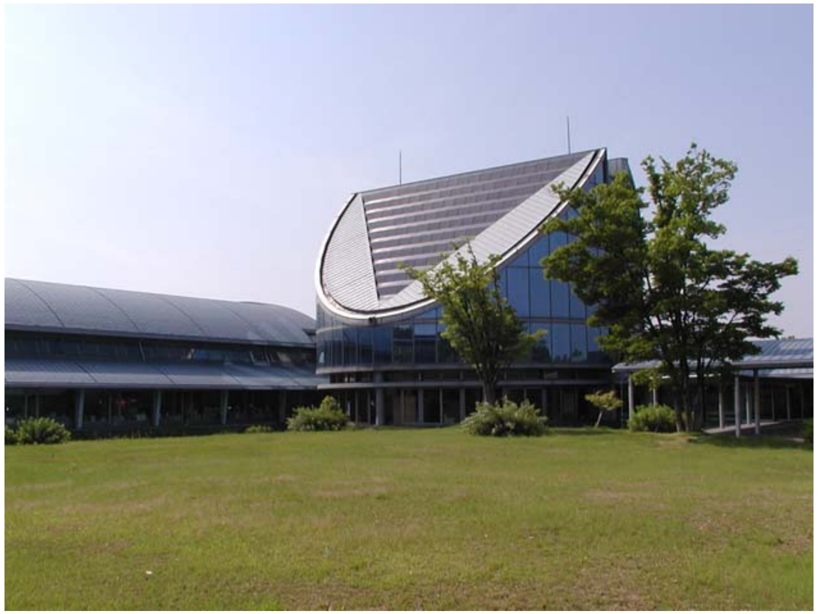
Current Status of CCS in Japan



February 25, 2008

Akito Ito
RITE

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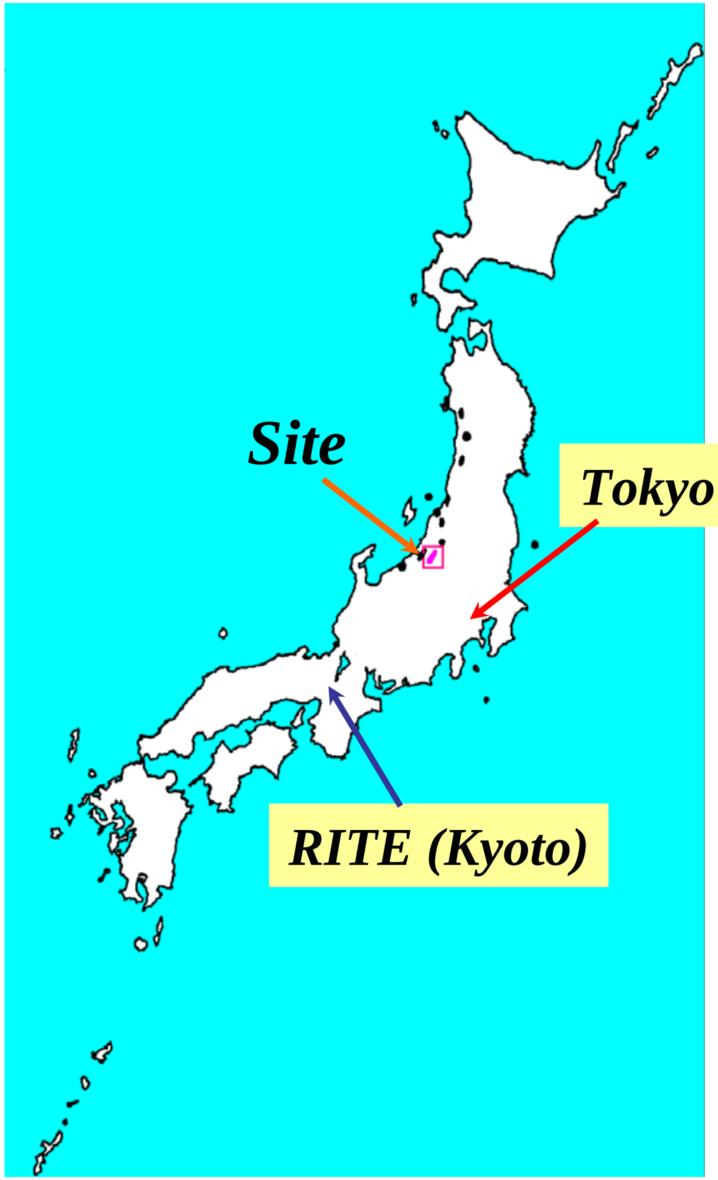
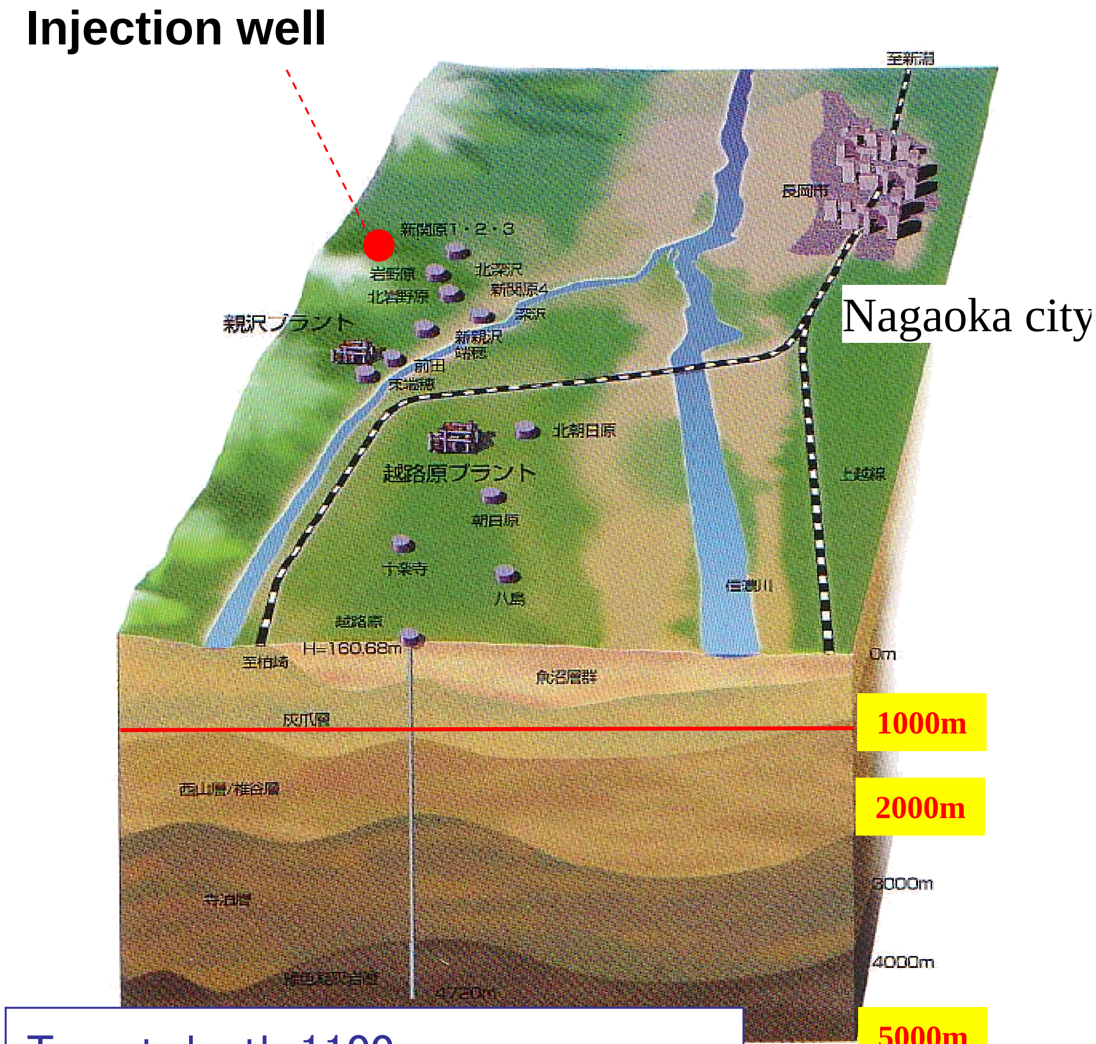
1. Nagaoka Project

Nagaoka site

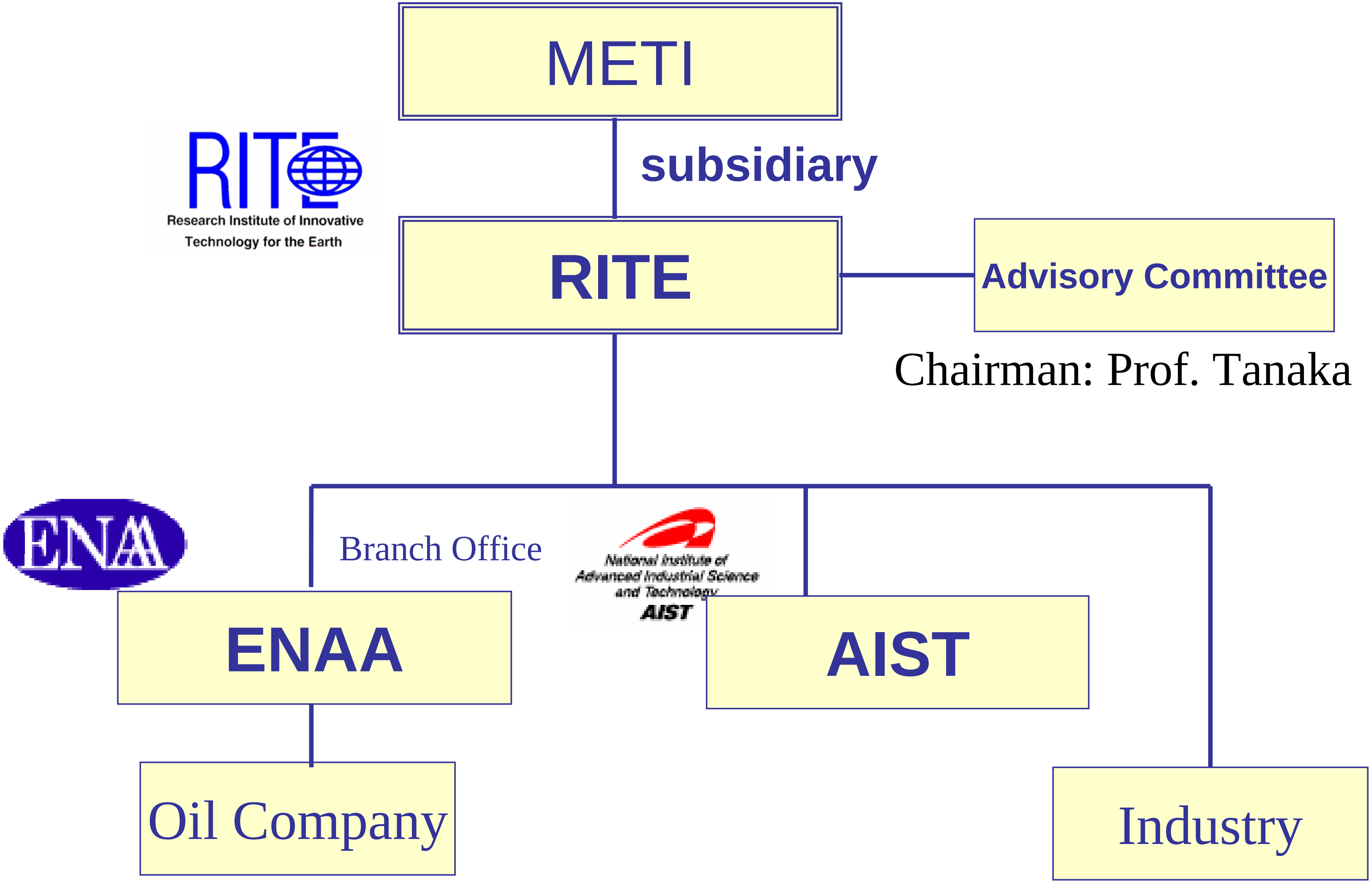




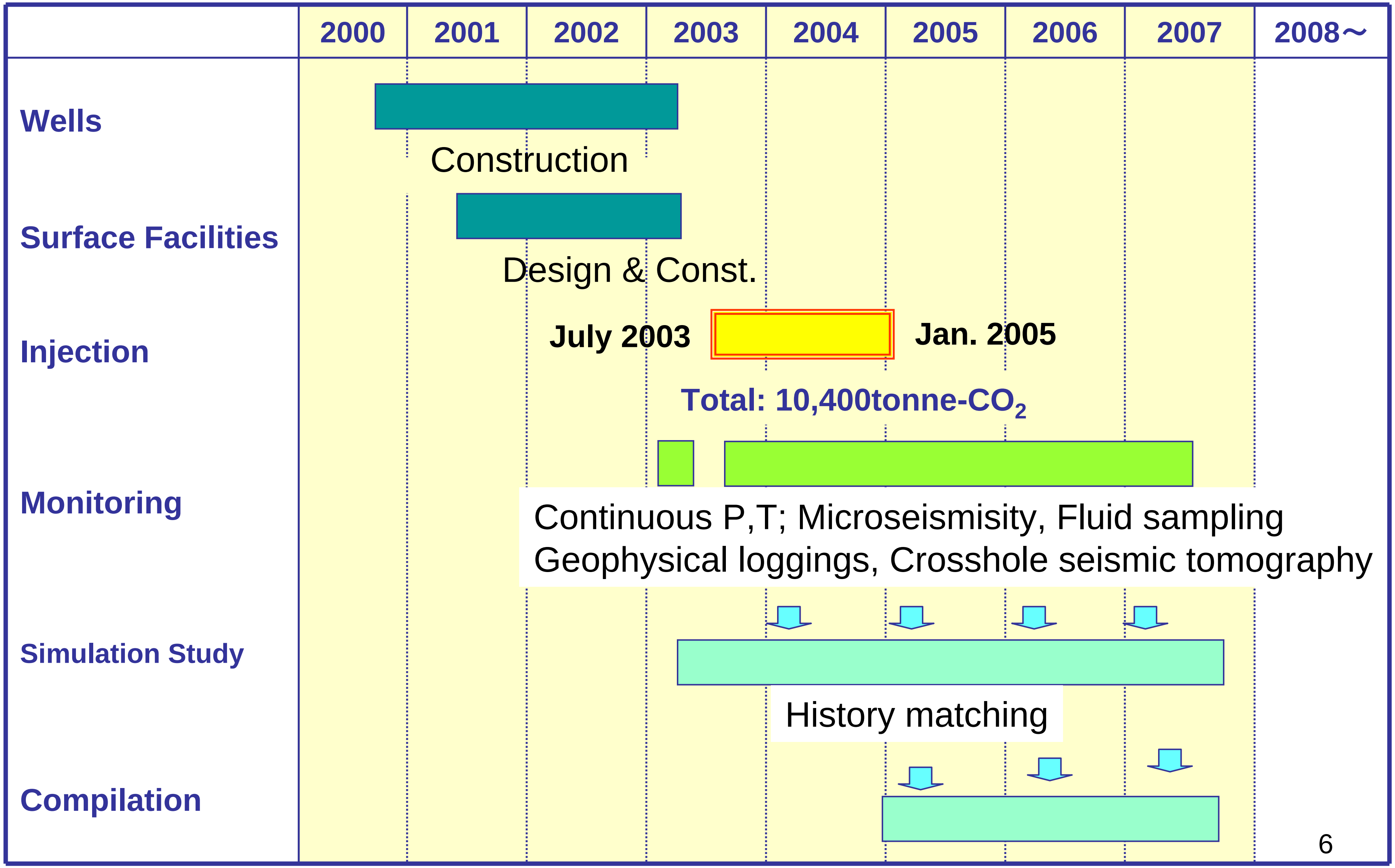
Target depth 1100 m

Gas production from 4500 m depth

Project scheme

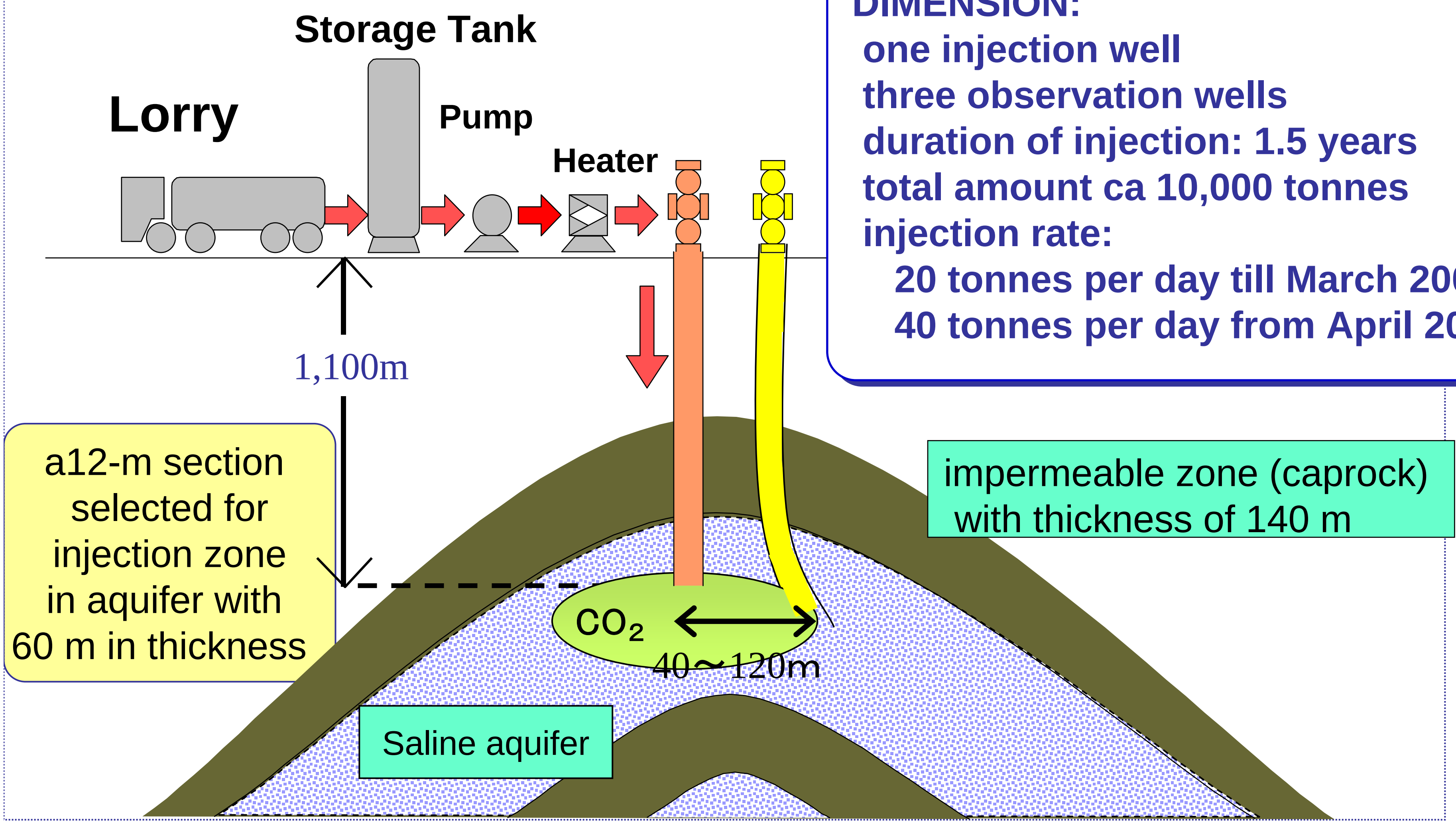


Project timeline



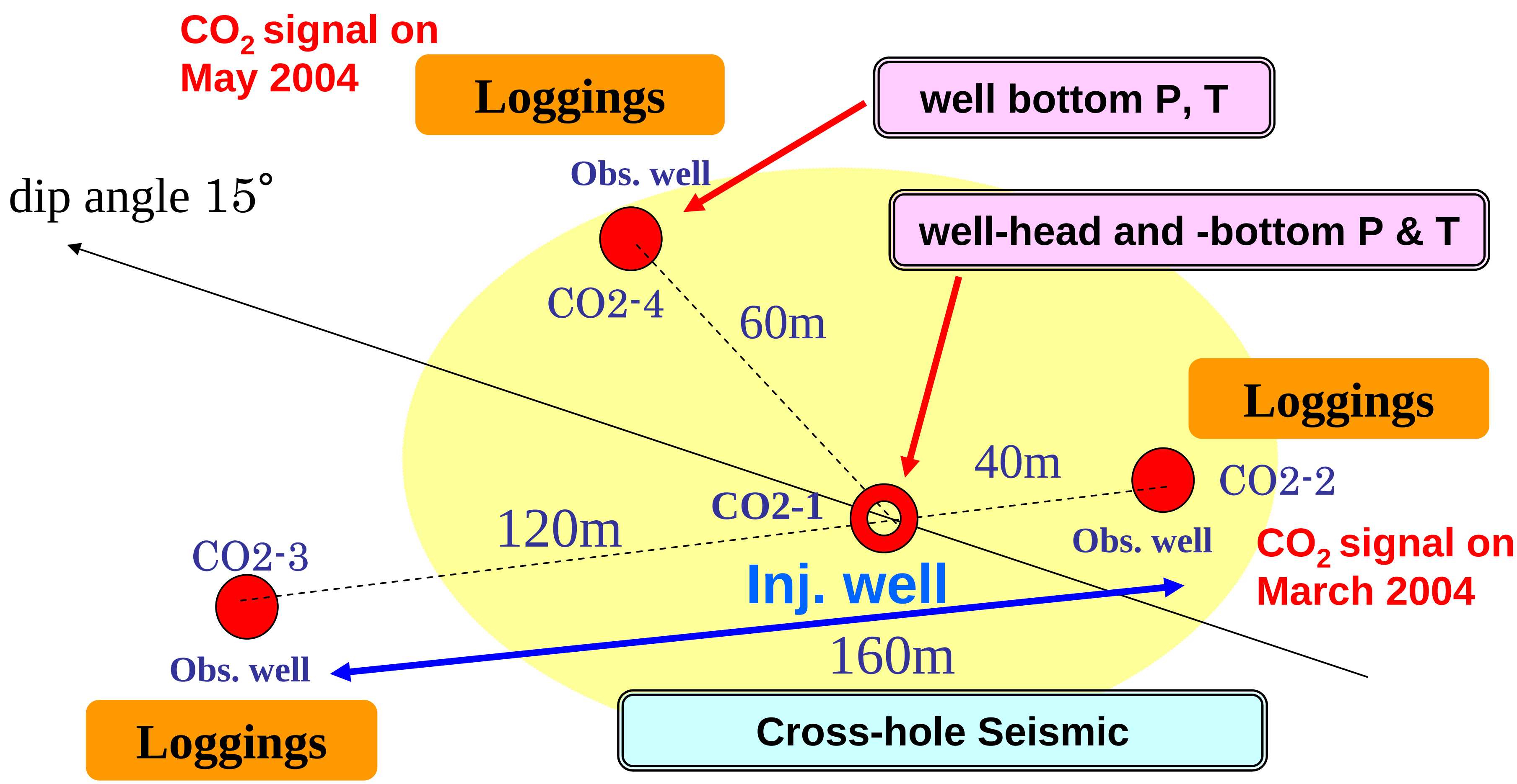
Completed surface facilities in June 2003

Injection test



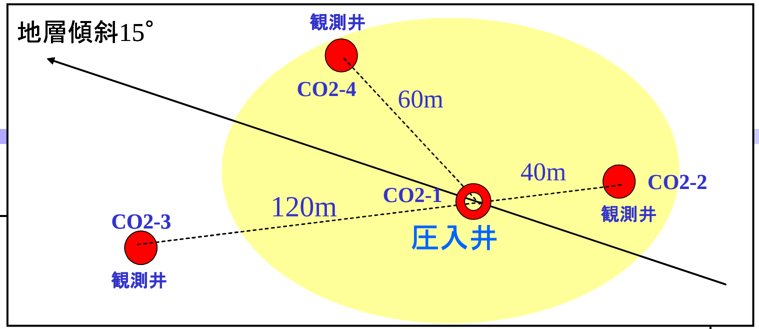
DIMENSION:
- one injection well
- three observation wells
- duration of injection: 1.5 years
- total amount ca 10,000 tonnes
- injection rate:
  - 20 tonnes per day till March 2004
  - 40 tonnes per day from April 2004

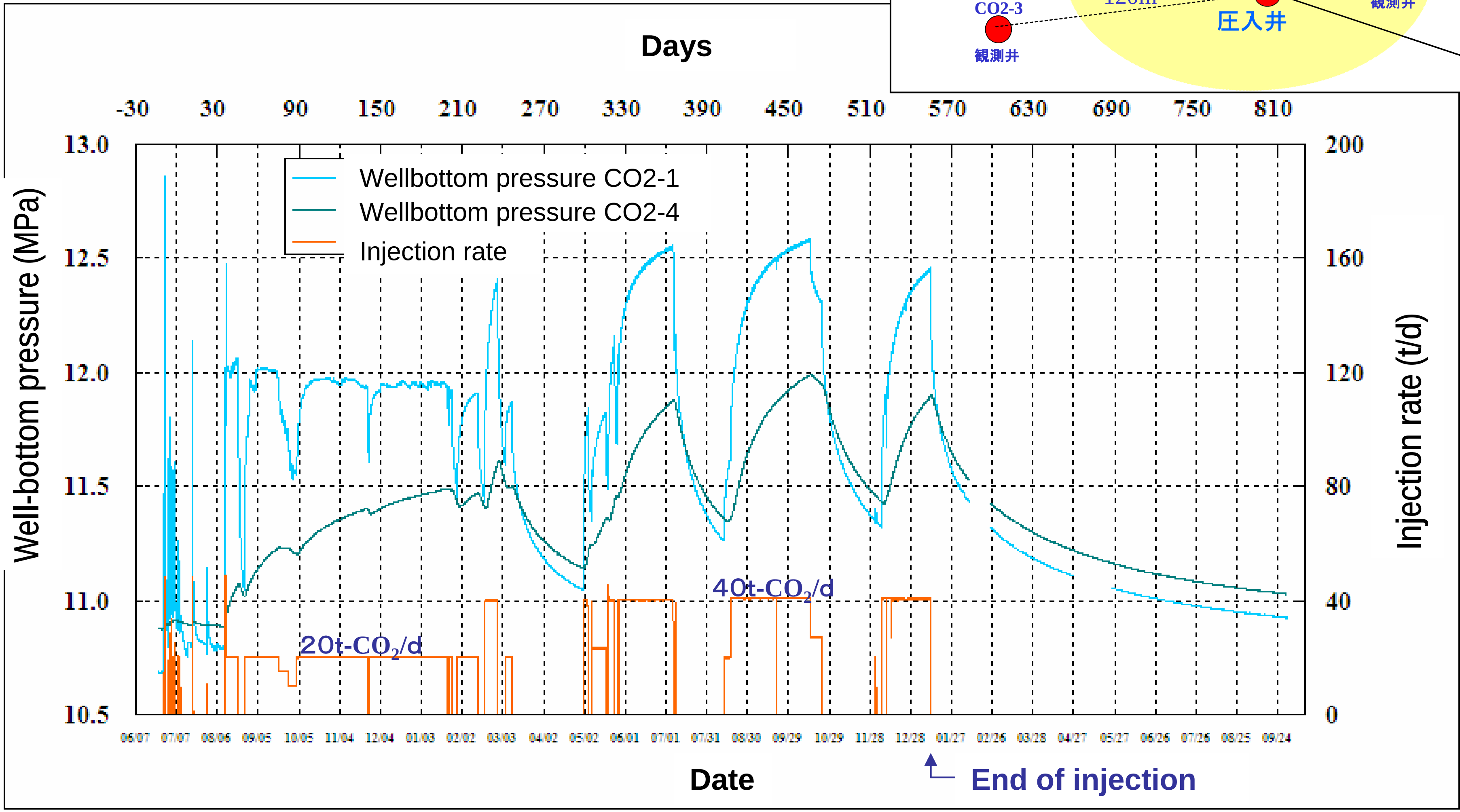
Monitoring



CO_2 signal on
May 2004
Loggings
well bottom P, T
dip angle 15°
Obs. well
well-head and -bottom P & T
CO2-4
60m
Loggings
40m
CO2-2
CO2-1
120m
CO2-3
Obs. well
CO_2 signal on
March 2004
Inj. well
160m
Obs. well
Loggings
Cross-hole Seismic

Pressure in the reservoir





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Wellhead P： 7MPa
Wellhead T： 34℃

Wellbottom P： 10.8～12.8MPa
Wellbottom T： 48～45℃

Rupture pressure is higher than 18.6MPa

CO_2 imaging by crosshole seismic tomography

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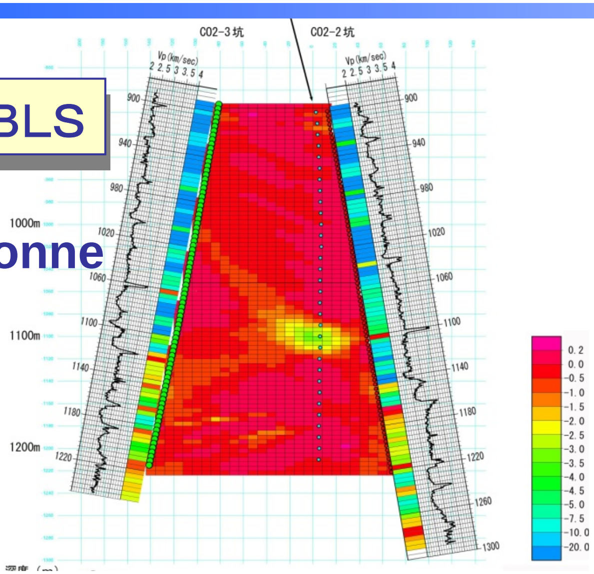
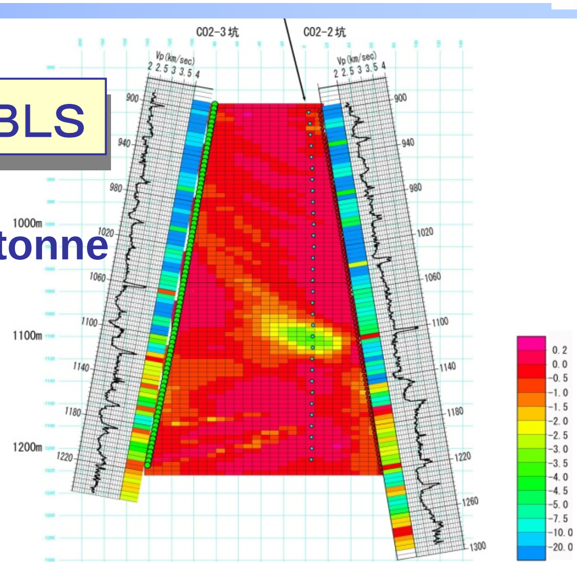
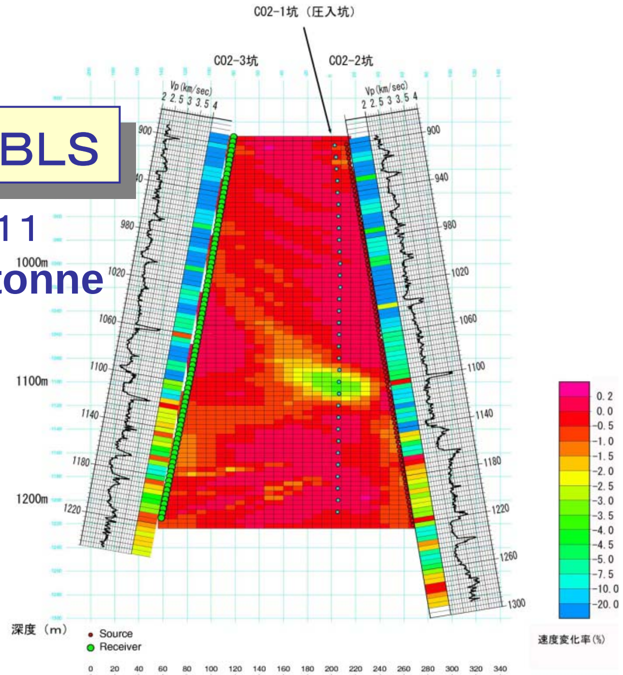
MS1／BLS
2004／1
3，200 **tonne**



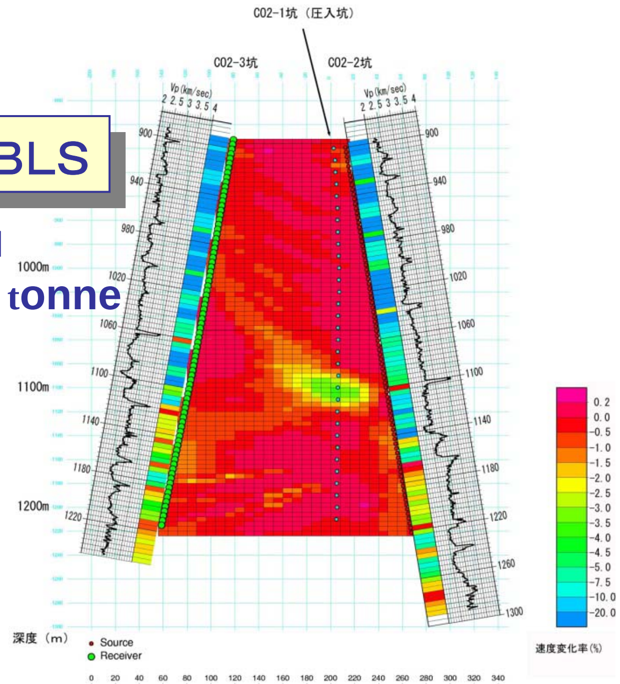
MS2／BLS
2004／7
6，200 **tonne**



MS3／BLS
2004／11
8，900 **tonne**



MS4／BLS
2005／1
10，400 **tonne**



Simulation results of CO_2 behavior

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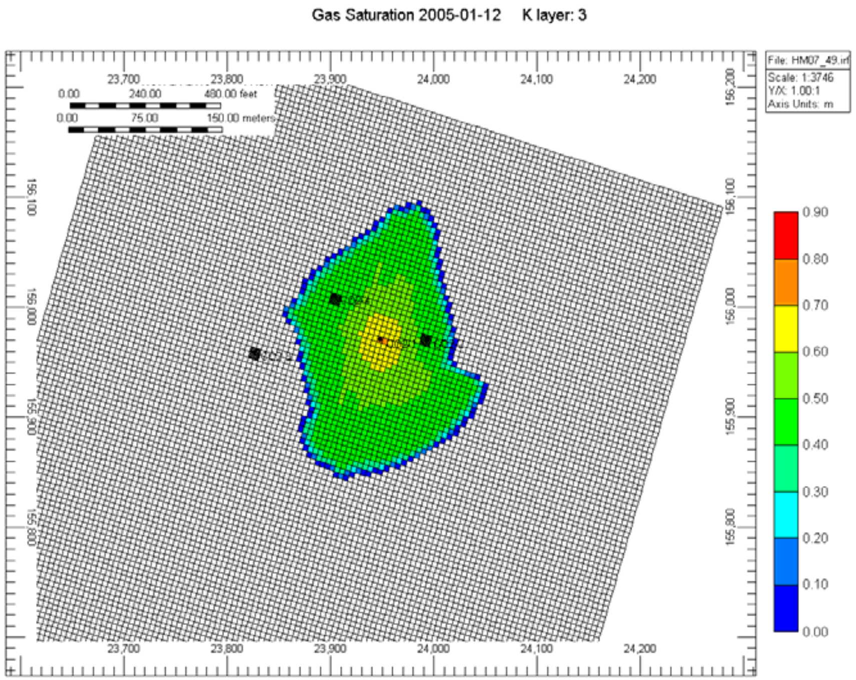
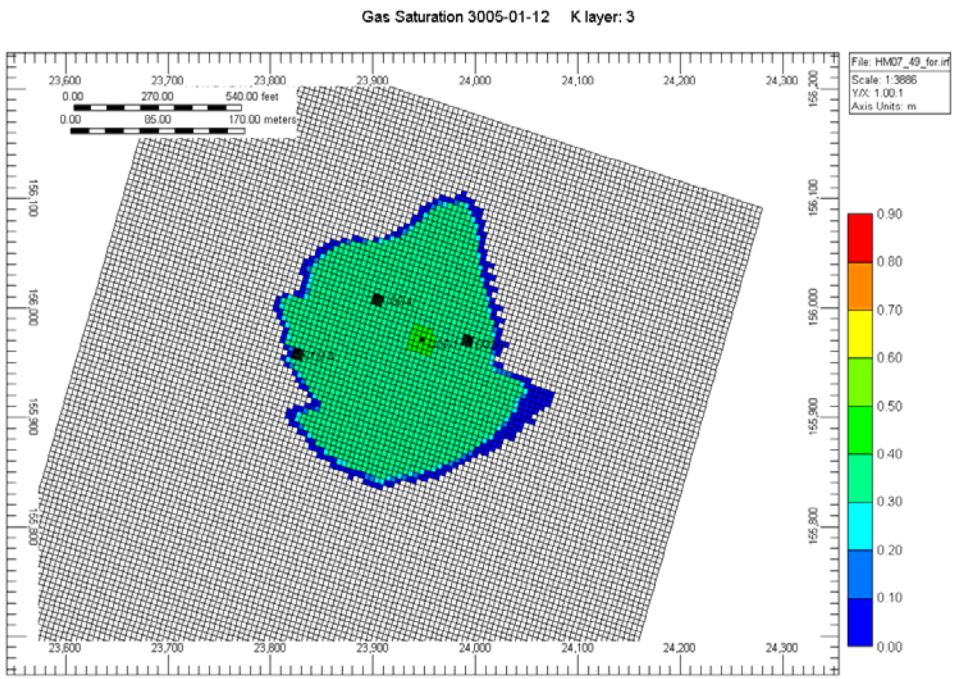
Distribution of CO_2 gas saturation rate

（Sgc=0.25, Sgrm=0.33)



At the end of injection



After 1,000 years

Simulator : GEM-GHG、 Formation ： Zone-2b Upper

Outcomes from Nagaoka project

1 10,400t-CO_2 was successfully injected into a saline aquifer of 1,100m depth

2 No CO_2 leakage by Niigata Chuetsu earthquake

3 Various kinds of monitoring technology were applied for identifying CO_2 migration and distribution

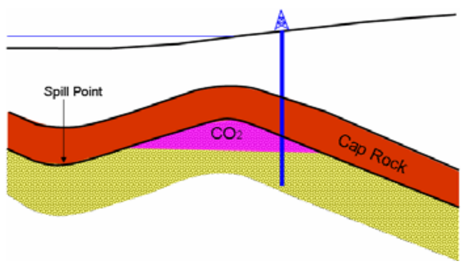
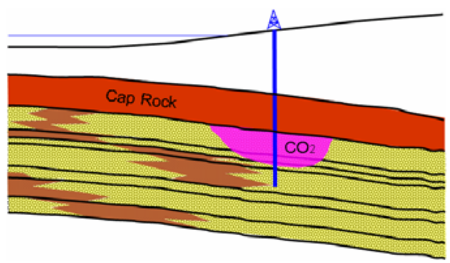
4 Long-term CO_2 behavior in 1000 years was clarified with newly developed simulator (GEM-GHG) based on those observation results

⇨ **Basic knowledge of aquifer storage in Japan towards practical application was obtained**

2. Major challenges of CCS implementation in Japan

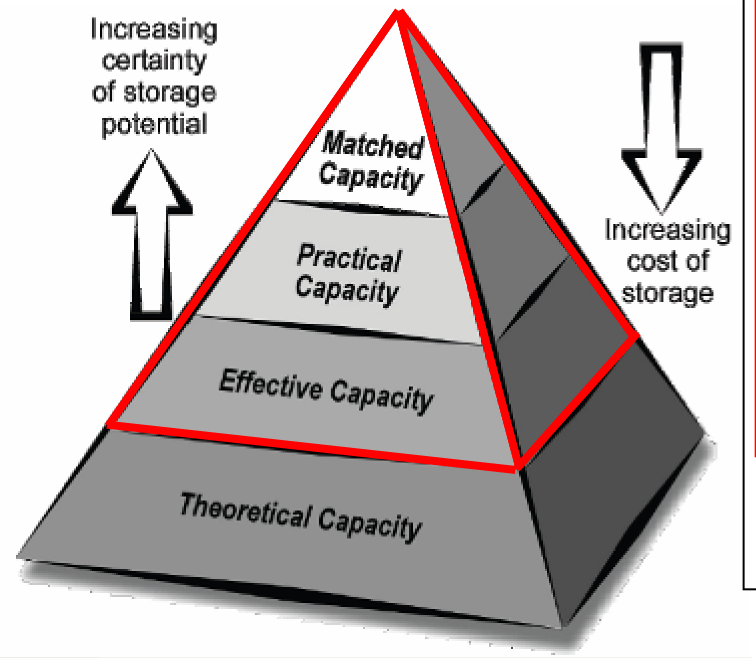
(1) Storage site

Evaluation for aquifer storage potential in Japan

data source		Category A (Anticline)	Category B * (Geologic structure without Anticline)
oil & gas field	data obtained during operation	A1: 3.5 Billion t-CO_2	B1: 27.5 Billion t-CO_2
Basic boring	public domain data by seismic and drillhole	A2: 5.2 Billion t-CO_2	
Basic survey	public domain data by seismic only	A3: 21.4 Billion t-CO_2	B2: 88.5 Billion t-CO_2
scheme			
sum		30.1 Billion t-CO_2	116.0 Billion t-CO_2
total		146.1 Billion t-CO_2	

Inland basins, such as Seto in land sea, Osaka Bay are excluded: based only on Public Domain Oil & Gas Exploring activity. *) deeper than 800m and shallower than 4,000m, located in waters shallower than 200m.

Techno-Economic Resources-Reserves Pyramid for CO_2 Storage Capacity



(Bachu et al., 2007b)

Matched capacity
Capacity obtained by detailed matching of large stationary CO_2 sources with geological storage sites.

Practical capacity
Capacity obtained by considering technical, legal and regulatory, infrastructure and general economic barriers.

Effective capacity
Capacity obtained by applying a range of technical (geological and engineering) cut-off limits.

Theoretical capacity
Physical limit of what the geological system can accept.

Storage potencial evaluated in this study corresponds to Effective Capacity.

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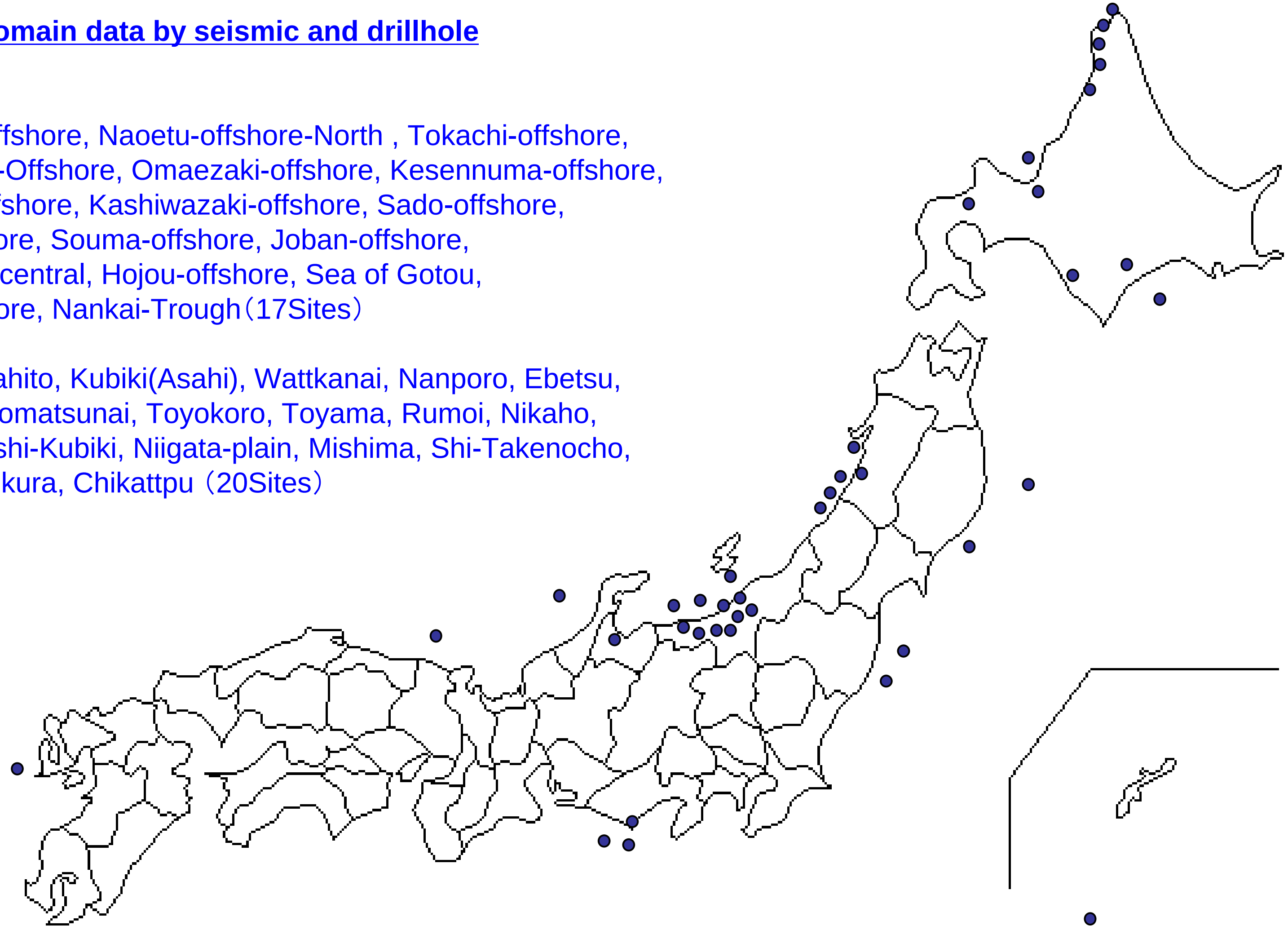
Category A2

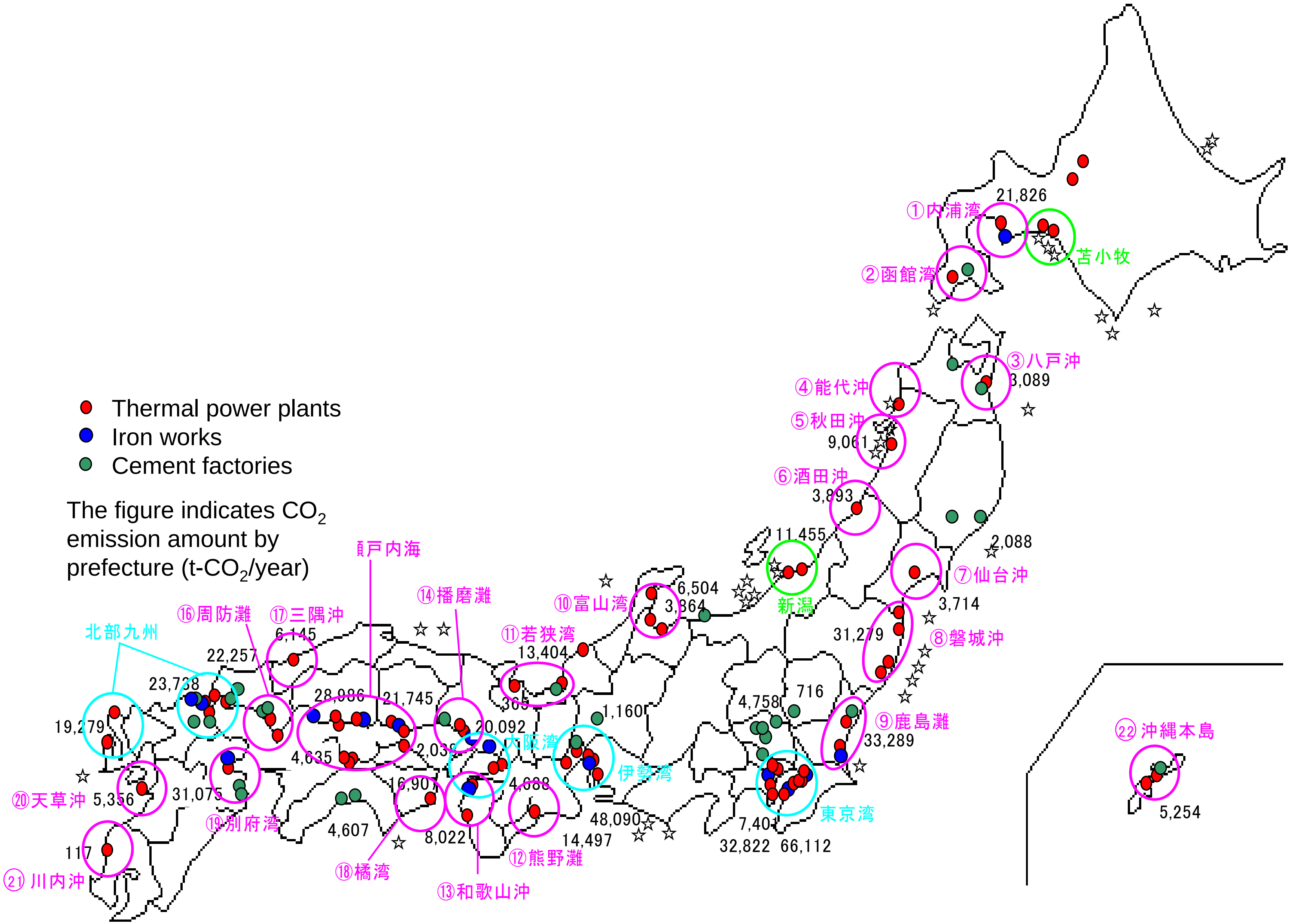
● **A2 sites are located in limited area of Japan, and many of them are not close to large emmision sources.**

A2：Public domain data by seismic and drillhole

〔Offshore〕
Miyakojima-offshore, Naoetu-offshore-North , Tokachi-offshore, Mogamigawa-Offshore, Omaezaki-offshore, Kesennuma-offshore, Kanazawa-offshore, Kashiwazaki-offshore, Sado-offshore, Kasumi-offshore, Souma-offshore, Joban-offshore, Yuri-offshore-central, Hojou-offshore, Sea of Gotou, Sanriku-offshore, Nankai-Trough（17Sites）
〔Onshore〕
Masugata, Mahito, Kubiki(Asahi), Wattkanai, Nanporo, Ebetsu, Niikattpu, Kuromatsunai, Toyokoro, Toyama, Rumoi, Nikaho, Sagara, Higashi-Kubiki, Niigata-plain, Mishima, Shi-Takenocho, Tehoku, Tomikura, Chikattpu（20Sites）



Major CO_2 emission sources in Japan

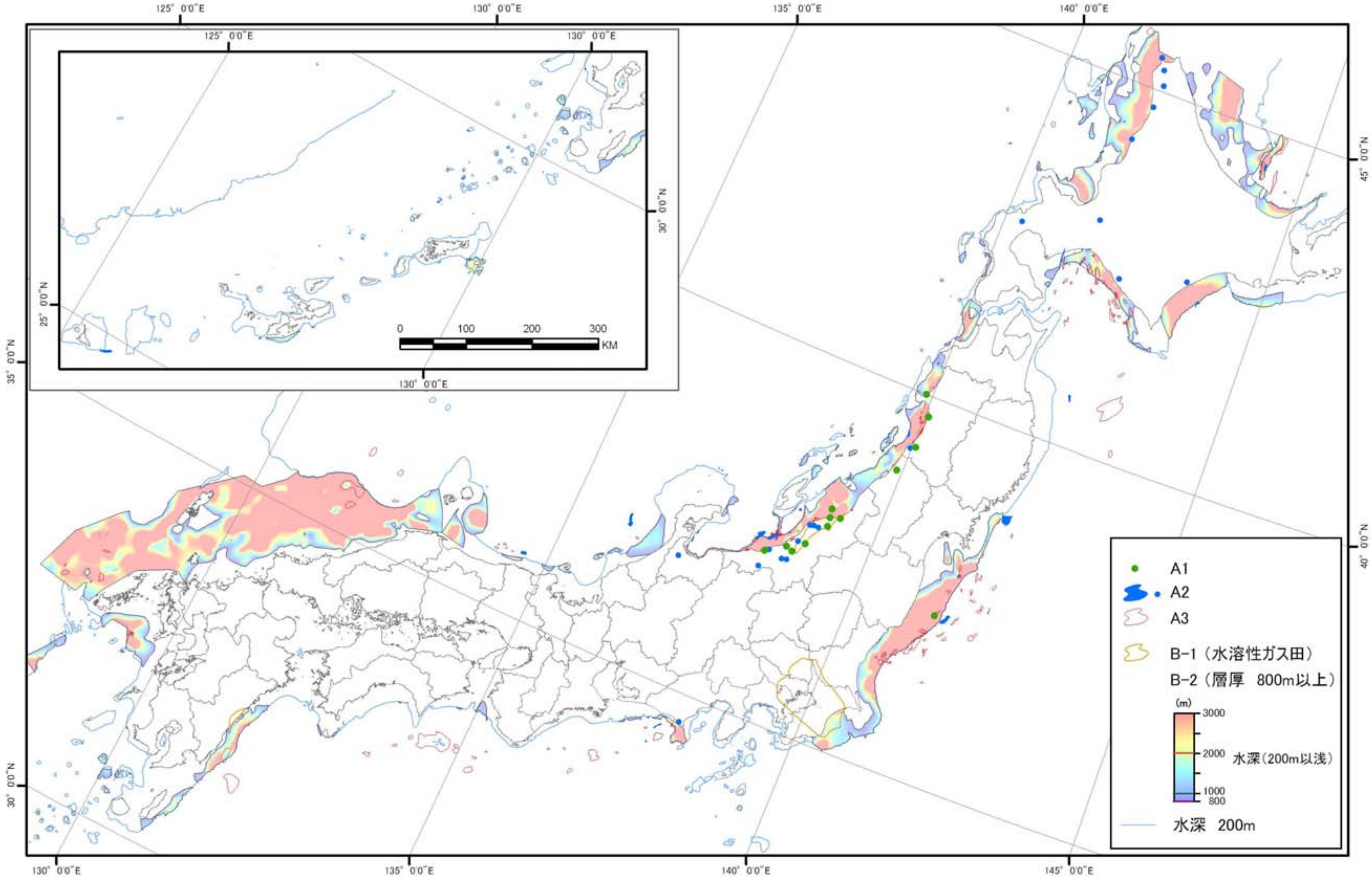


- Thermal power plants
- Iron works
- Cement factories

The figure indicates CO_2 emission amount by prefecture (t-CO_2/year)

Potential storage sites in Japan

- **Most of the sites are located offshore.**
- **There aren't sufficient data for coastal area.**



Storage site – Summary

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- Based on the existing data, the storage potential in Japan is estimated to be about 5.2billion tons for relatively reliable reservoir and about 146billion tons as ultimate possible value.

- Most of the data is from offshore and limited to the far area from emission sources.

- In order to implement CO_2 storage economically in Japan, it is important to survey and identify the reservoirs near emission sources.

2. Major Challenges of CCS implementation in Japan

(2) CCS Cost

Comparison with cost in IPCC SRCCS

RITE Research Institute of Innovative Technology for the Earth

● Current CCS cost in Japan is higher than that in IPCC SRCCS.

Case	Japan (US$/t-$CO_2$※)	IPCC SRCCS (US$/t-$CO_2$)		
	New PC plant -Aquifer storage	New PC plant -Aquifer storage	New NGCC plant -Aquifer storage	New PC plant -EOR
Capture & Compression	38	29-51	37-74	29-51
Transportation	7 1Mt-CO_2/y-20km	1-8 5-40Mt-CO_2t/y-250km		
Storage	21 0.1Mt/well/yr, ERD	0.5-8		△10-16
Total	66 1Mt-CO_2/yr 20km-ERD	30-70	40-90	9-44

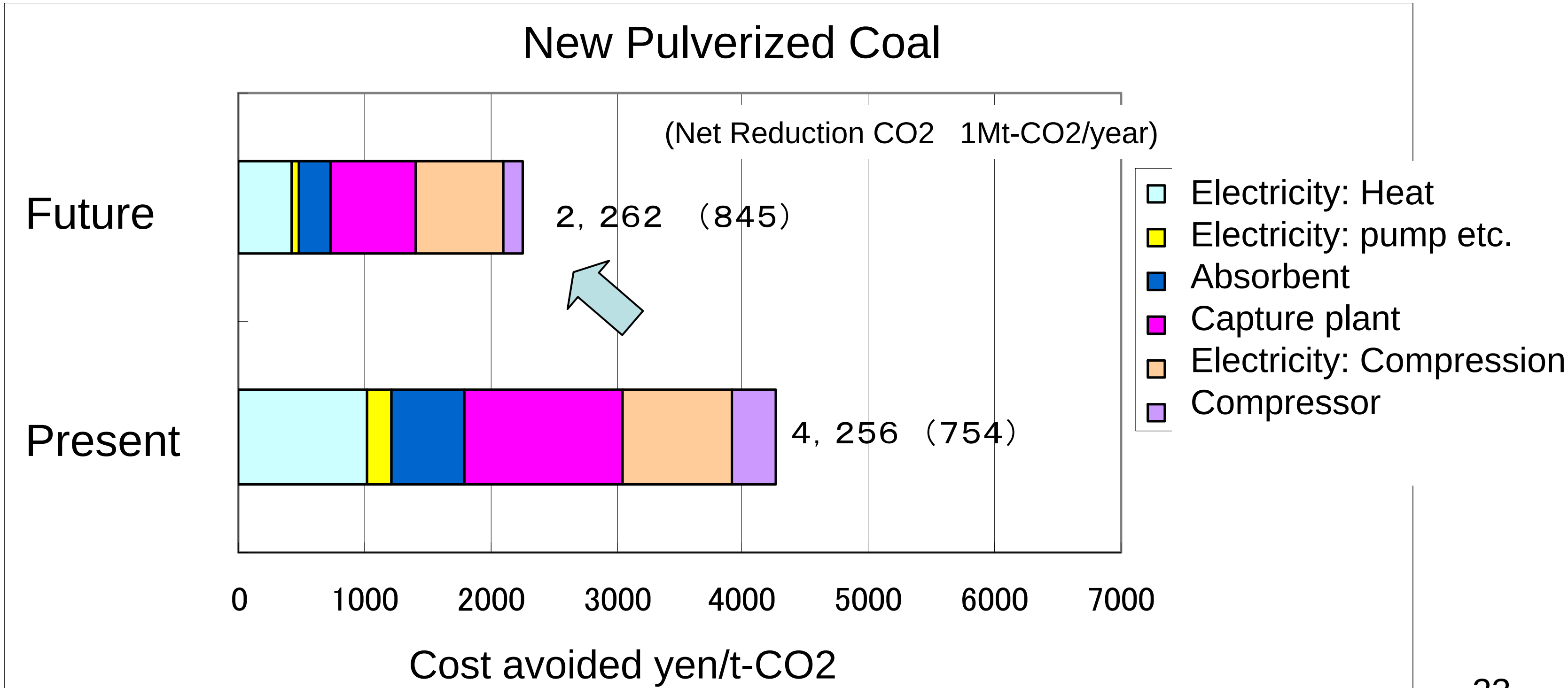
※Exchange rate: 110yen/US＄

Source : RITE/ENAA, 'Report on Development of Carbon Dioxide Geological Storage', 2006. (in Japanese)

IPCC SRCCS: Technical Summary of "IPCC Special Report, Carbon Dioxide Capture and Storage"

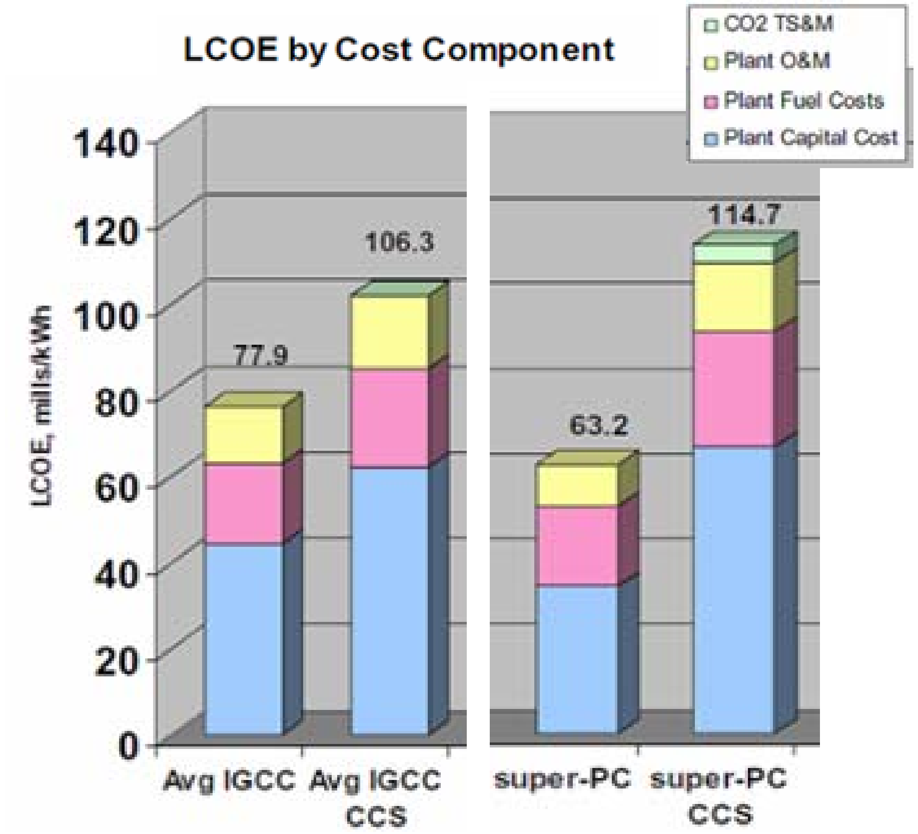
Capture cost reduction — Post-combustion

- **Reduction in calories required for CO_2 regeneration.**
- **Reduction in capture plant cost.**
- **Thermal integration of capture process with power plant.**



Capture cost reduction – IGCC

● **Capture cost is expected to be lower in IGCC than in PC. Therefore development of IGCC with CCS technology could be a strong option.**



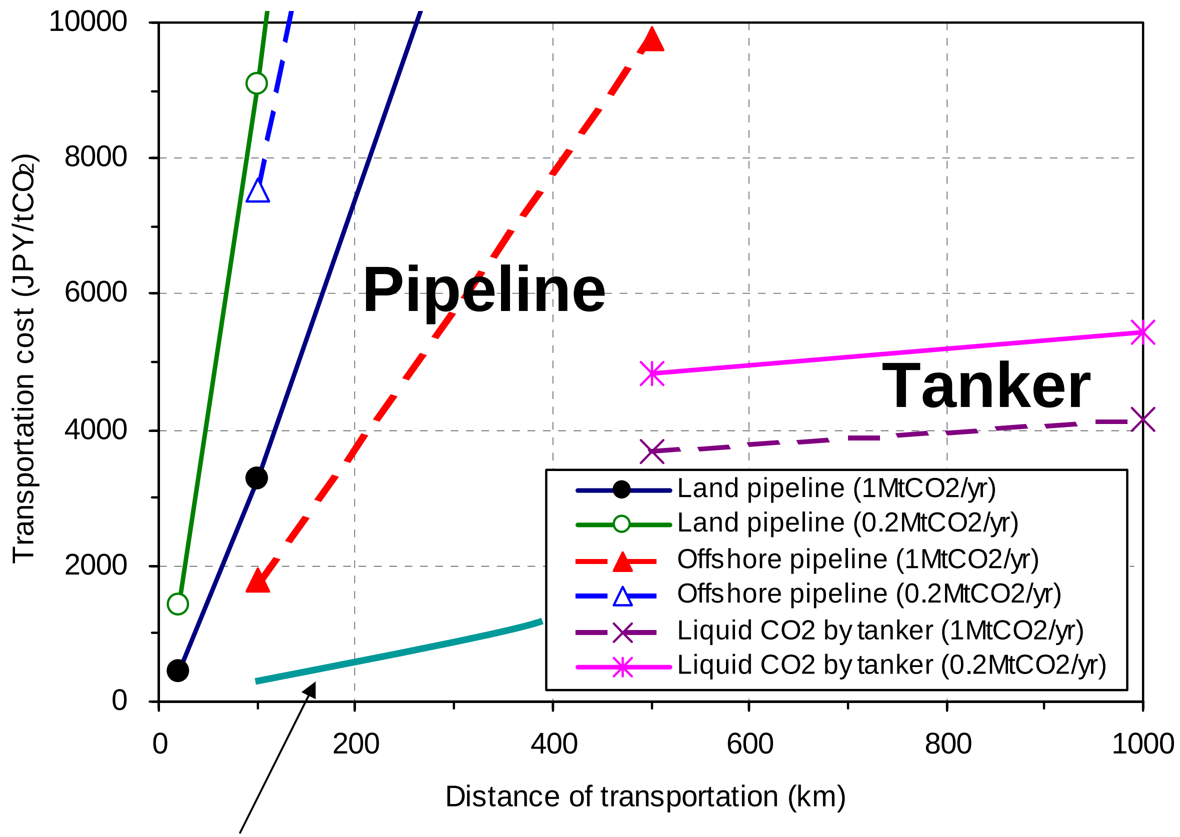
Source: DOE/NETL Report, May,2007

CCP IGCC demonstration plant in Nakoso

EAGLE IGFC pilot plant in Wakamatsu

Transportation cost

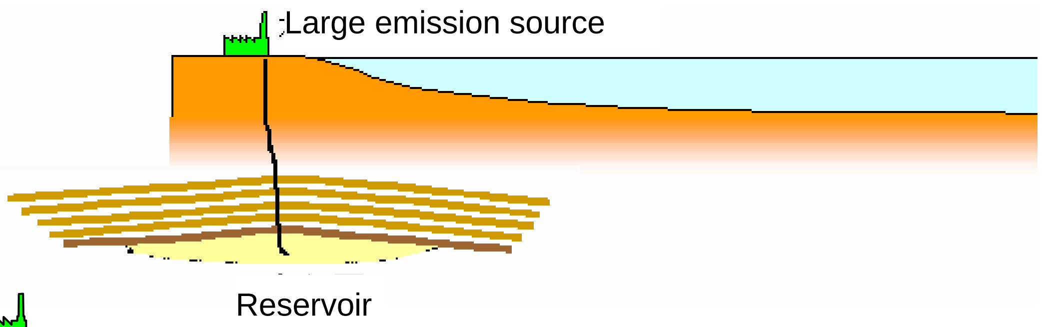
- **A long distance transportation is unrealistic in Japan due to high transportation cost.**
  Exploration of reservoirs at short distances from large CO_2 emission sources is necessary.



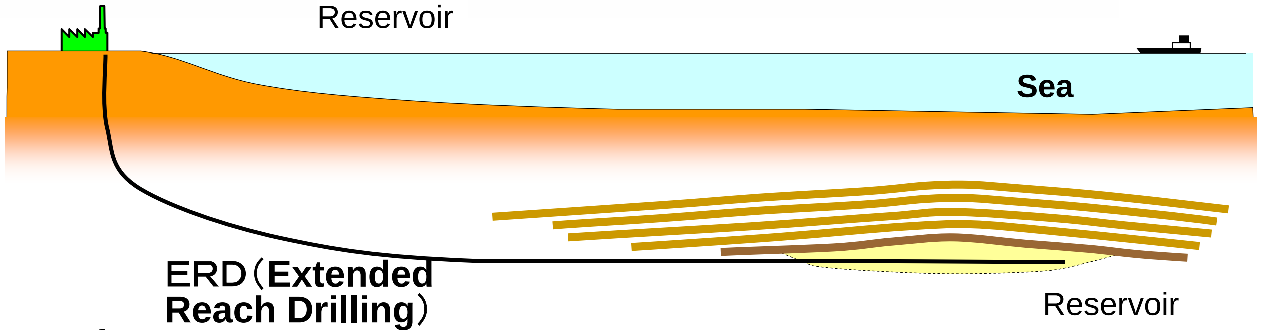
IEA-GHG 1.25Mt-CO2/yr

Comparison of injection methods

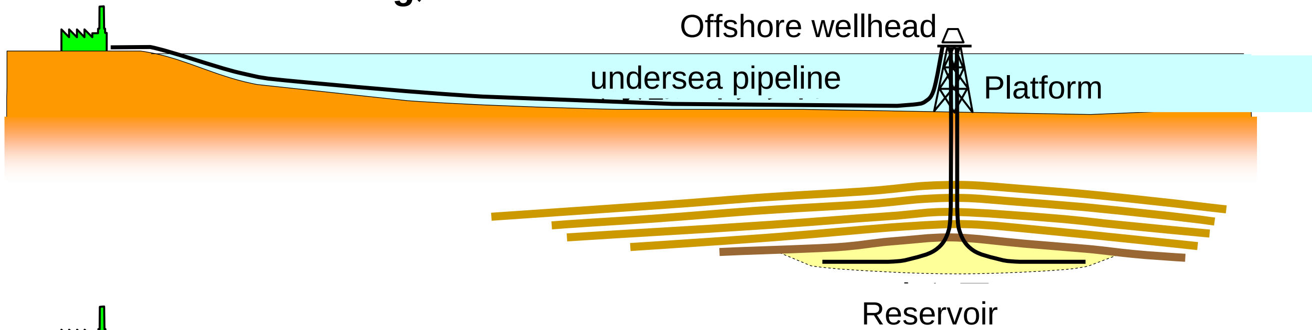
Onshore



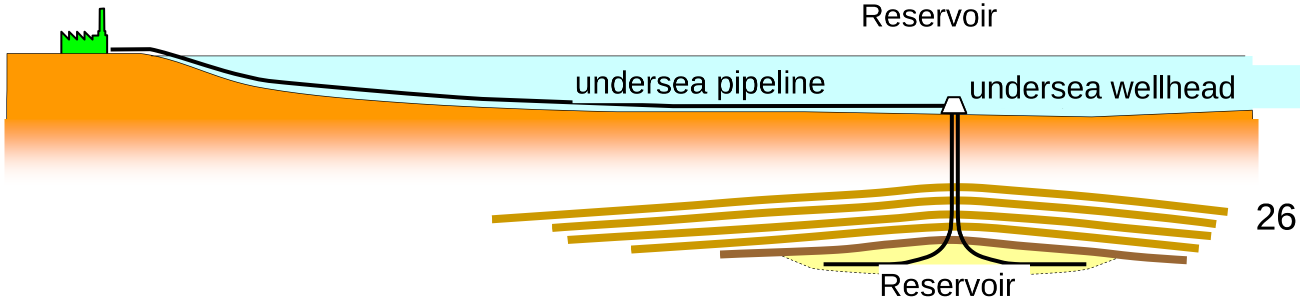
Coastal region (Extended Reach Drilling (ERD))



Coastal region (platform (offshore wellhead))

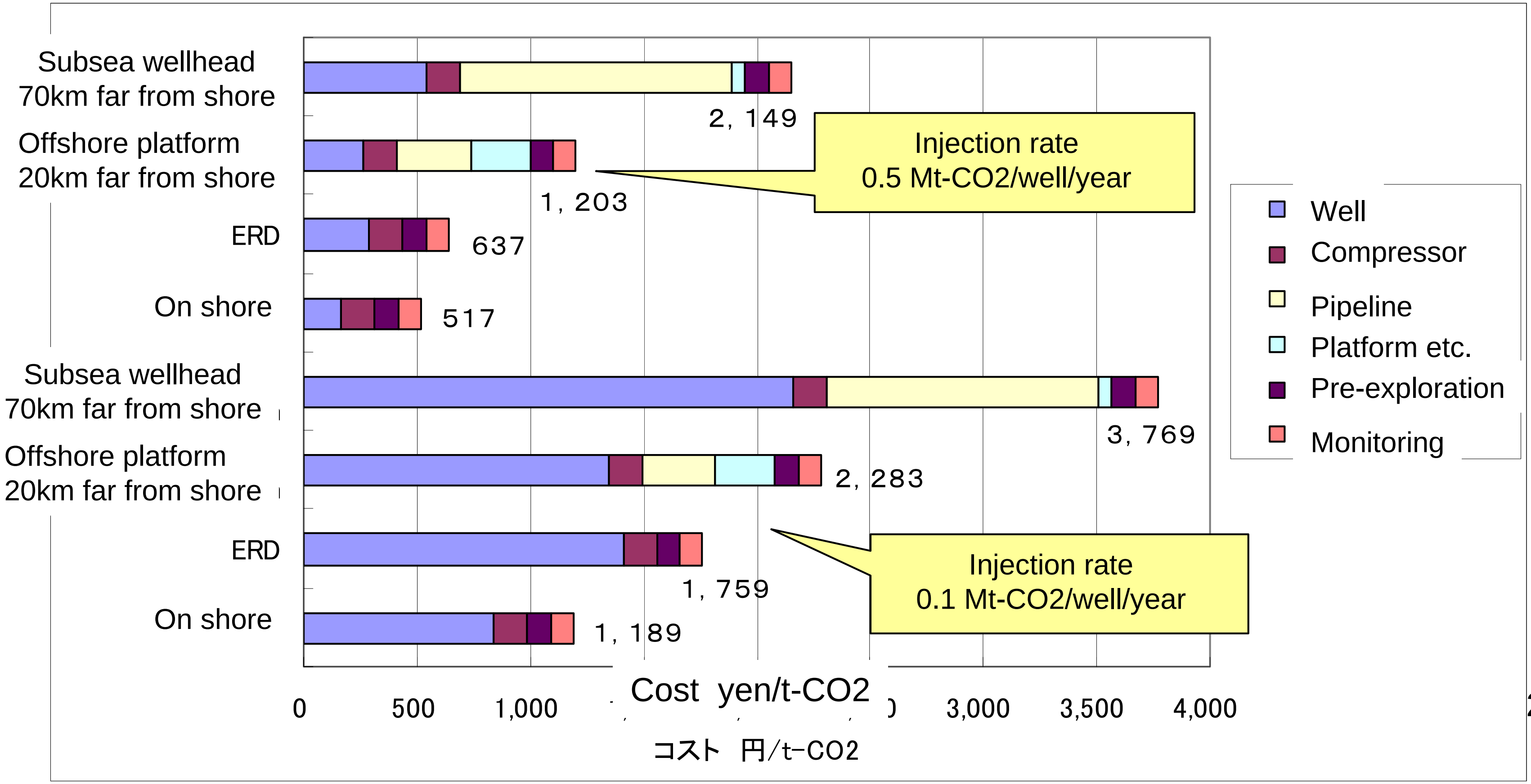


Coastal region (undersea wellhead)



Cost of CO_2 storage

●Cost becomes high when reservoirs being far from shore.
●Storage cost is heavily dependent on injection rate per well. To search reservoirs with a large penetration rate or to develop the technology which increase an injection rate per well, such as multi-lateral well, is important.



3. Capture technology
(1) Chemical absorption

CO_2 capture technology development in Japan

Capture technology	CO_2 source	Deveropement phase
Chemical absorption	Natural gas production H_2、NH_3 production	Commercial
	NG power plant	Pilot
	PC power plant	Demonstration
	Ironworks	Bench
Membrane	IGCC	Laboratory

Demonstration test of chemical absorption capture technology

Post-combustion from PC power plant

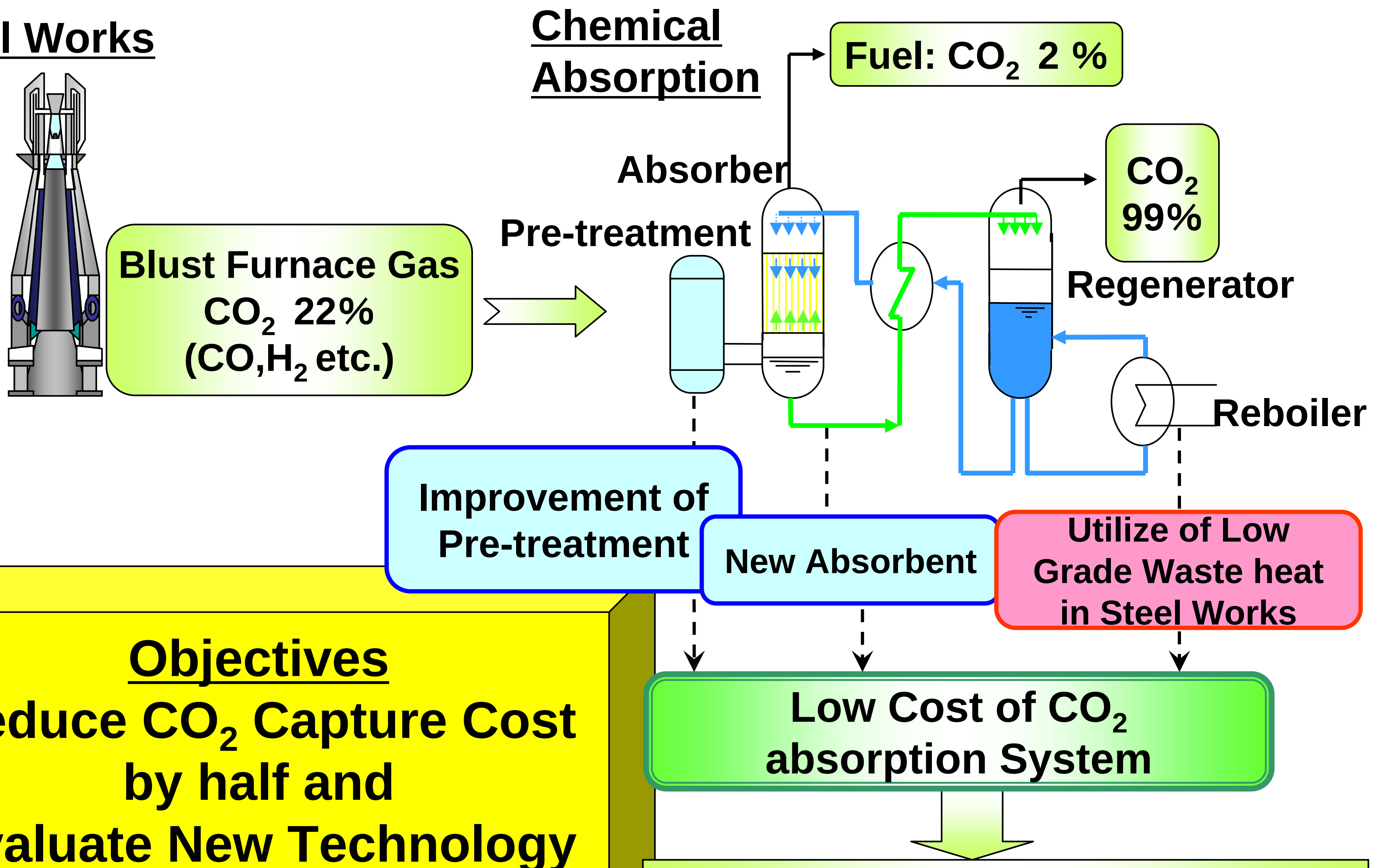
At J-Power Matsushima Thermal Power Plant

Carried out by Mitsubishi Heavy Industry

Client	Power Station, Japan
Solvent	KS-1
Capacity	10 T/d
Feed Gas	Coal Fired Boiler
Start-up	2006
Location	Nagasaki, Japan

MITSUBISHI HEAVY INDUSTRIES, LTD.

COCS project (Cost Saving CO_2 Capture System)



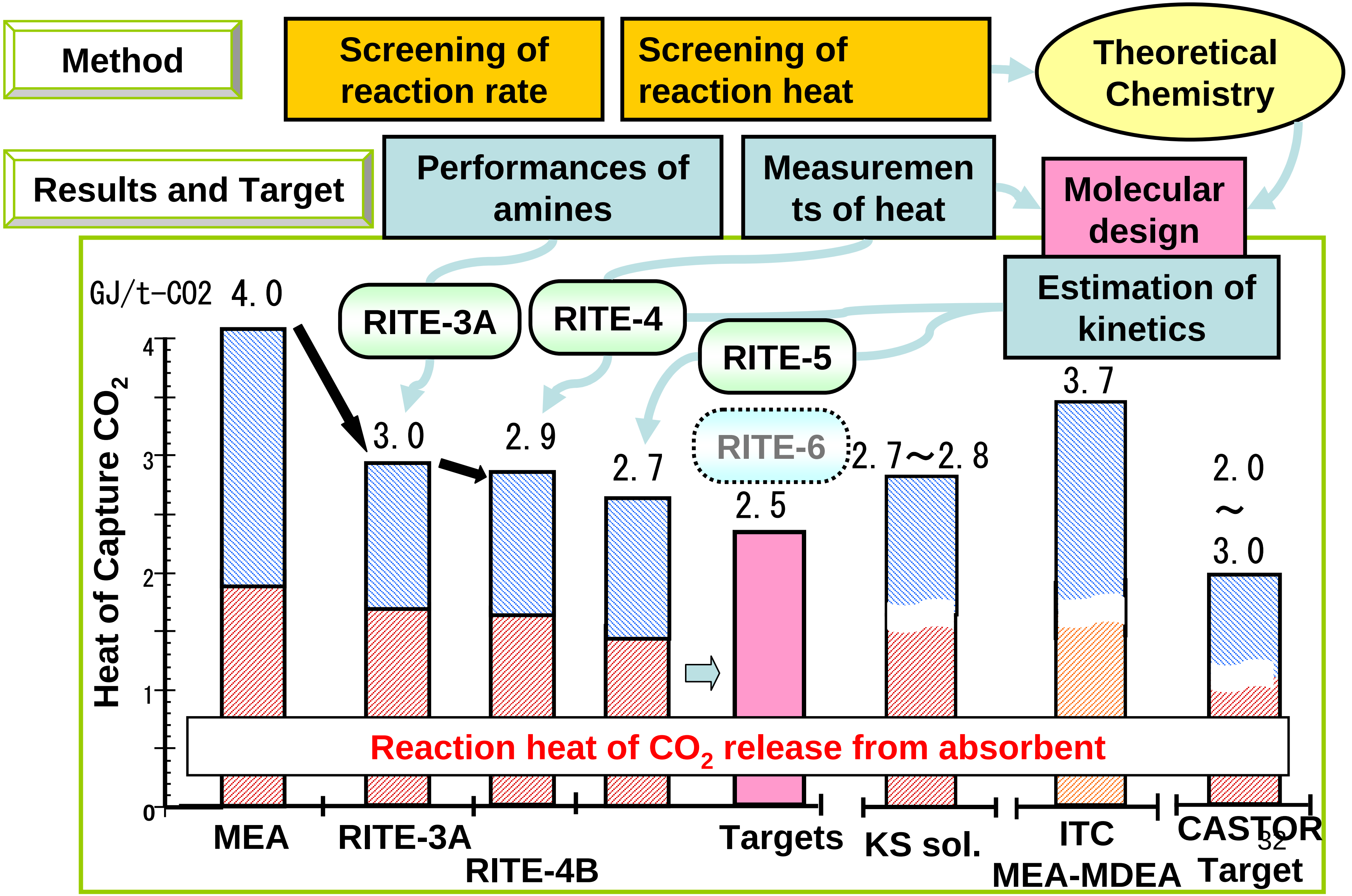
Objectives

Reduce CO_2 Capture Cost by half and Evaluate New Technology

Project Target : 2.5 GJ/t-CO_2

Future Target : 1.8 GJ/t-CO_2

Decreasing reaction energy by new absorbent



Bench scale apparatus using BFG gas

CO_2 Lord:1 t-CO_2/d

- **Location**： **Kimitsu ironworks of Nippon Steel Co.**
- **Absorber**： **Diameter 150 mm, Height 3600 mm (Fixed bed 1000mm x 2)**
- **Regenerator**： **Diameter 200mm, Height 3720 mm（Fixed bed 1000mm×2）**
- **Input (BFG)**： **100 m^3(STP)/h**

NIPPON STEEL ENGINEERING

Chemical absorption – Summary

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- **As capture technology for post-combustion system demonstration test of chemical absorption method for PC power plant is being carried out and bench-scale test is being carried out for ironworks.**

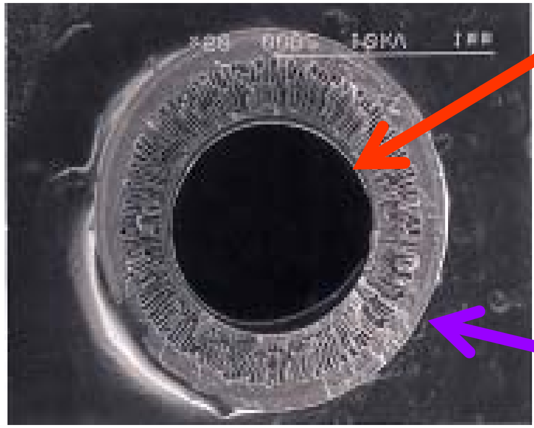
- **Major challenge of chemical absorption technology is reduction of CO_2 regeneration energy.**

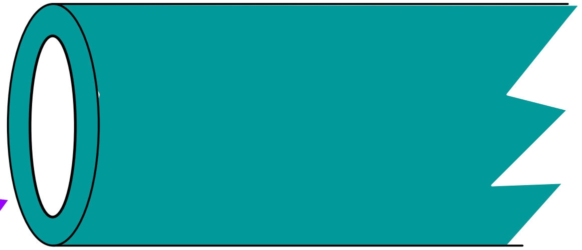
- **Long term cost target of chemical absorption is 2,000yen/t-CO_2 .**

3. Capture technology
(2) Membrane

200mm membrane module

Selective Layer ,
Chitosan + PAMAM Dendrimer



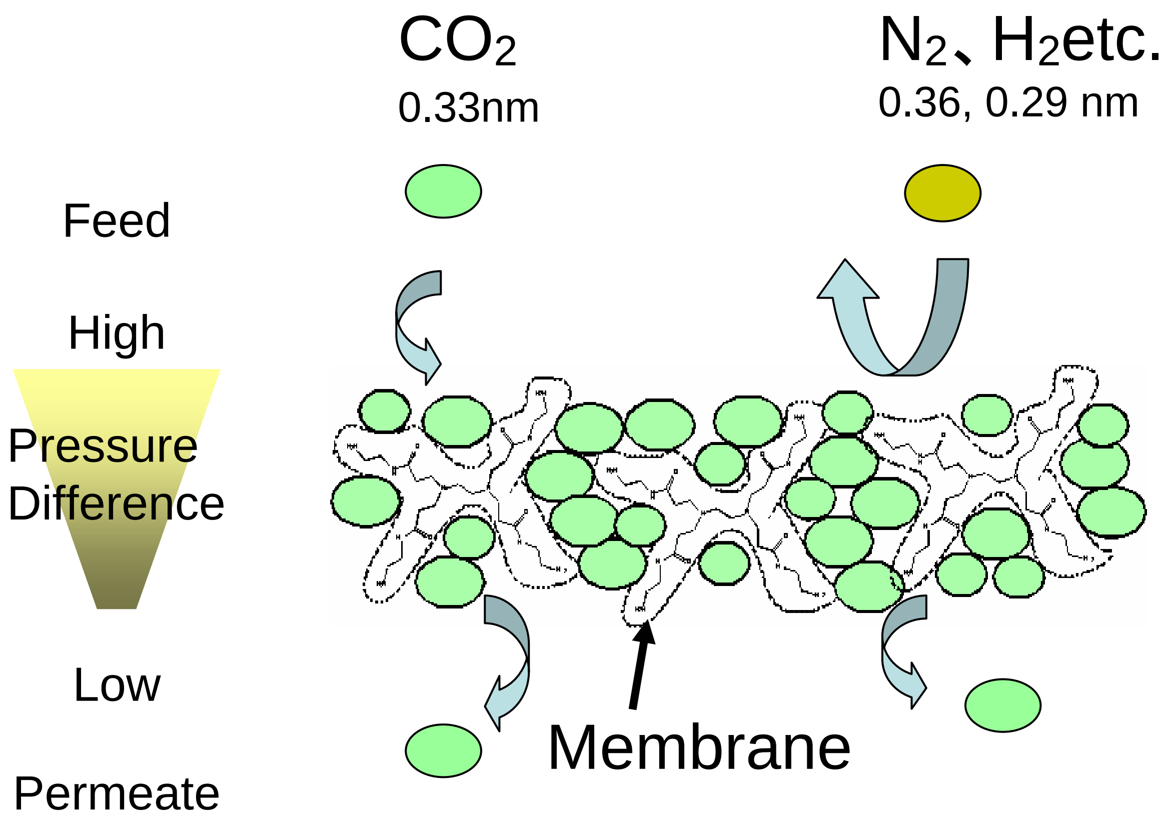


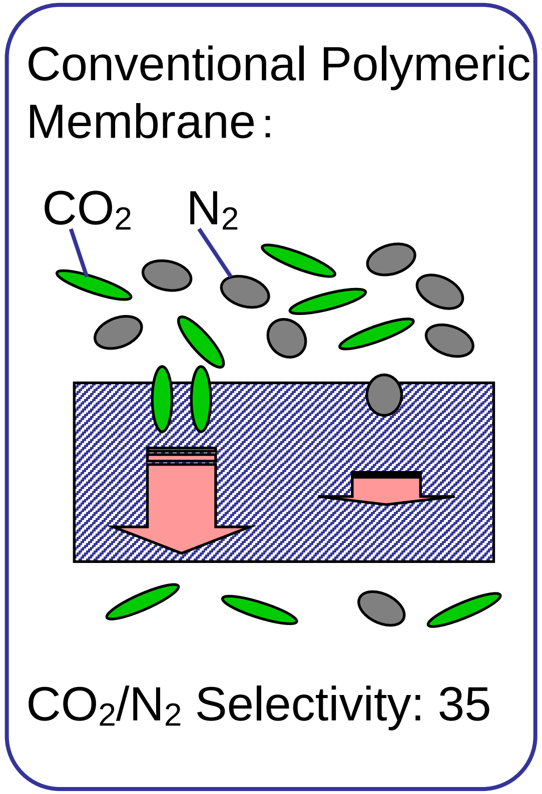
Support Substrate, PSF Hollow fiber

1 mm

200 mm , ϕ3/8 inch

Concept of CO_2 molecular gate membrane

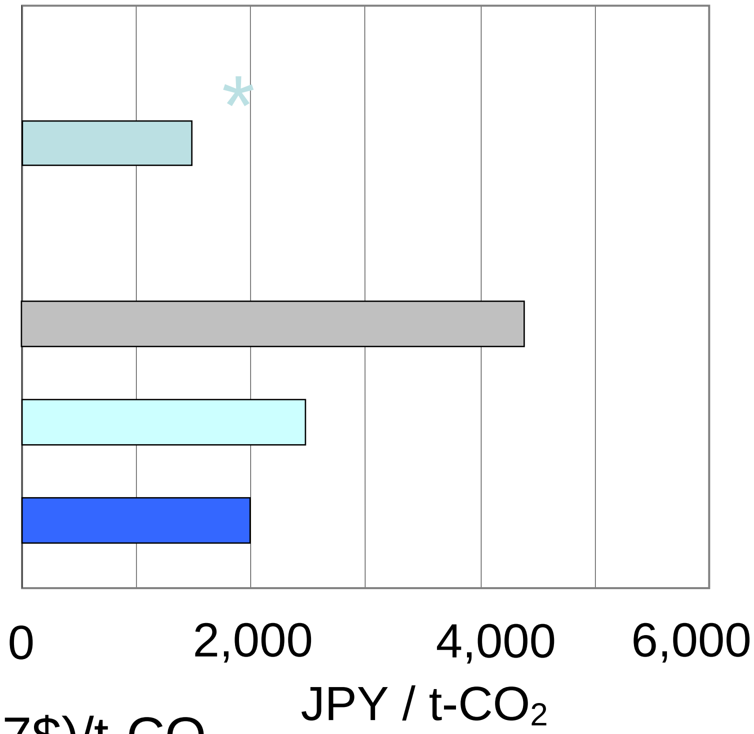




Target: CO_2 / H_2 , CO_2 / N_2 selectivity>100

Cost target of CO_2 capture development

CO_2 Capture	Gas Pres.	Gas Comp.	Membrane Performance (Target)
Membrane IGCC	4MPa	CO_2:40% H_2, H_2O	QCO_2 :$1x10^{-9}$ (m^3 m^{-2} s^{-1} Pa^{-1}) $\alpha CO_2/H_2$: 500
Chemical Absorption Flue gas Atmospheric pressure		Current (KS solution) 2010 Target(New Solvent) 2013 Target(New Solvent)	



Physical Absorption 1,600 ~4,400 JPY(13 ~ 37$)/t-$CO_2$

* Duration period Facility:15 years Membrane:5 years

Membrane Cost: 50,000 JPY/m^2 = 420 $ / m^2

Membrane technology － summary

- As method for CO_2 capture from high pressure gas such as IGCC, membrane technology has been developing in laboratory scale.

- Major challenges of membrane technology are CO_2/H_2 selectivity and endurance of membrane.

- Long term cost target of membrane technology is 1,500yen/t-CO_2

4. Prospects for CCS future

Japanese government CCS inisiative

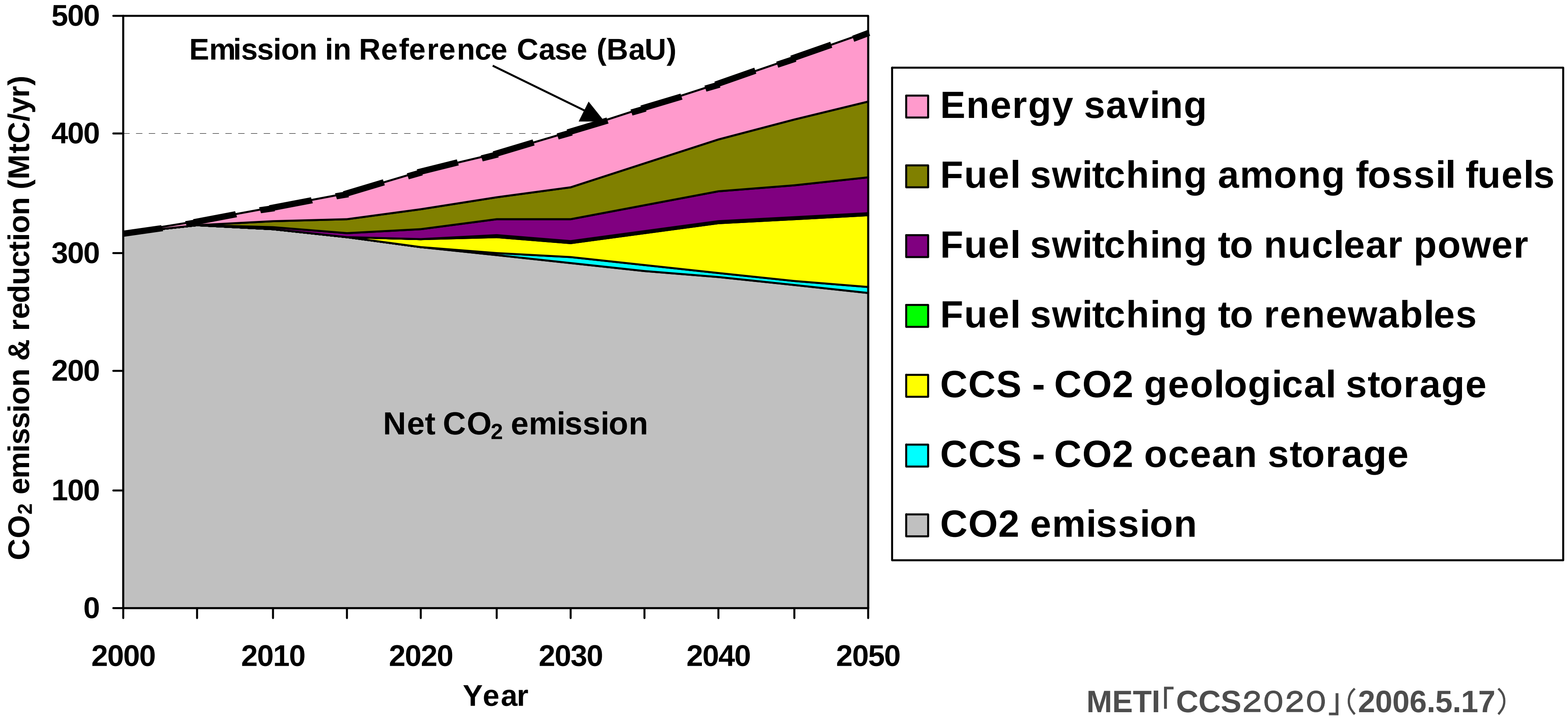
- CCS Working Group of METI has concluded last October that large scale demonstration test is necessory for the next step.

- CO_2 zero-emission coal fired power plant feasibility study is under consideration.

Validity of CO_2 geological storage

●About half of 5.2 Gt-CO_2, potencial in category A2, will be included in the cost-effective options by 2050.

※Emission reductions scenario：
Per GDP emissions should be reduced to half of that in 2000.



METI「CCS2020」(2006.5.17)

Conclusion

●Major challenges for implementation of CCS

1. To identify safe storage site near emission source
2. To reduce CCS cost by half

●Japan has first-class individual technologies for CCS.

However hereafter integration of those technologies is required.

In order to achieve this, large scale demonstration test is necessary.


Thank you
for your attention