regulação; países em desenvolvimento; Brasil.

## ABSTRACT

ROMEIRO-CONTURBIA, Viviane Roberto da Silva. **Carbon capture and storage legal and regulatory framework in developing countries: Proposals for Brazil.** 2014. Dissertation (Doctor of Science) - Graduate Program on Energy, University of Sao Paulo, Sao Paulo, 2014.

The main objective of this Ph.D. dissertation was to propose recommendations on how carbon capture and storage (CCS) should be regulated within the Brazilian environmental policy context and what would be the main legal and regulatory aspects that a CCS framework in Brazil should encompass. Primary data was generated through contextualized interviews with international and national stakeholders, and the research was complemented with a comparative country-case study to investigate CCS legal and regulatory progress across selected developing countries (Brazil, China, Mexico and South Africa). The main contribution from this dissertation is a concrete proposal of a CCS regulatory framework to possibly serve as the basis for a resolution to be enforced by the Brazilian National Environmental Council (CONAMA). The key issues herein covered were related to: (i) the indication of a competent regulatory authority to regulate CCS projects; (ii) the definition of property rights and CO<sub>2</sub> ownership at the subsurface; and (iii) the designation of environmental licensing requirements for CCS projects. Requirements for long-term liability were not included in the proposed framework, as the issue still remains controversial in Brazil at present, as stated by many interviewees. Therefore, it would be important to increase regulatory capacity building to support governmental authorities developing a common understanding on how responsibilities could be concurrently coordinated. Ultimately, the analysis and proposals of this dissertation intended to contribute to scholarship on CCS legal and regulatory frameworks globally as an effort to assure an effective protection to the environment and the society.

**Key-words:** Climate change; carbon capture and storage; regulation; developing countries; Brazil.



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## LIST OF ABBREVIATIONS AND ACRONYMS

ABCM - Brazilian Mineral Coal Association  
ANEEL - Brazilian National Electricity Regulatory Agency  
ANP - Brazilian National Agency of Petroleum, Natural Gas and Biofuels  
ANTAQ - Brazilian National Waterway Transport Agency  
ANTT - Brazilian National Terrestrial Transport Regulatory Agency  
BAU - Business as usual  
BECCS - bioenergy with carbon capture and storage  
BSER - single best system of emission reduction  
CCS - Carbon capture and storage  
CCS - Carbon capture, use and storage  
CDM - Clean Development Mechanism  
CENBIO - Brazilian Reference Center on Biomass  
CEPAC - Center of Excellence in Research and Innovation in Petroleum, Mineral Resources and Carbon Storage  
CETESB - Sao Paulo State Environmental Sanitation Technology Company  
CNCO<sub>2</sub> - National Register of Areas with Geological Storage of Carbon Dioxide  
CONAMA - National Environmental Council  
COP - Conference of the Parties  
COPPE - Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering  
DNA - Designated National Authorities  
DOE- U.S. Department of Energy  
ECBM - Enhanced Coal bed Methane  
EEZ - Exclusive Economic Zone  
EIA - Environmental Impact Assessment  
EIR - environmental impact report  
EOR - Enhanced oil recovery  
EPA - Environmental Protection Agency  
EPS - Emissions performance standards  
ESM - Environmentally Sound Management  
ETS - Emissions Trading Scheme  
EU ETS - European Union Emissions Trading Scheme  
FNCO<sub>2</sub> - National Fund for the Prevention and Remediation of Areas with Geological Storage of Carbon Dioxide  
GCCSI - Global Carbon Capture and Storage Institute  
GDP - Gross Domestic Product  
GEF - Environmental Facility  
GHG - greenhouse gas  
GIS - Geographic Information System  
IBAMA - Brazilian Institute of Environment and Renewable Natural Resources  
IEA - International Energy Agency  
IEE - Institute of Energy and Environment  
IG - Institute of Geosciences  
IPCC - United Nations Intergovernmental Panel on Climate Change  
IUPAC - International Union of Pure and Applied Chemistry  
Kgs. CO<sub>2</sub>/MWh - kilograms of CO<sub>2</sub> per megawatt-hour

Lbs. CO<sub>2</sub>/MWh - pounds of CO<sub>2</sub> per megawatt-hour  
LSIPs - large-scale integrated CCS projects  
LULUCF - Land Use, Land-Use Change and Forestry  
MMA- Ministry of Environment  
MtCO<sub>2</sub> - Million tons of carbon dioxide  
NGCC - natural gas combined cycle  
NRDC - National Development and Reform Commission  
NUPPREC - Carbon Emission Policy and Regulation Group  
OCDE - Organization for Economic Co-operation and Development  
OSPAR - Convention for the protection of the marine environment of the North-East Atlantic  
PUCRS - Pontifical Catholic University of Rio Grande do Sul .  
RFA - Regulatory Framework Assessment  
SACCCS - South African Centre for Carbon Capture and Storage  
SBPSC - Santos Basin Pre-Salt Cluster  
SDWA - Safe Drinking Water Act  
SENER - Mexican Electricity Federal Commission and the Mexican Ministry of Energy  
SNCO<sub>2</sub> - National System of Areas with Geological Storage of Carbon Dioxide  
STRATCO<sub>2</sub> - Support to Regulatory Activities for Carbon Capture and Storage  
TEMs - Technical Experts Meetings  
UFRJ - Federal University of Rio de Janeiro  
UIC - Underground Injection Control  
UNCLOS - United Nations Convention on the Law of the Sea  
UNECE - United Nations Economic Commission for Europe  
UNEP United Nations Environment Programme  
UNFCCC - United Nations Framework Convention on Climate Change  
UNICA - Brazilian Sugar Cane Industry Association  
USP - University of Sao Paulo  
WAG - Water Alternating Gas  
WG ADP - Working Group on the Durban Platform for Enhanced Action

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# **1. Introduction**

This dissertation has been submitted in partial satisfaction of the requirements for the degree of Doctor of Philosophy in Science at the Institute of Energy and Environment (IEE) of the University of Sao Paulo (USP). The proposed research is focused on regulatory issues related to the deployment of carbon capture and storage technology, and the research theme is linked to one of the IEE's research area entitled "Energy, Society and the Environment".

This introductory section presents the main motivations, problem characterization and research questions, as well as the hypothesis, objectives and research methodology, along with the structure of this dissertation and its intended contribution.

## **1.1. Motivations and problem characterization**

The scientific understanding of climate change and the evidences of the anthropogenic effects for the warming in the climate system have been gradually reinforced through the United Nations Intergovernmental Panel on Climate Change (IPCC). According to its Fifth Assessment Report published in 2013, "global warming is unequivocal, the amount of snow and ice has decreased, the sea level has risen, and the concentration of greenhouse gas (GHG) emissions has increased" (IPCC, 2013).

As the global understanding on the scientific basis on climate change increases, a range of international and national climate policies and agreements concurrently emerges to tackle global warming. The United Nations Framework Convention on Climate Change (UNFCCC), the most prominent international agreement on climate change, has established the ultimate objective of achieving "the stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (UNFCCC, 1992).

Since then, the international negotiations have been struggling to develop and implement agreements to tackle climate change, and more recently, the parties to the UNFCCC have recognized the scientific recommendation that by 2020 the increase in global average temperature should be lower than two degrees Celsius (2°C) compared

to pre-industrial levels. At the international level, a temporary system of voluntary pledges has been agreed under the UNFCCC Copenhagen (UNFCCC, 2009) and a new binding treaty has been under negotiating through the Durban Platform for Enhanced Action (UNFCCC, 2011a). At the domestic level, national and subnational governments have established or are in process of establish their climate policies. Some of them have even imposed mandatory, as the case of the states of California (United States) and Sao Paulo (Brazil), making efforts to put forward ambitious GHG emission reduction policies (Lucon and Goldemberg, 2010).

Since 2010, an analysis of the countries pledges and commitments is conducted by the United Nations Environment Programme (UNEP) to verify if they are consistent to limit on a least-cost approach the increase of global average temperature below two degrees. Nevertheless, the results indicate that such pledges and commitments have not been enough to reach the UNFCCC goal, and as of 2014 the negotiations presented limited practical results in terms of reducing GHG emissions. The expected outcomes in the upcoming UNFCCC Conferences of the Parties (COP's)<sup>1</sup> still remain unclear with insufficient agreement on how new efforts should be internationally coordinated, how the atmospheric budget should be allocated, and how burdens should be shared (Lucon, Romeiro and Pacca, 2013). In this complex gridlock, practical answers need to be created from both developed and developing countries to push forward the international negotiation regime (Victor, 2011 and Mattoo and Subramanian, 2012).

In order to achieve the political commitments and to increase the potential of GHG emission reductions in the mid and long-term, a range of climate mitigation technologies has been discussed to help countries move towards a lower carbon economy, including the carbon capture and storage (CCS). This technology consists in: (i) separating carbon dioxide (CO<sub>2</sub>) from point sources, mainly large CO<sub>2</sub> point sources, such as coal, gas or biomass-fired power plants; (ii) compressing and transporting the gas through pipelines, ships, among others; and (iii) storing the carbon dioxide in geological formations, such as depleted oil and gas fields, coal seams and saline aquifers (IPCC, 2005).

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<sup>1</sup> The 20<sup>th</sup> Conference of Parties will be held in the end of 2014 in Peru and the 21<sup>th</sup> Conference of Parties will be held in the end of 2015 in France.



According to the International Energy Agency (IEA, 2010a), CCS plays a vital role in reaching the required level of emission reductions in the future. As global GHG emissions remain increasing, it becomes less likely that the emissions gap<sup>2</sup> will be closed or considerably narrowed by 2020, and countries will have to rely on more complex, expensive and risky choices to limit the increase in the global average temperature below 2°C, increasing significantly the need to deploy more energy efficiency technologies and bioenergy with carbon capture and storage (BECCS) to reach the target (UNEP, 2013).

Scientists and policy-makers argue that the diffusion of CCS cannot be successfully reached based on a single context and that the technology should be shaped in a technological innovation system (Xianjin Lai, *et al.*, 2012). Seligsohn *et al.*, (2009) argue that key factors to successfully deploy CCS go beyond the development of the technology, mostly including greater finance support, long-term stewardship requirements and a legal and regulatory framework to ensure environmental and health protection.

Over the past years, a number of studies have recognized the establishment of a CCS legal and regulatory framework as a key issue for the large deployment of CCS globally. The United Kingdom CCS Roadmap (2012) also emphasizes that regulation is one approach by which governments can certainly influence on the deployment of technologies such as CCS. The United Kingdom (UK), for example, is putting in place a plan for a low carbon electricity market in which CCS will play a big role; the government has made £1 billion available to invest in early CCS projects, and the goal is to enable industry to build several CCS ready power plants by 2020 (UK CCS Roadmap, 2012). Reducing costs and creating a robust CCS legal and regulatory framework constitute some of the main strategies that the UK Government has been



























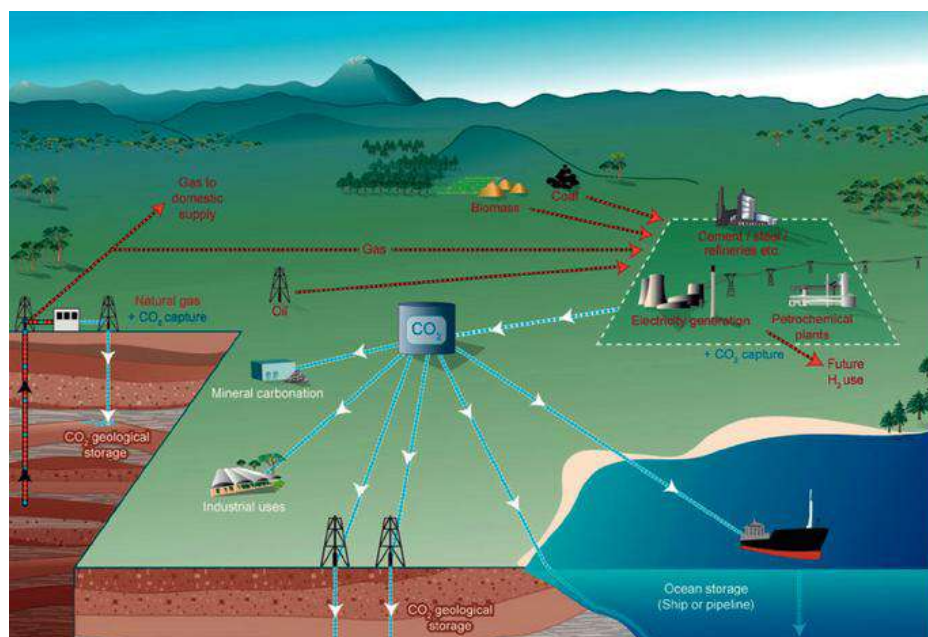








stationary source to the reservoir storage and other conditions, ships and tanker trucks are also feasible options (Figure 5):



**Figure 5 - Schematic diagram of possible carbon capture and storage systems.**

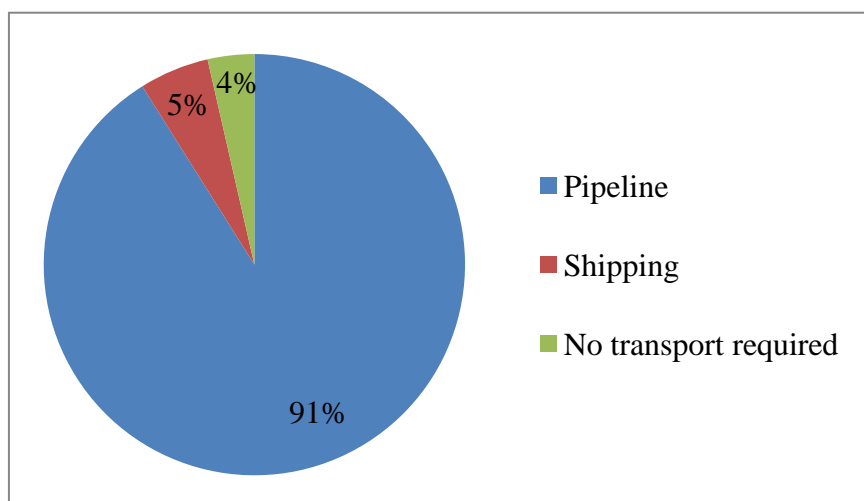
Source: IPCC, 2005.

One criterion to assess the economic feasibility of a CCS project in terms of CO<sub>2</sub> transport is the distance between the stationary source and the geological reservoir. The IPCC (2005) estimates a limit distance of three hundred kilometers (300 miles), but other factors, such as the degree of accessibility to the storage site, should be also considered to efficiently determine such viability.

Minimum requirements for the pipeline conditions such as a CO<sub>2</sub> stream dry and with no hydrogen sulphide H<sub>2</sub>S are also important to keep integrity and avoid corrosion, but according to the IPCC (2005), it would be possible (but more costly) designing a pipeline more resistant that could safely transport CO<sub>2</sub> streams that contain hydrogen sulphide and other impurities. As with hydrocarbon pipelines, CO<sub>2</sub> pipelines for onshore CCS projects require more careful on such technical requirements to avoid overpressure or even CO<sub>2</sub> leakage, especially in populated areas. However, there are no indications that the problems to be faced with CO<sub>2</sub> pipelines would be much more complex than those faced with hydrocarbon pipelines (IPCC, 2005).

Also, CO<sub>2</sub> transport that surpasses national boundaries may be required to comply with international law. There are a number of international environmental agreements that require specific conditions to allow the construction of trans-boundary CO<sub>2</sub> pipelines, and depending on the case, other countries may even share the decision-making process for the pipeline's environmental assessment. The implications of international environmental agreements for CCS project are further discussed in Chapter 3.

With regards to the current use of the different types of CO<sub>2</sub> transport options, as of August, 2014 approximately 91% of the 56 active and planned large-scale integrated CCS projects worldwide use pipelines to transport CO<sub>2</sub>, as shown in Figure 6:



**Figure 6 - Large-scale integrated CCS projects: CO<sub>2</sub> transport options. (56 active and planned projects as of August, 2014).**

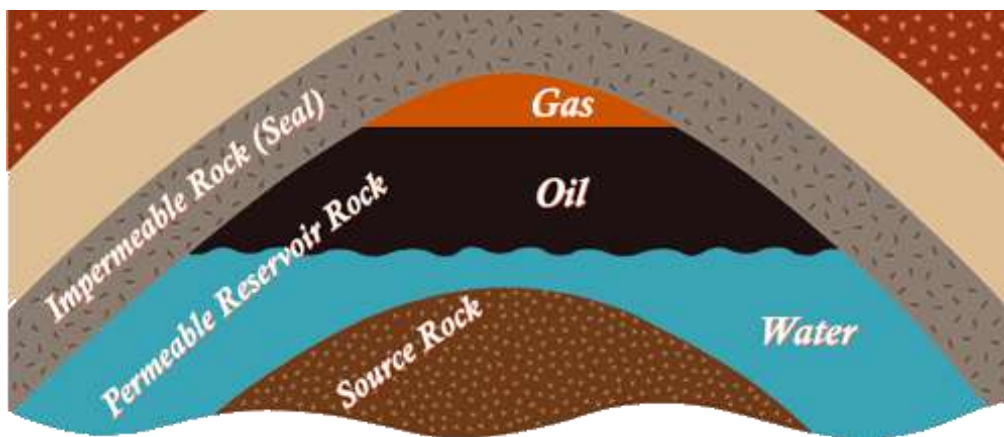
Source: GCCSI, 2014.

Few projects (4%) do not require transportation, as the case of the Pre-Salt Lula CCS Project operated by the Brazilian National Oil and Gas Company (Petrobras), as the CO<sub>2</sub> is separated from the fluid and re-injected into the same reservoir (to be discussed in Chapter 4).

### 2.2.3. CO<sub>2</sub> storage

The geological storage of carbon dioxide consists of injecting the gas under high pressure in deep geological formation and is considered the main component to effectively deploy a CCS project. From a technical perspective, once the supercritical CO<sub>2</sub> is injected, stratigraphical, residual, solubility and mineral mechanisms known as “trapping mechanisms” act to keep the gas stored (CO<sub>2</sub>CRC, 2012).

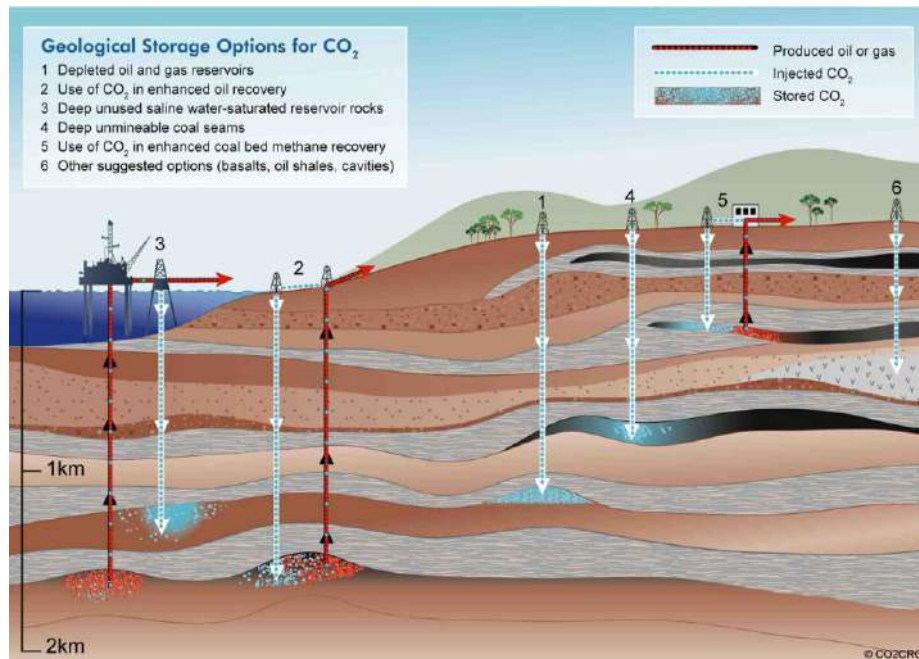
In order to assure the long-permanence of CO<sub>2</sub>, an appropriate geological reservoir needs to contain (i) permeable rock (with high porosity and high permeability) to allow the CO<sub>2</sub> to migrate downward and; (ii) an impermeable rock in the top (with low porosity and low permeability) which is a cap rock formation to seal and prevent the unintended upward movement of CO<sub>2</sub> and ultimately its leakage to the atmosphere (Figure 7).



**Figure 7 - Appropriate geological reservoir to store CO<sub>2</sub>**

Source: CO<sub>2</sub>CRC, 2012.

As briefly described in Chapter 1, the main types of geological reservoirs with large storage potential are depleted oil and gas reservoirs, saline aquifers (water-saturated reservoir rocks) and unmineable coal seams. There are also other suggested options such as oil shale and basalts as shown in Figure 8 (IPCC, 2005):



**Figure 8 - Geological Storage Options for CO<sub>2</sub>.**

Source: IPCC, 2005 and CO<sub>2</sub>CRC, 2012.

Although the storage of CO<sub>2</sub> in geological reservoirs for climate mitigation purposes is still lagging (with only few active large-scale CCS projects worldwide), the injection of the gas in deep formations is considered a common practice in the fossil fuel sector. In the case of CO<sub>2</sub> injection in oil fields, it can be associated with enhanced oil recovery (EOR), a method that has been largely deployed since the 60s to enhance the extraction of hydrocarbon in depleted oil fields (Ketzer, 2009). For CO<sub>2</sub> injection in coal seams, it can be also associated with enhanced coal bed methane (ECBM), that is, injecting CO<sub>2</sub> in depleted coal beds to increase the extraction of coal (as with EOR methods).

The main difference between an EOR or ECBM project and a CO<sub>2</sub> storage project for climate mitigation purpose is the fact that the former aims at optimizing oil or coal production (by increasing the reservoir pressure and enhancing the extraction of hydrocarbon), while the latter is intended to store CO<sub>2</sub> for a long time scale period<sup>6</sup>. Consequently, monitoring tools are essential to track the behavior of CO<sub>2</sub> migration.

<sup>6</sup> The CO<sub>2</sub> storage period is a controversial debate among scientists. According to Ketzer (2009), such period exceed the human timescale with more than millions of years (the called geological timeline). The Pre-Salt Oil Fields located in Brazil, for example, are estimated to have been existins for over 110 million

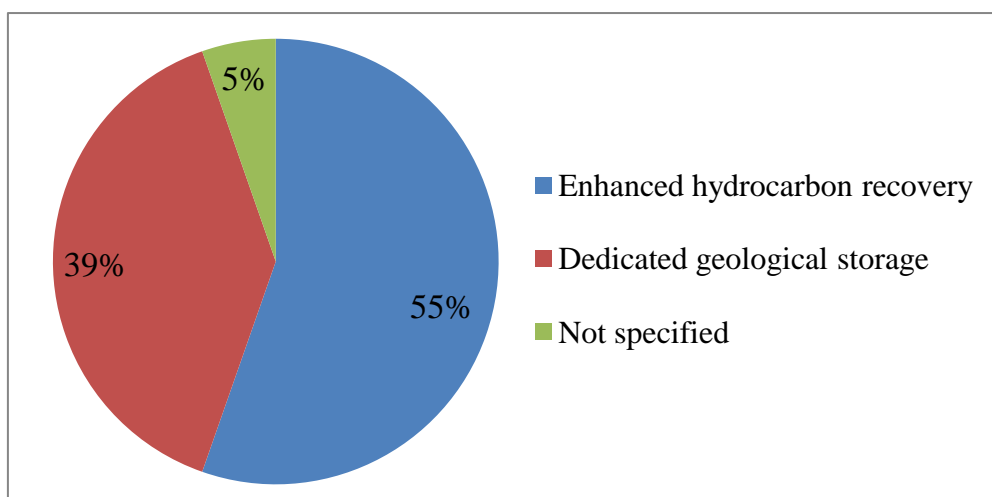
Table 2 shows the advantages and disadvantages of the three main options of geological reservoirs for CO<sub>2</sub> storage:

**Table 2. Analysis of geological reservoirs for CO<sub>2</sub> storage.**

Reservoirs	Storage Capacity	Advantages	Disadvantages
Coal seams	40 Gt CO <sub>2</sub>	Economic viable with ECBM Usually near to CO <sub>2</sub> sources	Low permeability Limited storage capacity
Oil Fields	930 Gt CO <sub>2</sub>	Economic viable with EOR Well- known storage structures	Usually far from CO <sub>2</sub> sources Average storage capacity
Saline aquifers	400 to 10.000 Gt CO <sub>2</sub>	Storage potential Geographical distribution	Unknown storage structures

Source: Varet, 2005; IEA, 2006.

With regards to the current use of the different types of CO<sub>2</sub> storage options, as of August, 2014 approximately 55% of the 56 active and planned large-scale integrated CCS projects worldwide associate enhanced hydrocarbon recovery to store CO<sub>2</sub> and 39% of the projects are dedicated to CO<sub>2</sub> geological storage, as shown in Figure 9.



**Figure 9 - Large-scale integrated CCS projects: CO<sub>2</sub> storage options. (56 active and planned projects as of August, 2014).**

Source: GCCSI, 2014.

years, and the oil contained in such fields must have been retained for at least some 80 million years (including the associated CO<sub>2</sub>).

Some of the main arguments to indicate the long-permanence of CO<sub>2</sub> in geological reservoirs are related, but not limited to: (i) the existence of natural oil and gas reservoirs which gases have been intact for geological timelines; (ii) the expertise with methods to inject and store fluids in geological reservoirs as the case of EOR and EBCM and even natural gas storage; and (iii) the experiences with CCS demonstration projects (IPCC, 2005; Ketzer, 2011).

Moreover, the existence of natural retention mechanisms (trapping mechanisms) associated with the increasing experience with computer simulation models to monitor and detect any unintended CO<sub>2</sub> migration or CO<sub>2</sub> leakage over time increase scientific certainties on the CO<sub>2</sub> storage effectiveness on geological reservoirs.

The key aspects to be considered for a risk assessment of CCS projects are (i) the amount of CO<sub>2</sub> to be injected in a geological reservoir; (ii) the density of the gas when stored; and (iii) the capacity of the geological reservoir and its pressure after the storage of CO<sub>2</sub> (IPCC, 2005).

Such aspects must be equally considered and a slight variation in one of them must be reviewed by the project operators and even by the competent regulatory authorities to prevent any CO<sub>2</sub> leakage. According to the IPCC (2005), the portion of stored CO<sub>2</sub> retained in appropriated and monitored reservoirs is approximately 99% in 100 years (a leakage of 1% of CO<sub>2</sub> in a period of 100 years is then acceptable).

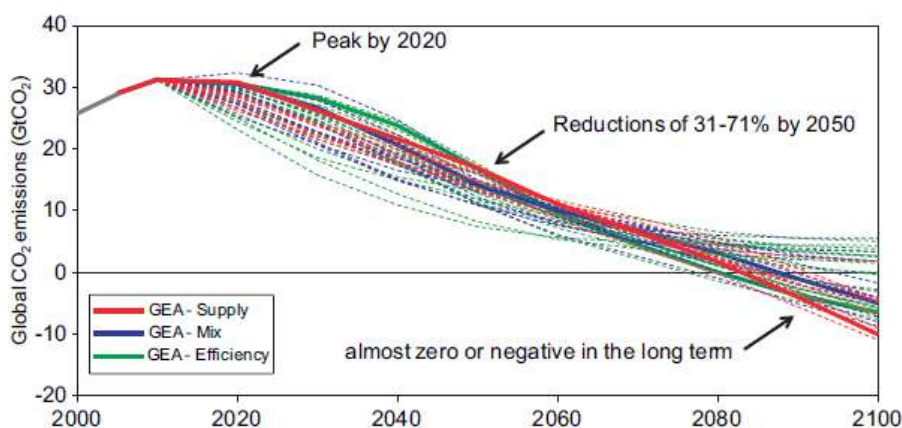
According Ketzer, (2009), once CO<sub>2</sub> is injected into a geological formation, the gas is dislocated downwards due to the difference of the gravity inside the reservoirs and difference of the fluids density, and there are also friction forces in the reservoir pores that acting oppose to the CO<sub>2</sub> displacement and result in the migration of the gas. Hence, the most appropriate geological reservoirs are those most likely to oppose to the CO<sub>2</sub> flow and that could finally retain the gas for thousands of years.

### 2.3. Carbon capture and storage in the international climate regime

CCS has been extensively discussed as a technology strategy for reducing global GHG emissions. In December 2010, the UNFCCC recognized during the 16<sup>th</sup> Conference of the Parties (COP-16) that CCS constitutes part of a relevant technology strategy for climate change mitigation and decided to include this option as a project activity under the clean development mechanism (UNFCCC, 2010), to be further discussed in Chapter 3 of this dissertation.

The combination of bioenergy and carbon capture and storage (BECCS) to result in negative emissions has been one of the key alternative options discussed by scientists and policymakers to achieve the 2DS target. As bioenergy production is considered carbon-neutral, capturing CO<sub>2</sub> from the fermentation process in a sugar mill and storing the gas in adequate geological reservoirs, for example, could result in “negative emissions” when considering the life cycle assessment of the bioenergy production (Möllersten, Yan and Moreira, 2003; Pacca and Moreira, 2009).

Many scenarios of the latest international assessments, reaching from the Fifth Assessment Report (AR5) of Intergovernmental Panel on Climate Change (IPCC, 2013) over the Global Energy Assessment (GEA, 2012) to the International Energy Agency’s Energy Technology Perspectives (IEA ETP, 2012) argue that BECCS is an essential component to the mitigation technologies portfolio (See Figure 100):



**Figure 10 - GEA scenarios showing the need for negative emissions 2000-2100**

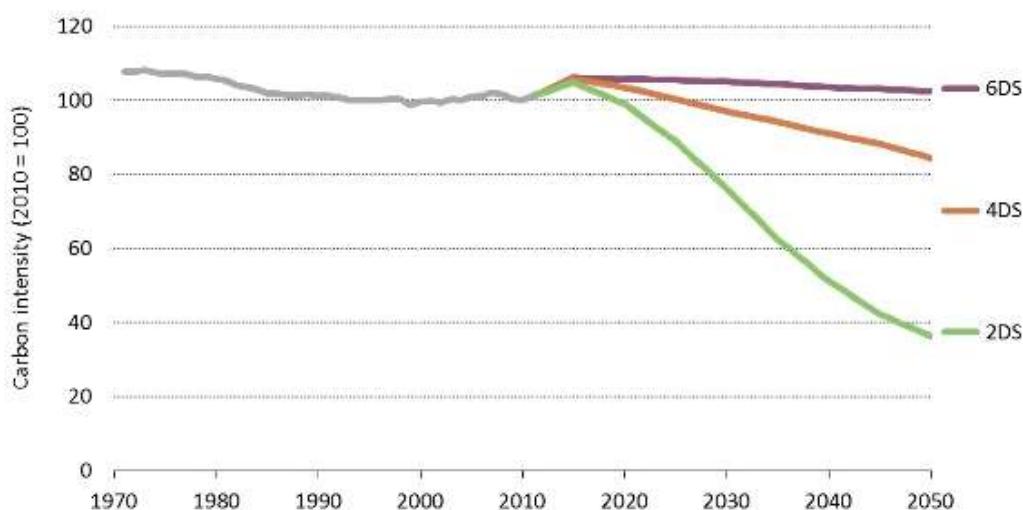
Source: Global Energy Assessment (GEA), 2012.



According to the scenarios, GHG emissions would peak by 2020, reducing to almost zero or negative between 2080-2100 to reach the 2DS, and deploying bioenergy with CCS would be essential to reach such target.

The 2014 Energy Technology Perspective (IEA ETP, 2014) also highlights the challenges of the global mitigation effort: cutting CO<sub>2</sub> emissions by 50% by 2050 to keep the concentration of CO<sub>2</sub> at 450ppm by 2050 in order to reach the 2°C Scenario (2DS).

ETP 2014 analyses three possible energy futures to 2050: (i) 6°C Scenario (6DS), based on current policies and technologies; (ii) 4°C Scenario (4DS) based on the countries' pledges to reduce emissions and increase energy efficiency; and (iii) 2°C Scenario (2DS) with strong policies and low carbon technologies to reduce emissions, as shown in Figure 11:



**Figure 11 - Energy Technology Perspective 2014**

Source: IEA ETP, 2014.

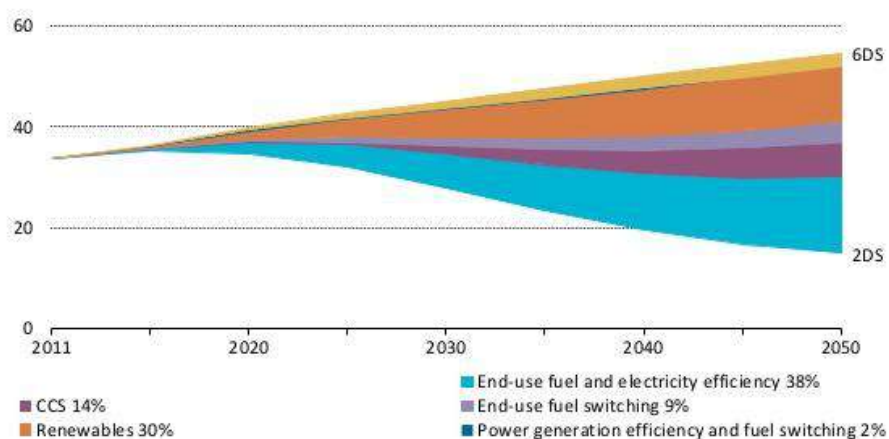
Under the 2DS, carbon capture and storage is an important part of the portfolio, as a range of technologies and measures are required to reduce CO<sub>2</sub> emissions from the power sector, mostly with energy efficiency, massive deployment of renewable and nuclear sources, and carbon capture and storage.



Still with strong climate policies, the diffusion of low carbon technologies may be hindered by many institutional, political and social aspects. Gokul *et al.*, 2014 suggest that restrictions to the wide deployment of renewable energy and CCS can be more expensive than those restrictions on nuclear or even bioenergy. According to the authors, limiting such technologies may led some scenarios impracticable

According to the IEA Blue Map Scenario (IEA, 2010a), CCS could deliver roughly 19% of the global GHG emissions reduction that is required by 2050, and reaching that goal would require the construction of 100 large-scale and integrated CCS projects (LSIPs) globally by 2020, and the construction of 3400 LSIPs by 2050.

However, an update of the IEA ETP indicated that such estimate is not realistic due to the low number of large-scale or demonstration CCS projects to date and the limited time left to achieve the necessary diffusion of CCS (IEA ETP, 2014), and that CCS would contribute to 14% to reach the 2DS (Figure 12):



**Figure 12 - Key technologies for reducing CO<sub>2</sub> emissions**

Source: IEA ETP, 2014.

According to the 2014 ETP, countries are not on track to achieve the 2020 targets for the 2DS, and carbon intensity of supply keeps constant. The necessary political support from countries to reach the intended GHG emission reductions has yet to be verified (IEA, 2014), and specifically on CCS, progress is lagging to reach the large-scale deployment projected for the 2DS.

## 2.4. Current status of global CCS projects

There are a number of databases updated with public data that provide maps with the existing CCS projects worldwide<sup>7</sup>. Because they use different methods and approaches to assess the projects, the total number of CCS projects in the many levels (active, planned, pilot, cancelled *etc.*) can vary significantly, and the number of active projects can also show a slight variation among the databases.

The Carbon Capture and Sequestration Technologies (CCCS) from the Massachusetts Institute of Technology (MIT), for example, provides an interactive map that shows the location of active CCS projects globally, including power plant and non-power CCS projects (MIT, 2014a). The database also includes cancelled or postponed projects, or even those that have provided no news or activity in a specific period of time (dormant projects). The Scottish Carbon Capture and Storage database presents a very comprehensive and updated world map of CCS projects (SCCS, 2014) of all levels and stages of development (planned, cancelled, pilot, operational and finished CCS projects), as follows in Figure 13:

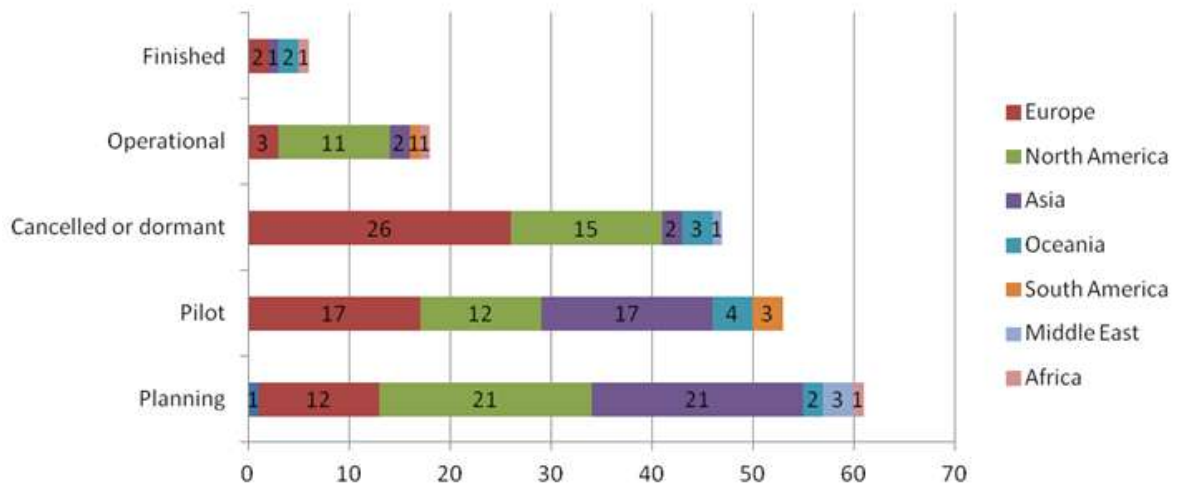


**Figure 13 - Global map of CCS projects at different stages  
184 CCS projects as of August, 2014**

Source: Scottish Carbon Capture and Storage (SCCS), 2014.

<sup>7</sup> For example, the IEA Greenhouse Gas Research and Development Programme CCS Database, the CO<sub>2</sub> Stored- UK CO<sub>2</sub> Storage Evaluation Database, the NETL Carbon Capture and Sequestration Database, the Scottish Center for Carbon Capture CCS Database, the Global CCS Institute Map *etc.*

With regards to the geographical distribution, the current number of CCS projects as of August, 2014 in the various levels and stages is 184, but only 18 of them are at operational scale. Europe contributes to 60 projects, followed by Canada and the United States with 59 projects. Asia (mostly China and South Korea) presents 43 projects in different levels of implementation (Figure 14).

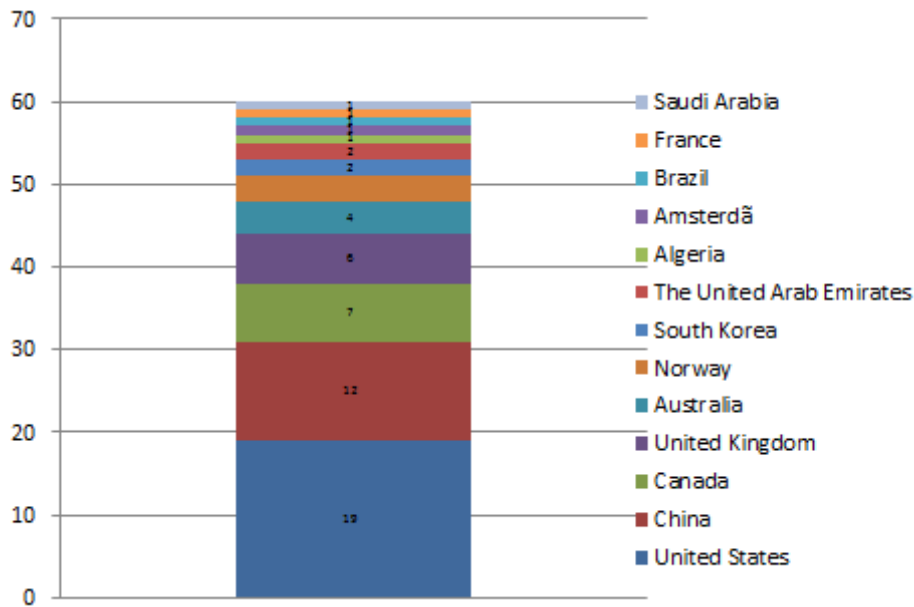


**Figure 14 - Distribution of global CCS projects at different stages 184 CCS projects as of August, 2014**

Source: Scottish Carbon Capture and Storage (SCCS), 2014.

The Global Carbon Capture and Storage Institute (GCCSI) also presents an interactive map (GCCSI, 2014) with an overview of the global large-scale integrated CCS projects (LSIPs). The map however does not include pilot or cancelled projects. According to the GCCSI, the LSIPs are defined at a scale of at least 800 million tons of carbon dioxide (MtCO<sub>2</sub>) annually for a coal-based power plant or at least 400 MtCO<sub>2</sub> annually for other emission-intensive industrial facilities (GCCSI, 2014).

As of August, 2014 there are 22 active and 34 planned large-scale integrated CCS projects globally (Figure 15):



**Figure 15 - Distribution of global large-scale integrated CCS Projects 56 LSIPs as of August, 2014.**

Source: Global CCS Institute, 2014

Nevertheless, the number of LSIPs has significantly changed and decreased in the past years. According to the GCCSI Database, for example, there were 73 active and planned projects in 2012, and as of August, 2014, the number has decreased to 56 active and planned projects only (a decrease of almost 24%).

Environmental concerns and a lack of clear regulatory requirements<sup>8</sup>, mostly on the long-term liability, for example, have led a CCS project in Germany to be cancelled (MIT, 2013b). The Vattenfall Company (a Swedish state-owned energy company) has canceled its CCS Project in Germany, as the Government has not managed to establish a CCS legal and regulatory framework, and to transpose the European Union Carbon Capture and Storage (EU CCS Directive 2009/29/EC) (European Union, 2009), to be further discussed in this dissertation.

<sup>8</sup> The Government of Germany has attempted to enact a CCS legislation in 2011 in which the operator would need to “contribute to the post-closure costs to cover the likely costs of monitoring the site for a further 30 years after liability has been transferred” (Global CCS Institute, 2012). However, Germany failed to enact such legal and regulatory framework in 2011, and only in 2012 an agreement was finally achieved, but different conditions were established and operators were required to retain liability up to 40 years (instead of the original proposal of 30 years) after the post-closure period.

In the United States, the Basin Electric Power, for example, withdrew the Antelope Valley 120 MW Project in 2010 due to lack of regulatory certainty regarding environmental legislation, high costs and lack of a long-term national energy strategy (MIT, 2014c). Table 3 presents a list of example of CCS projects that have been cancelled worldwide:

**Table 3. Example of CCS projects that have been cancelled.**

Country	CCS Project	Reason	Details
United States	Mountaineer (American Electric Power)	High costs	Rate payers were unable to assume an increased cost of electricity.
	Antelope Valley	High costs/regulatory uncertainties	High costs, lack of regulatory certainty regarding environmental legislation <i>etc.</i>
Germany	Jänschwalde(Vattenfall)	Regulatory uncertainties	The operator wanted the transfer of liability period to be reduced.
Australia	Kwinana(Hydrogen Energy)	Technical problems	Site lacked the necessary geologic properties to ensure secure storage of CO <sub>2</sub> .
The Netherlands	Barendrecht (Shell)	Lack of public acceptance	Opposition or lack of support from the local community.
United Kingdom	Longannet Power Station	Lack of governmental support	Not commercially viable without public support.

Source: Forbes and Romeiro, 2012.

Although most active and planned large scale integrated CCS projects is currently placed in developed countries, the share of CCS deployment in developing countries is expected to increase by 2025, and these countries should focus their capacity building on identifying the challenges and solutions to address the main barriers, which would include improving technical expertise, legal and regulatory frameworks and public education (MEF TAP, 2009).

As already mentioned, the establishment of proper CCS legal and regulatory frameworks is important to provide legal certainty and to ensure the effective stewardship of CO<sub>2</sub> storage sites (IEA, 2014).

While all of the developed countries that have active or planned large-scale and integrated CCS projects have already established their own legal and regulatory framework (having most of them requirements for liabilities), as of 2014 developing countries that have active or planned large-scale and integrated CCS projects have not yet enacted specific legal and regulatory frameworks, as shown in Table 4.

**Table 4. CCS legal and regulatory framework in countries with LSIPs.  
(56 active and planned large-scale integrated CCS projects – LSIPs)**

Country	LSIPs	CCS legal and regulatory Framework
United States	20	United States EPA’s Class VI Regulations
China	12	N/A
Canada	7	Canadian Standard CSA-Z741/ Alberta’s RFA
United Kingdom	5	United Kingdom Energy Act
Australia	3	Australia Offshore Petroleum and GHG Storage Act
Norway	2	European Union Directive 31/EC **
South Korea	2	N/A
Algeria	1	N/A
The Netherlands	1	European Union Directive 31/EC
Brazil	1	N/A
Saudi Arabia	1	N/A
United Arab Emirates	1	N/A

Source: Created by the author based on the Global CCS Institute (2014).

Specifically in the case of Brazil, the country has already one large scale and integrated CCS project (to be further discussed in Chapter 4), but as of 2014 no legal and regulatory framework for carbon capture and storage is available in the country. Therefore, the research proposed here is motivated by the relevance of ensuring that appropriated legal and regulatory framework is in place in countries where commercial and large-scale carbon capture and storage projects are being deployed.

### **3. Assessment on legal and regulatory tools that have implications for CCS**

This chapter presents an assessment of existing legal and regulatory tools as policy options that could have implications for CCS. There are currently many international and national legal and regulatory tools that could be somewhat relevant to CO<sub>2</sub> capture and geological storage activities, and many definitions and prohibitions within these frameworks could be adequately encompassed to regulate and/or encourage CCS projects.

Considering that reducing greenhouse gas emissions can be induced by several ways, the choice of a policy tool to regulate emission reductions depends on many factors: cost-effectiveness, monitoring and verification costs and political feasibility, among others (Dissou, 2005).

Geller (2003) and Stern (2007) discuss some policy options for the diffusion of clean technologies: (i) research & development and demonstration; (ii) financial incentives; (iii) information and best practices; (iv) training and capacity building; (v) market reform; removal of behavior barriers (vi) tariffs and taxes; (vii) voluntary agreements; (viii) international environmental treaties; (iv) code and mandatory emission performance standards; (x) market-based mechanisms and; (xi) specific legal and regulatory frameworks.

Since this dissertation is focused on the legal and regulatory aspects related to CCS, the main policy tools analyzed in this chapter are: (i) emissions performance standards (EPS) for CO<sub>2</sub> that have implications for CCS; (ii) international environmental agreements related to CCS and; (iii) existing CCS legal and regulatory frameworks worldwide.

### 3.1. Carbon dioxide emission performance standards

This section analyzes the existing CO<sub>2</sub> emission performance standards (EPS) for fossil-fired power plants and provides a comparison among them. In the past years, some countries have introduced CO<sub>2</sub> emission performance standards for fossil-fuel fired power plants, and monitoring their compliance may be important to understand the impact of such regulations to incentive strategies to reduce carbon emission including the deployment of CCS in the corresponding countries or states.

Through an emissions performance standard, a regulator specifies a level of emission to be released at the atmosphere and compliance may be achieved, for example either via investments in new equipment or via replacement of less energy intensive technologies. An emission performance standard defines an acceptable emission level per unit of output, and it has been one of the main tools to control environmental pollutants around the world. It consists on limiting the amount of certain pollutants that are released into the atmosphere and in the case of a CO<sub>2</sub> emission performance standard (CO<sub>2</sub> EPS), the limit is usually given per unit of CO<sub>2</sub> production (Wartmann, *et al.*, 2009). While in the United States this limit is given in pounds of CO<sub>2</sub> per megawatt-hour (lbs. CO<sub>2</sub>/MWh), in most of the other countries the limit is given by kilograms of CO<sub>2</sub> per megawatt-hour (kgs. CO<sub>2</sub>/MWh).

The main goal of a CO<sub>2</sub> EPS is to limit how much a fossil fuel-fired power plant can emit and this type of regulatory tool is commonly established as part of a package of measures to reduce GHG while keeping security of supply. Some of the key factors to set an emission performance standard are related to the availability of broader compliance options; the electricity grid emissions path of the country or state, any potential impacts on energy supply security, and other factors such as the commercial availability of CCS and the cost of its implementation in the power plant (Pew Centre on Global Climate Change, 2009).

Also, some factors such as the earlier the creation of an EPS, the stricter its level and the broader its scope of implementation may increase the potential of an EPS to achieve more carbon emission reductions. For example, an earlier creation of an EPS results in



higher emission reductions than a stricter EPS implemented later, *e.g.*, the implementation of a 500g CO<sub>2</sub>/kWh level EPS in 2015 could result in 53% higher emission reductions comparing to a 350g CO<sub>2</sub>/kWh EPS introduced in 2020 (Wartmann, *et al.*, 2009).

However, CO<sub>2</sub> EPS could hamper fossil fuel-fired electricity generation if issues such as energy security and long-term costs for the global power generation fuel mix are not taken into consideration. These standards could pose risks for security of supply, especially during periods of high demand of energy. In the other hand, if well implemented, those CO<sub>2</sub> EPS could help moving the energy market towards more sustainable systems of energy generation, such as renewable energies, or even natural gas and advanced coal technology, in opposed of banning new fossil-fired plant, which could be another practical option (Talberg and Nielson, 2009). The United States Environmental Protection Agency (EPA) establishes, for example, that aligning the timing of these requirements provides the industry more regulatory certainty, and may facilitate the industry's investment decisions (EPA, 2013).

The use of emission performance standards could play a key role in the development and implementation of climate policies throughout the different countries, and it can accelerate the process of generating energy efficiently, while enabling the development and dissemination of advanced technologies to reduce GHG emissions. These standards do not necessarily lead to the application of best available technologies, but they may hamper the participation of plants with a lower performance to increase their shares in the energy balance of a country. Also, a CO<sub>2</sub> EPS may be relevant to foster the deployment of certain clean technologies that otherwise would not be viable in a commercial scale, such as the carbon capture and storage.

In this topic, a comparative analysis of existing EPS for fossil fired power plants was done by compiling 20 EPS with different levels, scopes and timing of implementation. The study has identified 8 countries and 12 states and considered the following criteria: (i) the specific CO<sub>2</sub> emission restriction (EPS level) and; (ii) the coverage of existing and/or new power plants.

### **3.1.1. Australia**

Although the Australian Federal Government does not impose an EPS on existing or new fossil-fired power stations, few years ago there was an intention to impose an EPS for all new fossil fired power ‘below the level’ of 0.86 tCO<sub>2</sub>e/MWh (Australia, 2011). The Conservative proposal sets an emissions performance standard for power plants of 500kg of CO<sub>2</sub>/MWh (Australia, 2011).

Within the sub-national level, four states have indicated their intention to restrict CO<sub>2</sub> emission from the fossil fuel-fired power plants: Queensland, Western Australia, Victoria and South Australia.

(i) Queensland: The state has a requirement that all new fossil-fired power plants must deploy lower emission technology (Australia, 2011). The government of Queensland has revised the conditions for new fossil-fired power plants, and under the Queensland Government’s climate change strategy, these plants will need to use best practice low emission technologies and/or CCS ready, which is a unit that could be retrofitted with CCS when compulsory regulatory takes place (Australia, Government of Queensland, 2012).

(ii) South Australian Government: The state has proposed an EPS of 700 kg of CO<sub>2</sub>e/MWh for all new power generation plants and has set an emission intensity target of 500kgs. CO<sub>2</sub>e/MWh by 2020, and the announcement was made in December 2010 (Australia, Government of South Australia, 2011).

(iii) Victoria: The state announced in 2010 the intention to impose an EPS of 800 kg of CO<sub>2</sub> /MWh, but the restriction was abandoned (Australia, Government of Victoria, 2010).

(iv) Western Australia: both Queensland and Western Australia have the same requirement that all new fossil-fired power stations must deploy clean coal technologies such as CCS (Australia, 2011).

### **3.1.2. Brazil**

The Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), which is the Brazilian Ministry of Environment's enforcement agency, published in 2009 a Normative Instruction (IBAMA Normative Instruction n° 07/2009) that sets that all the fossil-fuel power plants must provide measures in their environmental licensing to reduce their carbon dioxide emissions. As an option to mitigate the emissions, at least one third of the CO<sub>2</sub> emissions should be reduced by reforestation and up to two thirds of the emissions should be compensated via renewable energy investments or energy efficiency measures (IBAMA, 2009). Nevertheless, the Normative Instruction was revoked in 2010 due to lack of legal basis (to be further discussed in Chapter 4).

### **3.1.3. Canada**

The Canadian Department of the Environment and Department of Health established in 2011 a strict emission performance standard for new fossil-fired power plants beginning operation after July 2015 and for existing power plants, depending on the commissioning date (power plants are subject to regulation at 50 years or if commissioned during the years 1970 to 1974 at the end of 2019 (Canada, 2011). The limit has initially been fixed at 375 kg of CO<sub>2</sub>/MWh, but it was raised to 420 kg of CO<sub>2</sub>/MWh, which is based on the expected level of high efficient natural gas units or natural gas combined cycle (NGCC) technology. The regulation is intended to induce the economy to a lower carbon emission from power generation, such as renewable energy, high efficient natural gas units or fossil fuel-fired power plants with CCS. The power plants will also be able to postpone the EPS requirement until 2025 if they commit to a process of planning and deploying CCS technology. In order to assure compliance, enforcement officers will conduct inspections and the entities will be subject to enforcement and penalties (Canada, 2011). This Act establishes several responses to violations, such as warning, injunctions, prosecution *etc.* In case of emergency circumstances, a suspension of the performance standards may be conceded whereas there is a significant risk of disruption to the electricity supply. The circumstance may be either unpredicted or that comes out from a formal declaration of emergency by the place where the power plant is based.

### ***3.1.4. European Union***

In 2008, the European Parliament's Environment Committee voted to support an emission performance standard of 500 kgs. CO<sub>2</sub>/MWh for all new coal plants to be built in the European Union after 2015. The requirement would be applied to all plants with a capacity over 300MW and would also provide measures to support large-scale CCS projects (Talberg, 2011). However, many European countries were opponents to the EPS proposal, as Germany, Denmark, France and Poland, and the standard was not included in the EU Climate Package

### ***3.1.5. Germany***

After Fukushima's nuclear disaster in 2011, the German government established a shutdown plan to close all of its nuclear power plants by 2020. In order to avoid electricity shortages in the country, the plan mention the construction of new fossil-fired power plants, which will have a limit of 770 kgs. CO<sub>2</sub>/MWh, while the old plants release 824 kgs. CO<sub>2</sub>/MWh (The Breakthrough Institute, 2011).

### ***3.1.6. United Kingdom***

The UK government has proposed in 2010 legislation to regulate carbon dioxide emissions from fossil fuel-fired power plants through emission performance standards. The limit corresponded to 400 kgs. CO<sub>2</sub>/MWh (which would definitely prevent the construction of any conventional fossil-fired power plant). An Emissions Performance Standards Report was ordered by the House of Commons to analyze what would be the factors that ought to be considered in setting the level for an EPS, but the proposal was rejected during the Parliamentary debate (Pew Centre on Global Climate Change, 2009). In 2012 the UK released a Draft Energy Bill, establishing an EPS of 450 kgs. CO<sub>2</sub>/MWh to be guaranteed until 2045. It also provides exemptions for coal power plants that are deploying CCS demonstration projects (United Kingdom, 2012).

### ***3.1.7. Scotland***

The Government of Scotland announced in 2009 that any new coal-fired power plant in the country will need to demonstrate CCS with a minimum of 300MW. Additionally, the Scottish government plans to install CCS technology in existing fossil-fired power plants (retro-fitted power plants) by no later than 2025. The latest Electricity Generation Policy Statement (Scotland, 2013) requires that all new coal power plants are fully equipped with CCS until 2020, with complete replacement of conventional power stations subsequently by 2025-30. This policy is also a kind of CO<sub>2</sub> emission performance standard and it is applied to coal only.

### ***3.1.8. United States***

In 2012 the Environmental Protection Agency (EPA) launched a proposal to limit GHG emissions from new power plants in the United States. The proposal established a standard of one thousand pounds of carbon dioxide per megawatt of electricity produced (1,000 lbs. of CO<sub>2</sub> per MW/h) for all new power plants (EPA 79 FR 1429). These plants could also deploy CCS to limit their carbon emissions per MW/h to levels similar to those of efficient natural gas combined cycle (NGCC) power plants. The power plants should comply with this requirement standard on a 30-year average basis, and EPA planned to add an affirmative defense to civil penalties for exceeding emissions limits caused by technical failures.

However, there were many opponents to the 2012 EPA's Proposal because the rule established the same standard for coal and natural gas power plants (Center for Climate and Energy Solutions, 2013). Hence, EPA has changed the 2012 proposal and the agency issued in September 2013 a new proposal for CO<sub>2</sub> EPS from new fossil fuel-fired power plants (EPA 79 FR 10750). The entitled "Carbon Pollution Standard for New Power Plants" is a substitute of a proposed announced in 2012, and as it sets different requirements for coal and gas power plants (EPA, 2013):

(i) Large natural gas power plant (more than 100 MW) could emit no more than 1,000 pounds of carbon dioxide per megawatt-hour (MWh) of electricity produced;

- (ii) Small natural gas power plant (less than 100 MW) could emit no more than 1,100 pounds of carbon dioxide per megawatt-hour (MWh) of electricity produced;
- (iii) Coal power plants with CCS to reach an annual rate of 1,100 lbs CO<sub>2</sub>/MWh.
- (iv) Coal power plants with no CCS for 7 years after the startup of the plant, but it would be required to reach an annual rate of between 1,000 lbs and 1,050 lbs CO<sub>2</sub>/MWh.

While the 2012 proposal relied on a single EPS and a single best system of emission reduction (BSER) for all new fossil fuel-fired power plants, the new proposal sets a separate EPS for integrated gasification combined cycle units that burn coal, petroleum coke and other fossil fuels that would be based on partial deployment of CCS as the best system of emission reduction. These changes also reflect important steps to reduce GHG emission from power plants as part of the U.S. President Obama's Climate Action Plan announced in June 2013 (US White House, 2013). According to the Daily Journal of the United States Government (Federal Register), the final rule is expected to be released by January, 2015.

In June 2014 the EPA published a "Carbon Pollution Emission Guidelines for Existing Stationary Sources" with the goal of reducing GHG emissions from U.S. fossil fuel power plants by 30% by 2030 based on 2005 levels (EPA, 2014). The states will implement the rule through a range of measures entitled "best system of emission reduction", mostly through investments in renewable energy sources, fuel switching from coal to natural gas and by increasing energy efficiency. Although the 2013 EPA's Proposal for new stationary sources included partial application of CCS among the BSERs in the aforementioned rule, the "Standards of Performance for GHG emissions from new stationary sources: Electric Utility Generating Units", the 2014 EPA's Proposal for existing stationary sources does not include CCS as a BSERs and refers to the technology only as an additional option, as "demanding full or partial CCS could imply on a larger impact on national energy prices" (EPA, 2014).

However the 2014 EPA's Proposal for existing power plants contains some implications that may be relevant for the development of CCS in the United States, once the stationary sources could deploy CCS to meet the EPA's requirements.

According to the proposal, CCS offers technical potential for CO<sub>2</sub> emissions reductions of over 90% or smaller percentages in partial applications. Also, the document states that there is still a potential to reduce emission increasing the level of CCS in the regulated power plants, and if such plants reduce its CO<sub>2</sub> emissions in a level lower than the required, a domestic carbon market could be possibly created.

At the state level, some U.S. states have also established GHG requirements for new fossil-fired power plants over the past years:

(i) California: The Californian Senate Bill 1368 was enacted in 2006 and sets an EPS at 1,100 lbs. CO<sub>2</sub> per MWh for new plant investments to meet a greenhouse gas performance standard based on the emission rate of combined cycle natural gas base load generation (U.S. State of California Senate Bill 1368).

(ii) Illinois: Illinois has an EPS (the Illinois statute, SB 1987) which requires that a new coal power plant must sequester 50, 70 or 90% of its carbon emissions (U.S. State of Illinois SB, 1987).

(iii) Maine: Following the Californian EPS, the State of Maine also established an EPS of 1,100 lbs. per MWh for new power plants (U.S. State of Maine).

(iv) Montana: Montana Governor Brian Schweitzer signed House Bill 25 in 2007 and the law prohibits the Montana Public Utilities Commission to approve electric power plants that are primarily fuelled by coal, with the exception that the plant captures and sequesters at least 50% of its carbon emissions (U.S. State of Montana HB 25).

(v) New Mexico: Following the Californian EPS, the State of New Mexico established the Statute SB 994 in 2007, setting an EPS of 1,100 lbs. per MWh for new power plants, and plants may capture and store carbon dioxide emissions to reach the limit of 1,100 lbs. CO<sub>2</sub>/MWh (U.S. State of New Mexico SB 994).

(vi) New York: The State of New York enacted the Power New York Act in 2011 which establishes an EPS for new power plants at a level of 925 lbs. CO<sub>2</sub>/MWh for new fossil fuel-fired plants (U.S. State of New York - Power New York Act, 2011).

(vii) Oregon: The State of Oregon enacted legislation in 1997 requiring an EPS, but in 2009 it expanded the coverage with the Oregon’s EPS law, SB 101, to all base load power plants, including coal, setting a new standard at 1,100 lbs. per MWh (U.S. State of Oregon SB 10)

(viii) Washington: Following the Californian EPS, the State of Washington also established in 2007 the Washington’s EPS law, SB 6001, which establishes an EPS at a level of 1,100 lbs. per MWh for new power plants (U.S. State of Washington SB 6001). The selected CO<sub>2</sub> EPS are summarized in Table 5, as follow:

**Table 5 - Summary of CO<sub>2</sub> EPS for coal power plants worldwide**

Country or State	EPS Level		Type of plant
Canada	825 lbs. of CO <sub>2</sub> /MWh	375 kgs. CO <sub>2</sub> /MWh	New/ existing
United Kingdom	880 lbs. of CO <sub>2</sub> /MWh	400 kgs. CO <sub>2</sub> /MWh	New (rejected)
U.S. New York	925 lbs. CO <sub>2</sub> /MWh	420 kgs. CO <sub>2</sub> /MWh	New
U.S. Federal	~1,000 lbs. of CO <sub>2</sub> /MWh	454 kgs. CO <sub>2</sub> /MWh	New
Australia	1,100 lbs. of CO <sub>2</sub> /MWh	500 kgs. CO <sub>2</sub> /MWh	New
European Union	1,100 lbs. of CO <sub>2</sub> /MWh	500 kgs. CO <sub>2</sub> /MWh	New
U.S. California	1,100 lbs. of CO <sub>2</sub> /MWh	500 kgs. CO <sub>2</sub> /MWh	New
U.S. Maine	1,100 lbs. of CO <sub>2</sub> /MWh	500 kgs. CO <sub>2</sub> /MWh	New
U.S. Oregon	1,100 lbs. of CO <sub>2</sub> /MWh	500 kgs. CO <sub>2</sub> /MWh	New
U.S. New Mexico	1,100 lbs. of CO <sub>2</sub> /MWh	500 kgs. CO <sub>2</sub> /MWh	New
U.S. Washington	1,100 lbs. of CO <sub>2</sub> /MWh	500 kgs. CO <sub>2</sub> /MWh	New
AU South Austr.	1,540 lbs. of CO <sub>2</sub> /MWh	700 kgs. CO <sub>2</sub> /MWh	New
Germany	1,694 lbs. of CO <sub>2</sub> /MWh	700 kgs. CO <sub>2</sub> /MWh	New
AU Victoria	1,760 lbs. of CO <sub>2</sub> /MWh	800 kgs. CO <sub>2</sub> /MWh	New (abandoned)
Scotland	CCS		New/existing
AU Queensland	Clean coal (with CCS)		New
AU Western Austr.	Clean coal (with CCS)		New
U.S. Montana	CCS - at least 50% of CO <sub>2</sub>		New
U.S. Illinois	CCS - 50, 70 or 90% of CO <sub>2</sub>		New
Brazil	Reforestation, en. Efficiency		New/existing (revoked)

Source: Created by the author.



The results indicate that the most stringent carbon emission restriction (EPS level) was proposed by Canada (825 lbs. of CO<sub>2</sub>/MWh), followed by the rejected UK EPS proposal (880 lbs. of CO<sub>2</sub>/MWh). Most of the countries and states have their restriction limited by 1,100 lbs. of CO<sub>2</sub>/MWh.

Apart from the State of New York (925 lbs. CO<sub>2</sub>/MWh), the United State Federal EPS, as well as most of the US state EPS have basically the same restriction (1,000 lbs. of CO<sub>2</sub>/MWh and 1,100 lbs. of CO<sub>2</sub>/MWh, respectively). Australia Federal EPS and the European Union EPS have also proposed 1,100 lbs. of CO<sub>2</sub>/MWh. The less stringent EPS come from South Australian State, Germany and Victoria State (1,540 lbs. of CO<sub>2</sub>/MWh, 1,694 lbs. of CO<sub>2</sub>/MWh and 1,760 lbs. of CO<sub>2</sub>/MWh, respectively).

About the coverage of new and existing plants: only new plants were included in the standards, excepting Brazil and Scotland (which EPS states that all the existing fossil fired power plants will have to comply with the EPS by 2025). The analysis also intended to verify the effective impact of the EPS for the new plants built after each regulation has been passed, but no fossil fired power plants built after the regulation came into force was identified.

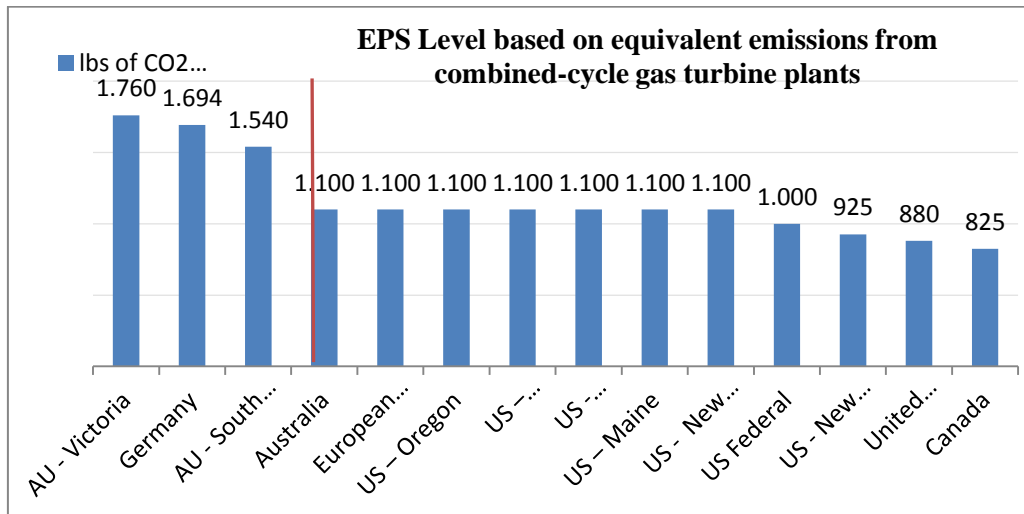
With regards to the criteria to design and regulate the emission performance standards, three systems were identified among the standards: (i) a system based on equivalent emissions from combined-cycle gas turbine plants; (ii) a system is based on the percentage of carbon dioxide emissions that have to be captured and stored through CCS; and (iii) a system based on a certain amount of carbon emission to be neutralized via reforestation, investments on renewable energy or energy efficiency, as the case of Brazil.

Another way to visualize the standards is analyzing the average level of restrictions and comparing them. Assuming that the average of the EPS level based on equivalent emissions from combined-cycle gas turbine plants is given by the Equation 1:

$$\overline{EPS} = \frac{1}{n} \sum_{j=1}^n EPS_j \quad \text{Equation 1}$$

Where J represents the countries and states and n is the number of countries and states.

The average level is 1,166 lbs. of CO<sub>2</sub>/MWh. It was found that 78% (or 11 EPS) of the EPS based on equivalent emissions from combined-cycle gas turbine plants are more stringent than the average level. Figure 16 shows a division red line of the national and states EPS:



**Figure 16 - EPS Level based on equivalent emissions from combined-cycle gas turbine plants**

Source: Created by the author.

The Figure 16 indicates that the EPS of most of the countries and states are above the average reduction of 1,166 lbs. of CO<sub>2</sub>/MWh, having the most stringent EPS from Canada (highest level of restriction) and the less stringent from Victoria, Australia. However, in terms of effectively reducing current CO<sub>2</sub> emissions more effectively, it would be important to include not only new, but existing fossil fuel-fired power plants. As aforementioned, Scotland was identified as the only nation that has created an EPS that includes both existing and new power plants (compliance by 2025). Besides the EPS in Scotland and Canada, the other regulations aim to ensure that all new fossil-fired power stations reach new best practice coal emissions standards and some of them incentive the deployment of Carbon Capture and Storage (CCS). From a perspective that these requirements should be applied only to new power plants, some authors argue that an emission performance standard for existing power plants established at the Californian level, for example, would certainly close them, which could result in potential power shortages.

Conversely, since most of the proposed standards apply only to new and modified sources, it is expected only a modest effect of these standards on the coal market within the next years. In order to achieve significant carbon emission reduction, both existing and new power plants should be included in an EPS regulation.

However, those standards are certainly important tools for the countries towards sustainable development and, consequently, to a low carbon economy. The fact that some countries already have carbon dioxide emission performance standards for new fossil-fired plant indicates some progress toward a less intensive effect on the climate. Through these rules, governments may send a clear signal about the future of CCS that, in conjunction with other policies and incentives, could support and accelerate the development and demonstration of CCS at a commercial scale. With those EPS in place, coal power plants without CCS would not be feasible, and this fact could provide a reason to deploy CCS and to encourage additional support for its development. Without this kind of requirement to control CO<sub>2</sub> emissions (or without a CO<sub>2</sub> tax, for example), it would be challenging for the companies to justify the high investments and increased costs to deploy CCS in a fossil fuel-fired power plant.

### **3.2. Correlated international environmental agreements**

There exist a number of global and regional environmental treaties that could have implications for offshore geological storage of CO<sub>2</sub>, notably the agreements on climate change and on the sea and marine environment. International law becomes particularly important in cases where the physical project boundary crosses national borders, enters international waters, or enters national waters that are governed by international treaties.

In the past years many parties of international environmental agreements have worked to amend the treaties in order to allow CCS projects under specific circumstances. This section summarizes the main international environmental agreements that have implications for CCS as a legitimate mechanism for CO<sub>2</sub> disposal, and it also presents some implications for trans-boundary CCS projects.

### ***3.2.1. London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter***

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter is the first international agreement to provide protection to the marine environment from the deliberate disposal at sea of wastes (London Convention, 1972). The Convention classifies waste management into three categories: (i) Annex I with a list of wastes that places an absolute prohibition upon the dumping of wastes; (ii) Annex II with a list of wastes that require a prior special permit to be obtained in order to dump; and (iii) Annex III with all other substances may be dumped, but require a prior general permit issued. CO<sub>2</sub> is not referred to in the Convention as a substance that cannot be dumped (Annex I) or that requires a special permit for dumping (Annex II). Therefore, it can be assumed that CO<sub>2</sub> is not prohibited from being dumped and will require permitting under Annex III.

The UCL Carbon Capture Legal Programme (CCLP, 2011) argues that whether CO<sub>2</sub> is in fact industrial waste (Annex I) or falls under other substances (Annexes II and III), it may still fall outside the need for permitting under the Convention, since the classification of dumping has exceptions that could be relevant to CCS. As of 2014, there is, however, no international consensus as to whether CO<sub>2</sub> storage may constitute placement, within the terms of the Convention (Romeiro and Parente, 2012).

The Convention is a framework for risk assessment and management and it includes guidelines for management as well as site selection, environmental impact assessment and monitoring. A new approach to waste management at sea was developed in the form of the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (London Protocol), as discussed below.

### ***3.2.2. London Protocol***

The Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter was created in 1996 as a new approach to waste management (London Protocol, 1996). It prohibits ocean disposal of any material not specified in the Protocol and it sets out a general prohibition on the export of wastes or other matter to other countries for dumping or incineration at sea. The Protocol entered into force in 2006, after its ratification by 26 countries (15 of which had to be Contracting Parties to the original Convention). The Protocol adopts a more stringent legal framework for preventing ocean waste disposal than its predecessor, the 1972 London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Convention). In effect, the two instruments will continue to apply in parallel until such time as more Parties ratify the Protocol.

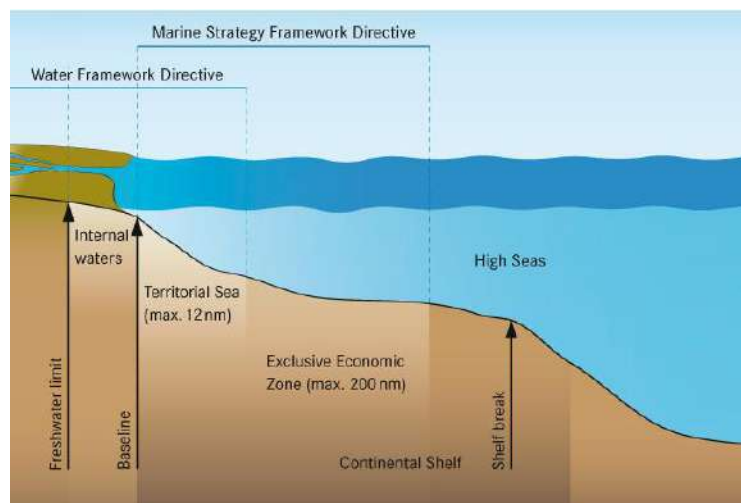
The London Protocol, which prohibits ocean disposal of any material not specified in the Protocol, requires that all the countries wishing to undertake trans-boundary CCS projects should enter into an agreement on their respective responsibilities. The document was amended in 2006 to allow “CO<sub>2</sub> streams from CO<sub>2</sub> capture processes” for sub-seabed CO<sub>2</sub> storage. The Contracting Parties to the Protocol (under the International Maritime Organization (IMO) adopted an amendment that came into force in 2007 and allows carbon dioxide storage in sub-seabed formations (IMO, 2012). According to the amendment, the CO<sub>2</sub> streams may be considered for dumping, as follows: (i) disposal is into a sub-seabed geological formation; (ii) composition of the streams consists overwhelmingly of carbon dioxide and no wastes or other matter are added for the purpose of disposing of those wastes or other matter.

Article 6 of the London Protocol was also amended in 2009 to allow for the export of CO<sub>2</sub> for CCS purposes (WRI, 2011), with the condition that all the protection standards are entirely addressed. Additionally, Parties adopted a work plan in 2010, with timelines to review the 2007 CO<sub>2</sub> Sequestration Guidelines (“Specific Guidelines for Assessment of Carbon Dioxide Streams for Disposal into Sub-seabed Geological Formations”) to encourage Parties to accept the amendment and bring the amendment into force (IMO, 2010).

### 3.2.3. *United Nations Convention on the Law of the Sea (UNCLOS)*

The United Nations Convention on the Law of the Sea (UNCLOS) was created in 1982 and it entered into force in 1994. The Convention was established to provide an overarching international agreement regulating the various uses of the world's oceans and seas. Its scope covers the use of resources, shipping, marine research, the exploitation of the exclusive economic zone and continental shelf, and the prevention and avoidance of marine pollution. The Convention presents the extent of national sovereignty over the different maritime zones, dividing the sea within national jurisdictions and beyond national jurisdictions (UNCLOS, 1982).

Within national jurisdictions, the maritime zones are divided as follows (Figure 17): (i) territorial Sea up to 12 nautical miles out to sea and the coastal state retains full sovereignty; (ii) contiguous Zone up 24 nautical miles from the coast and the coastal state can prevent and punish infringement of its laws; (iii) exclusive economic zone from the end of the territorial sea and up to 200 miles from the coast and the coastal state with sovereign rights of exploration of natural resources; (iv) continental shelf from the coastal state's territorial sea up to 200 nautical miles and the coastal state is entitled to explore and exploit the natural resources of the seabed and subsoil of the continental shelf; and (v) high seas beyond the Exclusive Economic Zone (EEZ) and all states enjoy freedom of fishing.



**Figure 17 - Jurisdictional zones of the UNCLOS and the OSPAR Convention**  
Source: OSPAR, 2010.

Beyond National Jurisdiction, the area no state can exercise sovereignty or sovereign rights over the Area and its natural resources as they are ‘common heritage of mankind’. The Convention also establishes an International Seabed Authority to regulate activities in this communal zone. States are required to ensure that their activities do not prejudice the environment of other states and must adopt laws and regulations which protect the marine environment from pollution emanating from land-based activities, seabed activities subject to national jurisdiction, dumping, vessels, and through the atmosphere.

The Convention does not imply in any prohibition to CCS activities, but its requirements may somewhat impact where activities are considered to represent pollution (Romeiro and Parente, 2012). There is no decisive view if CCS would be considered as a pollutant within the scope of UNCLOS. The London Convention of 1972 and the later Protocol of 1996 contain global rules and standards with regard to dumping and marine pollution. Although UNCLOS does not mention CCS, there are some provisions regarding the protection of the marine environment that could impact CCS projects, especially if the gas is considered to constitute pollution. It is uncertain, however, if CCS would be considered as a pollutant, which could be elucidated through amendment to address the implication for the technology (CCLP, 2011). Nations who aim to implement CCS under CDM with a trans-boundary component should follow the broad legislation of both UNCLOS and the London Convention, if they are Contracting Parties.

#### ***3.2.4. The Basel Convention***

The Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal was created in 1989 and it came into force in 1992. The goal of the Basel Convention is to assure an Environmentally Sound Management (ESM), which means the protection of human health and the environment by minimizing hazardous waste production whenever possible. ESM means addressing the issue through an “integrated life- cycle approach”, which involves strong controls from the generation of a hazardous waste to its storage, transport, treatment, reuse, recycling, recovery and final disposal (BASEL, 1989).

The Convention sets a framework to control trans-boundary movements of hazardous wastes across international frontiers (especially developing countries) and highlights in its Preamble, that States should take necessary measures to ensure that the management of hazardous wastes and other wastes. The Basel Convention was conceived on the principle that an appropriate management of trans-boundary movement of wastes could encourage environmentally sound management among the parties in order to reduce the volume of waste. There is no indication, however, if CO<sub>2</sub> would be considered a hazardous waste under the convention, except when it presents impurities during its capture process. Accordingly to IPCC (2005), the Basel Convention does not appear to directly impose any restriction on the transport of CO<sub>2</sub>.

### ***3.2.5. Convention on Environmental Impact Assessment in a Trans-boundary Context (ESPOO)***

The United Nations Economic Commission for Europe (UNECE) Convention on Environmental Impact Assessment in a Trans-boundary Context was created in 1991 and came into force in 1997. With 45 parties that have ratified this convention, it aims to prevent, reduce and control significant adverse trans-boundary environmental impact from proposed activities (ESPOO, 1991).

Its article 2 sets out the obligations of Parties to assess the environmental impact of certain activities. It also determines that States have to inform and discuss with each other the projects that are expected to have a relevant environmental impact across boundaries: "The Parties shall, either individually or jointly, take all appropriate and effective measures to prevent, reduce and control significant adverse trans-boundary environmental impact from proposed activities.

The Convention obliges states to provide an Environmental Impact Assessment (EIA) for all activities listed in Appendix I which are expected to provoke relevant trans-boundary impacts in another state, but it does not refer to CCS. Appendix I includes oil refineries, coal gasification plants, offshore hydrocarbon production *etc*, but does not mention CCS or requires an EIA for CO<sub>2</sub> transport. However, the Espoo Convention may be relevant with a possible extension of its scope in order to include CCS activities.



An amendment to Annex I would be a reasonable choice in respect of the recent amendment of the EU EIA Directive, which now includes CO<sub>2</sub> pipeline infrastructures within its scope. The Convention seems also likely to be applied to CCS projects that might have a trans-boundary impact to non-EU Members (CCLP, 2011).

### ***3.2.6. Convention for the protection of the marine environment of the North-East Atlantic (OSPAR)***

The OSPAR Convention is the current legal instrument guiding international cooperation on the protection of the marine environment of the North-East Atlantic. Work under the Convention is managed by the OSPAR Commission, made up of representatives of the Governments of 15 Contracting Parties and the European Commission, representing the European Union. It started in 1972 with the Oslo Convention against dumping. These two conventions were unified, up-dated and extended by the 1992 OSPAR Convention. Contained within the OSPAR Convention are a series of Annexes which deal with the following specific areas: (i) Annex I on the Prevention and elimination of pollution from land-based sources; (ii) Annex II on the Prevention and elimination of pollution by dumping or incineration; (iii) Annex III on the Prevention and elimination of pollution from offshore sources; and (iv) Annex IV on the Assessment of the quality of the marine environment.

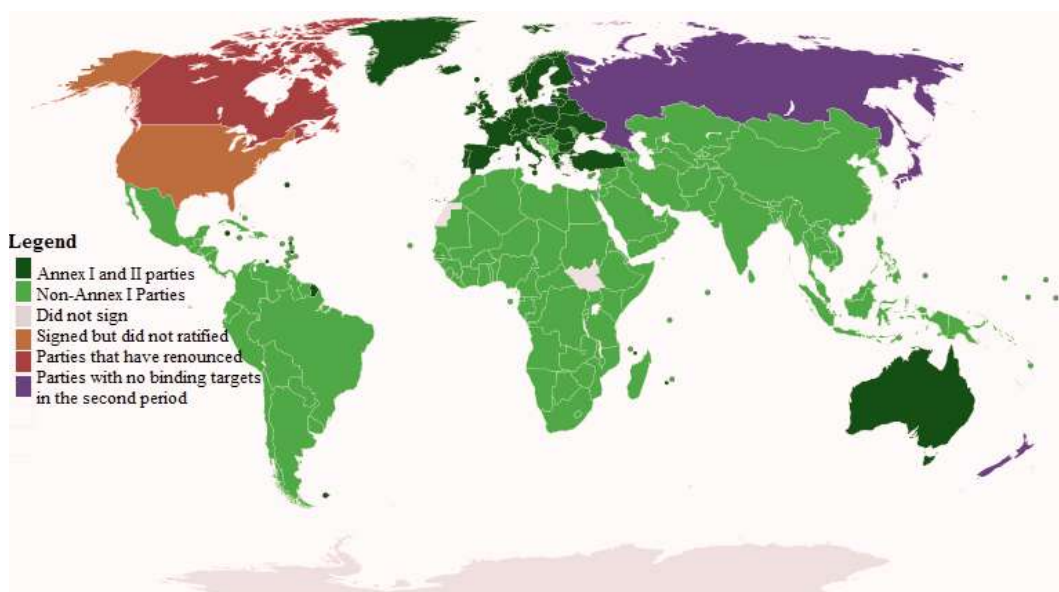
In 2002, the OSPAR Convention has address CCS, when it has commissioned a report to decide how CCS fits into the OSPAR framework. The report concluded that ship-based disposal of carbon dioxide is prohibited. However, carbon dioxide disposal from land based sources, off- shore activities, and for scientific study are permitted with authorization. The report also concluded that carbon dioxide injection into sub-seabed geological structures is allowed for offshore EOR activities. OSPAR was amended in 2007 to allow CCS, and guidelines for risk assessment and management were adopted. The Convention provides a strict frame for pre- venting ocean pollution and as a result, it could imply in barriers for CCS activities. However, because many countries are signatories of both OSPAR and the London Convention and Protocol, it more likely that the OSPAR Convention will adopt language explicitly allowing car- bon dioxide sub-seabed storage in the interest of legal cohesiveness.

### 3.2.7. *United Nations Framework Convention on Climate Change*

As earlier mentioned in Chapter 1, the United Nations Framework Convention on Climate Change (UNFCCC) is the widest international agreement on climate change, with a status of ratification that encompasses 196 parties (195 individual States). Having the main objective of achieving the stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (UNFCCC, 1992), the Climate Convention established the Kyoto Protocol in 1997, during the 3<sup>rd</sup> Conference of the Parties (COP-3).

The Protocol entered into force in 2005, and during the first period, 37 individual states and the European Community were committed to reduce GHG emissions to an average of 5% against 1990 levels (2008-2012) (UNFCCC, 1998). In 2012, during the COP-18 the Doha Amendment to the Kyoto Protocol (UNFCCC, 2012a) was adopted with a second commitment period by 18% below 1990 levels (2013-2020), but some parties such as Canada, Japan and Russia manifested that they would not sign up for a second commitment period.

The current members of the Kyoto Protocol as of 2014 are shown in Figure 18:



**Figure 18 - Member of Kyoto Protocol as of 2014.**

Source: UNFCCC, 2014.

The Kyoto Protocol establishes three regulatory instruments known as flexible mechanisms: (i) the clean development mechanism (CDM); (ii) the joint implementation (JI); and (iii) the Emissions Trading (ET). As the only of the three instruments that involve the participation of developing countries (the Non-Annex I Parties), the CDM is the focus of the analysis in this present topic.

The inclusion of CCS under the Clean Development Mechanism (CDM), a flexible mechanism created by the Kyoto Protocol in which developed countries (Annex I Countries) can implement projects to reduce their GHG emission in the developing countries (Non-Annex I Countries) was a subject of consideration by the Executive Board of the UNFCCC since 2005.

The discuss about allowing CCS to generate carbon credits under the UNFCCC is important to legitimate the technology, especially given the fact that the CDM is currently the only official instrument that could provide financial incentives for carbon dioxide reductions in the developing countries (Romeiro and Parente, 2012). Without the financial incentive given by the CDM, CCS would probably take place only in specific sectors in developing countries (Coninck, 2007).

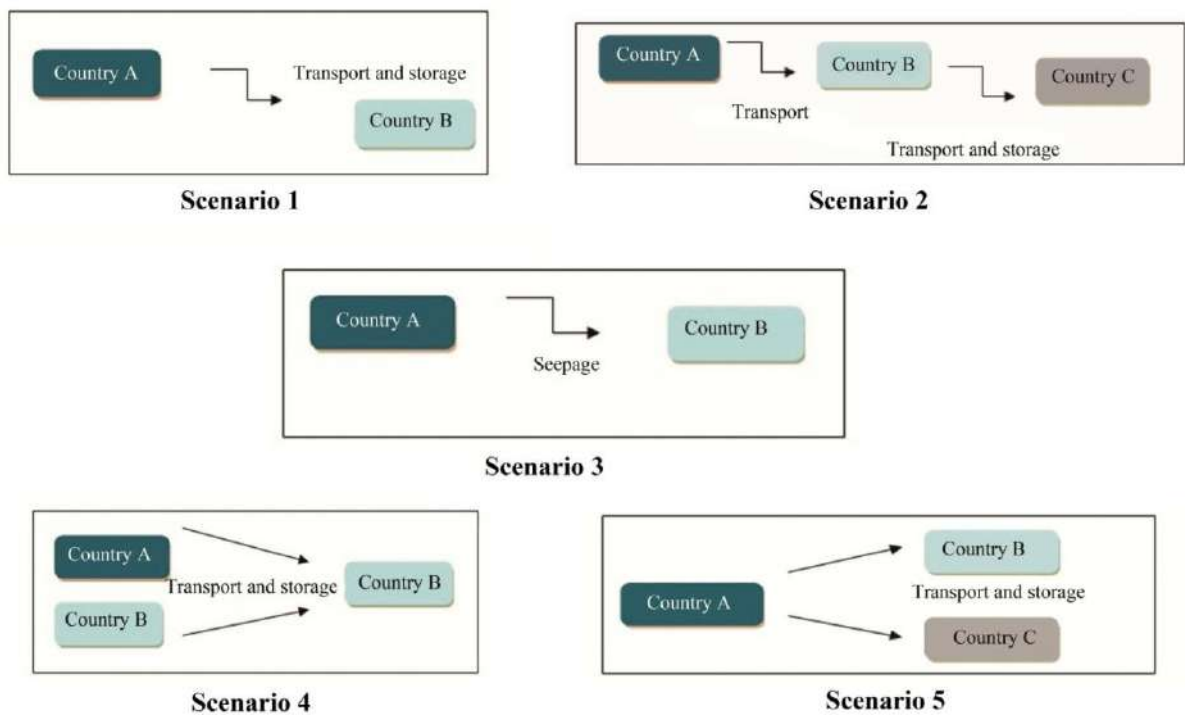
Proponents of CCS such as Australia, Japan, Norway, Indonesia, Qatar, Saudi Arabia and the United Arab Emirates have positioned themselves in favor of the inclusion of CCS under CDM, , and they argued that the inclusion of CCS under the CDM would be very helpful to avoid emissions of potentially billions of tones of CO<sub>2</sub> into the atmosphere. Nevertheless, opponents such as Albania, Bosnia and Herzegovina, Croatia, the Former Yugoslav Republic of Macedonia, Montenegro, Serbia and Turkey argue that CCS under the CDM should not imply in incentive to enhance the use of fossil fuel sources in developing countries (UNFCCC, 2010b).

Also, CCS could imply in an expensive way to enable the continued burning of fossil fuels, and deviate funds that should be allocated to renewable technology investments (Coninck, 2007). Given these divergent perspectives on the need for stringency in CCS regulations, the negotiations on this issue have become more contentious.

In 2010 the UNFCCC recognized during the 16<sup>th</sup> Conference of the Parties (COP-16) that carbon dioxide capture and storage places a relevant technology strategy for climate change mitigation and decided to include this option as a project activity under the clean development mechanism (UNFCCC, 2010a). In the subsequent year, the modalities and procedures for carbon dioxide capture and storage in geological formations as clean development mechanism project activities were approved during the COP-17 (UNFCCC 2011a). Additionally, it has also requested the Subsidiary Body for Scientific and Technological Advice (SBSTA) to consider the eligibility of trans-boundary CCS projects under the CDM, which involve the transport of CO<sub>2</sub> from one country to another or which involve geological storage sites that are located in more than one country.

For the purpose of CDM, and if CCS project with a trans-boundary component is allowed, the project would need to be implemented between developed countries (Annex I parties) and developing countries (Non-Annex I parties), or two developing countries could implement a project and sell their credits to a developed country. A trans-boundary CCS project between two developed nations would constitute a Joint Implementation (JI), which is also one of the flexible mechanisms created by the Kyoto Protocol, as already mentioned in this dissertation.

Trans-boundary issues can arise during the capture, transport and storage of CO<sub>2</sub> under various scenarios, for example: (i) Scenario 1: CO<sub>2</sub> is captured in Country A, transport and stored in Country B; (ii) Scenario 2: CO<sub>2</sub> is captured in Country A, transported through Country B and stored in Country C; (iii) Scenario 3: CO<sub>2</sub> is injected in Country A, but migrates and leaks in Country B; (iv) Scenario 4: More than one country utilizes a common storage site; and (v) Scenario 5: Storage site occurs in more than one third country (Figure 19):



**Figure 19 – Trans-boundary CCS – Possible scenarios**

Source: elaborated by the author.

If during the site characterization it is assumed a realistic probability of CO<sub>2</sub> migration to a third country, the countries should sign an approval letter as a requirement from the UNFCCC Executive Board. If unexpected seepage or any secondary effect occurs, as the case of Scenario 3, for example, Country A should discuss with Country B to repair and to ensure long-term storage and monitoring.

However, due to additional legal implication for trans-boundary projects, and recognizing that more practical experience on CCS projects under the CDM would be beneficial, the UNFCCC SBSTA, in its Thirty-seventh session during the COP-18 decided that the eligibility of trans-boundary CCS under the CDM should be postponed and further considered by Subsidiary Body for Scientific and Technological Advice in 2016 at its forty-fifth session (UNFCCC, 2012b). In a first phase, CCS should be eligible as a CDM project only when there is a very low probability of leakage and when long-term liability is well-established. By doing that, countries would have a period of “learning by doing”, in order to minimize any environmental and economic risks related to cross-borders CCS projects (UNFCCC, 2012b).

One of the main challenges faced by CCS technology is to identify who is liable in the case of leakage and migration of CO<sub>2</sub> from a geological formation. The issues concerning the global effects of leakage from a CCS project require clarifying the rights and responsibilities of CCS stakeholders, especially by the project owners and the relevant authorities.

Accordingly to Dooley, Trabucchi and Patton (2010), the first priority of any scheme considered to address long-term liability should be assuring the best site selection and operational practices in order to minimize the probability of problems arising in the future. Hence, it would be relevant that countries establish more centralized legal and regulatory frameworks for CO<sub>2</sub> storage projects that have a transboundary component (Romeiro and Parente, 2012). The analysis and the debate about the methodologies submitted for real cases may be helpful to elucidate other questions, to enhance the safety and to assure a sustainable inclusion of CCS under CDM.

Much work is still to be done by the CCS community to ensure that the implementation of CCS under the CDM is both environmentally effective and commercially attractive. Given the results of this analysis, it is recommended that developing countries establish a very centralized regulation of storage projects, where regulators consider how to most efficiently address this concern in order to reduce the chance of unintended consequences.

Finally, the inclusion of CCS under CDM should be analyzed on a case-by-case and country-by country basis: in the case of specific situations, such as additional work to solve particular questions will need to be done to provide satisfactorily guidance for the deliberation of trans-boundary CCS projects under the CDM.

### 3.3. Existing CCS legal and regulatory framework worldwide

Reducing costs, designing legal and regulatory frameworks and enhancing public acceptance have been some of the key issues to deploy CCS technologies in a large scale (Chen and Rubin, 2008). Having such issues resolved could then lead to more private investments in CCS in countries that have interests to implement the technology (Bowen, 2011). With regards to CCS legal and regulatory frameworks, significant advance has been reached worldwide in the past few years (IEA, 2012). Many countries, especially the developed countries (such as the United Kingdom, Australia and Canada) have been leading the development of such frameworks.

As earlier mentioned in Chapter 1 of this dissertation, the term “CCS legal and regulatory framework” discussed in the present study encompasses the legal and regulatory tools dedicated to set rules to ensure a safe and effective deployment of carbon capture and storage, such as (i) the role of competent regulatory authorities to regulate CCS projects; (ii) the main environmental licensing requirements; (iii) the definition of CO<sub>2</sub> ownership; (iv) the allocation of long-term liability *etc.* The frameworks analyzed in this dissertation do not include in policy tools to promote CCS demonstration projects, neither to provide incentives for CCS, such as financial support, governmental funds or carbon taxes. The terms legal and regulatory are used interchangeably to refer to:

(i) CCS legislation acts (legal frameworks that passed through a legislative process within a House of Representatives and a Senate), as the case of the Australia Offshore Petroleum (2006) and the GHG Storage Act and the United Kingdom Energy Act (2008).

(ii) CCS regulation norms (regulatory frameworks that have been not necessarily established as a law), as the case of the United States EPA’s Class VI Regulations (2010) and the UNFCCC Procedures and Modalities for CCS under the CDM (2011).

Those legal and regulatory frameworks typically intended to provide more transparency on the rules that the operators and investors would be requested to comply with, and can also increase public confidence and public perception on CCS.

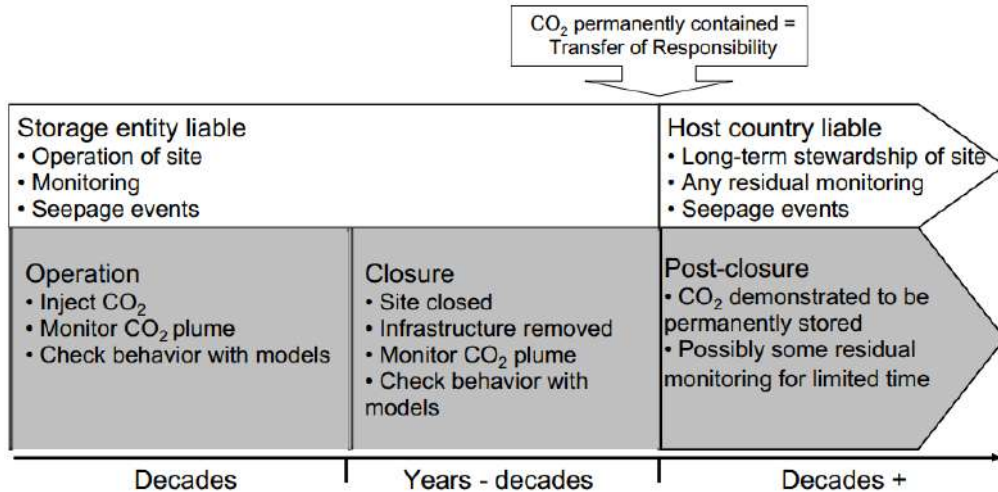
An interviewee from the Global CCS Institute argued that a CCS legal and regulatory framework does not need necessarily to be in place before the implementation of a CCS project. The many EOR projects developed globally were mentioned as projects that have not necessarily been regulated, but still some interviewees argued the need of a legal and regulatory framework for CCS in the presence of a carbon market or even mandatory targets to be established under the UNFCCC or a national climate policy. Also, most of the interviewees stated the relevance of having a CCS legal and regulatory framework before-hand, as investors to any kind of industry are likely to need to know the rules in advance.

For some aspects of CCS (especially for the CO<sub>2</sub> transport), an update of existing legal and regulatory frameworks may be sufficient for the purpose of regulating such activities. However, due to the uniqueness associated to the deployment of permanent CO<sub>2</sub> storage, some aspects such as post-closure and long-term liability may require the creation of new frameworks (Condor, 2011).

The definition of liability may be attributable to “an act done or omitted to be done by the lessee in the lessee’s exercise of rights under the agreement in relation to the injection of CO<sub>2</sub>” (Alberta CCS Statutes Amendments Act, 2010). For the purpose of the United Nations Framework Convention on Climate Change (UNFCCC), liability is “the legal responsibility arising from the CCS project to compensate for or remedy any significant damages, including damage to the environment, such as ecosystem damage, other material damages or personal injury” (UNFCCC, 2011b).

Liability issues can be operational (related to the capture, transport, injection or storage processes). In order to define the short, medium and long term liabilities during a CCS project, three phases are defined: (i) operation phase with the injection and monitor of the CO<sub>2</sub> to track its migration and behavior; (ii) closure phase with the site being closed and infrastructure removed; and (iii) post-closure with the demonstration that the CO<sub>2</sub> has been adequately stored. For each phase, a liable entity is allocated. For the operation and closure phases, the storage operator is typically the liable entity to remedy seepage events, as shown in Figure 20.





**Figure 20 - CO<sub>2</sub> storage site lifecycle and allocation of liable entities**

Source: Warren, 2011.

Designing rules for the long-term liability for a CO<sub>2</sub> storage site and any associated responsibilities (including measures to remediate the damages) is one of the most challenging issues when designing a CCS legal and regulatory framework. As carbon capture and storage still represents a recent mitigation technology, at present there are no real cases of actual conflicts with long-term liability, and hence policy-makers and scientists are challenged to anticipate questions on the extent of possible damages and the type of liability that parties will have to encompass and comply with.

As further analyzed, the most common approach to address liability in various jurisdictions encompasses the transfer of liability from the operators to the host country (a relevant authority) once CO<sub>2</sub> is demonstrated to behave as expected and to be effectively stored in a long-term stabilization projection (Warren, 2011).

Many developed countries such as Australia, Canada and the United States have experience in addressing most of the CCS regulatory issues that developing countries are currently facing to establish their own regulations, and it is important to analyze their efforts in order to share their regulatory experiences on CCS. As a lack of definition on long-term liabilities and associated implications may increase risks and costs for a CCS project, this topic assesses the main CCS legal and regulatory frameworks worldwide with a special focus on the rules regarding the transfer of long-term liability within each jurisdiction.

### **3.3.1. Australia**

The Government of Australia established in 2008 an offshore regulation for CO<sub>2</sub> storage based on existing petroleum legislation, through an amendment of the Offshore Petroleum Act 2006, currently renamed as Offshore Petroleum and GHG Storage Act 2006. The amendment also includes that the transfer of long-term liability from the operator to the Government will be done at the end of the post-closure period. According to the Act, the Relevant Authority may declare the closure assurance period for a CO<sub>2</sub> sequestration project if:

- (a) the site closing certificate is in force in relation to an identified GHG storage formation;
  - (c) on the decision day that is at least 15 years after the issue of the site closing certificate, the responsible Commonwealth Minister is satisfied that:
    - (i) the GHG injected into the formation is behaving as predicted in Part A of the approved site plan for the formation; and
    - (ii) there is no significant risk that a greenhouse gas substance injected into the formation will have a significant adverse impact on the geotechnical integrity of the whole or a part of a geological formation or geological structure (...)
- (Australia, 2006)

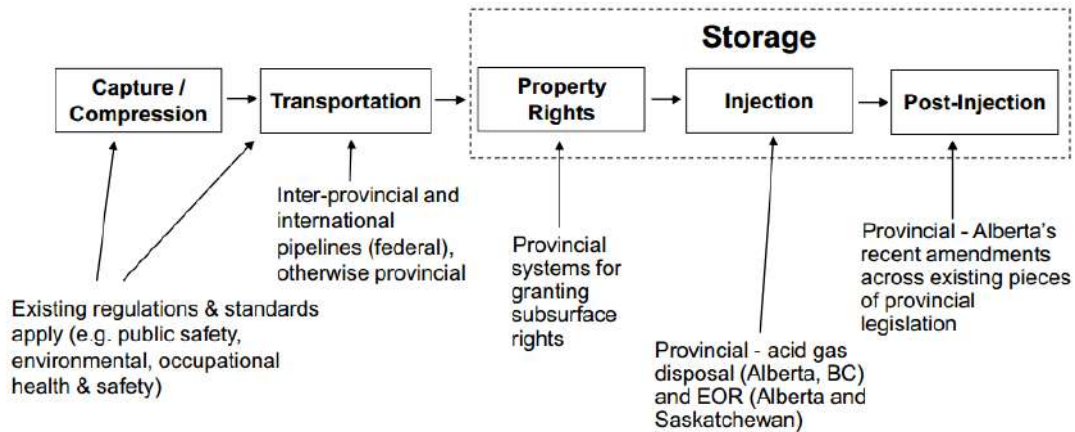
Additionally, section 391 of the Act requires that a pre-certificate notice related for a site closing certificate estimates the total costs and expenses for the long-term monitoring program, and that the amount of the security must equal such estimated costs.

However, according to an interview from the Australia Government, their CCS legislation has not been applied very much at present, as the carbon capture and storage industry in Australia is still very much in its beginning. So far only one Greenhouse Gas Assessment Permit has been awarded and no drilling or injection, even for appraisal purposes only, has occurred yet.

### **3.3.2. Canada**

In Canada, the jurisdiction is a shared responsibility and the ownership and regulation of natural resources are undertaken by the provincial jurisdictions (excepting interprovincial, national or international matters that are consequently undertaken by the federal jurisdiction). In this sense, the transport of CO<sub>2</sub> may fall under a provincial

jurisdiction or federal jurisdiction (if interprovincial or international pipelines, for example). For the storage of CO<sub>2</sub>, the provincial jurisdiction has the authority to grant property rights and to establish the procedures for the injection and post injection of CO<sub>2</sub>, as shown in Figure 21:



**Figure 21 - Existing legal and regulatory base - CCS chain in Canada**

Source: Natural Resources Canada, 2012.

Some provincial governments have already designed legal and regulatory frameworks for CCS projects, as the case of the Alberta, British Columbia, Nova Scotia and Saskatchewan. As Alberta has a solid regulatory experience of analogous oil and gas activities, including acid gas injection, the use of carbon dioxide for enhanced oil recovery purposes and high-pressure pipelines, the Provincial Government provides a good case of comprehensive legislative amendments to reduce CCS barriers and policy decisions to undertake long term liability for the stored CO<sub>2</sub>.

According to an interviewee from the Government of Alberta, greater regulatory clarity and certainty can positively assist future project proponents and can serve to further strengthen public assurance that CCS in Alberta will be conducted safely. As of 2014 there are two important pieces of regulation correlated to CCS in Alberta: the Alberta Carbon Capture and Storage Statutes Amendments Act (Alberta, 2010) and the Carbon Sequestration Tenure Regulation (AR 68/2011). The Alberta CCS Statutes Amendments Act entered into force in 2010 and it is an amendment act of the Energy Resources Conservation Act, the Mines and Minerals Act, the Oil and Gas Conservation

Act and the Surface Rights Act. The CCS Statutes Amendments Act conferred the Alberta Government the ownership of pore space and its competence to concede licenses and leases for CO<sub>2</sub> storage.

The Carbon Sequestration Tenure Regulation (AR 68/2011) creates the requirements to obtain pore space tenure rights for CO<sub>2</sub> storage. This regulation has been conceived under the Mines and Minerals Acts that has been amended by the aforementioned Alberta CCS Statutes Amendments Act (2010) to allow CO<sub>2</sub> storage in Alberta. It establishes the conditions for evaluation permits, leases and rights to drill wells, evaluates, tests and injects CO<sub>2</sub> in a corresponding area, and it sets two separate agreements for pore space tenure. The term of an evaluation permit to determine storage site suitability is 5 years from the term commencement date shown in the permit, and the term of a carbon sequestration lease is 15 years from the term commencement date shown in the lease. Other approvals for surface access and injection well licenses may be still necessary for compliance with other correlated regulations.

Few years ago, the Crown in Right of the Province of Alberta has also decided to improve the regulatory environment for CCS and in 2013 the Alberta CCS Regulatory Framework Assessment (RFA) was published. This framework aimed to gain a better understanding of the management of risks associated with large scale CCS and regulatory barriers to the adoption of CCS technology. The work around Alberta's CCS Regulatory Framework Assessment works to assure that large-scale disposal of CO<sub>2</sub> is comprehensively and transparently addressed in Alberta's regulatory framework.

Regarding the long-term liability, the ownership of the stored CO<sub>2</sub> is conferred to the government upon the issuance of a closure certificate from the Minister. With that, the Alberta Government undertakes all the responsibilities resulted from activities that were previously agreed with the operator. Although the Alberta CCS Statutes Amendments Act (2010) does not specify the minimum closure period, the Alberta CCS Regulatory Framework Assessment (Alberta Energy, 2013) provides some recommendation on long-term liability, including that a minimum closure period is needed before accepting liability for the site from the operator.

As defining the minimum time period may be difficult, such period varies broadly among countries and jurisdictions. Therefore, the Alberta Regulatory Framework Assessment recommends that:

The Government of Alberta should only grant a closure certificate after a period no shorter than 10 years after commencement of the closure period and when the lessee has demonstrated sustained compliance with required performance criteria for closure. As more experience is gained in CCS, the Government of Alberta should reevaluate the appropriateness of the performance criteria for closure and the minimum closure period (Alberta, 2013).

Such period is shorter comparing to other countries and jurisdictions, but if there is any remaining issue regarding the performance and monitoring of the site, a longer period may be imposed to demonstrate enough compliance on a case by case-basis (Alberta Energy, 2013). Additionally, before issuing the closure certificate, the operator is obliged to contribute to a post-closure stewardship fund to cover such responsibilities assumed by the government, as well as the costs of monitoring and managing the reservoirs.

According to the Alberta CCS Statutes Amendments Act (2010), the post-closure stewardship fund is intended to cover costs on monitoring the stored CO<sub>2</sub> related to its corresponding agreement between the operator and the Alberta Government. It has also the purpose of satisfying remaining responsibilities undertaken by the government, including the payment of remediation costs of orphan facilities in the surrounding area agreed between the parties.

With regards to the main lessons learned through the process of establishing the Alberta Regulatory Framework for CCS, the afore-cited interviewee from the Government of Alberta has highlighted that engaging key stakeholders was essential to strengthen the final deliverable. Having taken over eighteen months to complete, the process was well documented and defensible, and allowed for many issues to be explored in detail. He added that those who were involved in the process gained a greater understanding of CCS in Alberta, and it was a significant undertaking that called for appropriate resources.

### ***3.3.3. European Union***

The European Union Directive on the geological storage of CO<sub>2</sub> (EU Directive 2009/29/EC) was established in 2009 and it is part of the European Union's Climate Change Package. The Preamble of the Directive highlights the European Union commitment to limit global climate change to two degrees Celsius (2°C) by reducing 30% of GHG emissions in developed countries by 2020 and 60% to 80% by 2050, bearing that all the mitigation technologies should be considered (European Union, 2009). The main goal of the Directive is to protect and to provide safety for the environment and public health regarding any possible risk on CO<sub>2</sub> storage activities. The Directive underlines that "CCS is a bridging technology that will contribute to mitigating climate change". Hence, such technology should not create perverse incentives by increasing the use of non-renewable fuels, neither to reduce incentives on energy efficiency and renewable energies.

The EU Directive is usually cited as an enabling legislation, as it intends to be a supportive regulation to help the deployment of CCS instead of making it mandatory within the territory of the Member States. Therefore, the members can decide on allowing or not CO<sub>2</sub> storage within their territories. However, as stated in Article 39 of the EU Directive (2009), all Member States were requested to "transpose the Directive" (to bring into force domestic laws and regulations needed to comply with the Directive) by 2011 through communicating to the European Commission the text of their measures.

Although the EU Directive covers only few issues regarding CO<sub>2</sub> capture and transport (such as the third-party access to transport network and storage sites), such legal and regulatory framework is mostly focused on the CO<sub>2</sub> storage (both onshore and offshore). The site may be closed once CO<sub>2</sub> injection is permanently ceased, having the operator the responsibility to seal the site and remove the injection facilities. According to the Article 17 of the Directive, the operator keeps with the responsibility of monitoring, reporting and providing corrective measures after the site has been closed.

The EU Directive also addresses the transfer of liability from the operator to the competent authority upon the evidence that the CO<sub>2</sub> storage has been permanently contained and upon the condition that a minimum period is determined by the competent authority. Accordingly to Article 18 of the Directive:

This minimum period shall be no shorter than 20 years, unless the competent authority is convinced that the criteria about the evidences indicating that the stored CO<sub>2</sub> will be completely and permanently contained is complied with before the end of that period (European Union, 2009).

Additionally, as a post-transfer obligation, the operator needs to provide a financial contribution for the competent authority before formalizing the transfer of liability, as a way to cover projected costs of monitoring for a period of 30 years. Nevertheless, in order to avoid perverse incentives regarding the proper management of the site by the operator, the legal and regulatory framework specifies a list of exceptions for the transferred liability where the competent authority may still request the operator to cover some costs, such as lack of due diligence or negligence from the operator *etc.*

#### ***3.3.4. United Kingdom***

Since 2007 the United Kingdom Government has announced a series of tools to support and incentive investments for CCS (IEA, 2011). A review process of existing correlated legal and regulatory frameworks has been conducted to identify the main gaps of such regulations, and has identified a need for specific regulation to deal with the long-term storage of CO<sub>2</sub> and its possible environmental impacts.

As a result, the 2008 Energy Act (United Kingdom, 2008) established requirements to regulate offshore CO<sub>2</sub> storage in the United Kingdom, and the long-term storage of CO<sub>2</sub> has been considered through the transposition of the EU CCS Directive on the Geological Storage of Carbon Dioxide. The Act introduces a requirement that activities associated to CO<sub>2</sub> storage (and mainly associated to its permanent sequestration) need a license from the competent authority, and such license may contain provisions on the closure of a carbon storage site (Global CCS Institute, 2014).

The Government of the United Kingdom has transposed the EU CCS Directive through the aforementioned Energy Act 2008 and through amendments of existing legislation. Such Act has been one of the first CCS legal and regulatory frameworks to be established globally, and although it has been enacted a year before the EU Directive has been passed, the regulation was enough flexible to allow its transposition to the Directive (Global CCS Institute, 2011).

Under the authority of the Energy Act 2008, a regulation for CO<sub>2</sub> storage was passed in 2010 by the United Kingdom Parliament to introduce a permitting regime for offshore CCS activities and such regulation partially satisfied the United Kingdom's commitment to transpose the EU CCS Directive into UK domestic law. Such Act regulates, *inter alia*, the granting of licenses, the closure and post-closure periods. Regarding liability, the operator keeps with all the responsibilities during the post-closure phase for at least 20 years until the transfer of liability to the relevant authority, as per the requirements of the EU CCS Directive.

### **3.3.5. *United States***

As the United States Environmental Protection Agency (EPA) considers that CCS is one option within the mitigation strategies to reduce GHG emissions in the country, the Agency has established requirements at the federal level for operators that aim to store CO<sub>2</sub> for geological sequestration. The Class VI Rule Regulations has been framed under the existing Underground Injection Control (UIC) Program, which purpose is to protect underground sources of safe drinking water (EPA, 2011).

A new category of injection well has been created to allow CO<sub>2</sub> injection for geological sequestration, and the legal and regulatory framework establishes requirements (for permits, site characterization, financial responsibility *etc.*) for the underground injection of CO<sub>2</sub> in geologic formations. It does not regulate the capture and transport processes of the technology; neither has any implications for Enhanced Oil Recovery that uses CO<sub>2</sub>.



Because of the migration of CO<sub>2</sub> within subsurface geological reservoirs, the possibility of potential impurities in the fluid, as well as its corrosivity when mixed with water *etc.*, the goal of such legal and regulatory framework is to provide safety for drinking water when deploying technologies for geological sequestration of CO<sub>2</sub> in the United States.

With regards to the long-term liability and stewardship for site closure of CCS projects under the Class VI Rule, the EPA has been recommended by many stakeholders to transfer liability to the State or Federal government or even to a funded entity. The Safe Drinking Water Act (SDWA) only establishes that the operator must prove that the CO<sub>2</sub> storage doesn't imply in any risks for the safe drinking water, and that the operator needs to attend a series of regulatory requirements. Although EPA recognizes the relevance of such comments on long-term liability recommended by the stakeholders, the Agency has no authority, under the SDWA, to enforce the transfer of liability from the operator. However, in terms of the post-injection site monitoring, the EPA UIC Class VI Regulation sets that:

The proposed rule identified a default PISC timeframe of 50 years following the cessation of injection. This timeframe was based on a review of research studies, industry reports, and existing environmental programs. (EPA, 2010).

Therefore, during such period, the operators are required to monitor the site to track the behavior and migration of the CO<sub>2</sub> to assure that the drinking water is not exposed to associated risks of the CO<sub>2</sub> storage. The proposed timeframe may be adjusted (reduced or increased) after ending the CO<sub>2</sub> injection upon demonstration from the operator.

### **3.3.6. Norway**

Norway has two of the largest commercial CCS projects worldwide: the capturing of CO<sub>2</sub> from gas produced on the Sleipner fields (in operation since 1996), and on the Snøhvit fields (in operation since 2007). Although the country has no dedicated CCS legal and regulatory framework as of 2014, the Government of Norway, mainly the Ministry of Petroleum and Energy and the Ministry of Labor, has been working on new regulations that would cover CO<sub>2</sub> transport and storage in geological reservoirs on the Norwegian Continental Shelf under the existing petroleum legislation (IEA, 2014).

The main driver for such new CO<sub>2</sub> legislation in Norway is the fact that the country, as a Party to the Agreement on the European Economic Area, is obliged to implement the EU CCS Directive (2009) into Norwegian law. In terms of long-term liability time frame, the country has also indicated its intention to encompass the 20-year timeframe proposed by the EU Directive (Global CCS Institute, 2013).

The government has also the intention to transpose the CCS Directive into national law to allow the country joining the European Union Emissions Trading Scheme (ETS) with CCS projects. However, since the EU CCS Directive was adopted in 2009, the only two CCS projects in operation since 1996 and 2007, respectively, are regulated under the Petroleum Act and not under the CCS legislation.

Beyond such regulations correlated to CCS in Norway, the country has also an important law that incentivises the deployment of CCS: the Federal Government imposes a tax on CO<sub>2</sub> emissions through the Tax on Discharge of CO<sub>2</sub> in the Petroleum Activities on the Continental Shelf (CO<sub>2</sub> Tax Act n° 72 of 1990). The CO<sub>2</sub> Tax Act applies only to companies exploring for and producing oil and gas on the Norwegian Continental Shelf (Norway, 1990).

Regarding the influence of the CO<sub>2</sub> Tax Act on the implementation of CCS projects in Norway, an interviewee from the Norwegian Ministry of Petroleum and Energy indicated that the Act may to some extent have influenced the operators' decision to develop the two CCS projects in Norway, but it is important to bear in mind that the gas in these two fields is very rich in CO<sub>2</sub> and is not sellable without taking away CO<sub>2</sub> from the gas. Therefore, CO<sub>2</sub> capture was the only option if gas were to be produced from these two fields.

Although the competent environmental regulatory agencies would probably not have permitted the release of the captured CO<sub>2</sub> from these fields, regardless of the existence of the CO<sub>2</sub> levies Act, the carbon price in Norway successfully close the financial gap to deploy CCS technology in the country, as stated by a representative of the Norwegian Ministry of Petroleum and Energy published (IEA, 2014).

### 3.3.7. *United Nations*

As already mentioned in this chapter, CCS project activity was approved as a valid project type within the CDM during the COP-16, in 2010, and the “Modalities and Procedures for CCS in geological formations as CDM Project Activities” Regulatory Framework (UNFCCC, 2011b) was finally approved in 2011 during the COP-17. Although the negotiations resulted in the approval of such framework, opponents and skeptics have attempted to add a number of provisions into the draft regulation that may slow or even stop any CCS projects within the CDM architecture, and such regulatory framework indicates the possibility of some additional stringency for CCS projects.

First, a country may only host a CCS project under CDM if the host party has specific domestic legislation in place to govern CCS technology; and second, it must submit an agreement letter to the UNFCCC Secretariat, as follows:

A Party not included in Annex I to the Convention may only host a CCS project activity under the CDM if it has submitted an expression of its agreement to the UNFCCC secretariat to allow the implementation of CCS project activities in its territory and provided that it has established laws or regulations for CCS (UNFCCC, 2011b).

The Modalities and Procedures for CCS as CDM Project Activities focus on providing effective tools for the post-site closure and guidance on how to assure provisions for long term liability. An approach called as ‘mutatis mutandis’ was adopted by the UNFCCC Executive Board, which means that the original CDM requirements maintain the same for CCS under CDM, and rules would be changed only when required by the idiosyncrasies of the CCS technology.

The issue of liability for potential leakage of stored carbon dioxide or any other potential damage has been considered as one of the most challenging subjects related to CCS regulation, and it presents new challenges to CDM project activities or indeed any other mechanism that could generate carbon credits that are sold off immediately. The main question is how to ensure that some entity retains liability for the risk of future problems. One of the challenging tasks is to assure the approving projects only where appropriate liability management exists.

The host party needs to accept the allocation of liability and the transfer of liability from the project participant, and it should occur after the proper monitoring of the CO<sub>2</sub> storage site, as established in Paragraph 16 of the corresponding regulatory framework:

The monitoring of the geological storage site shall not be terminated earlier than 20 years after the end of the last crediting period of the CDM project activity or after the issuance of CERs has ceased, whichever occurs first. (UNFCCC, 2011b).

The transfer of liability may occur only if no seepage occurs in the past 10 years and under the circumstances that evidences from monitoring that the CO<sub>2</sub> storage will be permanently sequestered from the atmosphere in the long term. Particular attention has been focused on possible frameworks for addressing leakage (“non-permanence”). The document establishes that 5% (five per cent) of the Certified Emission Reduction (CERs) resulting from the CDM project need to be kept to a reserve account and oblige project participants using this reserve to offset any eventual net reversal of storage.

### ***3.3.8. Lessons learned from CCS legal and regulatory frameworks in developing countries***

As discussed in this chapter, many countries, mostly the developed countries, have been working towards creating and enhancing their own CCS legal and regulatory framework. Australia, for example, was the first country to establish a CCS legal and regulatory framework (in 2006), and the European Union then established a CCS Directive in 2009 with funding mechanisms for the post-closure period.

As these frameworks can provide valuable insights and guidelines, governments from developing countries could follow their paths on those in due course. It is expected that this set of regulations can lead other jurisdictions to create their own frameworks, and to improve and innovate in other issues that such regulations have not been able or intended to cover (Condor, 2011). Enhancing partnerships and exchanges between developing countries and international regulators on CCS, for example, could help policymakers increasing their CCS regulatory enforcement capabilities.

As stated by an interviewee from the Mexican Ministry of Energy (2014), the lessons learned from CCS experience in countries that already have CCS regulations should be

definitely considered when legal and regulatory framework proposals are in consideration by countries that have interested in deploying CCS. There are well fitted issues and other not to be considered for CCS implementation in specific countries, but it is important to conduct an analysis to assess the main legal and regulatory concerns from other countries and how their frameworks intend to solve the main challenges.

One preliminary step before establishing a legal and regulatory framework is whether to create a dedicated CCS legislation (as the case of the European Union) or to amend and add new provisions to existing legislation correlated to CCS (as the case of Australia). In either case, the existing laws from correlated legislation and environmental regulations play an important role in shaping the legal and regulatory approach (Seligsohn *et al.*, 2009). A dedicated CCS legislation can deal with the specific challenges regarding CCS in a broader approach to address in a single piece the multiple aspects of the capture, transport and storage.

It may be established for the entire CCS process (the EU CCS Directive is a dedicated piece of legislation that requires each member states to transpose the directive to their national laws *etc.*), or for CO<sub>2</sub> storage only (the U.S. Class VI Injection focuses on the CO<sub>2</sub> storage of demonstration projects). Conversely, other countries such as Canada and Australia have amended existing laws correlated to some aspects of CCS to gain efficiency and to make use of existing capacity (the Australian Act, for example, was amended to include offshore CO<sub>2</sub> storage).

With regards to the long-term liability, governments commonly require a minimum timeframe after the end of CO<sub>2</sub> injection to proceed with the transfer of liability. A reasonable degree of similarities regarding the liability issues in the operational phase and in the post-closure phase was identified in most of the analyzed regulations, as they provide clear distinction on the liability between the different phases of the CO<sub>2</sub> storage and the designed person or entity to be the responsible for any damage. Such timeframe differs significantly between the jurisdictions, varying from 10 years (as the case of Alberta, in Canada) to 50 years (as the case of the United States), as shown in Table 6:

**Table 6 - CCS legal and regulatory frameworks: implications for long-term liabilities.**

Country	CCS legal and regulatory framework	Adoption	Minimum period for transfer of long-term liability
Australia	Offshore Petroleum and GHG Storage Act	2006	At least 15 years after the issue of the site closing certificate.
United Kingdom	Energy Act 2008 and EU CCS Directive	2008	No shorter than 20 years
European Union	EU CCS Directive	2009	No shorter than 20 years
Norway	EU CCS Directive	2009	No shorter than 20 years
Canada, Alberta	CCS Statutes Amendments Act	2010	No shorter than 10 years
United States	EPA UIC Class VI Regulation	2010	50 years following the cessation of injection
United Nations*	CDM Modalities and Procedures for CCS	2011	No shorter than 20 years or after ending the issuance of CERs

Source: Elaborated by the author based on existing CCS legal and regulatory frameworks worldwide.

The responsibility to oversee a geological reservoir with stored CO<sub>2</sub> should be transferred from the operator to a competent authority after a certain period. As part of a plan for the post-closure stewardship, the timeframe and conditions for such transfer should be clearly stated in a proper regulation.

Given the present lack of experience on cessation of CO<sub>2</sub> storage reservoirs, the imposition of a minimum timeframe for the transfer of long-term liability may be arbitrary at this point (IEA, 2011). Also, the transfer of liability may never be completely clearly defined and almost always incomplete in some way (Macrory, 2011), and that many aspects related to the long-term storage of CO<sub>2</sub> are site-specific (as the adequacy of monitoring tools is largely based on the site specific conditions (WRI, 2008), and that such period may be adjusted (reduced or increased) depending on the specific characteristics of a CCS project and on the discretion of the corresponding relevant authorities of each jurisdiction.

## **4. Comparative country case study on CCS regulatory progress in developing countries with focus on Brazil**

This chapter presents a comparative country case study approach to investigate CCS legal and regulatory developments across selected developing countries. It also provides a more-detailed case study on the feasibility of carbon capture and storage in Brazil.

### **4.1. Four country-case study**

The selection of countries for the present country-case study was predominantly based on similarity in (i) economic status as developing countries; (ii) contribution to global GHG emissions; (iii) the presence of active or planned demonstrated or large-scale integrated CCS projects; and (iv) governance system.

First, the candidate countries were filtered based on their status as non-member of the Organization for Economic Co-operation and Development (OCDE) and Non-Annex I Parties to the United Nations Framework Convention on Climate Change.

A second step in case selection was to identify a set of developing country candidates with status as “emerging economies”. According to the Carbon Dioxide Information Analysis Center (CDIAC), as of 2014 the largest emitting developing countries (non-Annex I Parties and non-OCDE members) are (in order): China, India, Saudi Arabia, Mexico, Indonesia, and Brazil, all of which are in the top 15 CO<sub>2</sub> emitters globally.

As a third step for case selection, the remaining candidates were then evaluated for variation in the deployment level of CCS technologies, which was assessed by the countries with presence of active or planned demonstration or large-scale integrated CCS projects. This has the important significance of eliminating India and Indonesia.

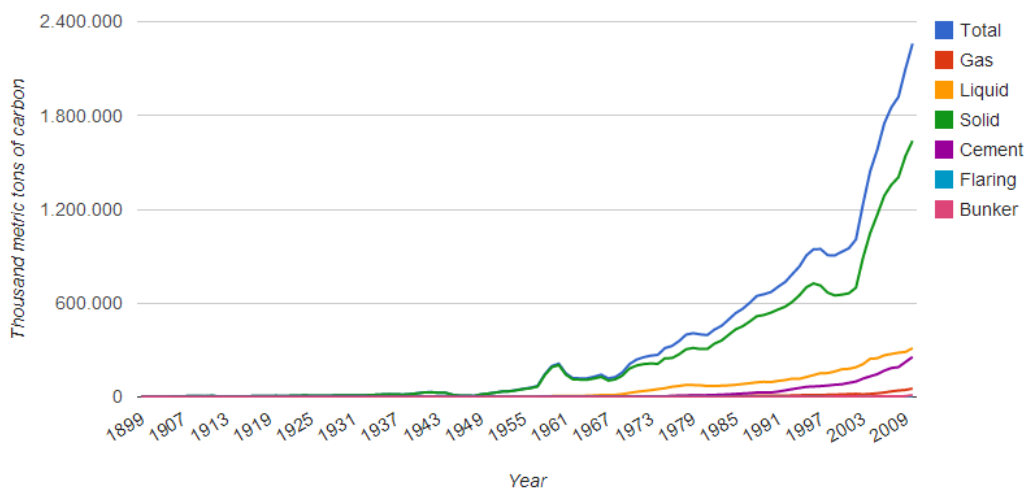
Finally, although the remaining candidates present some similarities in terms of economic development and energy balance, they are also very different in some important aspects, such as the political and regulatory governance systems. While finding similar governance environments (with only representative democracies) could facilitate data collection and analysis, such criteria would have the important effect of

eliminating China (and consequently Saudi Arabia). Since China is ranked as the top-developing countries in terms of active and planned large-scale integrated CCS projects and plays an important role on the development of the technology among the emerging economies, the country was retained in the sample. Therefore, Brazil, China, Mexico and South Africa constitute the set to be investigated under the proposed comparative country case study.

The following aspects were analyzed to compare each of the four countries: (i) the national GHG emissions profile; (ii) the presence of emissions performance standards (EPS) for CO<sub>2</sub> that could have implications for CCS; (iii) the participation in international environmental agreements related to CCS; and (iv) the initiatives and corresponding progress to create CCS legal and regulatory frameworks.

#### 4.1.1. China

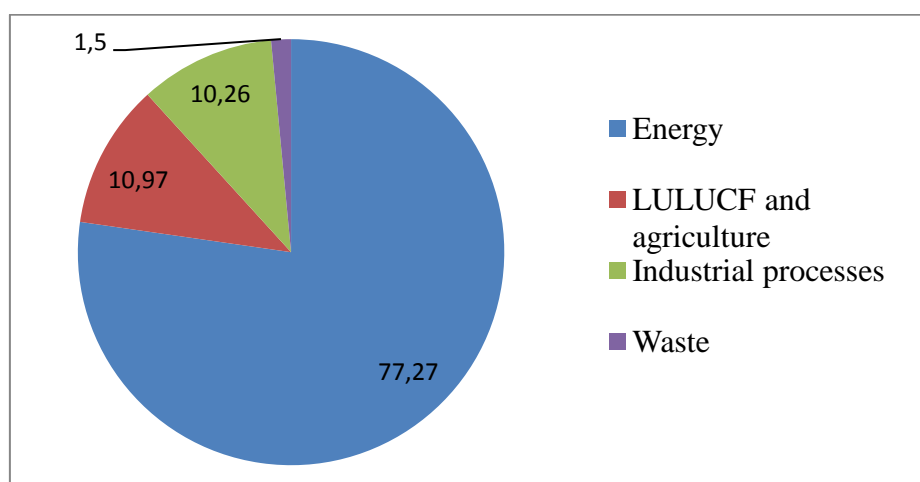
China is ranked as the 1<sup>st</sup> largest GHG emitter country in the world and as the 63<sup>th</sup> country on a *per capita* basis, having emitted 8.7 MtCO<sub>2</sub> in 2011 (CDIAC, 2014). According to the Carbon Dioxide Information Analysis Center (2014), CO<sub>2</sub> emissions in China increased from 0.67 GtCO<sub>2</sub> to 2.26 GtCO<sub>2</sub> in the period between 1999 and 2010 (an increase of approximately 421%), as follows in Figure 22:



**Figure 22 - CO<sub>2</sub> emissions in China (Mainland) by source (1899 – 2010)**  
Source: CDIAC, 2014.



As the largest CO<sub>2</sub> emitter, the National Development and Reform Commission (NRDC<sup>9</sup>) states that China is one of the most vulnerable countries to the adverse impact of climate change, and it is considered a major player in the international effort to tackle climate change (China, 2012). One of the greatest challenges in China is providing energy supply while reducing carbon emission concurrently, and as a party of the UNFCCC, the country has been facing pressure from many other countries (Huanga *et al.*, 2013). The imperative need to reduce GHG emissions from fossil fuel can be considered as the greatest driver to develop CCS technologies in China, where its GHG emissions come mostly from energy based on coal-fired power plants (Figure 23):

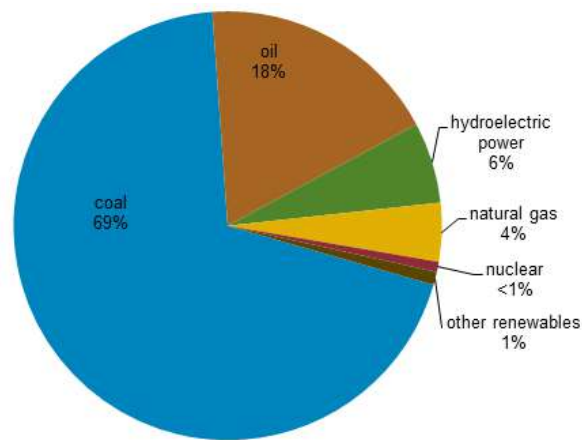


**Figure 23 - GHG emission in China in % by sectors (2005)**

Source: 2<sup>nd</sup> National Communication on Climate Change of China (UNFCCC, 2012b)

China remains as the major coal consuming country worldwide, demanding for almost half of the global coal consumption (47%), International Energy Outlook (2013). Having its economic development mostly based on energy produced from coal, the main driver for CCS in China is related to the abundance of coal reserves as shown in Figure 24.

9 The National Development and Reform Commission (NDRC) of the People's Republic of China was created in 1952 and aims at pushing forward a strategy of sustainable development in China, among others. More information is available at <http://en.ndrc.gov.cn/>.



**Figure 24 - Total primary energy consumption in China (2011)**

Source: U.S. Energy Information Administration, 2013.

China has ratified both UNFCCC and Kyoto Protocol, and as a Non Annex I party, the country has no binding targets until 2020. The country has manifested its intention to reduce its CO<sub>2</sub> emissions per unit of gross domestic product (GDP) by 40 to 45% by 2020 compared with the 2005 baseline and has announced in 2013 its first pilot program for emissions trade, the Shenzhen Emissions Trading Scheme (ETS). Since the country relies heavily on energy consumption from coal and it is likely to remain as the major source in the medium to long term (Yan Gu, 2013), deploying low carbon technologies to reduce GHG emissions is crucial for the country.

In this context, CCS is seen as an important technology in the mitigation portfolio of the country, and it has been mainly developed in China in the context of energy technology innovation (Xianjin Lai, *et al.*, 2012). According to the Scottish Global CCS Map (2014), as of 2014 there are 24 CCS projects in course in China at different levels and scales: 15 projects in planning, 07 pilot projects and 02 operational projects.

Three issues are identified as the most important factors to determine the future of CCS in China (Findlay *et al.*, 2009): (i) the location and suitability of CO<sub>2</sub> storage reservoirs in the country; (ii) the management of intellectual property rights for joint initiatives that have an international cooperation; and (iii) the establishment of a CCS legal and regulatory framework for the safety and effective use of CCS in the country.

Regarding policy and regulatory tools for CCS in China, the majority of the Chinese Climate Policies identifies CCS as a relevant option for the country's climate mitigation (Xianjin Lai, *et al.*, 2012). One of the most prominent pieces of climate legislation, the “Resolution of the Standing Committee of the National People's Congress on Making Active Responses to Climate Change”, was established in 2009 by the National People's Congress and recognizes CCS as an important measure to effectively tackle climate change in China.

We should accelerate the research, development and popularization of the major technologies in the climate change field, especially those technologies on conserving energy and increasing the efficiency of energy, clean coal, renewable resources, nuclear energy, low carbon *etc.*, explore and develop the technologies on carbon capture, its sealing up for preservation, as well as its utilization, and lay emphasis on the introduction, digest, absorption and re-innovation of the advanced technologies in the relevant fields. (China, 2009).

Promoting CCS is also a relevant mitigation option in the 12<sup>th</sup> Five - Year greenhouse gas Control Plan established by the State Council in China, which recognizes the need to develop CCS projects in the country and to enhance capacity building, financial security and policy support (China, 2013).

In terms of emission performance standards, there is no EPS as of 2014, as the country does not intend to prevent its domestic industry to produce energy from coal fired power plants, as stated by some interviewees. However, China has putting some efforts to develop “capture-ready” power plants (facilities that can be retrofitted with CO<sub>2</sub> capture technologies).

Concerning specific CCS legal and regulatory frameworks, as of 2014 there is no specific legislation in China to regulate CCS technology. Xianjin Lai, *et a*, (2012) argue that establishing a comprehensive policy to regulate CCS projects can lead to a stronger market, and one of the key regulatory issues to be clarified in China is the definition of standards to monitor and to verify the storage of CO<sub>2</sub>. If appropriately regulated to certify the monitor and management of the stored CO<sub>2</sub>, CCS technology could possibly support the reduction of GHG emissions from both existing and planned new sources in China (Yan Gu, 2013).

There are many laws and enforcement regulations for environmental health, safety *etc.* that are managed by various Chinese government agencies and that could affect CCS projects (Qian *et al.*, 2009). A specific CCS legal and regulatory framework in China is likely to include a range of existing regulations that will require joint coordination among the many ministries and stakeholders. Yet there remains various aspects of the technology that need to be clarified by a specific CCS legal and regulatory framework, including the definition of the access right and long-liability issues related to use of the underground space (Yan Gu, 2013).

According to an interviewee, the notion of liability is much less developed in the Chinese law, not only in the case of CCS, but also in other issues. The interviewee also highlights that China has been quite clear in almost exclusively deploy CCUS, as the country is very interested in CCS in the context of utilization. As a result, such fact may affect the nature of long-term liability because a CCS project will not be focused solely to the storage point-of-view, and therefore, their legal and regulatory framework for CCS may not gave the same structure as in other countries.

The United States and the European Union have established efforts to share capacity building on regulatory issues with China. The United States, for example, has created a project entitled “Building Regulatory Capacity in China-Guidelines for Safe and Effective Carbon Capture and Storage” Project, and the European Union has created the Support to Regulatory Activities for Carbon Capture and Storage (STRATCO<sub>2</sub>), which is a project to support the development of CCS regulations worldwide and has a specific case study for a CCS regulatory framework in China (STRATCO<sub>2</sub>, 2009).

However, until 2012 CCS was mostly deployed as research and development, and the technology was not necessarily a priority in the Chinese policy agenda. As of 2013, the Chinese NDRC supported the development of the technology, by launching a Notice of NDRC on Promoting Carbon Capture, Utilization and Storage Pilot and Demonstration (NDRC Climate [2013] Document N<sup>o</sup> 849) with focus on six primary working tasks, which include the promotion of standards and regulation in China. Since then, CCS agenda has been moving relatively fast in China, as the governmental level of interest in

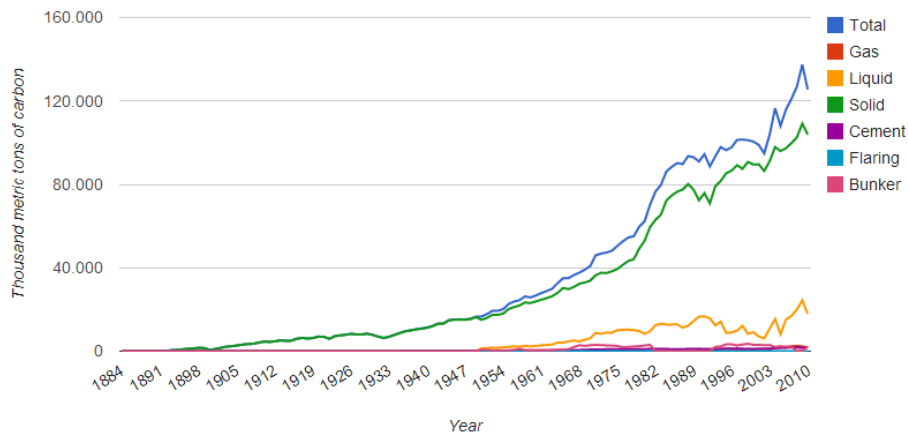
CCS was not very expressively until the DRC inclusion of CCS as a policy option, as stated by an interviewee.

As stated in the NDRC Guidance Document (China, 2013), in the near term CCS projects should be promoted based on practical experience of the technology in China and based on active engagement to provide guidance on the establishment of CCS standards and regulations. The document highlights the relevance of improving “the impact assessment of CCS, strengthening long-term security, environmental risk assessment and control, build up and improve related safety standards and a system of environmental regulations” (China, 2013).

Although all of those efforts may be an indicative of solid starts to support regulatory capacity building for CCS in China, they have never been in a point to be translated into regulation, and the country’s limitation to deal with CCS regulatory issues is still one barrier for the broad deployment of the technology, as stated by some interviewees. Additionally, the lack of a CCS legal and regulatory framework in China also implies on a legal barrier to include CCS projects within the aforementioned Chinese Emission Trading Schemes. Consequently, CO<sub>2</sub> emission reductions from CCS projects are currently not available to be traded within the seven pilot carbon markets in China (Liang and Reiner, 2013).

#### ***4.1.2. South Africa***

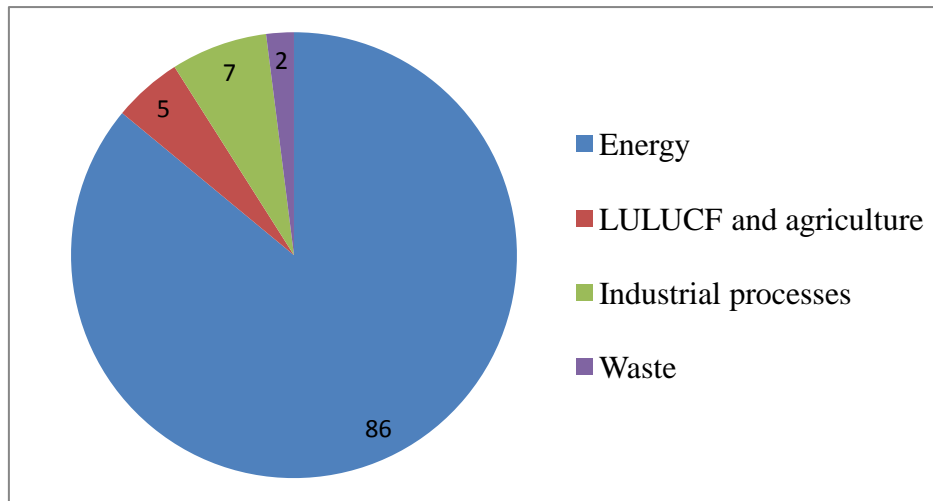
South Africa is ranked as the 12<sup>th</sup> largest GHG emitter country in the world and as the 38<sup>th</sup> country on a *per capita* basis. According to the Carbon Dioxide Information Analysis Center (2014), CO<sub>2</sub> emissions in South Africa increased from 90 MtCO<sub>2</sub> to 125 MtCO<sub>2</sub> in the period between 1999 and 2010 (an increase of approximately 38%), as follows in Figure 25:



**Figure 25 - CO<sub>2</sub> emissions in South Africa by source (1884 - 2010)**

Source: CDIAC, 2014.

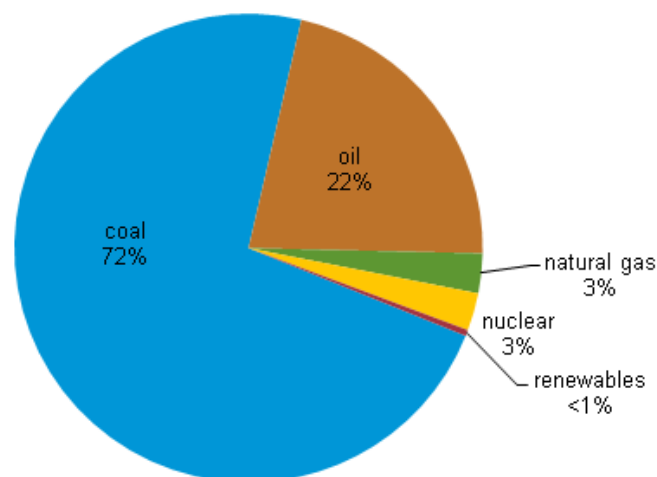
As in China, South Africa has most of its national GHG emissions coming from the energy sector (roughly 86% according to the 2<sup>nd</sup> National Communication on Climate Change of South Africa (UNFCCC, 2011), as follows in Figure 26:



**Figure 26 - GHG emission in South Africa in % by sectors (2000)**

Source: 2<sup>nd</sup> National Communication on Climate Change of South Africa (UNFCCC, 2011c).

Classified as the 6<sup>th</sup> countries in terms of hard coal production, its energy economy has been mostly driven by coal, and the main driver for CCS in South Africa related to the abundance of coal reserves (Figure 27). The government has recently started the development of two large coal-fired power plants, and as they will imply on increasing GHG emissions from fossil fuel in the country, the government decided that both plants should be “CCS ready”.

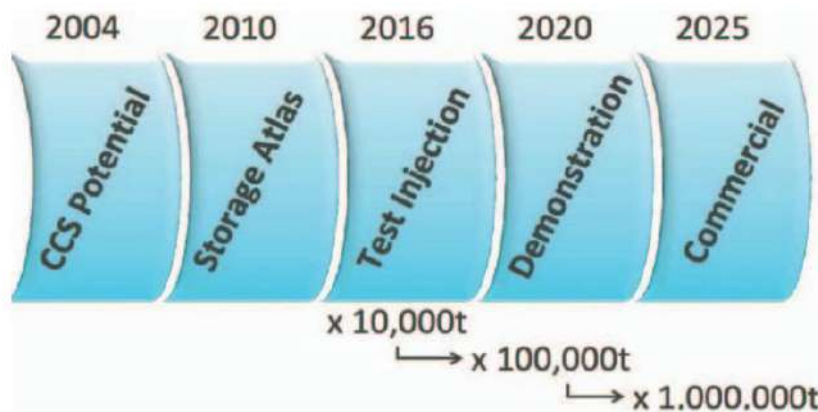


**Figure 27 - Total primary energy consumption in South Africa (2012)**

Source: U.S. Energy Information Administration, 2013.

South Africa has ratified both UNFCCC and Kyoto Protocol, and has no binding targets until 2020, but is committed to tackle global warming and has established voluntary pledges to reduce GHG emissions by 34% below business as usual (BAU) growth scenario by 2020 and 42% below the BAU growth scenario by 2025.

In terms of policy agenda for CCS, South Africa has included CCS as part of its energy and climate policies. The Government created in 2009 the South African Centre for Carbon Capture and Storage (SACCCS) to support the deployment of the technology in South Africa. The Centre has elaborated a roadmap for the large scale of CCS projects in South Africa based on five phases: (i) assessment of the feasibility of CCS and its potential for the country; (ii) elaboration of the Atlas on Geological Storage of Carbon Dioxide; (iii) operation of test injections sequestration by 2016 (postponed to 2017, according to the interviewee from SACCCS); (iv) operation of a demonstration plant by 2025; and (v) operation of large scale projects by 2025 as follows in Figure 28 (SACCCS, 2009):



**Figure 28 - Roadmap for the commercial application of CCS in South Africa**

Source: SACCCS, 2009.

Supported by the SACCCS, the Minister of Energy launched an Atlas on Geological Storage of Carbon Dioxide in South Africa in 2010 to provide geological maps with the potential and estimated capacity of the geological formations to store CO<sub>2</sub> in South Africa.

The Atlas on Geological Storage of Carbon Dioxide in South Africa estimates a geological capacity to store approximately 150Gt in depleted oil and gas formations, unmineable coal seams and deep saline formations. Due to geological storage space constraints, the Atlas presents that roughly 98% of the potential geological formation to store CO<sub>2</sub> is located offshore. Nonetheless, there is a plan to conduct an onshore demonstration project to be ready by 2020.

The National Government supports the deployment of CCS in South Africa (IEA, 2010), and the technology has been included in a series of policy instruments. The National Climate Change Response Green Paper, for example, was published in 2010 and emphasizes the establishment of a CCS legal and regulatory framework to support the technology as part of the portfolio of mitigation tools in the energy sector (South Africa, 2011). The National Climate Change Response White Paper, was published in 2011 and also mentions CCS as an important part of the country's climate change response policy (South Africa, 2012), and the Minister of Energy has then created an Interdepartmental Task Team (IDTT) as an inter-agency working group focused on CCS legal and regulatory aspects.



Regarding the clean development mechanism under the UNFCCC, South Africa's position is that only nuclear projects should be excluded from the project activities under the CDM. Although including CCS under the CDM was not the main concern for South Africa, the technology has been announced as a national priority for the government (Glazewski, Gilder and Swanepoel, 2012).

Although South Africa has a robust roadmap for CCS, the country still lacks a legal and regulatory framework for CCS. Nevertheless, the government has been working on reviewing domestic legislation that may be correlated to CCS or that may be amended for the purpose of the technology, and the Department of Energy (DoE) has initiated policy and legal regime with the World Bank by issuing a tender for the development of a CCS regulatory framework (Glazewski, Gilder and Swanepoel, 2012). Some of the main issues to be discussed and included in the framework would be (i) the ownership of CO<sub>2</sub>; (ii) the classification of CO<sub>2</sub>; the long-term liability; (iii) the identification of governance arrangements; (iv) the implications for CCS under the clean development mechanism; and (v) the implications for a CO<sub>2</sub> tax in South Africa.

The main conclusions are that CO<sub>2</sub> would be classified as a waste and could be potentially classified as hazard waste under the NEM Waste Act 59 of 2008. Also, the Department of Energy would serve as the competent regulatory authority for CCS projects, but many other governmental authorities could have correlations with such projects, such as the Department of Mineral Resources and the Department of Environmental Affairs, among others.

Over the past years, there has been a series of amendments in the national legislation and regulations that can be significant to CCS (as the case of national standards for the transport of hazardous and dangerous substances and standards for the storage of waste (Glazewski, Gilder and Swanepoel, 2012). According to one interviewee, it would be currently possible to take the next steps in the CCS Roadmap set out by SACCCS (namely to implement a pilot test injection) by using the current regulatory regime, with particular reference to the environmental legal regime. It is debatable, however, whether a large-scale project would be possible.

CCS is a climate change Flagship Programme of the Department of Environmental Affairs but is being driven by the South African Department of Energy (DoE). The DoE has been working on devising a CCS legal regime and, with financial assistance of the World Bank, undertook a project which concluded in late 2013 to take the preparatory steps to the process of devising regulation/legislation to deal with CCS.

The World Bank is currently holding a large amount of funds to be applied to developing CCS in a range of countries including South Africa (World Bank, 2011). The outcome of the project was to provide the DoE with three options to consider moving forward and that the DoE has not acted on, as yet. According to an interviewee, the DoE's delay in moving into the next stage of CCS might have to do with other pressing priorities, such as hydraulic-fracturing. Apparently, the DoE is to request the World Bank to provide further assistance to refine the study.

Currently there is no dedicated CCS legal regime in South Africa, such as there is for piped gas and possibly for fracking (shale gas). A dedicated regime would remove some of the guessing that needs to be done when considering how to implement CCS. For example, it is somehow uncertain yet if a pilot project could be really implemented according to the currently existing legal regime, and the conclusion still remains an interpretation of general environmental law, as the case of the law dealing with environmental impact assessment and the granting of permits to impact on environmental media (waste, water and air). It is also unclear how to apply such law to a CCS project, rather than deriving from the consideration of a CCS-specific regime.

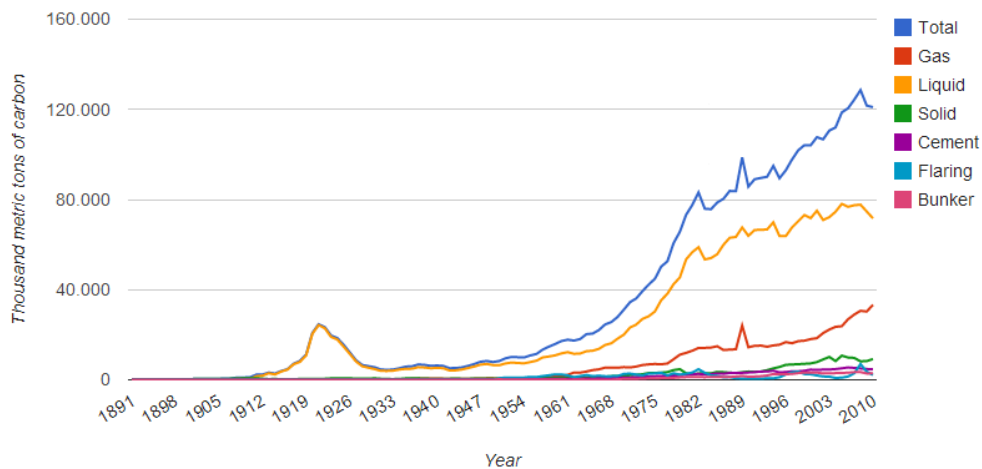
In the absence of a dedicated CCS legal regime, the only current understanding on the liability implications for the long-permanence of CO<sub>2</sub> is based on how the common law might be applied to this issue, alternatively to try and anticipate how existing financial provisions for environmental impact might be used.

Regarding the knowledge from CCS experience in countries that already have CCS regulations, one of the interviewees highlighted that there is a lot to learn from other countries and one approach taken by the South African government to legislate is by looking at international analogous cases. This was the case, for example, of the

Constitution, the environmental legal regime and even for regimes that are still being developed (such as that for fracking). Hence, there might be a good chance that lessons will be taken from international experience. Glazewski, Gilder and Swanepoel (2012) argue that although the current environmental legislation in place in South Africa (mostly related to natural resources and pollution) may fit the purposes of a demonstration CCS project, a specific CCS legislation needs to be established in the long-term to accommodate the peculiarities of such complex technology.

#### 4.1.3. Mexico

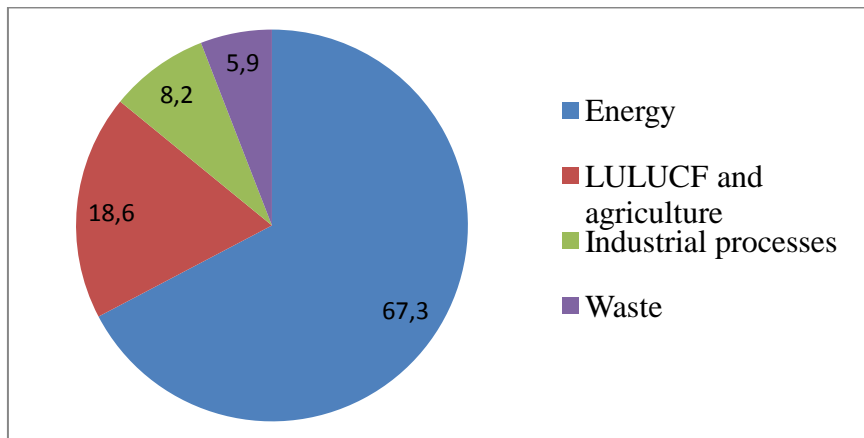
Mexico is ranked as the 13<sup>th</sup> largest GHG emitter country in the world and as the 96<sup>th</sup> country on a *per capita* basis. According to the Carbon Dioxide Information Analysis Center (2014), CO<sub>2</sub> emissions in Mexico increased from 85 MtCO<sub>2</sub> to 120 MtCO<sub>2</sub> in the period between 1999 and 2010 (an increase of approximately 41%), as follows in Figure 29:



**Figure 29 - CO<sub>2</sub> emissions in Mexico by source (1891-2010)**

Source: CDIAC, 2014.

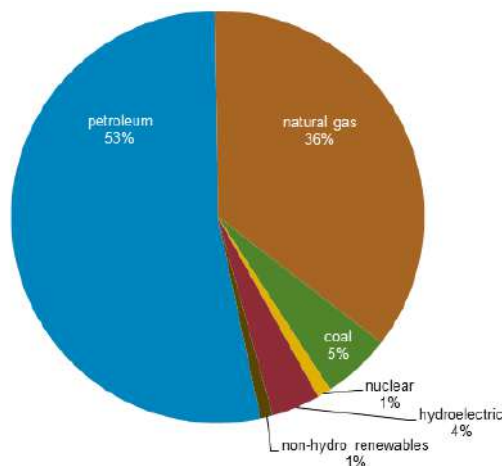
As with China and South Africa, Mexico has its national GHG emissions mostly originated by the energy sector ( 67,3% according to the 5<sup>th</sup> National Communication on Climate Change of Mexico (UNFCCC, 2012c) (Figure 30):



**Figure 30 - GHG emission in Mexico in % by sectors (2010)**

Source: 5<sup>th</sup> National Communication on Climate Change of Mexico (UNFCCC, 2012c).

Additionally, the country is one of the 10 largest petroleum producers globally, and the main driver for CCS in the country is related to the fact that petroleum and natural gas represent crucial elements for the economy, accounting for more than 90% of the total primary energy consumption (CDIAC, 2014) as follows in Figure 31.



**Figure 31 - Total primary energy consumption in Mexico (2012)**

Source: U.S. Energy Information Administration, 2013.

Mexico has ratified both UNFCCC and Kyoto Protocol, and as a Non Annex I party, the country has no binding targets until 2020. Nevertheless, the country is committed to tackle global warming and has established voluntary pledges to reduce GHG emissions by 30% below business as usual (BAU) growth scenario by 2020. According to an interviewee from the Mexican Ministry of Energy, there is no terms of emission performance standards in Mexico as of 2014, neither an intention from the government to propose one in the near term.

Regarding policy actions for CCS, the National Strategy on Carbon Capture, Use and Storage (CCUS) was developed by the Mexican Government in 2012 and the Mexican Electricity Federal Commission and the Mexican Ministry of Energy (SENER) launched the Mexico's CO<sub>2</sub> Storage Atlas. Under the North American Carbon Atlas Partnership, SENER (in cooperation with the U.S. Department of Energy (DOE) and the Natural Resources Canada - NRCan) has also supported the creation of the North American Carbon Storage Atlas. The Atlas mainly aims to offer a broad overview of large stationary CO<sub>2</sub> emission sources and potential CO<sub>2</sub> storage sites from geological reservoirs in Mexico, Canada and the United States (NACSA, 2014).

As stated by the interviewee, the country is undertaking a deep energy reform and the Mexican government has just integrated a CCS Ten-Years Road Map. The main goal of this initiative is to inform society about the key concepts on CCS. Additionally, it aims to spread awareness about the benefits and the challenges about CCS among government officials. The Ministry of Energy is also conducting a study to create a national proposal for CO<sub>2</sub>-EOR projects, but as an individual CO<sub>2</sub>-EOR demonstration projects have not advanced in Mexico, there is an effort to restart CO<sub>2</sub>-EOR projects as part of an integrated national plan. The Mexican Government is preparing an action plan to further structure a Long-Term National CCS Road Map.

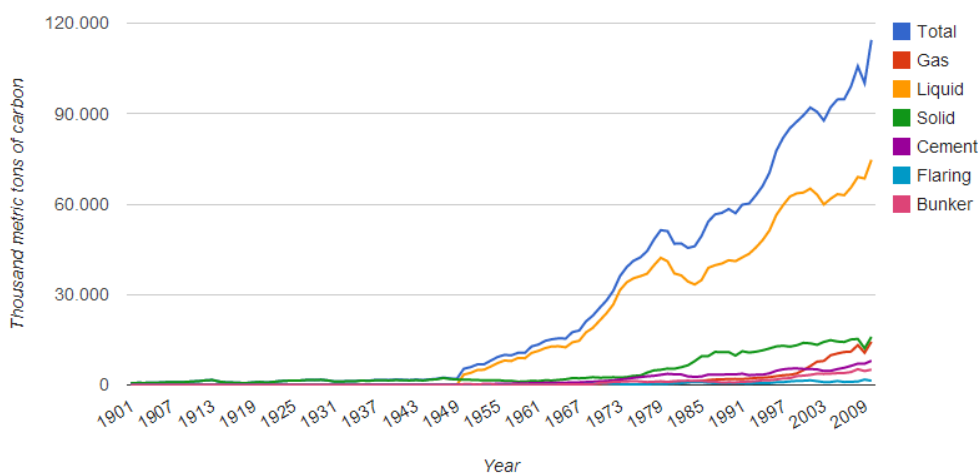
With regards to the current status of a legal and regulatory framework for CCS in Mexico, one of the next activities of the CCS Ten-Years Road Map is to analyze the legal and regulatory framework for CCS. As of 2014 the Mexican Secretariat of Energy, Secretariat of Economy and Secretariat of Natural Resources and Environment are

conducting a Regulatory Framework Analysis to identify the main guiding issues for a CCS legal and regulatory framework in Mexico. The study will encompass the following topics (IEA, 2014): (i) General regulations and permitting regimes; (ii) Already existing, applicable regulations; (iii) Specific CCS regulations needed to be developed; and (iv) Emerging CCS regulations.

The study aims at providing recommendations and suggestions on which regulations should be established and which existing regulations should be amended. Once the study is finished, the government will need to amend the actual regulations to permit CCS. When asked about how a legal and regulatory framework could help Mexico to foster the implementation of CCS projects, the interviewee highlighted the relevance of creating certainty for society, industry and investors in the reliability of the technology. The definition of rights and obligations for future stewardship of the stored CO<sub>2</sub> in geological reservoirs is also a key issue, but as long as the Regulatory Framework Analysis is still to be undertaken, there is no decision on this regard yet.

#### 4.1.4. Brazil

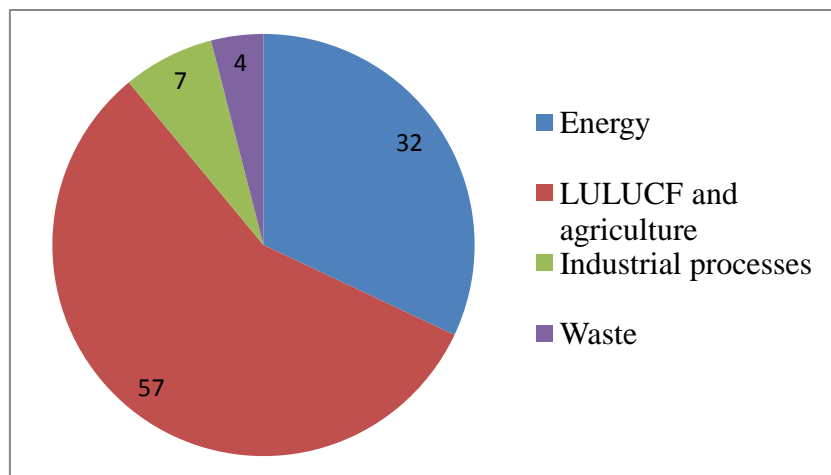
Brazil is ranked as the 15<sup>th</sup> largest GHG emitter country in the world and as the 123<sup>th</sup> country on a *per capita* basis. According to the Carbon Dioxide Information Analysis Center (2014), CO<sub>2</sub> emissions in Brazil increased from 56,9 MtCO<sub>2</sub> to 114 MtCO<sub>2</sub> (approximately 51%), in the period between 1990 and 2010, as follows in Figure 32:



**Figure 32** CO<sub>2</sub> emissions in Brazil by source (1901 - 2010)

Source: Carbon Dioxide Information Analysis Center, 2014.

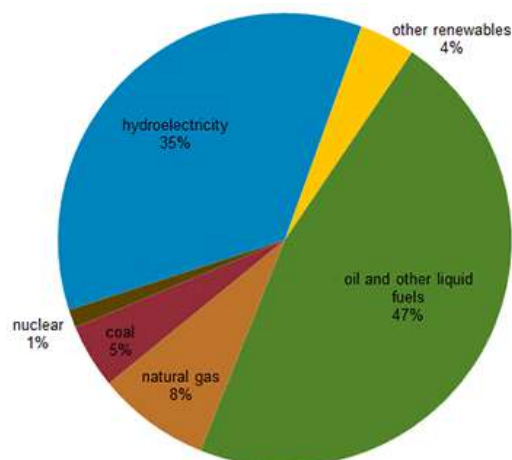
Over decades, one of the greatest challenges in Brazil terms of GHG emissions (Figure 33) was reducing deforestation rates. The governmental strategy in Brazil has been mainly focused on command-and-control policies to reduce its national GHG emissions from deforestation, as most of its GHG emissions were originated from Land Use, Land-Use Change and Forestry (LULUCF). Although the major source of GHG emission in Brazil derived from deforestation and land-use change represented 57% in the 2005 National Inventory, agriculture, livestock and energy represented 67% of the Brazilian GHG emissions in the 2010 National GHG Inventory (MCTi, 2013).



**Figure 33 - GHG emission in Brazil in % by sectors (2005)**

Source: MCTi (2013) and 2<sup>nd</sup> National Communication on Climate Change of Brazil (UNFCCC, 2012d)

Having account for approximately 39% of its primary energy produced from renewable energy in 2011 (Figure 34), Brazil has a comparatively clean energy system and has a special condition comparing to the world average rate of 13% of renewable energy (CDIAC, 2014).



**Figure 34 - Total primary energy consumption in Brazil (2011)**  
 Source: U.S. Energy Information Administration, 2013.

Because of the increasing oil and gas production partially driven by the Pre-Salt oil production, to be further discussed, the energy sector is predicted to become the major source of GHG emission in Brazil after 2020, as emphasized by many interviewees for this dissertation. The main drivers for CCS in Brazil are associated with (i) the increasing contribution of GHG emissions from the energy sector (MCTi 2013; Schaeffer, 2013); (ii) the high concentration of CO<sub>2</sub> in the Pre-Salt Oil Fields (Beck *et al.*, 2011; Melo *et al.*, 2011); (iii) the favorable source-sink match to deploy CCS in the country (Ketzer *et al.*, 2007); (iv) the potential to generate negative emissions from biomass and CCS projects (Pacca and Moreira, 2009); and (v) the possibility to generate carbon credits with CCS projects (UNFCCC, 2010).

In terms of emission performance standards, the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) published in 2009 the Normative Instruction n<sup>o</sup> 07/2009 establishing that all fossil-fuel fired power plants licensed by IBAMA should include in their environmental licensing processes measures to reduce CO<sub>2</sub> emissions (IBAMA, 2009). The Normative Instruction also refers to the UNFCCC and to the 2008 Brazilian National Plan on Climate Change and states that applicants for environmental licensing should submit in their Environmental Impact Assessment and respective Environmental Impact Report (IEA-EIR) a Mitigation Program to reduce CO<sub>2</sub> emissions according to the following criteria: (i) at least (1/3) one third of the CO<sub>2</sub> emission



reduction would need to be mitigated by forest recovery; (ii) up to (2/3) two thirds of the CO<sub>2</sub> emission reductions would need to be mitigated through investments in renewable energy or measures to promote energy efficiency.

The IBAMA Normative Instruction n° 07/2009 was clearly intended to reduce CO<sub>2</sub> emissions while promoting the increasing use of renewable energy. Nevertheless, since it created an obligation to an UNFCCC Non-Annex I country reducing its CO<sub>2</sub> emissions, the Normative Instruction has provoked a contentious discussion because of its impact on Brazilian projects under the clean development mechanism (CDM), previously mentioned in this dissertation. Its lack of legal basis had been a matter of debate since its creation, and it was then revoked in the following year throughout the IBAMA Normative Instruction n° 12/2010 (IBAMA, 2010).

With regards to international environmental agreements that have some implications for CCS, Brazil has ratified both UNFCCC and Kyoto Protocol, and as a Non Annex I party, the country has no binding targets until 2020. As a party of the United Nations Convention on Climate Change (UNFCCC), Brazil has presented its voluntary commitments to reduce GHG emissions from 36.1% to 38.9% in 2020 compared to a business as usual (BAU). This relative GHG emission reduction target compares to 15-18% of the emissions in 2005 or roughly 1 GtCO<sub>2</sub>.

Concerning specific CCS legal and regulatory frameworks, Brazil is short of CCS-related legislation. The absence of a clear rules and a competent regulatory authority to regulate the projects and is a risk for the private sector to invest in carbon capture and storage projects in the country. Although it is not likely that Brazil will establish such framework with specific rules for liability in the near term, it would be important to design at least a draft for future regulations on possible public authorities involved and associated responsibilities regarding CCS activities in the country.

#### 4.1.5. Analysis and discussion

The present comparison country-case study with China, South Africa, Mexico and Brazil intended to provide a range of deployment level in an approximately consistent economic, governance (with the exception of China), and deployment level context in a way to provide consistent and comparable results among each other. Considering that the main motivation to deploy CCS is to tackle climate change, CCS can be of particular interest for developing countries that have been intensely developing their economics and increasing their GHG emissions in absolute terms, especially in the case of China and South Africa. Most importantly, all of them, excepting Brazil, are greatly dependent on fossil fuel in their energy systems (Table 7). Such fundamental differences may indicate that these countries are likely to have different strategies for CCS.

**Table 7. Four country-case study: China, South Africa, Mexico and Brazil**

Topic	China	South Africa	Mexico	Brazil
Rank of CO <sub>2</sub> emitter (2014)	1 <sup>st</sup>	12 <sup>th</sup>	13 <sup>th</sup>	15 <sup>th</sup>
GHG (1900-2010)	Increase of 421 %	Increase of 38%	Increase of 41%	Increase of 51 %
GHG emission sector	Energy (77% as of 2005)	Energy (86% as of 2010)	Energy (67,3% as of 2010)	LULUCF (57% as of 2010)
Primary energy consumption	Coal (69%)	Coal (72%)	Oil (53%)	Oil (57%)
CO <sub>2</sub> EPS	No	No	No	2009 (revoked)
UNFCCC pledges	40-45% by 2020 2005 baseline	34% below BAU by 2020	30% below BAU by 2020	36.1-38.9% below BAU by 2020
LSIPs projects	12	No	No	1
CCS legal and regulatory framework	Some progress	Progress	Some progress	Few progress

Source: Elaborated by the author.

As of 2014 there are still many barriers to overcome before CCS is widely deployed in developing country, especially the need for more investments in logistics and infrastructure and the lack of appropriate legal and regulatory frameworks. As previously

cited, none of the developing countries that have large scale CCS projects has already established CCS legal and regulatory frameworks.

Due to the lack of experience on geological storage of CO<sub>2</sub> for mitigation purposes, interviewees from the different countries have stated that it could be too early to assume if such established rules would be sufficient to solve any potential incident arising from the long-term permanence of CO<sub>2</sub> in the future.

Based on the premises and analysis, in terms of CCS policies and regulations, South Africa has been certainly the most active of the four countries to advance on legal and regulatory frameworks for CCS, whereas Mexico and China have shown a slow but emerging interest in developing legal and regulatory assessments for CCS. The need by the Government of Brazil to advance on political and regulatory issues is critical to boost the diffusion of CCS technologies in the country, as emphasized by some interviewees. Although the country has a relatively clean energy balance, it is expected that energy will become the major Brazilian GHG emission source by 2020, and hence CCS could represent a strategic mitigation option in such country as it represents in the others.

Given the increasing emissions from developing countries with status as emerging economies, they are seen as important actors in the international climate negotiations (Román, 2011). A strong international climate regime with effective GHG emission reductions will need therefore to involve emerging economies to reduce their emission intensities (Hultman *et al.*, 2011), and any policy or plan to reduce global GHG emissions should consider strengthening investments and technology diffusion in emerging economies.

According to Román (2011), the deployment of CCS in developing countries has specific aspects to be considered, mainly the political priorities on social and economic development over environment concerns. The author argues that developing countries would only deploy large scale CCS projects if they concurrently fulfill other

social and economic development goals, indicating that CCS is more a political and strategic concern than only a technological option to solve a problem. Therefore, the perspectives for CCS in developing countries should take in account the political context that considers other interests and priorities.

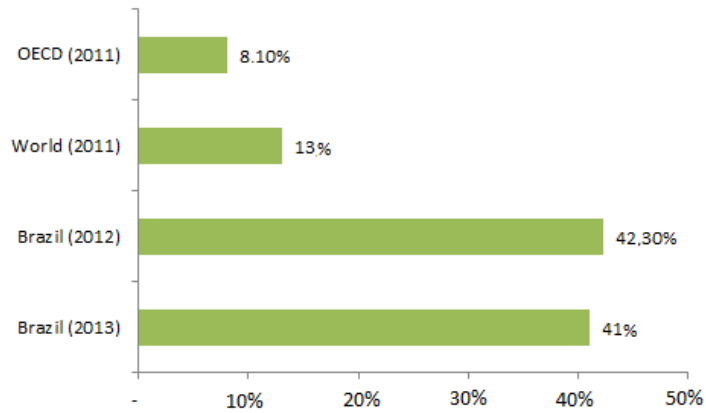
Also, while developing countries that are in process or interested to develop their own legal and regulatory frameworks should be informed by existing regulations from other countries, each national regulation must be shaped to encompass its country's specific legal and regulatory requirements. It is also important to bear in mind that an adequate regulation should allow flexibility to be reviewed and to be adapted as the state-of-art regarding the storage of CO<sub>2</sub> advances and more experience is obtained.

#### **4.2. Detailed case study: carbon capture and storage in Brazil**

Since the present dissertation has the main objective of proposing recommendations for a carbon capture and storage legal and regulatory framework in Brazil, this topic presents a more detailed case study on the status of CCS and the main barriers and challenges in that country. The previous topic has summarized the main opportunities to deploy CCS projects in Brazil (the increasing contribution of GHG emissions from the energy sector; the high concentration of CO<sub>2</sub> in the Pre-Salt Oil Fields; the favorable source-sink match to deploy CCS in Brazil; the potential to generate negative emissions from biomass and CCS projects and the possibility to generate carbon credits with CCS projects). Hence, the following sections examine each of the afore-cited items.

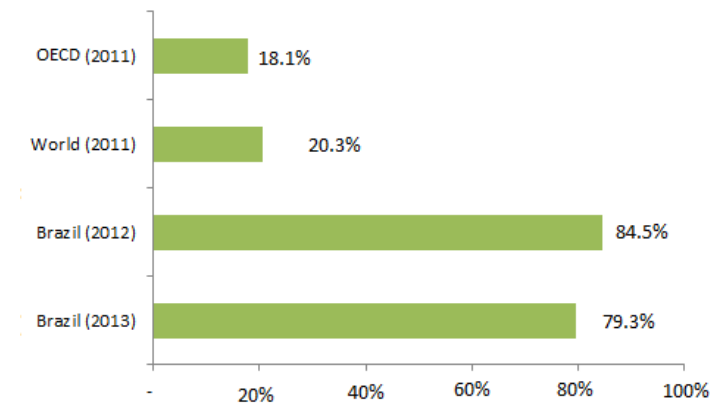
##### ***4.2.1 CCS for a transition to a lower carbon energy in the country***

Brazil has a comparatively clean energy system, with 41% of its primary energy produced from renewable energy, and has a special condition comparing to the world average rate of 13% of renewable energy (EPE, 2014), as shown in Figure 35:



**Figure 35 - Share of renewable energy in the energy system**  
Source: EPE, 2014

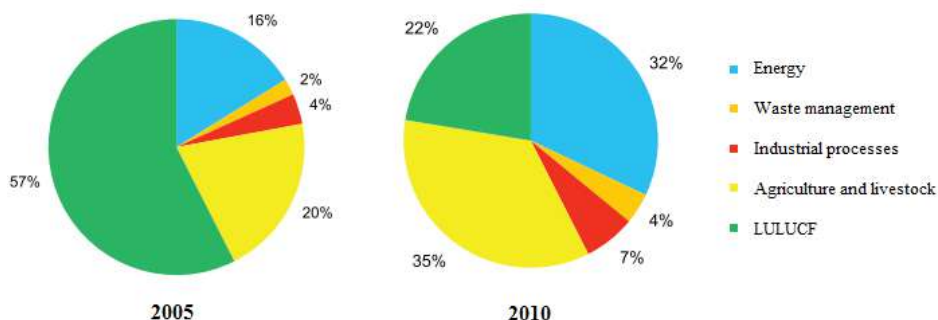
This particular condition is even more evident for the electricity generation mix, in which the country produces approximately 80% of its electricity based on renewable sources, mostly from hydropower. However, the rate of hydropower in the electricity matrix in 2013 reduced by 5.4% comparing to 2012, resulting in a decrease from 84.5% in 2012 to 79.3% in 2013 in the share of renewable energy in the electricity generation mix. Still considering such decrease, Brazil keeps in a favorable position comparing to the world average rate of 20.3% of renewable energy (EPE, 2014) (Figure 36):



**Figure 36 - Share of renewable energy in the electricity matrix**  
Source: EPE, 2014.

In the near term, it can be said that the specific energy system directly reflects in the climate policies of Brazil. While most of the climate policies in other countries are focused on reducing GHG emissions from the energy sector, Brazil has been mainly focused on command-and-control policies to reduce its national GHG emissions from

deforestation, as most of its GHG emissions were originated from LULUCF as shown in Figure 37.

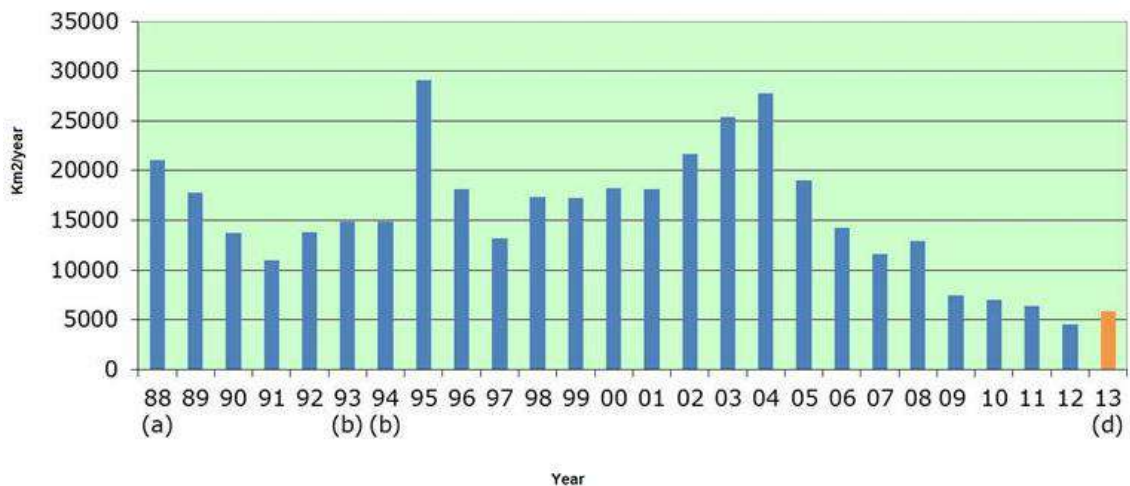


**Figure 37 - CO<sub>2</sub>e emissions in 2005 and in 2010**

Source: MCTi, 2013.

As previously mentioned in this chapter, the federal government established the National Policy on Climate Change setting voluntary pledges to reduce GHG emissions from 36.1% to 38.9% in 2020 compared to a business as usual (BAU). This relative GHG emission reduction target compares to 15-18% of the emissions in 2005 or roughly 1 GtCO<sub>2</sub>. The National Policy on Climate Change (Brazil, 2009) also established a voluntary pledge to reduce GHG emissions from deforestation in the Legal Amazon by 80% relative to the average deforestation in the years 1996-2005 and to reduce deforestation in the Cerrado Savannah by 40% relative to the average deforestation in the years 1999-2008.

Over the past years, the Brazilian Federal Government has been able to accomplish a significant share of emission reductions by decreasing deforestation rates in the Legal Amazon. The Satellite Monitoring System of the Brazilian Amazon Forest (PRODES) provides the annual deforestation rates in the Legal Amazon, and the latest data (PRODES, 2013) shows that the deforestation rates have reached their lowest level in 2012 (with a slight increase in 2013), as shown in Figure 38:



**Figure 38 - Annual deforestation rates in the Legal Amazon (1988-2013)**

Source: PRODES, 2013.

With the lowest level of deforestation rates in the Legal Amazon, the federal government has succeeded on reducing GHG emissions by 76.7% of the 80% relative to the average deforestation in the years 1996-2005.

As such, it could be assumed that carbon capture and storage has not appeared to be a mitigation option of primacy for Brazil in the past years or of great priority for the country’s climate policy. However, energy, agriculture and livestock already represent the main sources of GHG emissions in Brazil (MCTi, 2013), and it is expected that the role of fossil fuels in the medium to long term will largely increase. Furthermore, the national GHG emissions trends have changed over the past few years and are expected to continue, resulting in a significant change in the national GHG emissions profile.

The 2030 National Energy Plan<sup>10</sup> (EPE, 2007), for example, indicates that the installed capacity of coal is planned to be increased to 6,500 MW by 2030 (EPE, 2007). Yet the term of reference for the upcoming 2050 National Energy Plan (EPE, 2013) highlights several changes in the national energy system that have been strongly impacting the energy sector since the publication of the 2030 National Energy Plan 2007: the increasing obstacles to intensify the share of hydropower in the national electricity mix,

<sup>10</sup> In 2007 the 2030 National Energy Plan was published by the Brazilian federal Energy Planning Company (EPE) and the 2050 National Energy Plan is the second long-term study for the national energy planning.

the Fukushima accident and its impacts in the nuclear sector, the 2008 international financial crises, among others. Nogueira *et al.* (2014) reinforces those factors by highlighting some of the challenges that Brazil has been facing to keep its share of renewable energy in the electricity generation mix, including: (i) the possible changes in the hydrological regime due to global climate change effects; (ii) the delays in the transmission infrastructure; (iii) the modest penetration of wind energy; and (iv) the increasing share of thermal power plants.

Beyond those energy factors, there are also other important aspects to consider, such as the increasing concern on climate change and the increasing GHG emissions. Investing on lower carbon technologies is a key issue to overcome such challenges (EPE, 2014), and one issue to be further discussed in the upcoming 2050 National Energy Plan includes the feasibility of carbon capture and storage, especially in the context of new coal-fired power plants (EPE, 2013).

Lampreia *et al.*, 2011 lists a selection of the most important technologies for the energy system in Brazil by 2030, and Table 8 presents a summary of their main barriers/challenges and their probability to be largely developed by 2030.

**Table 8 - Summary of the most relevant technologies for the energy system in Brazil by 2030**



Technology	Likelihood of wide deployment by 2030
Run-of the river hydro power	Medium
Small hydroelectric plants	High
Liquid biofuels	High
Solid biomass (electricity)	High
Solid biomass (iron/steel)	Medium
Microalgae biofuels	Medium
Biogas	High
CCS offshore CO <sub>2</sub> reinjection	High
CCS other	Low
End use fuel efficiency	Medium
End use electricity efficiency	Medium
End use fuel switching	Medium
Power generation efficiency	Medium
Nuclear energy	Medium-high
Wind energy	High
Solar photovoltaics	Medium
Energy recovery from urban waste	High
Hydrogen technologies	Low
Transport sector efficiency	Medium
Transport sector fuel switching	High

Source: Lampreia *et al.*, 2011.

Also, given the particular energy system aforementioned, CCS in Brazil is likely to be more significant, in the near term, to the industry rather than for electricity generation, especially for those projects related to the industry and oil and gas production, or even to the biomass production (Beck *et al.*, 2011). Nogueira *et al* (2014), evaluates the future role of CCS in thermal power plants in Brazil up to 2050 by using three scenarios with carbon taxes, as follows in Table 9:

**Table 9 - Scenarios with possible CO<sub>2</sub> taxes in Brazil up to 2050.**

Scenarios	Carbon price	2020	2030	2040	2050
No CO <sub>2</sub> tax	USD/tCO <sub>2</sub> e	0	0	0	0
Moderate CO <sub>2</sub> tax	USD /tCO <sub>2</sub> e	10	15	22	32

High CO <sub>2</sub> tax	USD /tCO <sub>2</sub> e	30	44	66	97
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Source: Nogueira *et al.* (2014).

According to the study, in the absence of a carbon price, the first scenario stresses the importance of coal and sugarcane. The second scenario, with a moderate carbon tax, presents that the best cost-benefit option is mainly natural gas-combined-cycle (NGCC), where coal-fired power plants with CCS start getting relevance. The third scenario, with a higher carbon tax, demonstrates that all fossil fuel-fired power plants would be retrofitted with CCS technology (Nogueira *et al.*, 2014).

Besides the projects for coal in the electricity generation mix, the changes in the national GHG emissions trends in Brazil are expected to be even more accentuated with the massive oil resources found in 2006 in offshore deep water pre-salt reservoirs. The recent investments in the Pre-Salt Oil Fields might significantly imply on the increase of oil and associated natural gas production, and the domestic energy supply is predicted to become the major GHG emissions source beyond 2020.

#### ***4.2.2 The high concentration of CO<sub>2</sub> in the Pre-Salt Oil Fields***

The Pre-Salt Oil Fields are located below a dense salt layer with a depth from 5,000 to 7,000 meters below sea level and are named “Pre Salt” because they are positioned below a thick salt layer that is more than 2,000 meters (Petrobras, 2014). The salt layer works as a capping rock that traps the oil found in the Pre Salt reservoirs, as shown in Figure 39:



**Figure 39 - Pre Salt reservoirs**

Source: Petrobras, 2011.

The commercial production started in 2010 and Floating Production Storage Offloading FPSOs ships (platform ships) are used to explore and to store the oil and gas production. The volume of oil is so abundant that the oil production in Brazil can be duplicated in the next 10 years (Petrobras, 2014). Initially estimated to contain at least 8 billion barrels of oil equivalent (BOE), in June 2014 Petrobras disclosed that the estimated volumes of oil in the Pre-Salt Fields are in the order of 15 billion BOE (Petrobras, 2014).

The oil extraction from the Pre-Salt fields, however, faces many challenges with the high costs and complexities to drill deep horizontal wells through salt, the logistics to transport the oil and gas in long distances of 300km and the high concentration of CO<sub>2</sub>. Such fields were found to be more carbon intensive due to a higher concentration of carbon dioxide (CO<sub>2</sub>) in ultra-deep oil reserves.

Regarding the high content of CO<sub>2</sub>, there is a rule established by the Brazilian National Agency of Petroleum, Natural Gas and Biofuels (ANP)<sup>11</sup> that limits the concentration of CO<sub>2</sub> contained in the natural gas transported through pipelines to the coast by 3%.

<sup>11</sup> Created in 2007, the Brazilian National Agency of Petroleum, Natural Gas and Biofuels - ANP is the regulatory authority for activities that integrate the oil, natural gas in Brazil.

According to the ANP Technical Regulation n° 02 of 2008 under the ANP Resolution n° 16 of 2008:

The natural gas has to contain limit concentrations of potential corrosive components such as carbon dioxide and hydrogen sulfide in order to keep the equipment's security and integrity (ANP, 2008).

While some areas in the Pre Salt Fields do not present a high content of CO<sub>2</sub> in the fluid (such as the case of Iracema Sul with only 1% of CO<sub>2</sub>), others contain a high concentration of CO<sub>2</sub>, as the case of the Lula oil field that is located at the Santos Basin Pre-Salt Cluster (SBPSC) at approximately 300 km off the coast of Rio de Janeiro. Table 10 presents the estimated concentration of CO<sub>2</sub> in some areas at the Pre Salt fields.

**Table 10 - Estimated concentration of CO<sub>2</sub> in some Pre Salt Fields**

Pre Salt Field	FPSO	Estimated concentration of CO <sub>2</sub>
Sapinhoá	Sao Paulo	17%
Lula NE	Paraty	15%
Iracema	Mangaratiba	1%

Source: Petrobras, 2012.

The high concentration of CO<sub>2</sub> in the porous rocks imposes some operational risks that have never been faced before in similar offshore oil and gas exploitation (Petrobras, 2012). CO<sub>2</sub> can cause corrosion in the pipelines, and furthermore, it is one of the main Greenhouse gases that are provoking global climate change. According to Schaeffer *et al.* (2012), the intensification in oil and gas production from the Pre-salt Oil fields should be considered in a mid-term perspective of climate change policy in Brazil, and this fact has important implications for the deployment of CCS in the country. Hence, the Brazilian National Oil and Gas Company - Petrobras has decided to capture and re-inject CO<sub>2</sub> in the Lula Pre Salt Field for both Enhanced Oil Recovery (EOR)<sup>12</sup> and mitigation purposes (in order not to vent the remaining CO<sub>2</sub> that is not allowed to be transported via pipeline due to the 2008 ANP regulation).

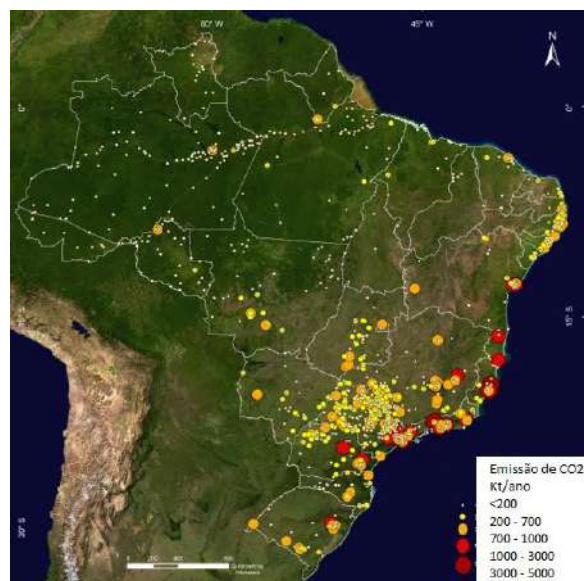
<sup>12</sup> The secondary recovery is the additional quantity of oil obtained through the injection of water. The main goals of such process are to increase oil extraction and to accelerate the production by increasing the pressure of the reservoir (Petrobras, 2012).

According to the GCCSI (2014), the CO<sub>2</sub>-EOR project at the Lula field (to be further discussed) represents the deepest CO<sub>2</sub> injection well in operation worldwide, and the success of EOR and carbon storage in the Pre-Salt Lula Oil Field may be an indicative of the relevance of deploying carbon capture and storage to reduce GHG emissions in the mid and long term in Brazil (Romeiro, 2014).

#### ***4.2.3 Favorable source-sink match to deploy CCS in Brazil***

As described in Chapter 2, a source-sink match is an important methodology to assess the feasibility of CCS in a certain country, as it consists of integrating all the data related to CO<sub>2</sub> capture (the source), transport and storage (the sink) with a Geographic Information System (GIS) (Machado, Rockett and Ketzer, 2013). The goal is to reduce the distances and avoid sensitive biomes and other important natural resources. Hence, the most relevant aspects to be considered are: the amount of available CO<sub>2</sub> stationary sources, the availability of proper transport and the technical characterization of adequate geological formations.

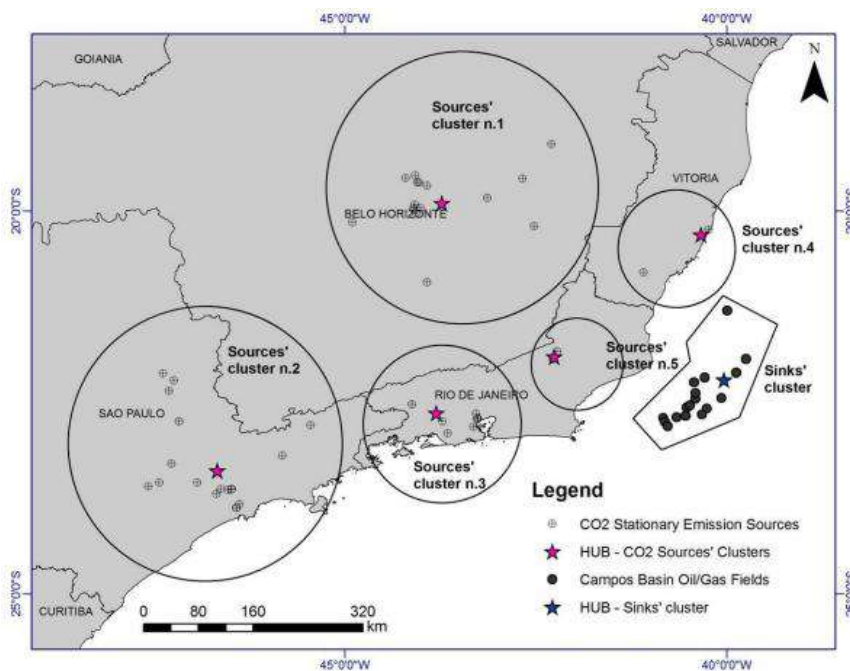
Figure 40 shows the Brazilian CO<sub>2</sub> emissions density (cement, energy, ethanol, ammonia, biomass, refinery and steel). Most of the stationary emissions are concentrated in the south and southeast regions:



**Figure 40 - Brazilian CO<sub>2</sub> emissions density map.**  
Source: CEPAC, 2014.

With regards to CO<sub>2</sub> transport in Brazil, there are still many obstacles to the wide deployment of CCS in large scale, mostly correlated to logistics and infrastructure challenges. Leal da Costa (2014) stresses the need of substantial investments to improve the infrastructure and to create (or adapt) a legal and regulatory framework to allow the transport of CO<sub>2</sub> through long-distance pipelines. An interviewee from the Brazilian National Agency of Petroleum, Natural Gas and Biofuels (ANP) has even emphasized the need of more investments for gas pipelines in the country.

One possibility to reduce the need of constructing multiple and long-distance CO<sub>2</sub> pipelines in Brazil would be transporting with short-term distance pipelines the CO<sub>2</sub> from stationary sources to a larger CO<sub>2</sub> collector hub. The CO<sub>2</sub> would be then transported through HUB to the geological reservoirs, and the gas could be even distributed to different wells. Rockett *et al.* (2012) presents a clustering approach at the Campos Basin. Figure 41 shows the clusters of CO<sub>2</sub> sources and sinks as well as their hubs:



**Figure 41 Clusters of CO<sub>2</sub> sources and sinks and their HUBs**

Source: Rockett *et al.*, 2012.

The longest HUBs would be those that link Source's clusters n° 1 and n° 2 to the Sink's cluster at the Campos Basin oil and gas fields. The distance would be roughly 700 for Cluster no 1 and 750km for Cluster no 2 (Rockett et al., 2012).

Leal da Costa (2014) also proposes a system to collect CO<sub>2</sub> and transport the gas to intermediate reservoirs (HUBS) to optimize the HUBS and establish a CO<sub>2</sub> transport network in Brazil, and presents an interesting regulatory issue regarding the creation of those CO<sub>2</sub> HUBs, which is the need of a state intervention to regulate the collection and transport of CO<sub>2</sub> in Brazil due to the natural monopoly characteristics inherent to the aforementioned CO<sub>2</sub> transport network. Natural monopoly activities are characterized by those activities in which the initial investments are high and the marginal costs are low (with a long return internal tax), as the case of electricity distribution and water services. Hence, having only one company to provide a specific service in the market can result in a lower cost than if there were many companies (Guimarães and Gonçalves, 2010).

According to the author, the creation of HUBs would be better performed with centralized services and would then generate economies of scope and economies of scale. Therefore, a regulatory framework would be necessary to minimize the information asymmetries and to control the tariff prices in those networks Leal da Costa (2014).

In terms of storage sites in Brazil, some studies (Ketzer *et al.*, 2007; Rockett, Machado and Ketzer, 2010; Machado, Rockett and Ketzer, 2013) stress the great capacity to store CO<sub>2</sub> in depleted oil fields and saline aquifers, both onshore and offshore as shown in Figure 42.



**Figure 42 - Geological storage capacity in Brazil**

Source: Rockett *et al.*, 2011.

Having a geological storage capacity of approximately 2.000 GT of CO<sub>2</sub> (Ketzer *et al.*, 2007; Román, 2011), the country encompasses almost 20% of the 11,000 GT capacity in the world, as shown in Table 11:

**Table 11 - Source-sink match in Brazil**

Basin	Capacity (Mt)	Source-sink match (Mt year)
Campos	4.8	31
Santos	148	80
Solimões	252	2.5
Paraná	462	135
Others	~1133	135
Total	~2000	248.5

Source: Ketzer *et al.* 2007.

Most of these reservoirs are situated in the south and southeast regions of Brazil, where most of the stationary sources of CO<sub>2</sub> emissions are originated, as shown in the previous Figure 41. Hence, the country has a favorable source-sink match to support the increasing exploration of the Pre-Salt Oil Fields as well as other CCS projects, including the possible deployment of biomass and carbon capture and storage (BECCS) (Ketzer *et al.*, 2007).



Such favorable geographic conditions Brazil has been even encouraging researches on CCS in Brazil (Machado, Rockett and Ketzer, 2013). However, it is important to bear in mind that the principal onshore storage site is located in the Parana Basin, under the Guarani Aquifer, the largest fresh water aquifer in the world (Ketzer *et al.*, 2007). This particular aquifer is shared by Brazil, Argentina, Uruguay and Paraguay, so any migration of CO<sub>2</sub> would also affect the drinking water in these neighboring countries. Were this to happen, the geopolitical consequences would obviously be enormous; consequently, that area will be possibly excluded as a potential storage site. Due to this fact, CO<sub>2</sub> storage is likely to be mostly deployed as an offshore initiative, in oppose of most of the countries (Ketzer *et al.*,2007).

Although offshore projects imply on more costs on construction, there are some important benefits such as less costs with logistics by reducing the need of extended pipelines and less public resistance by constraining CO<sub>2</sub> storage operations far from concentrated populated area. If carbon capture and storage projects are deployed onshore, a range of regulatory issues could arise, such as public acceptance, potential loss of biodiversity, state environmental regulatory issues etc. Contrarily, if the technology is mostly deployed offshore, such problems are likely to be less significant, especially for social acceptance from local communities.

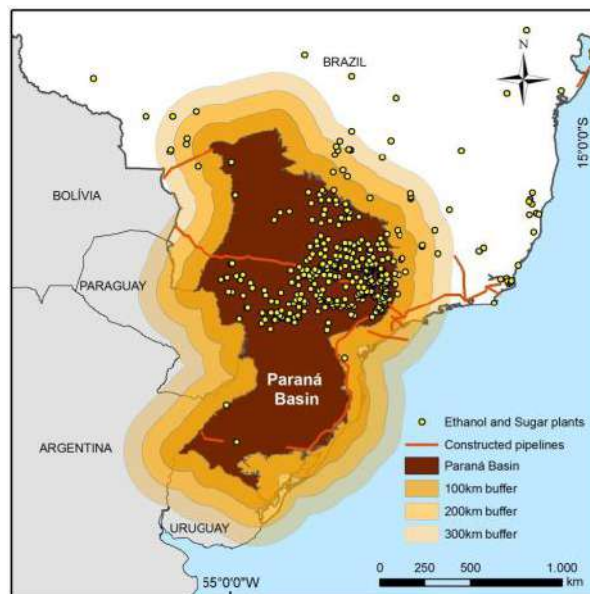
Hence, any CCS legal and regulatory framework in Brazil should take into account the country's international law of the sea obligations and offshore legislation (coastal area legislation).

#### ***4.2.4 Biomass and CCS: the opportunities associated with negative emissions***

According to the Brazilian Energy Planning Company (EPE, 2014), the expansion of the ethanol in Brazil is very promising. As of 2014, flex vehicles currently correspond to more than 90% of light vehicles and the fleet is annually increasing. Furthermore, for the next two decades new technologies are estimated to penetrate in the market, such as the hybrid and electrical cars (EPE, 2014).

Considering the large production of biofuels in its primary energy balance, Brazil has a large potential to deploy CCS projects associated with the production of biomass, but this option yet has to be explored in the country (Swedish Agency For Growth Policy Analysis, 2013). One of the main benefits to deploy BECCS in Brazil is associated with the opportunity to take advantage of the Brazilian achievements with ethanol, as the fuel would become the first one to provide negative emissions when considering its life cycle carbon balance (Pacca and Moreira, 2009). Brazil is a successful example of innovative energy policy as shown by the Ethanol Fuel Program. BECCS investments could serve as a tool for socio-economic and environmental development concurrently, and the country's learning experience concerning renewable energy, mainly biomass, might be a strategy to promote sustainable development.

A source-sink match conducted by CEPAC as part of the CARBMAP Research Program has investigated all sedimentary basins in Brazil and biomass stationary sources (Machado, Rockett and Ketzer, 2013). The study indicates a good possibility to deploy BECCS in Brazil, especially in the Paraná Basin. Almost 500 mills (sugar plants, ethanol plants or sugar plus ethanol plants) emit roughly 90 Mt of CO<sub>2</sub> and are situated within 300 km from the reservoir formation Paraná Basin (Figure 43 ), which is the limit distance recommended by the IPCC (2005).



**Figure 43 - Paraná basin source-sink matching for renewable sources**

Source: (Machado, Rockett and Ketzer, 2013)

More than half of the renewable CO<sub>2</sub> sources are located in the State of Sao Paulo, and the sedimentary Parana Basin has shown to have the greatest amount of matched renewable CO<sub>2</sub>, as the majority of the renewable CO<sub>2</sub> emissions are close to this basin (Oliveira *et al.*, 2013). Also, the rocks from the Parana Basin, especially from the Rio Bonito Formation, have the greatest potential to properly store CO<sub>2</sub>, not only because of its short distance to the a large amount of stationary CO<sub>2</sub> sources, but also because of its reservoir quality and depth. The study indicates that CO<sub>2</sub> can be adequately stored as carbonates in such reservoir, since the reaction of CO<sub>2</sub> with the rocks of the Rio Bonito Formation would result in calcium carbonate CaCO<sub>3</sub> at temperatures and pressures similar to those found for CO<sub>2</sub> storage in geological formations (Ketzer *et al.*, 2009)

However, the development of demonstration BECCS projects is still lagging in Brazil. The Federal government started a project<sup>13</sup> to prospect BECCS in Brazil, but it has been cancelled due to lack of financial support. The initiative was named “RCCS Project-Capture and Storage of CO<sub>2</sub> deriving from the fermentation process of sugar into ethanol in the State of Sao Paulo”. The state was selected mostly due to its high concentration of ethanol production (roughly 2/3 of the national production), and the project was based on capturing CO<sub>2</sub> from ethanol plants and store the gas in a saline aquifer. It was estimated that the costs to store 1 tCO<sub>2</sub> would be roughly USD 20, where in non-BECCS projects the costs could be up to USD 100 (because of the costs to separate the CO<sub>2</sub>. The project was targeted to capture and storage 1 million tCO<sub>2</sub> within 10 years, and would cost about USD 30 million. However, despite the fact that the Global Environmental Facility (GEF) through the World Bank would fund 30% of the project, it did not become financially viable due to lack of financial support (Moreira, 2011).

Although no BECCS demonstration project has been implemented in Brazil yet, some sugar mills in the northwestern region of Brazil have installed a system to capture CO<sub>2</sub> from fermentation to use the gas in industrial applications (Furtado 2014). One example

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<sup>13</sup> The coordinator institutions were the Brazilian Reference Center on Biomass (CENBIO) and the Institute of Geosciences (IG), both based on the University of Sao Paulo. Other partners included the State of Sao Paulo Environmental Sanitation Technology Company (CETESB), Petrobras, Shell, the Brazilian Sugar Cane Industry Association (Unica) and the Pontifical Catholic University of Rio Grande do Sul (PUCRS).

is the case of bioethanol distilleries equipped with CO<sub>2</sub> recovery plant (Pentair Haffmans, 2011). The project uses the capture system of the sugar cane mill that is used for scrubbing, and adds piping capture and purification with activated carbon filters. The company has already supplied two systems for sugar mills in the State of Alagoas (Grupo Usineiro Toledo and Usina Penedo), and in the State of Sao Paulo (Usina Vale, a mill that produces sugar and alcohol and sells the recovered CO<sub>2</sub>). The CO<sub>2</sub> recovery system enables the plants to reduce CO<sub>2</sub> emissions and generate additional income concurrently. The first system retrieves an average volume of 70 tCO<sub>2</sub>/day and the second 35 tCO<sub>2</sub>/day. Technically this system might be coupled with the technology detained by Petrobras, which pumps and stores CO<sub>2</sub> underground.

#### ***4.2.5 Carbon market and CCS: the opportunities associated with the generation of carbon credits***

Another strategic aspect where CCS may potentially play an important role is related to the generation of carbon credits, since the technology has a large mitigation potential and consequently a large potential to generate carbon credits (Ramón, 2011). As of 2014, CCS has been mostly discussed under the UNFCCC clean development mechanism. The negotiations on CCS-CDM have been postponed for a long period due to resistance from some parties, particularly from the Brazilian government (de Coninck, 2007). In an UNFCCC miscellaneous document published in 2010 with views related to carbon dioxide capture and storage in geological formations as a possible mitigation technology, the Brazilian government has expressed its opinion about carbon capture and storage:

Brazil, as stated in previous submissions, understands that CCS in geological formation is an option for the portfolio of mitigation options for stabilization of atmospheric GHG concentrations (UNFCCC, 2010c).

According to the document, Brazil states the relevance of accelerating R&D for CCS development, deployment and diffusion, and highlights that the spread of the technology in developing countries will rely on technical and financial costs, as well as on the transfer of technology and evaluation of environmental issues regarding CCS.

Nevertheless, when it comes to CCS-CDM projects, the Brazilian Government stressed that a CCS project has particularities that seem not to be compatible with the characteristics of a CDM project:

While acknowledging that CCS is a possible option for climate change mitigation, particularly for Annex I Parties in their effort to reduce their historical emissions, Brazil believes that CCS technologies are not appropriate in the framework of Clean Development Mechanism (CDM) and should not be eligible under the CDM (UNFCCC, 2010c).

The main reasons why Brazil expressed its disagreements on the inclusion of CCS within the CDM were related to the following issues: (i) non-permanence and long-term permanence, since the maximum period of a CDM project is 21 years or 60 years for Afforestation/Reforestation (A/R) activities; (ii) the challenges of measuring, reporting and verification in projects related to long-term storage of CO<sub>2</sub>; (iii) challenges to conduct a robust environment impact assessment (EIA); (iv) the uncertainties to determine a project activity boundary in a CCS project; (v) the needs for a multifaceted international regulatory framework to deal with possible international implications; (vi) the difficulty to determine the long-term liable entity in a case of CO<sub>2</sub> leakage; (viii) the possible perverse incentives with the impact of CCS in a CDM market, as a massive amount of carbon credits could drop the price of the Certified Emission Reductions – CERs; (ix) the lack of long-term experience with an unsuccessful injection of CO<sub>2</sub> and last; (x) the need of compensation and the lack of a proper insurance to cover long-term seepage or leakage of CO<sub>2</sub> (UNFCCC, 2010c).

At the time of the submission to the UNFCCC (2010c), the Brazilian Government suggested that CCS in developing countries should be developed within an UNFCCC funding, partnership or mechanism other than the CDM. Even so, the UNFCCC decided during the COP-16 (2010) to include CCS as a project activity under the CDM, as already discussed in Chapter 3 and provided the modalities and procedures in 2011 to elucidate the issues cited by the Brazilian Government.

However, over the past years, the country has revised its position, and in 2013 the Brazilian Government has submitted its views related to the implementation of mitigation actions under the Ad Hoc Working Group on the Durban Platform for Enhanced Action (ADP), and has observed that, although it is expected that countries will still use non-renewable energy sources for a substantial period of time, there is already in place a range of technologies that could substantially reduce GHG emissions from the deployment of fossil fuels (UNFCCC, 2013).

Hence, such technologies should be disseminated and deployed to their full potential and the UNFCCC should incentive their use by providing financial support from other instruments, such as the Green Climate Fund. Finally, the government highlighted that one of these technologies is CCS, and proposed that the ADP organizes a workshop by 2014 to discuss the current situation and perspectives of CCS as a mitigation technology and as a tool for sustainable development (UNFCCC, 2013). The UNFCCC has then scheduled an ADP Technical Expert Meetings on Carbon capture, use and storage (UNFCCC 2014) to October, 2014 as part of the UNFCCC Technical Experts Meetings (TEMs)

#### ***4.2.6 Status of CCS projects in Brazil***

Petrobras has been active to deploy CCS with ongoing research and development built on almost thirty years of experience with CO<sub>2</sub> injection for enhanced oil recovery (EOR) (Beck *et al.* 2011). A total of 40 projects have been developed with Brazilian universities and research centers, and roughly USD 17 million were invested in the period between 2006 and 2013 (Seabra and Grava, 2014). As of 2014, the company and the Global CCS Institute are conducting cooperative studies to identify where Brazil is placed on the CCS development lifecycle and to assess strategies and identify activities that could facilitate and support the country to move forward with CCS (Romeiro, 2014).

As of 2014, the current CO<sub>2</sub> demand for storage projects is low in Brazil. There are only three pilot projects and one large-scale integrated CCS project (Figure 44):



**Figure 44 - CCS projects in Brazil**

Source: Scottish Carbon Capture & Storage Map, 2014.

The Pre-Salt Lula CCS Project is the first large-scale integrated project (LSIP) installed in Brazil. The exploitation of the Lula Pre Salt Field (originally named as Tupi) was initiated in 2010, and the CCS project started operation in large scale since 2013. As already presented, the main motivation to deploy CO<sub>2</sub> geological storage in the Pre-Salt zone relates to the great content of CO<sub>2</sub> identified in some wells (in the case of the Lula field, an estimate of 15% of CO<sub>2</sub> (Petrobras, 2012).

The capture type of the project is pre-combustion and the method to separate the CO<sub>2</sub> from natural gas stream (natural gas processing) is through membrane process and absorption. The removal unit of CO<sub>2</sub> is composed by elements of membranes and the re-injected stream can contain 52% to 83% of CO<sub>2</sub>, depending on the concentration of each reservoir. Since the CO<sub>2</sub> is stored through direct injection, there is no additional pipeline to transport it, and the project captures approximately 700Mt CO<sub>2</sub>/ year (GCCSI, 2014).

As alternatives for the CO<sub>2</sub> storage, Petrobras has considered implementing EOR in such reservoirs and even storing CO<sub>2</sub> in saline aquifers (Seabra and Grava, 2014). As the storage in carbonate reservoirs still faces many challenges due to the complexity of

the permeability characteristics, the use of enhanced oil recovery through gas injection wells or through water alternating gas (WAG) was chosen as the main storage option in a carbonate reservoir at a depth between 5,000 to 7,000 meters below sea level.

Petrobras is also leading a pilot experimental project, the Miranga CCS Pilot Project, which is an offshore initiative located at the Miranga Field in the municipality of Pojuca, Bahia (at the Recôncavo Baiano). The project started in 2009 and completed its first phase in 2011. The capture type used is post-combustion to separate CO<sub>2</sub> from natural gas to be re-injected into a depleted oil field (such project is the only one in Brazil to store CO<sub>2</sub> in a field that is not currently boosting oil or gas). The injection of 14 Mt CO<sub>2</sub>/year is done through enhanced oil recovery technologies to test and to improve techniques that could contribute to the deployment of CCS projects in the Santos Basin's Pre-Salt Oil Fields (Scottish Carbon Capture & Storage, 2014).

Another pilot project is the Carbometano Porto Batista Project is being developed to look at enhanced coal bed methane (ECBM) production. The capture type used is post-combustion and the gas has been injected into the Charqueadas Coal Field, with the drilling phase finished and monitoring is ongoing (Beck, *et al.* 2011; Scottish Carbon Capture & Storage, 2014). Finally, the QPC Quimica Methanol Plant has a natural gas plant to produce methanol, and part of the captured CO<sub>2</sub> is supplied to the food and soft drinks industries in the surrounding area.

Besides Petrobras, other institutes have been undertaking research for CCS in Brazil. In 2006 the Research Institute Center of Excellence in Research and Innovation in Petroleum, Mineral Resources and Carbon Storage (CEPAC)<sup>14</sup> was also launched with the goal of evaluating the potential, risks, capacity and other aspects regarding geological storage of CO<sub>2</sub> in Brazil.

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<sup>14</sup> CEPAC is a joint initiative between Petrobras and the Pontifical Catholic University of Rio Grande do Sul (PUCRS) and presently undertakes four main research programs (CEPAC,2014): (i) the PRORESERVA, focused on the evaluation, characterization and quality prediction of oil reservoirs and saline aquifers and their interaction with stored CO<sub>2</sub>; (ii) the PROCARBO, focused on the coal technologies programs, ECBM and underground coal gasification; (iii) the PROINPO, focused on issues related to the CO<sub>2</sub> injection wells integrity; and (iv) the CARBMAP, focused on the CO<sub>2</sub> capture, transport and geological storage Brazilian Map.



It also aims at implementing pilot and demonstration CCS projects and training and enhancing capacity building on CCS and the Center will release a storage atlas by the end of 2014 to provide a mapping of storage at a country scale, and at basin scale for aquifers.

The Brazilian Mineral Coal Association (ABCM) has also invested in a Clean Coal Center focused on developing lower carbon technologies for coal, including with carbon capture and storage. Other initiatives, mainly from the academia, have been also focusing on CCS research and development in Brazil, as the case of the China-Brazil Center for Climate Change and Energy Technology Innovation (2009) coordinated by the Federal University of Rio de Janeiro (COPPE/UFRJ) and the Chinese Tsinghua University, and as the case of the Carbon Emission Policy and Regulation Group (NUPPREC) created by the University of Sao Paulo in 2012.

Nevertheless, although CCS is well recognized by Petrobras, some business sectors and by the academia, the lack of government support was highlighted as a significant concern by many experts, as well as the low priority given to the CCS in national and subnational climate policies in Brazil, as discussed in the next topic.

#### ***4.2.7 Policy and regulation for CCS in Brazil***

In 2008, the National Plan on Climate Change was created with the goal of supporting mitigation and adaptation actions in the country (MMA, 2008). The Climate Plan includes carbon capture and storage as a mitigation option, mainly in the following sectors:

Energy: improving energy efficiency (...), renewable fuel and carbon capture and storage.

Industry: the use of efficient equipment (...), control of GHG emissions and carbon capture and storage. (MMA, 2008).

Although the updated edition of the Climate Plan (Brazil, 2013) does not mention capture and storage of carbon, the updated document does not meant to replace the previous and serves only as a complement of the 2008 Climate Plan, as one representative of the Ministry of Environment has stated in an interview for this dissertation.

The National Fund on Climate Change was created in 2009 through the Federal Law n° 12.114 of 2009 (Brazil, 2009b) with the purpose of financing mitigation and adaptation projects in Brazil. Although the Climate Fund has provisions to finance projects that contribute to the storage of CO<sub>2</sub>, until June, 2014 no project focusing on CCS has been submitted to the Fund. Yet in 2009 the National Policy on Climate Change was established through the Federal Law n° 12.187 of 2009 (Brazil, 2009a) and regulated by the Federal Decree n° 7390 of 2010 (Brazil, 2010), as previously described in this dissertation. However, nor the law nor its decree (as well as the mitigation and adaptation sectoral plans established by the decree) provides any reference to carbon capture and storage.

At the subnational level, fifteen states have already established their state policies on climate change, and six of them refer to CCS somehow (described in such policies as "carbon sequestration" or "GHG capture and storage" ), as follows in Table 12 below:

**Table 12 - Subnational policies on climate change and their implication for CCS**

Law	Implications for CCS
State Law n° 12.050 of 2011 Bahia State Policy on Climate Change	Article 2 - The following definitions are applied for the purposes of this law: III- <u>GHG capture and storage</u> of: a process to remove GHG from the atmosphere and store the gas in reservoirs; Art. 4 - The Bahia State Policy on Climate Change aims at: III – reducing the growing rate of GHG emissions and the <u>capture and storage</u> of these gases.
State Law n° 9.531 of 2010 Espírito Santo State Policy on Climate Change	Article 1, II - promoting projects and methods to reduce and store GHG emissions. Art. 2 The following definitions are applied for the purposes of this law: XV - <u>Carbon sequestration: (...) the separation and removal of carbon from flue gases or through fossil fuel processing to produce hydrogen and the CO<sub>2</sub> storage for long periods in depleted oil and reservoirs, Unmineable coal seams and saline aquifer.</u>
State Law n° 16.497 of 2009. Goiás State Policy on Climate Change	<u>Article 3 - The goals of the Goiás State Policy on Climate Change consist in, III - stimulating business practices aimed at reducing or capturing greenhouse gases.</u>
State Law n° 13.798 of 2009 Sao Paulo State Policy on Climate Change	Article 4° - The following definitions are applied for the purposes of this law: XXXII. <u>Carbon sequestration: (...) the separation and removal of carbon from flue gases or through fossil fuel processing to produce hydrogen and the CO<sub>2</sub> storage for long periods in depleted oil and reservoirs, Unmineable coal seams and saline aquifer.</u> Article 5° - The specific goals of this law are: II. Promoting projects aimed at <u>reducing or capturing greenhouse gases</u> (...); Article 27 - X. Stimulate the incorporation of climate change issues in decision making concerning sectoral policies related to reduce and <u>capture GHG emissions</u> (...).

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State Law n° 5690 of 2010 Rio de Janeiro State Policy on Climate Change	Article 6 – The plans, programs, policies, goals and actions to reduce GHG emissions must attend the following sectoral guidelines: for the energy sector: promoting energy-efficiency (...) and supporting actions that envisage to promote <u>carbon sequestration</u> and the use of renewable energies.
State Law n° 13.594 of 2010 Rio Grande do Sul State Policy on Climate Change	Article 5° - The specific goals of this Law are: II – Promoting projects aimed <u>at reducing or capturing greenhouse gases</u> , including those projects under the UNFCCC clean development mechanism.

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Source: Elaborated by the author based on the Brazilian Subnational policies on climate change (last updated in August, 2014).

Among the subnational policies on climate change that refer to CO<sub>2</sub> sequestration, the state policies from Bahia, Espirito Santo and Sao Paulo are the policies that describe with more detail the concept of carbon sequestration for the purpose of CCS projects (artificial sequestration) and include the implementation of the technology among their policy goals.

With regards to the Brazilian Four-Year Plan (FYP), the current 2012-2015 FYP allocates specific budget for climate change actions and strategies to achieve the goals established by the 2008 National Plan on Climate Change, but provides no specific resources for research or projects on carbon capture and storage (Brazil, 2012).

Table 13 summarizes the main policy tools on climate change in Brazil and their possible implications for CCS.

**Table 13. Main policy tools on climate change in Brazil: implications for CCS**

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<b>Year of creation</b>	<b>Policy tool</b>	<b>Implications for CCS</b>
2008	National Plan on Climate Change	Yes
2009	National Policy on Climate Change	No reference
2009 to 2011	Subnational Policies on Climate Change	Yes, BA, ES, RJ and SP
2009	National Fund on Climate Change	Yes
2009	Emission performance standard	Revoked
2020	National Policy on Climate Change's Decree	No reference
2010	Mitigation and adaptation sectoral plans	No reference
2012	Four-Year Plan	No reference

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Source: Elaborated by the author.

Although CCS has not been directly referred to in 2012-2015 Four-Year Plan's objectives or actions for climate change, some recent governmental initiatives may indicate an evolving progress in the political agenda of CCS in Brazil.

The "Inova Sustentabilidade" initiative was created in 2013 and provided an opportunity for demands to develop research and projects on carbon capture and storage in Brazil. The initiative is a cooperation of the Ministry of the Environment (through the National Climate Fund), Brazilian Development Bank (BNDES) and the Research and Project Financing (FINEP). The main goal of this initiative is to increase energy efficiency in the industrial sector and the use of charcoal from sustainable productions that prevent GHG emissions through the deployment of carbon capture and storage technologies for coal power plants (FINEP, 2013).

Another important initiative under implementation by the federal government is the "GHG mitigation options in key sectors in Brazil" Project<sup>15</sup> (UNEP 2013b; MDIC, 2013; MCTi, 2014a). The goal of this Three-Year Project is to develop low-carbon scenarios for Brazil regarding the periods between 2012-2035 and 2035-2050. According to Schaeffer (MDIC, 2013) this project will result in one of the most comprehensive studies on GHG emission scenarios for Brazil. In the case of CCS, the project is focused on the following topics: (i) analysis of CCS technologies and economic feasibility for their application in Brazil; (ii) assessment of natural gas pipelines currently available in the country; (iii) technical and economic analysis on geological reservoirs to store CO<sub>2</sub>; (iv) assessment of a CO<sub>2</sub> transport network proposal that includes CO<sub>2</sub> pipelines to connect and concentrate the emissions sources in a central hub to finally transport them to the appropriate geological reservoirs; and (v) creation of a map with the main stationary point-sources of CO<sub>2</sub> in Brazil.

In addition, the Ministry of Science, Technology and Innovation in cooperation with the United Nations Development Programme (UNDP) formally required in 2014 a study to assess the technical and regulatory implications for carbon capture and storage projects in Brazil, especially under the UNFCCC clean development mechanism (MCTi, 2014b).

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<sup>15</sup> The project is executed through a partnership between the MCTi and the Global Environment Facility (GEF) and its total budget is USD 16 million (MDIC, 2013).

Such assessment is a first of a kind project demanded by the Brazilian government on CCS regulatory issues, and may indicate their growing interest on CCS as a possible mitigation tool for Brazil.

Yet Ramón (2011) highlights that the major barriers for CCS in Brazil are related to the high costs of the technology and the lack of a legal and regulatory framework, and recommends industrial regulation in Brazil to support the deployment of CCS in large scale. Lampreia *et al.*, 2011 has also identified the lack of regulation as one of the main barriers for the deployment of CCS in Brazil. The author has listed the most important technologies for the energy system in Brazil by 2030 (Table 14), and emphasizes the high costs and lack of incentives and regulations for CCS.

**Table 14 - Most relevant technologies for the energy system in Brazil by 2030**

Technology	Key bottlenecks	Likelihood of wide deployment by 2030
Run-of the river hydro power	Costs/susceptible to water level variations	Medium
Small hydroelectric plants	Initial investments/possible land use conflicts	High
Liquid biofuels	Land use conflicts/logistics	High
Solid biomass (electricity)	Lack of financial incentives/logistics/costs of new technology/cultural inertia	High
Solid biomass (iron/steel)	Lack of control over deforestation charcoal/logistics	Medium
Microalgae biofuels	Initial costs/need for R&D/cultural inertia	Medium
Biogas	Technological upgrade lag/costs	High
CCS offshore CO <sub>2</sub> reinjection	Costs/lack of regulation	High
CCS other	Higher costs/lack of incentives and regulation	Low
End use fuel efficiency	Costs of modern equipment	Medium
End use electricity efficiency	Costs of modern equipment	Medium
End use fuel switching	Land use conflicts/lobby for C intensive fuels/oscillation in natural gas supply	Medium
Power generation efficiency	Costs/lack of incentives	Medium
Nuclear energy	Social conflicts/NIMBY syndrome/regulatory delays	Medium-high
Wind energy	Costs per MWh/lack of incentives/financing constraints	High
Solar photovoltaics	Costs per MWh/cultural inertia/lack of incentives and national production	Medium
Energy recovery from urban waste	Urban waste logistics/education for separation	High
Hydrogen technologies	Costs/lack of incentives and know-how	Low
Transport sector efficiency	Technological delay/costs	Medium
Transport sector fuel switching	Associated land use conflicts/fossil fuel lobby	High

Source: Ramón, 2011.

With regards to the costs, Ketzer (2011) emphasizes that the issue of making the technology feasible still depends on public policies and incentives. Câmara *et al.* (2011) also highlights that the development of a legal and regulatory framework for CO<sub>2</sub> geological reservoir injection is an important issue to be done in Brazil. Proposals for CCS regulation in Brazil have been already discussed in some studies. Câmara (2009); Câmara (2010) and Câmara *et al.* (2011) present a regulatory framework Brazilian carbon dioxide geological storage (CGS) proposal and indicate that some of the

regulatory needs could be satisfactorily answered from the existing oil and gas legislation in Brazil. However, the proposal provided by Câmara (2009) and Câmara *et al.* (2011) was mostly focused on the geological storage of CO<sub>2</sub> in Brazil, and did not encompass regulatory implications for all the CCS activities (capture, transport and storage of CO<sub>2</sub>). Also, some issues such as the definitions for the environmental licensing requirements of CCS projects and the indication of competent regulatory authorities that address all activities related to a CCS project, for example, were not discussed in that study.

Leal da Costa (2014) presents an interesting study on the optimization of the transport of CO<sub>2</sub> in Brazil, and proposes technical aspects to mitigate CO<sub>2</sub> emissions from the energy sector that should be considered in a CCS regulatory framework in Brazil. The research is mostly focused on the technical and essential phases of a CCS project, and the author has tested the proposed regulatory framework with a case study in the state of Rio de Janeiro. However, Costa (2014) does not provide a broad definition of all possible competent regulatory authorities to be involved in all types of activities in a CCS project, which has been done in this present dissertation. The author, for example, indicates the Brazilian National Agency of Petroleum, Natural Gas and Biofuels (ANP) as the competent regulatory authority to regulate CCS projects in Brazil.

As the present dissertation understands that the ANP solely would not be the most appropriate authority, as other key sectors besides the energy sector could deploy large-scale CCS projects in Brazil (such as ethanol plants that capture CO<sub>2</sub>, for example, and store the gas in saline aquifer), it is assumed that a multidisciplinary approach with a diversity of possible competent regulatory authorities would be the most appropriate option to regulate different CCS projects in Brazil. Nevertheless, such studies represent important initiatives and efforts to support the deployment of CCS in Brazil, and they should be jointly considered, as they complement each other.

## **5. Proposals for a CCS legal and regulatory framework in Brazil**

The purpose of this chapter is to offer proposals for the development of a legal and regulatory framework for capture and storage in Brazil. As the Brazilian legislation does not provide specific provisions for CCS, the present dissertation intended to analyze and to propose recommendations to elucidate the main legal and regulatory challenges regarding the deployment of the technology, such as the definition of the responsible entities for the concession and inspect of CCS projects, as well as the criteria for environmental licensing and the long-term liability, among others.

### **5.1. Analysis and proposals**

Due to the diversity of legal and regulatory issues related to the implementation of a CCS project, it was necessary to limit the scope of the analysis and proposals according to the following aspects: (i) the indication of the competent regulatory authority; (ii) the definition of property rights and CO<sub>2</sub> ownership at the subsurface; (iii) the designation of environmental licensing requirements; and (iv) the allocation of liability. For each aspect, it was analyzed the corresponding legislation in place in Brazil in order to assess possible gaps and barriers. Real examples and analogous case were also cited to illustrate the discussion.

The analysis and proposals regarding the aforementioned aspects apply to all activities of a CCS project. As the activities related to the capture and transport of CO<sub>2</sub> are more known, the storage of CO<sub>2</sub> is considered the activity that faces more gaps and regulatory challenges, as further discussed.

#### ***5.1.1 Indication of the competent regulatory authority***

This item analyzes and proposes recommendations to identify potential regulatory authorities that could be involved in CCS projects in Brazil. As the regulation of CCS projects in Brazil is still a new subject, and especially because of the low demand of such projects, the federal government has not yet established a competent regulatory authority to address specific regulatory issues on the subject.

Due to the multifaceted aspects surrounding a CCS project, and especially due to the long-term liability of the CO<sub>2</sub> storage (to be further discussed in this chapter), the establishment of a specific competent authority could be ideally the most appropriated approach to regulate CCS activities. However, it is evident that the high costs involved would not be reasonable, especially given the current low demand of CCS projects in Brazil.

For different reasons, several Brazilian experts interviewed over the course of this dissertation have indicated the Brazilian National Agency of Petroleum, Natural Gas and Biofuels (ANP) as the more appropriated authority to regulate CCS activities in Brazil. Article 8 of the Federal Law number 9.478 from 1997 (which provides for the national energy policy and creates the ANP, among other measures) states that the main goals of the ANP are: “(...) to regulate, to make contracts and to supervise economic activities related to the oil, gas and biofuel industries” (Brazil, 1997).

According to the interviewees, the agency has a large expertise and experience with several processes and activities that are similar to the processes and activities of CCS projects, such as: (i) the regulation and supervision of pipelines and oil reservoirs; (ii) the storage of natural gas (including the access rights to such conceded reservoirs); (iii) the elaboration of tenders and bids to concede companies the right to explore oil and gas in onshore and offshore formations, among others. Câmara (2009) and Costa (2014) also indicate that since the oil and gas industry represents the primary sector that has been investing in CCS in Brazil, it would be more opportune having the ANP as the regulatory entity for CCS projects in the country.

Conversely, it was interesting to note that the only interviewee that has not agreed that the ANP would be the more appropriated authority to regulate CCS activities in Brazil was coincidentally from such agency. In the same sense, the present dissertation assumes that the ANP, according to its current legal competence, would not be the most appropriate regulatory authority to regulate CCS projects because of the following aspects:



(i) For the capture of CO<sub>2</sub>, various stationary sources do not operate under a concession regime (such as the cement and steel industries) and hence they would not need to be supervised by any regulatory agency during the process of CO<sub>2</sub> capture. Inversely, coal-fired power plants and oil and gas platforms are operated under a concession regime, but there would be no legal competent for the ANP to regulate CO<sub>2</sub> capture in coal-fired power plants, for example.

(ii) For the transport of CO<sub>2</sub>, it would be appropriated to have the ANP as the regulatory body only when the transport is done by gas pipelines already regulated by the agency under a concession regime. Such gas pipelines could, for example, be converted to CO<sub>2</sub> pipelines by a utility company that owns the corresponding concession. However, an interviewee from the ANP has mentioned that the agency ceases its obligations once the concession period is over, or once the pipeline becomes inoperable and is decommissioned. Hence, if such gas pipelines are intended to be converted to CO<sub>2</sub> pipelines, it is assumed that a new public call would be needed to concede the access right to transport CO<sub>2</sub> either by old gas pipelines or by new CO<sub>2</sub> pipelines. If such, the legal competence of the ANP would need to be altered to allow such possibility. Last, other transport options such as tanker trucks and ships that are also suitable for CCS projects should not be regulated by the ANP (at least as the agency is currently arranged).

(iii) For the storage of CO<sub>2</sub>, it would be appropriated to have the ANP as the regulatory authority only when the storage is done in oil fields that are currently regulated by the ANP (as the case of the Pre-Salt Lula Oil Field previously mentioned in this dissertation or a depleted oil reservoir that has not been decommissioned yet and hence is still regulated by the agency). In other cases where the storage of CO<sub>2</sub> is intended to be done in a decommissioned oil field, for example, it is assumed that a new public call would be needed to concede the access right to store CO<sub>2</sub> in such formation. As a similar situation with the transport of CO<sub>2</sub>, the legal competence of the ANP would then need to be altered to allow such possibility. Last, other storage options such as saline aquifers and coal mines that are also suitable for CCS projects should not be regulated by the ANP (at least as the agency is currently arranged).

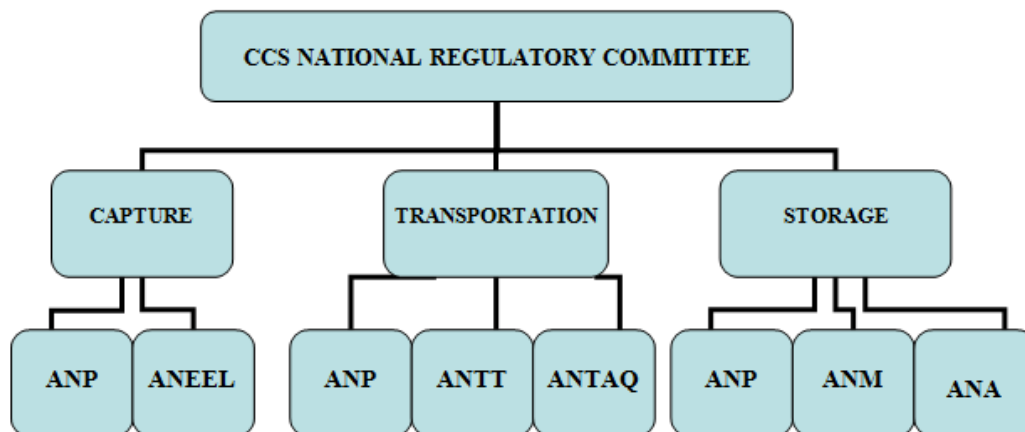
Although the only large-scale CCS project as of 2014 in Brazil is related to the oil and gas industry, it is important to bear in mind that in the mid and long-term there could be other viable options to deploy CCS in the country (as the case of a CO<sub>2</sub> capture from a sugar mill and the CO<sub>2</sub> storage in a saline aquifer in the Parana Basin cited in Chapter 4). Hence, the present dissertation proposes the indication of a “CCS Regulatory National Committee” that would be constituted by representatives from multiple regulatory agencies to regulate the various types of CCS projects, as follows:

(i) For the capture of CO<sub>2</sub>, a representative from the National Electricity Regulatory Agency (ANEEL) would be responsible to regulate CO<sub>2</sub> capture activities from coal-fired power plants and a representative from the National Agency of Petroleum, Natural Gas and Biofuels (ANP) would be responsible to regulate CO<sub>2</sub> capture activities from oil fields. Other industries that do not operate under a concession regime (such as cement and steel industries) would be regulated only by the competent environmental regulatory agency.

(ii) For the transport of CO<sub>2</sub>, a representative from the National Agency of Petroleum, Natural Gas and Biofuels (ANP) would be responsible to regulate CO<sub>2</sub> transport activities by gas pipelines or CO<sub>2</sub> pipelines. It is then proposed that the legal competence of the ANP is changed to allow such possibilities. A representative from the National Terrestrial Transport Regulatory Agency (ANTT) would be responsible to regulate CO<sub>2</sub> transport activities by tanker trucks and a representative from the National Waterway Transport Agency (ANTAQ) would be responsible to regulate CO<sub>2</sub> transport activities by ships.

(ii) For the storage of CO<sub>2</sub>, a representative from the National Agency of Petroleum, Natural Gas and Biofuels (ANP) would be responsible to regulate CO<sub>2</sub> storage in oil fields, a representative from the forthcoming National Agency of Mining (which is foreseen in the Bill number 5.807 of 2013) would be responsible to regulate CO<sub>2</sub> storage in coal mines and a representative from the National Water Agency (ANA) would be responsible to regulate CO<sub>2</sub> storage in saline aquifers.

The proposal indicating the competent regulatory authority for CCS in Brazil is summarized in Figure 45:



**Figure 45 - Proposal for the indication of a regulatory authority for CCS in Brazil**

Source: Elaborated by the author.

The representatives that would constitute the proposed CCS Regulatory National Committee would follow the requirements of a national legal and regulatory CCS framework to be further established and would attend periodic meetings to discuss broad regulatory issues that are in common to all CCS projects, such as the long-term liability requirements.

### *5.1.2 Definition of property rights and CO<sub>2</sub> ownership at the subsurface*

This item analyzes and proposes recommendations for the definition of property rights and CO<sub>2</sub> ownership at the Brazilian subsurface, and proposes a tool that could facilitate the allocation and transfer of CO<sub>2</sub> ownership.

In the context of the public international law, the States retain sovereignty over subsoil resources, and may regulate their exploitation solely based on national laws (Meirelles, 2005). Hence, Article 20 of the current Brazilian Federal Constitution (Brazil, 1988) establishes that all mineral resources (including those of the subsoil) are owned by the federal government (the Union):

Article 20. The following are property of the Union:  
IX - the mineral resources, including those of the subsoil;

Paragraph 1 - In accordance with the law, the participation in the results of the exploitation of petroleum or natural gas, hydric resources for the purpose of generation of electric power and other mineral resources in the respective territory, continental shelf, territorial sea or exclusive economic zone, financial compensation for the exploitation thereof, is assured to the States, Federal District and the municipalities, as well as to agencies of the administration of the Union (Brazil, 1988).

Consequently, there is no private ownership of such resources before public concessions are granted for their exploitation. The caption of Article 176 also states that the prospection and mining of mineral resources may only take place with authorization or concession by the Union for a certain period of time:

Article 176. Mineral deposits, under exploitation or not, and other mineral resources and the hydraulic energy potentials form, for the purpose of exploitation or use, a property separate from that of the soil and belong to the Union, the concessionaire being guaranteed the ownership of the mined product (Brazil, 1988).

Although the Federal Constitution refers to the ownership of mineral resources located in the Brazilian subsurface, the *Magna Carta* does not specify the extent and technical definition of the soil and subsoil, as well as if possible re-injected substances at the subsurface would be also owned by the Union.

Regarding this issue, the Brazilian Civil Code (Federal Law N° 10.406 of 2002) states that "the surface right does not imply on the use of the subsurface, unless if it is inherent to the object of a concession (Brazil, 2002). Yet the Brazilian Mining Code (Decree-Law N° 227 of 1967) does not define the concepts of surface and subsurface, but legally distinguishes them based on the presence or not of mineral resources by which exploitation is commercial viable. According to Article 3: "Mineral deposits constitute immovable properties, distinct from the surface where it is found" (Brazil, 1967). Thus, the mineral deposits can be found in both subsurface and surface, and the distinction between them is limited to a legal definition (Freire, 2007), whereas if the subsurface has legal implications when it has a potential scientific or economic value.

Therefore, the challenges related to a possible leakage of stored CO<sub>2</sub>, as well as the risks related to its long-term permanence in the subsurface require a clarification on (i) the ownership rights of the transport and storage of CO<sub>2</sub> and on (ii) the transfer of

ownership of CO<sub>2</sub> in order to delimit the liability of each agent involved in a CCS project. It is then necessary to understand the legal transfer of ownership in each activity of a CCS project.

This dissertation assumes that the main possibilities to transfer a CO<sub>2</sub> ownership would derive from the following activities:

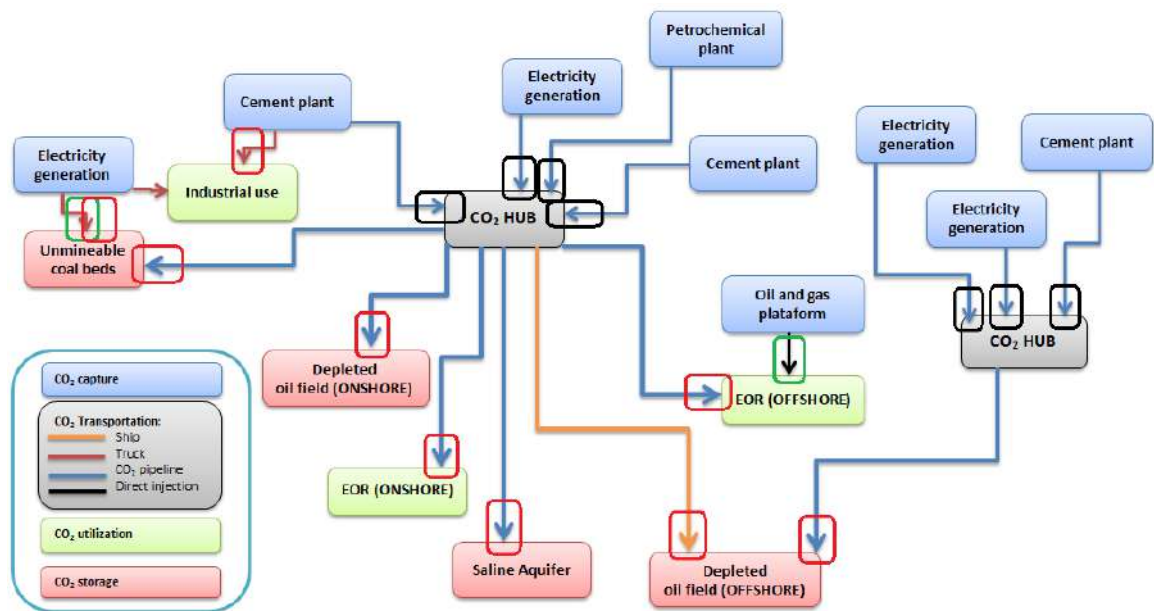
(i) CCS projects in which all activities (capture, transport and storage of CO<sub>2</sub>) are managed by the same operator, there existing no transfer of CO<sub>2</sub> ownership. For example, an oil company that captures CO<sub>2</sub> in an offshore platform, transports and stores the gas in a reservoir formation which concession has been conceded, as the case of the Pre-Salt Lula CCS Project. Another example could be an operator that captures the CO<sub>2</sub> in a coal-fired power plant, transport the gas through own tanker trucks or third-party tanker trucks (but the operator would still own the CO<sub>2</sub> property and possible liabilities) and stores the CO<sub>2</sub> in a geological formation by its own means.

(ii) CCS projects in which all activities (capture, transport and storage of CO<sub>2</sub>) are managed by the same operator, there existing one transfer of CO<sub>2</sub> ownership. For example, a coal-fired power plant that captures and transports CO<sub>2</sub> but transfers the CO<sub>2</sub> ownership to another company that would be responsible to store the CO<sub>2</sub>. The first company would serve only as the CO<sub>2</sub> source for a second company to finally store the CO<sub>2</sub>.

(iii) CCS projects in which all activities (capture, transport and storage of CO<sub>2</sub>) are managed by different operators, there existing two transfers of CO<sub>2</sub> ownership. For example, a coal-fired power plant (or even a cement or steel plant) that captures and transports CO<sub>2</sub> through tanker trucks or short-distance CO<sub>2</sub> pipelines to a pipeline hub that will then transport the CO<sub>2</sub> in long distances to a given geological reservoir. In this case, there would be a transfer of ownership (i) from the company that captures CO<sub>2</sub> to the concessionaire company that is responsible to transport the CO<sub>2</sub> in long distances with pipeline hubs and (ii) from such pipeline hubs company to the company responsible to store the CO<sub>2</sub> in a given geological reservoir. This company may be the

same that has captured the CO<sub>2</sub> or a different one, but the significant legal act here is the transfer of ownership during the process.

The following Figure 46 presents the possible stages over the course of a CCS project and shows the possible transfers of CO<sub>2</sub> ownership highlighted in circles:



**Figure 46 - Possible stages and transfer of CO<sub>2</sub> ownership in a CCS project.**

Source: Elaborated by the author

There are many possibilities of activities and companies involved in a CCS project (different stationary sources, different transport types and different geological reservoirs). As shown in Figure, the same geological reservoir could also store CO<sub>2</sub> from different projects, resulting in increased complexity for clarification of the responsibilities among the various agents.

Hence, this dissertation indicates that a broad access to information on areas with pipelines to transport CO<sub>2</sub> and areas with stored CO<sub>2</sub> is essential to prevent and to solve possible legal conflicts that may arise during or after the ending of a CCS project.

Thus, developing tools to validate and to disseminate relevant information to the possible stakeholders (companies, regulators and especially to local community located

close or above such areas) regarding all the activities of a CCS project (especially regarding the storage activity). More specifically, this dissertation proposes the creation of a National Register of Areas with Geological Storage of Carbon Dioxide or *Cadastro Nacional de áreas com Armazenamento Geológico de Dióxido de Carbono* (CNCO<sub>2</sub>).

The CNCO<sub>2</sub> would provide and disseminate relevant information about areas that contain infrastructure (CO<sub>2</sub> pipelines) to transport CO<sub>2</sub> and areas that contain stored CO<sub>2</sub>. The register would provide information on:

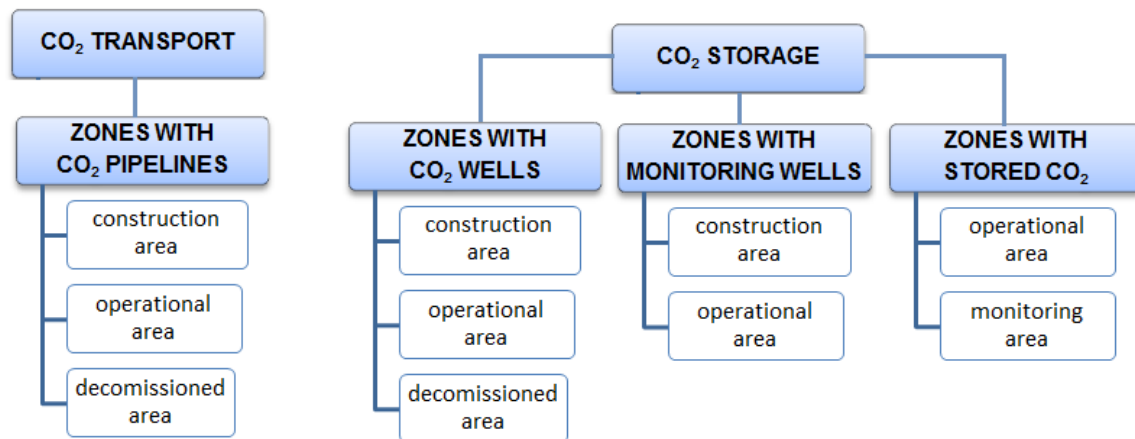
- (i) the existing pipelines to transport CO<sub>2</sub> in a respective area;
- (ii) the existing wells to store CO<sub>2</sub> in a respective area;
- (iii) the estimated geographical boundary of an area that contains stored CO<sub>2</sub>;
- (iv) the amount of CO<sub>2</sub> stored;
- (v) the monitoring plans to track CO<sub>2</sub> behavior;
- (vi) the contingent plans with actions to remedy any possible leakage or damage.

The CNCO<sub>2</sub> would be administered by the proposed CCS National Regulatory Committee and electronically available in the website of all regulatory agencies involved. Moreover, the CNCO<sub>2</sub> would integrate a National System of Areas with Geological Storage of Carbon Dioxide or *Sistema Nacional de Áreas com Armazenamento Geológico de Dióxido de Carbono* (SNCO<sub>2</sub>). The goals of the SNCO<sub>2</sub> would be:

- (i) Validating and disseminating relevant information to civil society (especially to local communities) about areas with CO<sub>2</sub> transport and CO<sub>2</sub> storage activities;
- (ii) Formalizing the transfer of CO<sub>2</sub> ownership among the different companies that capture, transport and or store CO<sub>2</sub>;
- (iii) Supporting the work of the regulatory authorities involved with CCS projects;
- (iv) Convening relevant documents and concessions granted by the regulatory authorities.

Other relevant information from other regulatory authorities could be also included in the proposed SNCO<sub>2</sub>.

Depending on the stages of a CCS project, the corresponding areas would be classified in different zones and status, as follows Figure 47:



**Figure 47. Zones and status of CCS projects under the SNCO<sub>2</sub>.**

Source: Elaborated by the author.

The updates on the National System of Areas with Geological Storage of Carbon Dioxide (SNCO<sub>2</sub>) would be also published at the Official Journal of the Federal Government of Brazil or *Diário Oficial da União (DOU)*. Any citizen could request detailed access of such information, unless if there is any confidentiality data assured by a confidentiality and data protection act.

### 5.1.3 Designation of environmental licensing requirements

This section analyzes and proposes recommendations on the implications of the current environmental licensing system in place in Brazil on CCS projects. The following circumstances were analyzed: (i) the extent of the environmental licensing rules; (ii) the specific requirements of the environmental licensing; and (iii) the type of approach for an environmental licensing with multiple activities

(a) The extent of the environmental licensing rules: this item analyzes if the environmental law in Brazil is broad enough to encompass the activities involved in the various CCS project activities. The environmental licensing is a legal requirement to be complied by any activity that uses natural resources and that is pollutant or can cause environmental degradation. Such regulatory tool is regulated by the National



Environmental Policy Act (Federal Law n° 6.938 of 1981) and involves the participation of civil society in the decision-making (through public hearings). Few years after passing the National Environmental Policy Act, the National Environmental Council (CONAMA) established the Resolution n° 01 of 1986 to request an environmental impact assessment (EIA) and environmental impact report (EIR) before the competent environmental regulatory agency concedes an environmental licensing for an activity or enterprise. The EIA-EIR is a tool to assess the impact of an activity or enterprise and to provide the corresponding measures to mitigate such impacts.

The CONAMA Resolution n° 237 of 1997 establishes three types of environmental permits in Brazil:

- I – Previous Permit - conceded at the preliminary stage of the activity or enterprise, approves its location and conception and attests its environmental feasibility;
- II – Installation Permit – authorizes the construction of an activity and includes measures for environmental control and other conditions.
- III – Operation Permit – authorizes the operation of the activity upon verification of effective compliance with environmental measures previously required (CONAMA,1997).

Such resolution also provides an annex (Annex 1) with a list of all the activities and enterprises subject to environmental licensing compliance in Brazil and the document was the main reference to assess if CCS projects should be subject of environmental licensing:

- (i) For the capture of CO<sub>2</sub>, the list includes large stationary source facilities with potential to include CO<sub>2</sub> capture technologies (such as coal-fired power plants, cement and steel plants, oil and gas, oil production platforms *etc.*);
- (ii) For the transport of CO<sub>2</sub>, the list includes a category on “transport, terminals and deposits”, establishing that all transport of dangerous goods, pipeline transport, marinas, ports and airports, ore terminals, petroleum and chemicals, deposit of chemicals and hazardous products are required to comply with environmental licensing processes.
- (iii) For the storage of CO<sub>2</sub>, the list includes a category on “extraction and mineral treatment” with a sub topic on well drillings and oil and gas production.

Although some CCS-specific activities are not expressly included in the CONAMA's Resolution, the list is not exhaustive and the competent environmental regulatory agency may require the licensing of other activities not previously listed (MMA). The Article 2 of the CONAMA's Resolution 237 (Brazil 1997) determines that:

It is a matter of the competent environmental regulatory agency to define the compliance criteria and details to be complemented by Annex 1 of this resolution, considering the specificities, environmental risks, the dimension and other characteristics of the enterprise or activity (CONAMA, 1997).

As discussed, the scope of the CONAMA's List should be broad enough to include practically all the productive sectors. According to Destefenni (2004), the list is illustrative and should be all-encompassing, as various activities and technologies are created over time and can be classified as users of environmental resources.

Therefore, it can be said that the national environmental law in Brazil is broad enough to require all the activities in a CCS project to comply with environmental licensing processes. As noted by one interviewee, the CONAMA's Resolution 237 (Brazil 1997) is essentially reproduced at the state and local level, as the case of the list of all the activities and enterprises subject to environmental licensing compliance annexed to the Decree n° 47.397 of 2002 and established by the Company of Environmental Sanitation Technology (CETESB) at Sao Paulo State. Hence, it is assumed that CCS projects with activities under state or local supervision would be also subject to scrutiny of an environmental licensing.

(b) Specific requirements for the environmental licensing: this item analyzes if a facility that has been already licensed needs to apply for a new environmental licensing process to include a CCS activity or if such facility could only update its permit.

The CONAMA's Resolution n° 237 (Brazil, 1997) states that the “design, construction, installation, expansion, modification and operation” of any enterprise or activity that uses environmental resources and that can be effectively or potentially pollutant is subject to environmental licensing by the competent environmental regulatory agency. Hence:

(i) For the capture of CO<sub>2</sub>, it can be assumed that a facility that has been already licensed (a coal-fired power plant in operation, for example), would need to request approval of the competent environmental regulatory agency to include a CO<sub>2</sub> capture activity as part of the environmental licensing. The only exception would be in cases where the environmental licensing of a facility anticipates the inclusion of CO<sub>2</sub> technologies (as the case of the Pre-Sal Lula Oil Field environmental licensing that already includes the capture, transport and storage of CCS as part of its activities).

(ii) For the transport of CO<sub>2</sub>, it can be assumed that either the installation of a CO<sub>2</sub> pipeline and the modification of gas pipelines to CO<sub>2</sub> pipelines would be subject of approval by the competent environmental regulatory agency.

(iii) For the storage of CO<sub>2</sub>, as the same above, it can be assumed that either the drilling of new wells or the modification of oil wells to store CO<sub>2</sub> would be subject of approval by the competent environmental regulatory agency.

The analysis on this issue is somewhat controversial, as some of the interviewees did not agree that a new environmental licensing would be needed for some CCS projects. According to some of them, the modification of a facility to incorporate CCS activities would not imply on changing the capacity or electricity production, and it could also result in excessive regulatory costs. However, the argument that the capacity of production of a power plant would not change may be debatable, as a facility with CCS would lose efficiency due to the additional energy needed to capture the CO<sub>2</sub> (as explained in Chapter 2 of this dissertation), and would therefore need to produce more energy to guarantee the same production prior to the installation of a CO<sub>2</sub> capture activity.

Another interesting debate on this topic was if it a facility would need to require a new licensing or to update an existing licensing only. According to an interviewee from IBAMA, in practice, modifications on an activity or enterprise current licensed are relatively common over time, and depending on the dimension of the modification, the competent environmental regulatory agency may only request a consent letter. In the case of an offshore oil production platform, for example, an operator may decide to drill

an additional well that was not expected and included in the corresponding environmental licensing, and such change may require only a consent letter by the IBAMA. For other activities with greater impact, as the expansion or the establishment of a new platform in an area already licensed, it is likely that a new previous permit would be required (or at least a new installation permit, depending on the case).

The requirement to request an update on a conceded permit or to submit a new license is still vague and there is no legal basis. In practice, any change in a licensed facility must currently be reported to the competent environmental regulatory agency in order to verify the need for a new license or not. As emphasized by the interviewee, in some cases of minor modifications there would be no need for the operator to request a consent letter to the competent environmental regulatory agency, but the lack of legal basis with clear requirements about this issue creates a burdening and unnecessary demand.

(c)The type of approach for an environmental licensing with multiple activities: this topic analyzes if the environmental permits need to be requested separately for each activity of a CCS project or whether it should be based on a unified approach in which a single request would cover all the activities of a CCS project.

Having only one environmental licensing for all activities of a CCS project has the advantages of reducing bureaucracy and delays on the process, as well as allowing the regulator to have an integrated perception of the entire project. However, a unified approach could result in greater complexity, especially in CCS projects involving multiple companies, or in projects whose basic information for each activity (capture, transport and storage) is not yet fully available at the time that the prior license is required.

Another concern relates to the possibility of having different competent environmental regulatory agencies to concede environmental licensing for each activity of a CCS project. The Complementary Law n<sup>o</sup> 140 of 2011 amends the 1981 National Environment Policy Act and establishes rules for the cooperation among the Federal, States and Municipal governments in the administrative actions related to environmental

management, including the actions related to the environmental licensing processes (Brazil, 2011). According to such law, the licensing is conceded by the competent state or local environmental regulatory agency (when the activity involves only one state or city) or by the Brazilian Institute for Environment and Renewable Natural Resources (IBAMA), when the activity<sup>16</sup> involves more than one state or offshore areas (such as the oil and exploitation on the continental shelf), among others.

Considering that a CCS project can encompass many companies and different competent environmental regulatory agencies over time, this study proposes the following approaches:

(i) Integrated approach with a single environmental permit for all the activities when the CCS project is operated by the same company (ies) over the entire project (without the transfer of CO<sub>2</sub> ownership over the course of the project), and when the competent environmental regulatory agency is the same for all the activities. For example, a coal-fired power plant based in Sao Paulo that captures CO<sub>2</sub>, transport the gas (by tanker trucks without the transfer of ownership) and stores it by own means in an oil field onshore located in Sao Paulo. Or an oil company that captures the CO<sub>2</sub> in an oil production platform and re-injects the gas by its own means in the same oil reservoir (as the case of the Pre-Salt Lula CCS Project).

(ii) Disintegrated approach with separate environmental permits for each activity when the CCS project is operated by the same company (ies) (without the transfer of CO<sub>2</sub> ownership over the course of the project), but in cases where the competent environmental regulatory agency to grant the permit is different for each activity of a CCS project (the facility that captures CO<sub>2</sub> is licensed by a state agency and the

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<sup>16</sup> Activities and enterprises (a) located or developed collectively in Brazil and in a neighboring country; b) located or developed in the territorial sea, in the continental platform or in the exclusive economic zone; c) located or developed in indigenous lands; d) located or developed in conservation units instituted by the Federal Government, except for in Environmental Protection Areas (EPAs); e) located or developed in 2 (two) or more States; f) of military character; g) destined to research, draw up, produce, pack, transport, store and dispose radioactive material, in any stage, or that use nuclear energy in any of its forms and applications, upon an opinion of the National Commission of Nuclear Energy (Cnen); or h) that meet the typology established by an Executive Branch act, from the proposition made by the National Tripartite Commission, assuring the participation of a member of the National Environment Council (Conama), and considering the criteria of size, polluting potential and nature of the activity or enterprise (Brazil, 2011).

transport and or the storage of CO<sub>2</sub> is licensed by the federal agency (IBAMA). For example, a coal-fired power plant that captures CO<sub>2</sub> and store the gas by its own means and responsibilities in an offshore geological formation.

(iii) Disintegrated approach with separate environmental permits for each activity when the CCS project is operated by different companies (with the transfer of CO<sub>2</sub> ownership over the course of the project), For example, a coal-fired power plant that captures CO<sub>2</sub> and transports the gas to a hub of CO<sub>2</sub> pipelines operated by an utility company that will transport the gas to a geological reservoir (onshore or offshore).

#### ***5.1.4 Allocation of long-term liability***

This section analyzes and proposes recommendations for the allocation of liability regarding CCS projects in Brazil, especially for the allocation of long-term liability. Before discussing specific liability issues for CCS, an assessment of the Brazilian Environmental Law was conducted to contextualize some of the key aspects that should be considered in a long-term liability rule for CCS in Brazil.

Under the Brazilian law, the civil liability can be defined as a legal obligation to remediate or repair any damage resulting from the breach of a legal duty (Venosa, 1996; Diniz, 1999; Cavalieri Filho, 2005; Gonçalves, 2009). The theory of civil liability constitutes part of the Obligatory Law, *i.e.* the right of a creditor against a debtor related to certain provision (Gonçalves, 2009), and can be based on the subjective concept of fault *lato sensu* (fault-based liability), with a need to prove the culpability to establish the obligation of indemnifying or based on the objective concept of fault *stricto sensu* (strict liability), regardless of culpability to establish the obligation of indemnifying, *i.e.* imprudence, negligence or misleading.

Conventionally based on fault-based liability, such notion of responsibility was altered by the National Environmental Policy Act of 1981, which replaced the subjective element and introduced the concept of strict liability. Both the 1981 Policy Act and the Brazilian Federal Constitution of 1988 impose the strict liability as the form to repair environmental damages:

“(...) the polluter is required, regardless of fault, to indemnify or remediate the damages caused to the environment”. (Brazil, 1981).

Federal Constitution of 1988, Article 225, §3º: “Conducts and activities considered harmful to the environment subject violators, individuals or legal entities, to criminal and administrative sanctions, regardless the obligation to repair the damages”. (Brazil, 1988).

The 2002 Brazilian Civil Code also reinforces these important changes on the rules of civil liability. According to the Code, the liability is “the legal obligation to repair imposed on a person that caused damages to others due to an unlawful act (Brazil, 2002). Its Article 927 states that "there will be a legal obligation to repair damage, regardless of culpability, in cases specified by law, or when a regular activity conducted by the perpetrator implies on risk to others".

The Tort Law in Brazil applies the “Integral Risk Theory<sup>17</sup>” where the responsibility to repair damage is dissociated from the subjective concept and is based on the simple presence of an activity or process that caused damage. Therefore, the environmental liability regime in Brazil represents a *propter rem* obligation, a Latin term that means that the liability is accounted of the owner). The *propter rem* obligation means that the obligation follows the holder of a real right, upon its status as owner or possessor (Rodrigues, 2002). The main environmental principles explicit in the Brazilian Federal Constitution (Brazil, 1988) implicitly include such notion of liability, as follows:

(i) Sustainable development principle: established in the head of Article 225, the Sustainable Development Principle (or Ecologically Balanced Environment Principle) states that: "all individuals have the right to enjoy an ecologically balanced environment, (...) for the present and future generations."

(ii) Prevention principle: also established in the head of Article 225, this principle imposes upon the Government and society an obligation to defend and preserve the environment and to adopt preventive measures to avoid environmental damages.

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<sup>17</sup> The civil liability regime in Brazil is based on the Theory of Administrative Risk (allowing exclusive liability), or on the “Integral Risk Theory” (the obligation to indemnify regardless of fault) (Diniz, 1996).

(iii) Precautionary principle: mentioned in item V of Article 225, this principle establishes that the government “controls the production, trade and use of techniques, methods and substances that may imply on risks for the life, quality of life and for the environment”. Hence, if there is an uncertainty on the risks of a particular activity, precautionary measures must be adopted to avoid possible environmental degradation.

(iv) Polluter pays principle: presented in § 2º of Article 225, this principle determines that “those who exploit mineral resources is required to restore the degraded environmental area, according to the technical solution defined by the competent environmental regulatory agency”. The polluter principle is all-encompassing in Brazil, which means that it is applied to direct and indirect contributors to an environmental damage.

(v) Liability principle: presented in § 3º of Article 225, this principle states that “behaviors and activities considered harmful to the environment will incur on criminal and administrative penalties, regardless of the obligation to repair the caused damages”. Hence, the persons or entities that caused an environmental degradation are required to assume the corresponding liabilities and the costs to repair or compensate such damage.

Hence, a person who purchases a contaminated land accepts the vendor’s liability to decontaminate the area and to repair any possible damage caused to third parties. In order to better allocate the liability, vendors and buyers need to negotiate indemnisations for existing and pre-existing environmental liabilities (which implies on the depreciation and devaluation of the land). However, such contractual agreements do not eliminate the right of an injured party to sue the new landowner.

This strict liability regime is applicable to any environmental damage regardless of the ownership of the contaminated area. The new landowner becomes joint liable to repair such damages. Despite of such joint liability, the new landowner may still sue the previous landowners who caused the contamination to recover such expenses. Because of this liability regime in the Brazilian law, due diligence for mergers and acquisitions is essential to evaluate possible environmental liabilities, as the analysis of previous environmental records and certificates of the area.



### ***5.1.5 Analogous cases on liability for CCS projects under the Brazilian law***

This section aims to discuss some analogous cases of activities that encompass the long-term liability issue as with CCS project. The analyses intend to compare how such activities are regulated under the Brazilian law.

#### ***a) Legislation on civil liability on nuclear damages***

As of 2014 the main rules on civil liability for nuclear damage in Brazil is based on two statutes. The first one is the Federal Law n° 6.453 of 1977 that provides rules for civil liability on nuclear damages and criminal liability for acts related to nuclear activities, and the second one is the Brazilian Federal Constitution of 1988 that concedes in its Article 2 the monopoly of the research, extraction, enrichment, reprocessing, industrialization and trade of nuclear minerals to the Federal Union.

The Article 4 of the Federal Law n° 6.453 of 1977 determines that "the liability to repair any nuclear damage caused by a nuclear accident will be exclusively of the operator of the nuclear installation, regardless of fault." Therefore, the nuclear damage comprises the strict liability, and the injured party does not need to prove the causality of the negligent action, since the components that constitute a nuclear liability are the conduct (the nuclear activity) and any the damage resulted from such activity. However, although Article 8 of the same law establishes that the operator "is not liable for any damage arising from nuclear accidents caused by armed conflict, hostilities, civil war, insurrection or a grave natural disaster of an exceptional character", the Federal Constitution does not provide any exception for the operator responsibility. The exclusion of liability (as in a case of fortuitous event and force majeure) does not exempt the operator from any liability for nuclear damage.

In the case of carbon capture and storage activities, a parallel comparison to the Federal Constitutions rules on civil liability for nuclear damages may imply that the operators of a CCS project would be the liable entities to respond for any damage related to the leakage of stored CO<sub>2</sub>, even in those accidents caused by armed conflict, hostilities, civil war *etc.*

Another relevant aspect of the 1977 Nuclear Law refers to the share of liability when there are two or more operators involved in a nuclear activity. The liability of more than one person or entity (parties) involved in an activity can be jointly liable or several liable. The jointly liability means that the persons or companies involved in a certain activity are liable up to the full amount of their relevant legal obligation. In opposite, the severally or proportionate liable means that the persons or companies involved in a certain activity are liable only for their respective part of the obligation.

The Article 5 of the Federal Law n° 6.453 of 1977 establishes that “When more than one operator is liable, they respond jointly, if impossible to determine which part of the damage is attributable to each operator” (Brazil, 1977). It means that in a nuclear accident that involves more than one operator, all of them are jointly liable. If one operator disappear or declares bankrupt, for example, the other operators remain fully liable. Then, the injured party may sue all the remaining operators. As all the natural resources located in the subsurface of the Brazilian territory is owned by the Federal Union, the share of liability is less complicated in the sense that the federal government would be ultimately the liable entity in a case of a nuclear accident.

However, CCS projects are most likely to be deployed by the private sector in Brazil, and one of the most challenging issues is related to the allocation of the long-term liability, especially in the cases where it is impossible to define who is the real liable for a possible damage resulting from the leakage of stored CO<sub>2</sub>. For example, if two stationary sources facilities store CO<sub>2</sub> in the same reservoir at the same period, they may share the responsibility equally (or based on the percentage of tons of CO<sub>2</sub> stored). Yet is unclear how the liability would be shared if for example the same two facilities store CO<sub>2</sub> in a reservoir that already contains CO<sub>2</sub> that has been stored by other companies in other periods of time.

In this case, the National System of Areas with Geological Storage of Carbon Dioxide - SNCO<sub>2</sub> proposed in this dissertation may play an important role in validating and coordinating relevant information of CO<sub>2</sub> storage activities (such as the amount of CO<sub>2</sub> stored by each operator, the purity of the gas, the terms of agreements among the correlated parties *etc.*).

With regards to compensations, the 1977 Nuclear Law also establishes an insurance of other financial compensation to ensure the operator liability to repair a nuclear damage. The type of compensation as well as its amount is determined by the National Nuclear Energy Commission (CNEN) at the time of the previous permit for the environmental licensing. However, as nuclear resources (and nuclear exploration) in Brazil is a monopoly of the Federal Union, the government is responsible to compensate any nuclear damage when the insurance is not enough or if the operate do not take appropriate actions to remediate such areas (due to financial constraints, for example).

***b) Legislation on civil liability in contaminated areas***

A contaminated area may be defined as the "land, soil, installation or buildings containing quantities or concentrations of any substance or waste that has been deposited, accumulated, stored, buried or infiltrators in a planned, accidental, or even natural way in conditions that cause or may cause harm to human health and to the environment" (MMA, 2009). The CONAMA's Resolution N° 420 of 2009 sets rules for the management of contaminated areas and the necessary tools to support decision-making on the most appropriate response options.

For the purposes of this Resolution, the following terms and definitions are adopted: V - Contamination: the presence of chemical substances in the air, water or soil, resulting from human activities, in concentrations that restrict the use of such environmental resources for current or intended uses, defined based on risk assessment to human health and protected goods in standardized or specific exposure scenario (CONAMA, 2009).

While the classification of CO<sub>2</sub> for storage purposes is not clearly specified in the Brazilian law, such rules on the management of contaminated areas may provide relevant background as analogous cases for managing civil liability. Managing a contaminated area involves specific techniques and plans to remediate and compensate any injured party, and the same would happen in areas with stored CO<sub>2</sub>. The Precautionary Principle established by the Federal Constitution (1988) should be prioritized and the possibilities of using or reusing such areas should take into account the potential risks on public health in local or adjacent communities, as well as the depreciation of properties around such areas.

Regarding liability, the CONAMA's Resolution n° 420 of 2009 establishes that the responsible operators of the contaminated areas must submit to the competent environmental regulatory agency a plan with actions to intervene and to remediate such areas. The document must contain:

- I – the control or removal of the sources of contamination;
  - II - the current and future land use of the area and its surrounding region;
  - III – a risk assessment to human health;
  - IV - intervention options and their technical and economic feasibility and their consequences;
  - V - the monitoring program of the required actions and its effectiveness; and
  - VI - the costs and timeframe to implement the proposed response options to achieve the goals previously established.
- CONAMA, 2009.

In the same sense, a contingency plan with response options to remediate areas with CO<sub>2</sub> leakage should be a relevant and prioritized tool to be required by any specific CCS legislation. The National System of Areas with Geological Storage of Carbon Dioxide (SNCO<sub>2</sub>) proposed in this dissertation also requires a monitoring plan to detect any undesirable migration of the CO<sub>2</sub> and a contingent plan with response options to repair any possible damage.

At the subnational level, the State of Sao Paulo established the State Law n° 13.577 of 2009 to regulate the protection of the soil quality and contaminated areas. Regarding civil liability, its Article 13 prescribes that:

- The following are joint liable for the prevention, identification and remediation of a contaminated area:
- I – the person or entity that caused the contamination and its successors;
  - II - the owner of the area;
  - III - the landowner;
  - IV - the usufructuary;
  - V - anyone who get benefits from the area directly or indirectly (Sao Paulo State, 2009).

As earlier discussed in this chapter, the environmental liability regime in Brazil is *prompter rem*, where the creation, transmission and elimination of a certain obligation are kept with the real right (the *rem*) as a binding responsibility (Venosa, 2003). The aforementioned state law is an example of such regime, by establishing strict rules for liabilities with the inclusion of the landowner as liable for the contaminated area.

While such state law may be a good example of the *prompter rem* obligation, it is important to distinguish in which cases this rule should be apply for CCS projects. This present dissertation recognizes that the landowner of an area with stored CO<sub>2</sub> should not be liable in case of a CO<sub>2</sub> leakage for the following arguments: first, in the absence of CO<sub>2</sub> leakage, the area is theoretically not contaminated only by the fact that there is CO<sub>2</sub> stored. Second, the Brazilian Law has no provisions on the definition of carbon dioxide (as a pollutant, hazard, waste, commodities *etc.*) and therefore, it should not be assumed that a potential leakage of CO<sub>2</sub> in a certain area would infer that it became a contaminated area.

Still the Sao Paulo State Law n° 13.577 of 2009 presents methods and tools for the liable entities to remediate areas that could be useful and analogous to a CCS legal and regulatory framework in Brazil, as the notion of compensation. One of the most common methods to repair an environmental damage is through financial compensation as an attempt to repair the damage caused. Yet there are other forms of indemnification, since monetary recompenses may not be enough for all the cases. In some countries, like in the United States, insurance repair contract is broadly used, but in Brazil it is not yet widely spread (Gonçalves, 2009).

The Sao Paulo State Law n° 13.577 of 2009 provides some financial tools to remediate and repair any damages caused by a contaminated area: (i) an environmental compensation; (ii) an environmental insurance and; (iii) a financial fund. Each of them is analyzed below to illustrate how they could be incorporated in a potential CCS legal and regulatory framework in Brazil.

The environmental compensation is required by the competent environmental regulatory agency over the environmental licensing of an enterprise or activity that can potentially contaminate an area. The sum to be compensated is defined by the competent environmental regulatory agency and the amount can be reduced up to 100% (one hundred percent) if the operator adopts "procedures to mitigate the risk of contamination, proportional to the degree of effective actions undertaken" (Sao Paulo, 2009). This could be a potential option for CCS projects, but it is important to bear in mind that the financial burden arising from the regulatory costs may hamper some

projects. Also, due to the long-term permanence of the CO<sub>2</sub> storage, the possibility of reducing the compensation amount when the operator adopts procedures to mitigate the risks (of CO<sub>2</sub> leakage) should not be taken into account.

The environmental insurance represents an insurance policy that covers a contingent plan (to control or remove the sources of contamination) previously approved by the competent environmental regulatory agency in the minimum amount of 125% of the estimated costs to remediate such area. In a CCS project, however, this option would not necessarily solve the issue of guaranteeing the long-term liability for a potential damage in the future. As emphasized by some interviewees, the timeframe of the stored CO<sub>2</sub> is indefinite and an insurance company may not be in operation anymore within hundreds of years.

Although the long-term liability issue has been not directly addressed, the law provides an interesting case to be potentially applied to CCS projects: the creation of a fund to identify and remedy “orphan” sites, the contaminated areas whose parties responsible for the contamination are unknown or have not taken appropriate actions to remediate such areas due to financial constraints.

The "State Fund for the Prevention and Remediation of Contaminated Areas or *Fundo Estadual para Prevenção e Remediação de Áreas Contaminadas* (FEPRAC) aims at protecting the soil against potential harmful changes and to identify and remediate contaminated orphan areas (Sao Paulo State, 2009). Although the financial resources to support the fund come from multiple sources, including from the state government budget, one of them comes from the environmental compensation previously cited.

In the case of CCS, one proposal could be the creation of a National Fund for the Prevention and Remediation of Areas with Geological Storage of Carbon Dioxide or *Fundo Nacional para Prevenção e Remediação de Áreas com Armazenamento Geológico de Dióxido de Carbono* (FNCO<sub>2</sub>).

The proposed National System of Areas with Geological Storage of Carbon Dioxide (SNCO<sub>2</sub>) could serve as a database to formalize and to inform the corresponding amount to be compensated (destined to the FNCO<sub>2</sub>) and the liability rules for each operator in a CO<sub>2</sub> storage activity. Nevertheless, contrarily to the Sao Paulo State Fund for the Prevention and Remediation of Contaminated Areas (where part of the financial resources comes from the state governmental budget), the FNCO<sub>2</sub> would be exclusively supported by CCS project operators through non-refundable grant assistance (to be charged through an environmental compensation, for example).

Câmara (2009) also suggests the creation of a public fund for the storage of CO<sub>2</sub> in Brazil as an economic and financial tool that would be coordinated by a competent regulatory authority. The fund would be used to cost expenses of such authorities, to invest on technologies related to CCS and to incentivize the development of new technologies for renewable energy in Brazil. The main financial sources would derive from CO<sub>2</sub> taxes and possible carbon credits resulting from CCS projects.

However, this dissertation proposes a fund that would be exclusively designated to repair any possible damage arising from the leakage of a CCS project after the post-closure of the project and after a possible transfer of liability from the project operator to the government. The creation of a CO<sub>2</sub> in Brazil is still unclear as well as the feasibility of carbon credits. Hence, it is assumed that it would be important to link the financial source of the proposed FNCO<sub>2</sub> to an existing and practical tool (such as a type of fee to be charged during the environmental licensing of a CCS project).

It is also important to bear in mind that the proposed FNCO<sub>2</sub> should not imply on financial burden in order not to hamper CCS projects. A regulatory impact analysis (RIA) to understand the potential impacts of a legal and regulatory framework and its likeliness to reach the intended goals would be also an important tool to avoid that costs become obstacles to the development of CCS projects in Brazil.

Hence, the short and medium term liability would keep with the project operators. If there is any damage to be repaired, the operators would be the liable entities. In the absence of immediate response from the liable operators of a CCS project, the remediate actions could be taken by the government (through the FNCO<sub>2</sub>), but the liable parties would be required to further reimburse the exact amount that was destined to repair the damage. For the long-term liability, it is recommended a transfer of liability after the post-closure of a CCS project from the project operators to the Federal Government, as in the case of the Government of Alberta, in Canada (Alberta Energy, 2013) where the government has assumed the long-term liability (as previously discussed in Chapter 4). The financial resources of the FNCO<sub>2</sub> would be solely used for the long-term liability after transferred to the government.

The transfer of liability is a controversial issue and there appears to be significant divergences on the opinion of the various interviewees, especially between representatives of the private sectors and representatives of the public sector. While some interviewees argue, for example, that the Brazilian government should assume the long-term liability, others think that the Brazilian Government would never accept the transfer of liability.

Some experts have even emphasized that this discussion should not be focused on the possibility of transferring the liability to the government, but what should be the conditions to transfer such long-term liability to the government. As the Brazilian Federal Constitution (Brazil, 1988) determines that all mineral resources located in the Brazilian subsurface are owned by the Federal Union (as discussed in the beginning of this chapter), and therefore the long-term liability would be ultimately transferred to the government in any case.



## 5.2. Draft proposal: CONAMA Resolution

In order to convene and formalize the main information and proposals discussed in this chapter, the present dissertation finally offers a concrete proposal of a legal act to be possibly endorsed as a Resolution by the Brazilian National Environmental Council (CONAMA). Given all the considerations discussed above, and considering the small number of CCS projects in Brazil and consequently the relatively low priority from the government, this dissertation recognizes that it could be too premature proposing the formality of long-term liability rules for CCS projects in Brazil at present. There would still have many regulatory issues to be discussed agreed, such as the duration of liability after the post-closure of a CCS project to transfer to the government, the share of liability when third parties are involved *etc.*

Finally, it is important to emphasize that the proposals presented here are intended to address environmental and safety regulatory issues, but they should not imply on financial burden on business and society. A regulatory impact analysis (RIA) to understand the potential impacts of a legal and regulatory framework and its likeliness to reach the intended goals would be also an important tool to avoid that costs become obstacles to the development of CCS projects in Brazil.

## CONAMA RESOLUTION – DRAFT PROPOSAL

### MINISTRY OF THE ENVIRONMENT NATIONAL ENVIRONMENTAL COUNCIL RESOLUTION n° X

*This Resolution establishes procedures for the environmental licensing of carbon capture and storage enterprises and activities for the purpose of reducing Greenhouse Gas emissions, creates the National System of Areas with Geological Storage of Carbon Dioxide (SNCO<sub>2</sub>), among other provisions.*

THE NATIONAL ENVIRONMENTAL COUNCIL (CONAMA), in the use of the legal attributions granted to it by Article 8, I of the Federal Law n° 6.938 of 1981, and in view of the provisions of its Bylaws, REINFORCES:

- (1) The importance of establishing rules and procedures for the prevention and environmental management to orient and guide carbon capture and storage enterprises and activities in Brazil, in order to ensure the effective protection of the environment;
- (2) That carbon capture and storage enterprises and activities may potentially cause significant environmental impacts;
- (3) The particularities and technical limitations on the long-term permanence of carbon dioxide (CO<sub>2</sub>) in geological reservoirs;
- (4) That public health, human well-being and the ecological balance should not be affected by any possible environmental impact resulting from the permanent storage of CO<sub>2</sub> in geological reservoirs;
- (5) That the National Environmental Council (CONAMA) is the competent authority to propose governmental policy rules and procedures for the appropriate management of the environment and natural resources in Brazil, and therefore DETERMINES:

**Article 1.** This Resolution establishes procedures for the environmental licensing of carbon capture and storage activities for the purpose of reducing Greenhouse Gas emissions, creates the National System of Areas with Geological Storage of Carbon Dioxide (SNCO<sub>2</sub>), among other provisions.

**Sole paragraph:** Carbon capture and storage activities designated as per the caput of the article herein are specific for the purpose of reducing Greenhouse Gas emissions from the Earth's Atmosphere.

## **CHAPTER I DEFINITIONS**

**Article 2.** For the purpose of this resolution, the following terms were adopted:

I - Activities with potential polluters and users of environmental resources: activities associated with the National Environmental Policy Act (Federal Law n° 6.938 of 1981), and those that are, by virtue of specific norms, subject to environmental control and supervision;

II - National Register of Areas with Geological Storage of Carbon Dioxide (CNCO<sub>2</sub>): the register that contains a list of enterprises or activities to store CO<sub>2</sub> in geological reservoirs in Brazil;

III - Carbon capture and storage: technology that consists of capturing, transporting and storing carbon dioxide in appropriate geological reservoirs;

IV - Greenhouse gas (GHG): gaseous constituent of the atmosphere, natural or anthropogenic, that when is in the Earth's Atmosphere absorbs and re-emits radiation at specific wavelengths within the spectrum radiation. GHGs include carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF<sub>6</sub>);

V- Greenhouse Gas emission: total mass of GHG released to the Earth's Atmosphere over a period of time.

VI - Injection wells and monitoring wells: vertical wells drilled in subsurface designed to inject or monitor CO<sub>2</sub> in geologic reservoirs for the purpose of its long-term permanence;

VII - Geological reservoirs: underground rock formations with specific properties (such as permeability, porosity, fractures, among others) that allow the trapping of fluids at depth, such as depleted oil fields, unmineable coal seams and saline aquifers.

## **CHAPTER II**

### **ENVIRONMENTAL LICENSING**

**Article 3.** Carbon capture and storage enterprises and activities are subject to environmental licensing requirements because of their potential to cause environmental impacts, and shall comply with specific rules related to the long-term permanence of the CO<sub>2</sub> to be stored in geological reservoirs.

**Article 4.** The design, construction, installation, expansion, modification and operation of any enterprise or activity that uses environmental resources and that can be effectively or potentially pollutant is subject to environmental licensing by the competent environmental regulatory agency.

**Article 5.** It falls within the competence of the IBAMA the environmental licensing for carbon capture and storage enterprises and activities:

- I- located or developed collectively in Brazil and in a neighboring country;
- II- located or developed in the territorial sea, continental platform or in the exclusive economic zone;
- III- located or developed in indigenous lands;
- IV- located or developed in 2 (two) or more states.

**Article 6.** It falls within the competence of the state competent environmental regulatory agency the environmental licensing for carbon capture and storage enterprises and activities:

- I- located or developed collectively in more than one municipality;
- II- located or developed in state protected areas;
- III- located or developed in areas which environmental impacts surpass the territorial boundaries of one or more municipalities;
- IV- located or developed in areas delegated by the Federal Union through legal instrument or agreement.

**Article 7.** It falls within the competence of the competent municipal environmental regulatory, after consultation with the federal and state competent environmental regulatory agencies, the environmental licensing for carbon capture and storage enterprises and activities with local impact and those delegated by the state through legal instrument or agreement.

**Article 8.** The concession of environmental licensing for carbon capture and storage enterprises and activities is subject to a prior Environmental Impact Assessment and its Environmental Impact Assessment Report (EIA/EIR).

§ 1º An individual EIA/EIR and corresponding environmental licensing shall be granted for each activity of a CCS project (capture, transport and storage of CO<sub>2</sub>) when they are implemented by different operators or involve more than one competent environmental regulatory agency.

§ 2º An integrated EIA/EIR and corresponding environmental licensing shall be granted for all activities of a CCS project (capture, transport and storage of CO<sub>2</sub>) when they are implemented by the same operators and involve only one competent environmental regulatory agency.

**Article 9.** In order to grant the environmental licensing for geological CO<sub>2</sub> storage activities, the competent environmental regulatory agency shall consult and consider the technical opinion of the competent regulatory agency corresponding to each activity:

I – The National Water Agency (ANA) for the licensing of geological CO<sub>2</sub> storage activities in saline aquifers;

II - The National Agency of Mining (ANM) for the licensing of geological CO<sub>2</sub> storage activities in coal seams;

III - The National Agency of Petroleum, Natural Gas and Biofuels (ANP) for the licensing of geological CO<sub>2</sub> storage activities in depleted oil and gas reservoirs.

### **CHAPTER III NATIONAL REGISTER**

**Article 10.** The NATIONAL REGISTER OF AREAS WITH GEOLOGICAL STORAGE OF CARBON DIOXIDE (CNCO<sub>2</sub>) aims at registering, in a mandatory basis, enterprises and activities that implement CO<sub>2</sub> storage activities in geological reservoirs in Brazil for the purpose of reducing Greenhouse Gas emissions and must provide information on:

I- the existing pipelines to transport CO<sub>2</sub> to the respective area;

II- the injection and monitoring wells to store CO<sub>2</sub> and monitor the respective area;

III- the estimated geographical boundary of the respective area;

IV- the amount of CO<sub>2</sub> to be stored in the respective area;

V- the monitoring plan to track CO<sub>2</sub> behavior in the respective area;

VI- the contingent plan with actions to remedy any possible leakage or damage.

**Article 11.** The CNCO<sub>2</sub> shall be integrated to a NATIONAL SYSTEM OF AREAS WITH GEOLOGICAL STORAGE OF CARBON DIOXIDE (SNCO<sub>2</sub>) that aims at:

I- validating and disseminating relevant information to civil society about areas with CO<sub>2</sub> transport and CO<sub>2</sub> storage activities;

II- formalizing the transfer of CO<sub>2</sub> ownership among the different operators that capture, transport and store CO<sub>2</sub>;

III- supporting the work of the competent regulatory authorities involved with carbon capture and storage enterprises and activities;

IV- convening relevant documents and concessions granted by the competent regulatory authorities;

§ 1º The updates on the SNCO<sub>2</sub> shall be published at the Official Journal of the Federal Government and made electronically available through the IBAMA website.

§ 2º Any citizen may request detailed access of the information herein, unless if there is any confidential information assured by a confidentiality and data protection act.

**Article 12.** The National Register of Areas with Geological Storage of Carbon Dioxide (CNCO<sub>2</sub>) and the National System of Areas with Geological Storage of Carbon Dioxide (SNCO<sub>2</sub>) will be founded, updated and controlled by IBAMA.

## **CAPÍTULO IV**

### **FINAL PROVISIONS**

**Article 13.** The IBAMA shall establish, through Normative Instructions, the complementary rules and procedures necessary for the enforcement of the present resolution.

**Article 14.** The non-compliance to the provisions of this Resolution shall entail to the infringer the penalties foreseen in the Federal Law nº 9.605 of 1998 that establishes penal and administrative sanctions arising from harmful and damaging activities to the environment, among other provisions.

**Article 15.** This Resolution shall come into force on the date of its publication and revokes the contrary dispositions.

**Chairman of the Board**

## 6. Conclusions

The main objective of this dissertation was to propose recommendations on how carbon capture and storage should be regulated within the Brazilian environmental policy context and what would be the main legal and regulatory aspects that a CCS framework in Brazil should encompass. It also analyzed the main lessons learned of the existing legal and regulatory tools related to CCS worldwide and the current CCS legal and regulatory progress in developing countries that already have active or planned demonstration or large-scale integrated CCS projects (LSIPs).

Chapter 1 provided an introduction of the research topic and a brief assessment of the main challenges and obstacles for CCS projects, including the lack of proper legal and regulatory frameworks. Some of these obstacles resulted in canceled and suspended CCS projects worldwide. As it was presented, the developed countries that have large-scale and integrated CCS projects have already established their own legal and regulatory framework, while the developing countries that have large-scale and integrated CCS projects have not yet enacted specific legal and regulatory frameworks as of August, 2014.

Chapter 2 presented a literature review for carbon capture and storage technologies worldwide and the current status of existing projects. The geological storage of CO<sub>2</sub> has been increasingly receiving more attention from academic and international research institutions, but the large scale deployment of CCS is still subject to a diverse of political, economic, environmental and social challenges. The number of large-scale integrated CCS projects has significantly decreased over the past few years. As of August, 2014, there are only 56 LSIPs projects whereas only 22 of them are active. Although EOR technologies have been deployed for decades, storing CO<sub>2</sub> in geological formations for the purpose of tackling climate change is still a relatively new option and faces several challenges and barriers.

Chapter 3 assessed existing environmental legal and regulatory tools as policy options that could have implications for CCS. The main tools analyzed in that chapter were: (i) CO<sub>2</sub> emissions performance standards; (ii) international environmental agreements; and

(iii) existing CCS legal and regulatory frameworks worldwide. This section has also assessed if establishing such frameworks are crucial to the widespread deployment of CCS technologies. One of the conclusions resulting from that assessment was that, although establishing a CCS legal and regulatory framework in a country does not imply that the number of CCS projects will necessarily increase, such frameworks could certainly provide more legal safety and reduce risks. As a side-effect, it could potentially lead to more initiatives and efforts to develop CCS in large scale.

As some CCS projects are in their planning phase, and considering that the discussion under a legislative process could take several years to be concluded, it would be important to start adapting existing laws to address some of the key CCS legal issues under the environmental policy context in emerging economies. Additionally, given the lack of experience on CO<sub>2</sub> storage in the long-term, it could be challenging to set general criteria for long-term liability requirements from existing regulations. Due to the high complexity on the long-term storage of CO<sub>2</sub> and its correlated liabilities, legal and regulatory frameworks should refer to some form of guidance, instead of trying to cover all encompassing requirements at once. In the same sense, some interviewees have stressed that CCS legal and regulatory frameworks should leave room for potential scientific and technical improvements in the future.

Chapter 4 provided a comparative country-case study on CCS legal and regulatory progress in developing countries, with a detailed case study for Brazil. At the time of writing this dissertation it was not clear whether developing countries would move quickly towards CCS demonstration and large-scale integrated CCS projects. As highlighted by many interviewees, much still depends on the financial support and on the outcomes of the UNFCCC negotiations to be defined in 2015 during the 21<sup>st</sup> Conference of Parties to be held in France.

Regarding the current CCS legal and regulatory developments in developing countries, most of the efforts to establish their frameworks, especially in the emerging economies, are still in their infancy (Brazil, China, Mexico, South Africa). One of the resulting findings of the case study in Brazil indicated that the contribution of CCS to efficiently tackle climate change is not yet well-understood by many policy-makers in Brazil.



Although the technology is well recognized by Petrobras, the business sectors and by the academia, the lack of governmental support was highlighted as a significant concern by the interviewees. The low priority given to CCS in national and subnational climate policies in Brazil also corroborates that concern. Interviews with some Brazilian stakeholders and regulatory authorities revealed that most of them are still unaware on how to deal with the multiple aspects related to the technology. At this stage, capacity building not only for the industry, but also for the government may be an important strategy to create the right environment to foster the deployment of CCS in Brazil.

Chapter 5 proposed recommendations for a CCS legal and regulatory framework in Brazil in response to the central research question of this research, which was “How carbon capture and storage should be regulated in Brazil considering the country’s environmental policy context?” Therefore, the main issues discussed and proposed herein were related to: (i) the indication of the competent regulatory authority to regulate CCS projects in Brazil; (ii) the definition of property rights and CO<sub>2</sub> ownership at the subsurface; (iii) the designation of environmental licensing requirements for CCS projects; and (iv) the allocation of long-term liability. As a result, this study has proposed the creation of (i) a National Register of Areas with Geological Storage of Carbon Dioxide; (ii) a National System of Areas with Geological Storage of Carbon Dioxide; and (iii) a National Fund for the Prevention and Remediation of Areas with Geological Storage of Carbon Dioxide. In order to convene the main information and proposals discussed in Chapter 5, this study has ultimately provided a concrete proposal of a CCS regulatory framework to possibly serve as the basis for a Resolution to be enforced by the Brazilian National Environmental Council (CONAMA). Requirements for long-term liability were not included in the proposed framework, as such issue still remains controversial and it could be precipitated including liability rules in a CCS framework in Brazil at present, as stated by many interviewees. Therefore, it would be important to increase regulatory capacity building to support governmental authorities developing a common understanding on how responsibilities could be concurrently coordinated

In terms of research limitations, accessing non-published data from governments and interviewing regulatory authorities, mainly from China, were some of the constraints to this study. As some of the international interviewees have mentioned, there is a culture of the Chinese government not to communicate with foreigners that they do not know and rely on. At the national level, it was also difficult to convene actual information from the government, as many of the regulatory authorities expressed to have little knowledge on carbon capture and storage technologies.

As there are many various aspects to be considered in a legal and regulatory framework for carbon capture and storage, the analysis and proposals offered in this dissertation did not aim at being exhaustive. Additional research on the legal and regulatory aspects for CCS could certainly provide more concrete support to improve feasibility on the technical level. Some key issues such as the indication of the competent regulatory authority and the implications for environmental licensing, for example, were discussed and proposals to overcome related barriers were suggested, but other relevant aspects such as the classification of CO<sub>2</sub> and the definition of access rights were not addressed in the present work. As all of the aforementioned issues are relevant for a comprehensive legal and regulatory framework, it is recommended that future and supplementary studies focus on them.

Finally, the analysis and proposals presented in this dissertation intended to contribute to scholarship on CCS legal and regulatory frameworks worldwide. Ultimately, the research intended to advance the deployment of CCS in Brazil by proposing recommendations for a legal and regulatory framework that could be feasible with the existing environmental policy and assure an effective protection of the environment and the society.

## REFERENCES

- Alberta (2010). **Alberta CCS Statutes Amendments Act**. The Legislative Assembly of Alberta. Third Session, 27th Legislature, 59 Elizabeth II
- Alberta (2011). **Carbon Sequestration Tenure Regulation**. Mines and Minerals Act A.R. 68/2011
- Alberta Energy. **Carbon Capture and Storage Regulatory Framework Assessment**. Electricity and Alternative Energy and Carbon Capture and Storage Division, 2013.
- ANP- Brazilian National Agency of Petroleum, Natural Gas and Biofuels (008). **Technical Regulation nº 02 of 2008 under the Resolution nº 16 of 2008**. Available [http://nxt.anp.gov.br/nxt/gateway.dll/leg/resolucoes\\_anp/2008/junho/ranp%2016%20-%202008.xml](http://nxt.anp.gov.br/nxt/gateway.dll/leg/resolucoes_anp/2008/junho/ranp%2016%20-%202008.xml) Last accessed in July, 2014.
- Australia, 2006. **Offshore Petroleum and Greenhouse Gas Storage Act. Act No. 14 of 2006 as amended**. <http://www.comlaw.gov.au/Details/C2013C00071> Last access in May, 2014.
- Australia. **Performance standards to reduce energy emissions**. Australian Department of Parliamentary Services, 2011.
- Australia, Government of Queensland. **Conditions for new fossil fired electricity generation**. Australia, 2012 Available at: <http://www.deedi.qld.gov.au/energy/fossil-fired-elec-gen.html> Last accessed in December, 2013.
- Australia, Government of South Australian. **The carbon intensity of South Australia's New Electricity Generation**. Discussion paper. Australia, 2011.
- Australia, Government of Victoria. **No emission limit on new fossil plants**, 2012. Available at: <http://www.theage.com.au/victoria/no-emission-limit-on-new-fossil-plants-20120327-1vwmu.html> Last accessed in December, 2013.
- Bahia (2011). **Bahia State Policy on Climate Change**. State Law nº 12.050 of 2011
- Basel Convention (1989). **Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal**. Available at <http://archive.basel.int/ratif/convention.html> Last accessed in December, 2013.
- Beck, Ulrich. Risk society: **rumo a uma outra modernidade**. Sao Paulo. Ed. 34, 2010.
- Beck, Brendan *et al.* **The Current Status of CCS development in Brazil**. Elsevier, Energy Procedia 4 (2011) 6148–6151
- Bowen, Frances. **Carbon capture and storage as a corporate technology strategy challenge**. Energy Policy, 2011. 39 (2011) 2256–2264.
- Brazil (1967) **Mining Code**. Decree nº 227 of 1967.
- Brazil (1977). **Nuclear Damages Civil Liability and Nuclear Activities Criminal Liability, and Other Measures**. Federal Law nº 6.453 of 1977.
- Brazil (1981) **National Environmental Policy Act**. Federal Law nº 6.938 of 1981
- Brazil (1988) **Brazilian Federal Constitution** of 1988.

- Brazil (1997) **National Oil Law**. Federal Law n° 9.478 of 1997.
- Brazil (2002) Civil Code. Federal Law n° 10.406 of 2002.
- Brazil (2009a). **National Policy on Climate Change**. Federal Law n° 12.187 of 2009.
- Brazil (2009b). **National Fund on Climate Change**. Federal Law n° 12.114 of 2009
- Brazil (2010). **National Policy on Climate Change Decree n° 7.390 of 2010**
- Brazil (2011). **Cooperation among the Federal, States and Municipal governments in the administrative actions related to environmental management**. Complementary Law n° 140 of 2011
- Brazil (2012). **Brazilian Four-Year Plan 2012-2015**. Federal Law n° 12.593 of 2012.
- Brazil (2013). **National Agency of Mining**. Bill number 5.807 of 2013
- California State (2006) - **Senate Bill 1368** (Stats 2006, ch. 598). Available at [http://www.energy.ca.gov/emission\\_standards/documents/sb\\_1368\\_bill\\_20060929\\_chaptered.pdf](http://www.energy.ca.gov/emission_standards/documents/sb_1368_bill_20060929_chaptered.pdf) Last accessed in December, 2013.
- Câmara, George. **Important aspects on the geological storage of CO<sub>2</sub> and a proposal for a regulatory framework in Brazil**. Master's Thesis. Federal University of Bahia, Salvador, 2009.
- Câmara, George; Andrade, José Célio; Rocha, Paulo Sérgio e Ferreira, Luiz Eraldo Araújo. **Análise e proposição para a regulação brasileira do uso da tecnologia de armazenamento geológico de CO<sub>2</sub>**. VI Congresso Nacional de Excelência em Gestão: Niterói, 2010.
- Câmara, George *et al.* **Regulatory framework for geological storage of CO<sub>2</sub> in Brazil- Analyses and proposal**. Elsevier, International Journal of Greenhouse Gas Control 5 (2011) 966–974.
- Canada (2011) **Reduction of Carbon Dioxide Emissions from Fossil-Fired Generation of Electricity Regulation in Canada**, 2011 Available at <http://www.gazette.gc.ca/rp-pr/p1/2011/2011-08-27/html/reg1-eng.html> Last accessed in December, 2013.
- Castro; P.; Hörnlein, Lena and Michaelowa, Katharina. Constructed peer groups and path dependence in international organizations: **The case of the international climate change negotiations**. *Global Environmental Change*. Volume 25, March 2014, Pages 109–120
- Cavaliere Filho, Sérgio. **Programa de Responsabilidade Civil**. 6 ed. Sao Paulo: Malheiros, 2005.
- CDIAC - Carbon Dioxide Information Analysis Center (2014). **Atmospheric Concentrations of CO<sub>2</sub> from Mauna Loa, Hawaii**. Available at [http://cdiac.ornl.gov/trends/co2/recent\\_mauna\\_loa\\_co2.html](http://cdiac.ornl.gov/trends/co2/recent_mauna_loa_co2.html) . Last accessed in July, 2014.
- Center for Climate and Energy Solutions. **EPA Regulation of Greenhouse Gas Emissions from new power plants**. Available at <http://www.c2es.org/docUploads/epa-new-q-a.pdf> Last access in June, 2014.

- CEPAC - Research Institute Center of Excellence in Research and Innovation in Petroleum, Mineral Resources and Carbon Storage. **CCS research programs**. Available at <http://www.pucrs.br/cepac/?p=cepac> Last accessed in June, 2014.
- Chen, C.; Rubin, E.S. **CO<sub>2</sub> control technology effects on IGCC plant performance and cost**. Energy Policy, 2008. Pages 915–924.
- China (2009). Chinese National People's Congress. **Resolution of the Standing Committee of the National People's Congress on Making Active Responses to Climate Change, 2009**. Available at <http://www.shnuodi.com/baike.asp?iid=100147> Last accessed in May, 2014.
- China (2012). National Development and Reform Commission of the People's Republic of China. **China's Policies and Actions for Addressing Climate Change**. Available at <http://www.ccchina.gov.cn/WebSite/CCChina/UpFile/File1324.pdf> Last accessed in May, 2014.
- China (2013). NDRC - National Development and Reform Commission Climate. **Guidance Document on Promoting Carbon Capture, Utilization and Storage Pilot and Demonstration in China**. NDRC Climate [2013] Document N° 849. Available at <http://decarboni.se/sites/default/files/publications/102106/notice-national-development-reform-commission-ndrc.pdf> Last accessed in June, 2014.
- Clarissa L. Melo *et al.*, 2011. **The challenges on the CCGS monitoring in the development of Santos Basin Pre-salt Cluster**. Energy Procedia 4 (2011) 3394–3398
- CONAMA (1997). **Environmental permits**. Resolution n° 237 of 1997
- CONAMA (2009). **Soil quality and management for contaminated areas**. Resolution n° 420 of 2009
- Condor *et al.* **A Comparative Analysis of Regulations for the Geologic Storage of Carbon Dioxide**. Energy Procedia 4 5895–5902. Elsevier, 2011
- Coninck, Heleen. **Trojan Horse or horn of plenty? Reflections allowing CCS in the CDM**. Energy Policy, 2007. 36 (2008) 929–936
- Corfee Morlot J. and Hohne, 2003. **Climate change: long-term targets and short-term commitments**. Global Environmental Change, 13 (2003), pp. 277–293.
- CO<sub>2</sub>CRC - Cooperative Research Centre for Greenhouse Gas Technologies. **CO<sub>2</sub> and long-term trapping mechanisms**. Available at <http://www.co2crc.com.au> Last accessed in January, 2014.
- Destefenni, Marcos. **Direito penal e licenciamento ambiental**. Sao Paulo: Memória Jurídica, 2004, p. 92.
- Diniz, Maria Helena. **Curso de Direito Civil Brasileiro e a responsabilidade civil**. 13ª edição. Sao Paulo: Saraiva, 1999.
- Diniz, Maria Helena. **Curso de Direito Civil Brasileiro e a responsabilidade civil**. 18ª edição. Sao Paulo: Saraiva, 2003.
- Dissou, Yazid. **Cost-effectiveness of the performance standard system to reduce CO<sub>2</sub> emissions in Canada: a general equilibrium analysis**. Resource and Energy Economics, 2005.

- Dooley, James. Chiara Trabucchi, Lindene Patton. **Design considerations for financing a national trust to advance the deployment of geologic CO<sub>2</sub> storage and motivate best practices.** International Greenhouse Gas Control. Elsevier, 2009.
- EPA - Environmental Protection Agency (2010). 40 CFR Parts 124, 144, 145, *et al.* **Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO<sub>2</sub>) Geologic Sequestration (GS) Wells;** Final Rule, 2010. Available at <http://www.gpo.gov/fdsys/pkg/FR-2010-12-10/pdf/2010-29954.pdf> Last access in April, 2014.
- United States - Daily Journal of the United States Government (2014). Standards of Performance for Greenhouse Gas Emissions From New Stationary Sources: **Electric Utility Generating Units.** Available at <https://www.federalregister.gov/articles/2014/01/08/2013-28668/standards-of-performance-for-greenhouse-gas-emissions-from-new-stationary-sources-electric-utility> Last access in June, 2014.
- EPA - United States Environmental Protection Agency (2013). Standards of Performance for GHG from New Stationary Sources: **Electric Utility Generating Units.** Available at <http://www.regulations.gov/#%21documentDetail;D=EPA-HQ-OAR-2013-0495-0001> Last accessed in January, 2014.
- EPA - Environmental Protection Agency (2014). Carbon Pollution Emission Guidelines for Existing Stationary Sources: **Electric Utility Generating Units.** 40 CFR Part 60. Washington D.C, 2014. Available at <http://www2.epa.gov/sites/production/files/2014-05/documents/20140602proposal-cleanpowerplan.pdf> Last accessed in June 2014.
- EPE - Brazilian federal Energy Planning Company (2007). **The 2030 National Energy Plan.** Available at [http://www.epe.gov.br/PNE/20070626\\_1.pdf](http://www.epe.gov.br/PNE/20070626_1.pdf) Last accessed in August, 2014.
- EPE - Brazilian federal Energy Planning Company (2013) National Energy Plan – Technical Note DEA 05/13. **Term of Reference for the 2050 National Energy Plan.** Available at [http://www.epe.gov.br/Estudos/Documents/Estudos\\_20/PNE%202050%20-%20Termo%20de%20Refer%20%C3%A2ncia%20\(TDR\).pdf](http://www.epe.gov.br/Estudos/Documents/Estudos_20/PNE%202050%20-%20Termo%20de%20Refer%20%C3%A2ncia%20(TDR).pdf) Last accessed in August, 2014.
- EPE - Brazilian federal Energy Planning Company (2014) Economic studies- Technical Note DEA 12/14. **Term of Reference for the 2050 National Energy Plan.** [http://www.epe.gov.br/Estudos/Documents/PNE2050\\_Premissas%20econ%C3%B4micas%20de%20longo%20prazo.pdf](http://www.epe.gov.br/Estudos/Documents/PNE2050_Premissas%20econ%C3%B4micas%20de%20longo%20prazo.pdf) Last accessed in August, 2014.
- Espírito Santo (2010). **Espírito Santo State Policy on Climate Change.** State Law nº 9.531 of 2010
- ESPOO - Convention on Environmental Impact Assessment in a Trans-boundary Context (1991). **United Nations Economic Commission for Europe (UNECE) Convention on Environmental Impact Assessment in a Trans-boundary Context.** Available at <http://www.unece.org/env/eia/ratification/convmap.html> Last accessed in December, 2013.
- European Union (2009). **Directive 2009/29/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 2003/87/EC so as to improve and**

- extend the GHG allowance trading scheme of the Community.** <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0063:0087:en:PDF> Last access in May, 2014.
- FINEP – Brazilian Research and Project Financing (2013). **Edital de seleção pública conjunta MMA/BNDES/FINEP de apoio à inovação tecnológica relacionada ao tema sustentabilidade - Inova Sustentabilidade.** Available at [http://www.bndes.gov.br/SiteBNDES/export/sites/default/bndes\\_pt/Galerias/Arquivos/pr odutos/download/Inova\\_sustentabilidade\\_Edital.pdf](http://www.bndes.gov.br/SiteBNDES/export/sites/default/bndes_pt/Galerias/Arquivos/pr odutos/download/Inova_sustentabilidade_Edital.pdf) Last accessed in June, 2014.
- Findlay *et al.* **Carbon capture and storage in China.** An E3G Report for Germanwatch Briefing paper. Germanwatch e.V., 2009
- Forbes, Sarah; Romeiro, Viviane. **The World Resources Institute (WRI) Launches New carbon capture and storage Regulatory Matrix.** Available at <http://insights.wri.org/news/2012/04/wri-launches-new-ccs-regulatory-matrix> Last access in October, 2013.
- Freire, Willian. **Regime jurídico dos recursos mineirais no Direito Brasileiro.** Rev. Jur., Brasília, v. 9, n. 84, p.16-40, abr./maio, 2007.
- Furtado, Marcelo. **Tecnologia Ambiental: Usinas Recuperam CO2.** Qd Editora. Available at <http://www.quimica.com.br/pquimica/tecnologia-ambiental/tecnologia-ambiental-usinas-recuperam-co2> Last accessed in July, 2014.
- GCCSI - Global Carbon Capture Storage Institute (2011). **Dedicated CCS legislation.** <http://archive.globalccsinstitute.com/networks/cclp/legal-resources/dedicated-ccs-legislation> Last access in May, 2014.
- GCCSI - Global Carbon Capture Storage Institute (2014). **Information about CCS projects around the world in an interactive map.** Available at <http://www.globalccsinstitute.com/resources/projects/map> Last access in August, 2014.
- GCCSI. **Germany Relevant implementing legislation.** Carbon Capture Legal Programme, 2012. Available at <http://www.globalccsinstitute.com/networks/cclp/legal-resources/dedicated-ccs-legislation/germany> Last access in May, 2014.
- Geller, Howard S. **Revolução energética: políticas para um future sustentável:** tradução Maria Vidal Barbosa; revisão técnica Márcio Edgar Schuler. Rio de Janeiro: Relume Dumará: USAid, 2003
- Global Energy Assessment (GEA). **Energy Pathways for Sustainable Development,** 2012
- Goldemberg, José ; Guardabassi, Patricia Maria. **Climate Change and 'historical responsibilities'.** Ambiente & Sociedade, v. 15, p. 201-206, 2012.
- Gokul Iyera, Gokul; Hultman, Nathan; Eom, Jiyong; McJeonb, Haweon; Patelb, Pralit and Clarkeb, Leon. **Diffusion of low-carbon technologies and the feasibility of long-term climate targets.** Technological Forecasting and Social Change. DOI: 10.1016/j.techfore.2013.08.025. In press, corrected proof.
- Gonçalves, Carlos Roberto. Direito Civil Brasileiro. **Responsabilidade Civil.** Volume IV. 4 ed. Sao Paulo: Saraiva. 2009
- Guimarães, Bernardo; Gonçalves, Carlos Eduardo. **Introdução à economia.** Rio de Janeiro: Elsevier, 2010

- Glazewski, J., Gilder, A. and Swanepoel, E. 2012. **Carbon Capture and Storage: Towards a regulatory and legal regime in South Africa**. Institute of Marine and Environmental Law (IMEL) and African Climate and Development Initiative (ACDI), University of Cape Town, Cape Town. 2012.
- Goiás (2009). **Goiás State Policy on Climate Change**. State Law nº16.497 of 2009.
- Hardin, Garret. The Tragedy of the Commons: **The population problem has no technical solution; it requires a fundamental extension in morality**. Science, Vol. 162.1968. Available at <http://www.sciencemag.org/content/162/3859/1243.full.pdf> Last accessed in May, 2014.
- Huanga *et al.* **The Study on Prospect and Early Opportunities for Carbon Capture and Storage in Guangdong Province**, China. Energy Procedia, 2013, 37: 3221 – 3232.
- Hultman, Nathan; Pulver, Simone; Romeiro, Viviane and Benney, Tabitha . Carbon Markets and Low-carbon Investment in Emerging Economies: **Experiences with CDM in Brazil and India**. Energy Policy. V. 39, p. 6698, 2011.
- IBAMA - Brazilian Institute of Environment and Renewable Natural Resources (2009). **Normative Instruction IBAMA nº 7 of 2009** (revoked by the Normative Instruction 12/2010/IBAMA/MMA).
- IBAMA - Brazilian Institute of Environment and Renewable Natural Resources (2010). **Normative Instruction IBAMA nº of 2010**.
- IDDRI - Institute for Sustainable Development and International Relations (2014). **Pathways to deep decarbonization**. IDDRI and SDSN. Interim 2014 Report.
- IEA - International Energy Agency (2006). IEA Energy Technology Essentials: **carbon capture and storage**. ETE01, December 2006. Available at <http://www.iea.org/techno/essentials1.pdf> Last accessed in February, 2014.
- IEA - International Energy Agency (2010a). **World Energy Outlook: 2010**, OECD/IEA, France, 2010.
- IEA - International Energy Agency (2010b).Carbon capture and storage: **legal and regulatory review**. 1<sup>st</sup> edition. OECD/IEA: France, 2010.
- IEA - International Energy Agency (2010c) **IEA CCS Model Regulatory Framework** OECD/IEA: France, 2010.
- IEA - International Energy Agency (2011).**Carbon capture and storage: legal and regulatory review**. 2<sup>nd</sup> edition. OECD/IEA: France, 2011.
- IEA - International Energy Agency (2012).**Carbon capture and storage: legal and regulatory review**. 3<sup>rd</sup> edition. OECD/IEA: France, 2012.
- IEA - International Energy Agency (2013). **Carbon capture and storage Technology Roadmap**. OECD/IEA, France, 2013.
- IEA - International Energy Agency (2014).**Carbon capture and storage: legal and regulatory review**. 4<sup>th</sup> edition. OECD/IEA: France, 2014.
- IEA ETP - International Energy Agency (2014). **Tracking clean energy progress**. 5<sup>th</sup> Clean Energy Ministerial. Korea, 2014 OECD/IEA, 2014.



- Illinois State (1987). **Clean Coal Portfolio Standard Law**. Public Act 095-1027, Senate Bill 1987.
- IMO—International Maritime Organization. **Information on work on CCS in Sub-Seabed Geological Formation and Ocean Fertilization under the London Convention and London Protocol**. 2010. Available at <http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Documents/COP%2016%20Submissions/IMO%20note%20on%20LC-LP%20matters.pdf> Last accessed in December, 2013.
- IPCC - Intergovernmental Panel on Climate Change (2005). **Carbon Dioxide Capture and Storage, Special Report**, B. Metz, O. Davidson, H. de Coninck, M. Loos and L. Meyer (eds.), Cambridge University Press, United Kingdom, 2005.
- IPCC - Intergovernmental Panel on Climate Change (2013). **Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change** [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.
- Ketzer, J. M., J. A. Villwock, G. Caporale, da Rocha, G. Rockett, H. Braum, and L. Giraffa. Opportunities for CCS in Brazil: **The CARBMAP Project**. 6<sup>th</sup> Annual Conference on CCS, Pittsburgh, Pennsylvania, 2007.
- Ketzer *et al.* Water–rock–CO<sub>2</sub> interactions in saline aquifers aimed for carbon dioxide storage: **Experimental and numerical modeling studies of the Rio Bonito Formation (Permian), southern Brazil**. Applied Geochemistry. Volume 24, Issue 5, May 2009
- Ketzer, J. Marcelo. **CCS development in Brazil**. CCS Legal and Regulatory Framework meeting. IEA: Paris, 2010. Available at [http://www.iea.org/work/2010/ccs\\_jan20\\_21/Brazil\\_Ketzer.pdf](http://www.iea.org/work/2010/ccs_jan20_21/Brazil_Ketzer.pdf) Last accessed in December, 2013.
- Ketzer, J. M. Medina. **Sequestro de carbono-empenhado no futuro**. Revista Brasileira Bioenergia. ISSN 1677-3926. CENBIO/IEE/USP. Ano 5. N<sup>o</sup> 10, 2011.
- Lampreia *et al.*, 2011. **Analyses and perspectives for Brazilian low carbon technological development in the energy sector**. Renewable and Sustainable Energy Reviews 15 (2011) 3432–3444.
- Leal da Costa, Isabella Vaz. **Regulatory framework proposal for carbon capture and geologic storage in Brazil and a case study for Rio de Janeiro State**. Ph.D. dissertation (Doctor of Science). Energy Planning - UFRJ/ COPPE, 2014.
- Liang, Xi; Reiner, David. **How China can kick-start carbon capture and storage**. China Dialogue, 2013. Available at <https://www.chinadialogue.net/article/show/single/en/6047-How-China-can-kick-start-carbon-capture-and-storage> Last accessed in May, 2014.
- London Convention (1972). **London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter**. <http://www.londonconvention.org/documents/lc72/LC1972.pdf> Last accessed in December, 2013.

- London Protocol (1996). **London Protocol Adopts Amendment Allowing for Sub-seabed Carbon Dioxide Storage**. [http://pdf.wri.org/css\\_06\\_12\\_08\\_london\\_protocol.pdf](http://pdf.wri.org/css_06_12_08_london_protocol.pdf) Last accessed in December, 2013.
- Lucon, O.; Goldemberg, J. Sao Paulo - The "Other" Brazil: **Different Pathways on Climate Change for State and Federal Governments**. The Journal of Environment & Development, v. 19, p. 335-357, 2010.
- Lucon, O. ; Romeiro, V. ; Pacca, S. Reflections on the international climate change negotiations: **A synthesis of a working group on carbon emission policy and regulation in Brazil**. Energy Policy, v. 59, p. 938-941, 2013.
- Machado, Claudia; Rockett, Gabriela; Ketzer, João Marcelo Medina. Brazilian Renewable Carbon Capture and Geological Storage Map: **Possibilities for the Paraná Basin**. Elsevier, Energy Procedia 37 ( 2013 ) 6105– 6111
- MEF TAP - Major Economies Forum Technology Action Plan (2009). **MEF TAP for carbon capture and storage**. Available at <http://www.majoreconomiesforum.org/images/stories/documents/MEF%20CCUS%20TAP%2011Dec2009.pdf> Last accessed in January, 2014.
- MMA - Brazilian Ministry of the Environment (2008), **National Plan on Climate Change**. Interministerial Commission on Global Climate Change. Brasilia, 2008.
- MMA - Brazilian Ministry of the Environment (2009). **Contaminated areas**. Available at <http://www.mma.gov.br/cidades-sustentaveis/residuos-perigosos/areas-contaminadas> Last accessed in July, 2014.
- Mattoo, Aaditya; Subramanian, Arvind. **Greenprint: A New Approach to Cooperation on Climate Change**. Center For Global Development (2012).
- MCTi - Brazilian Ministry of Science, Technology and Innovation (2013) **Annual Greenhouse Gas emissions estimates 2013**. Available at [http://www.mct.gov.br/upd\\_blob/0226/226591.pdf](http://www.mct.gov.br/upd_blob/0226/226591.pdf) Last access in May, 2014.
- MCTi - Ministry of Science, Technology and Innovation (2014a). **Ministerial Order nº 322 of of 2014 to establish a Technical Advisory Committee for the project “GHG mitigation options in key sectors in Brazil”**. Ministry of Science, Technology and Innovation.
- MCTi - Brazilian Ministry of Science, Technology and Innovation (2014b). United Nations Development Programme - UNDP Project BRA/07/002. **Study on the feasibility of the clean development mechanism to implement carbon capture and storage projects in Brazil**. Available at [http://www.mct.gov.br/upd\\_blob/0231/231856.pdf](http://www.mct.gov.br/upd_blob/0231/231856.pdf) Last accessed in August, 2014.
- MDIC – Brazilian Ministry of Development, Industry and Foreign Trade (2013). **Opções de Mitigação de Gases de Efeito Estufa (GEE) em Setores-Chave do Brasil**. Available at [http://www.mdic.gov.br/arquivos/dwnl\\_1378230469.pdf](http://www.mdic.gov.br/arquivos/dwnl_1378230469.pdf) Last accessed in August, 2014.
- Meirelles, Elizabeth de Almeida. O Aquífero Guarani: **uma proposta de regulamentação jurídica internacional**. Tese de Doutorado. USP/Direito, 2005.
- MIT - Massachusetts Institute of Technology (2014a). Carbon Capture and Sequestration Technologies from the Massachusetts Institute of Technology. **Carbon capture and**

- sequestration projects map.** United States, 2014. Available at [http://sequestration.mit.edu/tools/projects/map\\_projects.html](http://sequestration.mit.edu/tools/projects/map_projects.html) Last accessed in July, 2014.
- MIT - Massachusetts Institute of Technology (2014b). **Vattenfall Janschwalde Fact Sheet: Carbon Dioxide Capture and Storage Project.** Carbon capture & sequestration technologies, 2014. Available at [http://sequestration.mit.edu/tools/projects/vattenfall\\_janschwalde.html](http://sequestration.mit.edu/tools/projects/vattenfall_janschwalde.html) Last access in May, 2014.
- MIT - Massachusetts Institute of Technology (2014c). **Antelope Valley Fact Sheet: Carbon Dioxide Capture and Storage Project.** Available at [http://sequestration.mit.edu/tools/projects/antelope\\_valley.html](http://sequestration.mit.edu/tools/projects/antelope_valley.html) Last accessed in March, 2014.
- Moöllersten, Kenneth, Jinyue Yan, and Jose R. Moreira. 2003. Potential Market Niches for Biomass Energy with CO<sub>2</sub> Capture and storage-**Opportunities for Energy Supply with Negative CO<sub>2</sub> Emissions.** *Biomass and Bioenergy* 25 (3): 273–85. doi:10.1016/S0961-9534(03)00013-8.
- Montana State. **House Bill 25:** Available at [http://RAP\\_ResearchBrief\\_Simpson\\_EPS\\_Updated\\_2010\\_08\\_12\(2\)%20\(1\).pdf](http://RAP_ResearchBrief_Simpson_EPS_Updated_2010_08_12(2)%20(1).pdf) Last accessed in December, 2013.
- Moreira, J. R. **Projeto governamental pretende fazer CCS andar no Brasil.** *Revista Brasileira Bioenergia.* Ano 5. N° 10, 2011.
- Muller, B.; Hohne, N.; Ellermann, C. **Differentiating Historic Responsibilities for Climate Change.** Oxford Institute for Energy Studies. 2007. Available at <http://www.oxfordclimatepolicy.org/publications/DifferentiatingResponsibility.pdf> Last accessed in June, 2014.
- NACSA, 2014. **The North American Carbon Storage Atlas.** Available at [http://www.nacsap.org/?page\\_id=7](http://www.nacsap.org/?page_id=7) Last accessed in June, 2014.
- Natural Resources Canada. Canada update: **CCS legal and regulatory developments.** IEA 4th CCS Regulator Network Meeting, 2012. Available at <http://www.iea.org/media/workshops/2012/ccs4thregulatory/new/KathrynGagnon.pdf> Last access in April, 2014.
- New Mexico State. **House Bill 994:** Available at [http://legis.state.nm.us/lcs/\\_session.aspx?Chamber=S&LegType=B&LegNo=994&year=07](http://legis.state.nm.us/lcs/_session.aspx?Chamber=S&LegType=B&LegNo=994&year=07) Last accessed in November, 2013.
- NOAA/ESRL - National Oceanic and Atmospheric Administration/ Earth System Research Laboratory (2014). **Trends in Atmospheric Carbon Dioxide.** Available at <http://www.esrl.noaa.gov/gmd/ccgg/trends/#mlo> Last accessed in July, 2014.
- Nogueira *et al.* **Will thermal power plants with CCS play a role in Brazil's future electric power generation?** *International Journal of Greenhouse Gas Control* 24 (2014) 115–123
- Norway (1990). **Act 21 December 1990 n° 72 relating to tax on discharge of CO<sub>2</sub> in the petroleum activities on the continental shelf.** Norwegian Petroleum Directorate.

Oliveira, W. S. ; Machado, C. X. ; Rockett, G. C. ; Ketzer, J. M. M. **Brazilian map on renewable carbon capture and storage**. Energy Procedia. Volume 37, 2013, Pages 6105–6111

Oregon State. **Senate Bill 10**. Available at <http://www.leg.state.or.us/09reg/measpdf/sb0100.dir/sb0101.en.pdf> Last accessed in November, 2013.

OSPAR - Convention for the protection of the marine environment of the North-East Atlantic (1992) - **Ospar Comission**. Available at <http://qsr2010.ospar.org/en/ch02.html> Last accessed in December, 2013.

OSPAR - Convention for the protection of the marine environment of the North-East Atlantic. **OSPAR Quality Status Report**. Jurisdictional zones of the UNCLOS and the OSPAR Convention. 2010. Available at [http://qsr2010.ospar.org/en/ch01\\_02.html](http://qsr2010.ospar.org/en/ch01_02.html) Last accessed in October, 2013.

Pacca, Sérgio and J. R. Moreira. **Historical carbon budget of the Brazilian ethanol program**. Energy Policy, Volume 37, Issue 1, 2009

Pentair Haffmans, 2011. **Brazilian bioethanol distillery equipped with Co2 recovery plant from Pentair Haffmans**. Available at <http://www.x-flow.com/resources/images/546.pdf> Last accessed in July, 2014.

Petrobras - Brazilian National Oil and Gas Company (2011) Environmental Impact Report. **Integrated Projects for Oil and Gas in the Pre-Salt Fields, Santos Basin**. [http://licenciamento.ibama.gov.br/Petroleo/Atividade%20de%20Produ%C3%A7%C3%A3o%20e%20Escoamento%20de%20Petr%C3%B3leo%20e%20G%C3%A1s%20Natural%20do%20Polo%20Pr%C3%A9-Sal%20da%20Bacia%20de%20Santos%20-%20Etapa%201/EIA\\_Proj\\_Int\\_BS/Item\\_II-15\\_RIMA.pdf](http://licenciamento.ibama.gov.br/Petroleo/Atividade%20de%20Produ%C3%A7%C3%A3o%20e%20Escoamento%20de%20Petr%C3%B3leo%20e%20G%C3%A1s%20Natural%20do%20Polo%20Pr%C3%A9-Sal%20da%20Bacia%20de%20Santos%20-%20Etapa%201/EIA_Proj_Int_BS/Item_II-15_RIMA.pdf) Last accessed in July, 2014.

Petrobras - Brazilian National Oil and Gas Company (2012) Environmental Impact Assessment and Environmental Impact Report (EIA-EIR - Phase I). **Integrated Projects for Oil and Gas in the Pre-Salt Fields, Santos Basin**. Available at <http://licenciamento.ibama.gov.br/Petroleo/Atividade%20de%20Produ%C3%A7%C3%A3o%20e%20Escoamento%20de%20Petr%C3%B3leo%20e%20G%C3%A1s%20Natural%20do%20Polo%20Pr%C3%A9-Sal%20da%20Bacia%20de%20Santos%20-%20Etapa%201/028125-EIA-CP-0001-02.pdf> Last accessed in July, 2014.

Petrobras - Brazilian National Oil and Gas Company (2014). Environmental Impact Assessment and Environmental Impact Report (EIA-EIR - Phase II). **Projects for Oil and Gas in the Pre-Salt Fields, Santos Basin**. Available at <http://www.petrobras.com.br/lumis/portal/file/fileDownload.jsp?fileId=8A158398454825F401456C238831781E> Last accessed in July, 2014.

Petrobras - Brazilian National Oil and Gas Company (2014). **Pre-Sal additional volumes: 10 to 15 billions of BOU**. Available at <http://www.petrobras.com.br/fatos-e-dados/volumes-excedentes-do-pre-sal-10-a-15-bilhoes-de-barris.html> Last accessed in July, 2014.

Pew Centre on Global Climate Change. **A Performance Standards Approach to Reducing CO<sub>2</sub> Emissions from Electric Power Plants**. E.S. Rubin. White Paper Series, Coal Initiative Reports, June 2009.

Pindyck, R.S.; Rubinfeld, D.L. **Microeconomia**. Sao Paulo: Prentice Hall, 2002.

- PRODES - Satellite Monitoring System of the Brazilian Amazon Forest (2013). **Annual deforestation rates in the Legal Amazon (1988-2013)**. Available at <http://www.obt.inpe.br/prodes> Last accessed in August, 2014.
- Qian *et al.* **Identifying Near-Term Opportunities for Carbon Capture and Sequestration (CCS) in China**. Natural Resources Defense Council (NRDC), 2009.
- Rio de Janeiro (2010). **Rio de Janeiro State Policy on Climate Change**. State Law nº 5690 of 2010
- Rio Grande do Sul (2010). **Rio Grande do Sul State Policy on Climate Change**. State Law nº 13.594 of 2010
- Rocket, Gabriela C; Machado, C.X; Ketzer, J. M. **Diagnóstico do status atual do Brasil para implantação de projetos de captura e armazenamento geológico de CO<sub>2</sub>**. Revista Petro & Química. Ano XXXIV, nº 330, 2010.
- Rockett *et al.* The CARBMAP Project: **Matching CO<sub>2</sub> sources and geological sinks in Brazil using Geographic Information System**. Elsevier, Energy Procedia 4 (2011) 2764-2771.
- Rockett *et al.* **Large-scale carbon capture and storage in Brazil: a preliminary cost modeling for campos Basin's Oil Fields**. Sao Paulo, UNESP, Geociências, v. 31, n. 4, p. 485-503, 2012
- Rodrigues, Sílvio. Direito Civil - **Parte Geral das Obrigações**. 30<sup>a</sup> ed. Sao Paulo: Saraiva, 2002.
- Román, Mikael. Carbon capture and storage in developing countries: **A comparison of Brazil, South Africa and India**. Elsevier. Global Environmental Change 21 (2011) 391–401
- Romeiro, Viviane; Parente, Virginia. Carbon Capture and Storage and the UNFCCC: Recommendations to Address Trans-Boundary Issues. Low Carbon Economy (LCE) Vol. 3 No. 3A, 2012, pp. 130-136. doi:10.4236/lce.2012.323017.
- Romeiro, Viviane. **Carbon capture and storage provides low-emissions extraction for Brazil's pre-salt layer oilfields**. Global CCS Institute Insights. Available at <http://www.globalccsinstitute.com/insights/authors/VivianeRomeiro/2014/05/22/ccs-provides-low-emissions-extraction-brazils-pre-salt-layer-oilfields?author=MjE2MTg%3D> Last accessed in June, 2014.
- SACCCS South African Centre for Carbon Capture and Storage (2009). **Roadmap for the commercial application of CCS in South Africa** Available at <http://www.sacccs.org.za/roadmap/> Last accessed in July, 2014.
- Sao Paulo (2009a). **Sao Paulo State Policy on Climate Change**. State Law nº13.798 of 2009
- Sao Paulo State (2009b). **Soil quality and the management of contaminated areas**. State Law nº 13.577 of 2009
- SCCS - Scottish Carbon Capture and Storage. **Current status of CCS projects globally**. Scotland, 2014. Available at <http://www.sccs.org.uk/expertise/map.html> Last accessed in July, 2014.

- Scotland (2012). **Electricity Generation Policy Statement (EGPS, 2012)**. Available at <http://www.scotland.gov.uk/Resource/0038/00389294.pdf> Last accessed in November, 2013.
- Scotland (2013). **Electricity Generation Policy Statement**. The Scottish Government Riaghaltas na h-Alba. Available at <http://www.scotland.gov.uk/Resource/0042/00427293.pdf> Last accessed in June, 2014.
- Seabra P. N. C.; Grava, Wilson. **CCS technologies and projects for emerging economies: Brazil. CLSF Technical Group Meeting**. Seoul, 2014. Available at <https://www.cslforum.org/publications/documents/seoul2014/Pinto-BrazilTechnologiesProjectsEmergingEconomies-TG-Seoul03.pdf> Last accessed in June, 2014.
- Seligsohn *et al.* **CCS in China: Toward an Environmental, Health, and Safety Regulatory Framework**. World Resources Institute, 2009.
- Schaeffer, R. *et al.* **Energy-related climate change mitigation in Brazil: Potential, abatement costs and associated policies**. *Energy Policy*, Volume 49, October 2012, Pages 430–441
- South Africa (2010). **The National Climate Change Response Green Paper**. The Government of the Republic of South Africa.
- South Africa (2011). **The National Climate Change Response White Paper**. The Government of the Republic of South Africa.
- Stern, Nicholas. *The Economics of Climate Change: The Stern Review*. Cambridge University Press: Great Britain, 2007.
- STRACO<sub>2</sub> - Support to Regulatory Activities for Carbon Capture and Storage Project. **Support to Regulatory Activities for Carbon Capture and Storage**. Synthesis Report. European Union's Seventh Framework Program - FP7, 2009.
- Swedish Agency For Growth Policy Analysis (2013). **Energy Policy in Brazil: Perspectives for the medium and long term**. Available at <http://www.tillvaxtanalys.se/download/18.752e3f4c144bb4af26810e/1394799900000/Energisystem+bortom+2020+Brasilien.pdf> Last accessed in July, 2014.
- Talberg, Anita and Nielson, Leslie. **Performance standards to reduce energy emissions**. Australian Department of Parliamentary Services, 2011.
- The Breakthrough Institute (2011). **Germany's Plan to Phase Out Nuclear Jeopardizes Emissions goals**. Available at [http://thebreakthrough.org/blog/2011/06/analysis\\_germanys\\_plan\\_to\\_phase\\_out\\_nuclear.html](http://thebreakthrough.org/blog/2011/06/analysis_germanys_plan_to_phase_out_nuclear.html) Last accessed in December, 2013.
- United Kingdom (2008) **Energy Act. Chapter 3 - Storage of Carbon Dioxide**. Available at: <http://www.legislation.gov.uk/ukpga/2008/32/contents> Last accessed in July, 2014.
- United Kingdom CCS Roadmap: **supporting deployment of Carbon Capture and Storage in the United Kingdom**. Department of Energy and Climate Change, 2012
- UCL Carbon Capture Legal Programme **CCS in the Clean Development Mechanism**. (2011). Available at <http://www.ucl.ac.uk/cclp/ccsinCDM.php> Last accessed in November, 2013.

- UNCLOS - United Nations Convention on the Law of the Sea (1982). **UNCLOS**. [http://www.un.org/depts/los/convention\\_agreements/texts/unclos/unclos\\_e.pdf](http://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf) Last accessed in December, 2013.
- UNEP - United Nations Environment Programme (2013). **The Emissions Gap Report**. A Unep Synthesis Report. Nairobi, 2013.
- UNFCCC - United Nations Framework Convention on Climate Change (1992). **United Nations Framework Convention on Climate Change**, New York. FCCC/INFORMAL/84 GE.05-62220 (E) 200705. Available at <http://unfccc.int/resource/docs/convkp/conveng.pdf> Last accessed in November, 2013.
- UNFCCC (United Nations Framework Convention on Climate Change (1998). **Kyoto Protocol**. Available at <http://unfccc.int/resource/docs/convkp/kpeng.pdf> Last accessed in April, 2014.
- UNFCCC - United Nations Framework Convention on Climate Change (2009). **Copenhagen Accord (Decision-/CP.15)**, 2009. Available at: [http://unfccc.int/files/meetings/cop\\_15/application/pdf/cop15\\_cph\\_auv.pdf](http://unfccc.int/files/meetings/cop_15/application/pdf/cop15_cph_auv.pdf) Last accessed in December, 2013.
- UNFCCC - United Nations Framework Convention on Climate Change (2010a). Decision /CMP.6 - **Carbon dioxide capture and storage in geological formations as clean development mechanism project activities**. Available at [http://unfccc.int/files/meetings/cop\\_16/application/pdf/cop16\\_cmp\\_ccs.pdf](http://unfccc.int/files/meetings/cop_16/application/pdf/cop16_cmp_ccs.pdf) Last access in April, 2014.
- UNFCCC - United Nations Framework Convention on Climate Change (2010b). **Views Related to Carbon Dioxide Capture and Storage in Geological Formations as a Possible Mitigation Technology**. Subsidiary Body for Scientific and Technological Advice. Available at [www.unfccc.int/resource/docs/2010/sbsta/eng/misc02.pdf](http://www.unfccc.int/resource/docs/2010/sbsta/eng/misc02.pdf) Last access in April, 2014.
- UNFCCC - United Nations Framework Convention on Climate Change (2010c). **Views related to carbon dioxide capture and storage in geological formations as a possible mitigation technology. Submission from Brazil**. Available at <http://unfccc.int/resource/docs/2010/sbsta/eng/misc02a01.pdf> Last accessed in August, 2014.
- UNFCCC - United Nations Framework Convention on Climate Change (2011a). **Durban Platform for Enhanced Action**. Available at [https://unfccc.int/files/meetings/durban\\_nov\\_2011/decisions/application/pdf/cop17\\_durbanplatform.pdf](https://unfccc.int/files/meetings/durban_nov_2011/decisions/application/pdf/cop17_durbanplatform.pdf) Last accessed in February, 2014.
- UNFCCC - United Nations Framework Convention on Climate Change (2011b). **Modalities and Procedures for Carbon Dioxide Capture and Storage in Geological Formations as Clean Development Mechanism Project Activities**. [http://unfccc.int/files/meetings/durban\\_nov\\_2011/decisions/application/pdf/cmp7\\_carbon\\_storage .pdf](http://unfccc.int/files/meetings/durban_nov_2011/decisions/application/pdf/cmp7_carbon_storage.pdf) Last accessed in February, 2014.
- UNFCCC (United Nations Framework Convention on Climate Change (2011c) **2<sup>nd</sup> National Communication on Climate Change of South Africa**, 2011. Available at <http://unfccc.int/resource/docs/natc/zafnc02.pdf> Last accessed in July, 2014.

- UNFCCC (United Nations Framework Convention on Climate Change (2012a)). **Doha Amendment to the Kyoto Protocol**. Available at [http://unfccc.int/files/kyoto\\_protocol/application/pdf/kp\\_doha\\_amendment\\_english.pdf](http://unfccc.int/files/kyoto_protocol/application/pdf/kp_doha_amendment_english.pdf) Last accessed in April, 2014.
- UNFCCC (United Nations Framework Convention on Climate Change (2012b)). Subsidiary Body for Scientific and Technological Advice - Thirty-seventh session. **Carbon dioxide capture and storage in geological formations as clean development mechanism project activities**. Available at <http://unfccc.int/resource/docs/2012/sbsta/eng/l21.pdf> Last accessed in April, 2014.
- UNFCCC (United Nations Framework Convention on Climate Change (2012c)) **2<sup>nd</sup> National Communication on Climate Change of China**, 2012. Available at <http://unfccc.int/resource/docs/natc/chnnc2e.pdf> Last accessed in July, 2014.
- UNFCCC (United Nations Framework Convention on Climate Change (2012d)) **5<sup>th</sup> National Communication on Climate Change of Mexico**, 2012. Available at <http://unfccc.int/resource/docs/natc/mexnc5s.pdf> Last accessed in July, 2014.
- UNFCCC (United Nations Framework Convention on Climate Change (2012e)) **2<sup>nd</sup> National Communication on Climate Change of Brazil**, 2012. Available at <http://www.mct.gov.br/index.php/content/view/326984.html> Last accessed in July, 2014.
- UNFCCC - United Nations Framework Convention on Climate Change (2013). **Views of Brazil on the implementation of all the elements of decision 1/CP.17, (B) matters related to paragraphs 7 and 8 (Workstream 2), on the work of the Ad Hoc Working Group on the Durban Platform for Enhanced Action**. Available at [http://unfccc.int/files/documentation/submissions\\_from\\_parties/adp/application/pdf/adp\\_brazil\\_workstream\\_2\\_ccs\\_20130913.pdf](http://unfccc.int/files/documentation/submissions_from_parties/adp/application/pdf/adp_brazil_workstream_2_ccs_20130913.pdf) Last accessed in July, 2014.
- UNFCCC (2014a). **Status of Ratification of the Convention**. Available at [http://unfccc.int/essential\\_background/convention/status\\_of\\_ratification/items/2631.php](http://unfccc.int/essential_background/convention/status_of_ratification/items/2631.php) Last accessed in July, 2014.
- UNFCCC - United Nations Framework Convention on Climate Change (2014). ADP Technical Expert Meetings: **Carbon capture, use and storage**. 20-25 October 2014, Bonn, Germany. Available at <http://unfccc.int/bodies/awg/items/8421.php> Last accessed in August, 2014.
- United Kingdom (2008). **Energy Act 2008**. Chapter 32. Available at [http://www.legislation.gov.uk/ukpga/2008/32/pdfs/ukpga\\_20080032\\_en.pdf](http://www.legislation.gov.uk/ukpga/2008/32/pdfs/ukpga_20080032_en.pdf) Last access in April, 2014.
- United Kingdom (2012). **Draft Energy Bill: Pre-legislative Scrutiny First Report of Session 2012-13**. House of Commons Energy and Climate Change Committee.
- U.S. Energy Information Administration (2013). **International Energy Outlook**. Report Number: DOE/EIA-0484(2013).
- US White House. **The President's Climate Action Plan**. Executive Office of the President. June, 2013.
- Varella, Marcelo. (org). **Governo dos riscos**. Belo Horizonte, Unitar, 2005.



- Varet, Jacques. **CO<sub>2</sub> capture and geological storage**. The BRGM series “Geoscience Issues”. ISBN ADEME : 2-86817-800-6. ISBN BRGM : 2-7159-0970-5 ISBN IFP : 2-901638-10-4, 2005.
- Venosa, Sílvio de Salvo. Direito civil I - Teoria geral. **Introdução ao direito romano**. Sao Paulo: Atlas, 1996
- Venosa, Sílvio de Salvo. Direito Civil II - **Teoria Geral das Obrigações e dos Contratos**. Sao Paulo: Atlas, 2003.
- Victor; David G. Global Warming Gridlock: **Creating More Effective Strategies for Protecting the Planet**. Cambridge University Press (2011)
- Xianjin Lai, *et al.* Carbon capture and sequestration (CCS) technological innovation system in China: **Structure, function evaluation and policy implication**. Energy Policy, Volume 50, November 2012, Pages 635–646
- Yan Gu. Carbon capture and storage policy in China. Columbia Law School. **Center for Climate Change Law White Paper**, 2013. Available at <https://web.law.columbia.edu/sites/default/files/microsites/climate-change/files/Publications/Students/Yan%20Gu%20CCS%20Paper%20Final.pdf> Last accessed in May, 2014.
- Warren, Luke. **Approaches to the Allocation of Liability**. CCS Association, 2011. [http://unfccc.int/files/methods/other\\_methodological\\_issues/application/pdf/ccsa\\_liability.pdf](http://unfccc.int/files/methods/other_methodological_issues/application/pdf/ccsa_liability.pdf) Last access in April, 2014.
- Wartmann, Sina; Jaworski, Piotr; Klaus, Sebastian; Beyer, Catharina. Scenarios on the introduction of CO<sub>2</sub> **Emission Performance Standards for the EU Power Sector**. ECOFYS Germany, 2009.
- Washington State. **Senate Bill 6001**. Available at: <http://apps.leg.wa.gov/billinfo/summary.aspx?year=2007&bill=6001> Last accessed in November, 2013.
- World Bank (2011). Carbon Capture and Storage in Developing Countries: **a Perspective on Barriers to Deployment**. Natalia Kulichenko; Eleanor Ereira. Paper 25. June, 2011.
- WRI -World Resources Institute. Guidelines for Carbon Dioxide Capture, Transport, and Storage. Washington DC, 2008.
- WRI - World Resources Institute (2011). Carbon Dioxide Capture and Storage and the UNFCCC: **Recommendations for Addressing Technical Issues** 2011. Available at <http://www.wri.org/publication/carbon-dioxide-capture-and-storage-and-the-UNFCCC> Last accessed in September, 2013.

## ANNEX 1. Sample of legal and regulatory frameworks for CCS



# Offshore Petroleum and Greenhouse Gas Storage Act 2006

Act No. 14 of 2006 as amended

Division 8—Long-term liabilities

### 399 Closure assurance period

- (1) If:
- (a) a site closing certificate is in force in relation to an identified greenhouse gas storage formation; and
  - (b) the responsible Commonwealth Minister is satisfied that operations for the injection of a greenhouse gas substance into the formation ceased on a day (the *cessation day*) before the application for the site closing certificate was made; and
  - (c) on a day (the *decision day*) that is at least 15 years after the issue of the site closing certificate, the responsible Commonwealth Minister is satisfied that:
    - (i) the greenhouse gas substance injected into the formation is behaving as predicted in Part A of the approved site plan for the formation; and
    - (ii) there is no significant risk that a greenhouse gas substance injected into the formation will have a significant adverse impact on the geotechnical integrity of the whole or a part of a geological formation or geological structure; and
    - (iii) there is no significant risk that a greenhouse gas substance injected into the formation will have a significant adverse impact on the environment; and
    - (iv) there is no significant risk that a greenhouse gas substance injected into the formation will have a significant adverse impact on human health or safety; and
    - (v) since the cessation day, there have not been any operations for the injection of a greenhouse gas substance into the formation;

the responsible Commonwealth Minister may, by writing, declare that the period:

- (d) beginning at the end of the cessation day; and
- (e) ending at the end of the decision day;

is the *closure assurance period* in relation to the formation for the purposes of this Act.

(2) A copy of a declaration under subsection (1) is to be given to the holder of the site closing certificate.

#### **400 Indemnity—long-term liability**

##### *Scope*

- (1) This section applies if:
  - (a) a site closing certificate is in force in relation to an identified greenhouse gas storage formation; and
  - (b) when the application for the certificate was made, the formation was specified in a greenhouse gas injection licence; and
  - (c) there is a closure assurance period in relation to the formation; and
  - (d) the following conditions are satisfied in relation to a liability of an existing person who is or has been the registered holder of the licence (whether or not the licence is in force):
    - (i) the liability is a liability for damages;
    - (ii) the liability is attributable to an act done or omitted to be done in the carrying out of operations authorised by the licence in relation to the formation;
    - (iii) the liability is incurred or accrued after the end of the closure assurance period in relation to the formation;
    - (iv) such other conditions (if any) as are specified in the regulations.

##### *Indemnity*

- (2) The Commonwealth must indemnify the person against the liability.

#### **401 Commonwealth to assume long-term liability if licensee has ceased to exist**

##### *Scope*

- (1) This section applies if:
  - (a) a site closing certificate is in force in relation to an identified greenhouse gas storage formation; and
  - (b) when the application for the certificate was made, the formation was specified in a greenhouse gas injection licence; and
  - (c) there is a closure assurance period in relation to the formation; and
  - (d) a person who has been the registered holder of the licence (whether or not the licence is in force) has ceased to exist; and
  - (e) if the person had continued in existence, the following conditions would have been satisfied in relation to a liability of the person:
    - (i) the liability is a liability for damages;
    - (ii) the liability is attributable to an act done or omitted to be done in the carrying out of operations authorised by the licence in relation to the formation;
    - (iii) the liability is incurred or accrued after the end of the closure assurance period in relation to the formation;
    - (iv) such other conditions (if any) as are specified in the regulations; and
  - (f) apart from this section, the damages are irrecoverable because the person has ceased to exist.

##### *Commonwealth to assume liability*

- (2) The liability is taken to be a liability of the Commonwealth.



# United Kingdom Energy Act 2008

## CHAPTER 32

### Chapter 3 — Storage of carbon dioxide

#### *Activities requiring a licence*

##### **17 Prohibition on unlicensed activities**

- (1) No person may carry on an activity within subsection (2) except in accordance with a licence.
- (2) The activities are—
- (a) the use of a controlled place for the storage of carbon dioxide (with a view to its permanent disposal, or as an interim measure prior to its permanent disposal);
  - (b) the conversion of any natural feature in a controlled place for the purpose of storing carbon dioxide (with a view to its permanent disposal, or as an interim measure prior to its permanent disposal);
  - (c) the exploration of a controlled place with a view to, or in connection with, the carrying on of activities within paragraph (a) or (b);
  - (d) the establishment or maintenance in a controlled place of an installation for the purposes of activities within this subsection.
- (3) In this section, “controlled place” means a place in, under or over—
- (a) the territorial sea, or
  - (b) waters in a Gas Importation and Storage Zone.

##### **18 Licences**

- (1) The licensing authority may grant a licence to a person in respect of one or more activities within section 17(2).
- (2) *The licensing authority is—*
- (a) in the case of a licence in respect of activities within section 17(2)(a) to (c) and a controlled place which is not in, under or over the territorial sea adjacent to Scotland, the Secretary of State,
  - (b) in the case of a licence in respect of such activities and a controlled place which is in, under or over that territorial sea, the Scottish Ministers,
  - (c) in the case of a licence in respect of such activities and a controlled place only part of which is in, under or over that territorial sea, either the Secretary of State or the Scottish Ministers, and
  - (d) in the case of a licence in respect of activities within section 17(2)(d), whichever of the Secretary of State or the Scottish Ministers licenses the activities for the purposes of which the installation is established or maintained; and in this Chapter references to the licensing authority in relation to a licence falling within paragraph (c) are references to the person who grants the licence or, if the licence has not yet been granted, to whom the application for the licence was made.
- (3) The controlled place in respect of which a licence is granted may be determined by reference to the provisions of a Crown lease which has been or may be granted.
- (4) For this purpose a “Crown lease” means a lease of property forming part of the Crown Estate, or an authorisation to exercise rights forming part of that Estate (whether by virtue of section 1 or otherwise).

**DIRECTIVE 2009/31/EC OF THE EUROPEAN PARLIAMENT AND OF THE  
COUNCIL**  
**of 23 April 2009**  
**on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC,  
European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC,  
2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006**

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 175(1)

Having regard to the proposal from the Commission,

Having regard to the opinion of the European Economic and Social Committee(1)

After consulting the Committee of the Regions,

Acting in accordance with the procedure laid down in Article 251 of the Treaty(2)

*Article 18*

**Transfer of responsibility.**

Where a storage site has been closed pursuant to points (a) or (b) of Article 17(1), all legal obligations relating to monitoring and corrective measures pursuant to the requirements laid down in this Directive, the surrender of allowances in the event of leakages pursuant to Directive 2003/87/EC and preventive and remedial action pursuant to Articles 5(1) and 6(1) of Directive 2004/35/EC, shall be transferred to the competent authority on its own initiative or upon request from the operator, if the following conditions are met:

- (a) all available evidence indicates that the stored CO<sub>2</sub> will be completely and permanently contained;
- (b) a minimum period, to be determined by the competent authority has elapsed. This minimum period shall be no shorter than 20 years, unless the competent authority is convinced that the criterion referred to in point (a) is complied with before the end of that period;
- (c) the financial obligations referred to in Article 20 have been fulfilled;
- (d) the site has been sealed and the injection facilities have been removed.

The operator shall prepare a report documenting that the condition referred to in paragraph 1(a) has been met and shall submit it to the competent authority for the latter to approve the transfer of responsibility. This report shall demonstrate, at least:

- (a) the conformity of the actual behaviour of the injected CO<sub>2</sub> with the modelled behaviour;
- (b) the absence of any detectable leakage;
- (c) that the storage site is evolving towards a situation of long-term stability.

The Commission may adopt guidelines on the assessment of the matters referred to in points (a), (b) and (c) of the first subparagraph, highlighting therein any implications for the technical criteria relevant to the determination of the minimum periods referred to in paragraph 1(b).<sup>3</sup> Where the competent authority is satisfied that the conditions referred to in points (a) and (b) of paragraph 1 are met, it shall prepare a draft decision of approval of the transfer of responsibility. The draft decision shall specify the method for determining that the conditions referred to in paragraph 1(d) have been met as well as any updated requirements for the sealing of the storage site and for the removal of injection facilities.

If the competent authority considers that the conditions referred to in points (a) and (b) of paragraph 1 are not met, it shall inform the operator of its reasons.

**Draft decision -/CMP.7**

**Modalities and procedures for carbon dioxide capture and storage in geological formations as clean development mechanism project activities**

*The Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol,*

*Recalling* the provisions of Articles 3 and 12 of the Kyoto Protocol,

*Also recalling* decisions 3/CMP.1, 2/CMP.5 and 7/CMP.6,

1. *Adopts* the modalities and procedures for carbon dioxide capture and storage in geological formations as clean development mechanism project activities contained in the annex to this decision;
2. *Decides* to periodically review the modalities and procedures for carbon dioxide capture and storage in geological formations as clean development mechanism project activities and that the first review shall be carried out no later than five years after the adoption of this decision, on the basis of recommendations made by the Executive Board of the clean development mechanism and by the Subsidiary Body for Implementation, and drawing on technical advice provided by the Subsidiary Body for Scientific and Technological Advice, as needed;
3. *Further decides* that any revision of the modalities and procedures contained in the annex to this decision shall not affect clean development mechanism project activities already registered in accordance with these modalities and procedures or any project activities registered in accordance with the modalities and procedures contained in the annex to decision 3/CMP.1 or the annex to decision 5/CMP.1;
4. *Agrees* to consider, at its eighth session:
  - (a) The eligibility of carbon dioxide capture and storage project activities which involve the transport of carbon dioxide from one country to another or which involve geological storage sites that are located in more than one country;
  - (b) The establishment of a global reserve of certified emission reduction units for carbon dioxide capture and storage project activities, in addition to the reserve referred to in paragraph 21(b) of the annex to this decision;
5. *Requests* the Subsidiary Body for Scientific and Technological Advice to consider, at its thirty-sixth session, provisions for the type of project activities referred to in paragraph 4(a) above, including a possible dispute resolution mechanism, and for the global reserve of certified emission reduction units referred to in paragraph 4(b) above, with a view to forwarding a draft decision on these matters for consideration by the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol at its eighth session;
6. *Invites* Parties and admitted observer organizations to submit to the secretariat, by 5 March 2012, their views on the issues referred to in paragraph 4(a) and (b) above and requests the secretariat to compile the submissions into a miscellaneous document.

## **Monitoring**

16. The monitoring of the geological storage site shall:

- (a) Begin before injection activities commence, to ensure adequate time for the collection of any required baseline data;
- (b) Be conducted at an appropriate frequency during and beyond the crediting period(s) of the proposed project activity;
- (c) Not be terminated earlier than 20 years after the end of the last crediting period of the CDM project activity or after the issuance of CERs has ceased, whichever occurs first;
- (d) Only be terminated if no seepage has been observed at any time in the past 10 years and if all available evidence from observations and modelling indicates that the stored carbon dioxide will be completely isolated from the atmosphere in the long term. This may be demonstrated through the following evidence:
  - (i) History matching confirms that there is agreement between the numerical modelling of the carbon dioxide plume distribution in the geological storage site and the monitored behaviour of the carbon dioxide plume;
  - (ii) Numerical modelling and observations confirm that no future seepage can be expected from the geological storage site.

## **Liability**

22. The project participants shall clearly document in the project design document how the liability obligations arising from the proposed CCS project activity or its geological storage site, as defined in paragraph 1(j) of the annex above, are allocated during the operational phase, closure phase and post-closure phase in accordance with this decision.

23. Relevant provisions of laws and regulations of the host Party, including those referred to in paragraph 8 of the annex above, shall apply to matters related to liability.

24. During the operational phase and any time thereafter until a transfer of liability to the host Party has been effected in accordance with paragraph 25 below, liability, as defined in paragraph 1(j) of the annex above, shall reside with the project participants.

25. A transfer of liability from the project participants to the host Party shall be effected after:

- (a) The monitoring of the geological storage site has been terminated in accordance with the conditions for the termination of monitoring, as set out in paragraph 16 above;
- (b) The host Party has established that the conditions set out by the designated national authority in its letter of approval, referred to in paragraph 11 of the annex above, and those set out in the relevant laws and regulations applicable to the geological storage site have been complied with.

## **Annex 2. List of interviewees and contributors**

### **Brazilian experts**

<b>Name</b>	<b>Filiation</b>
Adriano Oliveira	Ministry of the Environment – MMA
Ana Nusdeo	Faculty of Law at the University of Sao Paulo - FADUSP
Bruno Sabbag	Ex-Brazilian Negotiator under the UNFCCC
Carlos Victal	Brazilian Petroleum Institute - IBP
Edson Montez	National Agency of Petroleum, Natural Gas and Biofuels - ANP
Elizabeth Meirelles	Faculty of Law at the University of Sao Paulo - FADUSP
Emílio la Rovere	Federal University of Rio de Janeiro - COPPE/UFRJ
Fernando Zancan	Brazilian Coal Association - ABCM
George Camara	Consultant and CCS expert
Isabella Costa	Ministry of Science, Technology and Innovation - MCTi and COPPE/UFRJ
Jefferson Soares	Energy Research Company - EPE
João Marcelo Ketzer	Center of Excellence in R&D in Petroleum, Mineral Resources and CCS - CEPAC
José Miguez	Ministry of the Environment – MMA
Josilene Ferrer	Environmental Company of Sao Paulo State - CETESB
Leandro Valentim	Brazilian Institute of Environment and Renewable Natural Resources - IBAMA
Marcelo Poppe	Center for Strategic Studies and Management - CGEE
Paulo Negrais	Petrobras Research & Development Center – Cenpes/Petrobras
Silvia Nascimento	Sao Paulo State Environment Secretariat - SMA-SP
Wilson Grava	Petrobras Research & Development Center – Cenpes/Petrobras

### **International experts**

<b>Name</b>	<b>Filiation</b>
Andrew Gilder	South African Law Firm ENSafrica
Andrew Ivory	Australian Government - Department of Industry
Brendan Beck	South African Centre for Carbon Capture and Storage - SACCCS
Chris Hendrix	Ecofys Consultancy



Craig Hart	School of Environment & Natural Resources, Renmin University of China
David Reiner	United Kingdom University of Cambridge
Jason Toner	Canadian Sustainable Energy Branch – Government of Alberta
Jessica Morton	Global Carbon Capture and Storage Institute – GCCSI
Jim Dooley	Joint Global Change Research Institute – JGCRI
Meade Harris	Global Carbon Capture and Storage Institute – GCCSI
Mette Agerup	Norwegian Ministry of Petroleum and Energy
Moisés Dávila	Mexican Ministry of Energy
Pamela Tomski	United States EPA Research Experience in Carbon Sequestration and GCCSI
Ricardo Esposito	United States Southeast Regional Carbon Sequestration Partnership - SECARB
Sarah Forbes	World Resources Institute – WRI
Sean McCoy	International Energy Agency – IEA
Thomas Bosecke	German Federal Ministry of Environment
Tim Dixon	International Energy Agency Greenhouse Gas R&D Programme - IEAGHG
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Xiaoliang Yang	Chinese Office of the World Resources Institute