UNU-IAS Working Paper No. 172

Status of CCS Technology in Japan and Brazil: A Comparative Analysis

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April 2013
Abstract
This article presents a comparative analysis of the technology status of Carbon Capture and Storage (CCS) in Japan and Brazil. Japan’s Greenhouse Gas (GHG) emissions had a declining trend until 2009 while Brazil’s had an increasing trend. Among Environmentally Sound Technologies (ESTs), the potential of CCS for GHG emissions mitigation has gained prominence. This research identifies the main activities, positions and contrasts of the actors involved in CCS technology implementation in Japan and Brazil. This analysis is based on literature review and a field survey done to collect primary data via visits to relevant organizations and experts. This data was enhanced by an analysis of patent deposits in the area of CCS in the two countries in the last twenty years. Regarding the legal framework for climate change, and CCS in particular, while responses to the main international decisions can be found in Japan, this is not the case in Brazil. In Japan, the public sector effectively cooperates together with the private sector and civil society. In Brazil, CCS activities are conducted by the private sector, which in turn puts pressure on civil society, in particular on academia. Currently, Japan is focusing on CCS capture technologies, while Brazil is focusing on CCS storage technologies. In summary, the CCS framework is currently carried out more efficiently in Japan than in Brazil.

Keywords: CCS Technology, Environmentally Sound Technologies, Climate Change, Japan and Brazil
1. Introduction

Over the last two decades, considerable effort in Science & Technology (S&T), Research & Development (R&D), and Engineering & Innovation (E&I) has been directed towards issues regarding carbon dioxide (CO\textsubscript{2}) emissions and their consequences on the climate of the planet. With the advancement of monitoring technologies and simulators of climate change, both the public sector as well as the private sector or non-profit organizations tend to agree about the impacts of anthropogenic activities on the climate of the planet.

Among the currently available technologies recognized for combating CO\textsubscript{2} emissions such as renewables, nuclear energy, power generation efficiency & fuel switching, end-use fuel switching, end-use electricity efficiency, and end-use fuel efficiency, the potential of CO\textsubscript{2} emissions mitigation with Carbon Capture and Storage (CCS) has gained prominence.

CCS technologies encompass a process that consists of separating, collecting and concentrating CO\textsubscript{2} emitted by stationary sources, transporting it to a suitable storage site, and storing it at the site for a long period, thus isolating it from the atmosphere (IPCC, 2005). Specifically for storage of CO\textsubscript{2}, the potential storage methods include geological storage, ocean storage (direct release into the ocean water column or onto the deep sea-floor), and industrial fixation of CO\textsubscript{2} in inorganic carbonates (IPCC, 2005).

Bachu and McEwen (2011) noted that various terms are used to describe CO\textsubscript{2} storage: CO\textsubscript{2} sequestration is used in the USA, CO\textsubscript{2} storage is used by UN agencies and in Europe, and terms such as CO\textsubscript{2} removal and CO\textsubscript{2} disposal are also used. Among the CO\textsubscript{2} storage options, one that is in a demonstration stage is geological storage. The IPCC (2005) defines geological reservoirs as a subsurface body of rock with sufficient porosity and permeability to store and transmit fluids.

CCS is important, because it can be implemented at existing and future sites. Furthermore, according to the International Energy Agency (IEA), CCS can control emissions in the short to medium term using technologies that are currently available or likely to become commercially available. Adequate CO\textsubscript{2} capture and storage can contribute to a 19 per cent worldwide reduction of total CO\textsubscript{2} emissions by 2050 (in BLUE Map scenario). This would represent 11.78 Gt (gigatonnes) reduction in 2050 in relation to the baseline emissions of 62 Gt (IEA, 2008). In a specific CCS study carried out by IEA in 2009 (IEA, 2009), it was said that in 2020 50 out of the 100 CCS projects worldwide would be in non-OECD countries, and in 2050 the forecast is 2,210 out of 3,400 projects worldwide.
However, among the solution technologies available, perhaps the wide use of CCS technologies is the most complex, as it does not depend on the efforts of one actor alone, but on united efforts. The success of the implementation of CCS technologies calls for the involvement of the public sector, private sector and civil society. When one of these actors is not involved due to principles or other priorities, it is certain that CCS projects will be unsuccessful.

Understanding the public sector as governments and its regulatory agencies, and the private sector as companies, and finally, civil society as academia, non-governmental organizations (NGOs) and society, Figure 1 shows the main issues identified for CCS among these actors.

![Figure 1: Main issues for CCS among the actors](image)

**Source:** Author’s Own.

In many cases, the large-scale use of CCS varies according to each country. Principally, when a comparative analysis of the CCS technologies status for implementation on a large scale between developed countries (Annex 1 Parties of the Kyoto Protocol) and developing countries (non-Annex 1 Parties of the Kyoto Protocol) is made, according to Román, CCS becomes a political and strategic issue, rather than simply a technological solution to a problem (Román, 2011). It is therefore important to analyse the evolution and success or failure of CCS large-scale use in Annex 1 and non-Annex 1 countries.
1.1 Justifications and Methods

There are various CCS projects. The existing data highlights that while some common strategies exist, there is no single set of public engagement activities that is relevant and applicable for each project. Each project requires a tailored approach based on specific community attributes and needs (Global CCS Institute). According to the Global CCS Institute, 26 CCS projects around the world have been canceled or delayed due to issues such as regulatory, financial, technical and public acceptance issues (Global CCS Institute). This paper aims to identify the gaps among actors to deploy successfully CCS projects for large-scale use.

The research group’s understanding is that the large-scale use of CCS technologies is critical for changing the current model of high-carbon intensive activity for a green economy. Batista (1993) suggests that before new and better environmental technologies become the norm, the market has to go through a transition period between the old modes of production using end-of-pipe technologies, and new, cleaner technologies, while seeking environmental practices that promote cleaner development. Thus, in any analysis of the diffusion of CCS technologies in developing countries it is vital to identify the gap and propose solutions for problems such as regulatory framework.

This paper shows a comparative analysis between the current situations of CCS technology implementation in Japan and in Brazil. Japan was chosen because among the developed countries it does not have a demonstrative or commercial large-scale CCS project, which makes it a suitable comparative reference for developing countries that are at the same stage, unlike other developed countries such as the USA, Canada or Norway that are more advanced in CCS technology implementation on a large scale. The choice of Brazil is associated with the current economic status of the country: the forecast for increased energy requirements in association with population increase, the recent discovery of the large Pre-salt cluster oil and gas field, and the Brazilian capacity for CO₂ storage.

Research was carried out in the two countries using exploratory, descriptive and analytical research methods that focus on qualitative and quantitative data. Primary data was collected through visits to companies/institutions and consultations with specialists such as researchers and stakeholders. Indirect observations came from participating in discussions and lectures on the subject of study and in forums with domain experts. Furthermore, participating in official

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1 In the current Petrobras exploratory context, the term pre-salt refers to a group of rocks located in the marine portions of the Brazilian coast, between the States of Santa Catarina and Espírito Santo, with potential for the generation and accumulation of oil beneath a wide salt layer which reaches, in some places, a thickness of 2,000 m. In particular, the area known as the Santos Basin Pre-Salt Cluster (SBPSC) is located in ultra deep water, between 1,900 and 2,400 m, about 290 km off the Rio de Janeiro coast, Southeast Brazil (Almeida et al., 2010).
meetings, with the approval of relevant authorities, and recording the results were very useful. Secondary data such as institutional documents, reports, studies, and projects were collected from various resources and analysed. This data was supplemented by a patent deposit analysis on CCS technologies in the two countries over the last twenty years.

This paper provides an introduction that addresses the most recent concepts and issues about climate change and global environmental governance. After the introduction, the current situation related to CO₂ emissions in the two countries in question is described. The results and discussions are presented through a comparative analysis of CCS technologies in Japan and Brazil from the perspectives of the public sector, private sector and civil society. Finally, the paper concludes with an overview of the outcome and main gaps found.

2. Current Situation Related to GHG Emissions in Japan and Brazil

The countries researched are currently among the 10 biggest economies in the world. Figure 2 shows the Gross Domestic Product (GDP) of Japan and Brazil in comparison with the other main economies in the world. Japan is the second economy among developed countries and Brazil is the fourth among developing countries.

![Gross Domestic Product (purchasing power parity) per Country plus European Union in 2011 by CIA](image)

**Figure 2:** Gross Domestic Product (purchasing power parity) per Country plus European Union in 2011 by CIA

**Source:** Author’s own, based on data from the CIA

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Regarding Greenhouse Gas (GHG) emissions, both countries have published their GHG national inventories. However, due to being an Annex 1 nation, Japan annually elaborates its GHG national inventory (Japan Ministry of the Environment, 2011) while Brazil elaborated a more complete GHG national inventory in 2009 (Brazil, Coordenação-Geral de Mudanças Globais do Clima Ministério da Ciência e Tecnologia, 2010). Furthermore, both countries reported their GHG emissions for the United Nations Framework Convention on Climate Change (UNFCCC) according to the Kyoto Protocol. Because Japan is in Annex 1 of the Kyoto Protocol it has a GHG emissions target with 1990 emissions as a reference. The target given to Japan for the first commitment period (five years from 2008 to 2012) is to reduce average emissions of GHG by six per cent from the base year (1990 for CO₂, methane and nitrous oxide, and 1995 for HFCs, PFCs, and sulfur hexafluoride).

Brazil does not have a target because it is not in Annex 1 of the Kyoto Protocol, but in 2010 the Brazilian government sent its Nationally Appropriate Mitigation Actions (NAMAs) to the UNFCCC. In this document the Brazilian government established its GHG emissions target for reduction between 36.1 and 38.9 per cent projected GHG emissions for 2020. Figure 3 shows the GHG emissions situation in Japan and Brazil according to national inventories and the UNFCCC documents ³ elaborated with global warming potential (GWP) values.

³ The country targets adopted in this work were obtained from official documents issued by the Embassy of Japan in Germany (Note Verbale) to UNFCCC in 26 January 2010, and from the Embassy of the Federative Republic of Brazil to UNFCCC in 29 January 2010. The Japanese document establishes a 25 per cent emissions reduction in 2020 (base year – 1990), which is premised on the establishment of a fair and effective international framework in which all major economies participate and in agreement with those economies on ambitious targets. After the Great East Japan Earthquake in 2011 and the nuclear power plant accident in Fukushima the Japanese government submitted the document Clarification of Quantified Economy-Wide Emission Reduction Targets to UNFCCC.
It can be seen in Figure 3 that there are differences between Japan’s GHG emissions and Brazil’s GHG emissions. The data for Japan indicates that the effort to reduce GHG emissions has had results and it can achieve the established targets. While for Brazil, the data indicates that there is an increase in GHG emissions and it will require great effort to achieve the established targets.

It is also interesting to examine CO₂ emissions per capita. CO₂ emissions per capita in Japan in 2005 were 10.04 tonnes (Japan Ministry of the Environment, 2011) while in Brazil CO₂ emissions per capita in 2005 were 9.10 tonnes (Brazil, Coordenação-Geral de Mudanças Globais do Clima Ministério da Ciência e Tecnologia, 2010). It is important to emphasize that the population in Brazil will continue to increase until 2020 (see Figure 4) and the Japanese population will remain stable. This means that Brazil will have to work harder to reduce GHG emissions. Another aspect that needs to be analysed in Brazil’s current GHG emissions situation is the growing need for energy. According to The National Energy Plan – 2030 (Brazil, Ministério de Minas e Energia, 2007), in 2030 Brazil will need 557 Mtoe (Mega tonnes of oil equivalent) which would be an increase of 237 per cent in 23 years (in
2007, 239 Mtoe was supplied). In this plan the proportion of renewable power generation will increase from 46 per cent in 2007 (110 Mtoe) to 46.5 per cent in 2030 (259 Mtoe). The highest growing energy source is natural gas which will rise from 9.29 per cent in 2007 to 15.5 per cent in 2030. This is related to the recent discovery of oil and gas fields offshore, the Pre-salt cluster with reserves currently estimated at 14 billion barrels (IEA, 2011). This discovery will put Brazil among the biggest hydrocarbon producers in the world. However, the initial test in Pre-salt reservoirs, specifically at Tupy, shows that the presence of CO₂ in natural gas is between 8–12 per cent (Almeida, 2010). This percentage is considered significant in comparison with the composition of other hydrocarbons.

To achieve the national GHG emissions reduction targets, Brazil has elaborated a legal framework for climate change. In this legal framework, Brazil launched the National Plan on Climate Change that resulted in the National Policy on Climate Change which established the GHGs emissions reduction targets, two climate change funds and the Brazilian Panel on Climate Change. This framework is shown in Figure 4, and it is possible to observe that the Brazilian legal framework for climate change is recent, e.g. the National Plan was launched in 2007 and the National Policy in 2009 after COP15 in Copenhagen.

In addition to the framework for legal climate change, there are other initiatives in Brazil in the energy sector operated by the Brazilian government. Although these initiatives are older than the National Plan on Climate Change, they are very important. Among these initiatives, a few can be highlighted, such as CT-Petro (R&D in oil and gas sector) created in 1999, PROINFA - Alternative Energy Source Incentive Program, created in 2002, PROCEL (National Energy Conservation Program), created in 1985 and Federal Oil & Gas and Biofuels Agency (ANP) – Ordinance number 10 from 1999.
The Japanese legal framework for climate change issues began in 1990 with the Action Plan to Arrest Global Warming. In 1993 the Guideline for Measures to Prevent Global Warming (National Guideline 93) was established. After the adoption of the Kyoto Protocol by the Japanese government, the Law Concerning the Promotion of Measures to Cope with Global Warming was formulated in 1998. In this year, the Energy Conservation Law was reviewed and the Act on Promotion of Global Warming Countermeasures was approved. In 2002, the Act on Promotion of Global Warming Countermeasures and Energy Conservation Law were amended after the ratification of the Kyoto Protocol by the Japanese government.

After entering the Kyoto Protocol, the Japanese government launched the Kyoto Protocol Target Achievement Plan in 2005 and another amendment in the Energy Conservation Law was made. The plan was partially revised in 2006 and totally revised in 2008. In July 2008, the Japanese government launched the Action Plan for Achieving a Low-carbon Society.

It is important to emphasize the other Japanese governmental initiatives for the main sectors responsible for GHG emissions. These include the Basic Act on Energy Policy, Biomass Nippon Strategy, Strategic Technology Roadmap (Energy Sector), Law Concerning the Rational Use of Energy, Top Runner Programme, and Cool Earth Innovative Energy
Technology Programme. In Japan there are obligations stipulating target reductions on local governments and co-operation with developing countries.

It can be seen that the Japanese legal framework for climate change basically follows main international climate change events. Figure 5 shows, in chronological order, the relationship between international climate change events and the evolution of the Japanese legal framework for climate change. The development of Japan’s overall policy framework to tackle climate change has been a slow, gradual process (Tamura), unlike what has happened in Brazil.

![Figure 5: Policies and Strategies on Climate Change in Japan](http://www.unep.org/DEC/PDF/Casestudies/CCJapandraft.pdf) (accessed in May 2012).

**Source:** Author’s own based on Figure 2 from the study “Strengthening Legal and Policy Frameworks for Addressing Climate Change in Asia: Japan” (draft for discussion purposes only)4

### 3. Comparative Analysis of CCS Technologies in Japan and Brazil

There are currently five CCS projects in operation around the world (in Salah, Algeria; Sleipner and Snøhvit, Norway; Rangely, the United States; and Weyburn-Midale, Canada and the United States) (IEA, 2010). These projects encompass all aspects of CCS, namely capture, separation, transport and storage. According to the International Energy Agency (IEA) 19–43 projects will be in operation by 2020. Among these projects the Japanese government has committed itself to 1–2 projects worth USD 0.1 billion (IEA, 2010).

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4 This study was elaborated by Kentaro Tamura - Institute for Global Environmental Strategies (IGES). http://www.unep.org/DEC/PDF/Casestudies/CCJapandraft.pdf (accessed in May 2012).
In its study “IEAGHG, ‘Global Storage Resource Gap Analysis for Policy Makers’, 2011/10, September, 2011” the IEA Greenhouse Gas R&D Programme (IEAGHG) presented a list of selected CCS projects for 2020 recommendation. The projects were selected from available databases (IEAGHG, Global CCS Institute, MIT, Bellona, Scottish Centre CCS and CO2CRC) based on their status in February 2011 for bankability status on the 2015–17 horizon (IEAGHG, 2011). 124 potential bankability CCS projects were selected, 3 in Brazil and none in Japan.

In the IEA Blue Map scenario, it is expected that CCS technologies will capture over 10 Gt of CO₂ emissions in 2050, with an accumulative storage of around 145 GtCO₂ from 2010 to 2050 (IEA, 2009). The CO₂ storage capacity of the world, considering all geological storage options, is between 1,678 Gt (lower estimate) and 101,100 Gt (upper estimate), including storage options that are not economical (IPCC, 2005). The geological storage capacity in Japan is 146.1 GtCO₂ (Ohsumi, 2007) and the capacity in Brazil is more than 2,035 GtCO₂ (Rockett et al., 2011).

The geological storage capacity potential of Japan and Brazil can play an important part in reducing GHG emissions due to their economic situation and, consequently, the existing anthropogenic stationary GHG emissions sources. However, the CCS activities in both countries are recent in comparison with other countries such as the US, Canada and Norway. In Japan, CCS activities began in 1988 with the investigation on “Direct Ocean Disposal of Carbon Dioxide” in several laboratories (Ohsumi, 2007). While in Brazil, CO₂ injection tests were carried out in 1991 by Petrobras (Lino, 2005).

Currently, both countries have carried out several CCS activities such as R&D, roadmaps and pilot projects. The pilot project carried out in Nagaoka, Japan injected CO₂ from 2003 to 2005 into a gas field onshore (RITE, n.d.) and another pilot project was carried out near Yubari city, in the Ishikari Coal Basin in Hokkaido. Both were small-scale projects.

In Brazil there were two pilot projects. The Petrobras Miranga Project contemplated three different storage scenarios: enhanced oil recovery (EOR), depleted gas reservoir, and saline aquifer (Beck et al., 2011). The Centre of Excellence in Research on Carbon Storage (CEPAC) carried out another Brazilian pilot project with support from Petrobras and Copelmi (a Brazilian coal-producing company). The CEPAC Carbometano Porto Batista Project is under development to investigate enhanced coal bed methane recovery (ECBM) (Beck et al., 2011).
While the CCS activities in both countries are at similar stages, there are relevant differences in the application of the CCS technologies. In Japan, the public sector effectively participates together with the private sector and civil society, whereas in Brazil CCS activities are carried out by the private sector, which in turn puts pressure on the civil society, in particular on academia. Although CCS is not receiving the necessary attention from the Brazilian public sector, the development of CCS technologies is important in order to pursue a low carbon economy in Brazil. CCS technologies are considered one of the most significant measures for emission reduction in the Brazilian industrial sector (Lampreia et al., 2011).

3.1 Public Sector

Public sector interest in several issues concerning CCS via policies, strategies and actions to address the issue in question can be found, especially with regard to GHG emissions issues. Countries have had to take a position in international forums such as the Conferences of the Parties (COP) to the UNFCCC. For example, recently at COP 16 held in Cancun, Mexico, CCS technologies were considered eligible under the Clean Development Mechanism (CDM), but before the decision, the UNFCCC had consulted several countries and organizations about this inclusion.

The Japanese government supported the adoption of the inclusion of CCS under CDM. In addition to CCS efforts being led by developed countries, there has also been a rapid spread of CCS technologies among developing countries. CCS under CDM will enable the effective transfer of the technological, human and financial resources from developed countries to developing countries (UNFCCC, 2011). The Brazilian government is not against the use of CCS, but it believes that CCS is not eligible as a CDM for several reasons. These include the lack of expertise in the implementation of CCS in developing countries, the high costs of dissemination and technology transfer, the evaluation of environmental impact, as well as the process being capital and technology intensive (UNFCCC, 2010).

According to the Brazilian government, CCS is typically a transitional technology to be used by an economy based on fossil fuels transitioning towards a low-carbon economy. The Brazilian government recognizes that CCS may be useful. Thus, CCS technology could be considered until countries have full confidence in renewable energy. However, CCS under CDM would result in perverse incentives for increased production of fossil fuel energy in developing countries, which would enhance the existing technological gap between the developed and developing world (UNFCCC, 2010).

The Brazilian Climate Change National Plan stipulates that CCS technologies have to be and will be developed by the Brazilian private sector to continue to be able to sustain its viability.
The magnitude of GHG emissions, due to expected growths in the oil and gas industries in the next few years, will require the use of large-scale mitigation technologies as CCS technology. However, costs are still very high, requiring more investment in new and cheaper technologies. Besides, it is a technology in development and calls for new ways to promote it (BRAZIL, 2009).

The government’s participation in the promotion of CCS technologies cannot resume with only the private sector responsible for implementation of the technology. For CCS technologies to succeed, it is necessary for governments to promote a favourable environment for it. This should include policies and laws (GHG emissions reductions targets), a CCS regulatory framework, participation in international agreements, investments, prioritizing CCS technologies in mitigation technologies, support in R&D and pilot projects, and if possible, the development of a carbon trade scheme and taxes. It can be said that government participation is critical for the success of CCS technologies.

According to the IEA (2012), CCS technologies are critical for achieving the targets of the 2 degrees scenario (Energy Technology Perspectives 2012 2°C Scenario). The current funding and policy environment represents a very serious challenge, as sustained effort by governments around the world is needed to promote CCS. The number of large, integrated operational projects remained constant throughout 2011, which was the result of new projects entering the development pipeline and cancellations of existing projects. Given the high capital cost, risks associated with initial projects and the fact that CCS is motivated primarily by climate policy, the technology needs strong government backing by way of CO₂ emissions-reduction policies and dedicated demonstration funding (IEA, 2012).

Table 1 shows the main work done by the Japanese and Brazilian governments to promote the implementation of CCS technologies related to the main CCS technology issues. From an overview of the number and importance of the work in Japan, it can be seen that the Japanese government is more interested in the implementation and diffusion of CCS technologies.

**Table 1**: Government participation in CCS critical issues and its intensity

<table>
<thead>
<tr>
<th>Japan</th>
<th>CCS Issues &amp; Intensity</th>
<th>Brazil</th>
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<td></td>
</tr>
<tr>
<td>Marine Pollution Act (Law relating to the Prevention of Marine Pollution and Marine Disaster) and Desirable Safety and Environmental Standards for the Implementation of CCS.</td>
<td>CCS Framework Regulatory</td>
<td></td>
</tr>
<tr>
<td>The Japanese government has budgeted USD 116 million for study on large-scale CCS demonstration since fiscal year 2008 (FY 2008). Government subsidy via the Japan CCS Company USD 208.2 million. Australian Callide Oxyfuel Project USD 32 million. Existing tax incentives available from the MOE for the development of technology to combat global warming (inclusive CCS technologies).</td>
<td>Investments</td>
<td></td>
</tr>
<tr>
<td>Action Plan for Building a Low Carbon Society, 2008: - CCS technology has the potential for massive emissions reductions in thermal power generation, which accounts for roughly 30 per cent of Japan’s emissions, and in the steelmaking process, which accounts for roughly 10 percent; - Japan will commence verification test on large scale at an early stage from 2009 onward and implementation by 2020; - Japan is working to resolve issues such as enhancing environmental impact assessments and monitoring, putting legislation in place, and ensuring public approval'. Strategic Technology Roadmap (Energy Sector) – Energy; Technology Vision 2100 - METI, 2005; Cool Earth-Innovative Energy Technology Program</td>
<td>Priorities</td>
<td></td>
</tr>
<tr>
<td>According to National Policy on Climate Change the Brazil priorities are: Land Use - Amazon Deforestation and Cerrado Deforestation; Agriculture and Cattle-Raising - Pasture Recovery, Agriculture-Cattle Integration, No-till Farming, Biological Nitrogen Fixation; Energy - Energy Efficiency; Biofuel Implementation Use, Energy Supply Expansion of Hydroelectricity, Alternative Source; Other - Ironworks – Replace coal with charcoal</td>
<td></td>
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</tbody>
</table>

Indirect investments for oil & gas private sector companies as Petrobras via ANP Ordinance 10/99 - set a tax of 1 per cent on oil & gas production has be invested in R&D
As major world events related to GHG emissions directly reflect the policies and laws of Japan, the same can be said of CCS technology. The main CCS policy established by the Japanese government in July 2008 (Action Plan for Achieving a Low-carbon Society) is connected to the G8 decision made in June 2008 in Hokkaido, Japan. In this meeting, the G8
decided to support the recommendations of the IEA and the Leadership Forum on Carbon Sequestration (CSFL) on the execution of 20 projects involving CCS on a large scale, because they believed that CCS would play a critical role in combating climate change and meeting energy security challenges (G8 2008 Summit, 2008). It is necessary to highlight that this G8 decision did not influence the Brazilian government’s position on CCS technologies.

After primary data collection of the organizations, it is possible to say that the Japanese government’s main structure for CCS technologies is composed of the Ministry of Economy, Trade and Industry (METI), responsible for policies, guidelines and implementation of the large-scale demonstration projects. Supervised by METI, there is the New Energy and Industrial Technology Development Organization (NEDO) that conducts various activities focusing on research and development related to oil-alternative energy technology, technology for the efficient use of energy, and industrial technology, in particular about CCS technologies conducting the zero-emission coal thermal power technology development project, and the Research Institute of Innovative Technology for the Earth (RITE).

RITE was launched in July 1990 to implement the Japanese government plan “New Earth 21” as a foundation based on the Civil Code. Currently RITE is considered an institution of public interest. RITE recognizes global warming and considers the economic development of developing countries the key factor in this problem. However, another important factor is the barrier set for nuclear expansion since the accident of Fukushima Daiichi nuclear power plant. RITE focuses on developing technologies for mitigating global warming, particularly those of CCS. At present, RITE is carrying out the Nagaoka CCS demonstration project, CO₂ geological storage capacity study, research on separation technologies: membranes and absorbents, ocean sequestration R&D and workshops and symposiums. The other public research institution is the National Institute of Advanced Industrial Science and Technology (AIST), which is carrying out research on CO₂ storage and fixation capability evaluation, underground storage and ocean sequestration.

In addition to R&D in Japan, the Japanese government has established international partnerships and bilateral agreements with a focus on CCS technologies:
- Asia-Pacific Partnership on Clean Development and Climate (APP)
- The Global CCS Institute (the Japan Regional Office opened in February 2012)
- Japan-EU Cooperation on Energy Technology
- Japan-US CCS Cooperation Meeting

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5 Data collected from interviews and organization’s publication such as the institutional journal “RITE Today”, 2012, vol. 7 Annual Report in http://www.rite.or.jp/index_e.html, accessed in May 2012.
Joint statement on the enhancement of cooperation on climate change and energy security by the Japanese and Australian governments
Demonstrative project of oxyfuel CCS in Australia
Demonstration study on CCS-EOR for coal fired power plants in China
Feasibility study of CCS and EOR in Indonesia by METI

3.2 Private Sector
The private sector is led by profit. Nowadays with the increase in discussions about environmental issues the private sector is taking this into consideration. This is due to an increased awareness in the private sector about social responsibility and/or public image. According to Porter and Brown (1996) the production sector has historically been seen as an opponent of national environmental policies and global and environmental issues, and as a threat to competitiveness due to the imposition of additional costs. However, most of the R&D in environmental technologies can be found in the private sector.

The participation of the private sector in environmental technologies should be supported by the public sector via a well-built political structure and strategies. If the public sector wants to impose taxes, fines and a legal framework, then it has to clarify priorities, make public investment and create incentives and market instruments such as carbon markets. As well as this, it is important to create an atmosphere of innovation in order to attract the private sector to large-scale use of environmental technologies as this is the main sector responsible for the spread of environmental technologies.

3.2.1 Japanese Private Sector
The development of CCS technologies in Japan has occurred with interaction between the public sector and private sector. Government policies and strategies have a direct influence on the private sector. For example, after the launch of the “Cool Earth 50” by the government in May 2007, the steel industry and the public sector co-organized the initiative COURSE 50 (CO₂ Ultimate Reduction in Steelmaking Process by Innovative Technology for Cool Earth 50). COURSE 50 comprises six steel companies, NEDO and a joint implementation with seven universities, two companies and RITE. The active participation of the government in R&D CCS technology activities has also occurred in other private sectors such as energy, principally in coal powered energy. There are subsidies via METI and NEDO for Japan Coal Energy Center (JCOAL).

Many actions for the development of CCS technologies in Japan traditionally have focused on CO₂ capture and separation from stationary sources. In May 2008, the private sector founded Japan CCS Co. Ltd. (JCCS). JCCS consists of 36 shareholder companies: 11
electricity companies, 4 petroleum, 5 engineering, 4 petroleum resource developing, 5 trading, 2 iron and steel, 2 gas utilities, 1 chemical, 1 nonferrous metal and cement and 1 steel pipe industry. These companies are responsible for providing investment and personnel. JCCS is contracted by the Japanese government via METI and NEDO for the development of CCS projects. Furthermore, JCCS interacts directly with civil society through their research actions. Figure 6 shows the framework of the JCCS project. Currently the main projects are the site characterization for CO₂ storage (Tomakomai project, Kitakyushu project, Nakoso-Iwaki Oki project) and the Combined IGCC and CCS Feasibility Study in Fukushima.

**Figure 6:** Project Framework  
**Source:** Image provided by Japan CCS Co during visit to company

The interaction between the public sector and the private sector in Japan can be seen here. This interaction is not via fines or taxes but via investment and incentives. The Japanese
private sector also participates in multinational CCS projects such as in Salah in Algeria and it has also done international partnerships such as in the Callide Oxy Fuel Project. Table 2 shows the main CCS technology work done by the Japanese private sector.

**Table 2: Status of Japanese companies in CCS**

<table>
<thead>
<tr>
<th>Project Name or Action</th>
<th>Country or Region</th>
<th>Company</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osaki CoolGen</td>
<td>Japan</td>
<td>Osaki CoolGen Corporation</td>
<td>IGCC + Carbon Capture Plant (net electric output: 170MW) to be constructed by 2019.</td>
</tr>
<tr>
<td>Callide Oxy Fuel Project</td>
<td>Japan, Australia</td>
<td>IHI Co., J-Power, Mitsui and JCOAL</td>
<td>Demonstration project in Australia. The Callide Oxyfuel Project is a joint venture between CS Energy, the Australian Coal Association, Xstrata Coal, Schlumberger, and Japanese participants, J-Power, Mitsui and IHI Corporation. The project has also received financial support from the Australian, Queensland and Japanese governments.</td>
</tr>
<tr>
<td>COURSE 50 (JISF)</td>
<td>Japan</td>
<td>Kobe Steel Ltd., JFE Steel Co., Nippon Steel Co., Nippon Steel Engineering Co., Sumitomo Metal Ind. and Nisshin Steel Co.</td>
<td>Developing technologies to reduce CO₂ emissions by 30% from steelmaking process. Two technologies: “CO₂ capture from blast furnace gas” &amp; “Hydrogen reduction of iron ore”. NEDO investments.</td>
</tr>
<tr>
<td>Participation in the “In Salah project”</td>
<td>Algeria</td>
<td>JGC Corporation</td>
<td>JGC is a part of the In Salah project providing project engineering, procurement and construction.</td>
</tr>
<tr>
<td>Participation in national and international projects</td>
<td>Japan, Malaysia, India, Middle East, Europe, North Sea and Korea</td>
<td>Mitsubishi Heavy Industries Ltd. (MHI)</td>
<td>MHI is the leading Japanese technology provider for post-combustion carbon capture.</td>
</tr>
<tr>
<td>Bilateral Agreements</td>
<td>Japan, US</td>
<td>Mitsubishi</td>
<td>Alliance of Mitsubishi (Japan) and Battelle (US).</td>
</tr>
<tr>
<td>New projects</td>
<td>India</td>
<td>NTPC Ltd - Toshiba Corp in India</td>
<td>India’s largest power producer, commenced very preliminary discussions with Toshiba Corp to build a pilot project in India for capturing and storing carbon emissions.</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-------------------------------------------</td>
<td>----------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Victoria</td>
<td>Australia</td>
<td>Nippon Steel Engineering</td>
<td>Under their Regional Development Victoria programme, the Victorian Government has provided USD 2 million to Nippon Steel Engineering to investigate the feasibility of coal to synthetic gas technology.</td>
</tr>
<tr>
<td>Gorgon Joint Venture Project</td>
<td>Australia</td>
<td>JGC Corporation</td>
<td>JGC is one of the project partners that was awarded the “Front-End Engineering Design (FEED) and an option for the Engineering, Procurement and Construction Management (EPCM) Contract” by the Gorgon LNG Joint Venture Project in Western Australia.</td>
</tr>
<tr>
<td>Participation in national and international projects</td>
<td>Japan, North America and Europe.</td>
<td>Hitachi</td>
<td>Contract to build the steam turbine for Canada’s SaskPower Boundary Dam Integrated CCS Demonstration Project. It had carried out pilot scale test of post-combustion technology with Tokyo Electric Power Company in the early 1990s. In recent years, it closed contracts in North America and Europe. In the area of Oxy-fuel combustion, it had carried out a FEED study on Coal fired power plant with FORTUM oy. in Finland. It is also the supplier for EAGLE IGCC project.</td>
</tr>
<tr>
<td>Feasibility study of CCS-EOR in China</td>
<td>China</td>
<td>Toyota</td>
<td>Toyota studied a feasibility of CCS-EOR in China in cooperation with the Research Institute of Innovative Technology for the Earth from year 2006 to 2007. Toyota reported the findings and result of the study to METI.</td>
</tr>
<tr>
<td>Projects for CO₂ storage</td>
<td>Japan</td>
<td>Japan CCS Co.</td>
<td>Tomakomai project, Kitakyushu project, Nakoso-Iwaki Oki project and Combined IGCC and CCS Feasibility Study, Fukushima.</td>
</tr>
</tbody>
</table>

**Source:** Author’s own. Data collected during visit to Global CCS Institute Japan Regional Office.

### 3.2.2 Brazilian Private Sector

In Brazil CCS technologies have been developed mainly in the Oil and Gas sector, but the public sector also has a direct influence on actions. In 1999 the Federal National Agency for Oil, Gas and Biofuel (ANP) established (regulation 10/99) the obligation for oil and gas companies to invest 1 per cent of their oil and gas production in R&D⁶. The

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main oil and gas company that invests in CCS technologies in Brazil is Petrobras. Between 2006 and 2009 the company invested USD 30 million in climate change and CCS technologies. Additional investments of USD 200 million are expected for the 2010–2015 period (Petrobras, 2010).

The company is currently developing CO₂ capture projects with approximately ten Brazilian universities focusing on adsorption, modelling and technology capture simulation, inorganic membranes, chemical looping, ionic liquids, metal organic framework, nanostructured solids and CO₂ chemical conversion⁷.

The company has a pilot project in Bahia State which is supported by the Brazilian coal industry and National Council for Scientific and Technological Development (CNPq), an agency linked to the Ministry of Science and Technology (MCT). Another pilot project in Rio Grande do Sul State is being carried out by the Centre of Excellence in Research on Carbon Storage (CEPAC). In addition, the company participates in international CCS projects and alliances.

Petrobras also contributes to the development and operation of the Thematic Network on Climate Change (Rede CLIMA), which focuses on technical cooperation and financial support for science and technology organizations nationwide. Created in 2008 by the National Institute for Space Research and the Ministry of Science and Technology, the network comprises 12 institutions and aims to develop national capacity in carbon capture, transport and storage areas (Petrobras, 2010). Figure 7 presents the R&D Brazilian network for CCS technologies.

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Figure 7: Basic organization for development of CCS technologies in Brazil

Source: Author’s own based on reference (Petrobras, 2010) and presentations by Petrobras employees in technical conferences.

3.2.1 Comparison of CCS-related Patents

A simple way to check the status of R&D in a country is to analyse its patent deposits. Here the definition drawn up by the UNFCCC with the World Intellectual Property Organization (WIPO) about International Patent Classification (IPC) Green Inventory should be highlighted. The IPC Green Inventory was developed by the IPC Committee of Experts by WIPO to facilitate the search for patent information relating to Environmentally Sound Technologies (ESTs) as listed by the UNFCCC (Jolly and Philpott, 2012).

In the IPC the Green Inventory has a specific topic about pollution control which focuses on carbon capture and storage technologies. Altogether there are nine IPC codes related to CCS Technologies. After analysis, the codes can be associated with specific CCS areas (capture or storage). However, it was not possible to associate the codes to the CCS transport area. Table 3 shows the IPC Green Inventory CCS Technologies codes and the description of each code and the main class in which it is included and the relation to CCS areas.
Table 3: CCS Technologies codes in IPC Green Inventory

<table>
<thead>
<tr>
<th>The Section IPC Green Inventory Code and description</th>
<th>CCS Technologies in IPC Green Inventory</th>
<th>Description</th>
<th>Relation between IPC Green Inventory codes and CCS area</th>
</tr>
</thead>
<tbody>
<tr>
<td>B01D 53/00: Separation of gases or vapours; Recovering vapours of volatile solvents from gases; Chemical or biological purification of waste gases</td>
<td>B01D 53/14</td>
<td>By absorption</td>
<td>Capture</td>
</tr>
<tr>
<td></td>
<td>B01D 53/22</td>
<td>By diffusion</td>
<td>Capture</td>
</tr>
<tr>
<td></td>
<td>B01D 53/62</td>
<td>Carbon oxides</td>
<td>Capture</td>
</tr>
<tr>
<td>B65G 5/00: Storing fluids in natural or artificial cavities or chambers in the earth</td>
<td>B65G 5/00</td>
<td>Devices assisting manual conveyance of articles over short distances, e.g. in storage depots, warehouses or factories</td>
<td>Storage</td>
</tr>
<tr>
<td>C01B 31/00: Carbon; Compounds thereof</td>
<td>C01B 31/20</td>
<td>Carbon dioxide</td>
<td>Capture</td>
</tr>
<tr>
<td>E21B 41/00 (included 02, 04, 06, 08 and 10): - in situ inhibition of corrosion in boreholes or wells - Manipulators for underwater operations, e.g. temporarily connected to well heads - Work chambers for underwater operations, e.g. temporarily connected to well heads - Underwater guide bases, e.g. drilling templates; Levelling thereof - Guide posts, e.g. releasable; Attaching guide lines to underwater guide bases</td>
<td>E21B 41/00</td>
<td>Equipment or details not covered by groups E21B 15/00-E21B 40/00</td>
<td>Storage</td>
</tr>
<tr>
<td>E21B 43/00: Methods or apparatus for obtaining oil, gas, water, soluble or meltable materials or a slurry of minerals from wells</td>
<td>E21B 43/16</td>
<td>Enhanced recovery methods for obtaining hydrocarbons</td>
<td>Storage</td>
</tr>
<tr>
<td>E21F 17/00: Methods or devices for use in mines or tunnels, not covered elsewhere</td>
<td>E21F 17/16</td>
<td>Modification of mine passages or chambers for storage purposes, especially for liquids or gases</td>
<td>Storage</td>
</tr>
</tbody>
</table>
With the CCS technologies IPC Green Inventory codes, a search was made in the European Patent Office\(^8\) for the Japanese and Brazilian patent deposits in the last twenty years. The search was made in several patent offices worldwide and was referenced with the applicant and the publication date. The data was analysed by the number of patents deposited by country as the actors’ contribution. For the actor contributions in the public sector, the patents related to public agents with CCS technology relations in Japan were RITE, AIST and Agencies; and in Brazil, CNPq, FINEP and CAPES were considered. For the private sector, all patents related to companies, company partnerships or private associations were considered. For civil society the patent deposits made by universities, research centres, persons and nongovernmental organizations (NGOs) were considered. It is important to highlight that there are patent deposits made by partnerships between actors, but in this case, the analysis considered the main applicant. Table 4 shows the research results.

**Table 4:** Patent deposits from 1992 to May 2012 of the CCS Technologies in IPC Green Inventory made by Japan and Brazil

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The data analyses demonstrate that the private sector is the main actor in R&D and E&I CCS technologies given the number of patent deposits in the last twenty years. While in Japan the actors focus on CCS technology capture and separation, in Brazil the focus is on CCS technology storage. Among the nine codes, Brazil has more patent deposits than Japan in two codes and these two codes relate more to storage activities. It is important to highlight that Petrobras is the main applicant, e.g. in E21B 41/00 code in Brazil, of 19 deposits Petrobras accounted for 16 and in E21B 43/16 code of 18 Brazilian deposits, Petrobras accounted for 15.

It can also be seen that in Japan the number of the patent deposits increased in the period from 2004 to 2012. This increase indicates the effective participation of the Japanese public sector with specific policies and strategies for climate change and ESTs such as the Law Concerning the Promotion of Measures to Cope with Global Warming, Kyoto Protocol Target Achievement Plan, Cool Earth-Innovative Energy Technology Program and Action Plan for Building a Low Carbon Society. On the other hand, in Brazil an emphasis on the Oil and Gas sector can be noticed due to ANP’s ordinance 10/99. One important consideration that is the ANP ordinance 10/99 does not focus on CCS technologies but in general on R&D for the Oil and Gas sector, the companies are responsible for the allocation of resources.
3.3 Civil Society
The participation of civil society in CCS technology projects occurs in two ways, or via the actors as universities, nonprofit institutions and NGOs or via communities and community associations. However, the focus of the actors concerning CCS technologies is different. Traditionally, the universities focus on S&T, R&D and education while other actors focus on benefits and losses, land use and its value, environmental issues, and health and safety issues.

With regard to R&D in academia or nonprofit organizations, it was possible to verify its main field of interest in CCS technologies. The analysis was made by collecting information during visits to organizations, identifying the organizations involved in CCS projects or via analysis of patent deposits. There are organizations that focus on more than one CCS area and these organizations normally have a specific centre for each area, and in this study case, each organization was recognized in analysis in terms of their area of focus. Figure 8 shows the main academic and non-profit organizations involved in R&D CCS technologies with a focus on policies, capture, and storage.

![Figure 8: Academics or non-profit organizations involved in R&D CCS technologies and their respective area of “focus” in Japan and Brazil, listed in Annex 01](image)

**Source:** Author’s own based on data collected during visits, presentations by Petrobras employees at technical conferences and reference (Global CCS Institute, 2009)

Another important aspect that needs special attention in CCS technologies is education. It is necessary to educate the public as well as communities about CCS. For the CCS projects to be successful it is necessary to carry out educational activities, discussions at specific forums and workshops, and create a specific educational structure between the actors to establish.
For the experts, CCS technology issues can be addressed at congresses or workshops specifically organized to discuss these technologies. This is being done in both countries, in Japan by RITE or academia e.g. United Nations University (UNU)\(^9\) or non-profit organizations such as the Institute for Global Environmental Strategies (IGES)\(^{10}\). In Brazil the main events have been organized by Petrobras and the Brazilian Petroleum, Gas and Biofuels Institute which is a non-profit private association.

For communities it is necessary to take action with a focus on increasing peoples’ understanding of CCS technologies via the public sector or the private sector. Furthermore, there is a need for local actions involving the community associations and residents. An example of this in Japan is the Tomakomai CCS Project conducted by JCCS and supported by the public sector. In April 2008, the civil society organized the "Tomakomai CCS Promotion Council", which was established in Tomakomai city. The council consists of local government authorities, industries, local fishing cooperative, and experts and is aimed at the promotion of the CCS project (Yamanouchi, 2011). In this research, no actions promoting CCS technologies involving the communities or communities associations was found in Brazil.

CCS technologies are still in development, which implies that there is a need for future studies to enhance this research. In the near future, with the expected large-scale use of CCS technologies it will be necessary to re-analyse CCS technologies and participation of actors, due to the increase in actors and new barriers that will appear.

4. Conclusions
This study has attempted to analyse the area of CCS technologies in Japan and Brazil. Current climate change policies of both countries were considered and as Japan and Brazil have responded to the requests of the GEG in the last twenty years in particular about the large-scale use of CCS technologies. The main public and private sector actions related to CCS technologies were analysed as well as the response of civil society to public and private sector stimulus.

Initially, in the GHG emission context, the trends in GHG emission reduction varied between the countries. If Japan keeps on the same course as before the Fukushima accident, it will

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\(^9\) Climate Change, Carbon Sequestration, and the Law of the Sea, 27 May 2011, 15:30 - 17:00 at UNU-IAS in Yokohama.

\(^{10}\) Workshop on Post COP 17 Looking Ahead from Durban, February 2012. IGES introduced the main outcomes at COP17 and CMP7 including Carbon Capture and Storage (CCS), materiality, as well as negotiations on new market mechanisms. NCCCI and the Indonesian Carbon Management Association presented a suggested framework and possibilities of a future Indonesian carbon market.
probably reach its targets set, while Brazil, due to trends in population and the economic situation of the country, will possibly need to expand its GHG emission reduction efforts. Brazil’s potential to reduce GHG emissions should aim to put the country in a favourable situation on the GEG. To do this, it is important to explore the maximum potential of ESTs.

In Brazil the industrial sector alone is expected to increase its emissions from 180 MtCO₂e per year in 2005 to 360 MtCO₂e per year in 2030 in the base case scenario (Lampreia, 2011). The use of CCS technologies is critical for industrial sectors such as steel, chemical, oil & gas, and cement. It is important to contribute to Brazil’s performance in GHG emission reduction but there is a lack of policies and strategies on the part of the Brazilian government to stimulate the private sector to do this.

In addition, the Brazilian government should carry out other important actions such as offering incentives in R&D for industrial sectors and encouraging promotion and discussion with communities. In addition, the elaboration of a framework specific to CCS technologies among the actors would promote the large-scale use of CCS and attract foreign investments. The experience in the oil & gas sector could be a reference for the other industrial sectors. Due to the government incentives for R&D in the oil & gas sector, advances in CCS storage technologies have been made and this sector can be considered as a reference for other industrial sectors.

The government in Brazil does not support CCS technologies via investments, policies and strategies, while in Japan, the government focuses on CCS technologies in an attempt to reach the targets set. However, the Japanese public and private sectors need to pay attention to R&D and E&I in CCS storage technologies. In the current situation for large-scale use of CCS technologies in Japan this country can be considered a supplier of the CCS capture technologies. Regarding the CCS framework between the actors in Japan, it has been carried out well because it has led to intensive interaction among actors. Table 5 reviews the current situation of actors in Brazil and Japan.

<table>
<thead>
<tr>
<th></th>
<th>Japan</th>
<th>Brazil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Sector</td>
<td>engaged</td>
<td>no engaged</td>
</tr>
<tr>
<td>Private Sector</td>
<td>engaged</td>
<td>engaged</td>
</tr>
<tr>
<td>Civil Society</td>
<td>engaged</td>
<td>slightly engaged,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>depending on the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>private sector</td>
</tr>
</tbody>
</table>

Source: Author’s own
Due to the importance of CCS technologies in combating GHG emissions, demonstrated by the G8’s decision in 2008, it is important to emphasize the need to carry out new research, development, demonstration and deployment in the short term, e.g. the comparative analysis between CCS projects implementation in Japan and Brazil. This research has attempted to express the current situation of CCS technologies and indicate what areas require greater attention on the part of actors involved.

**Acknowledgements**

Universidade Federal da Bahia in particular Professor José Célio Andrade, Universidade Salvador (Laureate) in particular Professor Paulo Rocha, United Nations University Institute of Advanced Studies (UNU-IAS) in particular Professor José Puppim, Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES), Research Institute of Innovative Technology for the Earth (RITE) in particular to Dr. Eng. Ziqiu Xue, and the institutions visited in Japan and Brazil.
References


Brazil, 2009. Law number 12.187, Establishes the Climate Change National Policy, among other decisions, Brasília.


Ohsumi, T., 2007. Perspectives on CCS implementation in Japan”. RITE Workshop on CCS, Kyoto.


Annex 01 - List of institutions

Japan:
Central Research Institute of Electric Power Industry
Kyoto University
Marine Ecology Research Institute
Mizuho Information & Research Institute
The Institute of Applied Energy
Tokyo Institute of Technology
Institute for Global Environmental Strategies
Hokkaido University
Tohoku University
University Of Tsukuba
The University of Tokyo
Nagoya University
Kyoto University
Osaka University
Tokyo University
Tamagawa University College
Chuo University
University Waseda
International Center for Environmental
Japan Atomic Energy Research Institute
National University Corporation Nagoya University
Bussan Nanotech Research Institute Inc.
National University Corporation Kitami Institute of Technology
National University Corporation Nagoya Institute of Technology
Isuzu Ceramics Research Institute
University Keio

Brazil:
Universidade Federal do Ceará
Universidade Federal do Rio de Janeiro
Universidade Federal de Minas Gerais
Instituto Nacional de Pesquisas Espaciais
Pontifícia Universidade Católica do Rio Grande do Sul
Universidade Federal do Ri Grande do Sul
Universidade Estadual de Campinas
Instituto Nacional de Tecnologia
Pontifícia Universidade Católica do Rio de Janeiro
Universidade Estadual do Norte Fluminense
Universidade Federal da Bahia
Centro de Excelência em Pesquisa e Inovação sobre Petrólleo, Recursos Minerais e Armazenamento de Carbono - CEPAC
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ISSN 1564-8427
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