- International Workshop on CO_2 Geological Storage, Japan -

February 20, 2006

Socio-Economic and Environmental Studies for CCS Technology Deployment
- Cost, Potential and Deployment Scenarios -

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  - **Role of CCS for CO_2 mitigation in the world**
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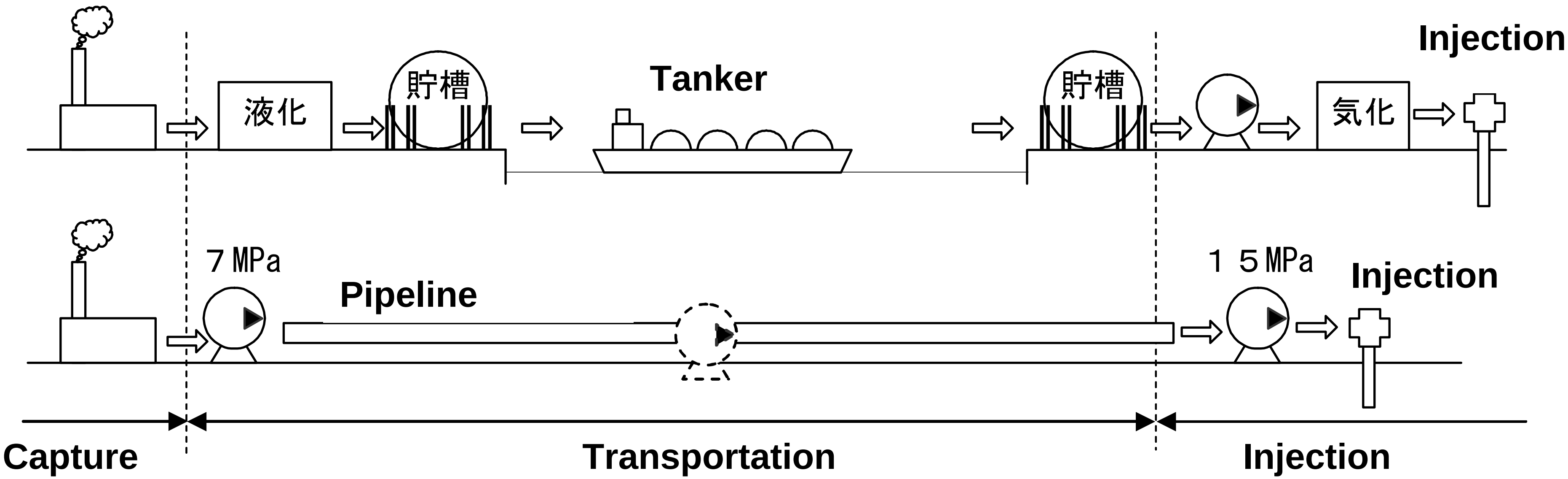
I. Economic Evaluation of CO_2 Geological Storage in Japan

Cost Analyses

Cost Analyses of CCS: Overview (1)

Assumed amounts of captured CO2: 1.0 and 0.2 MtCO2 per year



- CO2 capture cost
- CO2 transportation cost
- CO2 injection cost
- Geological survey cost
- Monitoring cost

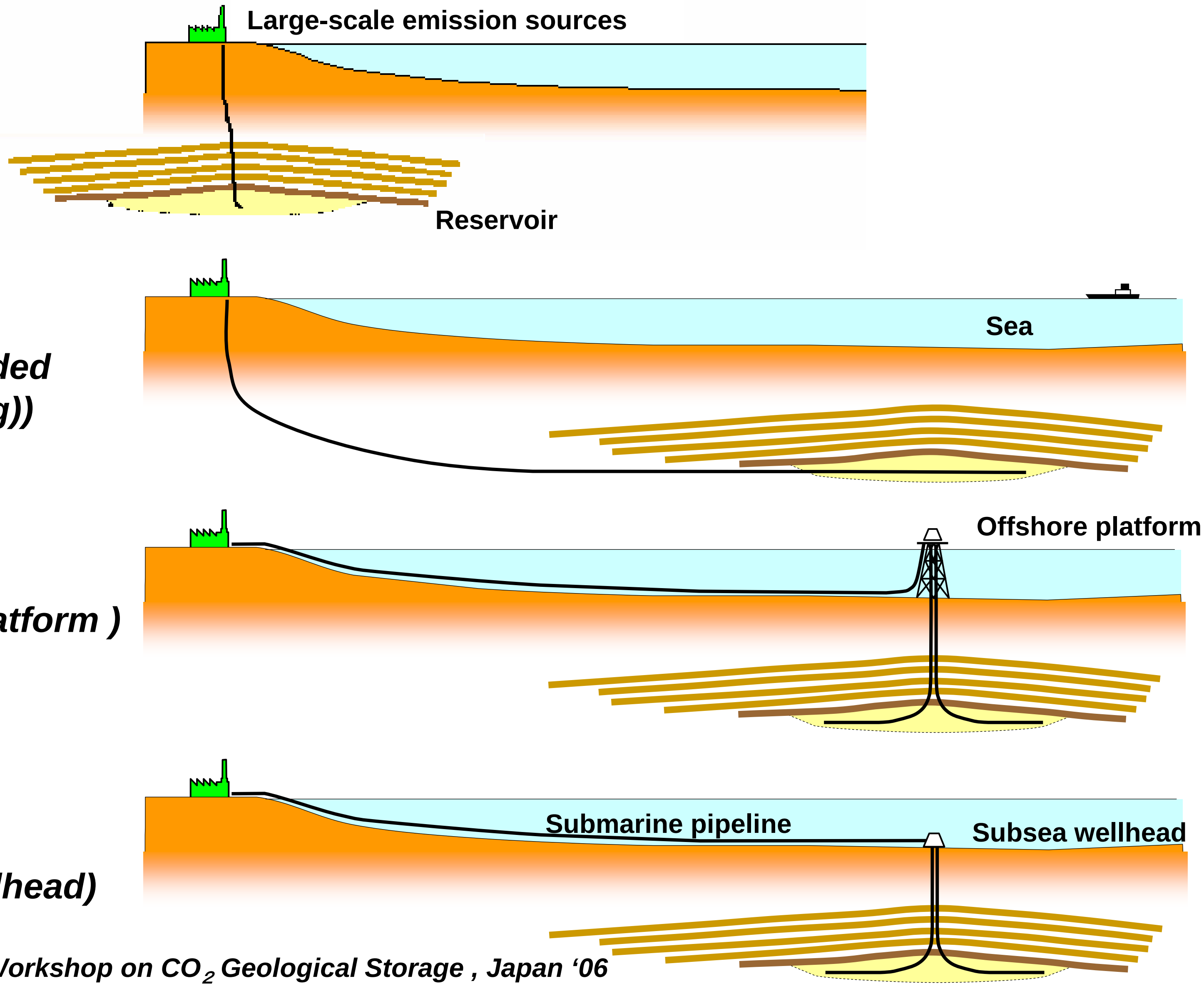
Cost Analyses of CCS: Overview (2)

Land area

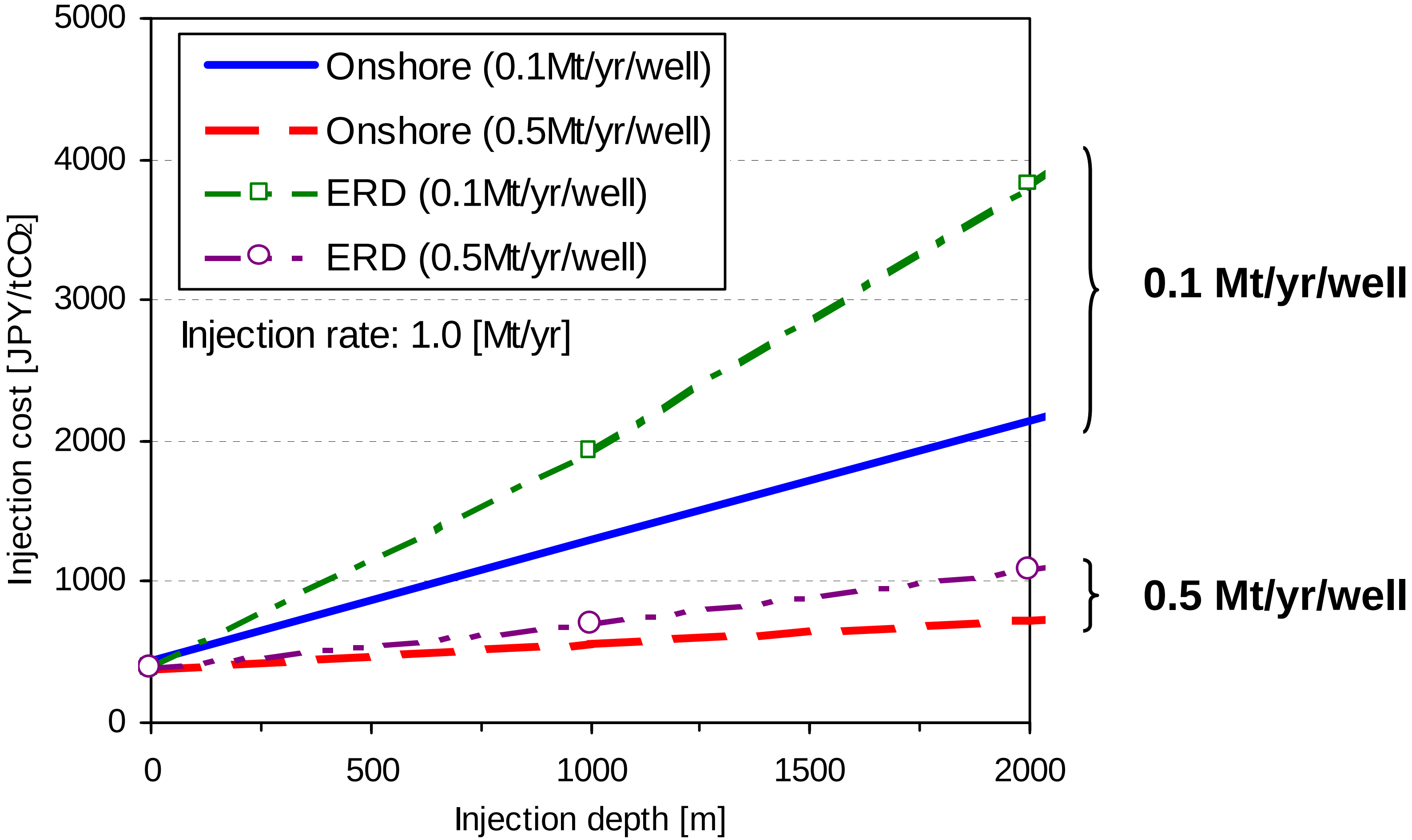
Offshore (ERD (extended reach drilling))

Offshore (Offshore platform)

Offshore (Subsea wellhead)

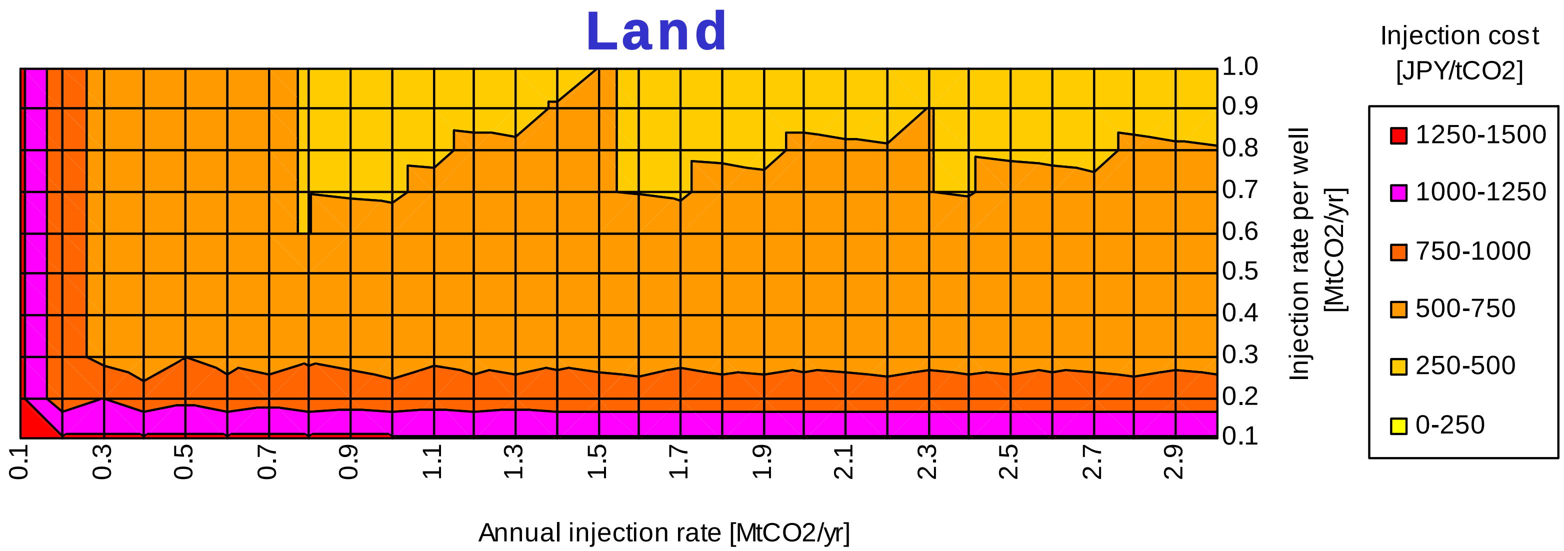


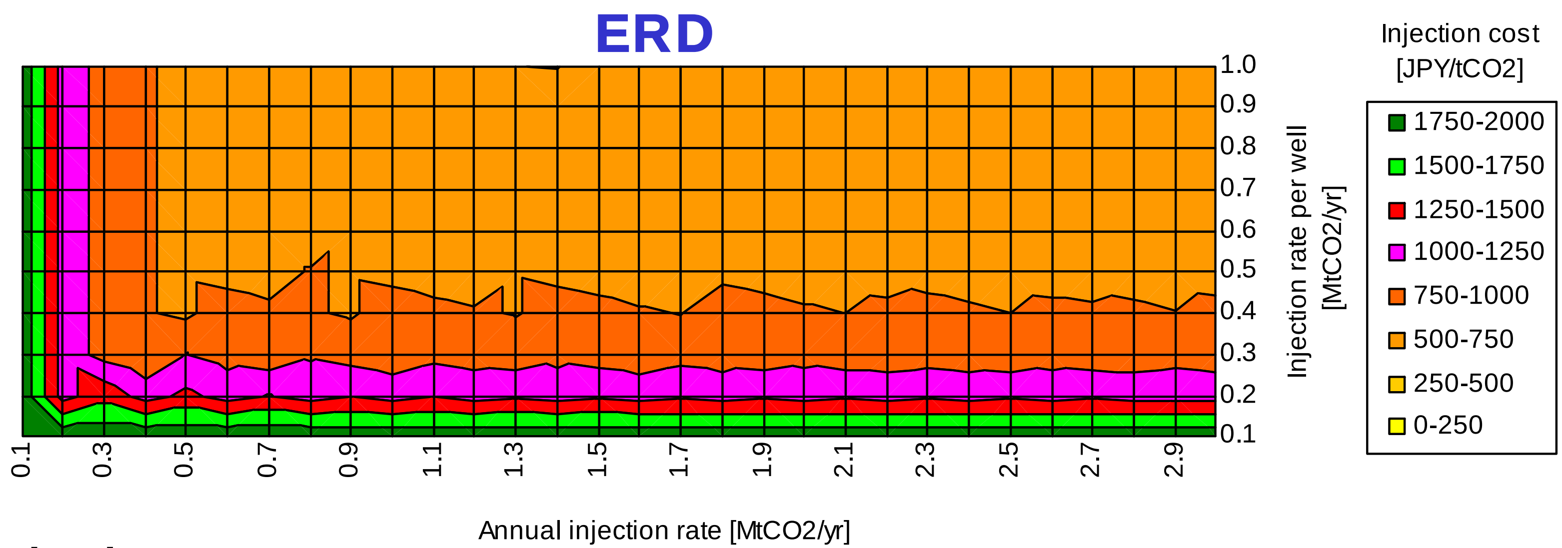
CO_2 Onshore and Offshore (ERD) Injection Costs depending on injection depth



Injection Cost

Depending on amounts of annual injection and injection rate per well



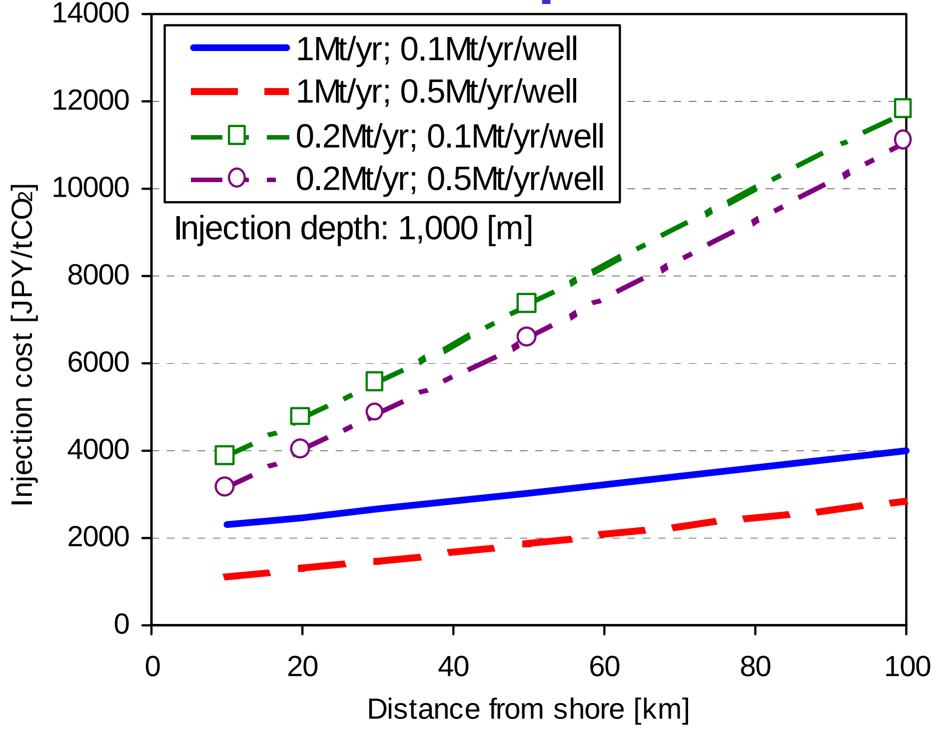


Inter

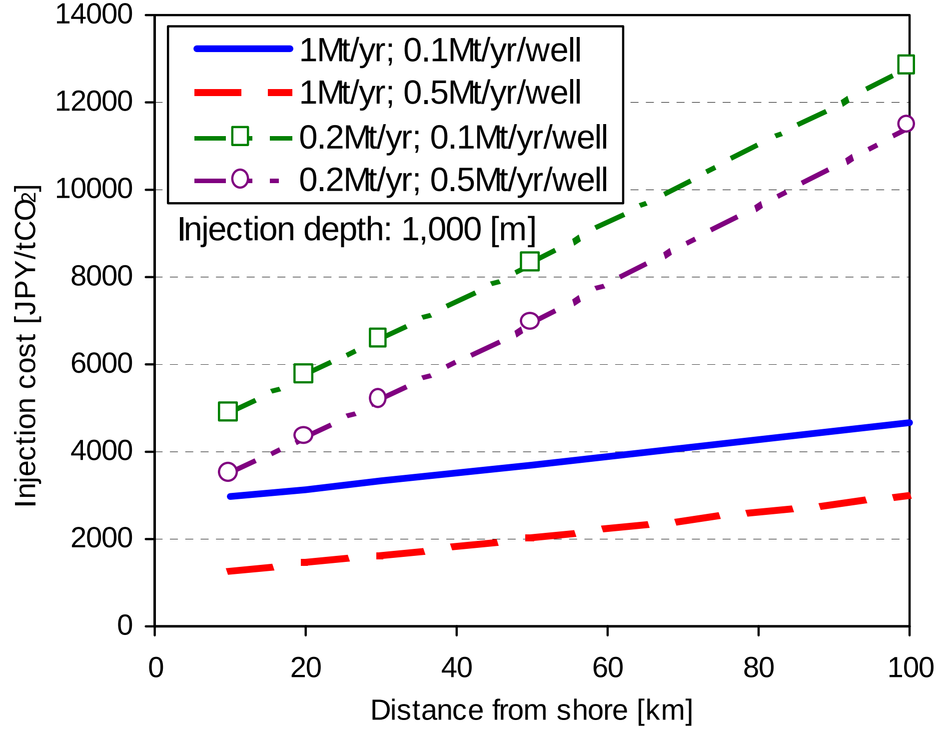
Injection depth: 1000m

CO2 Offshore Injection Costs
Depending on distance from shore

Offshore platform



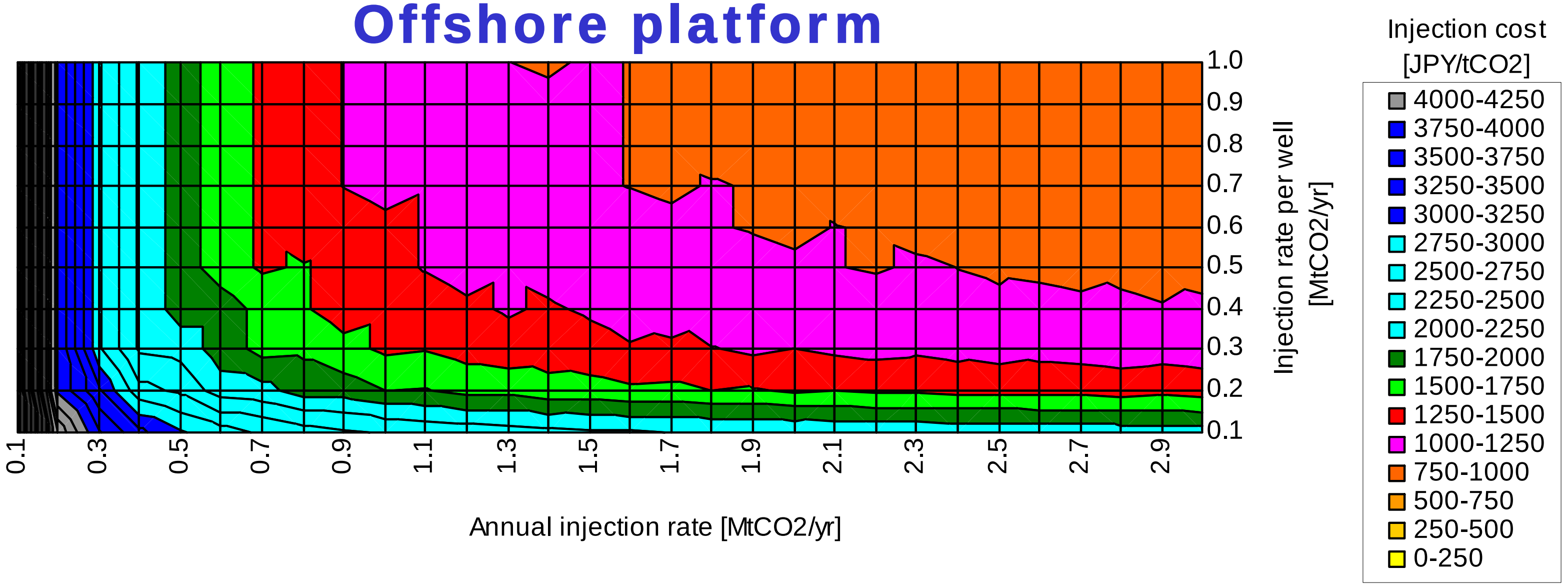
Subsea wellhead



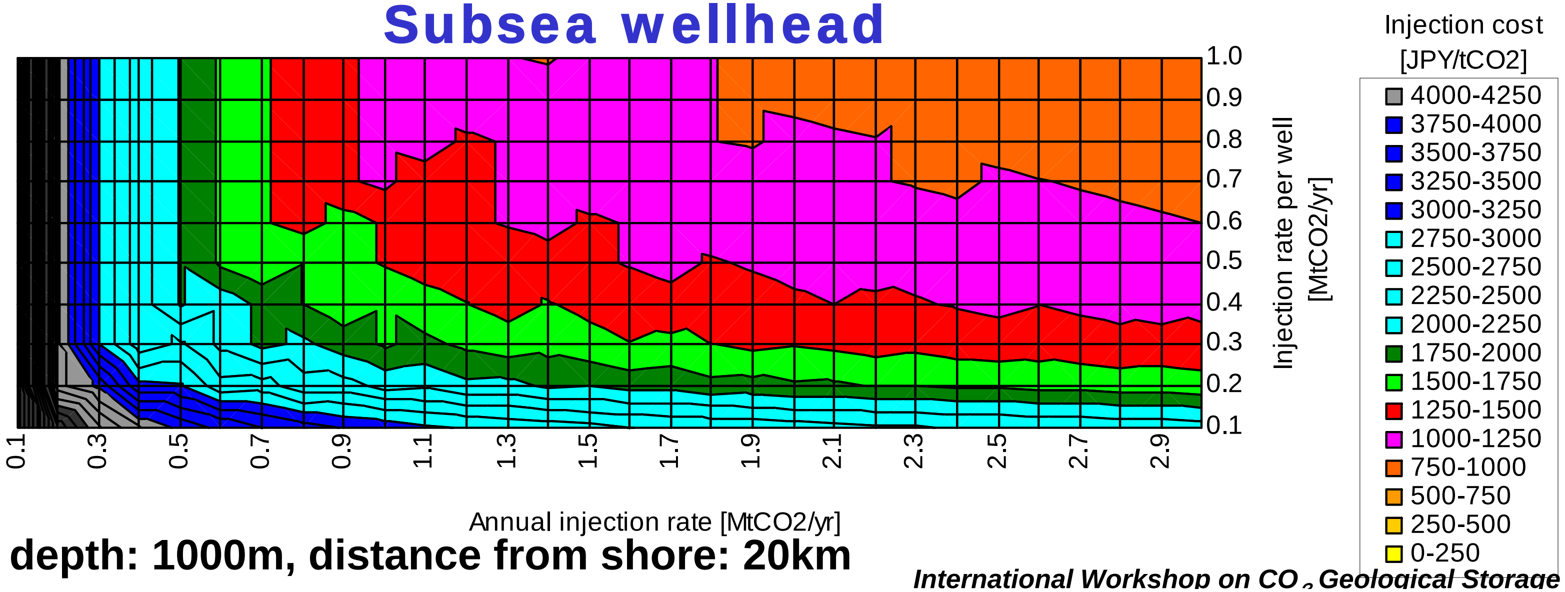
Injection Cost

Depending on amounts of annual injection and injection rate per well

Offshore platform



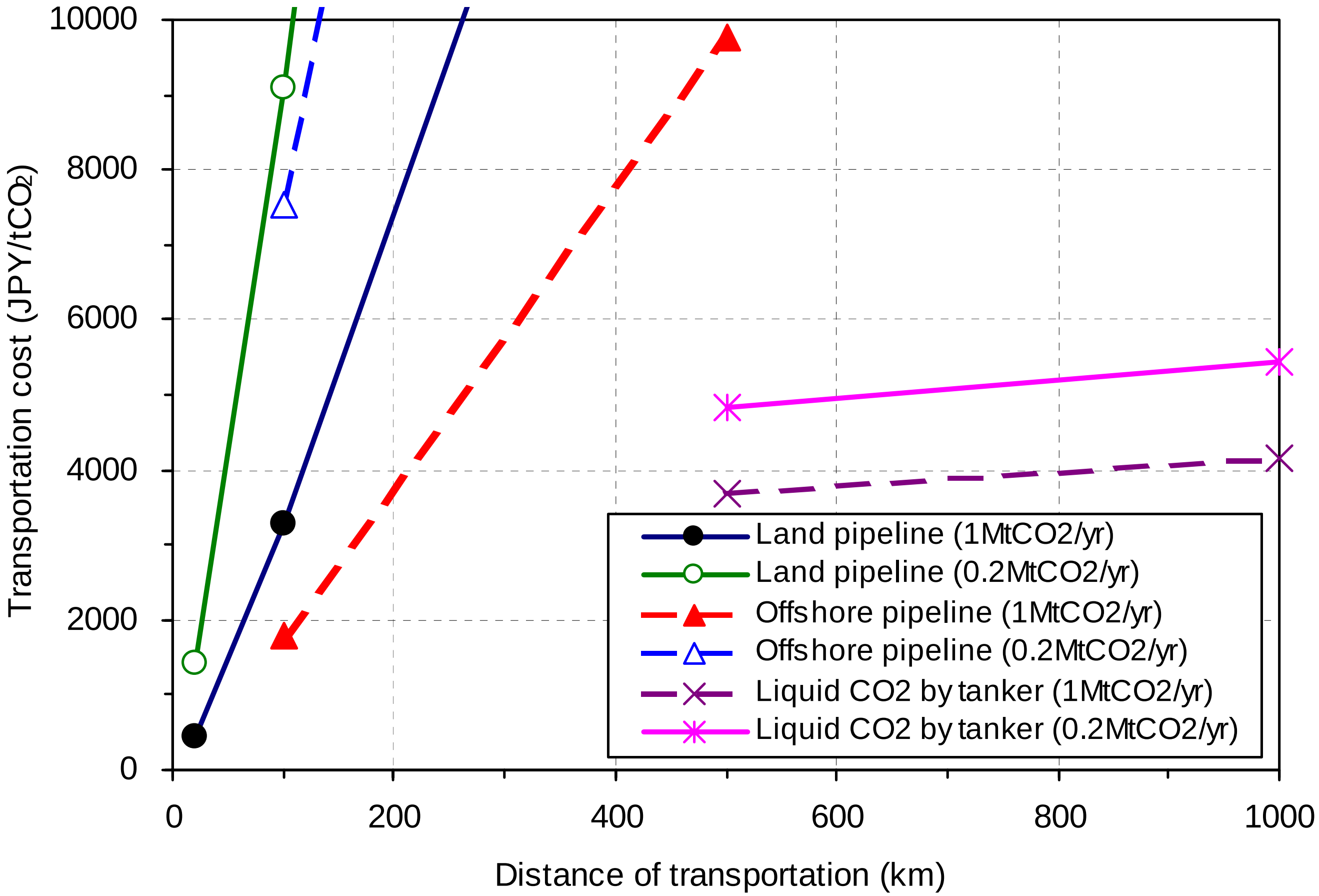
Subsea wellhead



Inter

Injection depth: 1000m, distance from shore: 20km

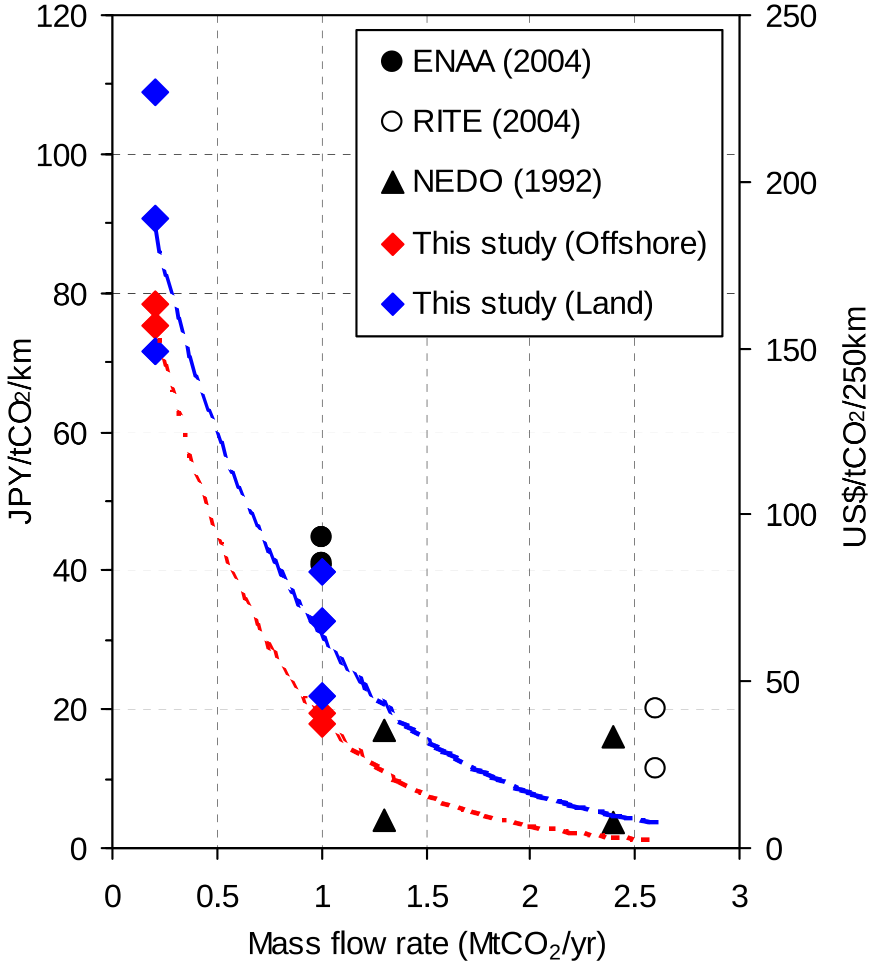
CO_2 Transportation Cost

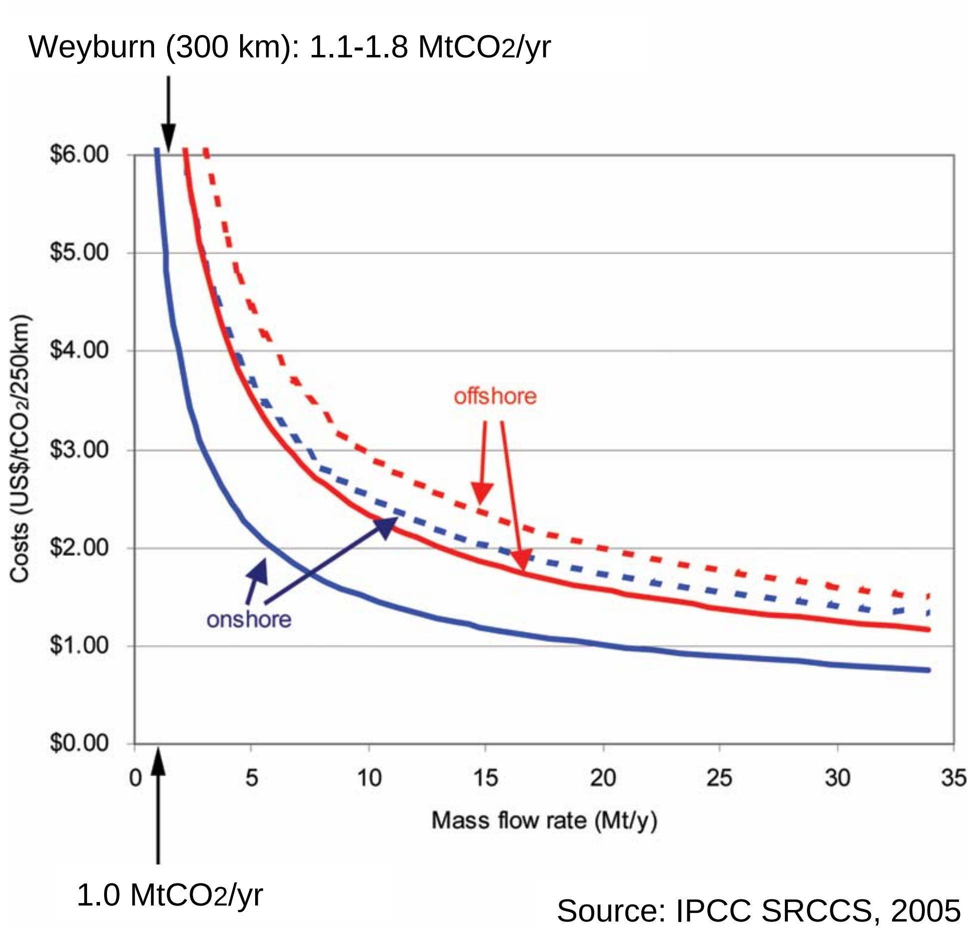


Note: Costs of land purchase/rent for the pipeline on land and those for the indemnity for fishery due to the offshore pipeline construction are excluded.

- **Scale of economy for the pipeline is large.**
- **Land CO2 pipeline cost is higher than the offshore pipeline cost in Japan.**

CO_2 Transportation Cost
- Comparison with the SRCCS -

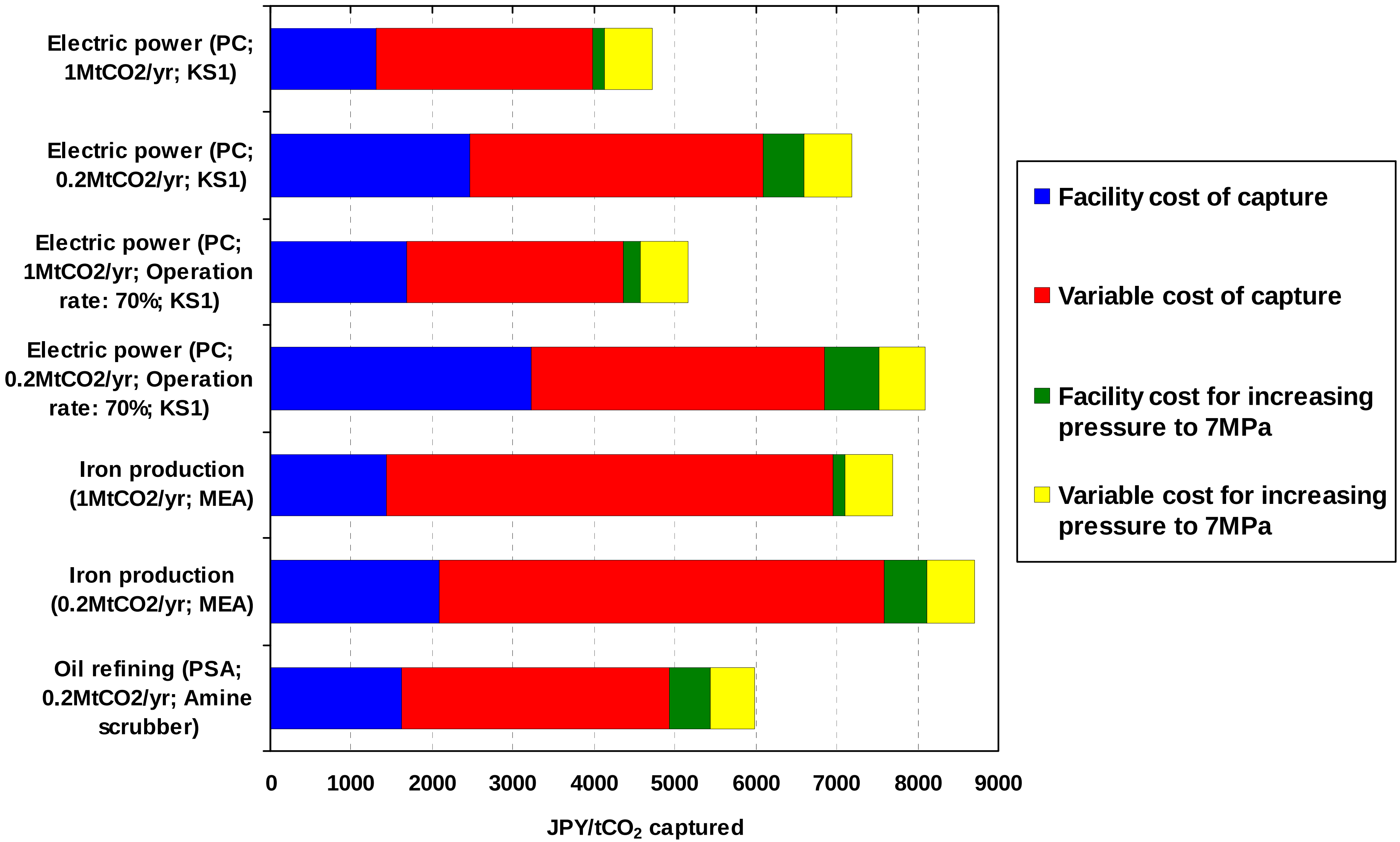




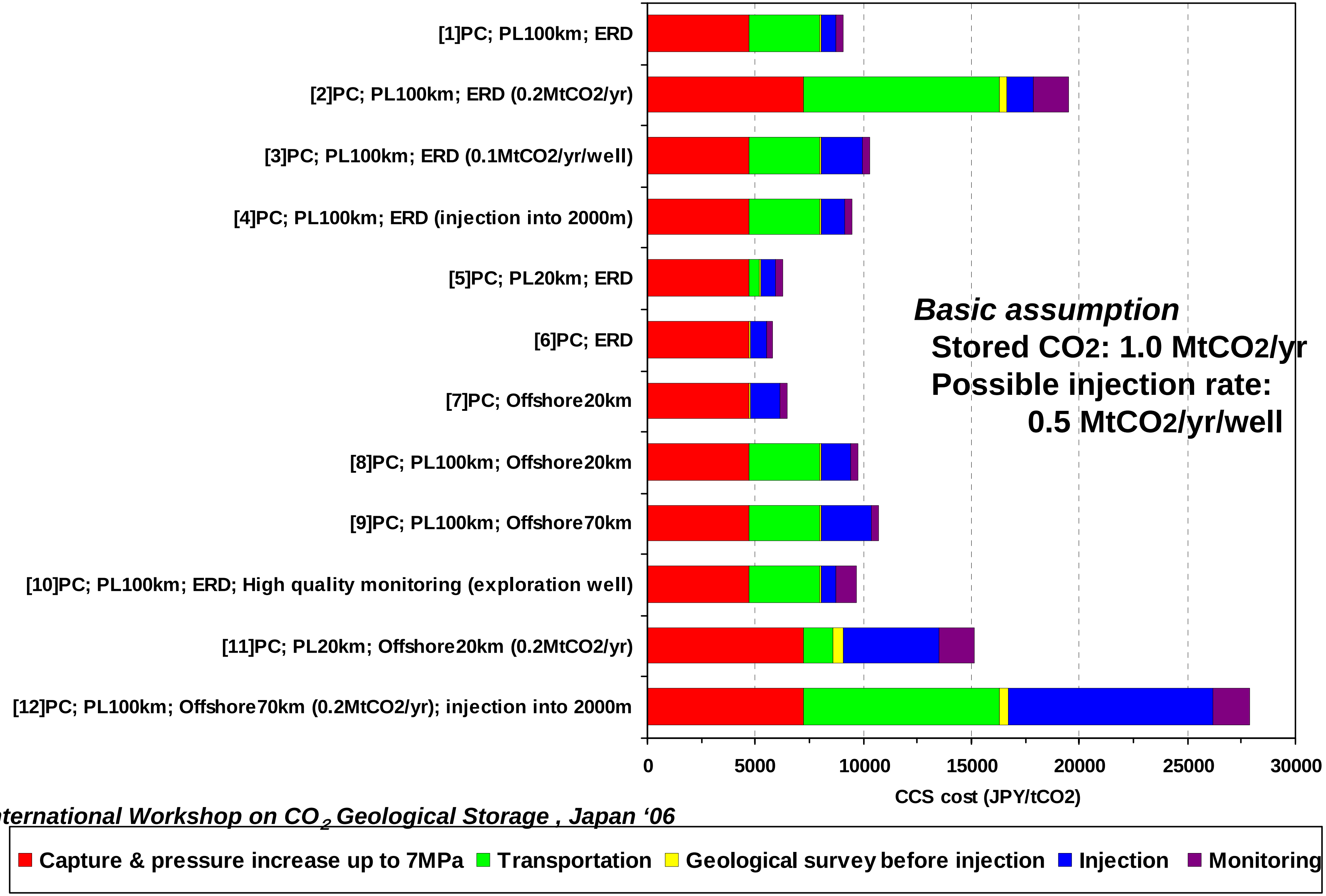
Source: IPCC SRCCS, 2005

- **CO_2 pipeline cost in Japan is considerably higher than that reported in the world.**

Sensitivity of CO2 Capture Cost



Sensitivity of CCS Costs



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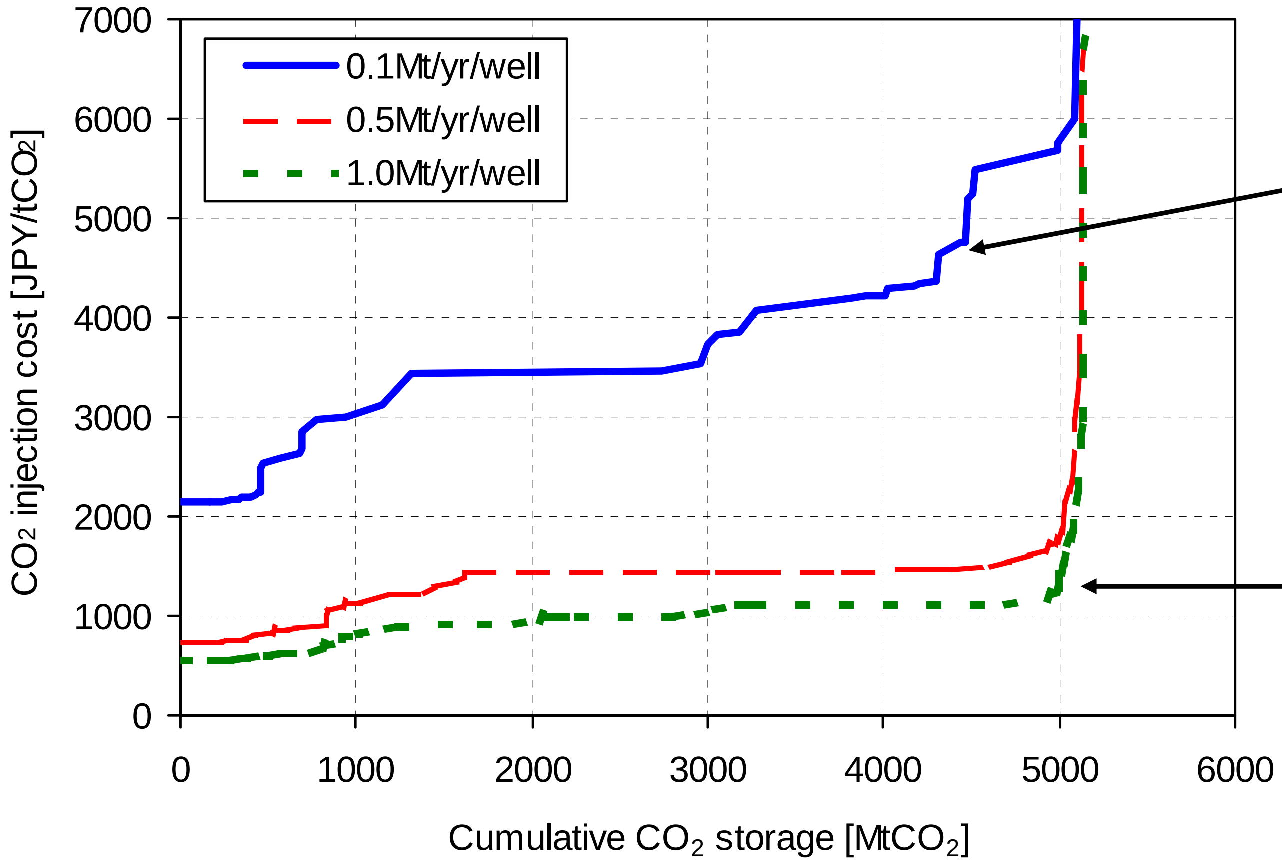
CO_2 Injection Costs and Potentials (1) (Preliminary)

Potentials were corresponding to only the reservoirs which were examined by actual boring data.



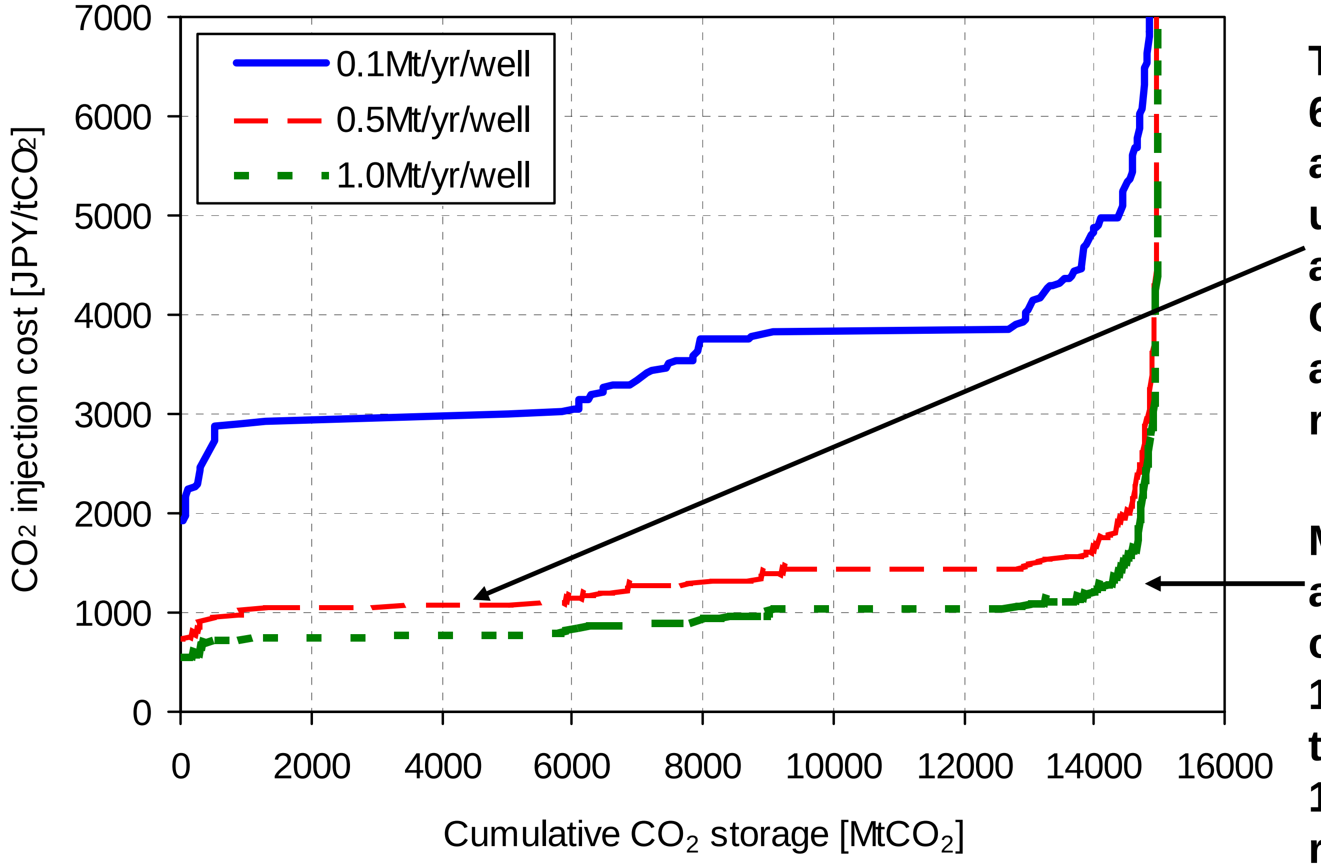
The injection cost is considerably high and increases rapidly in the case of 0.1 MtCO2/yr/well.

Most of the reservoirs are available with the cost under approximately 1,100 and 1,500 JPY per ton of CO2 in the case of 1.0 and 0.5 MtCO2/yr/well, respectively.

Note: This cost covers only the CO2 injection cost for the onshore storage and the CO2 injection cost from shore for the offshore storage.

CO_2 Injection Costs and Potentials (2) (Preliminary)

Potentials were corresponding to the reservoirs which were examined by geophysical exploration data.



The reservoirs by about 6,000 MtCO2 are available with the cost under approximately 800 and 1,100 JPY per ton of CO2 in the case of 1.0 and 0.5 MtCO2/yr/well, respectively.

Most of the reservoirs are available with the cost under approximately 1,100 and 1,500 JPY per ton of CO2 in the case of 1.0 and 0.5 MtCO2/yr/well, respectively.

Note: This cost covers only the CO2 injection cost for the onshore storage and the CO2 injection cost from shore for the offshore storage.

Implications from the Cost Analyses

- The cost of CO_2 geological storage is approximately JPY6,000 per ton of CO_2 for the scale of 1 $MtCO_2$ per year if the distance between the emission source and the storage site is small.
- The transportation cost of CO_2 is considerably high in Japan. Therefore, it is very important to consider the matching between the emission source and the storage site.
- It will be important to explore the reservoirs including non-anticline saline aquifer near large-scale emission sources because of the large dependency of the cost on the distance between the the emission source and the storage site.
- Possible CO_2 injection rate is a key for the CCS cost in Japan.
- The CO_2 capture cost still accounts for a large proportion in the CCS cost, and therefore, the development for the technology achieving the low cost is important.

I. Economic Evaluation of CO_2 Geological Storage in Japan

Deployment Scenario

Outline of a Model for Evaluation of CO_2 Geological Storage Deployment in Japan

- **Intertemoral MIP model** minimizing the system costs under the consideration of scale of economy for CO2 transportation and injection facility.
- **Model time span: 2000-2050**
  - Representative time point: 2005, 2010, 2015, 2020, 2025, 2030, 2040, 2050
- **Regional resolution:**
  - 47 land regions by prefecture
  - Onshore and offshore reservoirs having anticline structure
  - Ocean storage point
- **Interregional transportation: CO_2, Electricity**
- **Bottom-up modeling for energy supply and CCS technologies**
- **Primary energy supply: coal, oil, LPG, LNG, hydro energy, geothermal energy, photovoltaics, wind power and nuclear power.**
- **Energy demand side: top-down treatment using long-term price elasticity for solid, liquid (gasoline, light oil, heavy oil), gaseous fuels and electricity**
- **Electricity demand and supply are formulated for 4 time periods: instantaneous peak, peak, intermediate and off-peak periods**

Other Assumptions

- **Cost reduction of renewable energies**

  Wind power: -1%/yr, Photovoltaics: -3%/yr

- **Population: 0.127 in 2010, 0.118 in 2030, 0.101 in 2050 (billion people)**
  (Source: National Institute of Population and Social Security Research (2002), Population Projection for Japan: 2001-2050; the mid. scenario)

- **Per-capita GDP growth: +1.5 %/yr between 2000 and 2050**

- **Per-GDP final energy growth: IPCCC SRES B2**

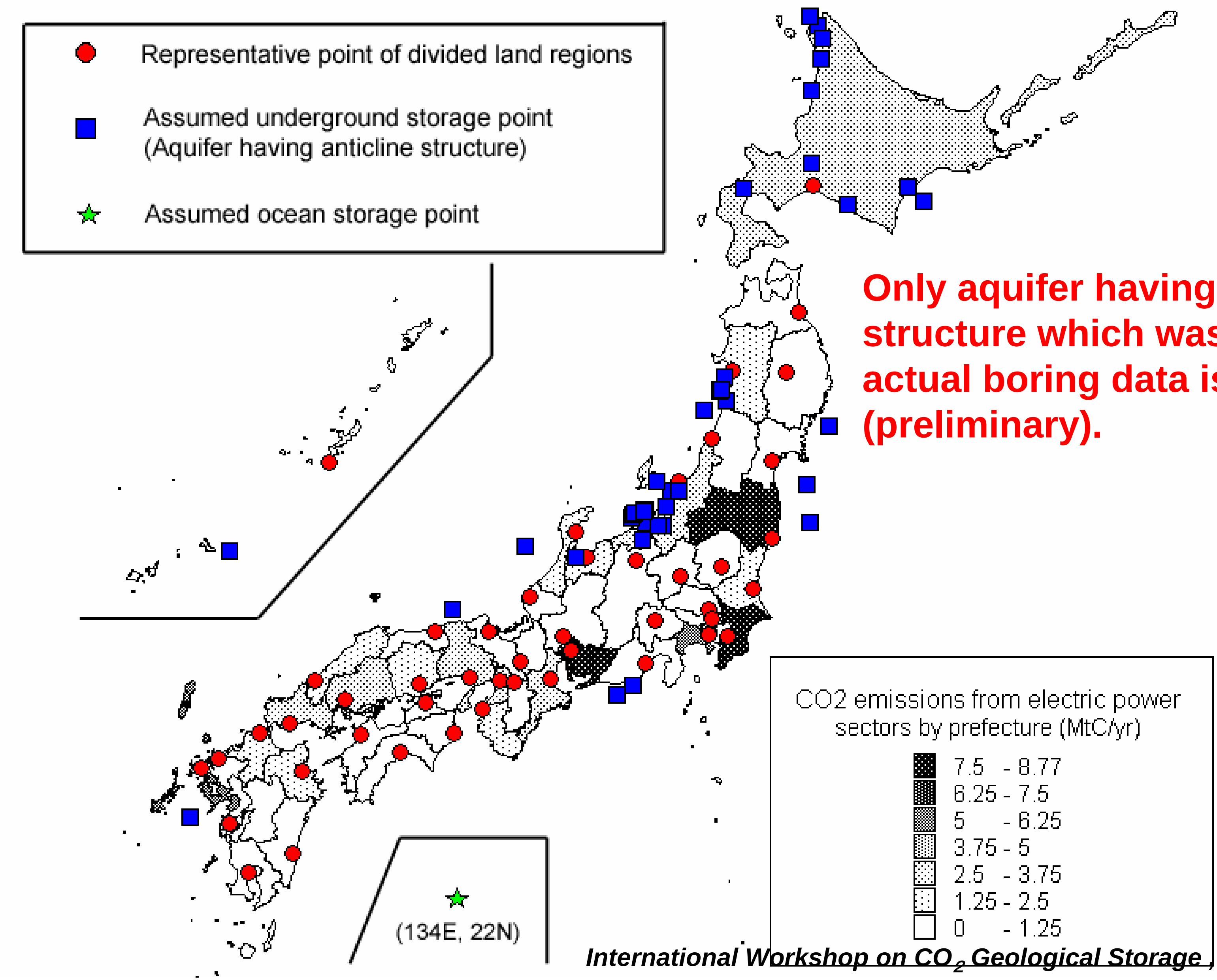
- **Long-term price elasticity in final energy demand:**

  Electricity: -0.2, Non-electricity: -0.3

- **Assumed maximum capacity of nuclear power: 61.85 GW**
- **Variable cost of nuclear power: 2 ¢/kWh**
- **CO2 ocean sequestration is available only after 2020.**

etc.

Region Division in the Model



Only aquifer having anticline structure which was examined by actual boring data is considered (preliminary).

Simulation Cases

- CO_2 emission constraint

  Case 1: Per-GDP CO_2 emission in 2050 is 1/3 relative to that in 2000.
  (The same assumption to the Energy Technology Vision 2100)

  Case 2: Per-GDP CO_2 emission in 2050 is 1/2 relative to that in 2000.

- Possible CO_2 injection rate

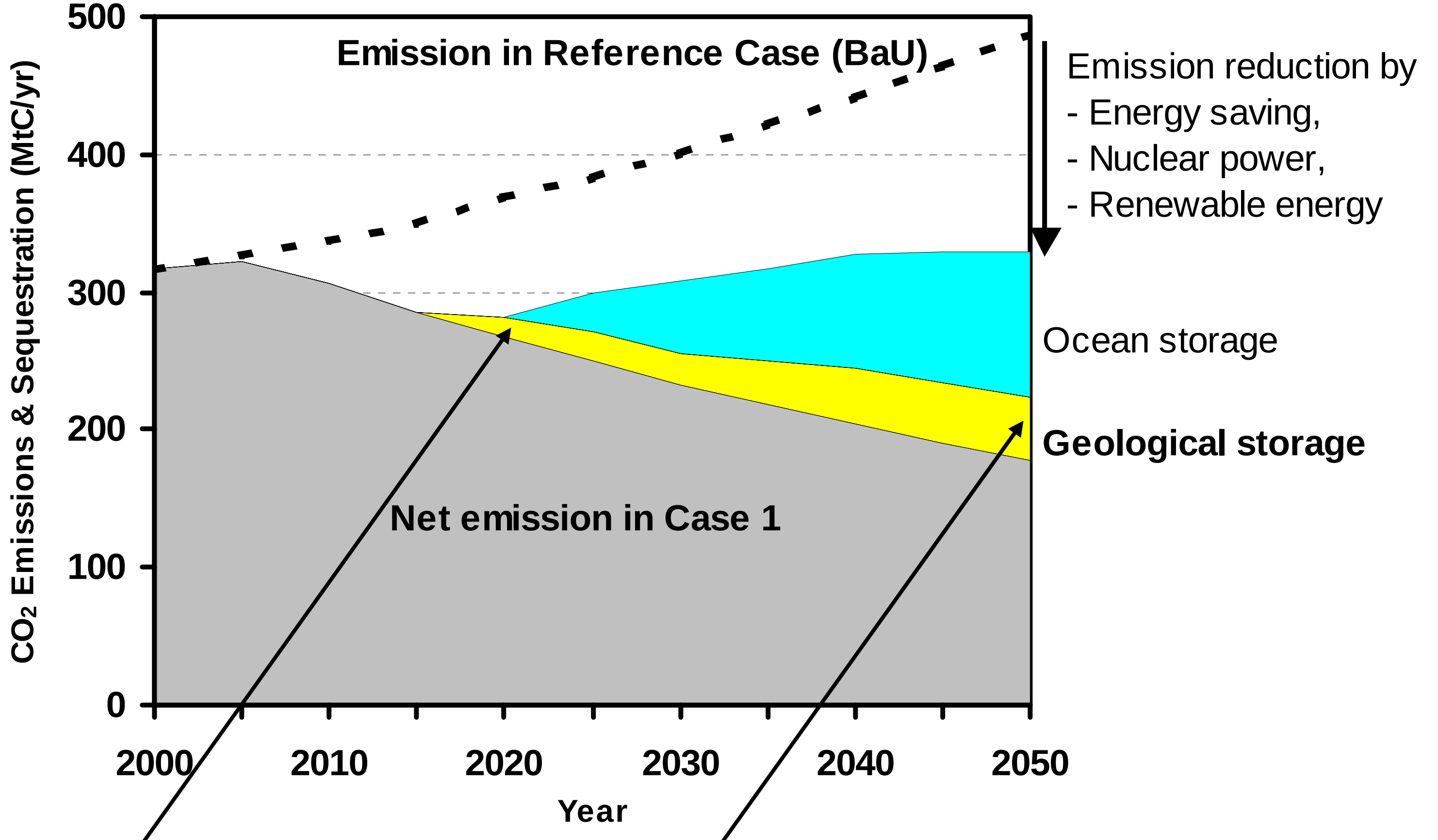
  Case A: 0.5 MtCO_2/year/well

  Case B: 0.1 MtCO_2/year/well

Case 1-A	Case 1-B
Case 2-A	Case 2-B

CO_2 Emissions and Sequestration in Japan

Case 1-A

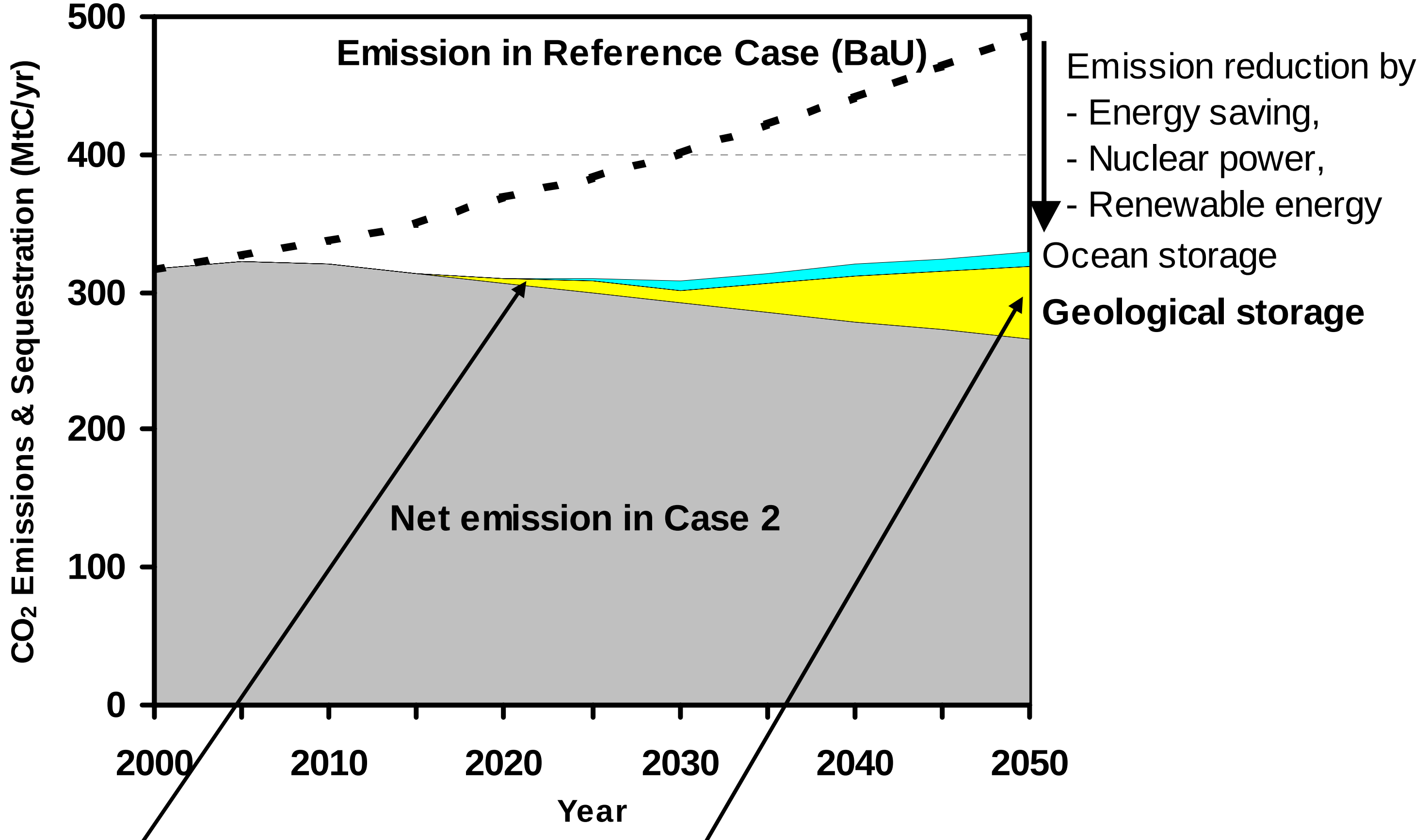


Approximately 14 MtC/yr (52 MtCO2/yr) in 2020

Approximately 47 MtC/yr (170 MtCO2/yr) in 2050

CO_2 Emissions and Sequestration in Japan

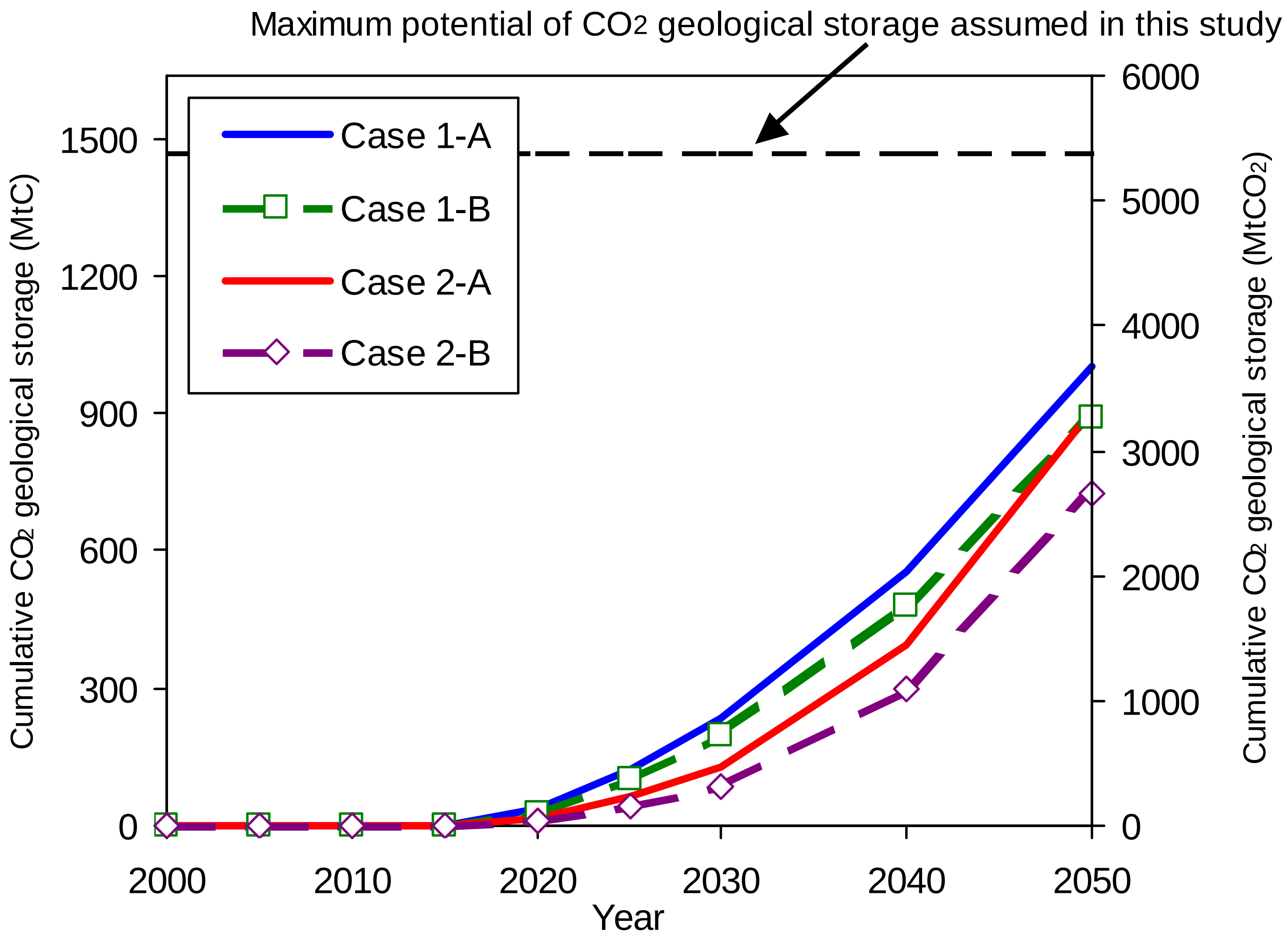
Case 2-B



Approximately 4 MtC/yr (16 MtCO2/yr) in 2020

Approximately 52 MtC/yr (190 MtCO2/yr) in 2050

Cumulative CO2 Geological Storage in Japan



Implications from the Analyses for CCS Deployment in Japan

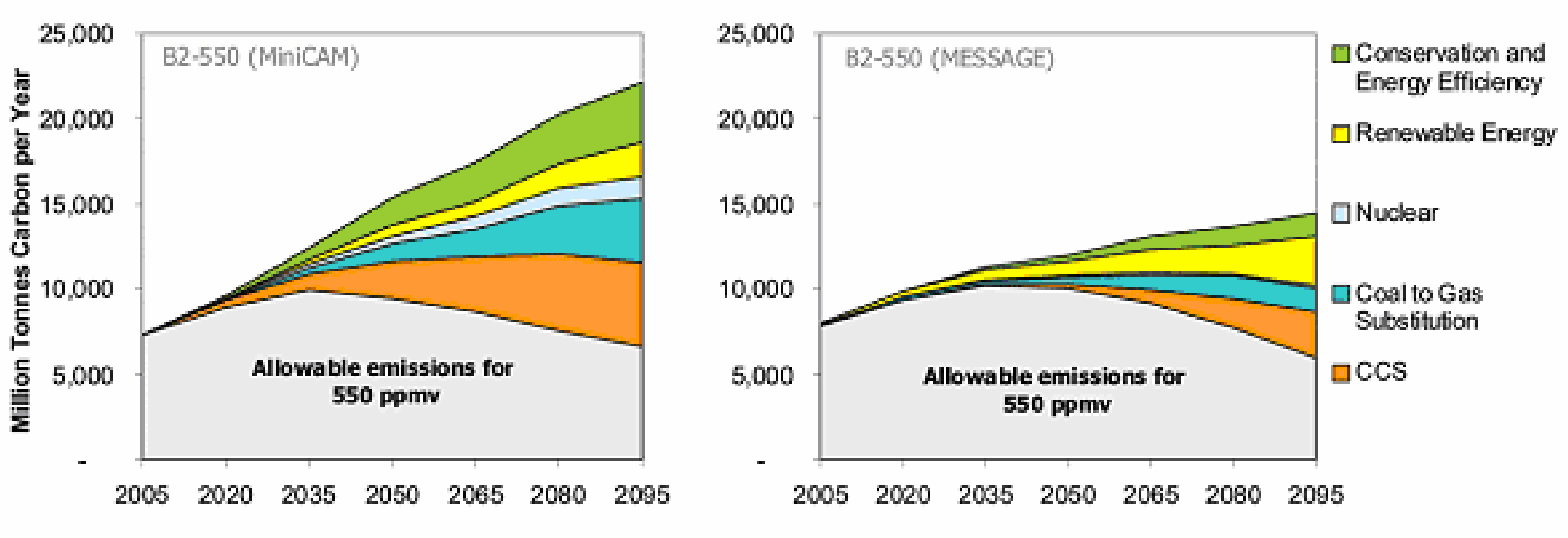
- CO_2 geological storage is a cost-effective option for CO_2 emission reduction in Japan, even if the scale of economy of CO_2 transportation and injection is considered.
- The amount of the cumulative CO_2 storage between 2000 and 2050 is around 3 $GtCO_2$ according to the analyses.
- However, the deployment scenarios obtained through the analyses consider only economic factors. We should pay attention to non-economic factors for the deployment scenario such as public perceptions and other infrastructures without consideration in the model.

II. Perspectives of CCS in the World

Perspectives of CCS Deployment in the World (IPCC SRCCS)

CO_2 emission reduction effects of technological options for the CO_2 stabilization at 550 ppmv

MiniCAM model (PNNL) **MESSAGE model (IIASA)**

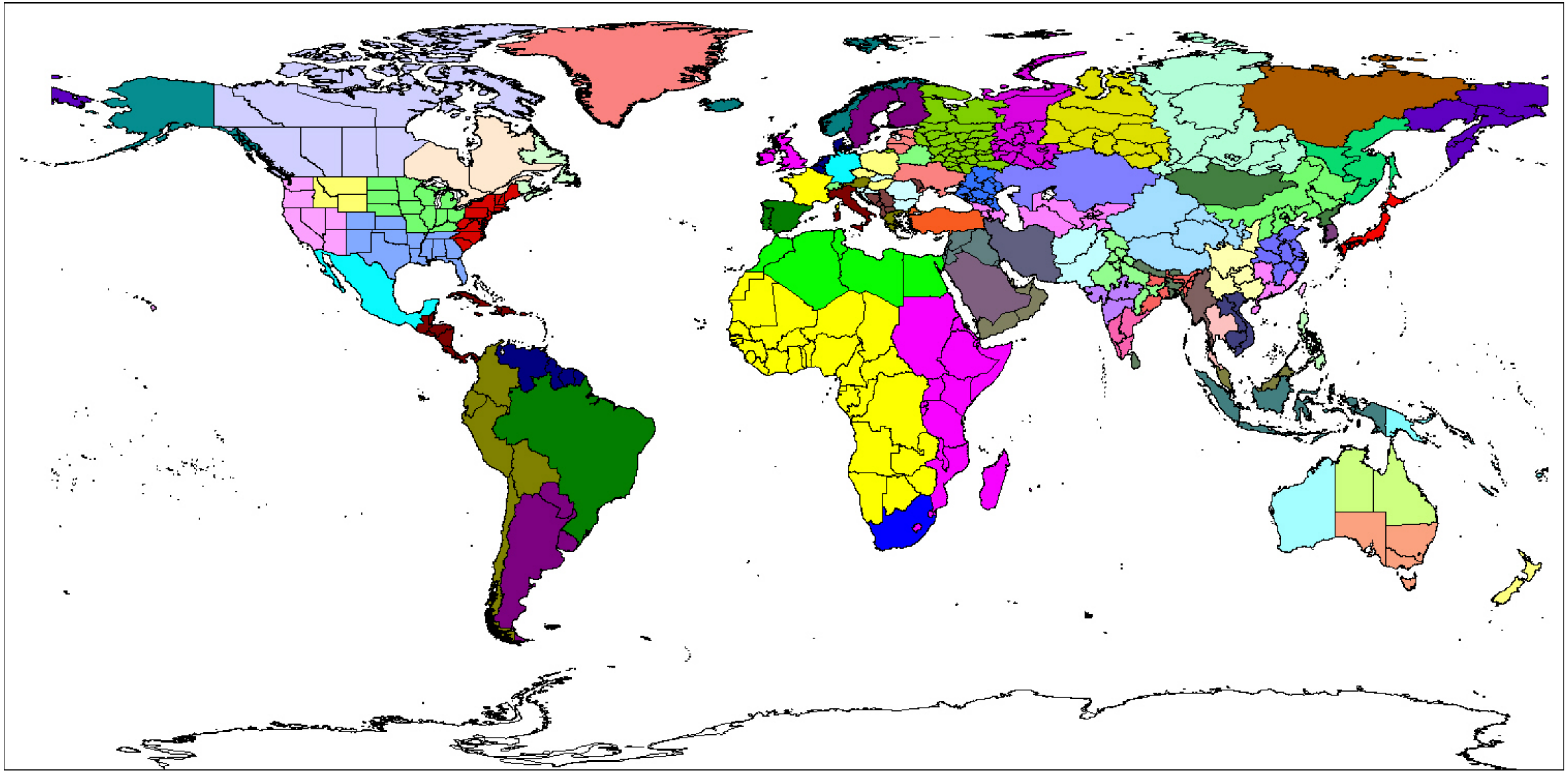


Source: IPCC SRCCS

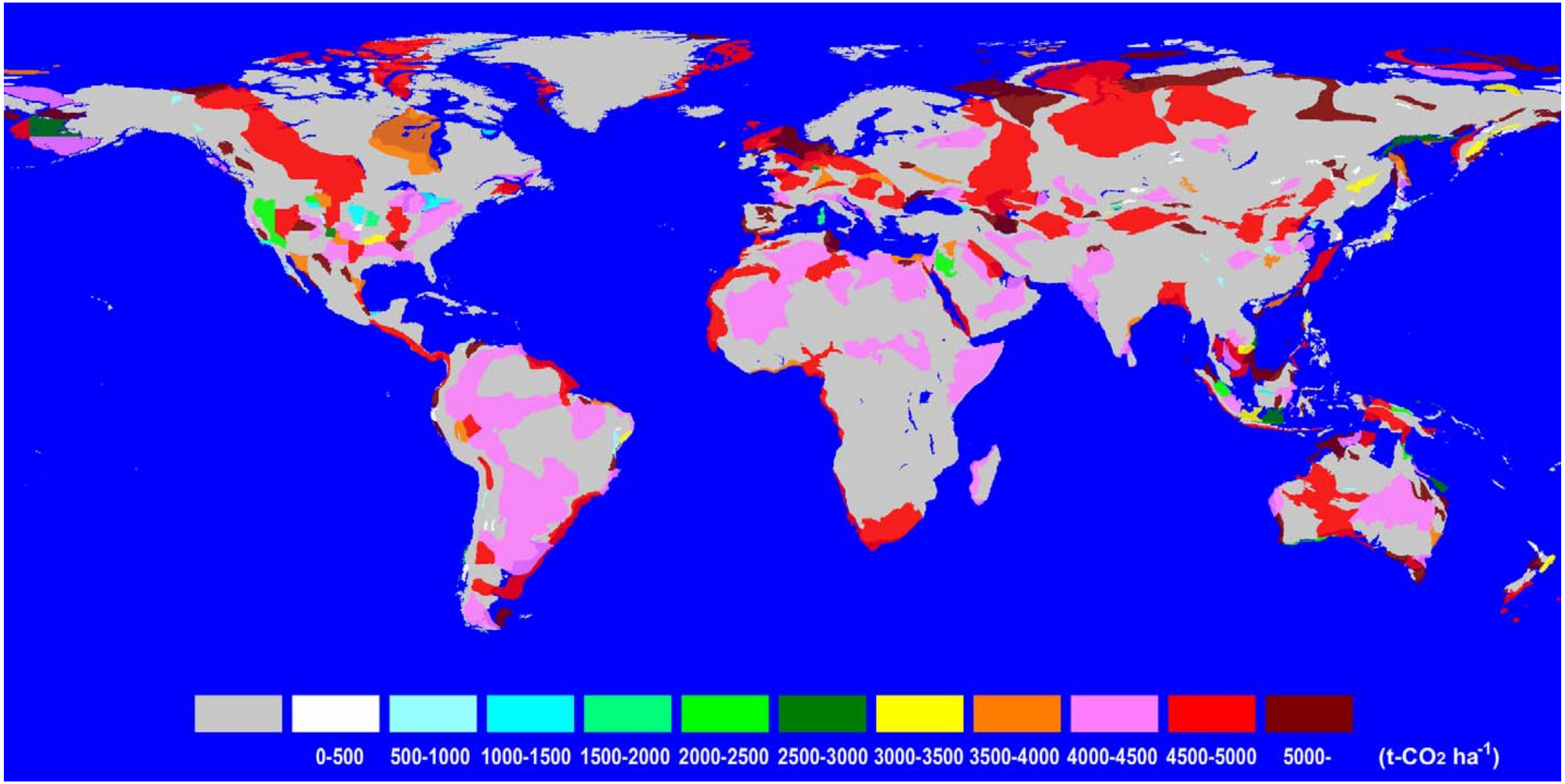
Outline of DNE21+ Model

- Linear Programming Model (minimizing the world energy system cost)
- Evaluation time period: 2000-2050 (or -2100)
- World divided into 77 regions
- Energy supply side: bottom-up, demand side: top-down
- Primary energy: coal, oil, natural gas, hydro&geoth., wind, photovoltaics, biomass and nuclear power
- Final energy demand: solid, liquid, gaseous fuels, and electricity
- Electricity demand and supply are formulated for 4 time periods: instantaneous peak, peak, intermediate and off-peak periods
- Interregional trade: coal, crude oil, natural gas, methanol, hydrogen, electricity and CO_2
- Existing facility vintages are explicitly modeled.

Model Regions in DNE21+ Model



CO_2 Sequestration Potential into Aquifer



Note: The potential was estimated by RITE based on a sedimentary basin map of USGS. The "ideal" potential of aquifer sequestration is shown.

Assumed Potential and Cost of CO_2 Sequestration

	Sequestration potential (GtC)	Sequestration cost† ($/tC)
Oil well (EOR)	**30.7**	**81 – 118‡**
Depleted gas well	**40.2 – 241.5††**	**34 – 215**
Coal-bed (ECBM)	**40.4**	**113 – 447‡‡**
Aquifer	**856.4***	**18 – 143**
Ocean	**–**	**36****

† Cost of CO_2 capture and interregional transportation excluded.

‡ The proceeds from recovered oil excluded.

†† 40.2 is the initial value in 2000, and the capacity increases with natural gas production.

‡‡ The proceeds from recovered gas excluded.

* The potential is the "practical" one, which is 10% and 20% of the "ideal" potentials for onshore and offshore, respectively.

** The cost includes that of CO_2 liquefaction.

Source: Hendriks, et al.; USGS; Stevens, et al.; IEA-GHG; Kotsubo et al.

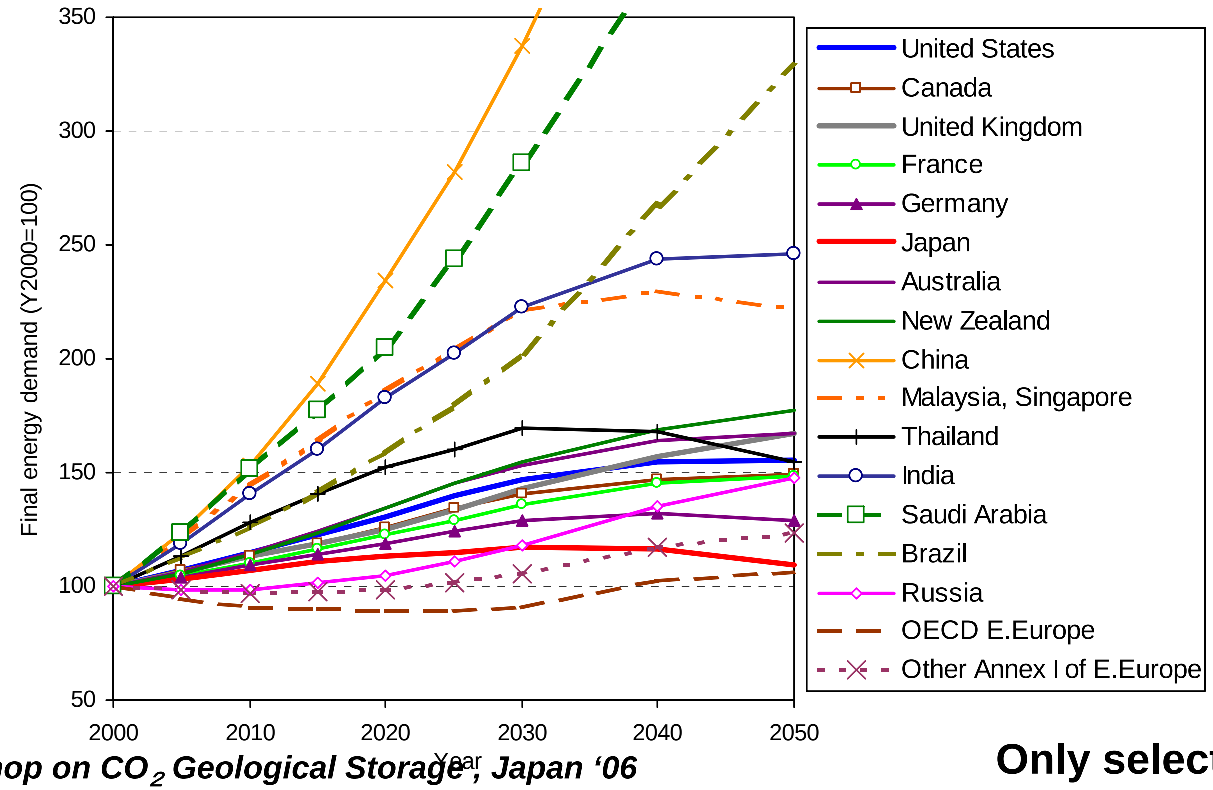
Note: the potentials and costs are assumed by region in the model.

Comparison data: Technical Summary in IPCC SRCCS

	Lower estimate		Upper estimate	
	(Gt-CO_2)	(GtC)	(Gt-CO_2)	(GtC)
Oil & gas fields	675	184	900	245
Unminable coal seams (ECBM	3-15	1-4	200	55
Deep saline formations	1000	273	Uncertain, but possibly 10^4	≈2700

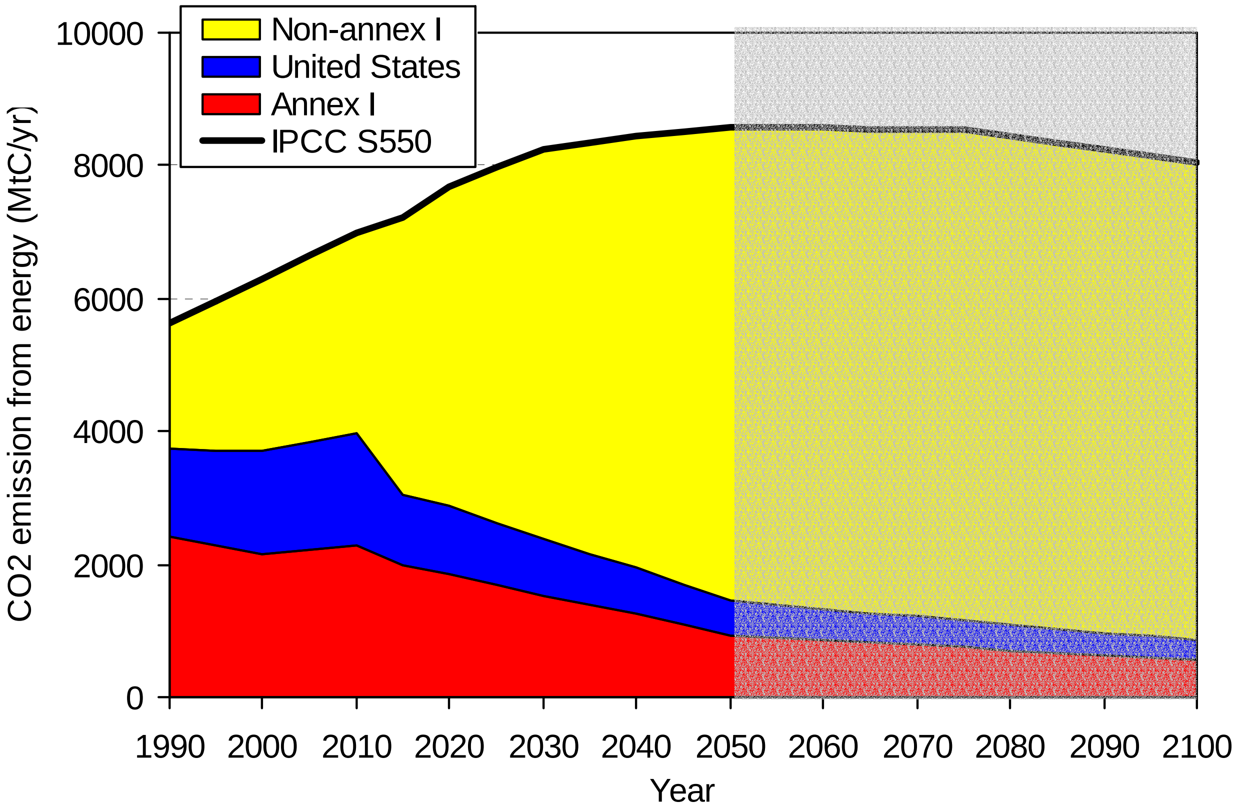
Assumption of Final Energy Demand

- **Population: IPCC SRES B2 (Task Group on Scenarios for Climate Impact Assessment (TGCIA))**
- **Growth rate of GDP per cap: IPCC SRES B2 (adjusted by WEO; Perspective of Energy Research Institute in China)**
- **Growth rate of final energy per GDP for reference case: IPCC SRES B2**



Only selected regions

Assumed Regional CO_2 Emission Limit for S550



*** IPCC S550: The CO_2 concentration stabilization scenario at 550 ppmv by IPCC WG1**

Year 2010: Kyoto target for Annex I countries excluding US

Per-GDP CO_2 emission reduction of 18% by 2010 for US

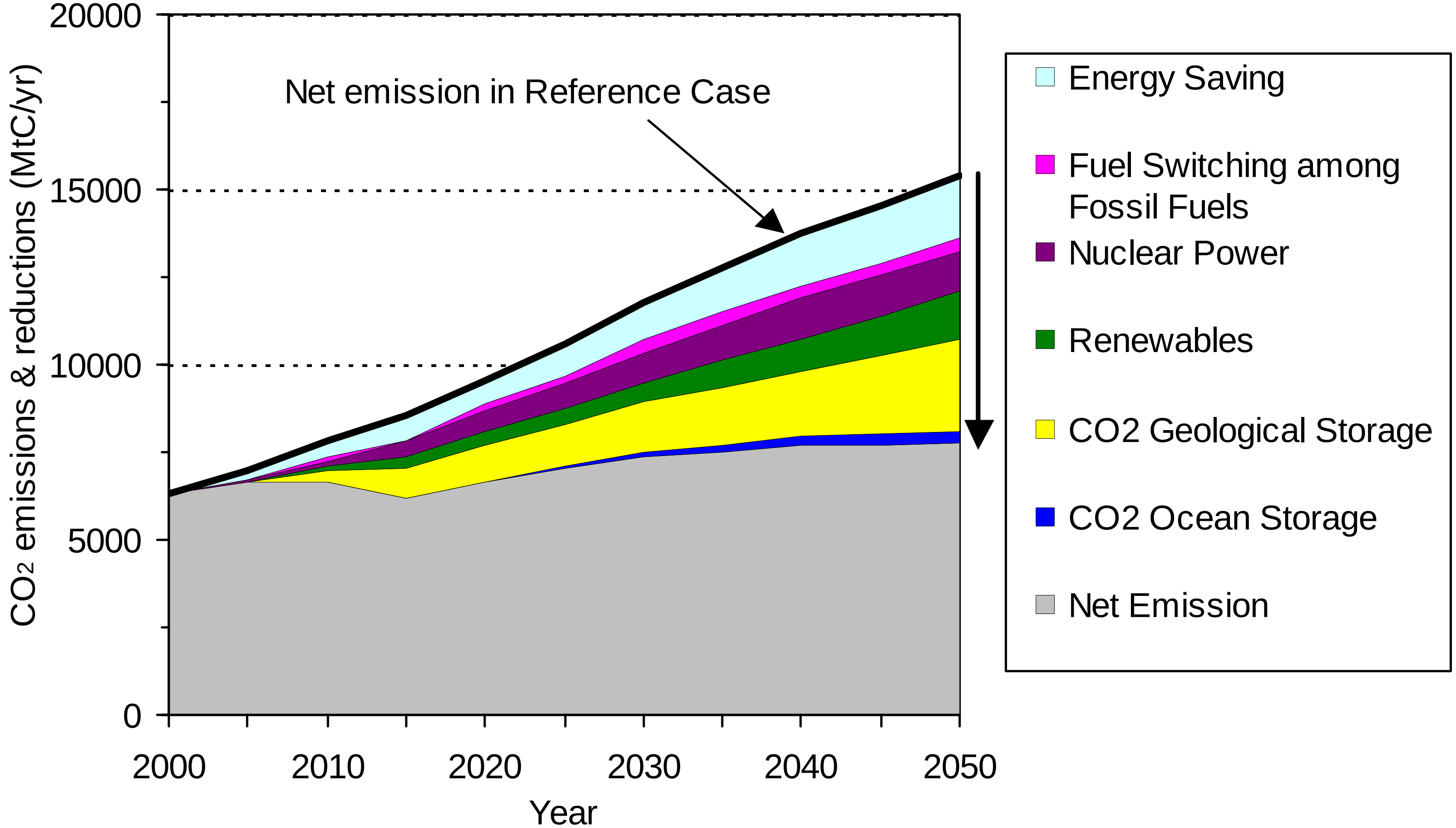
Year 2015 (Years 2013-2017) and thereafter:

UK-proposed-target for Annex I (Approximately 60% reduction in 2050 relative to in 1990)

Emission reductions for Non-Annex I countries to keep the S550 in total

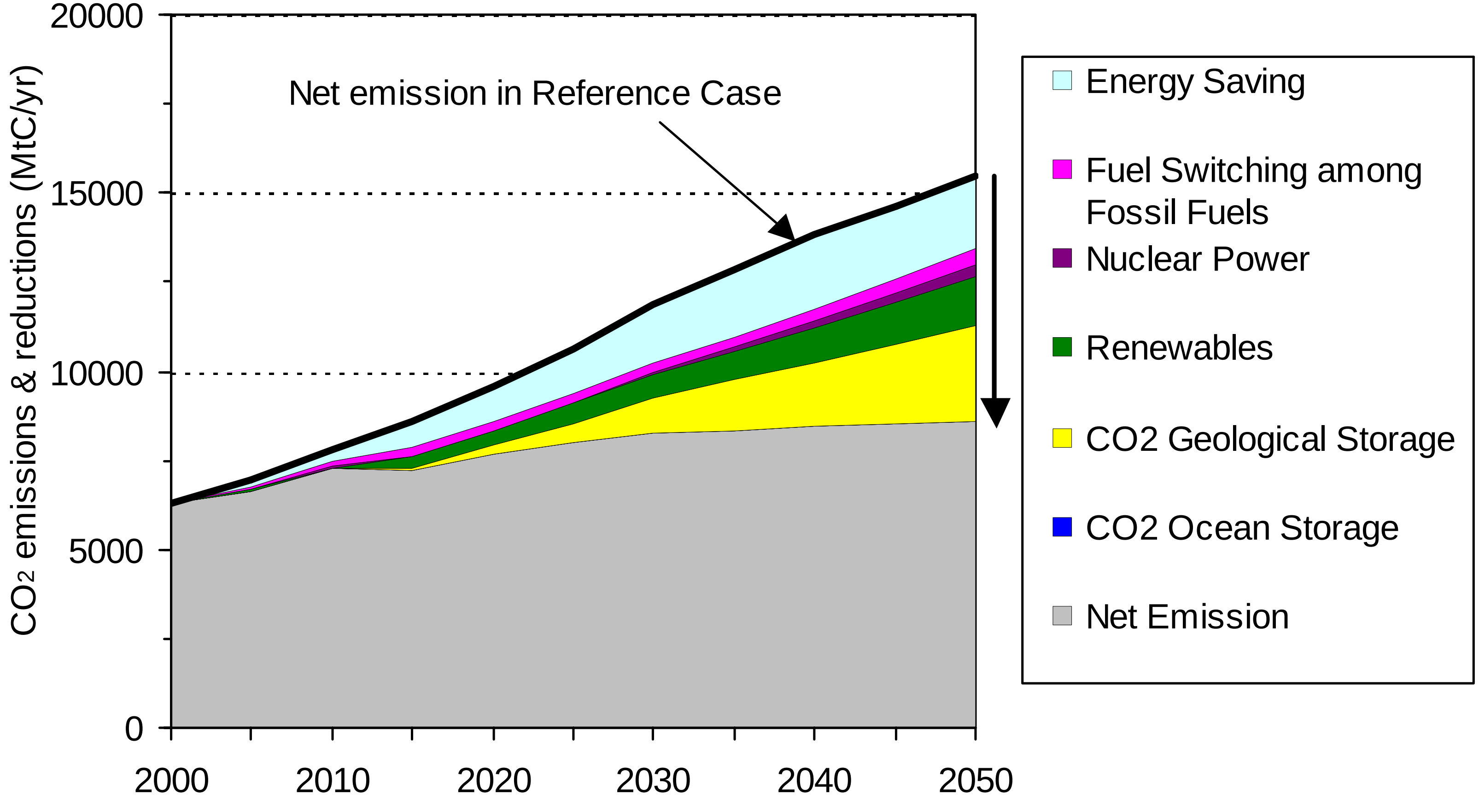
CO_2 Emission Reduction Effects of Technological Options

- CO_2 Concentration Stabilization Case (IPCC S550) - Burden share: KP+UK Proposal w.o. Emission Trading



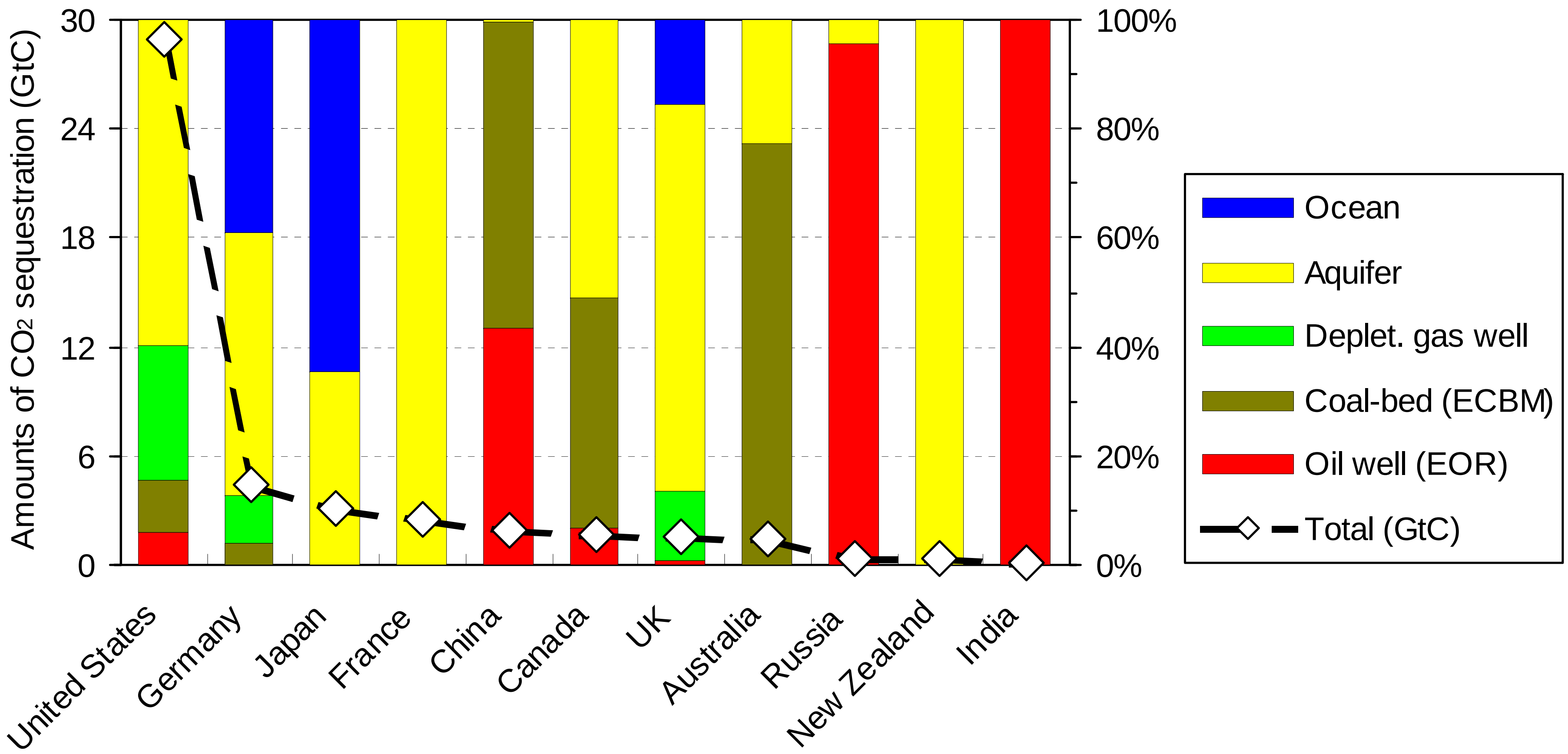
CO_2 Emission Reduction Effects of Technological Options

- CO_2 Concentration Stabilization Case (IPCC S550) - with Emission Trading



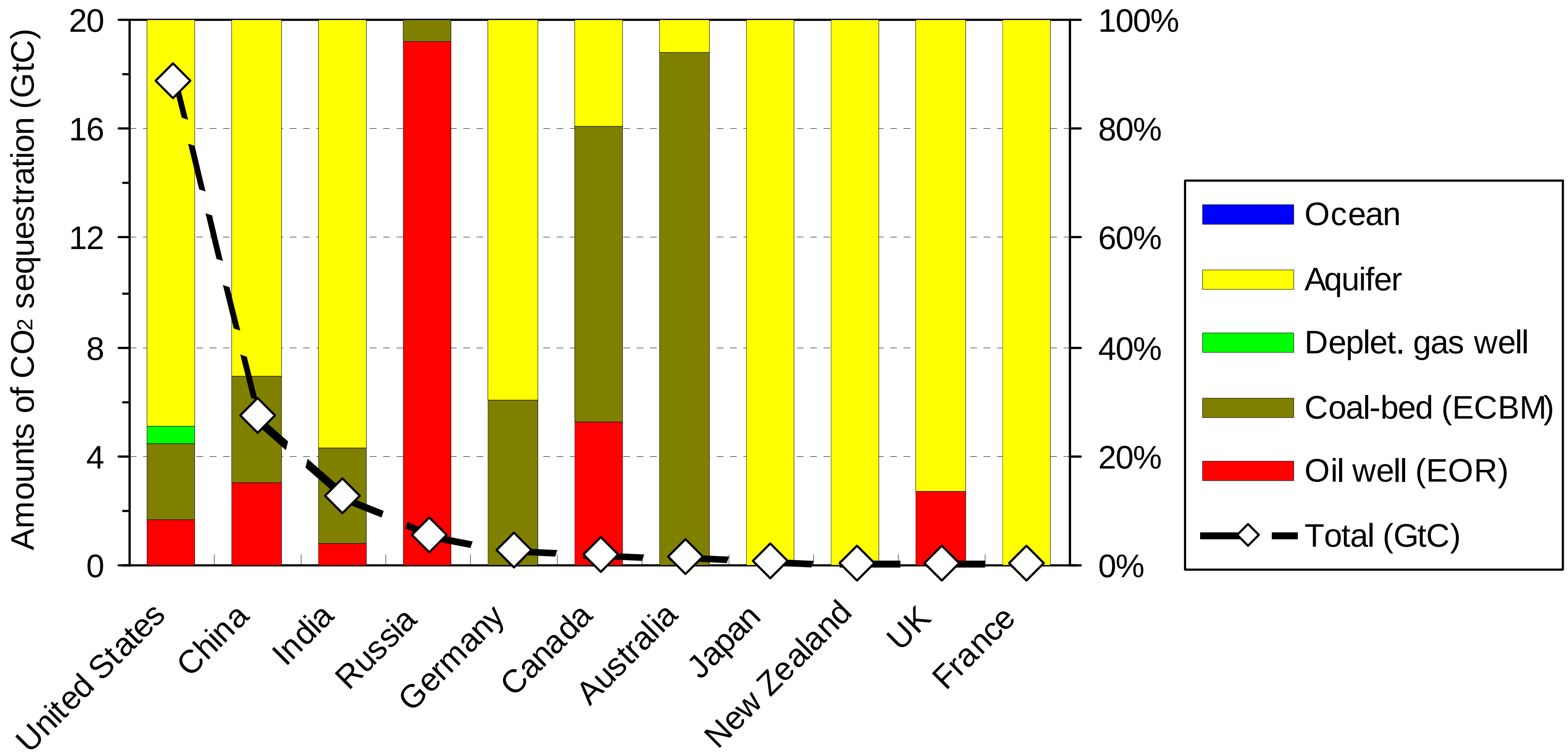
Cumulative CO_2 Sequestration between 2000 and 2050 by Region

- CO2 Concentration Stabilization Case (IPCC S550) - Burden share: KP+UK Proposal w.o. Emission Trading



Cumulative CO_2 Sequestration between 2000 and 2050 by Region

- CO2 Concentration Stabilization Case (IPCC S550) - with Emission Trading



Implications from the Analyses for CCS Deployment in the World

- The model analysis revealed the regional differences in use of the CO_2 sequestration technologies.
- As regional CO_2 sequestration perspectives under the assumed emission reduction scenario:
  - **The amount of the cumulative sequestration is large and all the four types of underground CO_2 sequestration technologies are utilized in US.**
  - **Sequestration into aquifer and coal-bed (ECBM) is important for Canada and Australia.**
  - **Sequestration into aquifer and ocean plays a major role in Japan.**
  - **EOR and/or ECBM play a major role in Russia and Non-Annex I countries such as China and India.**
- The opportunity for CO_2 geological storage also exists in the world, but the cost-effectiveness for regions will be sensitive to the flexible mechanism.