

Expectation to Nuclear Transmutation

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- 1 The demand for primary energy and electricity is increasing year by year.
- 2 The global warming is becoming a more serious problem.
- 3 The development of renewable energy has to be promoted. However, it will require sufficient resources of time and budget.
- 4 Human beings cannot help depending on nuclear energy as well as other energy resources which do not emit CO₂.

5 Nuclear technology must be developed

5-1 The safety technology of nuclear energy has to be developed for the future.

5-2 The technology for the back-end of the nuclear fuel cycle has to be enhanced. The site for final disposal of nuclear wastes has to be determined as soon as possible in Japan, which is a responsibility of the Central Government.

- 5-3 The research and development of innovative technologies, such as Accelerator Driven Systems, have to be promoted in order to encourage the progress of final disposal.
- 5-4 The research and development of nuclear technologies for reactor decommissioning, safety technology, back-end, etc., have to be promoted intensively through international cooperation.

1. The demand for primary energy and electricity is increasing year by year.

Explosion of world population

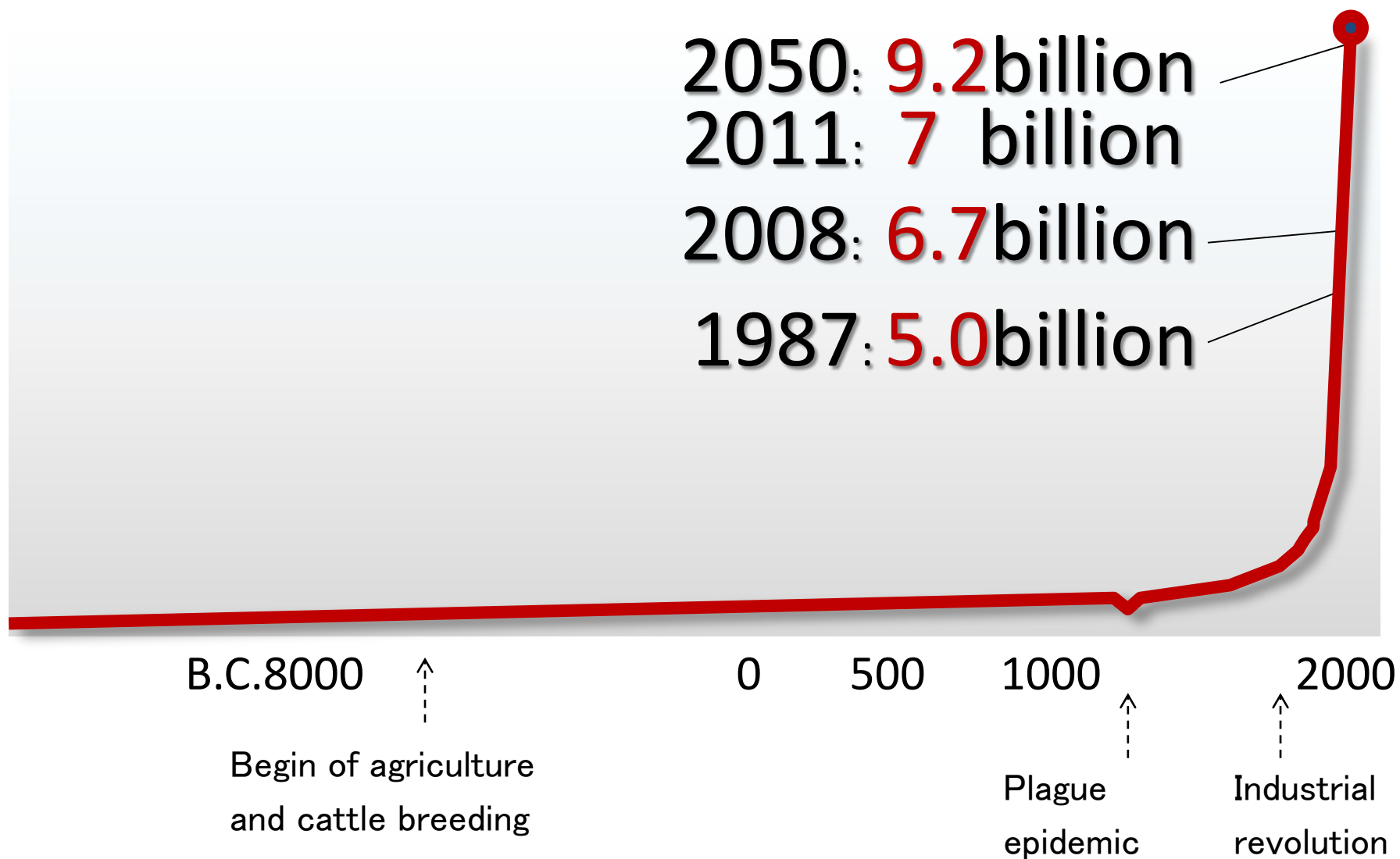
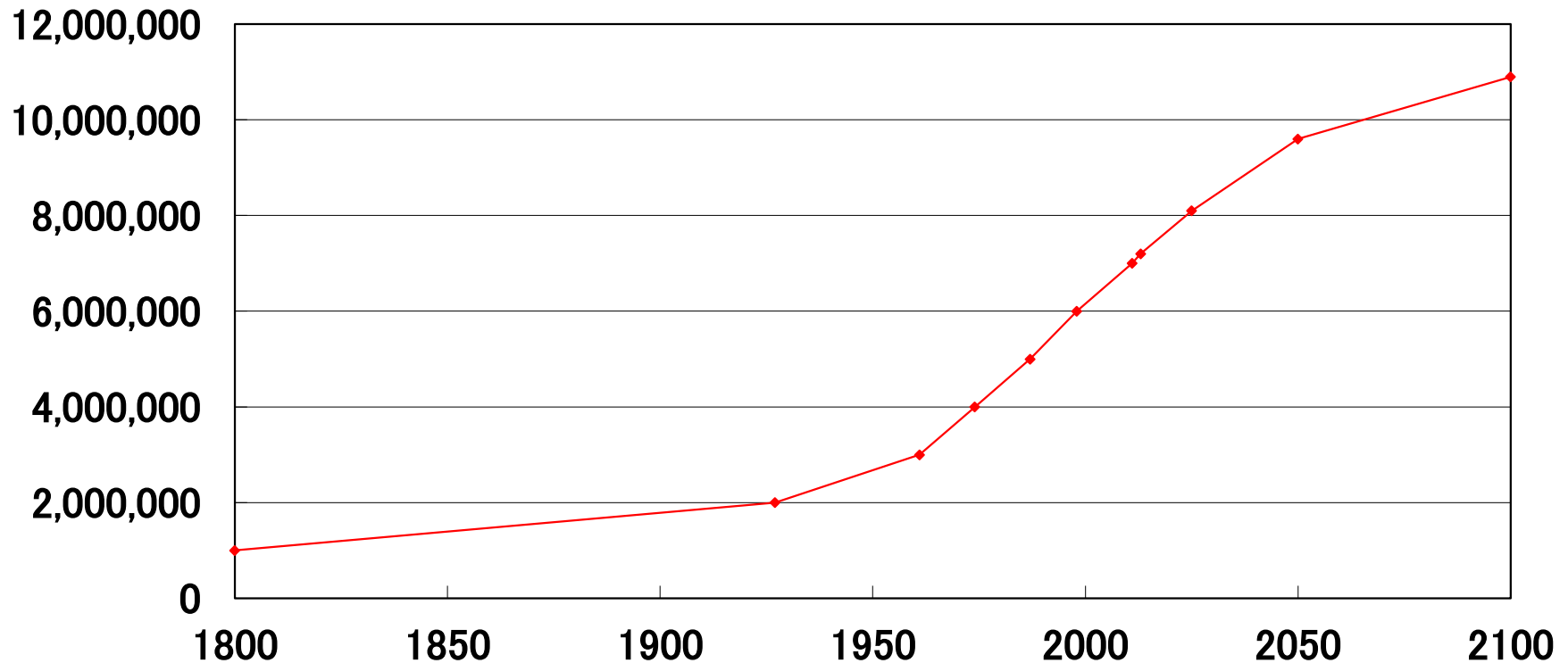


Fig.1 Estimation of World Population(medium variant)

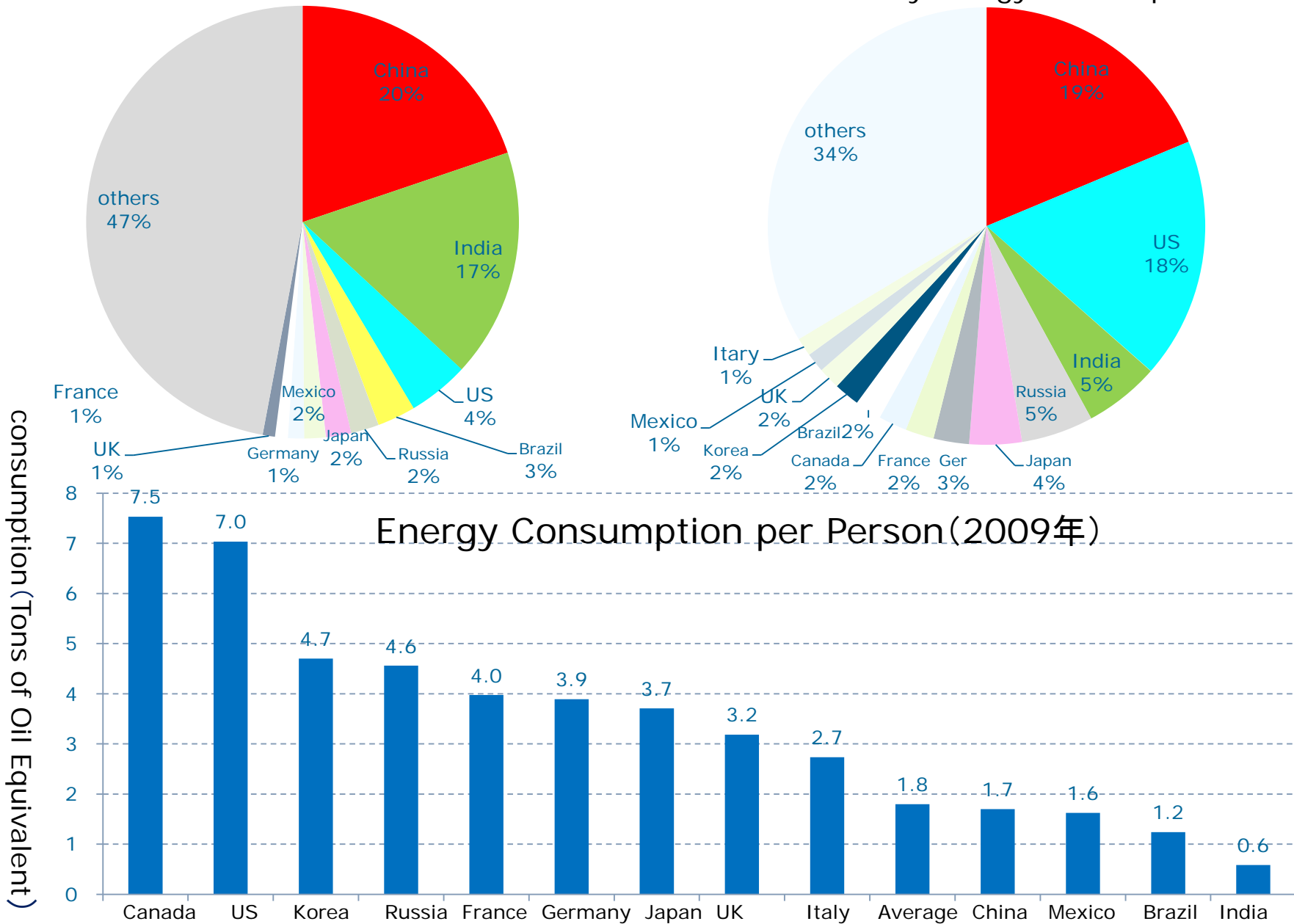


Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat World Population Prospects: The 2010 Revision,
<http://esa.un.org/unpd/wpp/index.htm>

Regional Population and Energy Consumption per Person

world population(2009年)

World Primary Energy Consumption(2009年)



A simple arithmetic tells us that the total demand for primary energy in near future will be 3,2 more than the present consumption.

$$\frac{10\text{billion}}{7\text{billion}} \times \frac{4\text{tonsoe}}{1,8\text{tonsoe}} = 3,2$$

Table 2.3 ▶ World primary energy demand by region in the New Policies Scenario (Mtoe)

	1990	2000	2010	2015	2020	2030	2035	2010-35*
OECD	4 521	5 292	5 404	5 465	5 530	5 553	5 579	0.1%
Americas	2 260	2 695	2 677	2 751	2 792	2 795	2 806	0.2%
United States	1 915	2 270	2 214	2 246	2 260	2 206	2 187	0.0%
Europe	1 630	1 765	1 837	1 817	1 829	1 835	1 847	0.0%
Asia Oceania	631	832	890	897	909	923	927	0.2%
Japan	439	519	497	472	465	450	447	-0.4%
Non-OECD	4 058	4 536	6 972	8 158	9 001	10 424	11 147	1.9%
E. Europe/Eurasia	2 617	999	1 137	1 209	1 250	1 349	1 407	0.9%
Russia	880	620	710	750	774	837	875	0.8%
Asia	1 589	2 248	3 936	4 808	5 400	6 351	6 839	2.2%
China	881	1 196	2 416	3 020	3 359	3 742	3 872	1.9%
India	317	457	691	837	974	1 300	1 516	3.2%
Middle East	210	365	624	715	792	935	1 012	1.9%
Iraq	21	28	38	77	113	145	160	5.9%
Africa	388	496	690	750	819	932	984	1.4%
Latin America	331	429	586	675	740	856	905	1.8%
Brazil	138	184	262	309	346	413	444	2.1%
World**	8 779	10 097	12 730	13 989	14 922	16 417	17 197	1.2%
European Union	1 633	1 683	1 713	1 681	1 678	1 667	1 670	-0.1%

*Compound average annual growth rate. ** Includes bunkers.

The demand in countries other than OECD in 2035 will be 1.6 times more than in 2010. The demand for primary energy in the world in 2035 will be 1.35 times more than in 2010. We should be careful that this increase of 35% will occur only in 25 years from now.

$$\frac{11347Mtoe}{6972Mtoe}=1,6$$

If this increase continues linearly for the next 100 years, we find a 140% increase, namely altogether 2.4 times more than the present consumption.

According to IEA, the demand for electricity in the world in 2035 will be 1.73 times more than in 2011, which is an increase two times as fast as that for the primary energy. See the second table.

$$\frac{31859Twh}{18443Twh}=1,73$$

Table 6.1 ► Electricity demand* by region and scenario (TWh)

			New Policies		Current Policies		450 Scenario	
	1990	2010	2035	CAAGR 2010-35	2035	CAAGR 2010-35	2035	CAAGR 2010-35
OECD	6 592	9 618	11 956	0.9%	12 635	1.1%	11 013	0.5%
Americas	3 255	4 659	5 939	1.0%	6 133	1.1%	5 442	0.6%
United States	2 713	3 893	4 769	0.8%	4 892	0.9%	4 374	0.5%
Europe	2 321	3 232	3 938	0.8%	4 247	1.1%	3 676	0.5%
Asia Oceania	1 016	1 727	2 078	0.7%	2 255	1.1%	1 895	0.4%
Japan	758	1 017	1 095	0.3%	1 201	0.7%	976	-0.2%
Non-OECD	3 494	8 825	19 903	3.3%	22 254	3.8%	16 931	2.6%
E. Europe/Eurasia	1 585	1 350	1 978	1.5%	2 214	2.0%	1 754	1.1%
Russia	909	834	1 234	1.6%	1 405	2.1%	1 092	1.1%
Asia	1 049	5 352	13 705	3.8%	15 431	4.3%	11 438	3.1%
China	558	3 668	8 810	3.6%	10 149	4.2%	7 167	2.7%
India	212	693	2 463	5.2%	2 617	5.5%	2 096	4.5%
Middle East	190	680	1 466	3.1%	1 609	3.5%	1 260	2.5%
Africa	262	569	1 195	3.0%	1 289	3.3%	1 077	2.6%
Latin America	407	875	1 559	2.3%	1 711	2.7%	1 401	1.9%
Brazil	214	451	824	2.4%	904	2.8%	744	2.0%
World	10 086	18 443	31 859	2.2%	34 889	2.6%	27 944	1.7%
European Union	2 227	2 907	3 415	0.6%	3 694	1.0%	3 220	0.4%

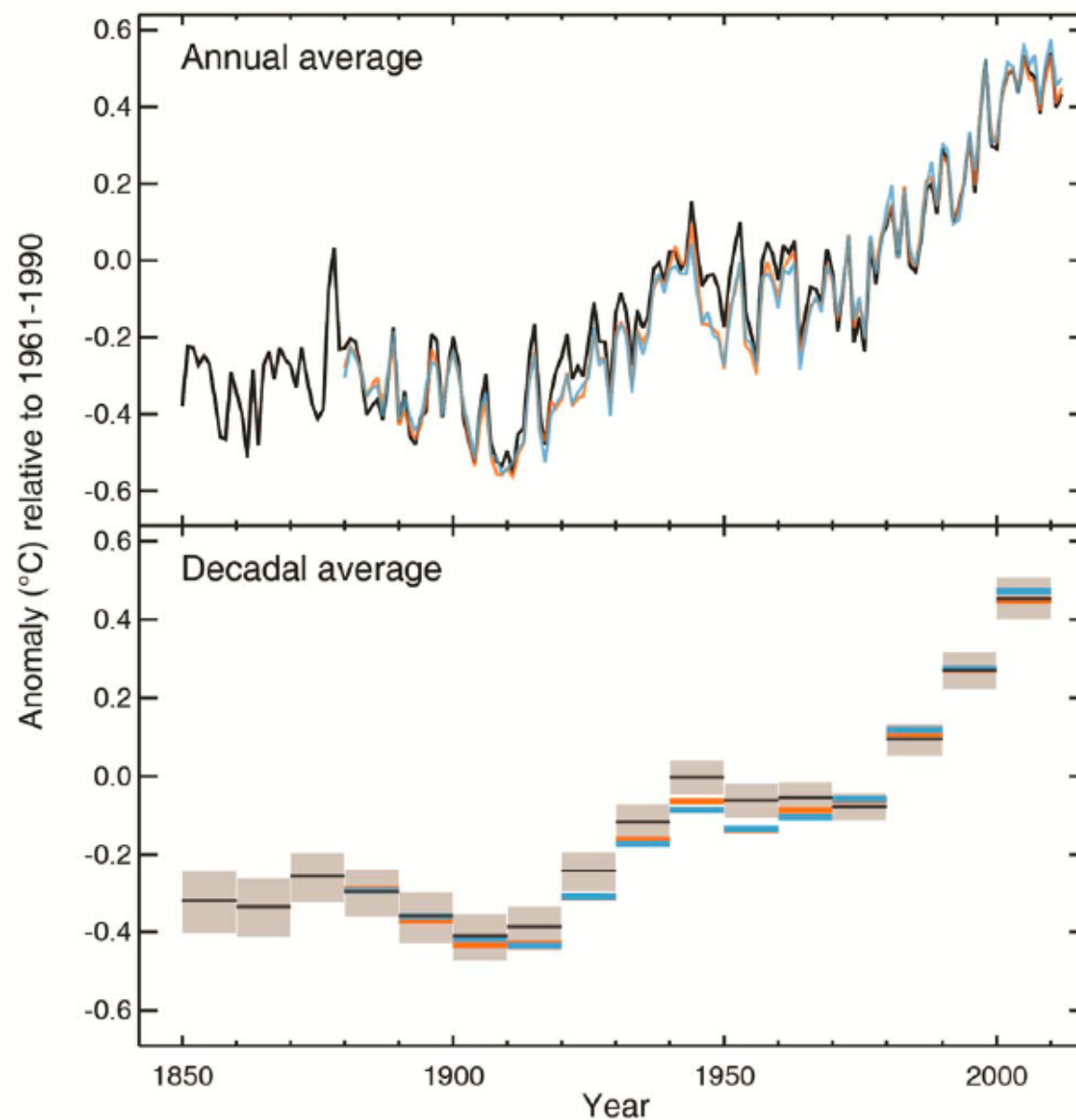
2 The global warming is becoming a more serious problem

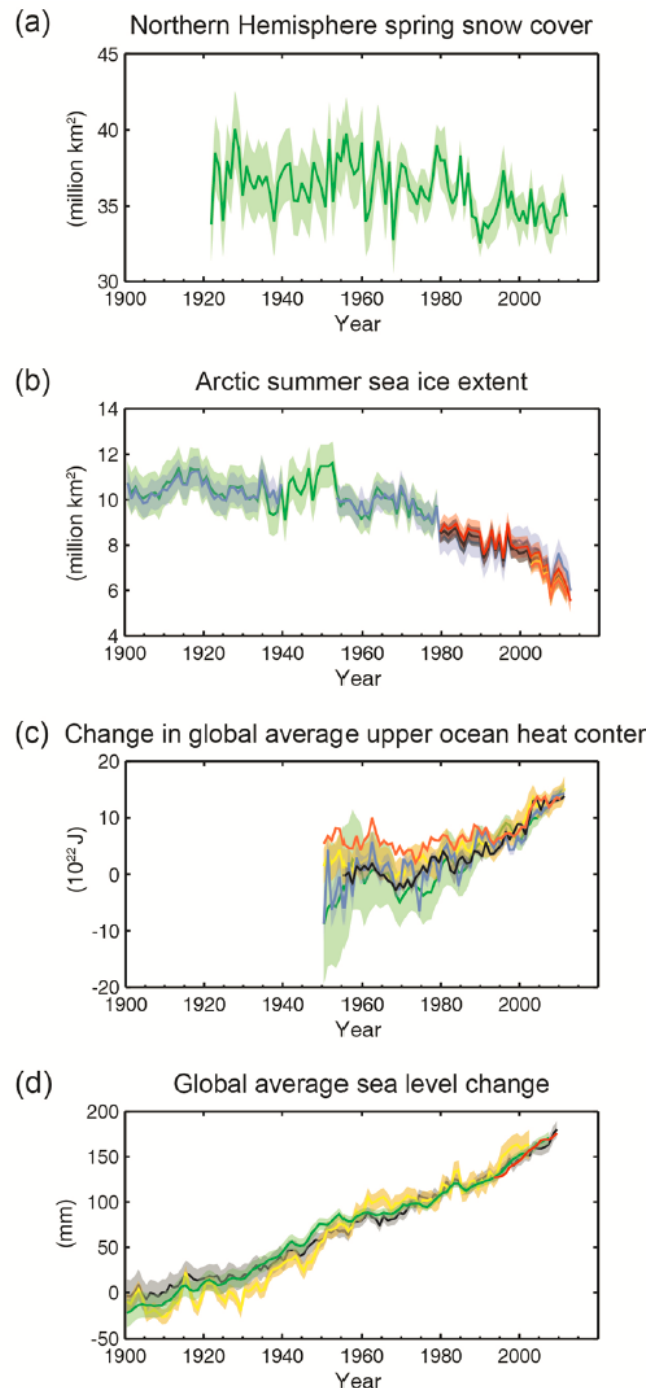
According to the Working group I Contribution to top the IPCC Fifth Assessment Report Climate Change 2013.

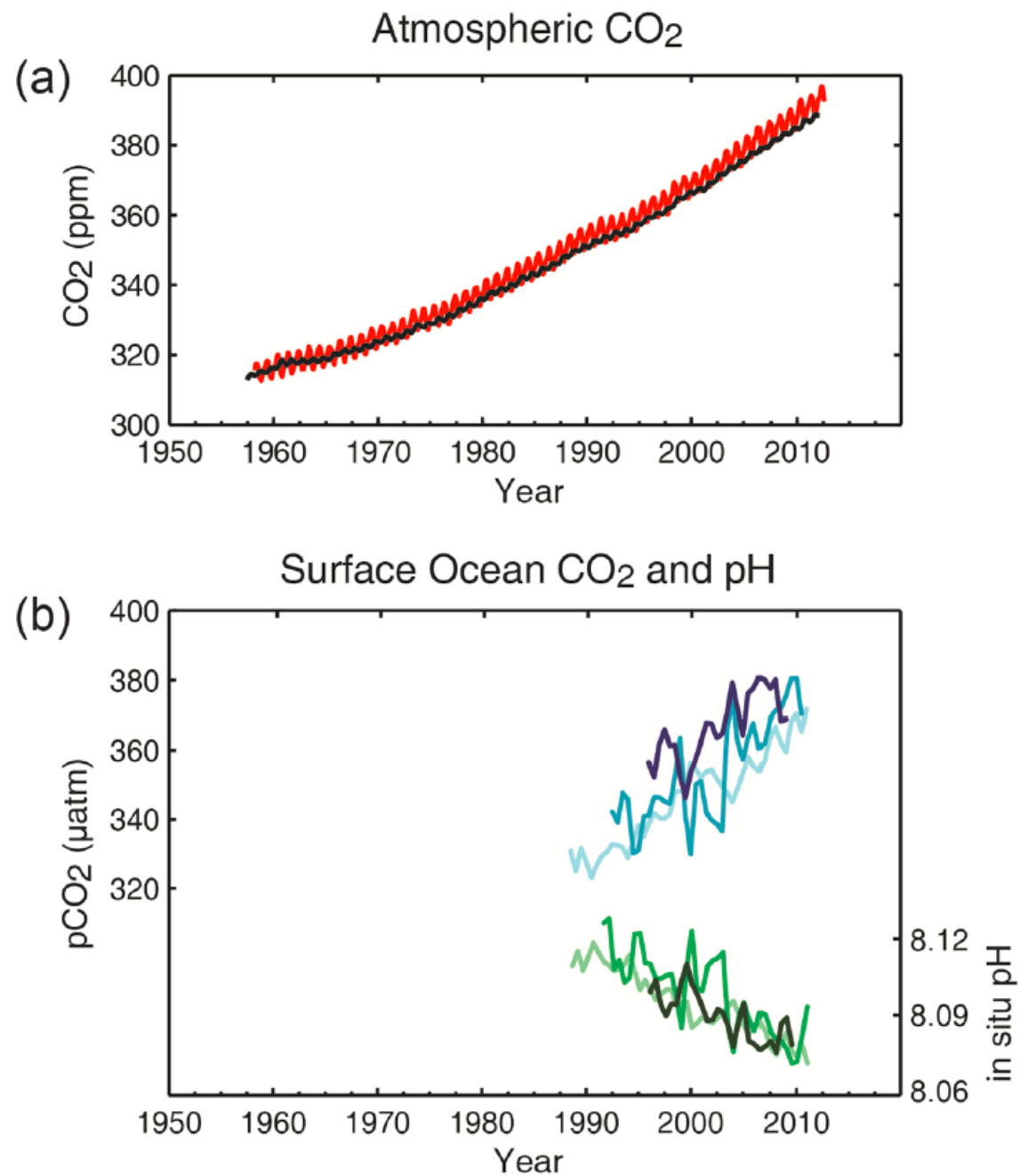
Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level have risen, and the concentrations of greenhouse gases have increased.

Figure SPM.1 [FIGURE SUBJECT TO FINAL COPYEDIT]

(a) Observed globally averaged combined land and ocean surface temperature anomaly 1850–2012



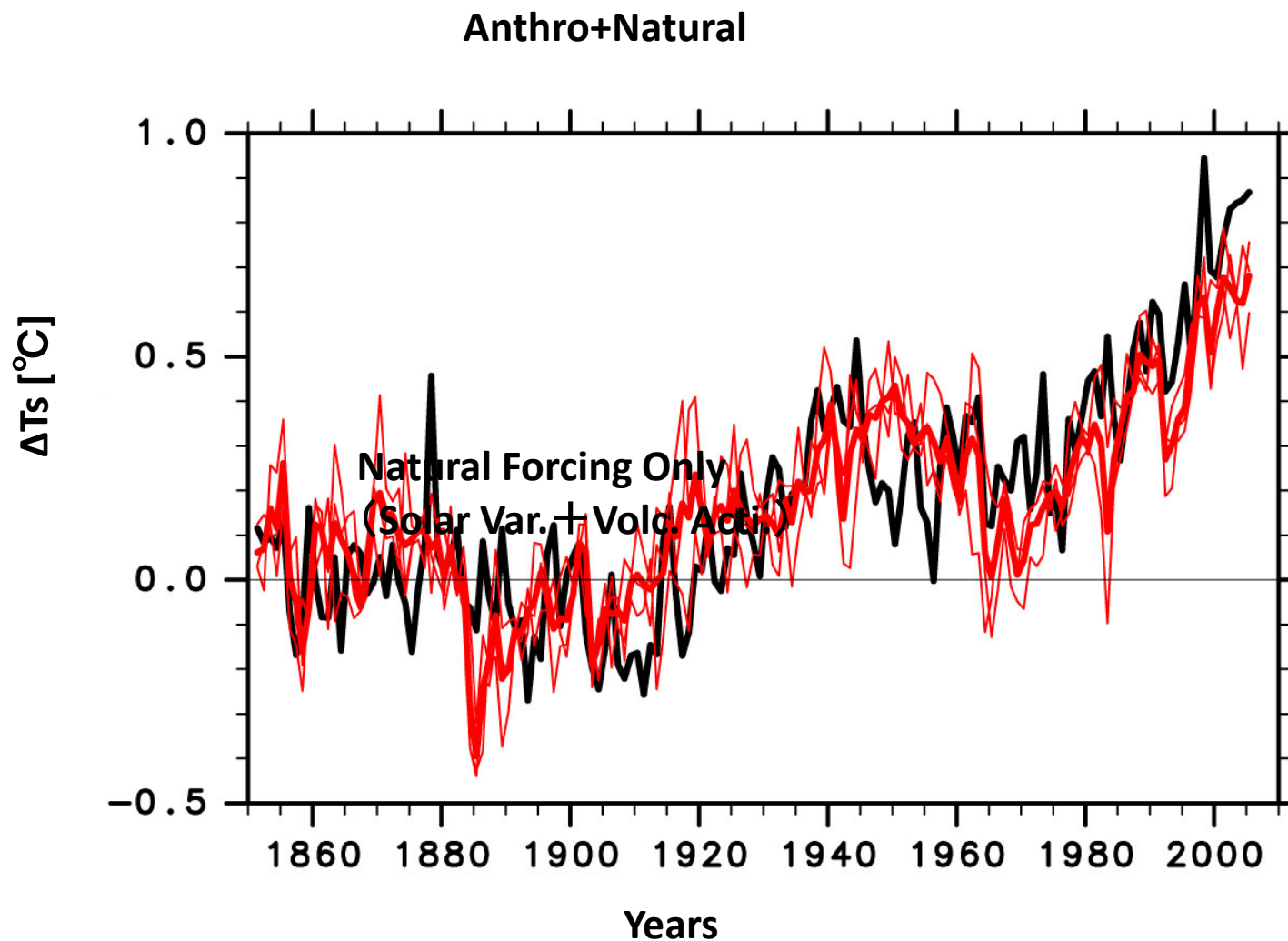


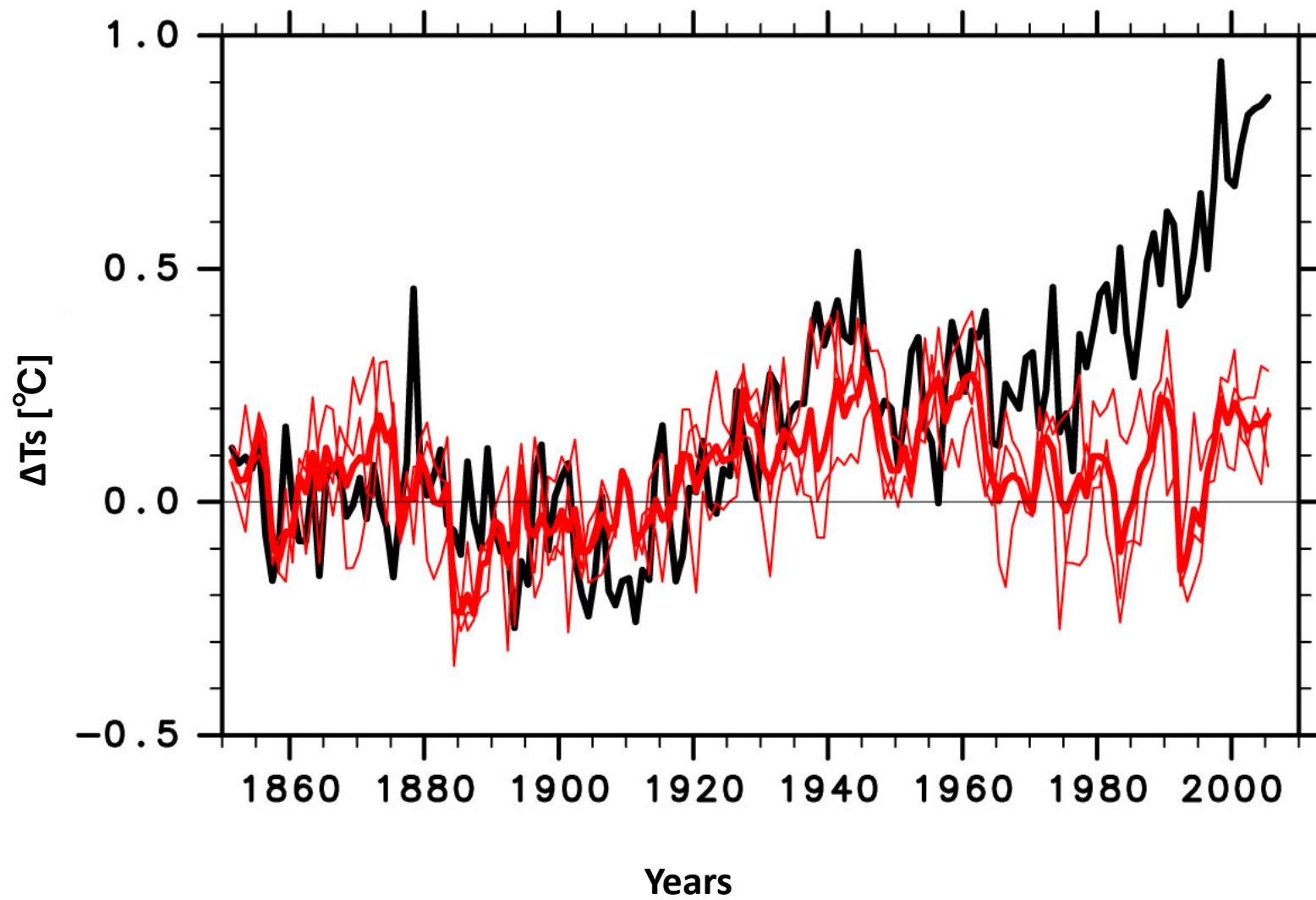


Professor Akimasa Sumi and his collaborators have carried out computer simulations using climate models for many years.

According to their results, it seems very very clear that the anthropological emission of greenhouse gases (mainly CO₂) is a main contributor to the global warming.

20Century Climate Change Simulation by MIROC-Earth System Model



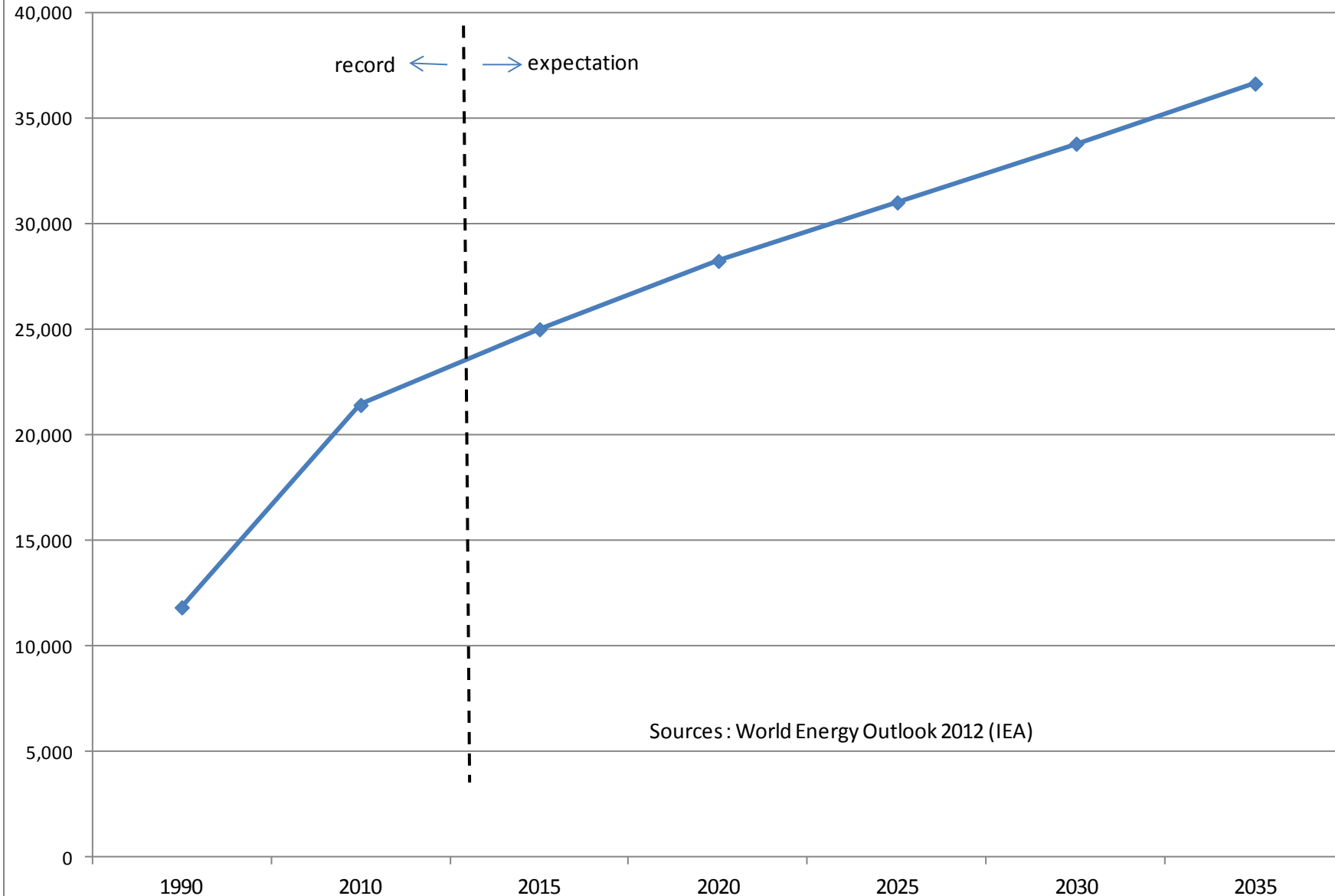


3 The development of renewable energy has to be promoted.

However, it will require sufficient resources of time and budget.

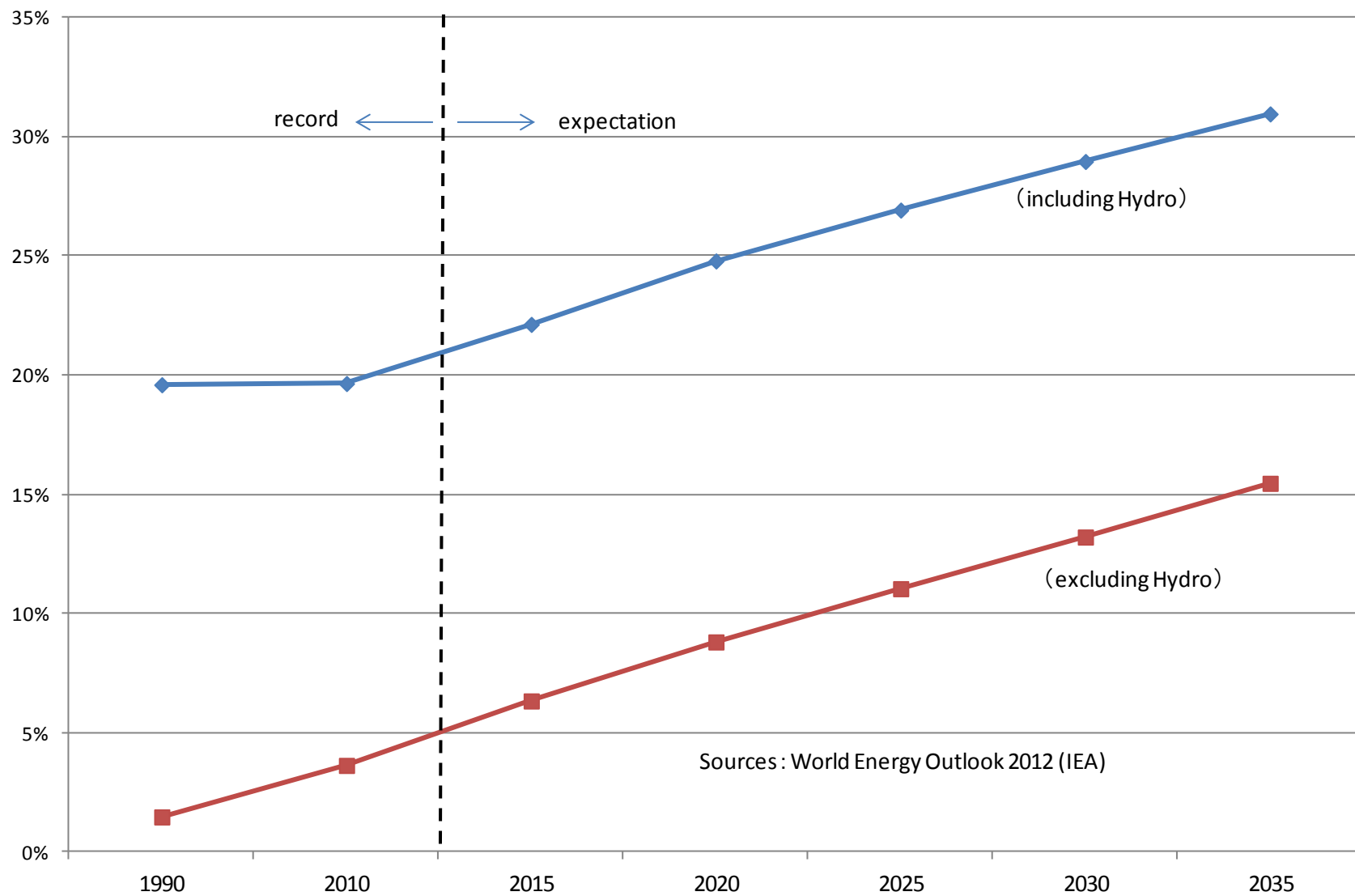
World electricity production

× TWh



Sources : World Energy Outlook 2012 (IEA)

Share of renewables in world electricity production

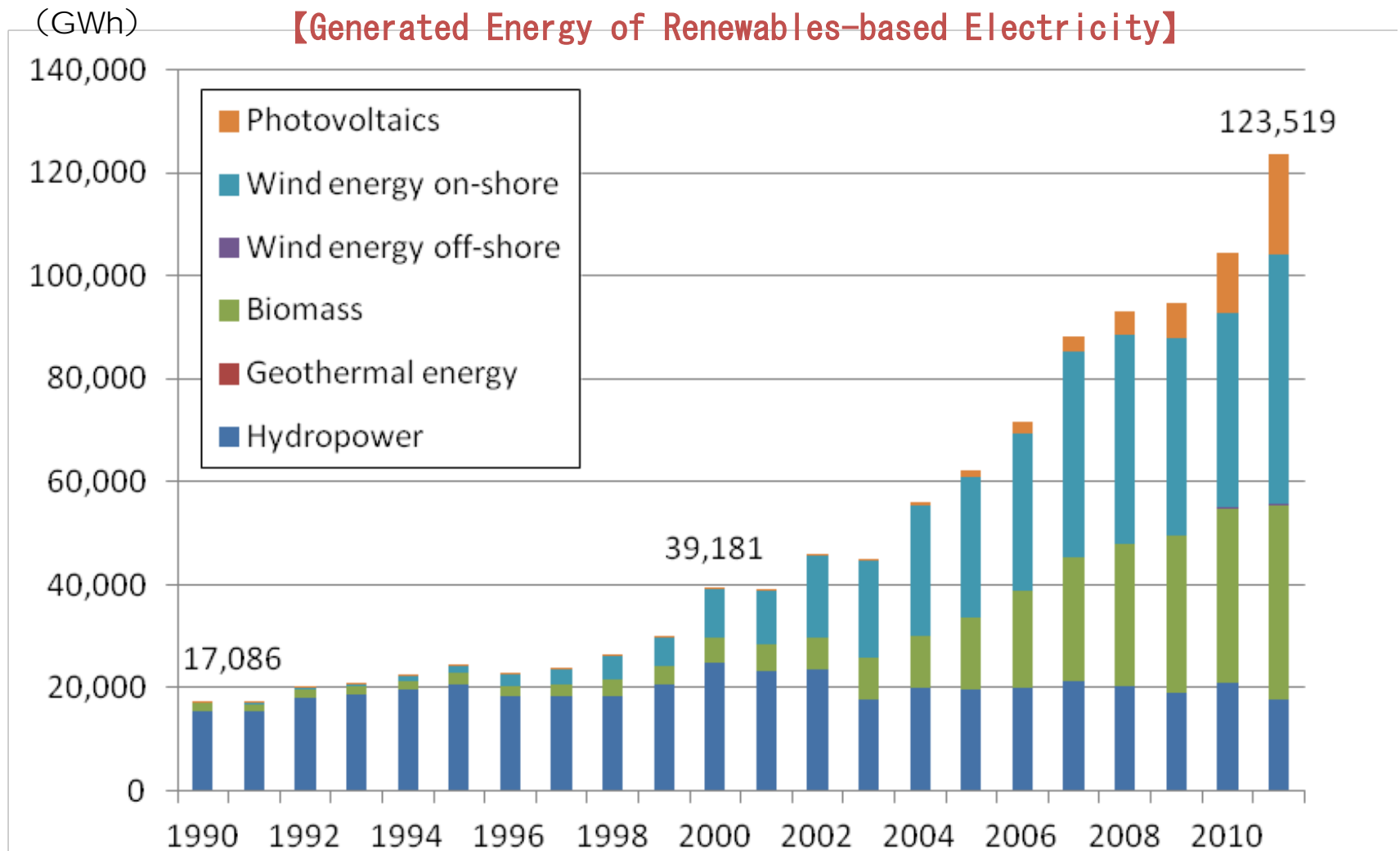


The electric power generated by renewable energy is predicted as Fig. shows.

The electric power generated by renewable energy other than water power increases very slowly from about 4% in 2010 to only 15% in 2035, as shown in Fig. , while the electric power generated by nuclear energy will be kept almost constant from 13% in 2010 to 12% in 2035.

Development of renewables-based electricity generation in Germany

■ Increased trippled(from 2000 to 2011)



Source : BMU) 「Entwicklung der erneuerbaren Energien in Deutschland im Jahr 2011」

Taking off that generated by water power, we have 82.9 billion kWh. The total electric power generation in Japan was 976.2 billion kWh in 2010.

Namely the electric power generated by renewable energy other than water in Germany in 2010 was only 8,5% of the total electric power generation in Japan in the same year.

The electric power generated by nuclear energy in Japan was 300.4 billion kWh in 2010.

Therefore the electric power generated in Germany by renewable energy other than water in 2010 is only 28% of it.

Even if Japan strives as much as Germany, it takes at least thirty years to replace the nuclear energy by renewable energy.

Meanwhile Japan must depend on fossil fuel, which increases the CO₂ emission into the air.

In order to import fossil fuel, the deficit in foreign trade of Japan, which is now already more than 4 trillion yen (about \$40 billion), will continue to increase.

When we stop all nuclear power stations in Japan, the renewable energy must be increased not only to replace the nuclear energy but also the energy produced by fossil fuel. It is really possible in near future? It is time for us to deliberate the future of energy in Japan in order to guarantee the energy security, to avoid the global warming and to stabilize the economy of Japan.

4 Human beings cannot help depending on nuclear energy as well as other energy resources, including renewable energy, which do not emit CO₂ into the air.

It is now very clear that it is almost impossible for renewable energy in near future to replace fossil fuel. Both nuclear energy and renewable energy are necessary, not only in Japan but also in the world. At the same time we must develop a new technology to fix the CO₂ emission from fossil fuel.

5 Nuclear technology must be developed.

5-1 The safety technology of nuclear energy has to be developed for the future.

Concerning nuclear energy, we must not stop researching and developing new advanced reactors in which more safety is guaranteed against natural calamity as well as man-made disaster. Small scale nuclear reactors also should be developed in order to decentralize electric power stations.

If economical problems are overcome, smaller scale reactors might be easier to guarantee safety.

5-2 The technology for the back-end of the nuclear fuel cycle has to be enhanced. The site for final disposal of nuclear wastes has to be determined as soon as possible in Japan, which is a responsibility of the Central Government.

Not only Japan but almost all countries including Germany, USA, Britain and Russia have not yet decided the location for final disposal, except Finland and Sweden. This decision must be made irrespectively whether to continue nuclear power stations or not.

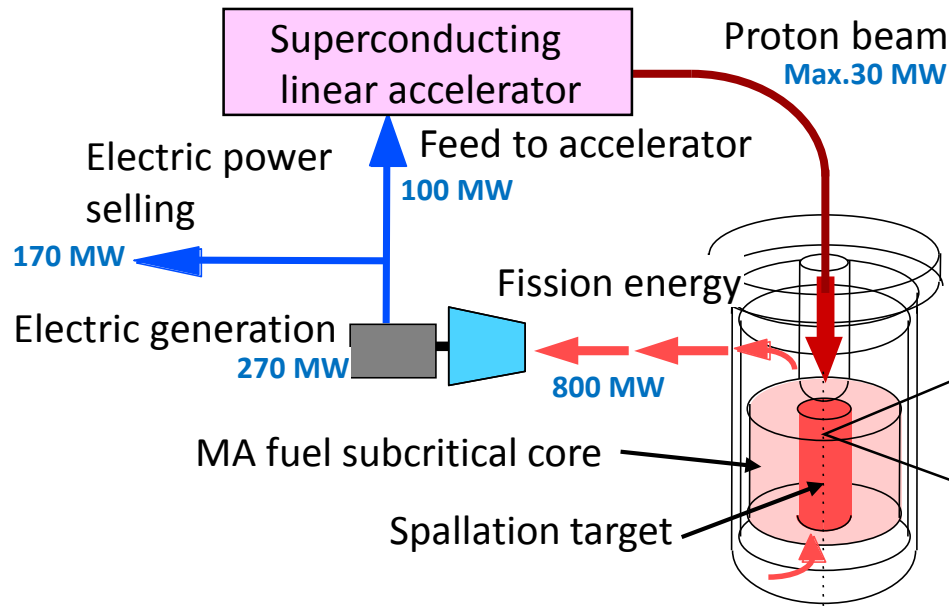
5-3 The research and development of innovative technologies, such as Accelerator Driven Systems, have to be promoted in order to encourage the progress of final disposal.

It is extremely important to shorten life times of many radioactive nuclei in the nuclear wastes.

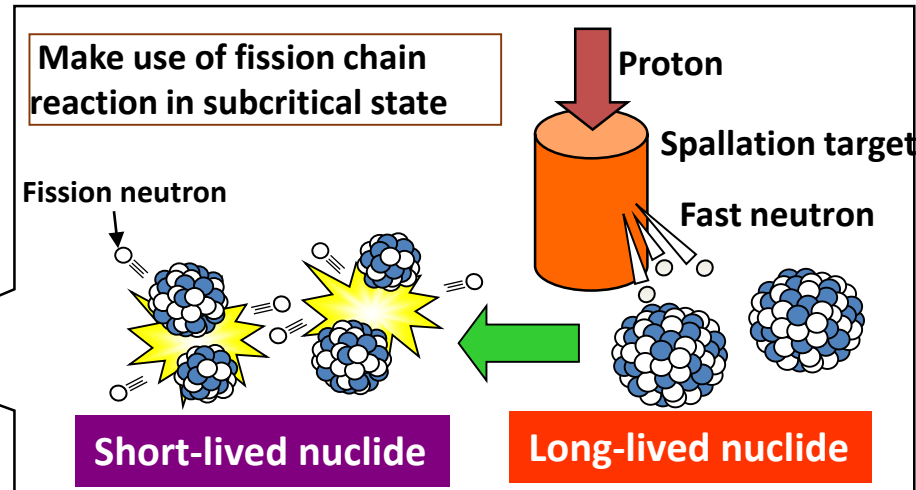
The role of nuclear transmutation technology is one of the main themes of this Symposium.

The Accelerator Driven System is one of the most promising methods to transmute radioactive nuclei to those of shorter life times.

Transmutation using Accelerator-Driven System(ADS)



Principle of transmutation by ADS



Mechanism of ADS:

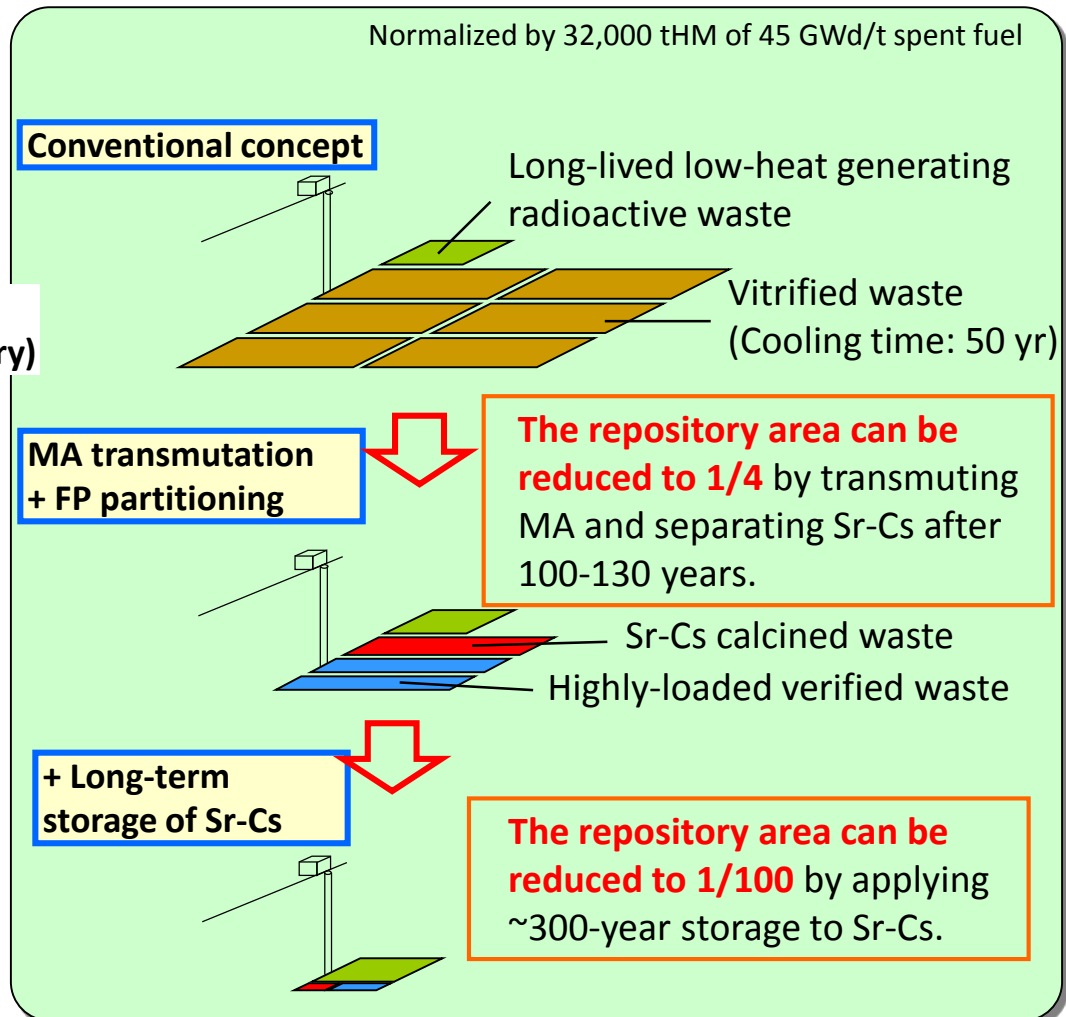
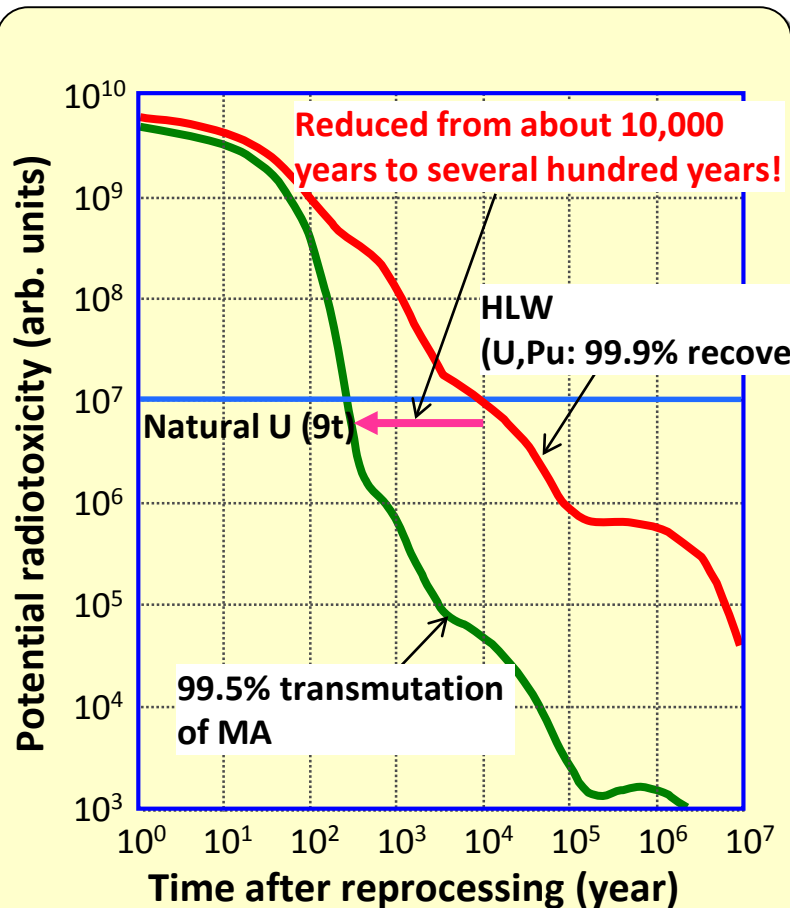
- Protons are accelerated by a **superconducting accelerator** with high intensity.
- Protons are directed to a **lead-bismuth (Pb-Bi) target** through a beam duct and a beam window.
- The Pb-Bi combines a **reactor coolant** with a **spallation target**.
- Major composition of the reactor fuel is **MA**.
- Spallation reactions generate a large number of neutrons.
- MAs are transmuted by neutron-induced fission reaction.
- Neutrons generated by the fission are also used for the transmutation.
→ neutrons are increased by 20 times by a **fission chain reaction**.
- The electricity generated by ADS is partly fed to its own accelerator.

Feature of ADS:

- If the accelerator runs down, fission chain reactions come to a stop. → **High safety**
- Existing reactors (critical reactors) with a large amount of MAs cause safety difficulties, but that is not the case in ADS.
- Pb-Bi is chemically-inactive.

Effect of P&T

- ◆ Reduction of long-term potential radiotoxicity
- ◆ Possible reduction of repository area



5-4 The research and development of nuclear technologies for reactor decommissioning, safety technology, back-end, etc., have to be promoted intensively through international cooperation.

Nuclear technologies for reactor decommissioning, safety technology, back-end, etc, must be urgently developed. They are very important especially in Japan after the Fukushima Daiichi Accident.

Fukushima would be a very good candidate for us to construct an international center for researching and developing technologies for reactor decommissioning.

Conclusion

For the future of human beings, nuclear technology is indispensable to guarantee the safety of energy and to reduce CO₂ in the air which causes the global warming.

For promoting nuclear technology, we must encourage young researchers to be interested in nuclear science and engineering. Education is very important for this purpose.

You experts of nuclear science and technology should be very proud of your specialty. It is the most important time for you to solve very difficult problems after the accident of the Fukushima Daiichi Nuclear Power Station.

I sincerely hope that you will overcome this crisis caused by the Fukushima accident.

Let us change the misfortune into good luck for the future of human beings.

Thank you very much for your listening to me.