

# CO<sub>2</sub> Transport, Storage and Monitoring R&D Progress in Republic of Korea

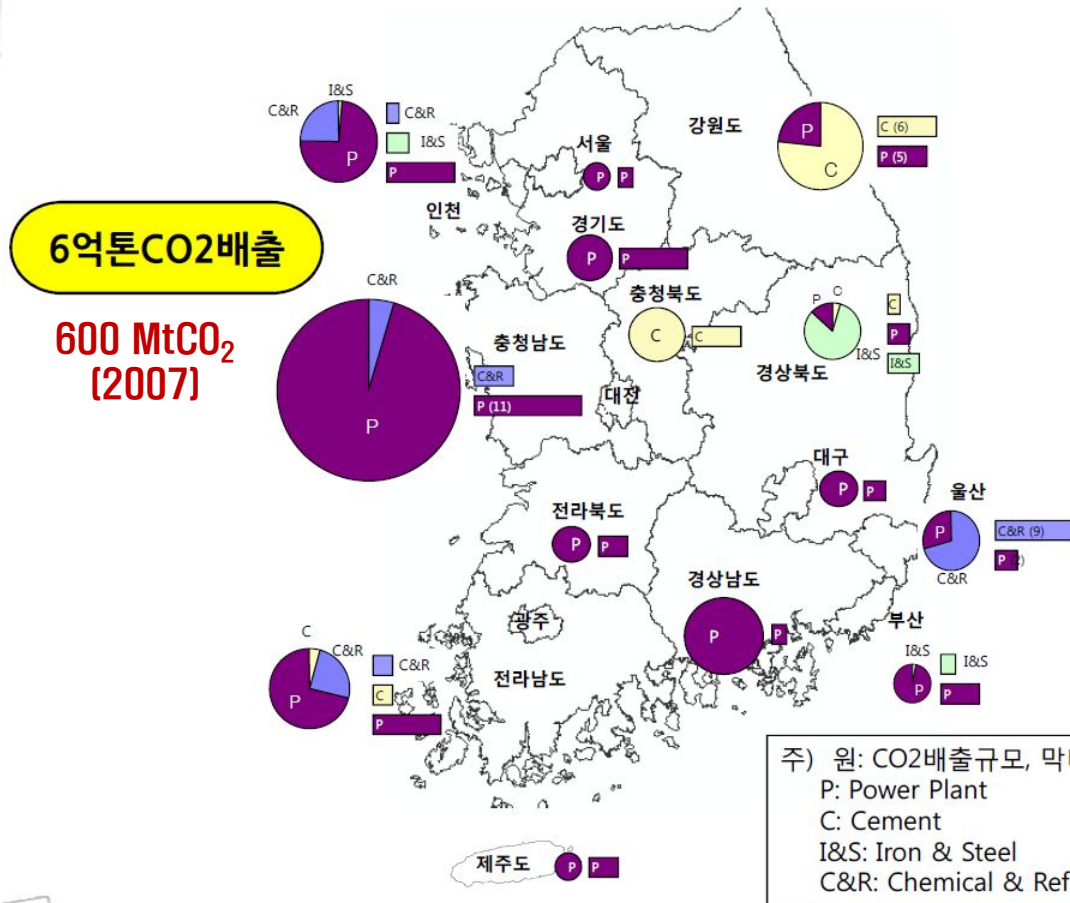
2012. 9. 17

C. Huh<sup>1</sup>, S.G. Kang<sup>1</sup>, M.H. Park<sup>2</sup>, Y.G. Park<sup>1</sup>

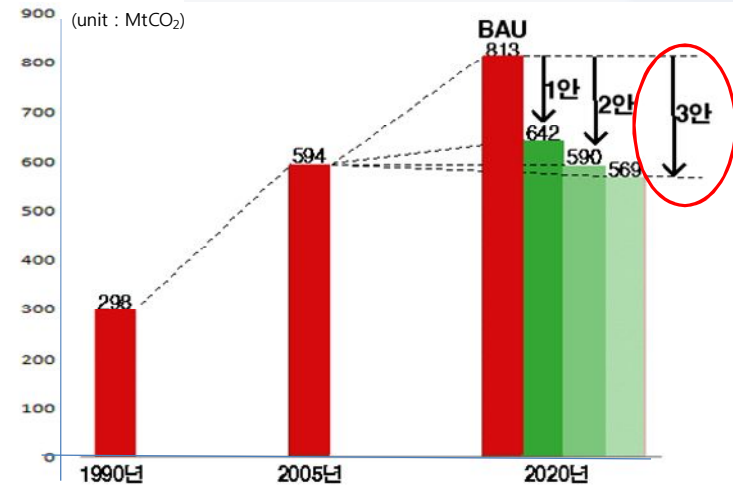
<sup>1</sup>Korea Institute of Ocean Science and Technology (KIOST)

<sup>2</sup>Korea National Oil Cooperation (KNOC)

# GHG reduction in Korea



Korea Scenario for GHG Reduction

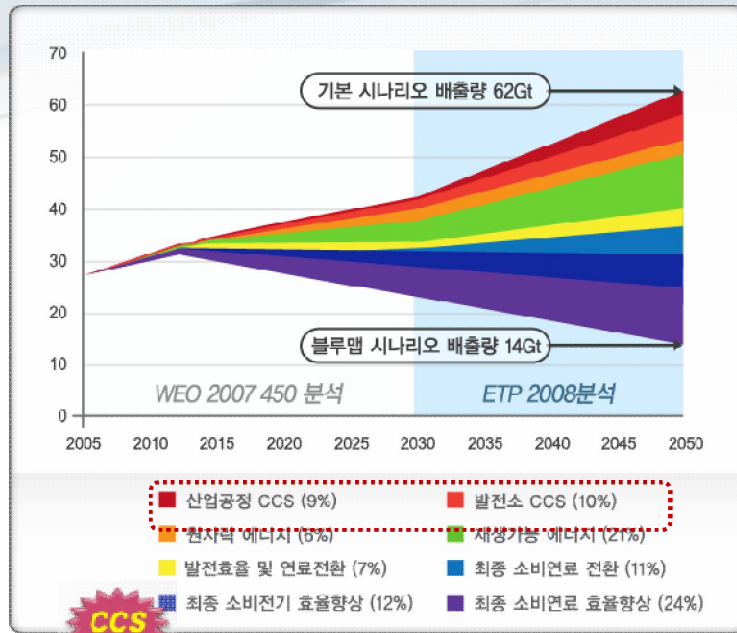


(President Committee on Green Growth, '09.12)

Korea declared the 30% reduction of GHG on basis of BAU by 2020 (President Lee at COP-15, 2009).

- To reach this target, CCS should be employed as one options to mitigate GHG emission.
- Korea CCS strategy is currently being prepared.

# CCS activities in Korea



## [National strategy for CCS technology development and deployment]

- Green growth 5-year plan ('09.7)
- Strategy for development and commercialization of major Green technology('09.5)
- **Korea CCS Master Plan('10.7)**
- **Roadmap of offshore geological storage of CO<sub>2</sub> ('10.11)**  
(Ministry of Land, Transport and Maritime affairs)

## ● Korea suggested CCS as a key solution for achieving mid-term reduction goals(President Committee on Green Growth, 2009)

- (2016) CCS demonstration plan for 1Mt CO<sub>2</sub> reduction
- (2020) Scale up to 3Mt (IEA 20 by 20)
- (2030) CCS deployment plan of 32Mt CO<sub>2</sub>/year  
(10% of national CO<sub>2</sub> reduction)



# Korea CCS Master Plan

(10.7,13. green growth Korea)

## Projects

## Ministries



### Basic R&D

- Innovative basic technology development for CO<sub>2</sub> capture
- Innovative basic technology development for CO<sub>2</sub> storage
- Pilot scale demonstration for capture-storage (10Kt)
- (biological and chemical) technology development for CO<sub>2</sub> conversion and utilization

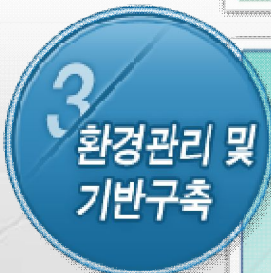
MEST  
MEST  
MEST  
MEST(ME)



### Demonstration Commercialization

- Commercialization in conjunction with demonstration
- Pilot demonstration for CO<sub>2</sub> capture technology (10-30MW)
- Large scale(100-300MW) demonstration(capture-storage integration demonstration)
- CO<sub>2</sub> transport(carrier, pipeline) technology development
- CO<sub>2</sub> storage capacity evaluation(offshore GS/onshore GS)
- CO<sub>2</sub> storage site selection and management(offshore GS/onshore GS)

MKE  
MKE  
MKE(MLTM)  
MLTM  
MLTM/MKE  
MLTM/ME



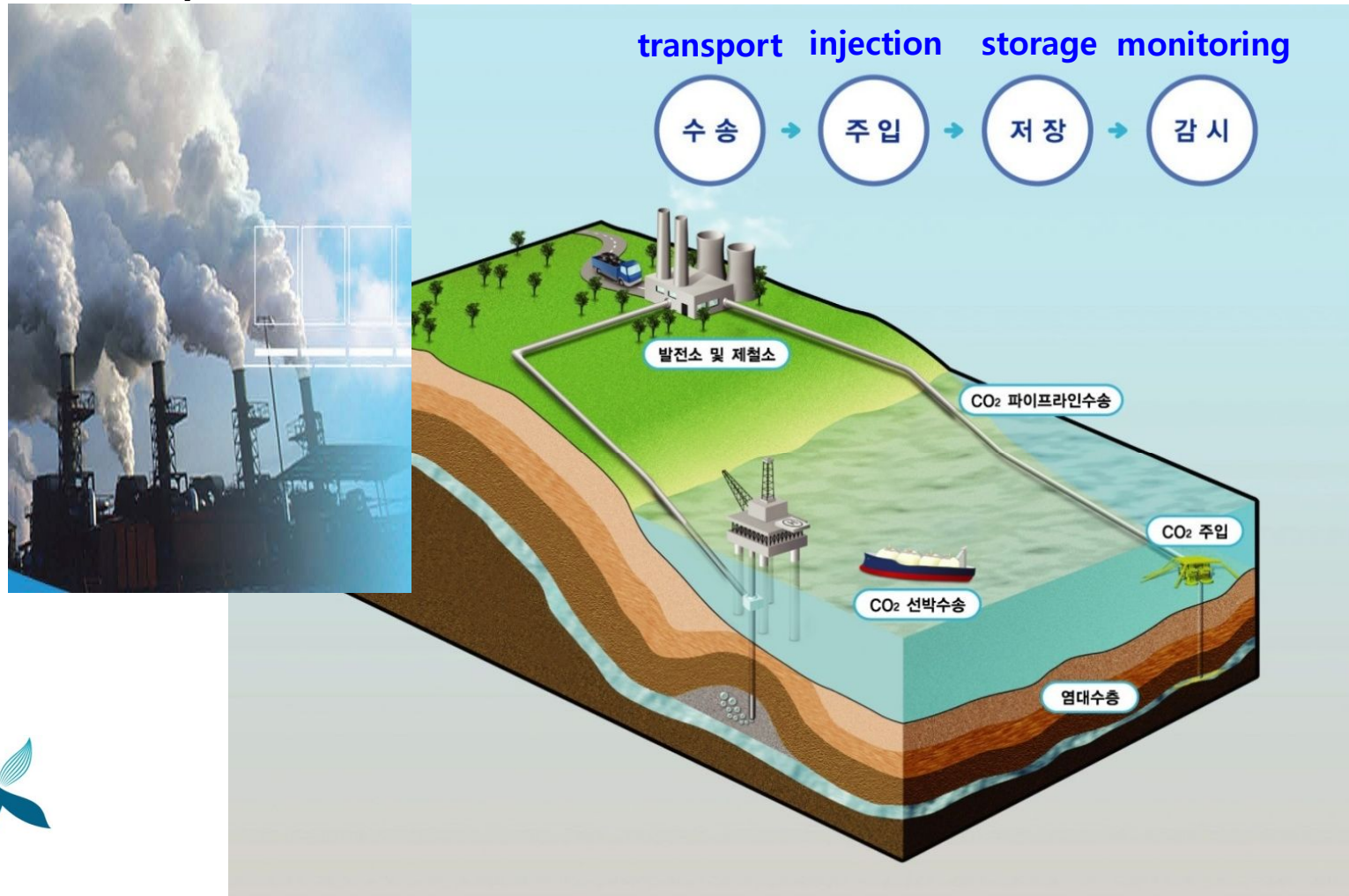
### Framework Social Infra.

- Legal and regulatory framework(offshore GS/onshore GS)
- Environmental protection technology development(offshore GS/onshore GS)
- Commercialization assistance(tax, incentive, finance, etc.)
- Human resource development
- public understanding
- International collaboration and network

MLTM/ME  
MLTM/ME  
MKE(MOSF)  
MEST/MKE/MLTM/  
ME/MOSF

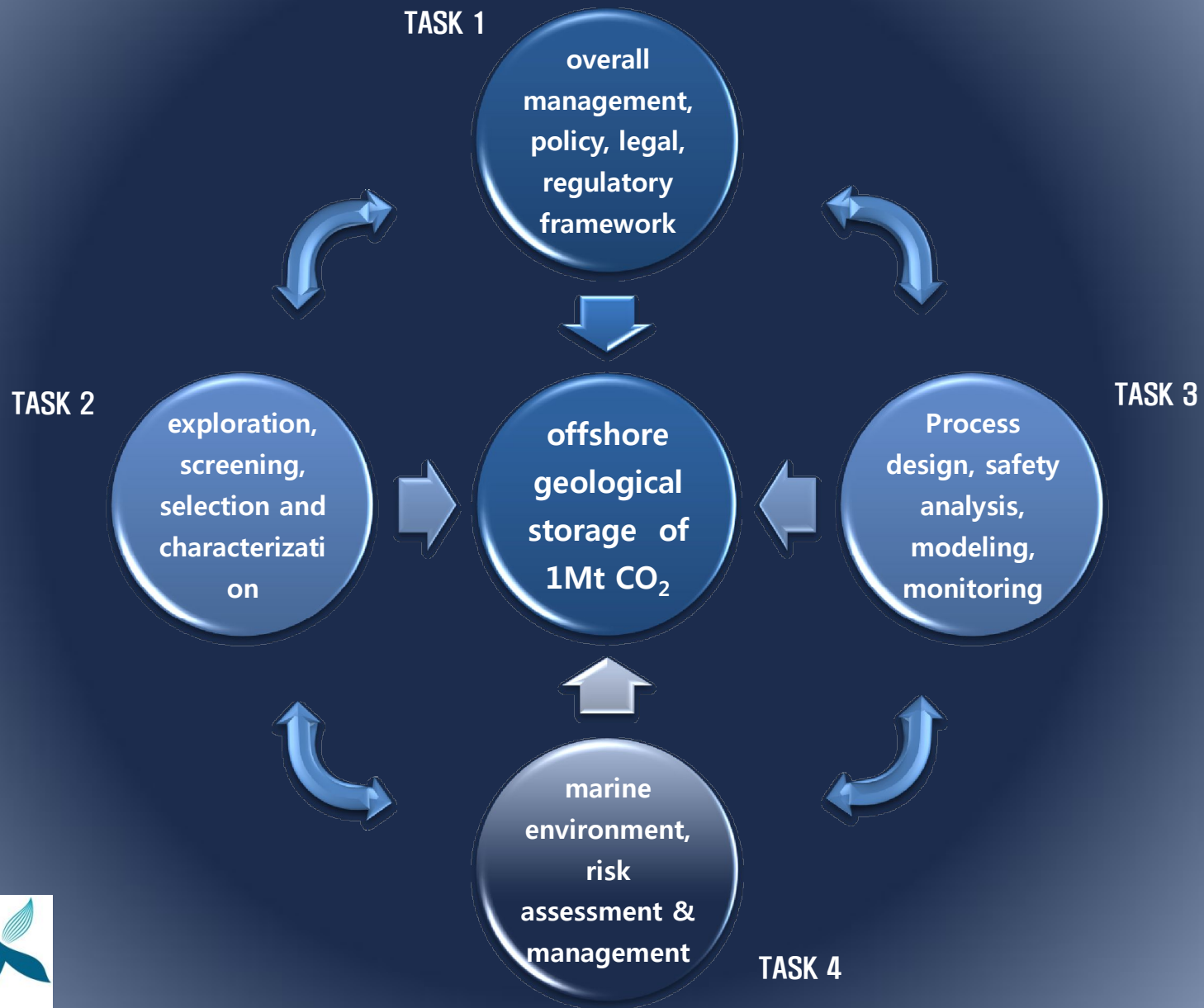
# Overview of KIOST offshore CCS project

Development of technologies to transport and store CO<sub>2</sub> captured from large CO<sub>2</sub> sources (power plant and steelworks) into the **sub-seabed geological formations** (aquifers, oil/gas fields) in response to large scale reduction in greenhouse gas emissions under climate change and post-Kyoto regime, including **site selection, transport system design and environmental leak prevention**, etc. **(Phase 2, 2011~2015, 66M USD)**





# R&D framework (offshore geological storage)



# R&D framework (offshore geological storage)



# Overview of TASK 1

## ○ overall management, policy, legal, regulatory framework

- general project management and construction of technology network between sub-projects
- international network
- policy, legal and regulatory framework development
- economic evaluation for application of domestic offshore CCS
- building the infrastructure for demonstration and commercialization of large scale offshore CCS and PO/PA(public outreach/public acceptance) activities

### [legal and regulatory framework]

국가 CCS 종합 추진계획(안)

2010. 7. 13.

대한민국정부 관보

해양환경정책관실 해양보전과

IMO

제정기관	해양수산부	제정일자	2010. 7. 13.
제정목적	해양수산부	제정번호	17178
제정일자	2010. 11. 18	제정기관	해양수산부
제정일자	2010. 11. 18	제정번호	17178

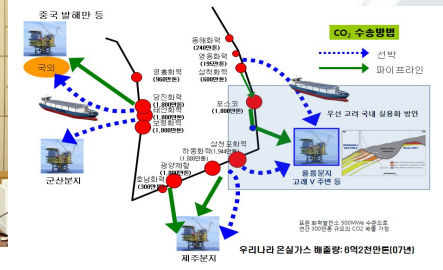
CO2 해양저중저장 추진계획

2010. 7. 13. 육상(상업용)의 부차간 역할분담에 따라 부인부의 세부추진계획을 수립하여 시행하고자 합니다.

### [international cooperation]



### [deployment scenario]



### [technology network between sub-projects, PO/PA activities]





# Policy and regulatory framework

(International) 1996 London protocol to London convention  
: amendment to the London Protocol for offshore geological storage of CO<sub>2</sub>

o '06.11, amendment to Annex1 of the London Protocol

- Adding CO<sub>2</sub> stream to the list of wastes or other matter that may be considered for dumping
- Limited to CO<sub>2</sub> stream captured with the object of offshore CCS
- Application in enforcement regulations under "Marine Environment Management Act " in Korea(2010.9)

o '09.10 the London Protocol Article 6 amendment

- Allowing the export of CO<sub>2</sub> stream for CCS
- Transboundary issues of stored CO<sub>2</sub> stream(now under discussion)



(Domestic) To establish CCS management system under Marine Environment Management Act in accordance with London protocol

Marine Environment Management Act

Classification of CO<sub>2</sub> Site regulation Storage permission

해양환경관리법

폐기물 관련 규정

1. CO<sub>2</sub>의 해양지중저장을 위한 규정 개선
2. 폐기물 종류 및 기준 개선
3. 탐사/실증사업 추진을 위한 저장소 지정규정 - 해양환경관리법 제23조
4. CO<sub>2</sub> 해양지중저장 규정 사전연구 - 타 연구결과 반영하여 연차 별로 세부규정 마련

CCS 추진주체

1. CO<sub>2</sub> 해양지중사업의 추진주체 설치 근거 마련
2. 실증/실용화 단계별 추진주체

MRV

보고·감독·지원

1. CO<sub>2</sub> 해양지중저장 사업 보고 및 감독규정 검토 - 해양환경관리법 제115조 등
2. 저장소의 관리책임 근거
2. 인력양성, 기술개발 등 지원 규정 마련

CCS business Liability transfer

기타 규정

others

1. CCS 해양지중저장 실증시설은 해양시설에 해당, 관련 규정 검토 - 이어도 해양과학 기지, 기상관측시설 등 포함
2. 기후변화협약 등 국제협력 근거 마련
2. 2011 정책로드맵에 따라, 필수 규정 검토 - 안전, 환경기준 등

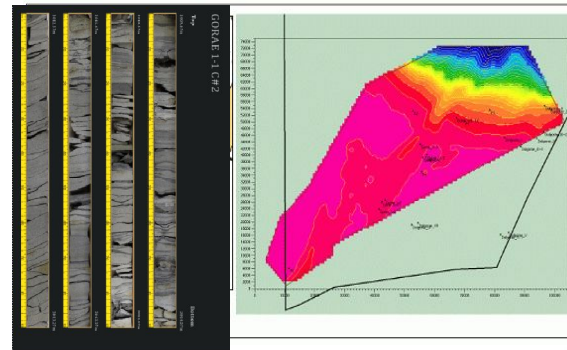
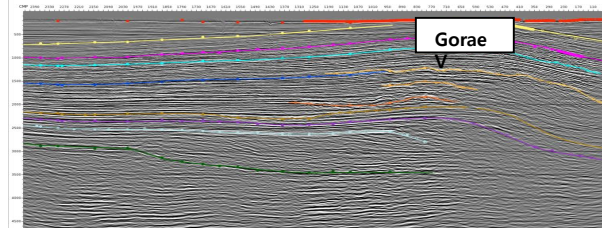
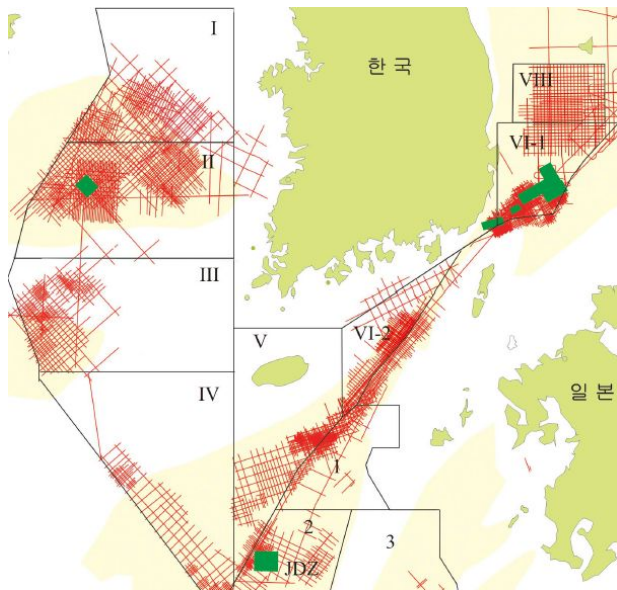
# Overview of TASK 2

## ○ Construction of carbon storage atlas and selection of demonstration sites in Korea offshore sediment

- DB construction, reinterpretation of existing exploration data
- new seismic survey, test drilling
- characterization of candidate site by stratigraphic/structural and drilling data analysis
- selection of candidate site for demonstration project of 1Mt CO<sub>2</sub> scale



### [reinterpretation of existing exploration data]



Seismic data : >280,000 L-km (2D)KNOC,  
>5,000 L-km (2D) KIGAM & KORDI

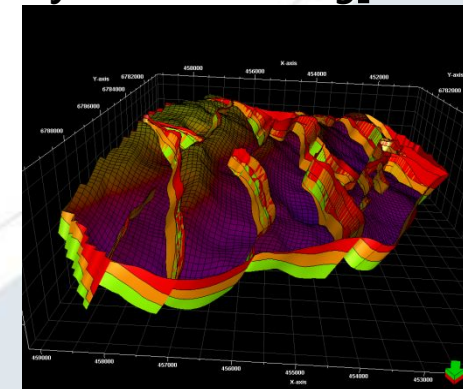
Well log /core data : 44 wells

Geological reports

### [site survey-seismic/drilling]



### [Geological structure model/ dynamic modeling]



### [basin structure/sequence interpretation/DB construction of each basin]

# Offshore basin for CO<sub>2</sub> storage

## Exploration data

Well data : 5  
 Seismic : 35,827 L-km(2D)  
 298 km<sup>2</sup>(3D)

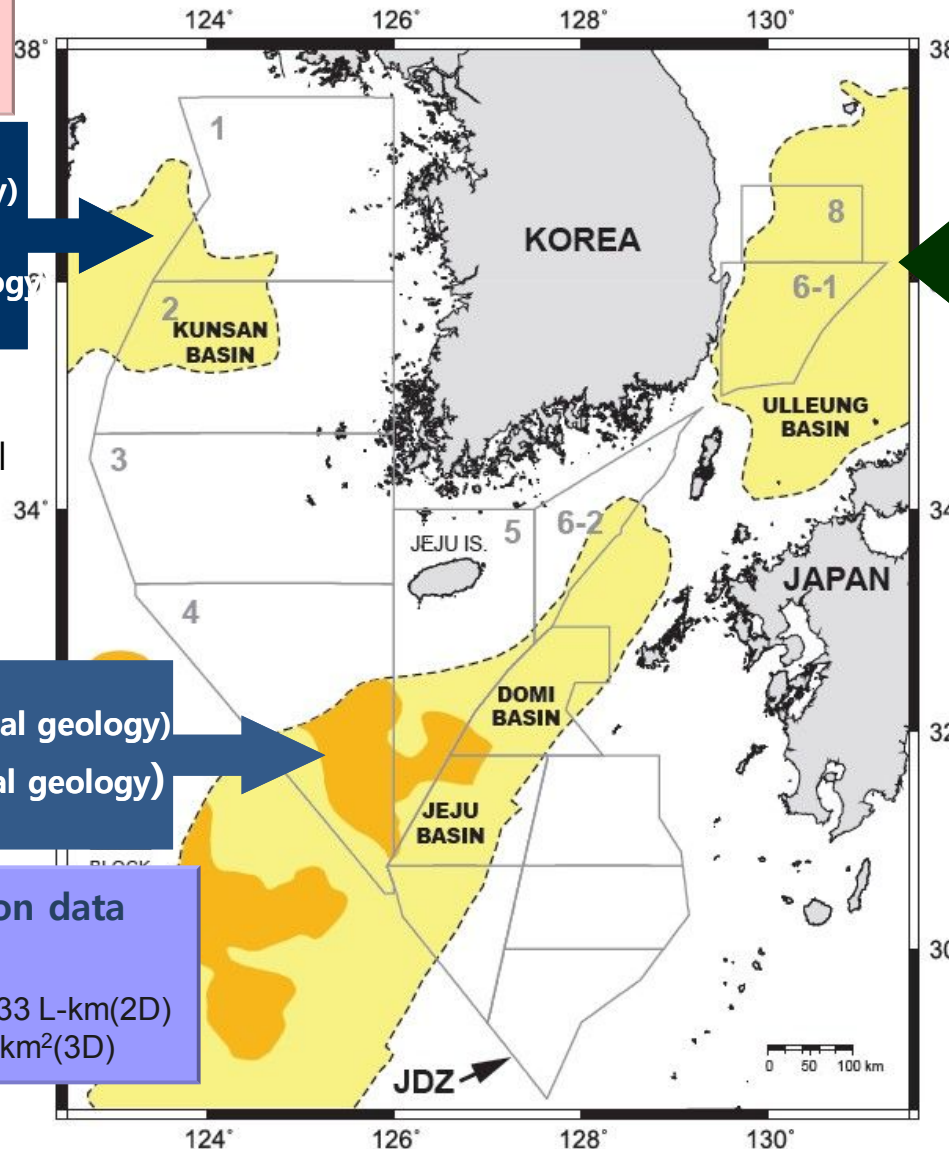
Jeju Univ. (regional geology)  
 NHRI (biostratigraphy)  
 Yonsei Univ. (structural geology)

**2. Kunsan/Jeju basin:**  
 research on regional  
 geology, potential  
 storage site

Bukyong Univ. (regional geology)  
 Yonsei Univ. (structural geology)

## Exploration data

Well data : 15  
 Seismic : 57,133 L-km(2D)  
 563 km<sup>2</sup>(3D)



**KNOC (overall/basin analysis)**  
**NHRI (non-deformation zone)**  
**Chonnam Univ. (Core DB)**  
**CO2CRC (Review)**  
**Univ. Texas, Austin**  
**Univ. Texas, Dallas**

## Exploration data

Well data : 23  
 Seismic : 15,897 L-km(2D)  
 2,161 km<sup>2</sup>(3D)

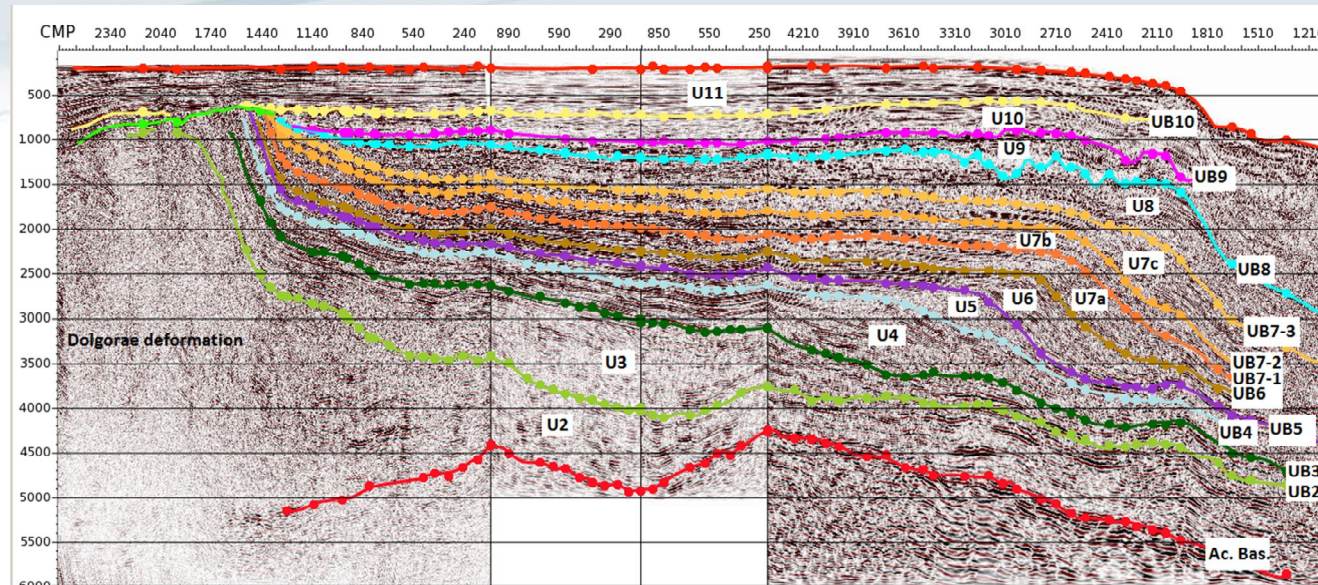
- 1. Ulleung basin:** stratigraphy, sedimentology, location and storage capacity of CO<sub>2</sub> storage site
- 3. DB construction for domestic offshore CO<sub>2</sub> storage site (Ulleung basin)**



## Analysis of existing E&P data

- 8,500 kilometres of 2D seismic lines (305 seismic lines) covering an area of 7,000 km<sup>2</sup>
- Five 3D blocks (Gorae-block-VI, Dolgorae 1, Gorae 1, Gorae 2 and North-Dolgorae) covering an area of 2,360 km<sup>2</sup>
- 25 wells with log data
- Stacking velocities (only for Gorae-block-VI)
- DST reports
- Interpretation reports
- Core and cuttings data
- Core photos and measured sections of cored intervals
- Microfossil datasets

# Analysis of existing E&P data

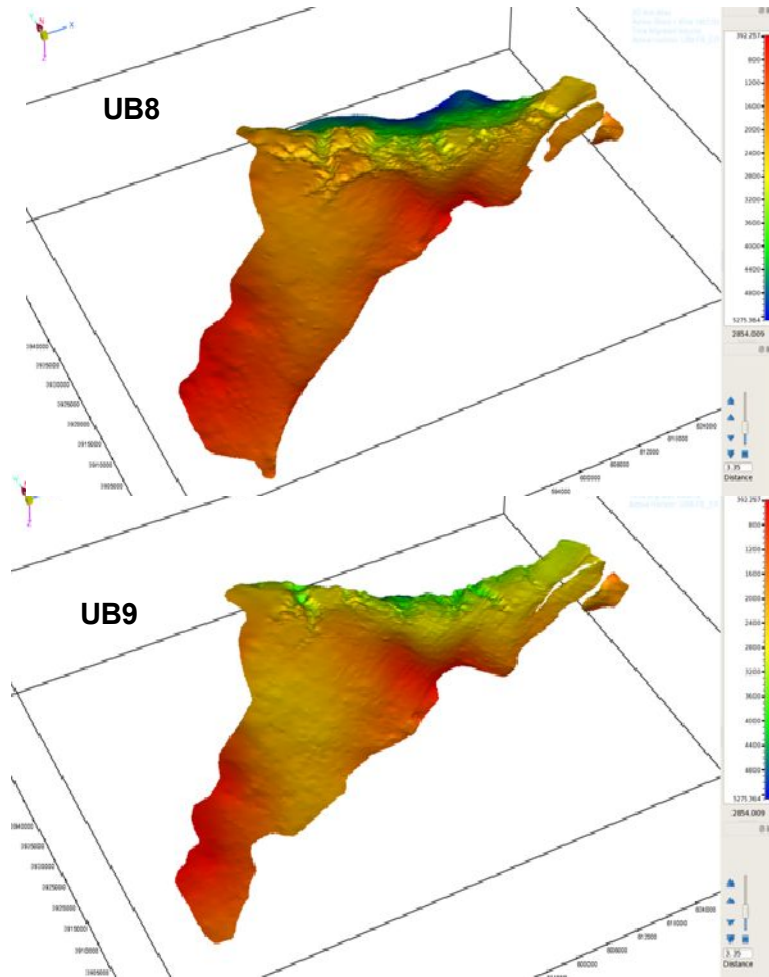


<interpretation section showing total 13 seismic units, KNOC 2012>

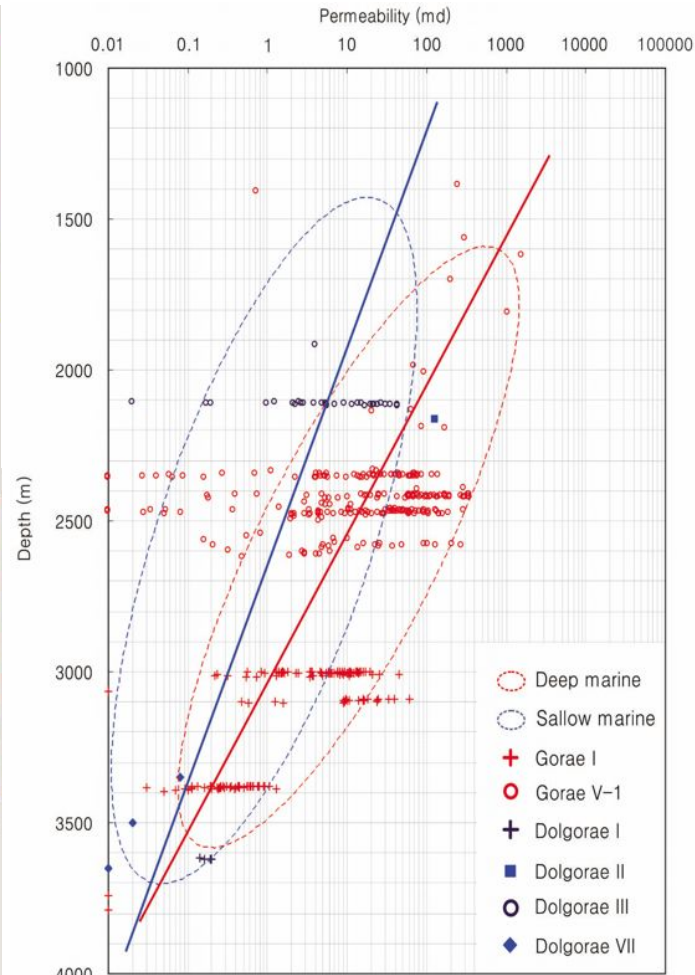
- 13 Seismic Unit
  - interpretation on the basis of seismic reflection criteria and sequence stratigraphy
  - understanding of depositional patterns and features of basin through seismic interpretation
- Creation of 32 polygons (800~3,000m)
- identification of major prospects
  - these prospects is classified as stratigraphic traps and structural traps

# Preliminary evaluation of storage site

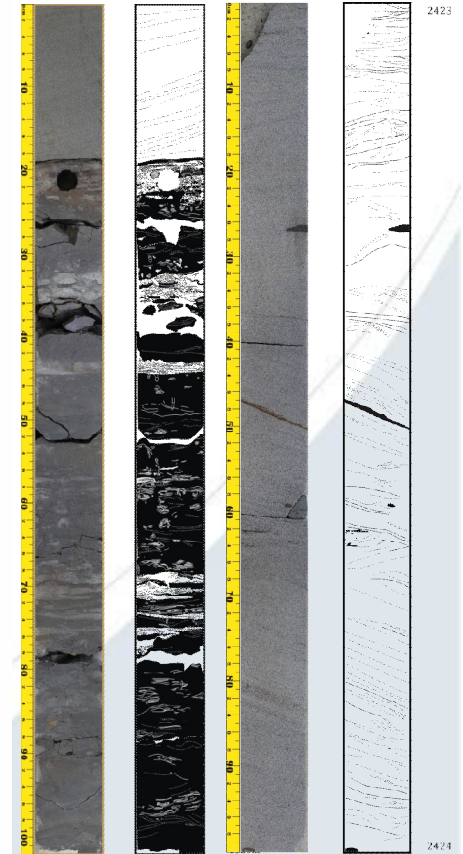
3D views of UB surfaces (in TWT)



Porosity & permeability



Core data



• Scope of analysis

- upper boundary: 800 m below seafloor, suggested by NETL
- lower boundary: limited to a depth of 3,000m where porosity and permeability decrease rapidly



# Overview of TASK 3

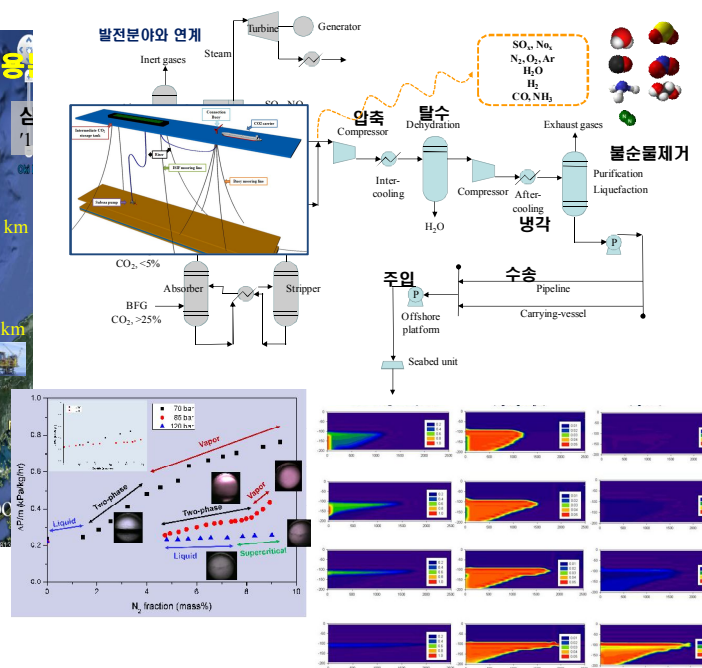
## Offshore CCS process design, safety analysis and subsurface CO<sub>2</sub> modeling & monitoring

- Process design of CO<sub>2</sub> transport (pipeline, carrier) and offshore injection
- Safety analysis, certification
- Subsurface CO<sub>2</sub> modeling and monitoring
- Leak detection and prevention

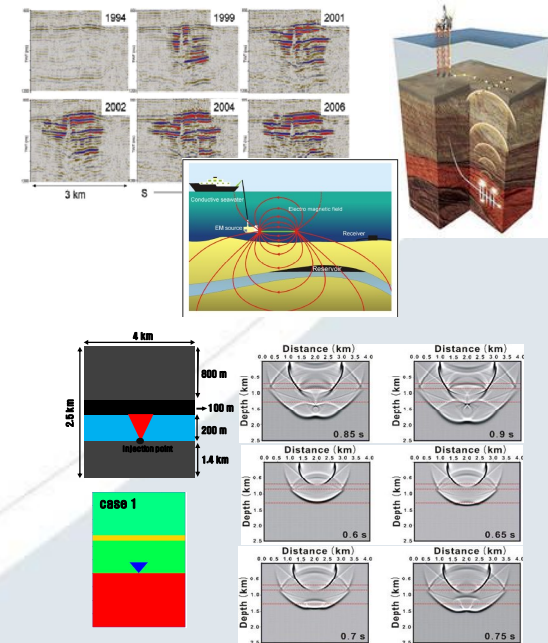
### [transport scenario]



### [process design and modeling]



### [geophysical monitoring]



# CO<sub>2</sub> transport

- route(method) : pipeline 3, carrier 2 (+1)
- CO<sub>2</sub> source-sink : source 2 (P, H), sink 1 (E)
- CO<sub>2</sub> capacity(annual) : 5 step

	Case 1	Case 2	Case 3	Case 4	Case 5
Poryung (W)	1Mt	1Mt	1Mt	1.5Mt	3Mt
Hadong (S)	0	0.5Mt	1Mt	1.5Mt	3Mt

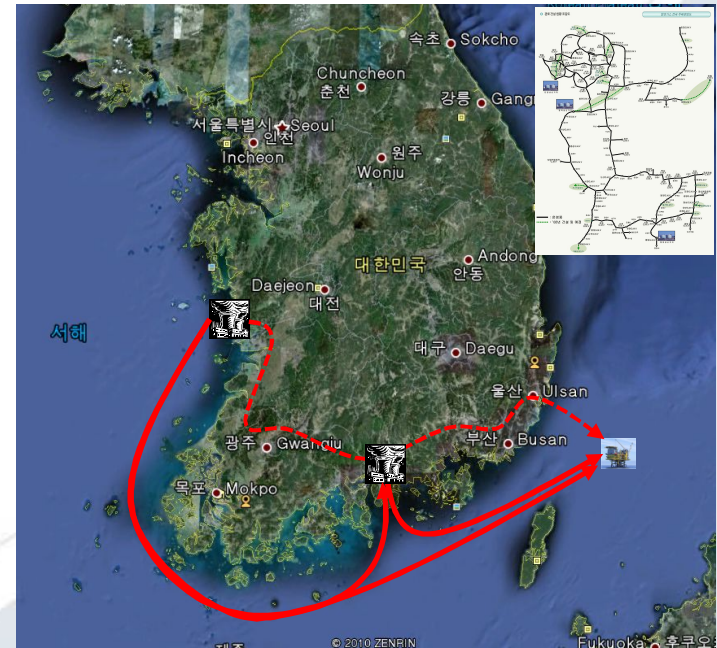
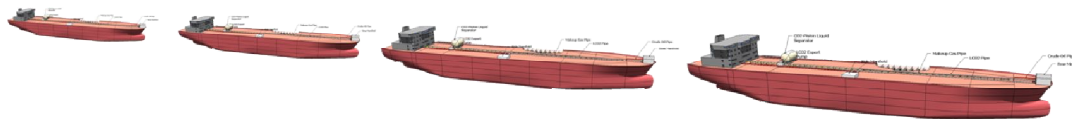
pipe I.D. 1 : P-H 0.3m, H-hub-E 0.5m

pipe I.D. 2 : P-H 0.5m, H-hub-E 1.0m

pipe I.D. 3 : P-H 1.0m, H-hub-E 1.0m

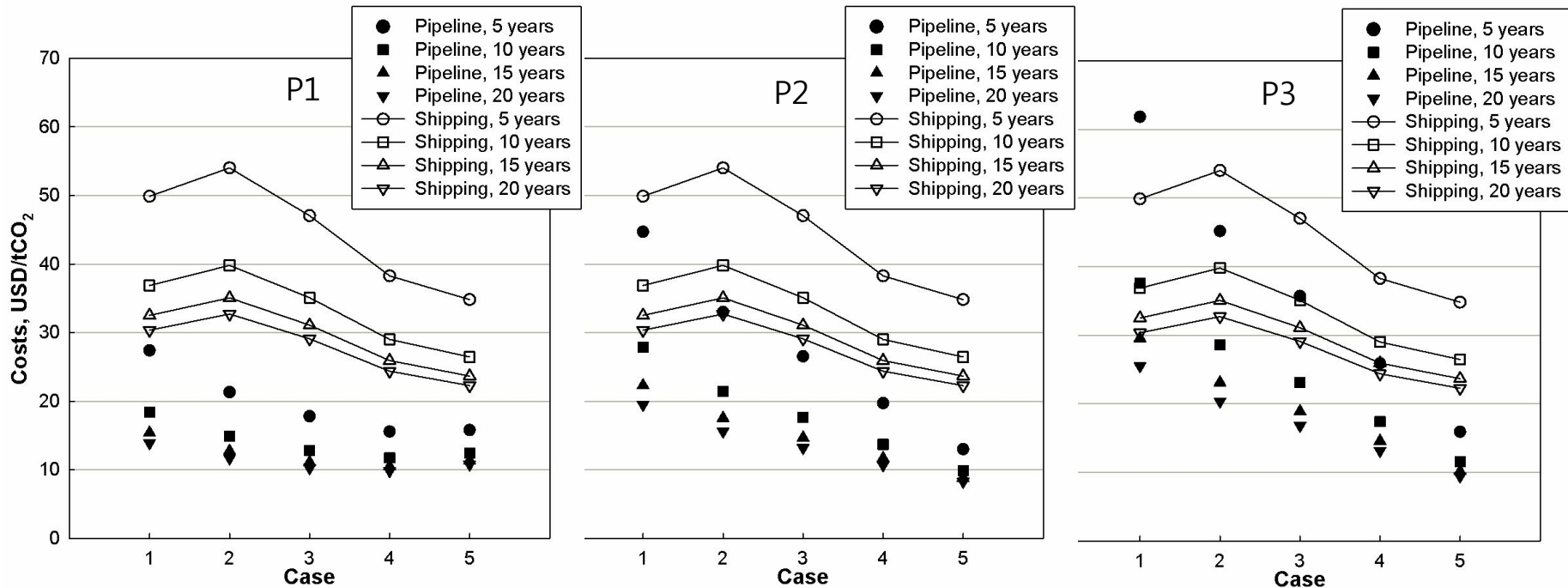
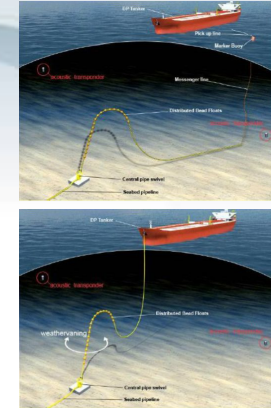
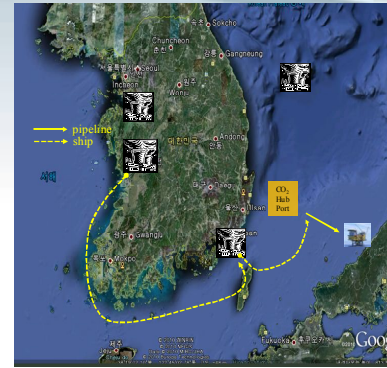
carrier : 4 size

(20k, 40k, 80k, 120k)



# CO<sub>2</sub> transport

- Pipeline is cheaper than vessel
- There are some competitive conditions.
- Social expense is not considered.
- Hybrid transport scenario (pipe-hub-carrier) can be applied.
- Direct injection w/o platform is now considered.



Case 1: P 1.0Mt, H 0Mt  
 Case 2: P 1.0Mt, H 0.5Mt  
 Case 3: P 1.0Mt, H 1.0Mt  
 Case 4: P 1.5Mt, H 1.5Mt  
 Case 5: P 3.0Mt, H 3.0Mt

P1: P-H 0.3m(ID), H-E 0.5m(ID)  
 P1: P-H 0.5m(ID), H-E 1.0m(ID)  
 P1: P-H-E 1.0m(ID)



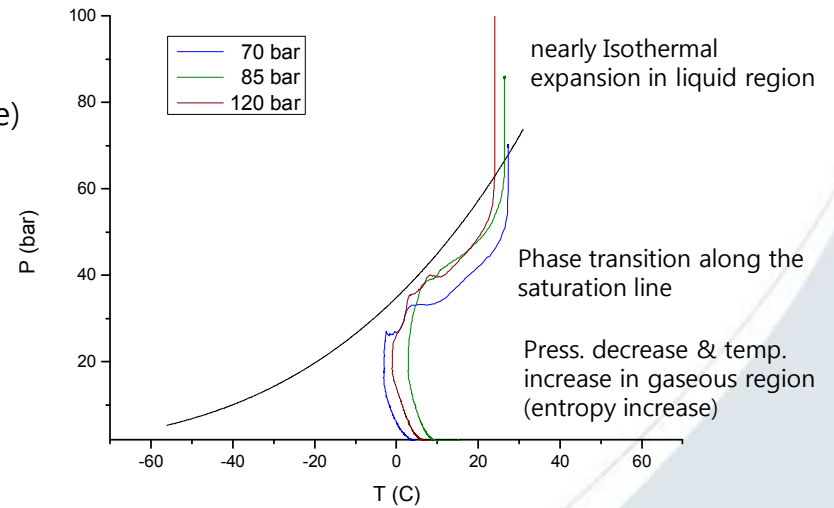
# CO<sub>2</sub> depressurization (blow-down)

Test Section

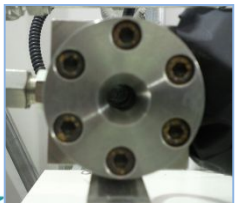


- Transport Test Section  
**Length : 56,191.8 mm**  
 In. Dia. : 3.8608mm  
 Tube t : 1.24mm
- Low Pressure Receiver with BP regulator (regulate T/S back pressure)

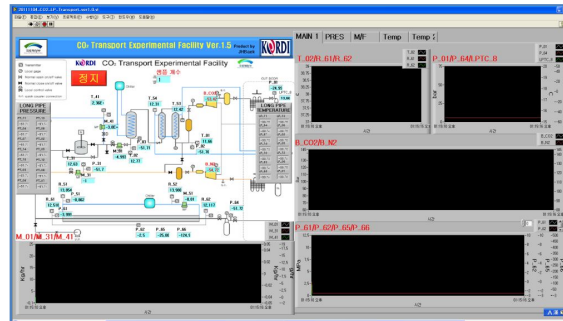
Low Pressure Receiver



High Pressure View Cell (with CCD camera)

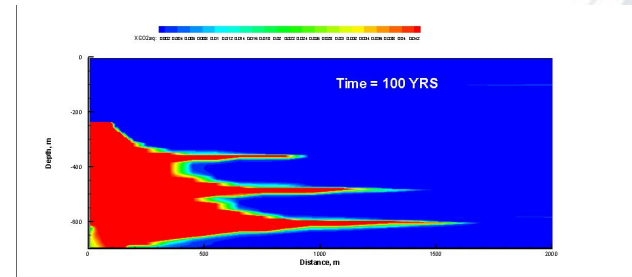
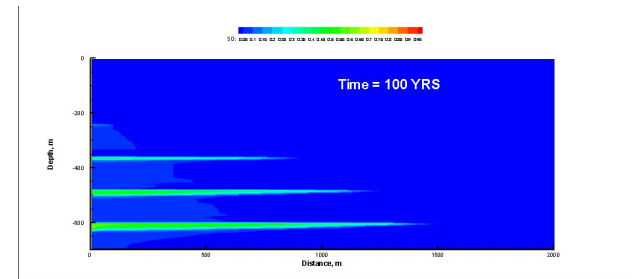
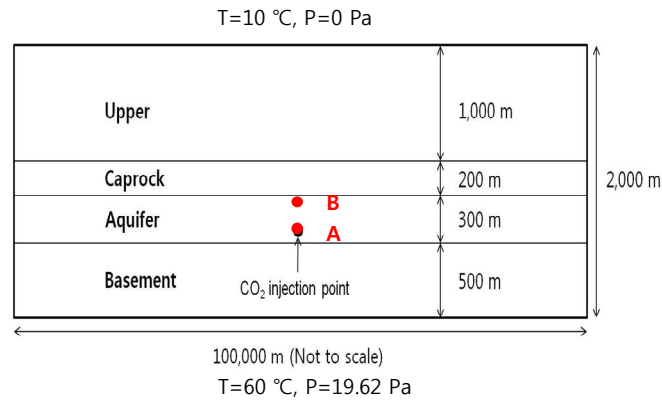
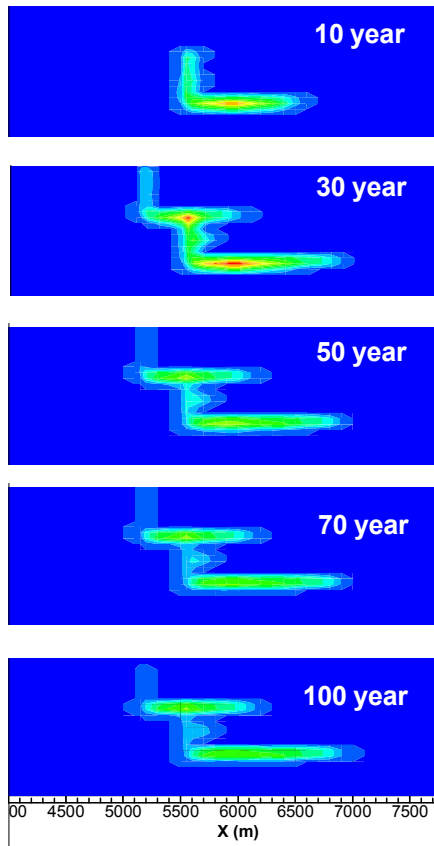


LabView DAQ Program

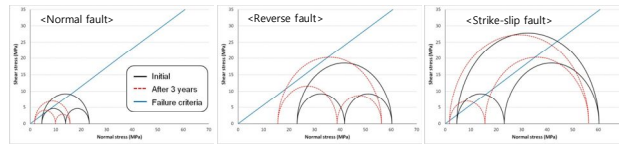


# Subsurface CO<sub>2</sub> modeling

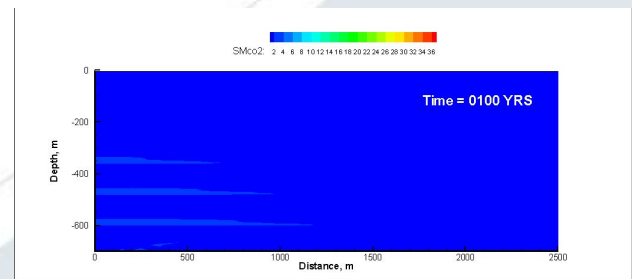
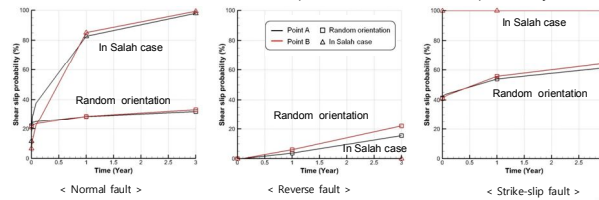
- Geomechanical, Hydrogeological, Thermal, Geochemical modeling
- Analysis of long-term behavior and leakage due to shear failure of joint, etc



- Shear failure analysis of joint : Mohr-Coulomb, Friction angle - 30°, (point A)  
Movement of Mohr circle after 3 years → Increase of joint shear failure zones → Increase of CO2 potential leakage



- Shear failure probability of joint  
Normal fault → Reverse fault → Strike-slip fault (Increase of failure probability)

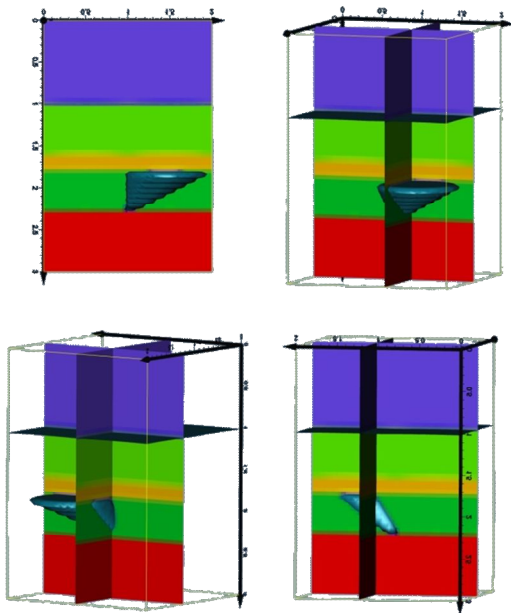


# Subsurface CO<sub>2</sub> monitoring

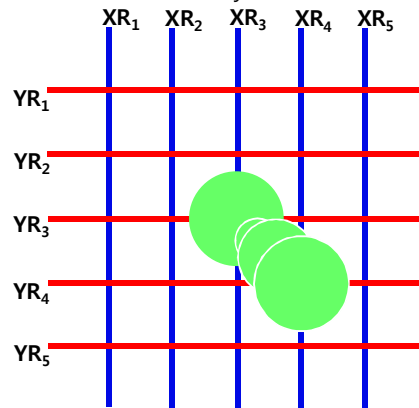
- Review and analysis of existing monitoring technique (NETL, DTI, etc.)
- Development of geophysical monitoring algorithm
  - 4D seismic, mCSEM, microseismic, gravity

< Scenario 2 >

CO<sub>2</sub> moves to southeast from center of model



To understanding the distribution of CO<sub>2</sub> through an array of receivers



< Scenario 1 >

CO<sub>2</sub> moves in the middle to upper

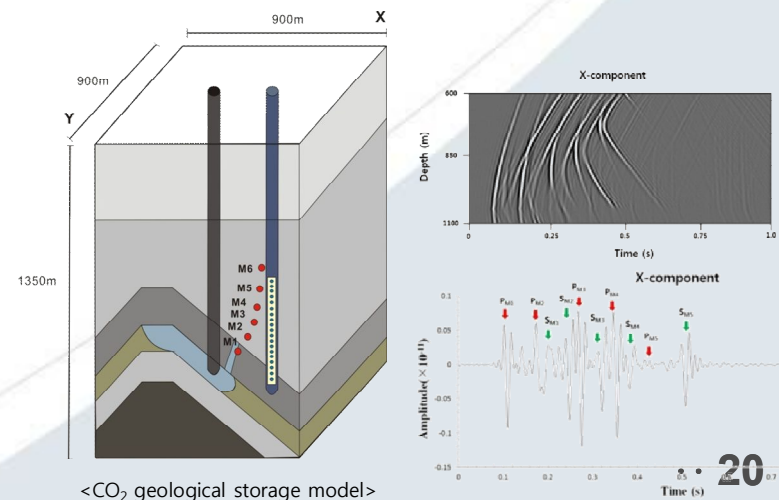
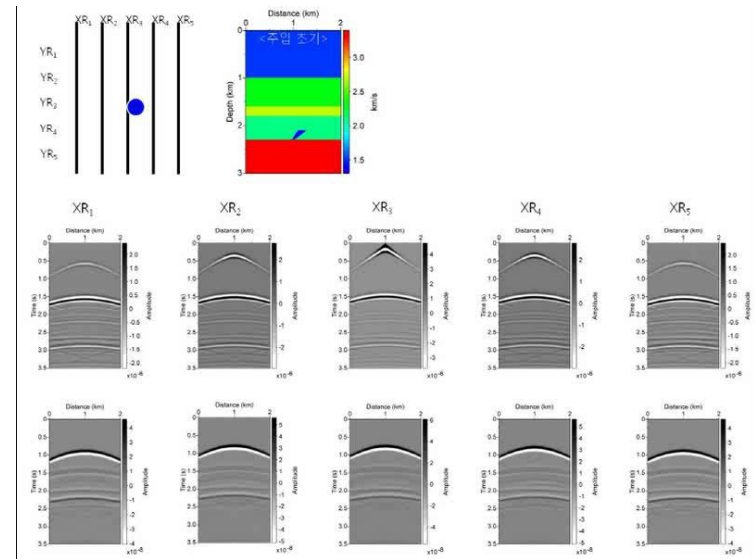
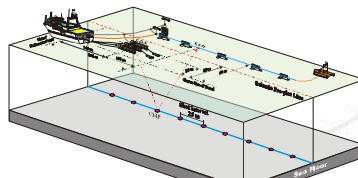
< Scenario 2 >

CO<sub>2</sub> moves to southeast from center of model

Source location : middle

XR : X direction receiving point line

YR : Y direction receiving point line



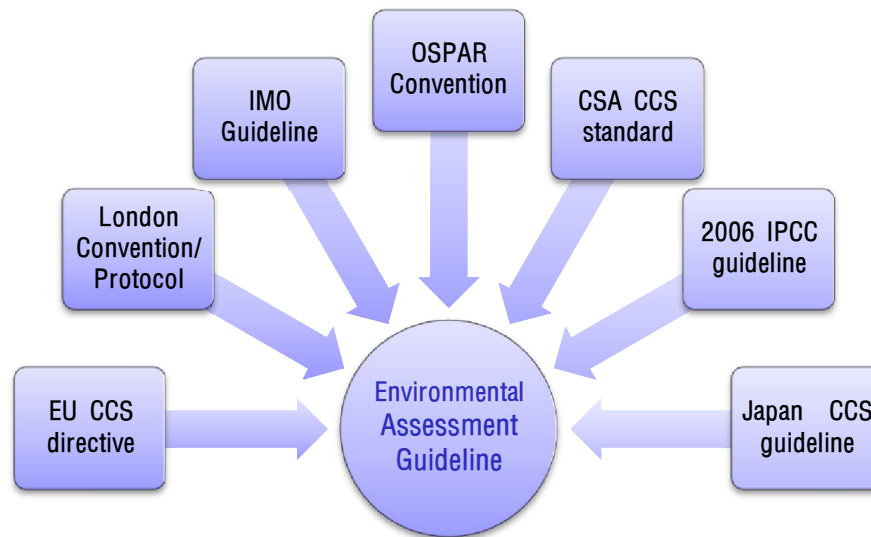


# Overview of TASK 4

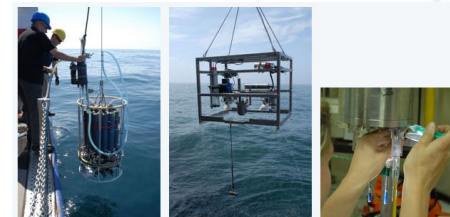
## ○ Environmental risk assessment and management

- based on IMO LP & Marine Environment Protection Law
- Risk assessment of leak in offshore environment
- Baseline monitoring of candidate CO<sub>2</sub> storage site
- Environmental management framework

### [environmental assessment]



### [ baseline monitoring]



# Environmental risk assessment and management

Event- or Process-Driven Leakage Probability

Fate Modeling of CO<sub>2</sub> In Marine Environment

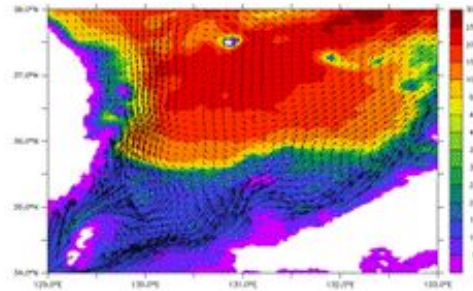
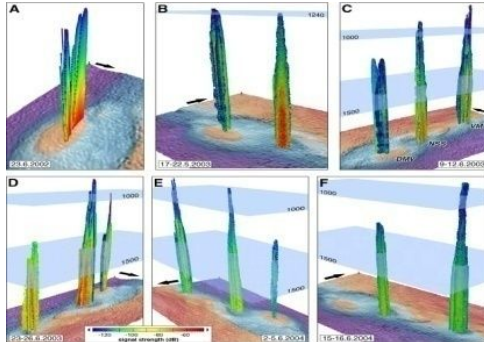
Likelihood of Exposure and Biological Effect

CO<sub>2</sub> Release

CO<sub>2</sub> Fate

Safety / Risk

- Scenario Development
- Leakage Model
- Estimation of Probable Release to Environment

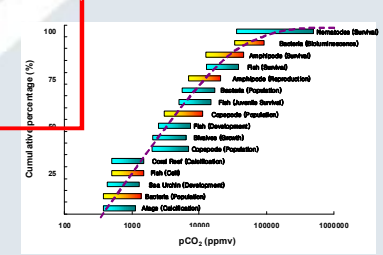


- Human Health and Ecosystem Risk Assessment
- Biological Effect Database
- Risk Management and Communication



- Fate Model of CO<sub>2</sub> in Environment
- CO<sub>2</sub> Flux Monitoring Method Development
- Estimation of Possible Exposure Concentration

Development of Risk Assessment and Management System for Environment-Friendly Ocean CCS Project



**Thank you**

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