RITE
Research Institute of Innovative
Technology for the Earth

CCSワークショップ2007

―CO_2 分離回収貯留技術の最前線―

CCSWorkshop2007

平成19年2月15日(木)
けいはんなプラザ 3F「ナイル」

February 15th (Thu) 2007
The Keihanna Plaza in Kyoto

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主　催　財団法人 地球環境産業技術研究機構（RITE）

共　催　財団法人 エンジニアリング振興協会

後　援　経済産業省、京都府、社団法人化学工学会、社団法人日本エネルギー学会、社団法人物理探査学会、エネルギー・資源学会、石油技術協会、株式会社けいはんな

2月15日（木）

9:45	開会挨拶　RITE研究所長　茅　陽一
	来賓挨拶　兵庫県立大学副学長　鈴木　胖

＜招聘者講演＞

10:00	「CCSの現状と将来への挑戦」	IEA-GHGプログラム　John Gale（UK）
10:50	「欧州の主要な分離回収連携プロジェクトについて」	国立エネルギー研究所（ECN） Daniel Jansen（オランダ）
11:40	「中国におけるCCSの現状と展望について」	科学技術部　FU Ping（中国）
12:30	昼食休憩	
13:30	「我が国におけるCCS関連政策の動向について」	経済産業省　産業技術環境局 西尾　匡弘

＜RITE研究発表＞

13:50	「CO_2分離回収技術の現状と将来」	化学研究グループ　藤岡　祐一
14:40	コーヒーブレイク	
15:10	「地中貯留におけるCO_2挙動モニタリングについて一長岡実証試験サイトの実例紹介一」	CO_2貯留研究グループ　薛　自求
16:10	「日本における地中貯留の経済性評価と有効性」	プログラム研究チーム　高木　正人
16:50	「わが国でのCCS適用の展望」	CO_2貯留研究グループ　大隅　多加志

17:50　閉会挨拶　RITE専務理事　樋口　正治

18:00　意見交換会

2月16日（金）

RITE研究施設見学会	午前10時～12時

February 15th (Thu.)

9:45	Opening Remarks	Yoichi Kaya (Director-General of RITE)
	Guest Speech	Yutaka Suzuki (Vice-principal of Hyogo University)

<Invited Speakers>

10:00	CCS Current Status and Future Challenges	John Gale (Deputy General Manager of IEA GHG project, UK)
10:50	Overview of European CCS projects and on the work going on at ECN and in the Netherlands	Daniel Jansen (Programme Manager of ECN, Netherlands)
11:40	Status of and Perspectives on CCS in China	Fu Ping (Program Officer of MOST, China)
12:30	Lunch Time	
13:30	Japan's Recent Policy Development on CCS	Masahiro Nishio (Deputy Director, Ministry of Economy, Trade and Industry, Japan)

<Presentations from RITE>

13:50	Present and Future of CO_2 Capture technology	Yuichi Fujioka
14:40	Coffee Break	
15:10	Geophysical monitoring of geological CO_2 sequestration in saline aquifers-Lessons from the Nagaoka pilot-scale project	Ziqiu Xue
16:10	Economic Evaluation of CO_2 Geological Storage in Japan	Masato Takagi
16:50	Perspective on CCS implementation in Japan	Takashi Ohsumi

17:50	Closing remarks	Masaharu Higuchi (Senior Managing Director of RITE)

February 16th (Fri.)

"The laboratory tour of RITE facilities" 10am to 12 am

Program

CCS Current Status and Future Challenges

John Gale

Deputy General Manager, IEA Greenhouse Gas R&D Programme (IEA GHG)

講演1

Born 29th June 1956, Pershore, United Kingdom

1. Current Position:
   Deputy General Manager, IEA Greenhouse Gas R&D Programme (IEA GHG)
2. Education and Degrees
   BSc Pure and Applied Chemistry, Bristol University, 1981
3. Teaching and Research
   Research Manager, British Coal Corporation, 1981-1990
   Group Manager, CRE Group Ltd, 1991-1993
   Principal Consultant, IMC Group Ltd, 1994-1999
   Manager, IEA Greenhouse Gas R&D Programme, 1999 to present
4. Research Area
   Clean coal utilisation and environmental management, Energy and Environment
5. Awards
   2 publication awards
6. Activities in Academic Societies
   Fellow Royal Society of Chemistry
7. Government Activities
   Member various advisory panels for UK DTI and DEFRA
8. International Activities
   Co-ordinating lead author, IPCC Special Report on CO_2 Capture and Storage,
   Member FutureGen sub surface advisory panel,
   Editor in Chief, International Journal on Greenhouse Gas Control.
9. Principal Publications (Books only)
   None

Abstract

Considerable progress in the development and implementation of CO_2 capture and storage (CCS) has occurred in recent years. Despite recent developments we cannot yet regard that this technology as being fully developed. In the last few years, we have seen a number of new gas and oil field storage projects being developed. However, the power sector is the one industry that has the largest number of large point source emissions worldwide. To ensure that global emissions of CO_2 are reduced significantly to avoid climate change then the power sector has to be fully engaged in CCS activities. Several power companies around the world are investing in pilot scale facilities for both post combustion capture and oxy fuel combustion. However, to date, there are no full scale demonstrations of CO_2 capture either, post or pre combustion. Such demonstrations are necessary to demonstrate the potential for this technology in the power sector.

In the oil sector, the current high price of oil should provide an incentive to develop projects. However, we have not seen the development of numerous large CO_2-EOR projects in regions like the North Sea as might have been expected. The reasons for this need to be considered to understand why this potentially attractive option is not taking off because there could be implications for developing CCS projects in other geological formations. In the gas sector, gas fields with high CO_2 contents are now being developed to meet increasing gas demand worldwide. The natural gas produced from such fields has to be sweetened to make it suitable for pipelines or LNG production. With the capture cost being the major cost in the whole CCS system, then in these cases the incremental additional cost of CO_2 transport and storage is small. For the power sector, however, the potential incentives are not as obvious. At current trading levels ($8-10/t CO_2) emissions trading will not provide sufficient financial support to even cover the costs for CCS. One challenge ahead, therefore, is to reduce the costs of capture predominantly so that the incentive gap can be narrowed.

Whilst CCS is attractive in developed countries, it needs to be made attractive to developing countries as well. This can be achieved by getting CCS included as a CDM project by the Conference of the Parties and by developing methodologies that allow its wide spread application in a reasonable timescale. This process began at COP 11 in Montreal in November 2006 but we must not underestimate the challenge ahead to get CCS accepted.

A more technical challenge lies with aquifer formations. These formations globally represent the largest storage potential; however, they are the reservoirs that are least well explored and researched. Oil and gas fields have been geologically explored and we have a growing confidence that the CO_2 once re-injected into such formations will be contained there for thousands of years. This confidence will grow as more oil and gas formation projects come on stream. For aquifers, we have to build a more comprehensive global dataset of their geological characteristics and containment potential. This will require a considerable research investment but who will fund such an activity is not currently clear. We also need more large scale aquifer injection projects and more monitoring of such projects to continue to develop confidence in aquifer storage formations as safe and effective storage options.

Developing confidence that CO_2 once injected into geological formations will remain securely contained is another key challenge that faces us. Information is growing at a modest pace and confidence is growing with it. Discussions with NGOs that have taken place have softened the stance by such environmental pressure groups to geological storage. However the broader public have not come into contact with development plans for CCS projects in their localities. Currently we know from studies undertaken that the general public across the globe is either unaware or indifferent to CCS. Therefore to prevent local community issues coming to the fore as a major hurdle to CCS development, there is a growing need for more education and awareness building on this technology option.

Note

講演2

Overview of European CCS projects and on the work going on at ECN and in the Netherlands

Daniel Jansen

Programme Manager "Clean Fossil Fuels"
Energy Research Centre of the Netherlands

Date of birth	September 10, 1953
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Nationality	Dutch

WORK EXPERIENCE

- Dates (from - to) 2000- Present
- Name of employer Energy Research Centre of the Netherlands
- Occupation or position held Programme Manager "Clean Fossil Fuels"

- Dates (from - to) 1990 - 2000
- Name of employer Energy Research Centre of the Netherlands
- Occupation or position held Manager System Assessment Group

- Dates (from - to) 1982-1990
- Name of employer Energy Research Centre of the Netherlands
- Type of business or sector Energy research
- Occupation or position held Principle Scientist

- Dates (from - to) 1980 - 1982
- Name of employer Neratoom
- Occupation or position held Project engineer

EDUCATION AND TRAINING

- Dates (from - to) 1972 - 1980
- Name of organisation Technical University of Eindhoven
- Title of qualification M.Sc. Chemical Engineering

Abstract

In this presentation an overview will be given on the CO_2 capture technology developments in Europe and more specific on the CO_2 capture technology developments work at ECN in the Netherlands.

Before focussing on the pre combustion technologies that are being developed at ECN an broad overview will be given on the capture technology work that is being performed as part of the three big European RTD projects in Europe i.e. **CASTOR, ENCAP and CACHET**. The main objective of all these three projects is the reduction of the capture costs, from 50-60 € down to 20-30 € per ton of CO_2

CASTOR

CASTOR, "CO_2 from Capture to Storage", is an European initiative grouping 30 partners (industries, research institutes and universities) coming from 11 different European countries and partially funded by the European Commission under the 6th Framework Program. The overall goal of CASTOR is to develop and validate, in public/private partnerships, all the innovative technologies needed to capture CO_2 and store CO_2 in a reliable and safe way.
CASTOR's capture technology development is focussed on post combustion.
The objectives of work on post-combustion capture are:

- Development of absorption liquids, with a thermal energy consumption of 2.0 GJ/tonne CO_2 at 90% recovery rates
- Pilot plant tests showing the reliability and efficiency of the post-combustion capture process.

Some breakthrough in absorption technology is needed and CASTOR is addressing key issues like: energy consumption, reaction rates, contactor improvements, liquids capacities, chemical stability and corrosion, desorption process improvements.

ENCAP

ENCAP is a project whose objective is to develop new pre-combustion CO_2 capture technologies and processes for power generation. It aims at technologies which meet a target of at least a 90% CO_2 capture rate and a reduction in the cost of capture of 50% compared to present. The future large-scale development of these technologies will depend on significant improvements in their cost and other aspects that may improve their competitiveness against conventional energy sources and renewables. The capture technology developments in ENCAP are focussed on

- pre-combustion capture technologies mainly for coal
- Oxy fuel boiler technologies
- Chemical Looping Combustion
- High-Temperature Oxygen Generation for Power Cycles

CACHET

CACHET is a 3-year, integrated research project, funded by the European Commission that aims to develop technologies to reduce greenhouse gas emissions from power stations by 90%. CACHET is a strong and diverse international consortium of highly experienced research institutes, universities, energy businesses, engineering and manufacturing companies. CACHET is co-ordinated by BP with funding from the joint industry/government CO_2 Capture Project (CCP) and EU.
The overall goal of the CACHET project is to develop innovative technologies which will substantially reduce the cost of CO_2 capture whilst simultaneously producing H_2 from natural gas fuel. CACHET targets reduction of capture costs to 20 to 30 €/ton with a 90% capture rate and CO_2 delivered at pipeline pressure for storage.
Four pre combustion capture technologies are being developed within the framework of CACHET, these are:

1. HyGenSys a novel PowerGen Steam Methane Reforming (SMR) process producing commodity hydrogen as fuel for carbon emission free electric power generation
2. Chemical Looping Reforming and one step one-step de-carbonisation process
3. Development and testing of H_2 membrane reactors using Pd alloy membrane technology to capture CO_2
4. Development and testing of the Sorption Enhanced Water Gas Shift (SEWGS) process

The second part of the presentation will highlight the most recent results of the work at ECN on CO_2 capture technology development and the current developments in the Netherlands on CCS. ECN's pre combustion technology development is focussed on the development of Pd/ alloy and CO_2 separating membrane reactors and on sorption enhanced reactors for CO_2 capture both in natural gas fuelled combined cycles and in IGCC power plants. ECN's RTD work is part of the earlier mentioned EU project CACHET, the Dutch **CATO** programme and the GCEP programme of Stanford University.

CATO programme

CATO represents a strong knowledge network in the field of CO_2 Capture and Storage in the Netherlands, assessing and developing new knowledge, technologies and approaches in this field. The aim of CATO is to identify whether and how CO_2 Capture and Storage (CCS) can contribute to a sustainable energy system in the Netherlands, from an economical, technical, social and ecological point of view and under which conditions this option could be implemented in the energy system.
The CATO project is structured in seven distinct work packages, as described below:

1. System analysis & Transition
2. Capture of CO_2 — 2.1 Post-combustion — 2.2 Pre-combustion — 2.3 Denitrogenated conversion
3. Storage of CO_2 — 3.1 Storage gas fields — 3.2 Storage coal fields (ECBM)
4. Mineralisation — 4.1 Subsurface mineralisation — 4.2 Surface mineralisation
5. Monitoring, safety and regulations
6. Communication

The CATO programme is implemented by a strong consortium of Dutch companies, research institutions, universities and environmental organisations, led by the Utrecht Centre for Energy research (UCE). Given its size, 25.4 million Euro, the CATO programme can be regarded as the national research programme on CCS in the Netherlands. CATO runs from 2004 until the end of 2008.

Status of and Perspectives on CCS in China

FU Ping

Program Officer, Office of Global Environmental Affairs, the Ministry of Science and Technology of China

born on June 5, 1977 in Jiangsu Province, China

1. Current Position
   Program Officer, Office of Global Environmental Affairs, the Ministry of Science and Technology of China
2. Education and Degrees
   B.A. in economics, Renmin University of China, 2001
   Second B.A. in engineering, Tsinghua University, 2001
   M.A. in engineering, Tsinghua University, 2004
3. Teaching and Research
   Research assistant, Department of Environmental Science and Engineering, Tsinghua University, 2004-Present
4. Research Area
   climate change
5. Awards
6. Activities in Academic Societies
7. Governmental Activities
   Program Officer, Office of Global Environmental Affairs, the Ministry of Science and Technology of China, 2004-Present

Note

Abstract

China takes carbon capture and storage (CCS) technology as a possible potential promising one to reduce CO_2 emission in future. With international assistance, China started the research and development on CCS technology.

This presentation introduces briefly China's energy use, CO_2 emission and future energy scenario, and then illustrates the status of CCS technology development in China, as following.

I. Some preliminary researches on CCS technology have been implemented that laid a good basis for this technology development in China. Such research activities include estimations of CO_2 storage capacity, EOR and ECBM research with small-scale pilot projects, and planning of "Greengen" for electricity production. However, the issues such as risk assessment, social impacts, public awareness and regulations on CCS, have hardly yet been studied.

II. Multilateral and bilateral cooperative activities on CCS in China. China is one of the initial members of the Carbon Sequestration Leadership Forum, and actively engaged in the activities of the Forum. To implement the substantial technology development on CCS, China signed MOUs of the cooperation on CCS technology with EU and UK respectively. In addition, China is engaged in another cooperative project COACH under EU FP6. The research activities under the MOUs are expected to start in April 2007.

III. Some thoughts on future actions. To speed-up the research and development of CCS technology, China is willing to cooperate with more countries and international organizations. In order to make substantial progress on research and development on CCS technology, a long term and stable financial support mechanism shall be established, and such financial mechanism and such financial support shall be made available to developing countries that are willing to take such actions. Since China will continue to rely on coal as a dominated energy supply in future to support the social and economic development, it is expected that the CCS technology development would be combined with the R&D of clean coal technology, and the CCS technology development roadmap would be planned in line with China's energy structure. For example, China has huge amount coal bed methane which is a kind of clean energy resources, and therefore China should pay more attention to the development of ECBM technology that can enhance the recovery of coal bed methane while huge amount of CO_2 being stored.

Note

我が国におけるCCS関連政策の動向について

西　尾　匡　弘

経済産業省　産業技術環境局　環境政策課　課長補佐

講演4

主要経歴：

1990年～1994年	通商産業省工業技術院機械技術研究所 入省 エネルギー部熱工学課 研究官
1994年～2000年	通商産業省工業技術院機械技術研究所 エネルギー部熱工学研究室 主任研究官
1995年	通商産業省工業技術院ニューサンシャイン計画推進本部 研究開発官付に併任
2001年～2004年	独立行政法人産業技術総合研究所エネルギー利用研究部門 熱・物質移動制御研究グループ 主任研究員
2004年～現在	経済産業省産業技術環境局環境政策課 課長補佐

Japan's Recent Policy Development on CCS

Masahiro Nishio

Deputy Director for Environmental Policy Division, Ministry of Economy, Trade and Industry (METI)

Researcher, Energy Engineering Department, Mechanical Engineering Laboratory, Agency of Industrial Science and Technology, MITI, 1990-

Senior Researcher, Energy Engineering Department, Mechanical Engineering Laboratory, AIST/MITI, 1994-2000

Officer, New Sunshine R&D Programme Promotion Headquarter, Agency of Industrial Science and Technology, MITI, 1995

Senior Research Scientist, Institute for Energy Utilization, National Institute of Advanced Industrial Science and Technology (AIST), 2001-2004

Deputy Director, Environmental Policy Division, METI, 2004-

要　旨

二酸化炭素回収・貯留（CCS：Carbon Dioxide Capture and Storage）は、発電所や工場等の大規模発生源から分離回収した二酸化炭素を地層に貯留する技術である。本発表では、我が国における最近のCCS関連政策の動向について説明する。

CCSは、2005年に公表されたIPCCの特別報告書においても「大気中温室効果ガス濃度安定化における主要な対策の一つ」と位置付けられており、地球温暖化問題の対応策として期待されている。また、G8等の国際会議においてもCCS推進が頻繁に議論され、欧米諸国・産油国を中心に、商業レベル、研究レベルの具体的なプロジェクトが進行している。

経済産業省としては、90年代からRITE（地球環境産業技術研究機構）等の関係機関を通じてCCSの技術開発を行い、基礎的知見の獲得・蓄積を図ってきている。本発表では、CCSに関するロードマップ等の技術開発政策の概要について述べる。

また、昨年10月からは、国際的な動向も踏まえつつ、幅広い視点から、CCS推進のための政策提言を行うべく、産学の有識者11名で構成される「CCS研究会」を設置して議論を行っているところである。本研究会では、地球温暖化対策の重要な選択肢の一つであるCCSに関し、温暖化対策としての位置づけ、最近のCCSを巡る情勢の変化、CCS推進に当たっての課題を整理するとともに、政策提言を行い、報告書の形で結果を取りまとめる予定である。本発表では、CCS推進の課題等について、CCS研究会での議論を紹介する。

Abstract

CCS, Carbon Dioxide Capture and Storage, is a process to separate CO_2 from power plants and other industrial sources and to store CO_2 in such locations as geological formations. This presentation describes Japan's recent policy development on CCS.

The Special Report on Carbon dioxide Capture and Storage (SRCCS) published by the IPCC in 2005 considers CCS as an option in the portfolio of mitigation actions for stabilization of atmospheric green house gas concentration. It is expected that CCS will become a countermeasure for global warming issue. In various international meetings, such as those of G8, promotion of CCS is frequently discussed recently, and concrete projects are now underway, both at commercial and research levels, mainly in the EU, the US and oil producing countries.

METI has been carrying out technology developments though RITE and other relevant organizations since 1990s, thereby acquiring and accumulating knowledge on CCS. This presentation outlines the technology policy such as roadmap on CCS.

Moreover, in last October, METI set up a "CCS Study Group," consisting of 11 members from industry and academia, with the view to compiling policy recommendations for CCS promotion from wider viewpoints based on international discussions on CCS. This Study Group is aiming at sorting out discussions on CCS as global warming countermeasures, on recent changes in situation surrounding CCS, and issues for promoting CCS. And, the Study Group will make policy recommendations and will compile conclusions as a report. The presentation introduces discussions at the Study Group on issues to promote CCS and other matters.

講演5

CO_2回収技術の現状と未来

藤　岡　祐　一
RITE化学研究グループリーダー

生年月日：昭和28年10月30日

現　　職：(財)地球環境産業技術研究機構　化学研究グループリーダー
奈良先端科学技術大学院大学客員教授

主要経歴：

昭和51年３月　東京大学工学部化学工学科卒業
昭和53年３月　東京大学大学院工学系化学工学修士課程修了
昭和53年４月　三菱重工業株式会社入社　長崎研究所　化学研究室
平成７年５月　米国　マサチューセッツ工科大学エネルギー研究所　客員研究員
平成９年５月　工学博士の学位取得（東京大学）
平成９年７月　三菱重工業㈱長崎研究所　化学研究室　室長
平成16年４月　三菱重工業㈱長崎研究所　次長
平成18年１月　(財)地球環境産業技術研究機構　化学研究グループ主席研究員
平成18年７月　(財)地球環境産業技術研究機構　化学研究グループリーダー
奈良先端科学技術大学院大学客員教授

専門分野：化学システム工学、地球環境工学

著　　書：流動層ハンドブック（培風館　1999）分担執筆
図解CO_2貯留テクノロジー（工業調査会　2006）分担執筆

学会活動：化学工学会　環境部会幹事

CO_2 separation and capture technology: Present and future

Yuichi Fujioka
Leader, Chemical Research Group, RITE

EDUCATION:

B.E., from Department of Chemical Engineering, Faculty of Engineering, the University of Tokyo (1976)
M.E., from Chemical Engineering, the University of Tokyo (1978)
Dr. Eng. from Faculty of Engineering, the University of Tokyo (1997)

OCCUPATION:

1978 - 2005 Nagasaki Research & Development Center, Mitsubishi Heavy Industries, Ltd.
- 1995 Visiting Researcher of the Energy Laboratory, Massachusetts Institute of Technology
- 2002 Senior Research Manager, Chemical Research Laboratory
- 2004 Deputy General Manager, Nagasaki Research & Development Center

2006 - Leader, Chemical Research Group, Research Institute of Innovative Technology for the Earth (RITE)

SPECIALITY:

Chemical systems engineering
Global environment engineering

Note

講演5

要旨

近年、エネルギー消費はGDPの増大とともに急増しており、その90%は化石エネルギーによってまかなわれている。地球温暖化につながるCO_2問題の解決には、再生可能エネルギーの活用が必須である。しかし、経済不況をともなわず、再生可能エネルギーを基盤とした社会へ移行させるために、いましばらく化石エネルギーに頼らざるをえない。スターンレビューでは地球温暖化に対処しないと毎年５%以上のGDPロスが発生すると予測し、GDP１%程度の対策費の支出を主張している。化石エネルギーが潤沢に使用できる期間に、太陽光、風力、バイオマスなどの再生可能エネルギーへの転換を促進すべきと考える。この間はエネルギー利用効率向上と、日本の先進的な省エネ技術の海外移転と、CCS（CO_2回収貯留）技術によって地球環境を保全しながら、エネルギー利用基盤の世代交代をスムーズに図る努力が必要である。

CCSのCO_2隔離の消費エネルギーの７～９割はCO_2分離回収プロセスであると試算されている。CCSの促進にはCO_2分離回収エネルギー低減が重要である。CO_2分離回収技術には、化学吸収法、物理吸収法、膜分離法、吸着分離法などがあり、最も実用化が進んでいるひとつが化学吸収法である。この化学吸収法は、現時点で理論エネルギーの15倍以上のエネルギーを必要としている。従来の燃料転換装置の最もエネルギー効率の高いシステムへのCO_2分離回収装置の設置が、最もエネルギー効率の高いシステムとはならないケースがある。

CCSはCO_2の分離対象は大規模排出源が適しており、火力発電所や製鉄所から排出されるCO_2を対象としている。天然ガスと石炭を燃料とする火力発電所では、相対的に負荷変動対応の少ない石炭発電所からのCO_2回収が望ましく、そこからCO_2分離回収技術の適用が進んでいくと想定している。

現在RITEでは、経済的なCO_2分離回収技術を早急に提供するために、化学吸収法を改良してCO_2回収コストの半減を狙った微粉炭燃焼ボイラ排ガスからのCO_2回収技術と、石炭ガス化などの加圧のガス源から物理吸収法よりも低コストの可能性のある膜分離法の開発を進めている。膜法の開発においては膜素材から開発を進めている。これらCO_2分離技術の進展を紹介する。

Note

Abstract

The world's energy consumption is increasing rapidly with increases of GDP. Fully 90% of energy is fossil provided. The increase in is causing global warming; thus, it is indispensable for the resolution of the problem that renewable energy be utilized. However, if this is to be achieved without economic depression, the reality is that for sometime more we must depend on fossil energy to facilitate a shift to a world utilizing renewable energy.

Stern Review insists that if we do not address the issue of global warming, it predicts that there will be 5% or more of GDP loss occurring every year. Hence, we should spend 5% of GDP annually on measures against global warming.

Conversion to renewable energy, such as solar energy, wind force, and the biomass needs to be promoted in the period when fossil energy can still be used plentifully. The aim be to smoothly introduce an alternative energy infrastructure during this period; endeavoring to preserve the global environments by efficient improvements in energy utilization, the overseas relocation of Japan's advanced energy-saving technologies, and the utilization of CCS (Carbon Capture and Storage) technology.

The CO_2 capture process takes approximately 70 to 90 percent of the total energy consumption in CCS. Energy reduction for CO_2 separation and capture will prompt the utilization of CCS. Methods applicable include chemical absorption, physical absorption, membrane separation, and adsorption in CO_2 separation and capture technology.

The chemical absorption method is an advanced technology. It needs the energy of 15 times or more of theoretical energy at present. Installation of a CO_2 separation unit into the system with the highest energy efficiency of a fuel conversion system without a CO_2 separation unit can't always make a system having the highest energy efficiency within a CO_2 separation unit.

CCS facilitates a CO_2 decrease in large-scale conversion systems such as power plants and ironworks. A CO_2 separation unit is thus relatively desirable for use in a coal power plant compared to a natural gas plant. It is assumed that there will be applications of CO_2 separation and capture technology to the power plants.

RITE will offer the technology of an economical CO_2 separation unit. We improve the absorption solution of the chemical absorption method at half the cost of the pulverized coal combustion boiler. From pressurized gas in the coal gasification process, we develop a membrane separation method for which the cost is even lower than that of the physical absorption method, We are developing material for separation in the development of the membrane separation method. We introduce the progress of these CO_2 separation technologies.

Note

地中貯留におけるCO_2挙動モニタリングについて
― 長岡実証試験サイトの実例紹介 ―

薛　自求

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講演6

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現在に至る

専門分野：岩石力学、主に岩石物性測定

Geophysical monitoring of geological CO_2 sequestration in saline aquifers--Lessons from the Nagaoka pilot-scale project

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Apr. 1993　Kiso-Jiban Consultants Co.
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Apr. 2002　Research Institute of Innovative Technology for the Earth

Specialty: Rock Mechanics (seismic rock physics)

要　旨

二酸化炭素（CO_2）帯水層貯留に係る基本技術は、油田にCO_2を圧入して石油の増進回収をはかるCO_2-EORとほぼ共通する。圧入されたCO_2の挙動を把握するには、弾性波を用いた物理探査法が主流となっている。石油増進回収では採取が困難な原油にCO_2を効果的に吸収させることを目的として、圧入されたCO_2の挙動をモニタリングしている。これに対し、帯水層貯留では長期挙動予測モデルの構築を念頭に、CO_2がいかに圧入井から遠方へ広がるかを中心にCO_2モニタリングが実施されている。現状では帯水層貯留の長期安全性を議論するために、圧入されたCO_2挙動の把握だけでなく、弾性波データに基づいたCO_2貯留量評価も行われるようになっている。このような広義的CO_2モニタリングはMeasurement, Monitoring and Verification（MMV）とも呼ばれている。一方、弾性波データに基づいてCO_2貯留量を評価するには、モニタリングで得られた弾性波速度や比抵抗といった地球物理的パラメータを孔隙率や飽和度のような貯留層パラメータに変換する必要がある。本講演では広義的CO_2モニタリングの観点から、長岡実証試験サイトで得られたCO_2挙動モニタリングの結果を中心に、帯水層貯留におけるCO_2モニタリングの現状と課題について述べる。長岡実証試験サイトでは圧入されたCO_2の挙動を把握するために、坑井間トモグラフィ、物理検層、温度圧力計測、地層流体試料の採取・分析及び微動観測を実施した。主な観測項目を以下に示す。

(1) 温度・圧力測定

圧力・温度計測は圧入対象である貯留層Zone-2の圧力・温度変化を連続的に測定する。

(2) 坑井間弾性波トモグラフィ

坑井間弾性波トモグラフィでは観測井OB-2～OB-3を対象に、CO_2圧入開始前に1回（BLS）、圧入中～圧入終了に5回測定（MS1～MS5）した。

(3) 物理検層

物理検層（音波、比抵抗、中性子、ガンマー線）は、観測井OB-2、-3、-4を対象に実施した。

(4) 地層流体試料採取・分析

地層流体採取・分析は貯留層におけるCO_2の性状が直接に確認した。

(5) 微動観測

CO_2圧入期間中の微動発生状況を観測した。

長岡におけるCO_2圧入実証試験は地下1100mの深部塩水層に我が国で初めてであり、また陸域の深部塩水層としては世界でも初めてである。CO_2貯留状況についてはさらなる解析や検討が現在も継続中であり、まだ解明すべき点が多いものの、実証試験の成果は大いに注目されている。今後はCO_2分離回収から貯留までの一貫した実証試験の実現が強く望まれる。

Note

講演6

Abstract

In comparison to the offshore location of the SACS (Saline Aquifer CO_2 Storage) project, the Japanese Nagaoka project undertaken by RITE and ENAA looks at the geophysical monitoring of CO_2 injection in an onshore saline aquifer. The CO_2 was injected into a thin permeable zone of the reservoir at 20-40 tonnes per day. The CO_2 injection started on July 2003 and ended on January 2005. The total amount of injected CO_2 is about 10,400 tonnes. The pilot-scale demonstration allowed an improved understanding of the CO_2 movement in a porous sandstone reservoir. The results of time-lapse crosswell seismic tomography indicate an area of P-wave velocity decrease possibly due to CO_2 saturation, and the CO_2-bearing zone near the injection well expanded clearly along the formation up dip direction during CO_2 injection. The presence of CO_2 was also identified by induction, sonic and neutron logging at the observation wells. The time-lapse crosswell survey can provide valuable insight into the CO_2 movement within porous sandstone reservoirs. We have demonstrated that the time-lapse well loggings can detect CO_2 breakthrough at the Nagaoka pilot site of CO_2 geological sequestration. The CO_2 breakthrough was identified by induction, sonic and neutron loggings. We found that the neutron and sonic logs showed a similar result of CO_2 distribution in the observation well OB-2. Induction log only detected half width of the CO_2-bearing zone compared to the neutron and sonic logs. Our results suggest that less contributions of CO_2 saturation to resistivity resulted in small changes in induction logging in the partially saturated reservoir. The sonic P-wave velocity decreased significantly due to the breakthrough of injected CO_2 in the observation wells. We confirmed that P-wave velocity reduction in sonic log agreed fairly well with laboratory measurement on drilled core samples from the pilot site. Based on a rock-properties model in conjunction with Gassmann's equation, we successfully matched the history changes of sonic P-wave velocity and estimated CO_2 saturation after breakthrough in two observation wells out of three. From the time-lapse results we also found CO_2 saturation strongly responded to the intermittent injection at the CO_2-bearing zone. During the injection period the driving force of CO_2 movements could be the pressure gradient combined with the density difference (buoyance) between formation water and CO_2. We will continue our well logging program from 2005 through 2007, to monitor the CO_2 movements mainly driven by the buoyant force. Our filed measurements indicate that the pressure buildup due to CO_2 injection is gradually decreasing.

Note

Note

日本における地中貯留の経済評価と有効性

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講演 7

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「CO_2 固定化・有効利用技術戦略マップ」の策定に従事

受　　賞：日本金属学会技術開発賞（2002 年）

Cost Evaluation of CCS Technology and Deployment Scenarios in Japan

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Research Area: Organic and Inorganic Chemistry

Awards:

Technology Development Award of the Japan Institute of Material (2002)

Principal Publications:

Carbon dioxide Capture and Storage Technology, Kogakuchosakai, 2006

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Note

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要　旨

地中貯留は地球温暖化対策として大きな役割を果たすと国際的に期待されている。では、我が国で地中貯留を実施するとどの程度費用がかかるのだろうか？地中貯留は我が国にとっても有効な選択肢となりうるのだろうか？本講演ではコスト分析を中心に、我が国の地中貯留の現状と将来に向けての課題について考えてみたい。また、総合経済モデルを用いたわが国での地中貯留の有効性評価についても紹介したい。

（地中貯留の構成要素とわが国でのコスト）

地中貯留は大規模排出源からのCO_2の分離回収、排出源から貯留層までの輸送、貯留層へのCO_2の昇圧・圧入の各工程から構成される。それぞれの工程別にわが国でのコストを算出し、IPCC特別報告書との比較を行った。分離回収コストは地中貯留コスト全体の６割以上を占め、最も影響が大きい。将来に向けて大幅なコストダウンが必要であり、これは海外においても同様である。一方、輸送コストや貯留層への圧入コストは海外に比べ、わが国の方が遙かに高くなっている。パイプライン輸送における建設工事の制約や、貯留層の浸透率が低いことなどがコスト高の要因である。このため、地中貯留の実現のためには各工程でのコストダウンの検討とともに、輸送距離を短くするために排出源近傍での貯留層の探索が大きな課題となるであろう。

（総合経済モデルからみた見た地中貯留の有効性）

CO_2削減対策技術としてわが国での地中貯留の有効性について総合経済モデルを用いて検討した。本モデルはエネルギーシステムの総コストを最小にするものである。CO_2輸送コストが極めて大きく、輸送・圧入設備の規模の経済が強く働くため、CO_2排出量と貯留サイトの位置関係や設備の規模の経済を考慮できるようにした。2050年にGDP当たりのCO_2排出量を2000年の1/2にするという削減シナリオのもとでは、基礎試錐データのある「地下深部塩水層（帯水層）」52億t-CO_2の半分程度が2050年には経済性を持つ可能性があることが示された。海外よりも多少割高だが、地中貯留はわが国でも重要なCO_2削減の選択肢であると考えられる。また、貯留層の開発が進めば経済的ポテンシャルはさらに増大していくことが期待される。

Note

Abstract

Carbon dioxide capture and storage (CCS) is expected to play an important role as an effective mitigation option in the world. Then, how much will expense when we carry out CCS in Japan? Does CCS become an effective mitigation option in Japan? In this presentation, firstly I would like to focus on present cost of CCS in Japan and then mention the agenda to be examined for cost reduction. In addition, I also would like to show results of effectiveness evaluation study of CCS which used a mix-integer programming model.

Component of CCS and Cost Evaluation

CCS consists of capture of CO_2 from large-scale emission source, transportation from discharge source to the storage site, compression, and injection to reservoirs. Cost in each process was calculated and compared with that in IPCC special report (SRCCS). A capture cost is predominant and holds more than 60% of the whole CCS cost. The large cost reduction is required in capture process as mentioned in foreign cost studies. In contrast, transportation and injection costs are much higher than those found in IPCC-SRCCS. Limitations in pipeline construction and low penetration rate of reservoirs are factors in such a higher cost in Japan. Minimizing transportation distance is required for reduction in transportation cost and this means that a search of reservoirs near emission sites will become an important issue along with cost reduction in each process.

Effectiveness Evaluation of CCS in Japan based on Mix-integer Programming Model

The effectiveness of CCS as a mitigation option in Japan was examined by using a Mix-integer Programming Model which was designed to evaluate CCS and other mitigation technologies in the energy system, especially in considering the high cost of CO_2 transportation and large dependence of the cost of transportation and injection on the facility capacity. Under the CO_2 emission constrain that per-GDP CO_2 emission in 2050 is half of the amount in 2000, this model analysis showed about cost-effective cumulative potential in 2050 is almost half of examined category A2 (deep saline aquifer for which geological data have been obtained by boring, 5.2 Gt-CO_2). Although cost of CCS is estimated to be relatively high compared to other countries, CCS is still considered to be one of the cost-effective options for CO_2 emission reduction in Japan and cost effective potential is expected to be become larger with developing available reservoirs.

Note

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わが国でのCCS適用の展望

大　隅　多加志

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平成 12 年 4 月　財団法人　地球環境産業技術研究機構　出向
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専門分野：地球化学（海洋・地震・火山・エネルギー技術関連）

著　　書：気候変動に関する政府間パネル（IPCC）CO_2 回収貯留特別報告書（2005）
第 6 章「海洋」執筆者
図解 CO_2 貯留テクノロジー（RITE 編；2006 年 12 月　工業調査会刊）分担執筆

CCS implementation in Japan

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Graduate School in Science, the University of Tokyo, in 1978
Working with Tokyo Institute of Technology as Instructor, from 1978 - 1987,
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Expertise: Geochemistry of ocean, earthquake, volcano and energy-related technologies

Author of Books:
Chapter 6 of IPCC Special Report on Carbon Dioxide Capture and Storage
(Oxford Univ. Press 2005)
Chapter 2 of "CO_2 Storage Technology Illustrated" (Kogyo Chosa-kai 2006 edited by RITE, in Japanese)

要　旨

日本における二酸化炭素(CO_2)地中貯留の検討は、1990年ころ、国内から排出されるCO_2を海外でEOR（石油増進回収）に利用する提案として開始された。現在、世界での研究の主流となっている帯水層貯留（Aquifer Storage）の概念を、はじめて提唱したのは日本の研究者であった（小出，1992年）ところから、1993年には、日本近海での帯水層貯留に関する容量推定が実施されている。

1997年の京都議定書採択の時点では、CCSは、日本が実際に選択する技術としては、かならずしも想定されていなかったかもしれない。CO_2海洋隔離技術開発が先行したからである。

2000年にRITEはCO_2地中貯留技術開発を開始した。実際に地中に圧入されたCO_2の挙動が、詳細に解明され、CO_2地中貯留を多くの人々に現実の技術として理解してもらうことができた。

回収から貯留までのコストは、依然として実際の適用にとっての壁であるものの、CO_2削減のための他の方策と冷静に比較してみれば、その実適用に踏み切るべき時にきている。

Abstract

Examination of the oversea EOR use of captured CO_2 from domestic industries was the start of the studies on underground geological storage of CO_2 in Japan. After two years from the start, Koide et al. (1992) proposed a new concept of "aquifer storage" and based on this concept, the domestic potential around the Japanese Archipelago for CO_2 storage was estimated in 1993.

In 1997, when the Kyoto Protocol was adopted, Japan was probably not aiming at the actual domestic implementation of CCS; because the prioritized R&D target at that time was CO_2 ocean storage.

However, the R&D on aquifer storage of CO_2 including planned geological site survey activities was initiated by RITE in 2000. Successful small-scale CO_2 injection conducted between 2003 and 2005 revealed clearly the detailed behavior of supercritical CO_2 in aquifer, providing a basis of the people's understanding of the technology.

Although we have still to overcome the cost barrier for the full-scale CCS implementation in Japan, we are now at the final stage to plan the picture of CCS implementation up to 2020.

Note

Research Institute of Innovative
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