No fast reactor, no survival beyond 21st century

Let's talk on fast reactors toward our future

December 11th, 2009
Main Hall, Plaza-Bansho, Tsuruga

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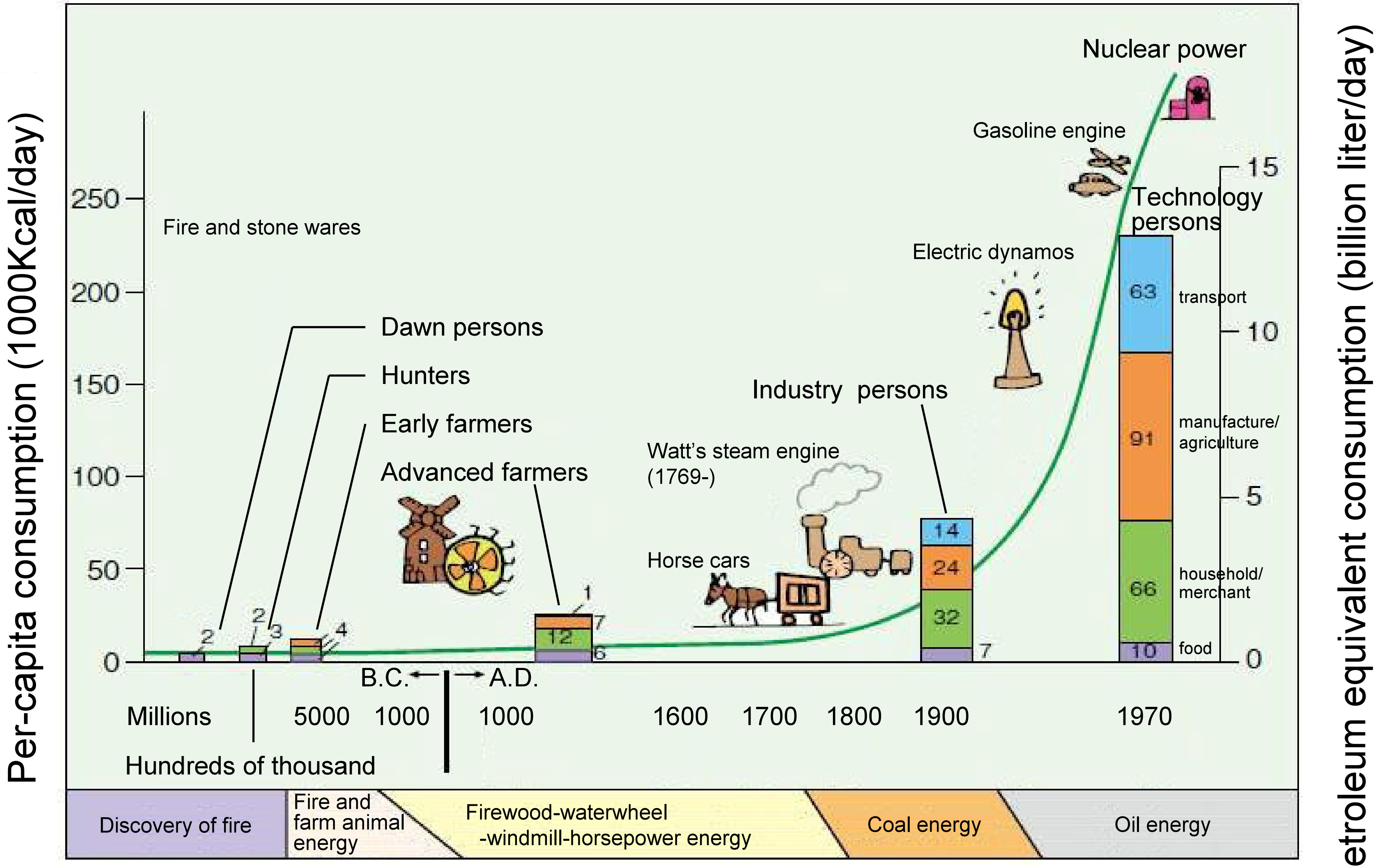
Civilized societies evolve with energy

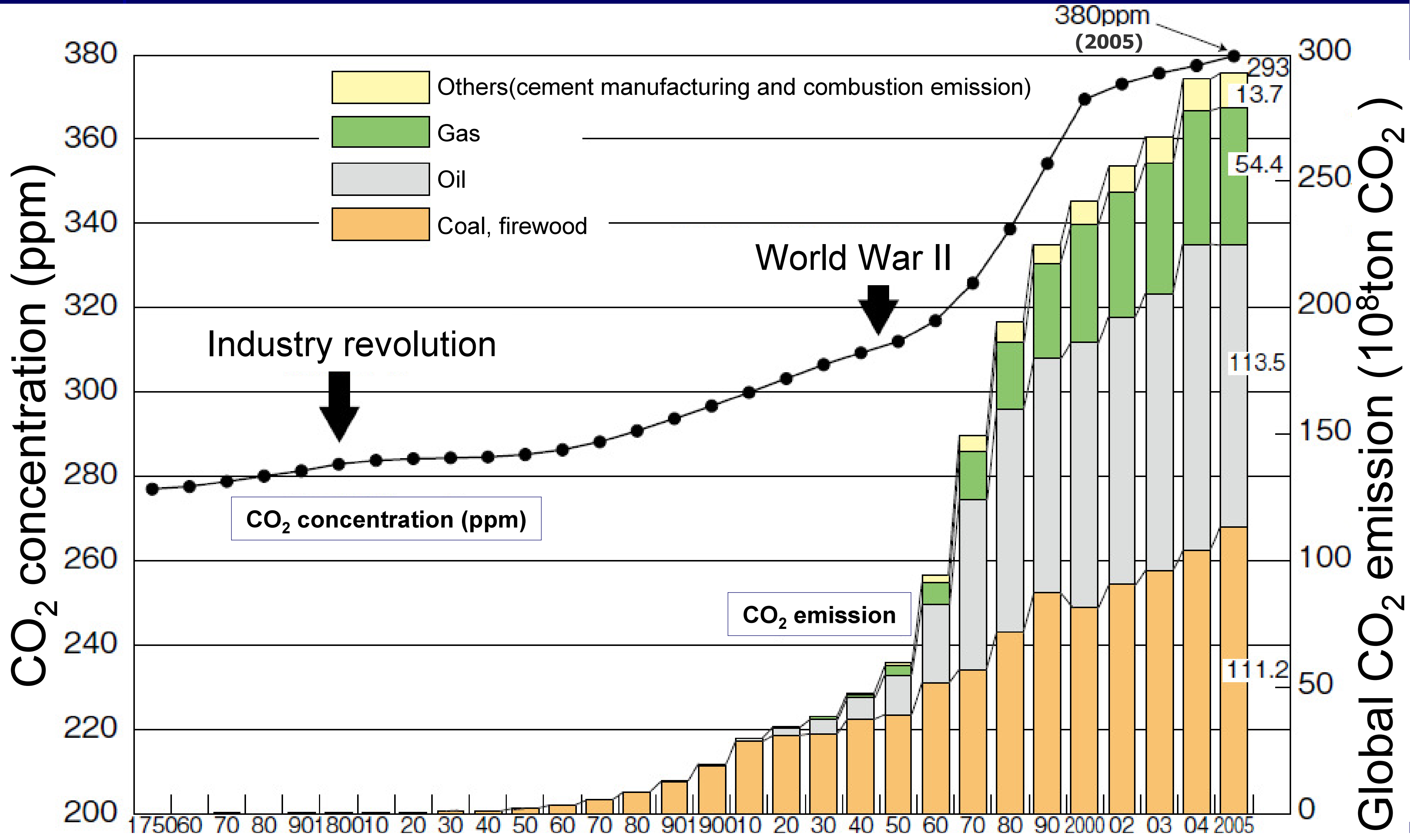


Dawn persons: East Africa, 1 million years ago, foods only
Hunters: Europe, 10,000 years go, firewoods for heating and cooking
Early farmers: fecund delta, B.C.5000, cereal growing and use offarmers farm animal energy

Advanced farmers: Northwest Europe, 1400, coal for heating, waterwheel, wind, and transport by animals
Industry persons: U.K., 1875, steam engines
Technology persons: U.S.A., 1970, use of electricity, foods for human and animals

Reference: National Institute for Research Advancement "Considerations on Energy"

Evolutions of CO_2 emission from fossil fuel and atmospheric concentration of CO_2



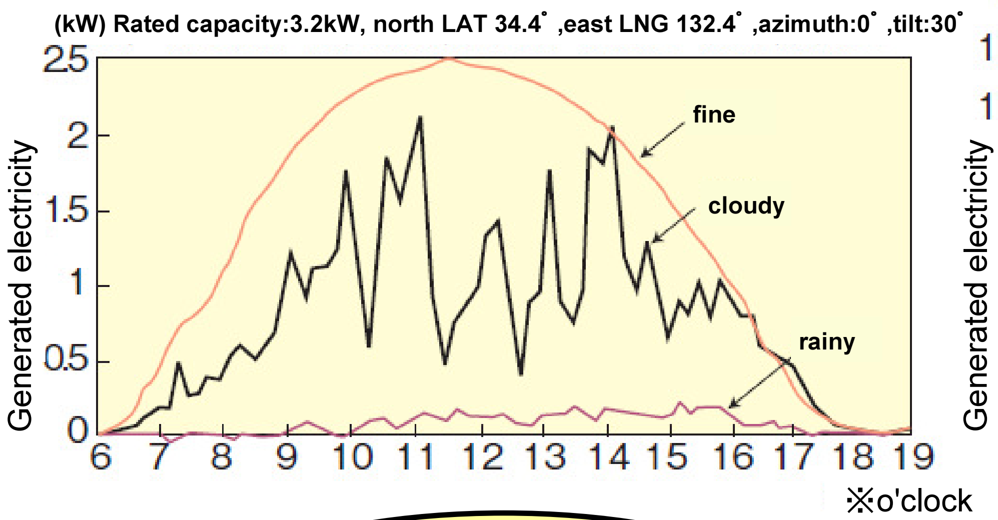
Note: Summations are rounded off Reference: Home Page of Carbon Dioxide Information Analysis Center, ORNL

Two options toward independent civilized society

Two approaches for clean electricity source	
Solar origin energy	Terrestrial energy
Solar heat・photovoltaic hydro・wind	Geothermal （decay heat of radioactive isotopes） Nuclear（fission）（fusion）
Huge amount Low density high power fluctuant・irregular	Inexhaustible ($E=mc^2$) High density high power Stable
Collection&storage to improve in EPR index	Confinement technique and social comprehension
Distributed electricity source	Backbone electricity source

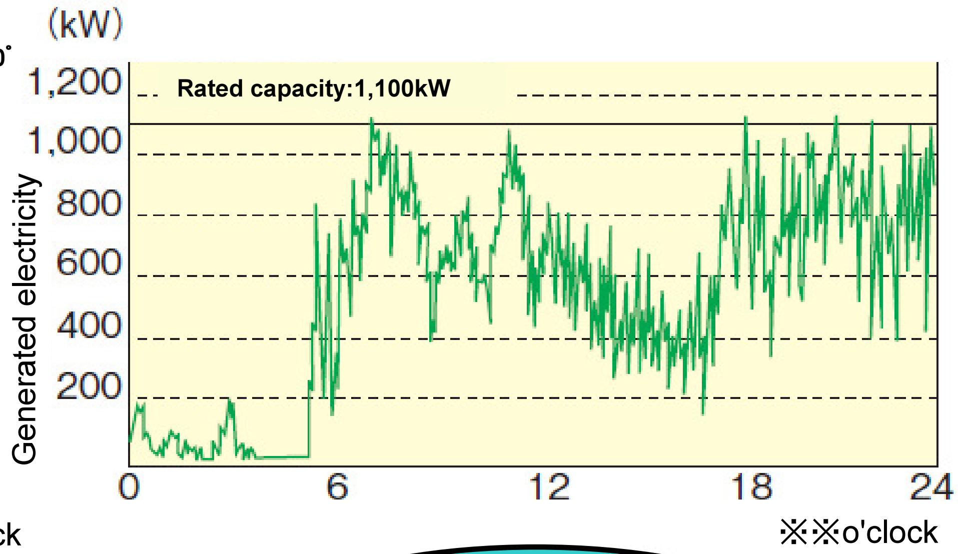
Fluctuation of photovoltaic and wind power generations

Fluctuation of photovoltaic power (spring)



photovoltaic power is subject to time and weather

Fluctuation of wind power (winter)

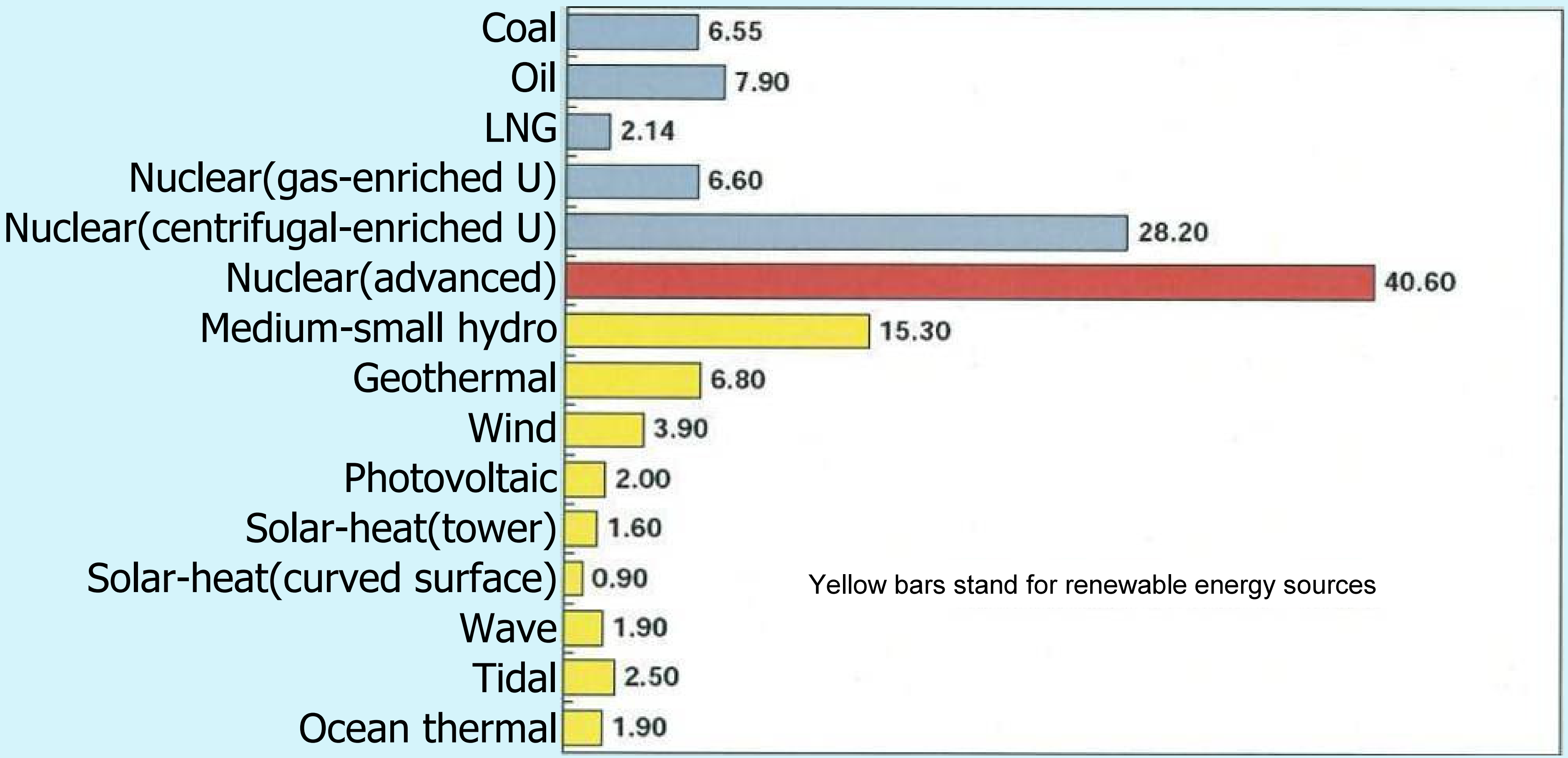


wind power is subject to the velocity

Reference : ※ brochure of Federation of Electric Power Companies
※※Horikappu Power Station, Hokkaido Electric Power Co., Inc.

Kurobe dam

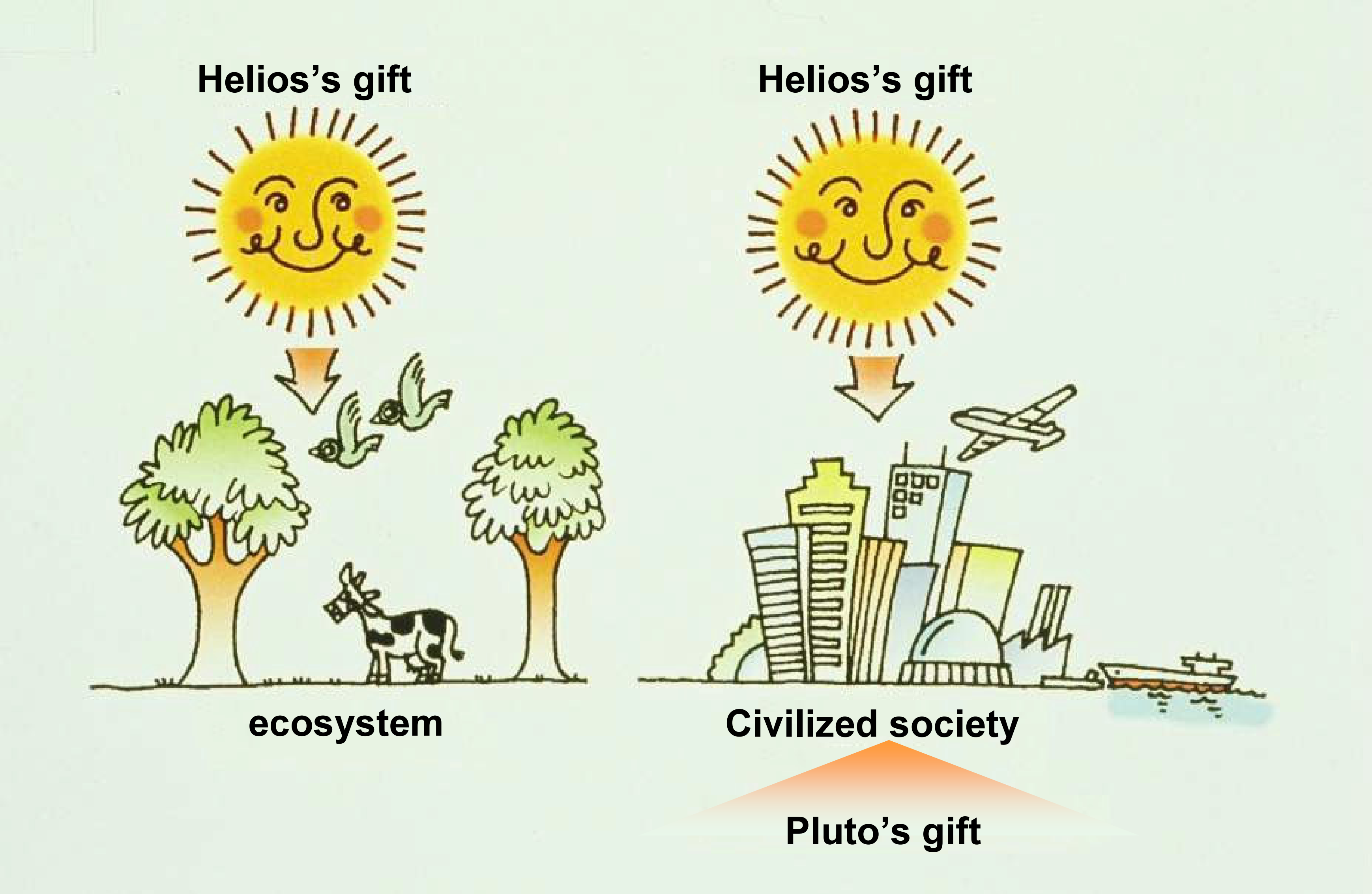
Estimations of power generation methods in EPR index



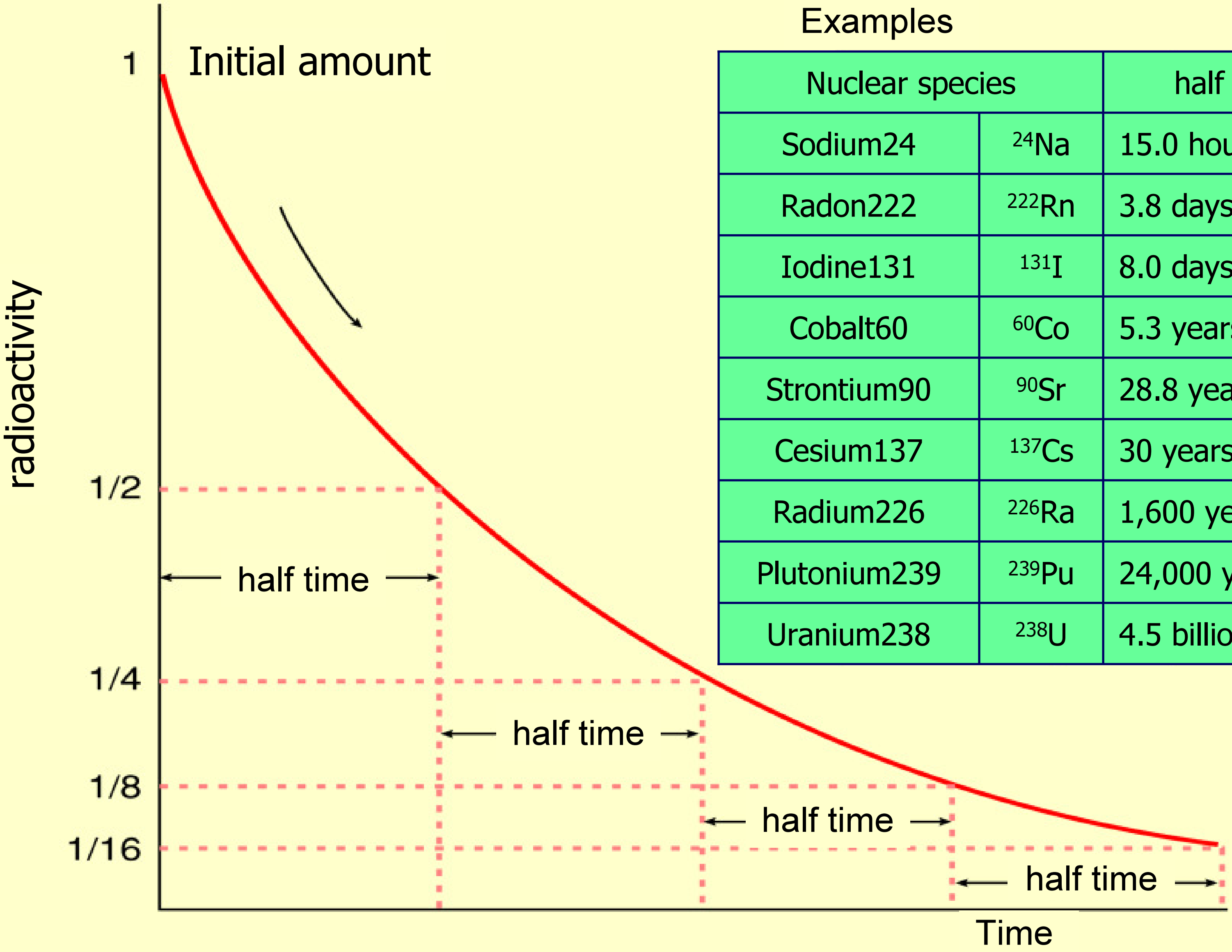
EPR（Energy Profit Ratio） ＝ Energy output ÷ Energy expenditure

Reference : "CRIEPI News No.439" from Central Research Institute of Electric Power Industry

Ancient radioactive waste as our resource
Terrestrial energy



reduction of radioactivity



Examples

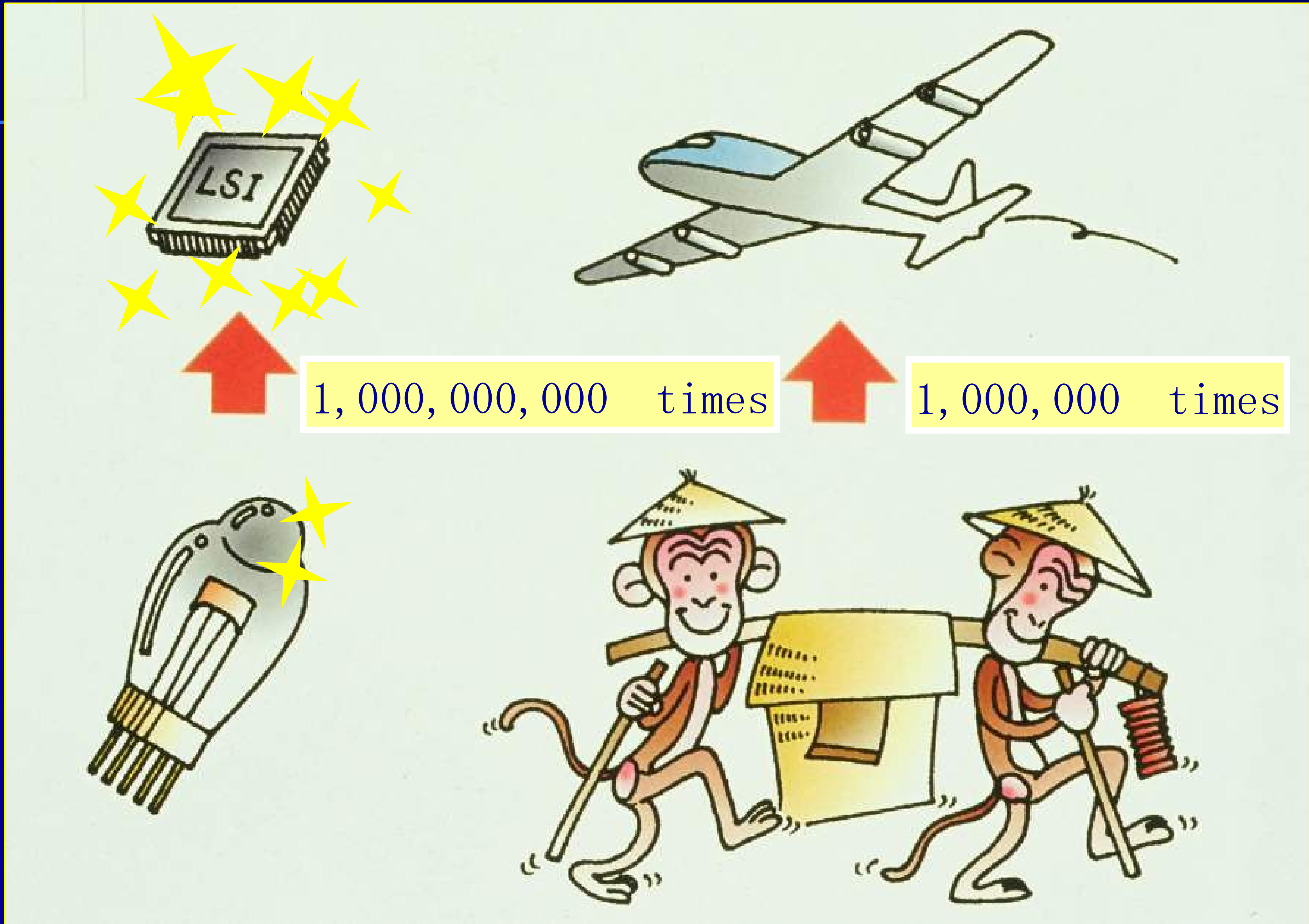
Nuclear species		half time
Sodium24	^{24}Na	15.0 hours
Radon222	^{222}Rn	3.8 days
Iodine131	^{131}I	8.0 days
Cobalt60	^{60}Co	5.3 years
Strontium90	^{90}Sr	28.8 years
Cesium137	^{137}Cs	30 years
Radium226	^{226}Ra	1,600 years
Plutonium239	^{239}Pu	24,000 years
Uranium238	^{238}U	4.5 billion years

Terrestrial energy

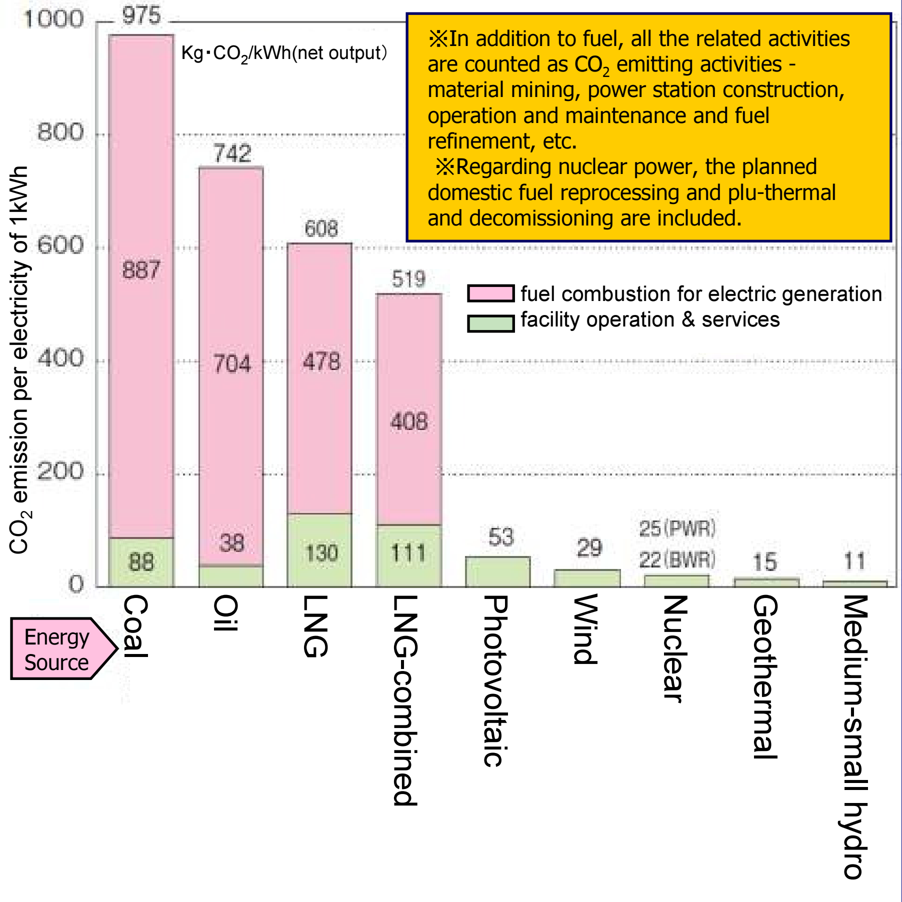
Long-lived radioactive elements

Nuclear species	Half time	Abundance ratio	Nuclear decay
thorium-232	14 billion years	～100%	α
uranium-238	4.5 billion years	99.3%	α
uranium-235	0.7 billion years	0.7%	α
potassium-40	1.3 billion years	0.01%	β
plutonium-239	24 thousand years	—	α

Civilized society cannot survive without new paradigm technologies

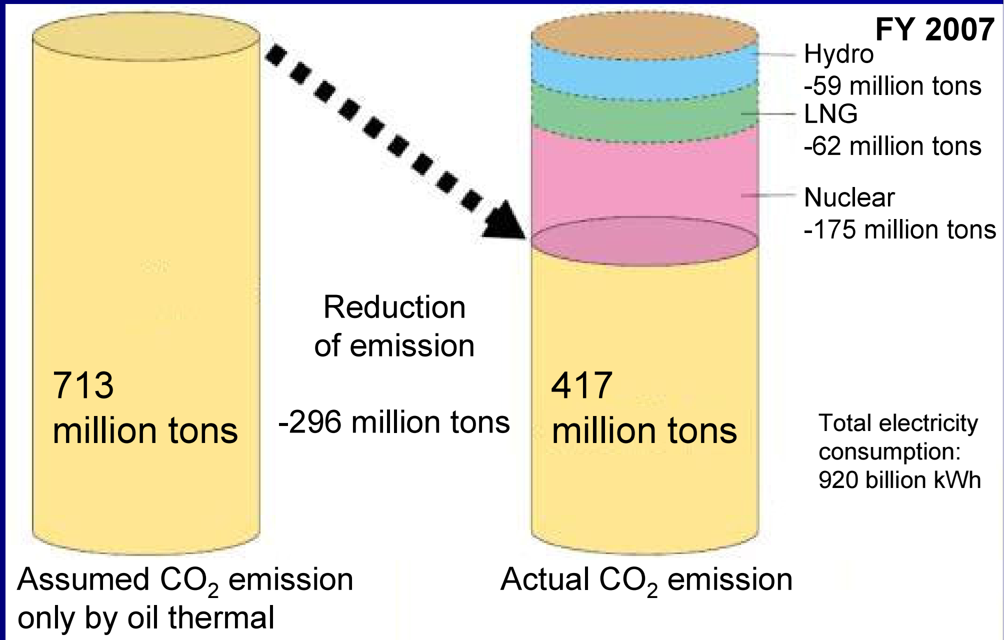


CO_2 emission of electric sources



Reference : Central Research Institute of Electric Power Industry
"Evaluation of Electric Generation Technologies by Lifecycle CO_2 Emission" (March, 2000)
"Evaluation of Nuclear Electric Generation Technology by Lifecycle CO_2 Emission"(August, 2001)

CO_2 emission reduction by nuclear power



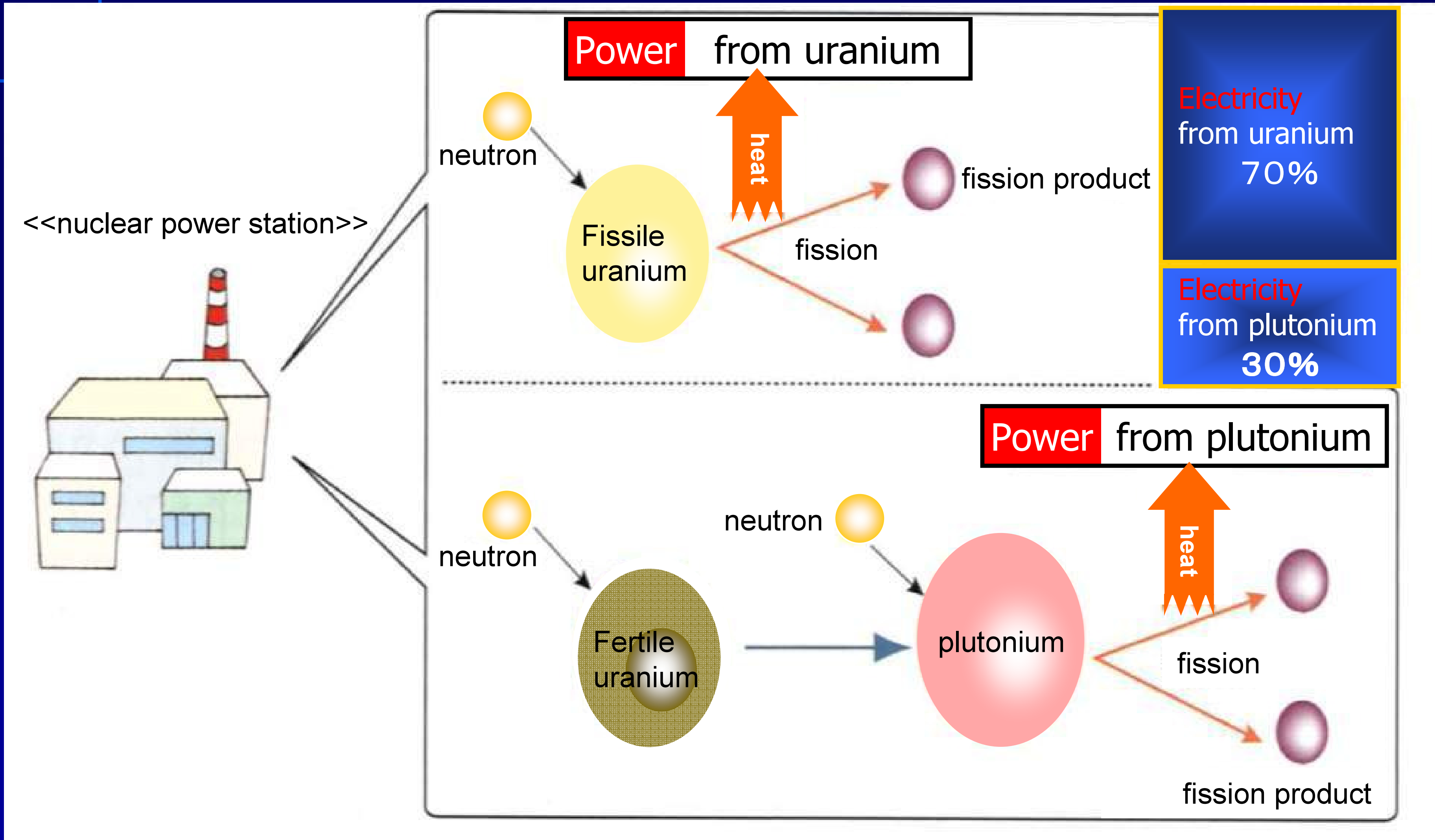
Reference : Preliminary Calculation by Federation of Electric Power Companies

Current status of new energy sources v.s. potential of nuclear energy

	nuclear	Photovoltaic	Wind
Power generation cost	JPY 4.8～6.2/kWh	JPY 46/kWh	[large] JPY 10～14/kWh [medium-small] JPY 18～24/kWh
		Supposed to generate million kW (≒ 1 nuclear station)	
Required site area	Total:0.6km² [RV and turbine uildings:0.012km²]	～67km² ≒lake Toya (70.7km²)	～ 246km² City of Otaru (243.13km²)
Utilization factor	Japan：70% U.S, Germany, Korea：90%	12%	20%

Reference : Calculated based on "Atomic nation Plan"(Aug., 2006) by Agency for Natural Resources and Energy

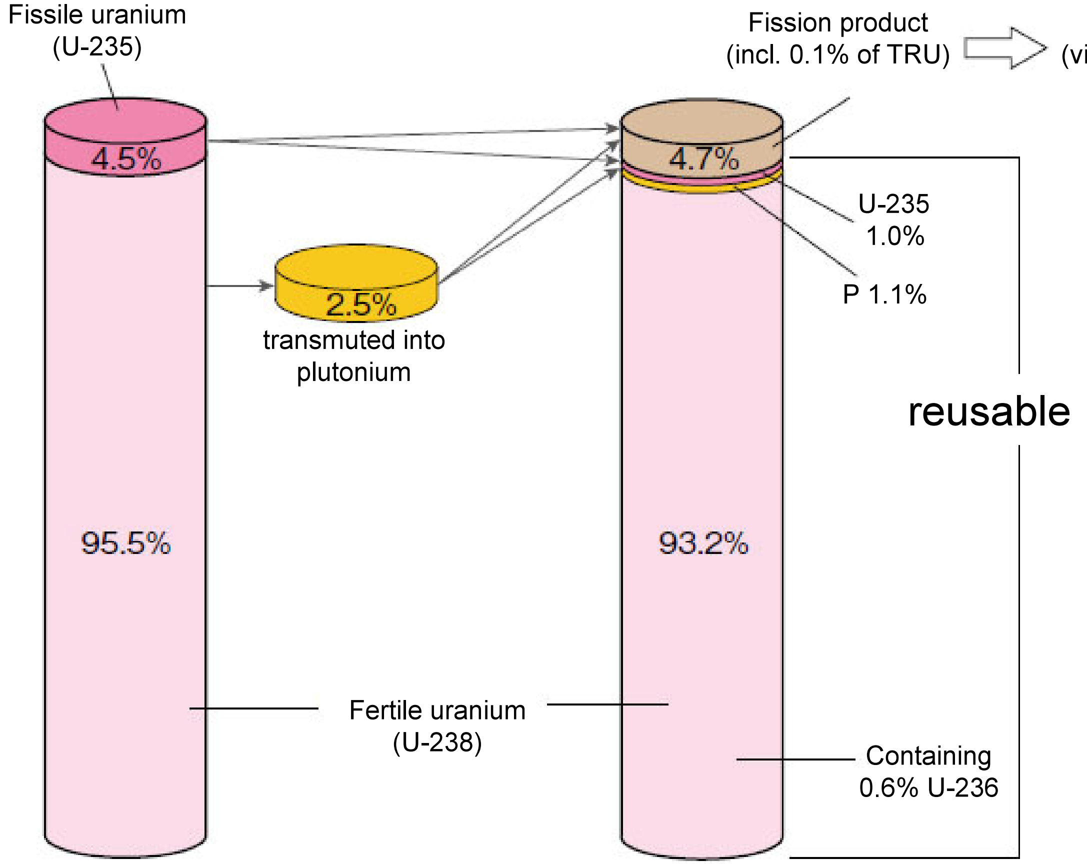
Mechanism of nuclear power generation



Reference: "Questions on plu-thermal" by The Denki Shimbun

Change of uranium fuel by burnup in LWRs

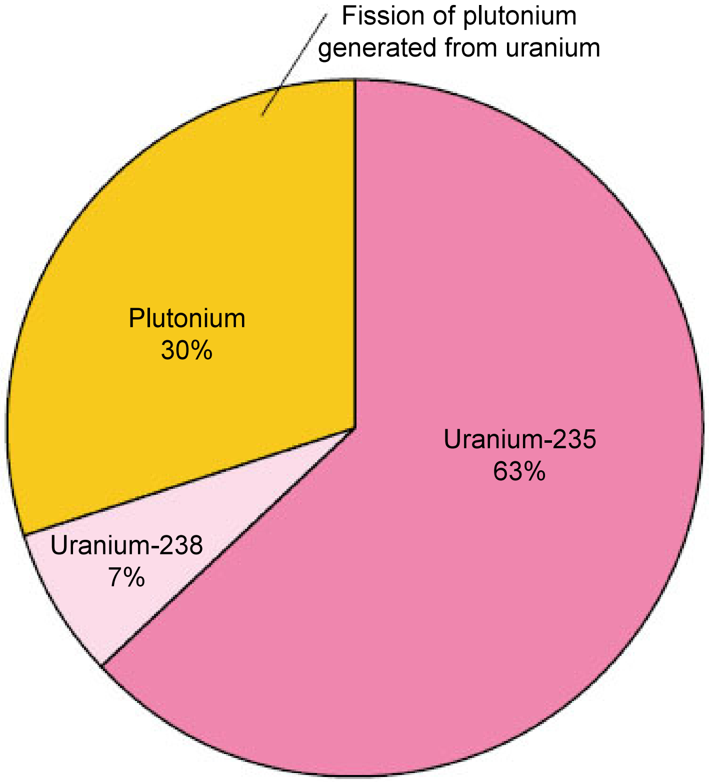
Energy production: assumed average burnup: 4,5000MWD/tU



Before electric generation
(fresh fuel enrichment: 4.5%

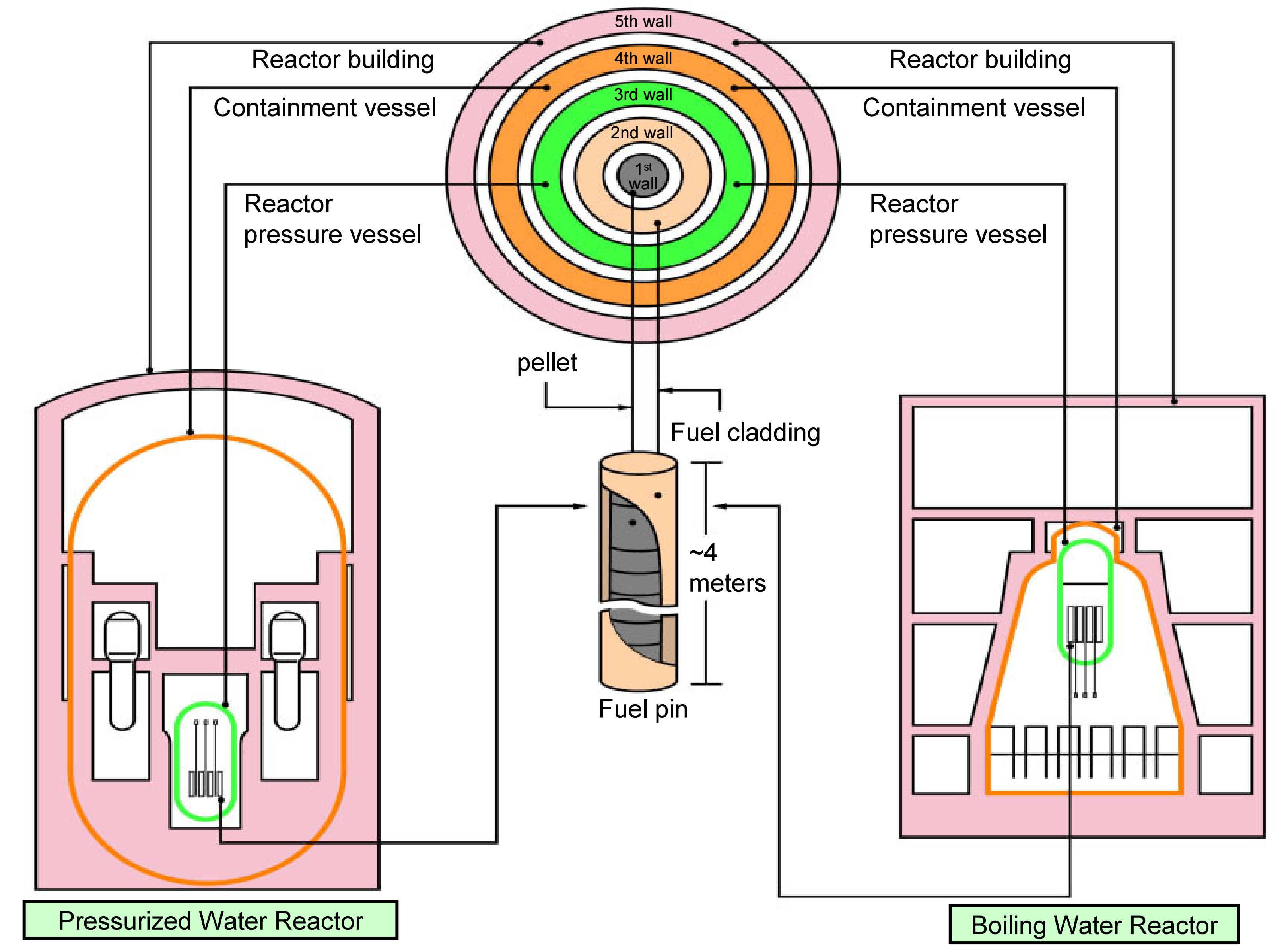
Spent fuel
after electric generation

Composition change of uranium fuel due to electric generation



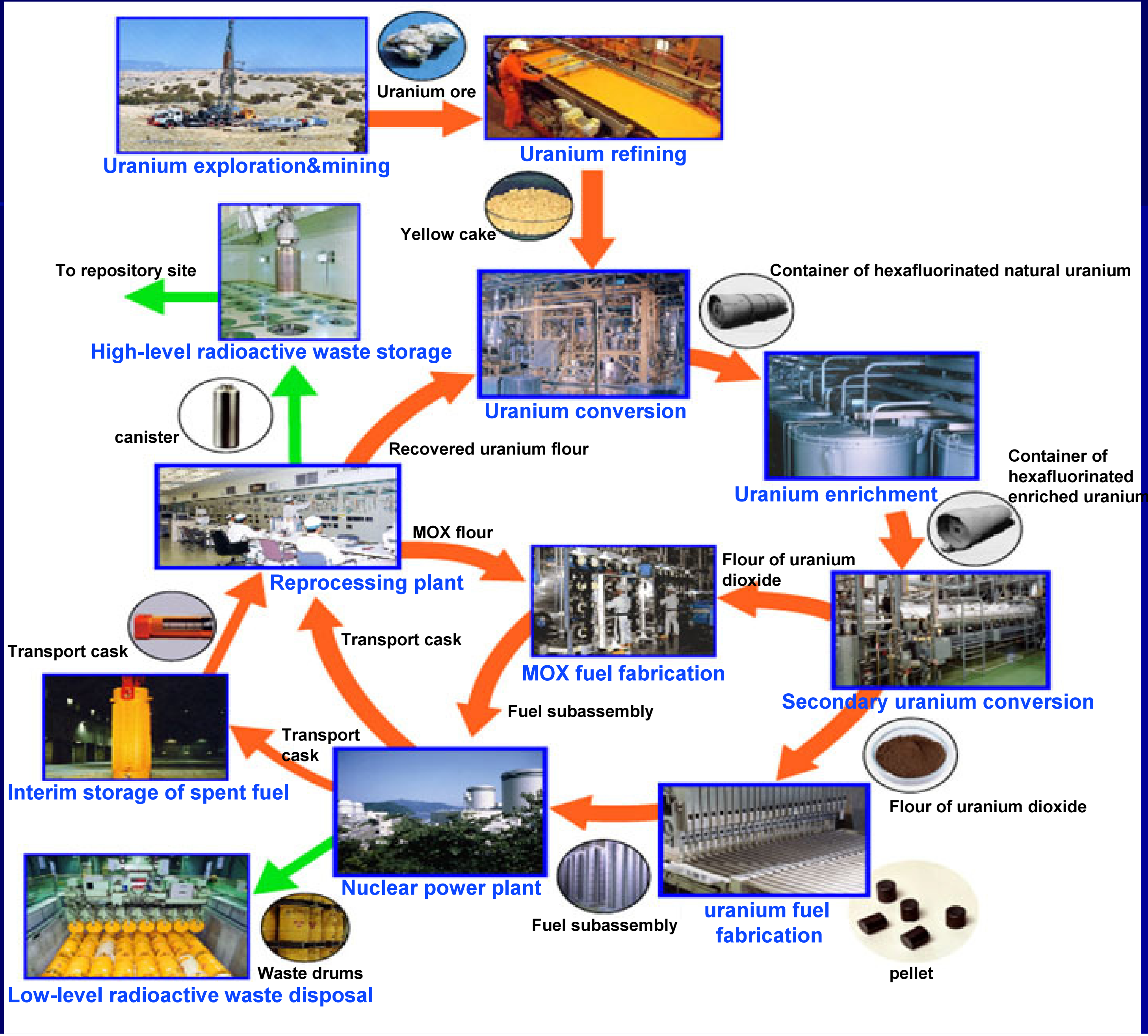
Contributions of electric generation by involved elements
~4.6%w of uranium fuel is consumed

Quintuple walls confining radioactivity

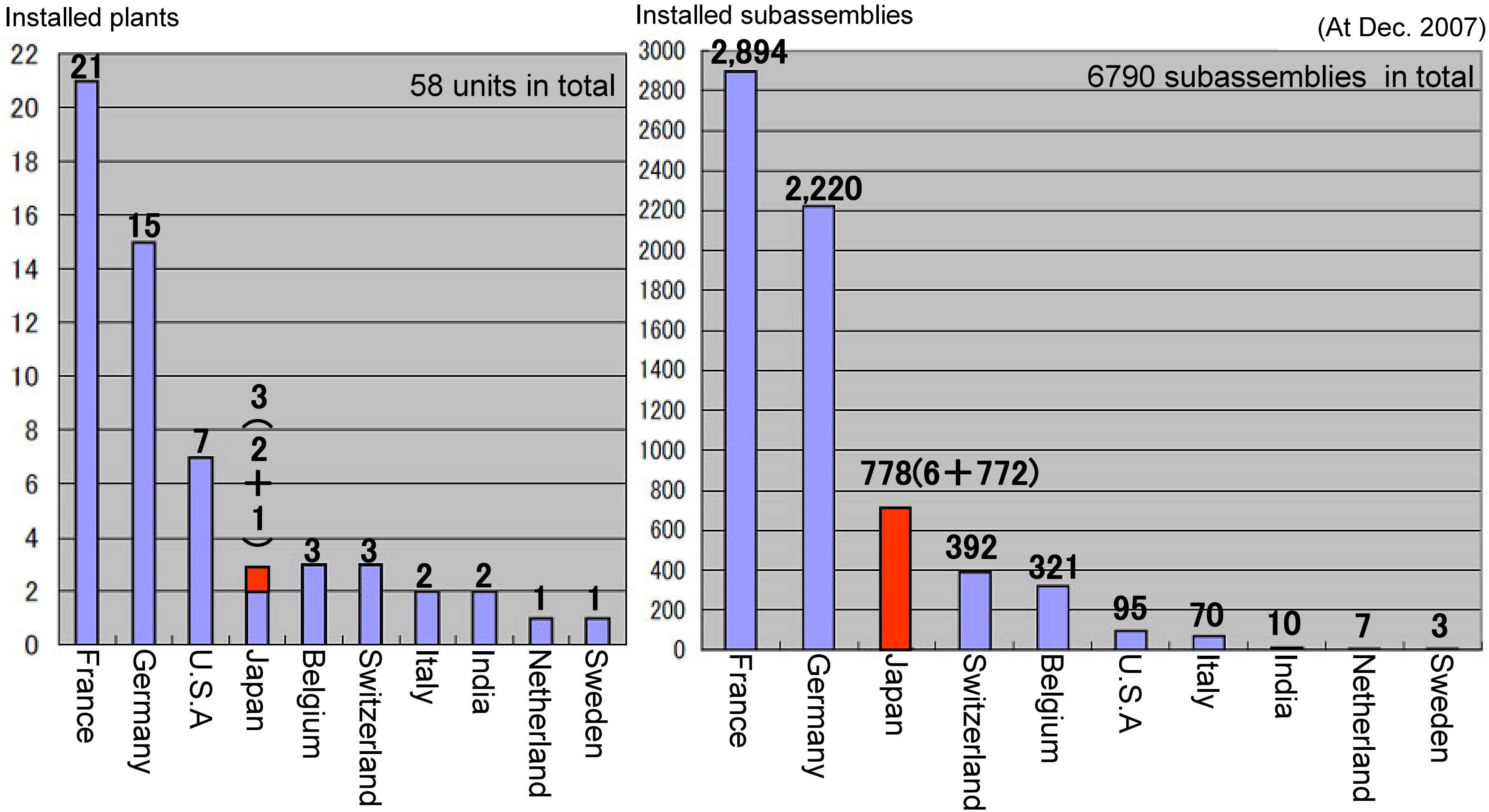


LWR is "The Little Match Girl"

LWR nuclear fuel cycle



Achieved plu-thermal in the world

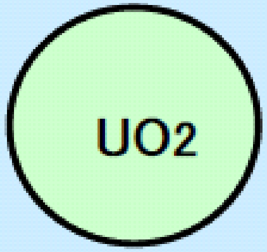
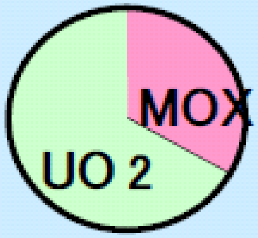
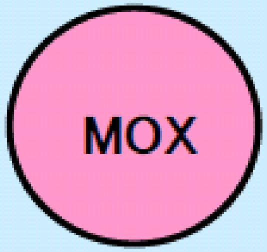


Note 1:Japan conducted plu-thermal also in Fugen with 772 subassemblies(March 2003)
Note 2:MOX fuels are installed at Dec. 2007 in France(20 units), Germany(10 units), Switzerland(3 units), Belgium(2 units) and U.S.A(1 unit)

Reference: "Nuclear Power in 2008" by Agency for Natural Resources and Energy

Suppression of surplus plutonium by plu-thermal

Plutonium balance

		Pu kg/tonHM	Pu increase
UO2		Pu-t 0kg ⇒ Pu-t 11kg (Pu-f 7.5kg, 68%)	Pu-t 11kg (Pu-f 7.5kg)
MOX 1/3 Core		Pu-t 23kg (Pu-f 16kg) ⇒ Pu-t 23kg (Pu-f 12kg, 52%)	Pu-t 0kg (Pu-f −4kg)
MOX Full Core		Pu-t 70kg (Pu-f 48kg) ⇒ Pu-t 45kg (Pu-f 22kg, 48%)	Pu-t −25kg (Pu-f −26kg)

Fast neutron and thermal neutron

- Fast neutron

  Generated neutron at the immediate aftermath of nuclear fission with a high velocity

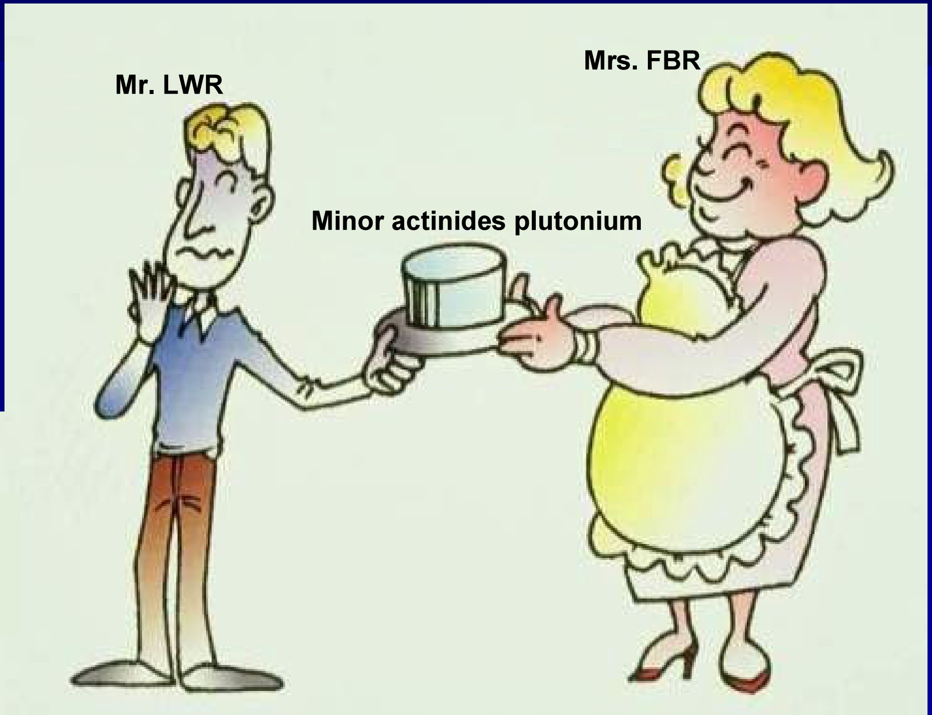
  - ~14000 km/sec (1MeV)

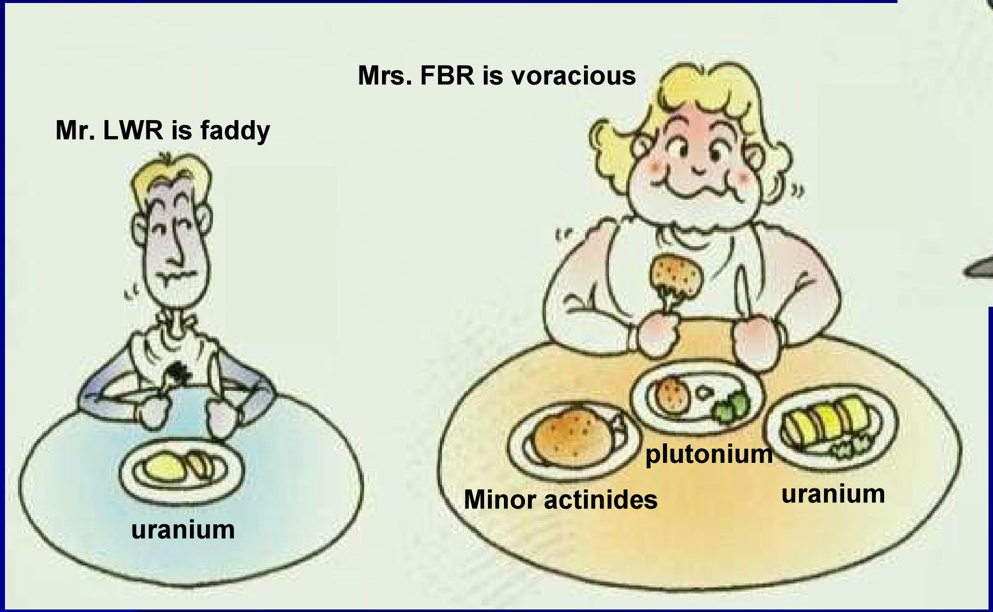
- Thermal neutron

  Neutron with decreased velocity by collisions with water and graphite, etc., to facilitate nuclear fissions of uranium-235

  - ~2.2 km/sec

FBR to convert "wet firewood" into energy

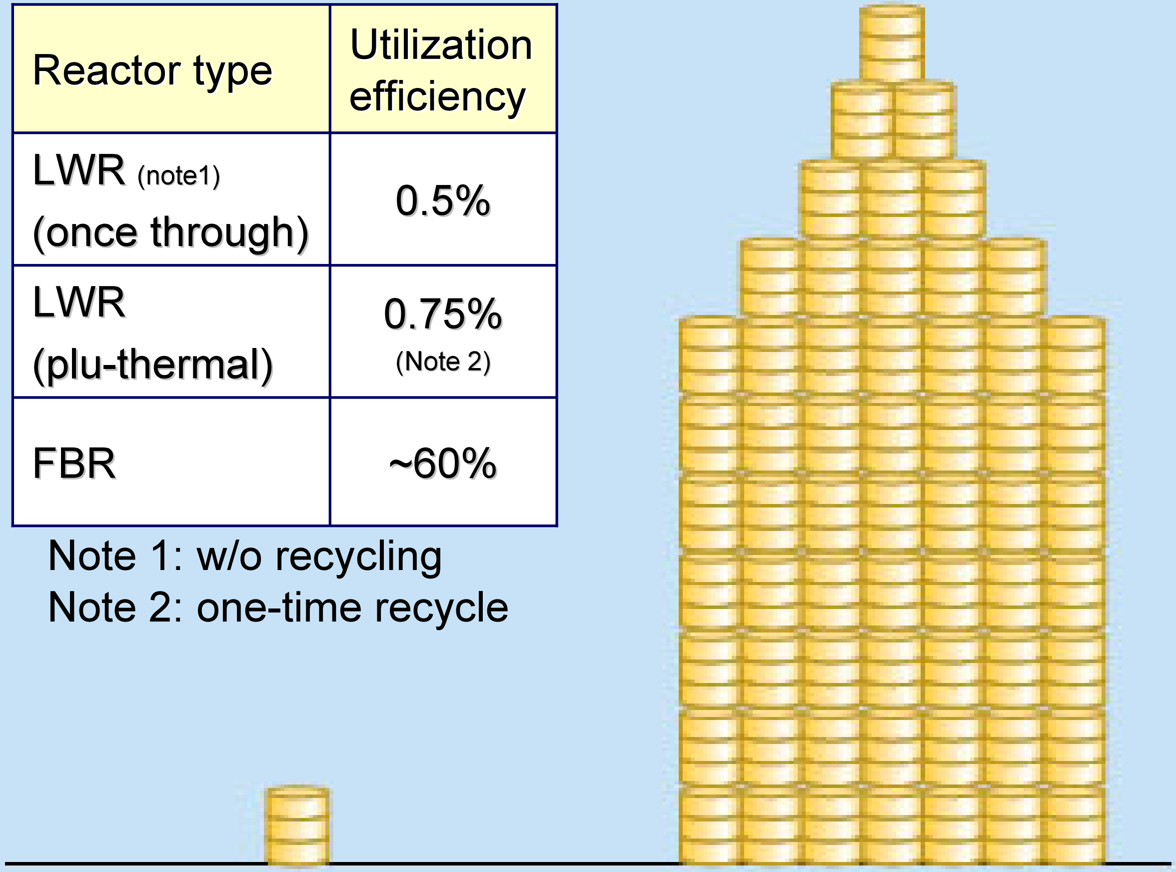




Effective use of uranium resource

Reactor type	Utilization efficiency
LWR (note1) (once through)	0.5%
LWR (plu-thermal)	0.75% (Note 2)
FBR	~60%

Note 1: w/o recycling
Note 2: one-time recycle



Exclusive use of uranium-235

Use of uranium-238 through conversion to plutonium

Reference Atsuyuki Suzuki "plutonium"

First commercial reactor of each country

- U.S.S.R Obninsk 5MW 27 Jun. 1954
  graphite moderated heavy water cooled
- France Marcoule G-1 5MW 06 Jan. 1956
  graphite moderated gas cooled
- U.K. Calder Hall 60MW 23 May 1956
  graphite moderated gas cooled
- U.S.A. Shippingport 50MW 02 Dec. 1957
  Pressurized light water cooled

Why fast reactor started late

- **A born peaceful use technology**
- **Use of exotic material**
- **Victim of political fights as a symbol of peaceful use**

Fast reactors sacrificed by political fights in countries

U.S.A.:Carter administration’s plutonium moratorium

Germany: Nuclear abolition policy of Social Democratic Party & Green Party

French: Green Party’s abrogation of Superphenix by decree of minister of environment

JAEA's Tokai reprocessing plant

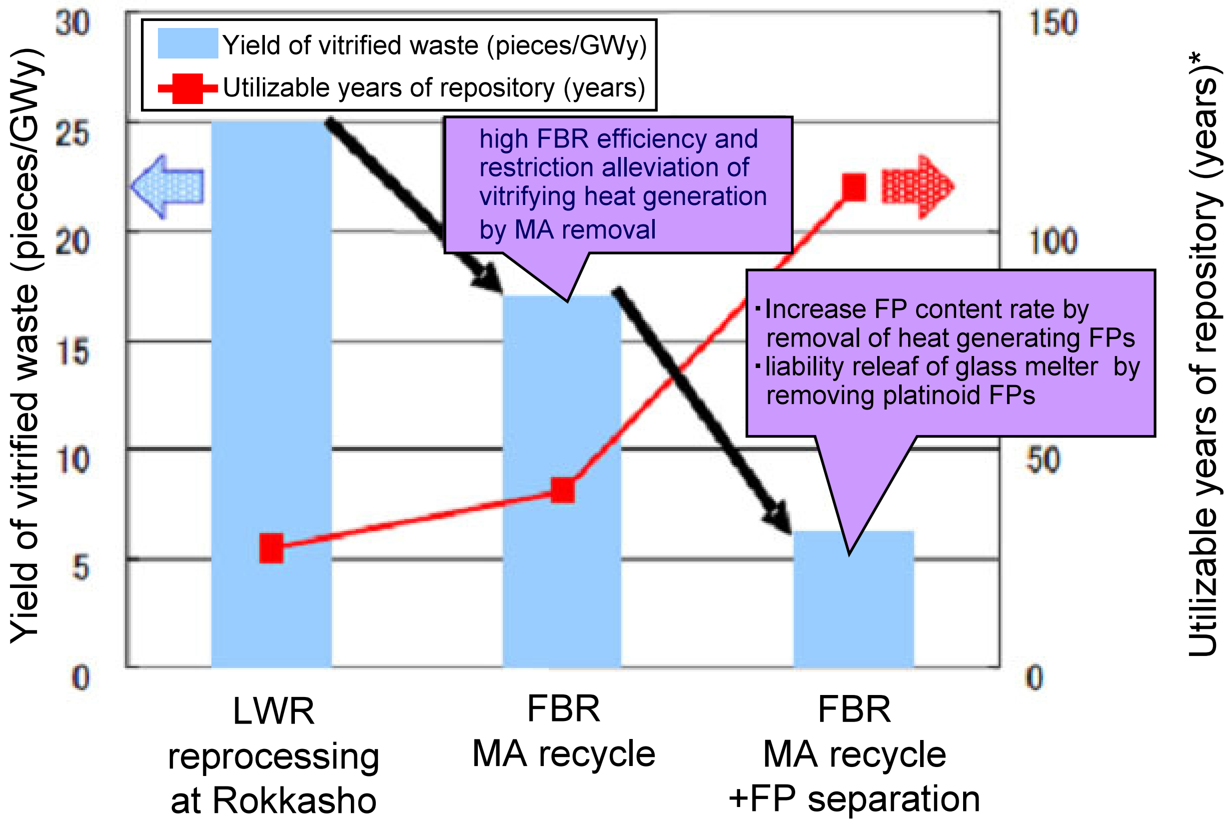
JAEA's Tokai plutonium fuel test building

Comprehensive strategy for sustainability-centered development

	Conventional concept	Sustainable concept
Resource and environment factors	・abundant acquirement and use of energy resource ・priority on cheaper energy ・"therapy deal" environmental measure	・energy resource utilization without adverse legacy ・planned use of limited resource ・minimize environmental impact of resource exploitation
Development policy of advanced reactors	・priority on reactor performance ・cost competition with LWRs ・recycling as an adjunct of reactor technology ・separate development of fuel cycle	・priority on consistency with backend ・compensation of LWR's defects ・reactor as a element of fuel cycle ・unified development of cycle and reactor
International cooperation	・embargo on information export for national interest ・country-by-country development strategy and structure	・information share for common interest ・sped-up development, cost saving ・internationally cooperated development strategy and structure

Radioactive waste reduction by FBRs

FBRs have potential in volume reduction of high-level radioactive waste jointly by minor actinide (Np, Am, Cm) recycle and high thermal efficiency. (Further reduction is possible if separate disposal of heat generating FPs will be put into practice.)



Utilizable years of repository (years)*
Stands for period to saturate repository volume for 40,000 vitrified pieces, assuming total installed nuclear power as 58GWe,

Reference: Abstract of "Report on Feasibility Study Phase II"

Nuclear fuel cycle

- FBR's advantage (breeding, multiple plutonium recycle, easing HLW disposal)…. Complementing LWR system