Role of Nuclear Fusion in Energy and Environment

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Socio-Economic Research progress from 1996-

① COE comparison among tokamak reactor (‘96-’97)

-- Nuclear Fusion **38**(1998)885-902

② Life cycle energy gain & CO_2 emission (‘97-’98)

-- Fusion Engineering and Design **48**(2000)483-498

③ Evaluation of NF in world energy&environment (‘99-’02)

-- Energy Policy **31**(2003)775-797

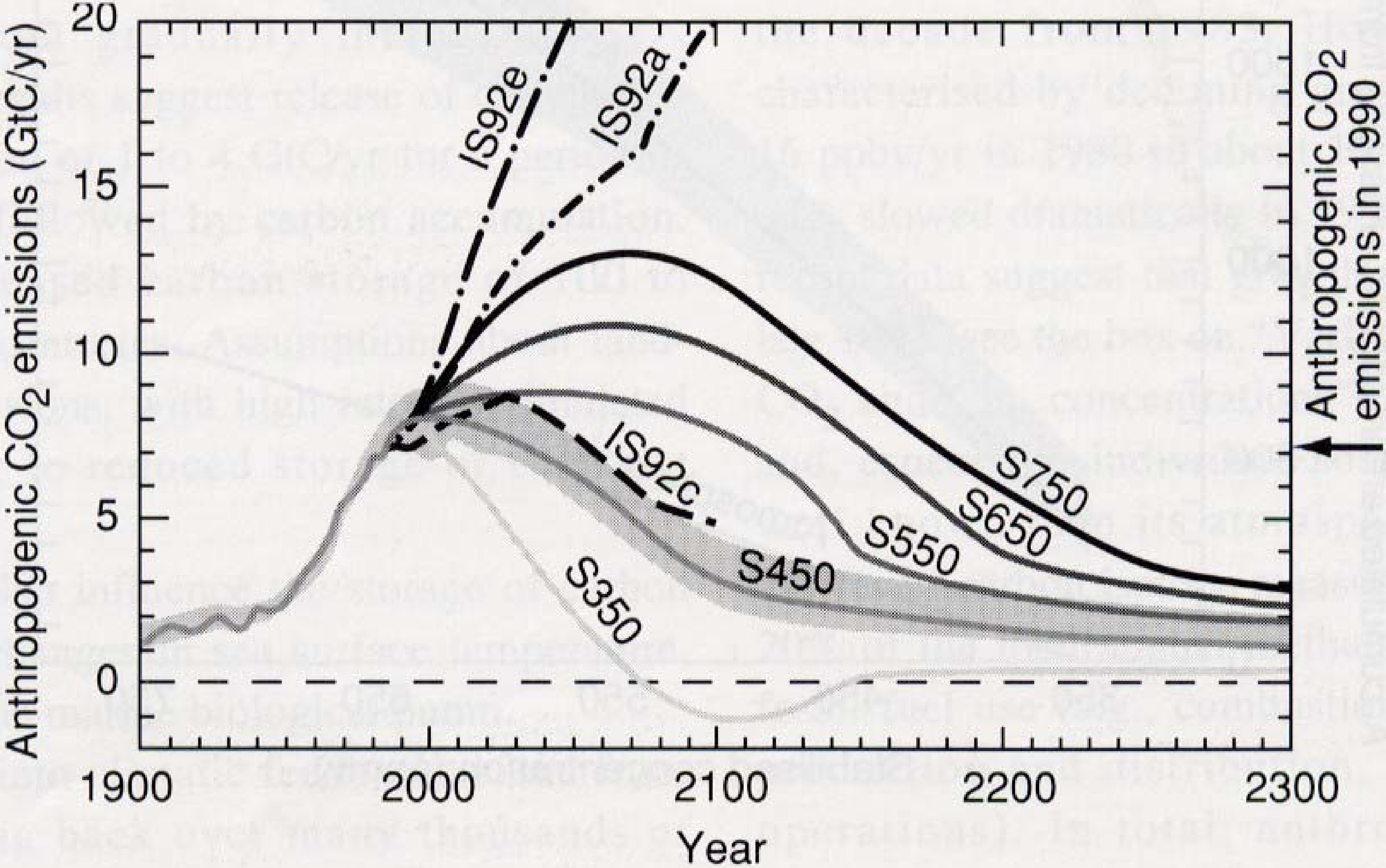
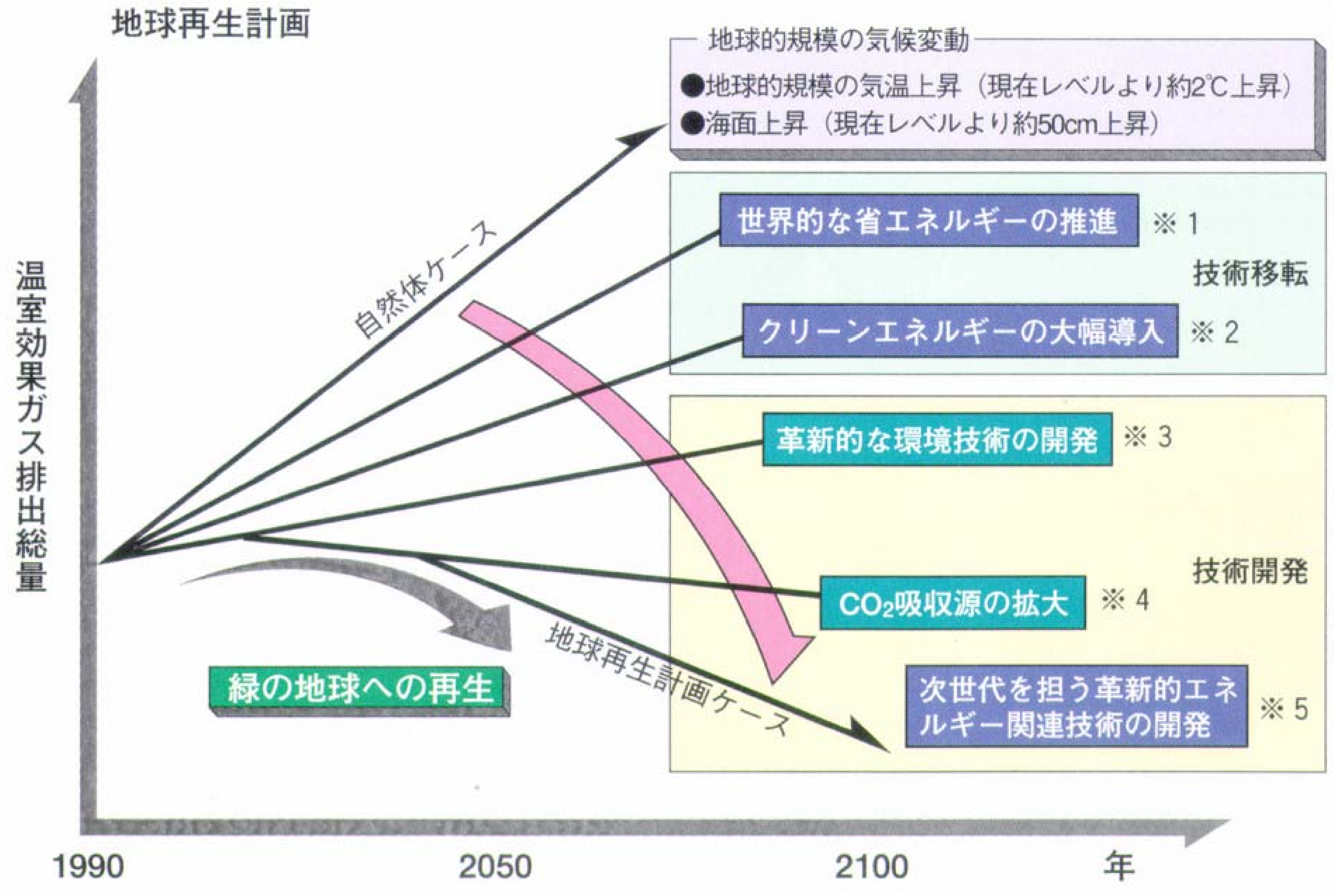

Anthropogenic CO2 emissions (GtC/yr)
20
15
10
5
0
1900
2000
2100
2200
2300
Year
IS92e
IS92a
IS92c
S750
S650
S550
S450
S350
Anthropogenic CO2 emissions in 1990

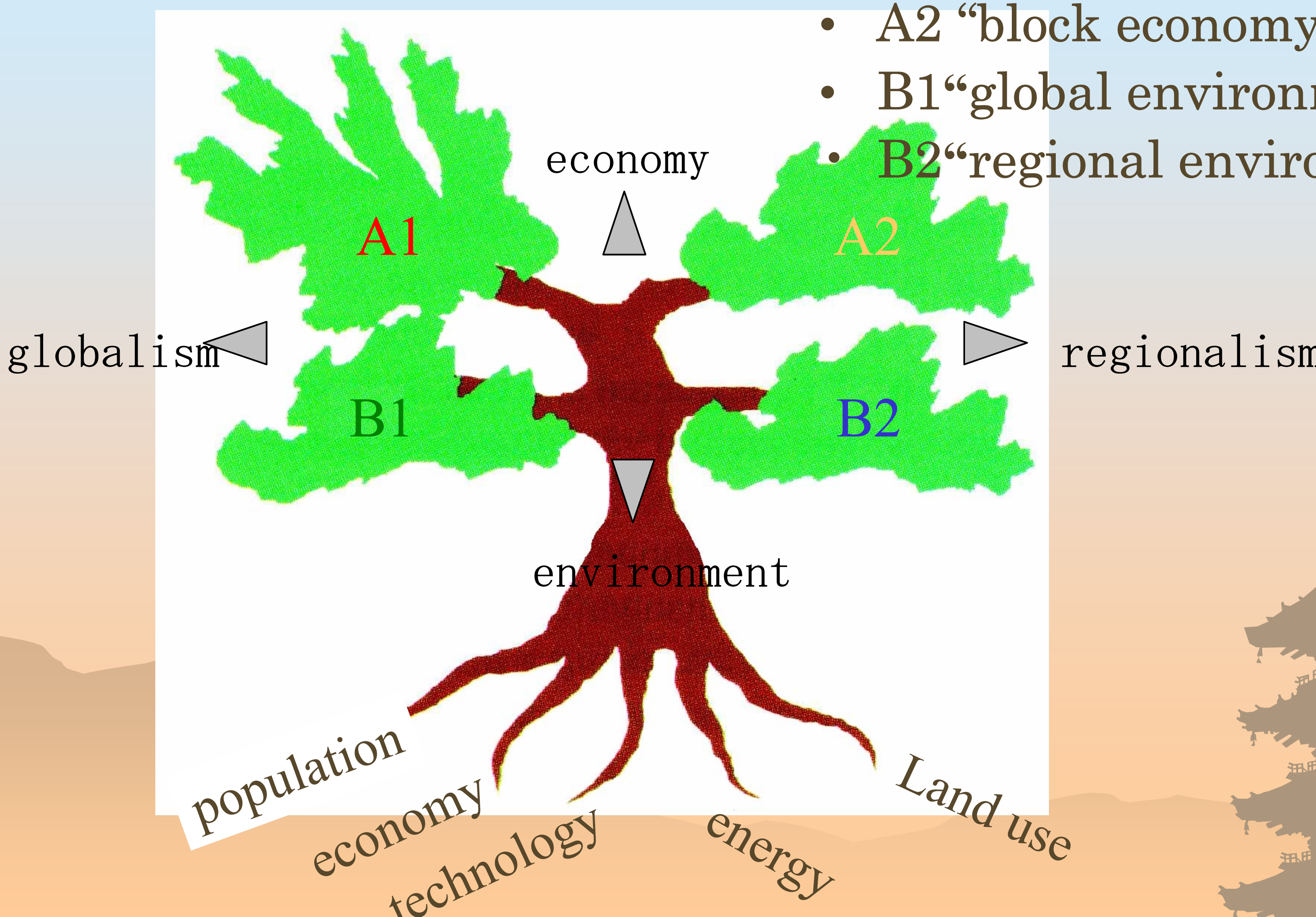
Image picture of “new earth plan”



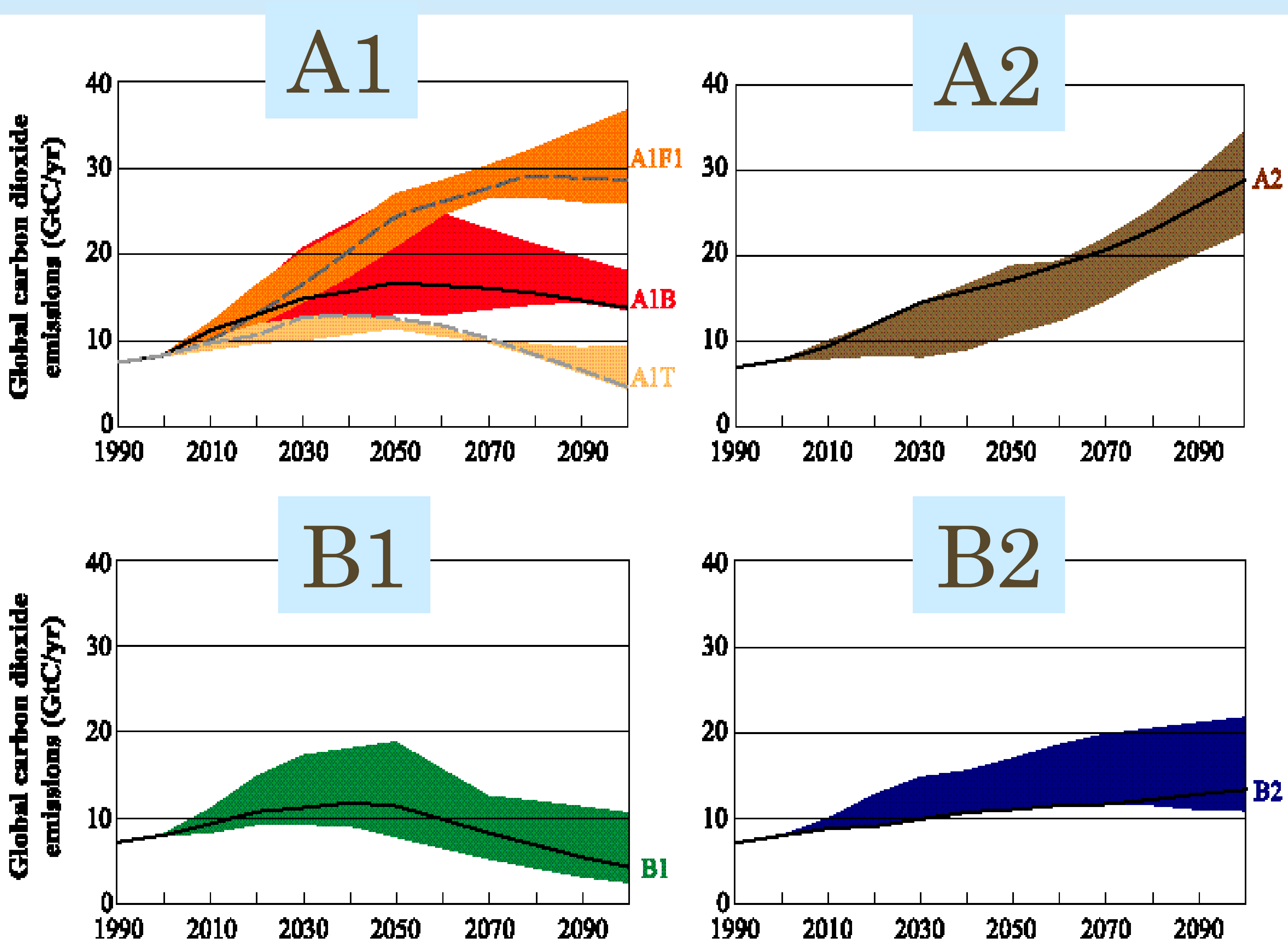
※1　総合的な省エネルギーの推進、フロンの廃止等
※2　太陽光発電・燃料電池など新・再生可能エネルギーの技術開発・導入、安全性確保に十分配慮した原子力の導入促進等
※3　CO_2固定化・有効利用技術開発、生分解性プラスチック、新世代冷媒開発、環境調和型生産プロセス技術開発、CO_2海洋隔離技術開発等
※4　植林・森林保全、砂漠緑化、海洋のCO_2固定能力の強化等
※5　宇宙太陽発電技術・核融合技術の開発等

IPCC SRES world

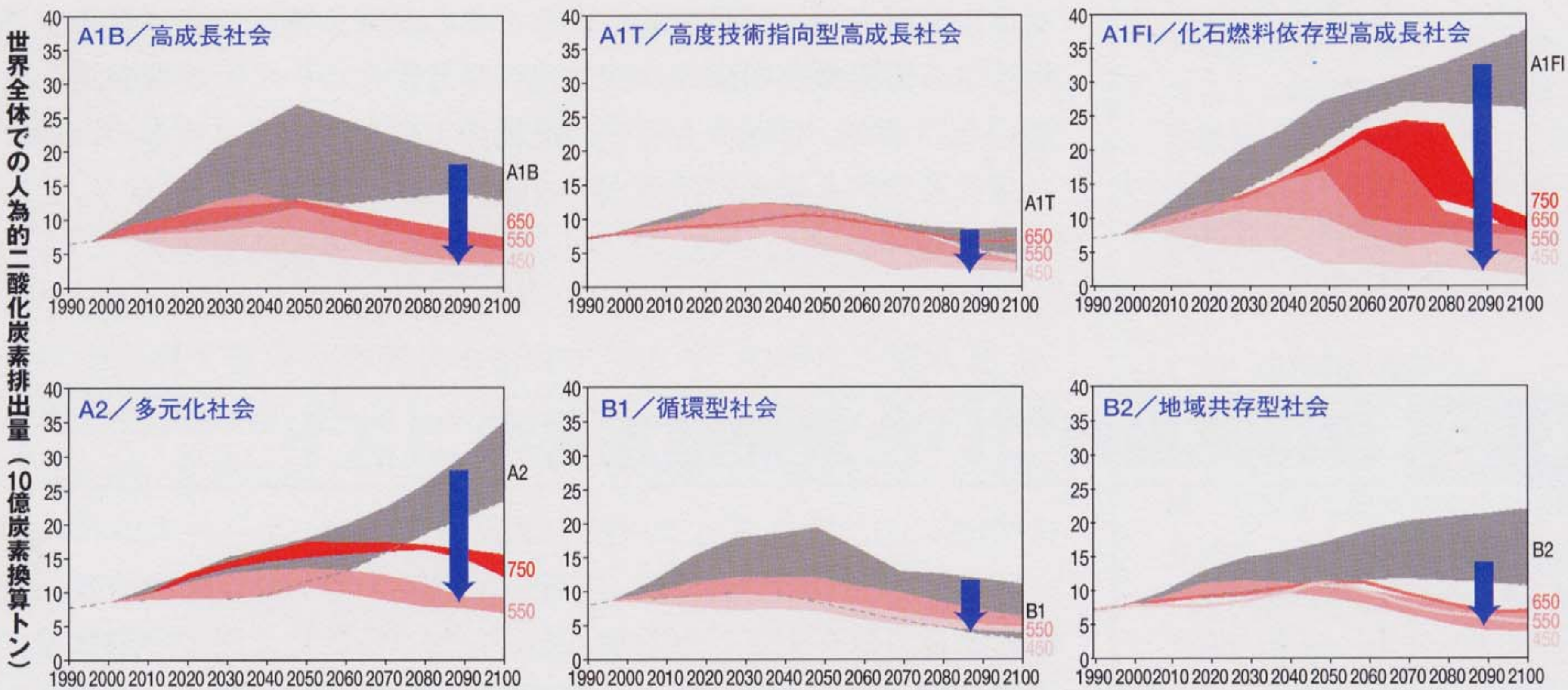
- A1 “global economy”
- A2 “block economy”
- B1“global environment”
- B2“regional environment”



CO_2 emissions scenarios (BAU)



Range of atmospheric CO_2 reductions from BAU to stabilization are very wide.



（各図の上の帯は対策なしの排出シナリオ、他の帯は大気中二酸化炭素濃度を450〜750ppmに安定化するための対策シナリオ、矢印は450〜550ppmに安定化するための排出削減量を示す。それぞれの帯は、9つのモデルによるシミュレーション結果の幅を示す）。

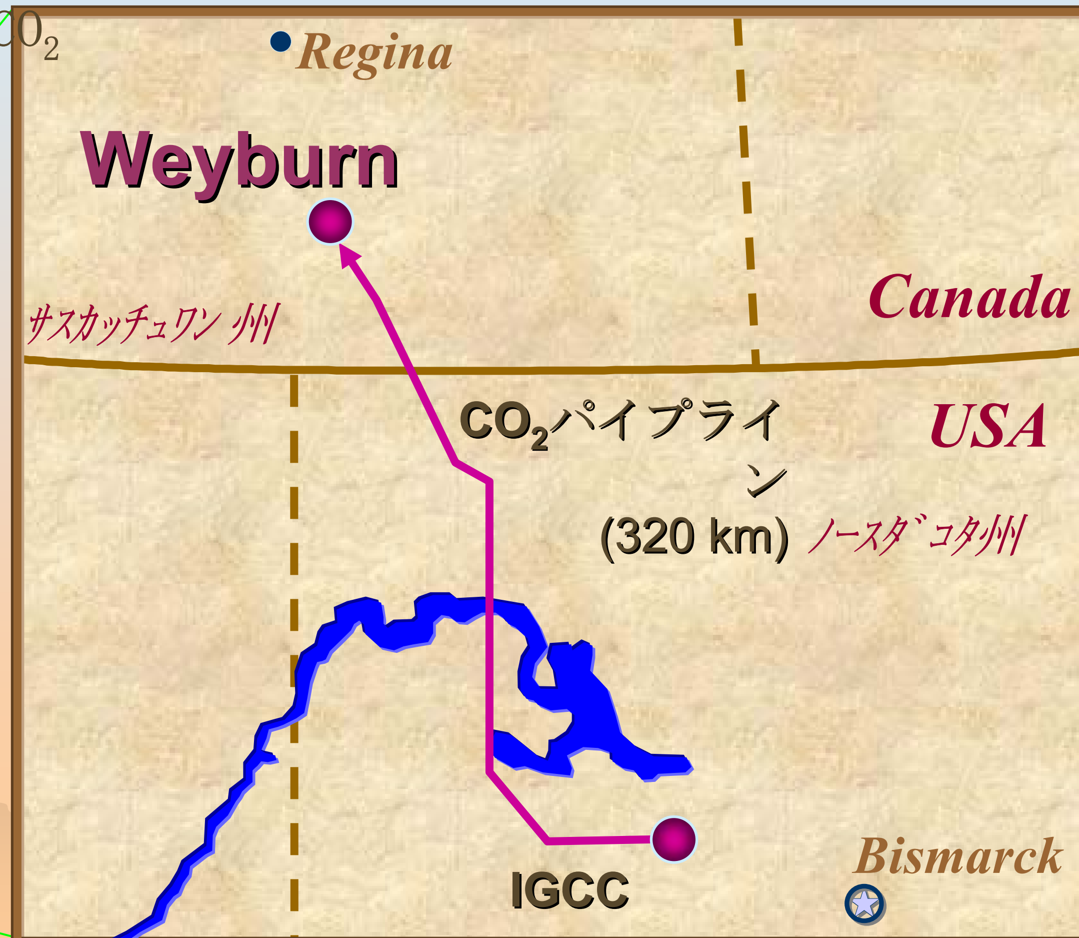
Technological Strategies for Atmospheric CO_2 reductions (1)

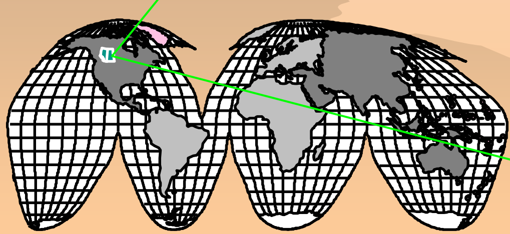
- Category
  - Improvement of present tech. (short term: 2010 ～2030: KP&after)
    - Already existing or close to realization/commercialization
    - Energy conservation and efficiency improvement (eg; fuel cell) etc.
    - Fuel switching (coal&oil to natural gas)
    - Promoting conventional renewables and nuclear (eg; generation IV)
  - Advanced, bridge tech. (intermediate term: 2030～2050)
    - Already or close to demonstration
    - High efficiency fossil-fired power (eg; IGCC, 1700℃ class gas turbine)
    - Carbon capture& storage/sequestration
    - Advanced nuclear (HTTR, PBMR, nuclear fuel cycle and FBR) & biomass
  - Innovative tech. (long term: 2050 ～)
    - Undemonstrated, Experimental level
    - Nuclear Fusion, Space Power Satellite (SPS), geo-engineering

IEA Weyburn CO_2 Monitoring Project

- 1954年に発見された油田。
- 広さ：　約180 km^2

- EORのためにCO_2を供給。
- 5,000 t-CO_2/日、20年間、総計2,000万 t-CO_2





Characteristics of innovative (& some of advance) techs.

Nuclear fuel cycle, FBR, SPS, geo-engineering, and NF are somewhat similar in the sense that:

(i) they have been expected "dreaming" technologies in public,
(ii) their devices and operating systems are relatively large or huge,
(iii) physics/engineering/manufacturing barriers are relatively high enough to spend long time to demonstrate their technological feasibility
(iv) economic competitiveness had not obtained at present
(v) side effects are assumed afraid on the use of the technologies.

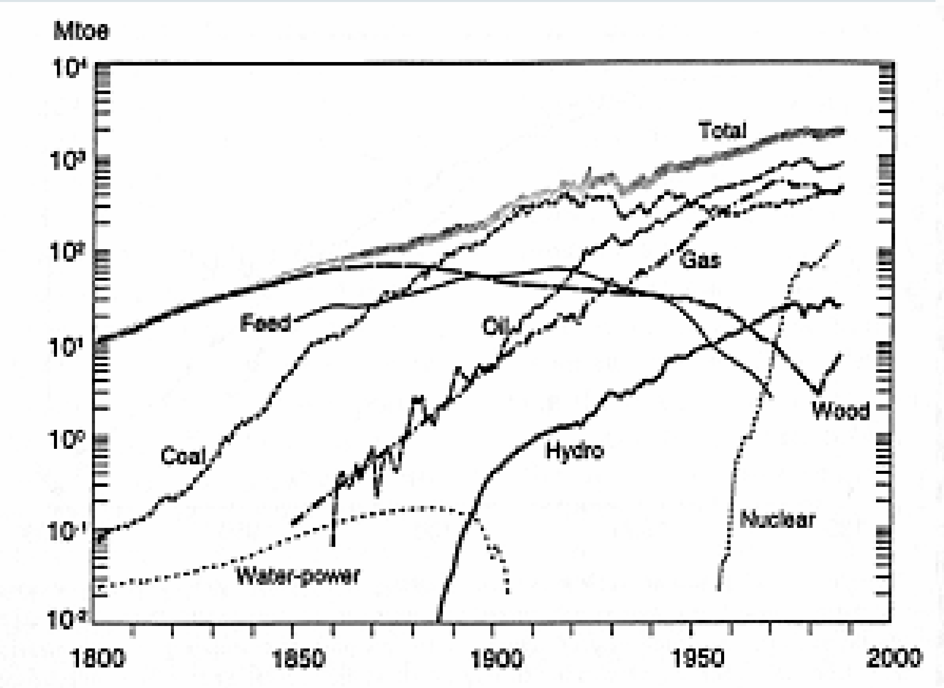
Technological Strategies for Atmospheric CO_2 reductions (2)

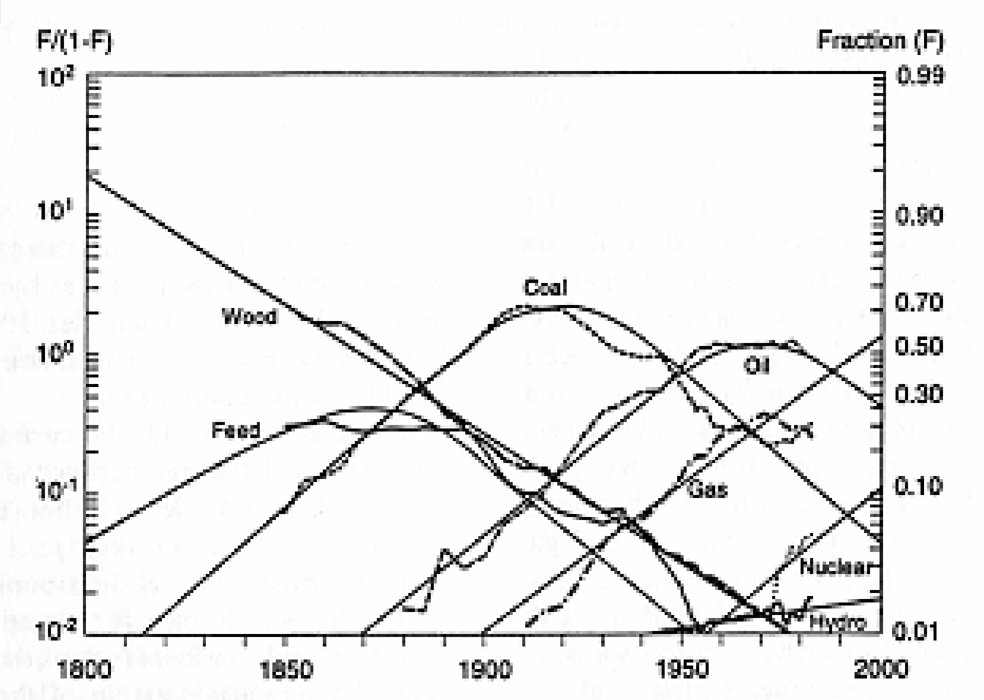
- Example of Japanese automobile industry in 1970s
  - 1970-1975: Severe regulation of NOx emission
  - Start with improvement of engines (Honda CVCC)
  - Few years after: installation of new catalysts in exaust pipe
  - Present: GDI / Hybrid car / Fuel Cell Vehicle / Electro Vehicle
- Lessons read from the experience
  - Path to core innovation seems “the best” (eg; FCV, EV) , however, long-term expenditure is required.
  - Moreover, “the best technologies” are not always win market competition because of the cost of the technologies and social infrastructure (supply chain, distribution of the fuel or energy).
  - End of pipe, GDI, and Hybrid car seems “second best” but have advantage in compatibility with existing fossil fuel infrastructure, and is realistic in the short / medium term (relatively easy,low cost)

Technological Strategies for Atmospheric CO_2 reductions (3)

- Inertia in energy system changes
  – Plant Vintage (replacement)
  – Supporting Industrial technologies
  – Infrastructure (supply chain, distribution)
- Introduction step of the technologies
  – From “easy, early & cheap” to “difficult, late & costly” +*regret*
  – Improve present tech. → bridge tech. → innovative tech.
  – step of “fossil fuel → renewable/nuclear → innovative” is natural.

Historical trends shows us existence of inertia in energy systems' change





- Andrii Gritsevskyi, Nebojsa Nakicenovic, "Modeling uncertainty of induced technological change", *Energy Policy* 28(2000)907-921

To obtain social support, expected benefit for taxpayer should be explained

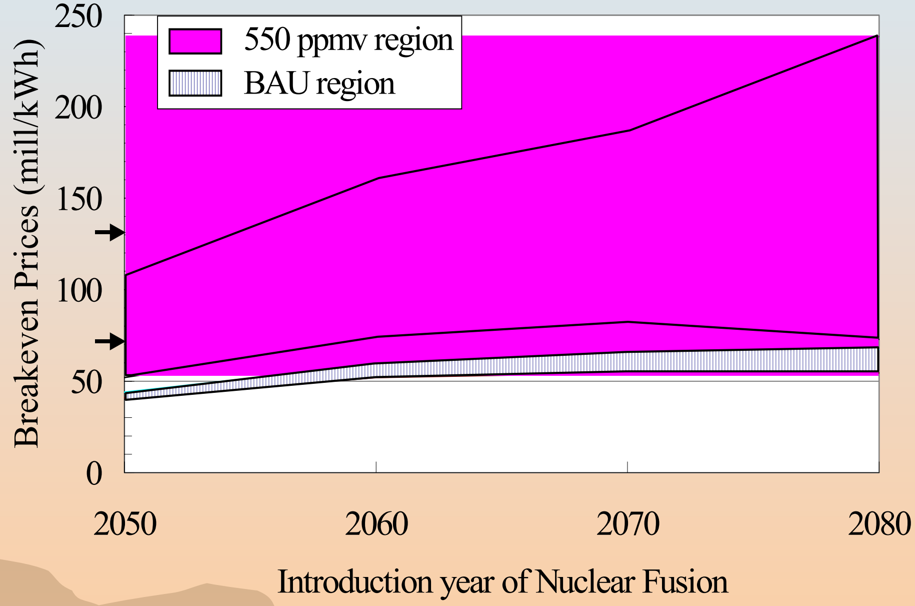
- Even though the innovative technologies are “backstop”, prospect from when and how much should be explained.
- Benefit that taxpayer can directory feel …
  - Economy
  - Convenience
  - Safety
  - Environmental compatibility

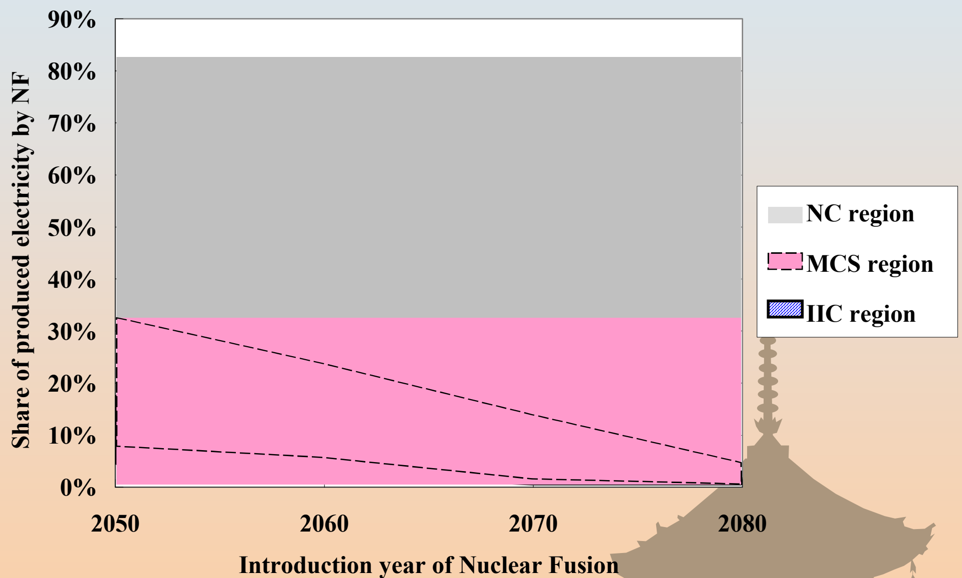
  etc.
- The benefit felt is larger and earlier the better.

To introduce earlier and to obtain larger share in energy system …

- Early demonstration, realization, and introduction
- Global energy modeling tells us
  - Economic competition (COE, capital/operation cost)
  - CO_2 regulation
  - Introduction year
  - Annual supply potential
  - Penetration speed in market (Breeding ratio)
  - Total supply potential
  - Usage (solid, liquid, gas, electricity)

  etc.





- K.Tokimatsu et al., "Role of nuclear fusion in future energy systems and the environment under future uncertainties", *Energy Policy* **31**(2003) 775-797

From view point from life cycle analysis …

- Can Nuclear Fusion have advantages to NFC/FBR and SPS ?
  - Expectation for simple front-end/back-end in supply chain (compared with peak point of power core complexity)
- My expectation in fusion systems study
  - From not only power reactor study
  - To supply chain system study (front end to back end)

Summary

- Continuous CO_2 reductions (till 2100 and more) are required with meeting energy demand.
- Strategic technological mixture have been investigated for CO_2 reductions from energy systems
- Lessons read from Japanese automobile industry
  - Path to core innovation seems “the best”, however, long-term expenditure in time and cost is required.
  - Moreover, “the best technologies” are not always win market competition because of the cost of the technologies and social infrastructure (supply chain, distribution of the fuel or energy).
- “fossil fuel → renewable/nuclear → innovative” step
- The benefit for taxpayer is larger and earlier the better.Early demonstration, realization, and introduction are desired.
- Simple front-end/back-end in energy supply chain seems strong point of nuclear fusion.