Energy situations in Japan

before and after the Fukushima nuclear accident

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Outline

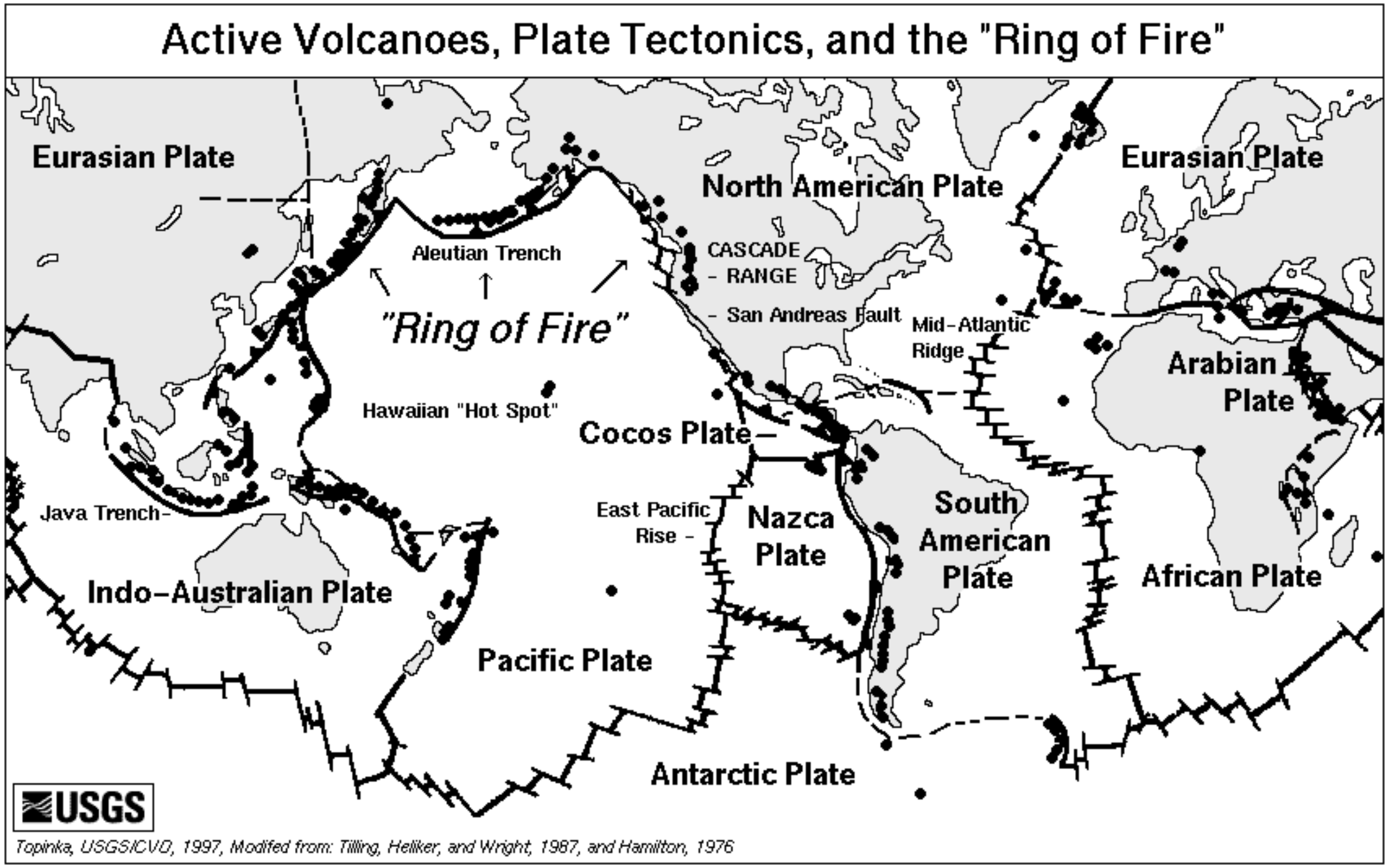
1. Fukushima 2011.3.11
2. Four reports of the accident
3. Japanese energy policy before 2011.3.11
4. Turmoil in the Japanese energy policy after 2011.3.11
5. A personal projection of energy sources for Japan to 2050
6. Summary

1. Fukushima 2011.3.11

The first half: tsunami in Miyagi Prefecture

The latter half: tsunami at the Fukushima
Dai-ichi nuclear power station
by a mobile phone of a worker


VIDEO COURTESY: NHK
LIVE
AP
NHK WORLD
SENDAI
JAPAN



Japan is situated very close from both the Pacific and the Philippine Plates

Fukushima Dai-ichi nuclear power station

2. Four reports (Date of issue of each report)

(1) The National Diet of Japan Fukushima Accident Independent Investigation Commission (2012.7.5)

(2) The Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company (Government) (2012.7.23)

(3) The Fukushima Daiichi Nuclear Accident Power Station Disaster (Independent) (2012.2.27)

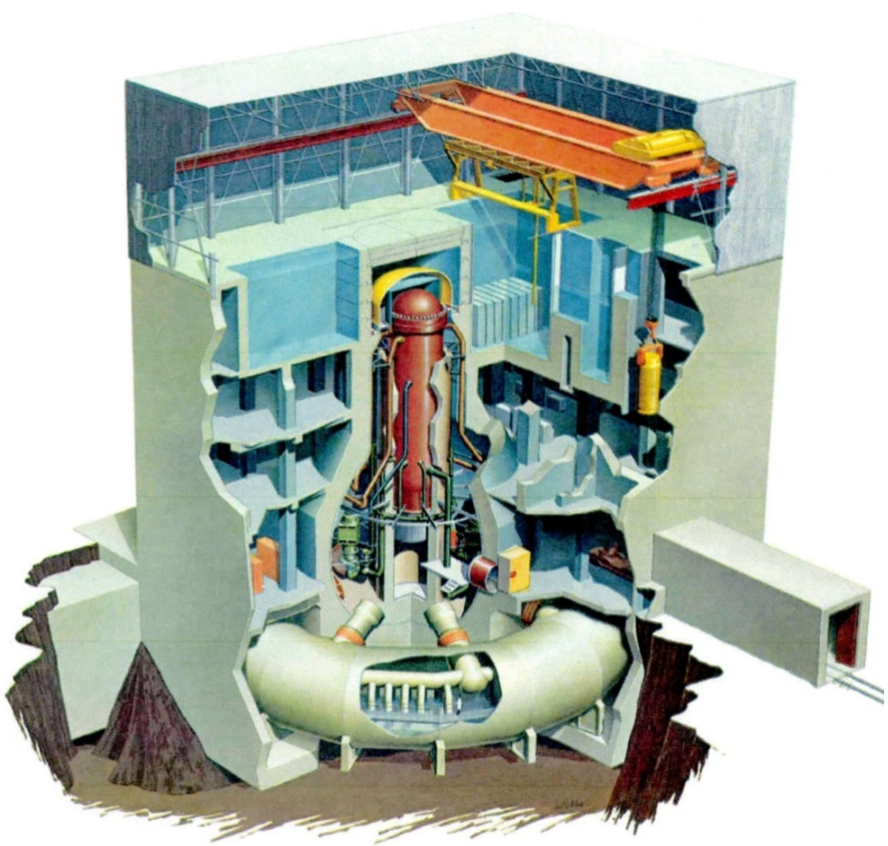
(4) The Investigation Committee on the Fukushima Nuclear Accident (TEPCO) (2012.6.20)

Reports and documents

All 6 reactors at the Fukushima Dai-ichi nuclear power station:
the boiling water reactor (BWR)

Mark I Containment

Reactor Concepts Manual — Boiling Water Reactor Sy



DRYWELL TORUS

at the time of the earthquake

Units 1, 2 and 3:
in operation

Units 4~6:
under regular maintenance

The earthquake triggered the scram systems for Units 1~3 to insert the control rods into the reactor cores to shut down chain reactions there

This happened as intended.

However, even after the reactors had been shut down, they still required active cooling to remove the decay heat, amounting to about 6% of the normal thermal power output of each reactor.

Loss of grid electricity due to the collapse of the transmission towers leading to Units 1~4 by the earthquake had automatically triggered the emergency diesel generators to power the reactor cooling system.

However, the generators were put out of action by the tsunami which arrived at the power station some 50 minutes after the initial earthquake The 14 m high tsunami overwhelmed the plants' seawall, which was only 10 m high, and the rooms housing the emergency diesel generators and most of the auxiliary batteries were inundated.

After this period, Units 1~3 experienced different histories due to different actions (or rather, "inactions") of emergency cooling systems:

*the IC (isolation condenser) for Unit 1,
*the RCIC (reactor core isolation cooling system) for Units 2 and 3 and
*the HPCI (high pressure coolant injection system) for Unit 3.

In the end, the reactor cores of all three Units had been overheated and melted down, so that the zirconium cladding of the fuel elements reacted with water to produce hydrogen gas.

The gas had built up to dangerous concentrations in the reactor buildings
→successive explosions of the buildings for
Units 1 at 15:36 on 12th March
Unit 3 at 11:01 am on 14th March
Unit 4 at around 6:10 am on 15th March (caused by hydrogen leak)
→the containment vessel of Unit 2 was damaged at around 11:00 am on 15th March but no hydrogen explosion of the building

Severe contamination of the surrounding area due to release of radio-active materials of (6.3~7.7)x10^{17} Bq (5.2x10^{18} Bq released at Chernobyl).

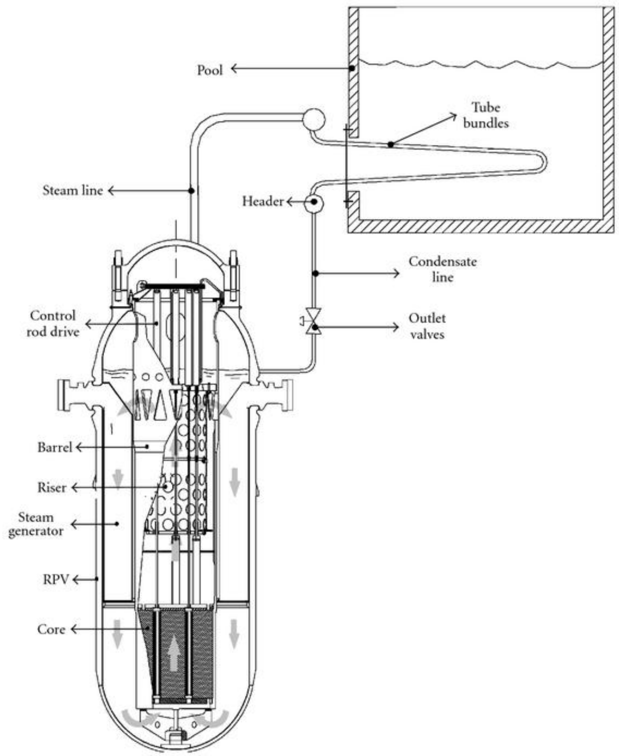
Unit 1

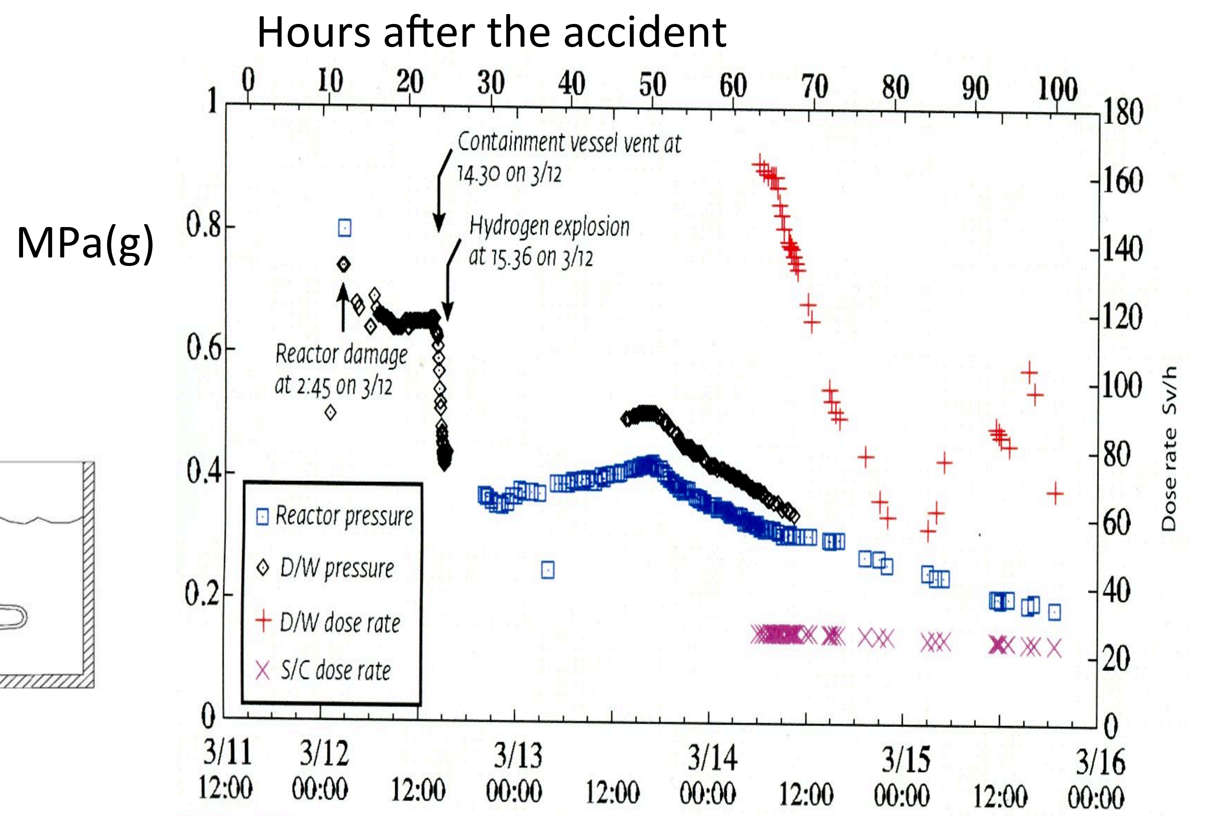
0.46 GW

March 1971

IC

Isolation Condenser





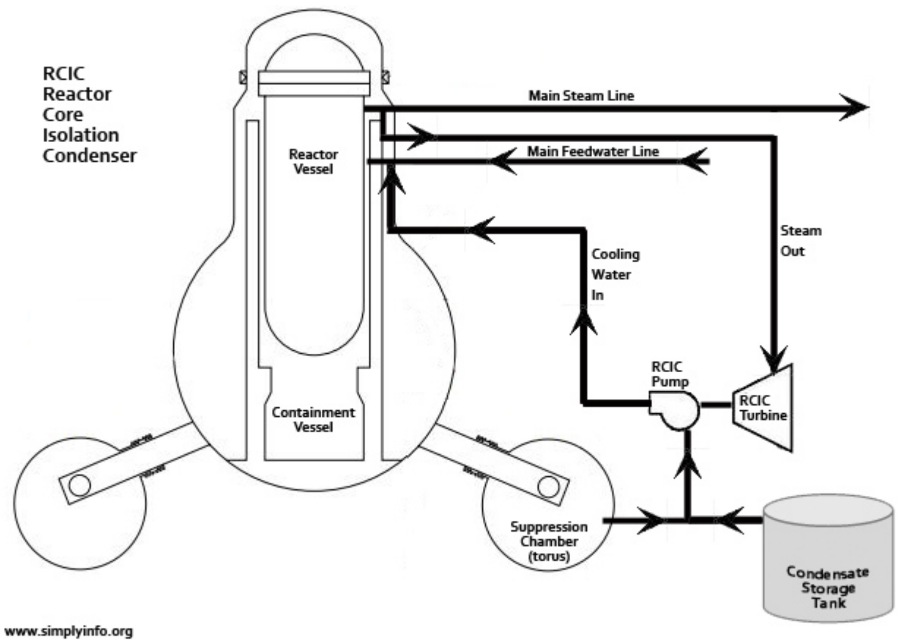
Unit 2

0.78 GW

July 1974

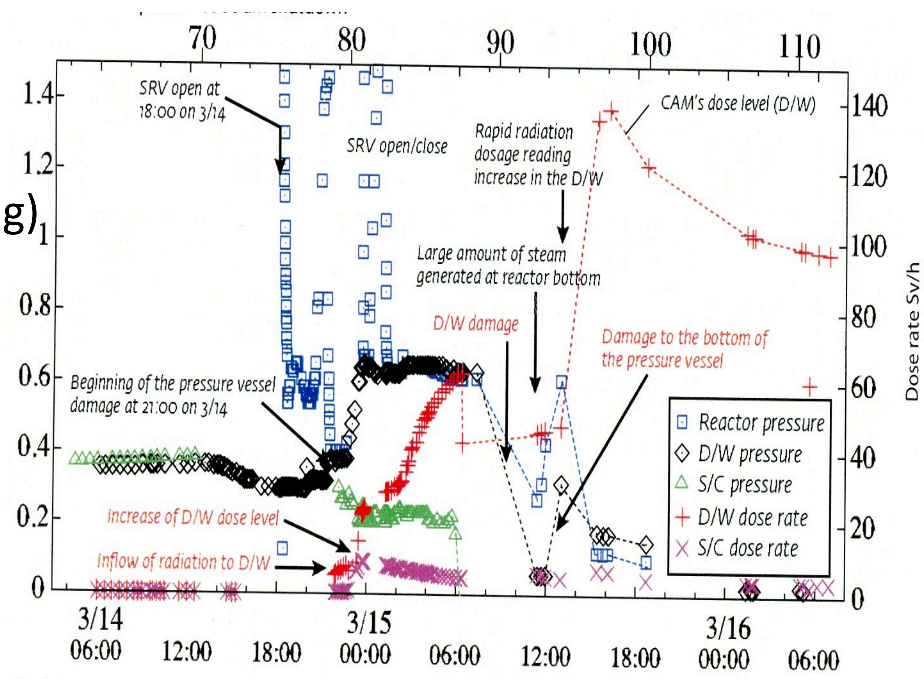
RCIC

Reactor Core Isolation Condenser



Hours after the accident

MPa(g)



Unit 3

0.78 GW

March 1976

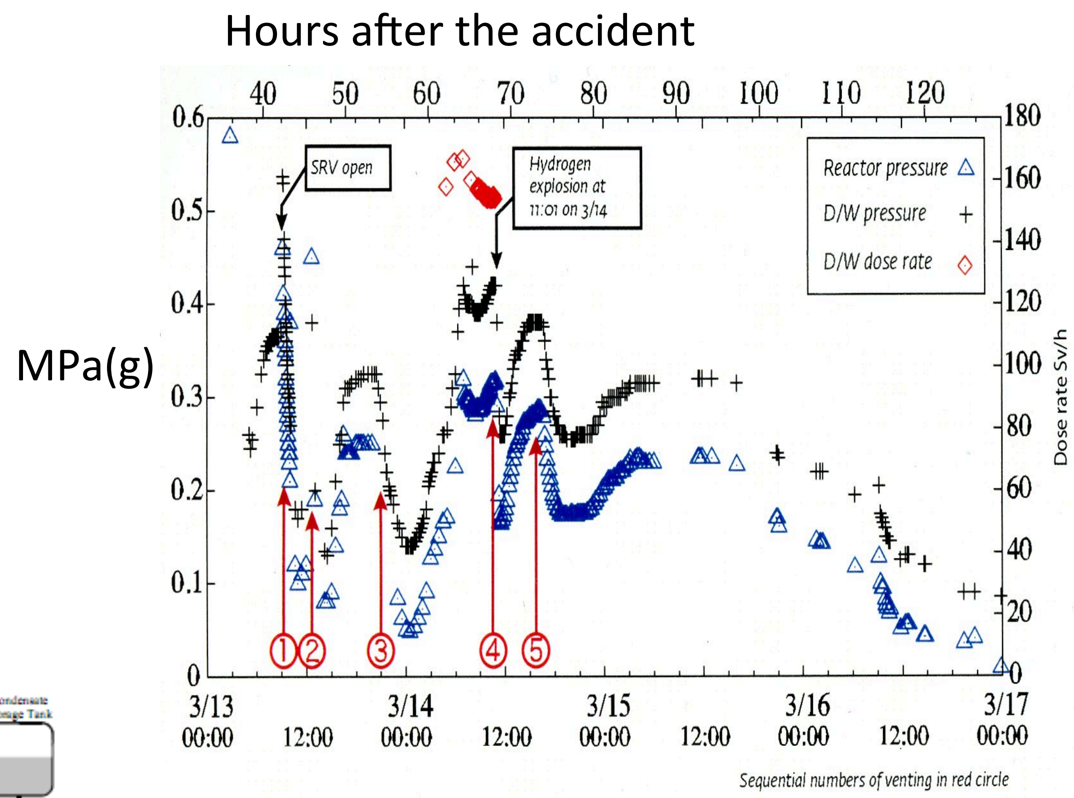
RCIC

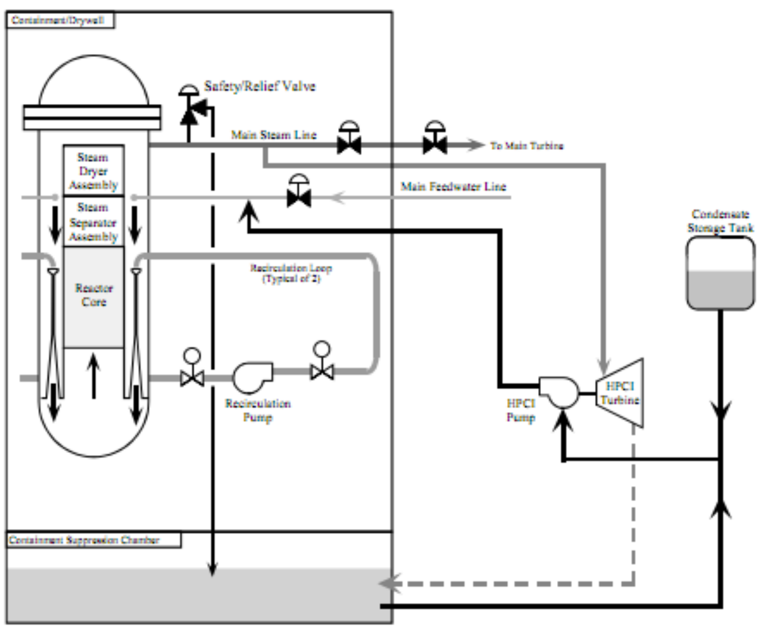
Reactor Core Isolation Condenser

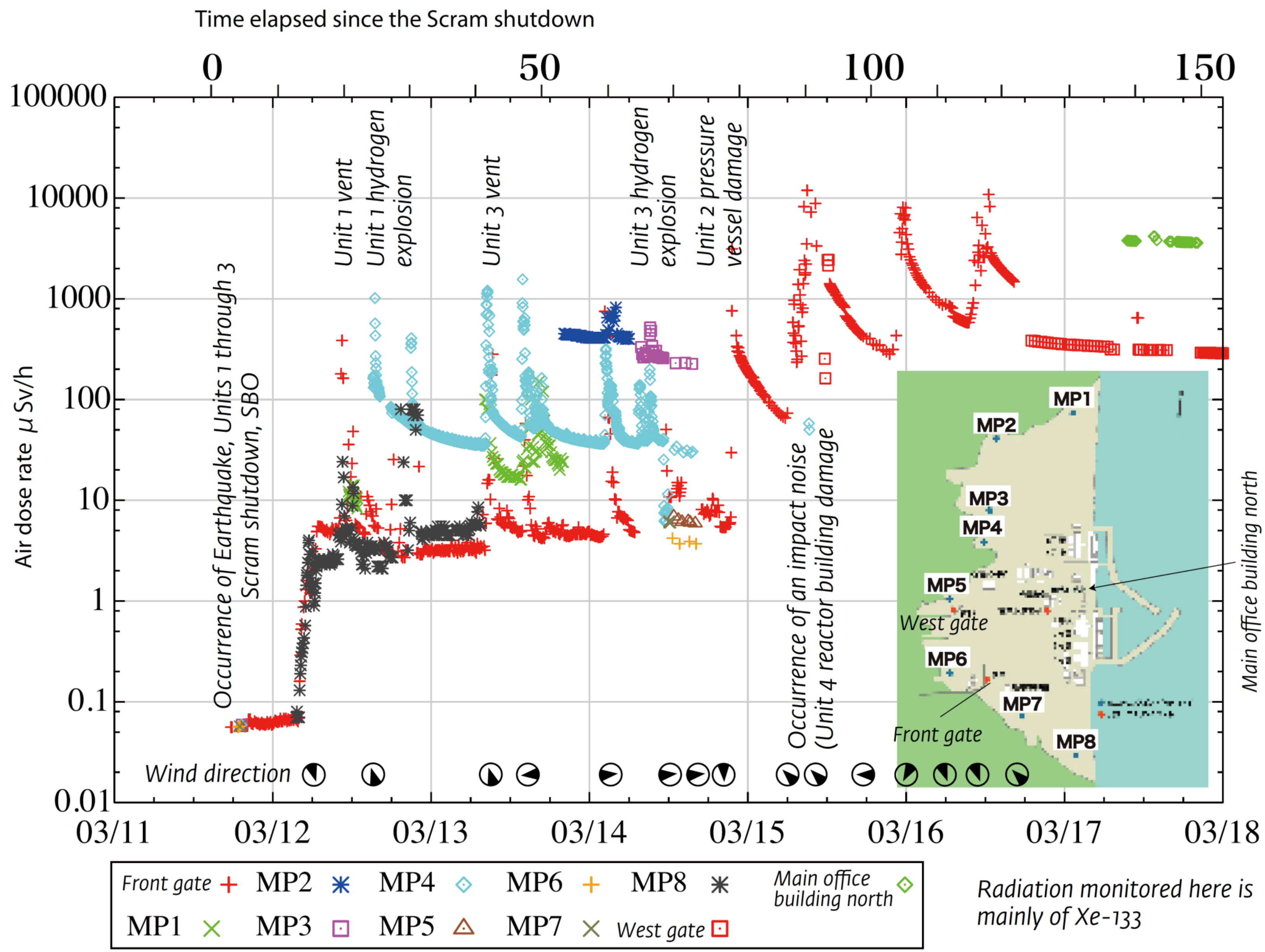
+

HPCI

High Pressure Coolant Injection







Note the unit of the ordinate at 1,000 μSv/h (=1 mSv/h)=8.76 Sv/y, if the dosage continues at this level for one year.

page 47 of The National Diet report

Damage and its effect and success or failure of accident preventive efforts				Fukushia Daiichi nuclear power plant					
				Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
Earthquake	Maximum acceleration①	Among all the recording maximum acceleration date on the base mat of the reactor building, the record set with the largest difference from the design basis earthquake is indicated. (Units: Gal)		460	550	507	319	548	444
	Design basis earthquake②			487	438	441	445	452	448
	Difference②−①			27	Δ 112	Δ 66	126	Δ 96	4
Tsunami	Inundation height③ (main building area)	Heights from the applicable peil, namely Onahama Peil for Fukushima Daiichi and Daini, Onagawa Peil for Onagawa, and Hitachi Peil for Tokai Daini, are indicated. (Units: meter)		15.5				14.5	
	Elevation above sea level ④ (same as above)			10				13	
	Difference④−③			Δ 5.5				Δ 1.5	
Shutdown	Scram			O	O	O	–	–	–
Cooling	Power source	AC pwr	External pwr source / Transmission, transformation	× (0/5)				× (0/2)	
			On-site pwr source / Emergency diesel generator	× (0/2)	× (0/2)	× (0/2)	× (0/2)	× (0/2)	Δ (1/3)
		DC pwr	D/C pwr source	× (0/2)	× (0/2)	O (2/2) →×	× (0/2)	O (2/2)	O (2/2)
		On site pwr source	M/C	× (0/5)	× (0/7)	× (0/6)	× (0/5)	× (0/8)	Δ (3/7)
			P/C	× (0/5)	× (4/7)	× (0/6)	× (2/5)	× (2/9)	Δ (3/7)
	Reactor cooling	High-pressure water injection		O→× (IC)	O→× (RCIC)	O→× (RCIC, HPCI)	–	–	–
		Depressurization		×	O (SR valve)	×	–	O SRV, (Pressure vessel top valave open)	–
		Low pressure water injection		×	×	×	–	O (MUWC)	O (MUWC)
		Containment vessel cooling or depressurization		×	×	×	–	–	–
		Removal of residual heat to the ultimate heat sink		×	×	×	–	O (RHR SHC)	O (RHR SHC)
		Seawater cooling instrument system (CCSW, RHRS, RSW, and so on)		× (0/2)	× (0/2)	× (0/2)	× (0/2)	× (0/2)	× (0/2)
Containing	Pellets, fuel rod cladding			×	×	×	–	O	O
	Pressure vessel, containment vessel			×	×	×	–	O	O
	Reactor building			×	×	×	×	O	O

able 2.1.5-2: Summary of
amages and its effects and
ccident preventive efforts at

O: **no damage or success**

Δ: **partial functionality loss or failure**

[red]: Excess of the design basis or functionality loss of all equipment instruments

[yellow]: Narrow margin to the tolerance or functionality loss o

page 48 of The National Diet report

Damage and its effect and success or failure of accident preventive efforts					Fukushia Daini nuclear power plant Unit 1	Unit 2	Unit 3	Unit 4
Earthquake	Maximum acceleration①			Among all the recording maximum acceleration date on the base mat of the reactor building, the record set with the largest difference from the design basis earthquake is indicated. (Units: Gal)	254	243	277	210
	Design basis earthquake②				434	428	428	415
	Difference②−①				180	185	151	205
Tsunami	Inundation height③ (main building area)			Heights from the applicable peil, namely Onahama Peil for Fukushima Daiichi and Daini, Onagawa Peil for Onagawa, and Hitachi Peil for Tokai Daini, are indicated. (Units: meter)	7 (14.5 on the south side of Unit 1)			
	Elevation above sea level ④ (same as above)				12			
	Difference④−③				5 (△1.5 on the south side of Unit 2)			
Shutdown	Scram				○	○	○	○
Cooling	Power source	AC pwr	External pwr source	Transmission, transformation	△ (1/4)			
			On-site pwr source	Emergency diesel generator	× (0/3)	× (0/3)	△ (2/3)	△ (1/3)
		DC pwr	D/C pwr source		○ (2/2)	○ (2/2)	○ (2/2)	○ (2/2)
		On-site pwr source	M/C		△ (9/11)	○ (7/7)	○ (11/11)	○ (7/7)
			P/C		△ (7/10)	△ (6/8)	△ (9/10)	△ (6/8)
	Reactor cooling	High-pressure water injection			○ (RCIC)	○ (RCIC)	○ (RCIC)	○ (RCIC)
		Depressurization			○ (SR valve)	○ (SR valve)	○ (SR valve)	○ (SR valve)
		Low-pressure water injection			○ (MUWC)	○ (MUWC)	○ (MUWC)	○ (MUWC)
		Containment vessel cooling or depressurization			○ (MUWC)	○ (MUWP)	○ (RHR-S/C cooling)	○ (MUWC)
		Removal of residual heat to the ultimate heat sink			○ (RHR-LPCI)	○ (RHR-LPCI)	○ (RHR-SHC)	○ (RHR-LPCI)
		Seawater cooling instrument system (CCSW, RHRS, RSW, and so on)			× (0/2)	× (0/2)	△ (1/2)	× (0/2)
Containing	Pellets, fuel rod cladding				○	○	○	○
	Pressure vessel, containment vessel				○	○	○	○
	Reactor building				○	○	○	○

The number of people used to have been living in the three affected zones (shown below) and to have had to be evacuated remains at 81,291 (as of 1st October 2013)

Three zones of affected areas:

(1) The area impossible to live in the near future

337 km^2,

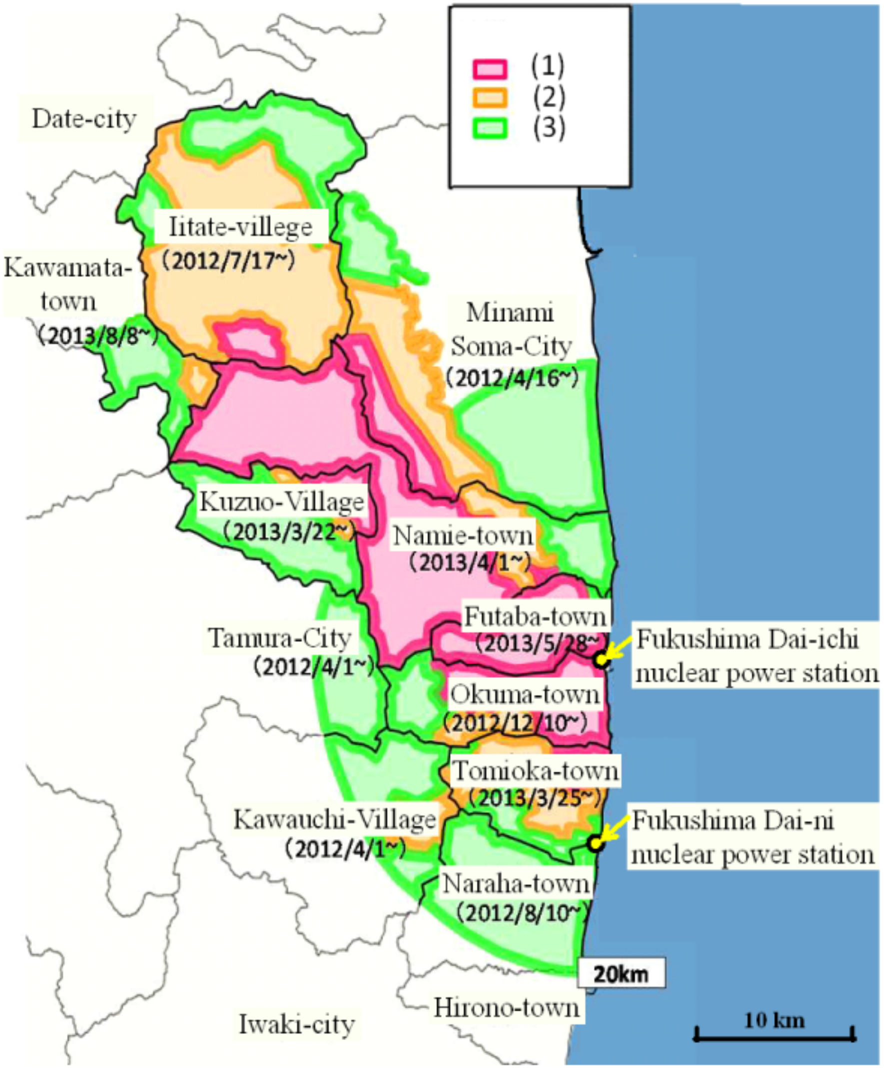
(2) The area to be accessible but not allowed to live

304 km^2, and

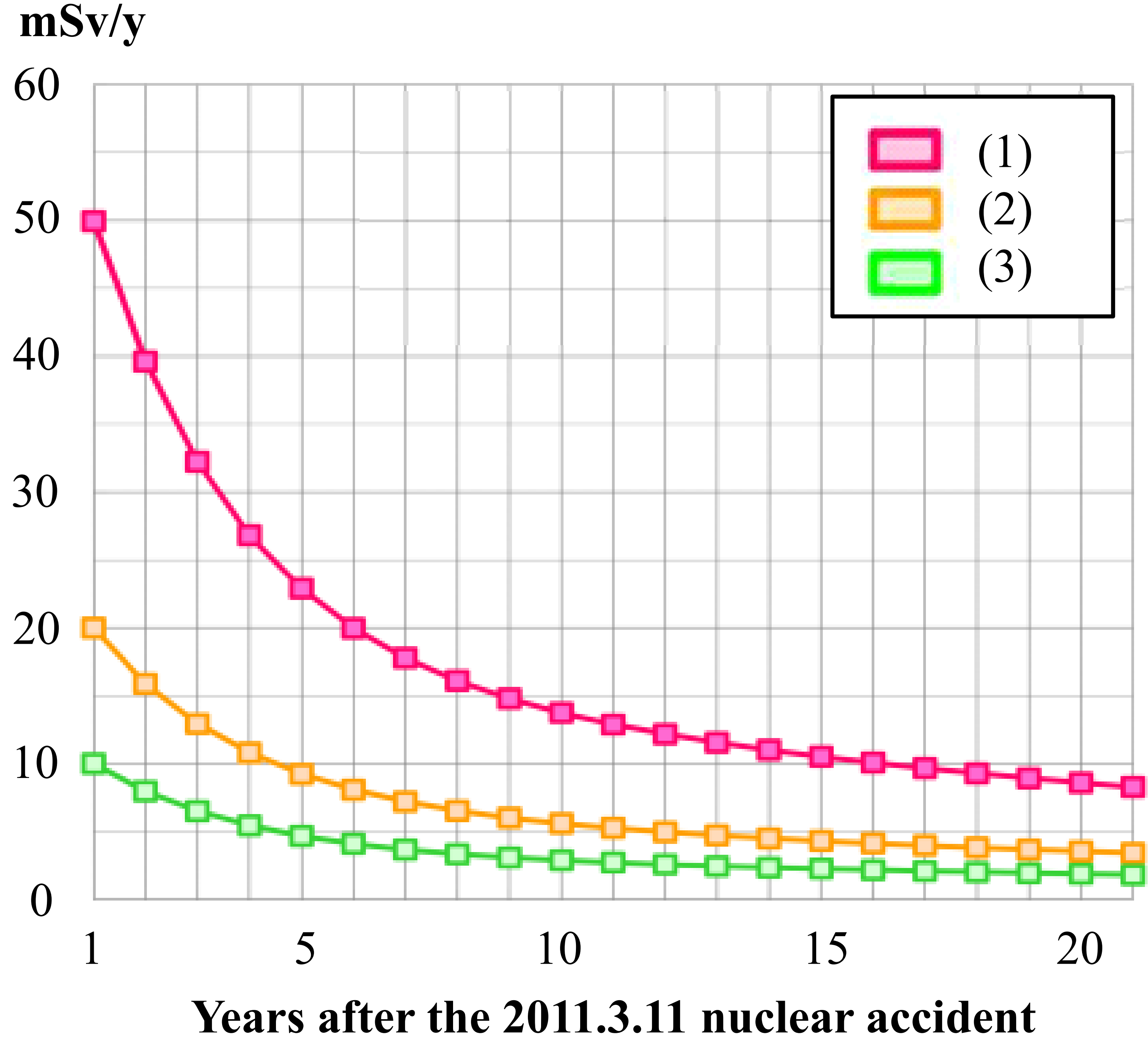
(3) The area to be preparing for living in the near future

509 km^2,

totaling 1,150 km^2 (34 km□)



The three zones (1), (2), and (3)


mSv/y
60
50
40
30
20
10
0
1
5
10
15
20
Years after the 2011.3.11 nuclear accident
(1)
(2)
(3)

The main causes of the nuclear accident:

(1) SBO (the station black-out) by the earthquake
→destroyed the electricity transmission towers leading to the nuclear power station,

(2) by the tsunami arrived at the power station after about 50 min
→inundated the emergency diesel and auxiliary battery power areas,

and

(3) heavily damaged/destroyed roads leading to the power station
→badly hampered the arrival of repair parts to the power station.

Professor K. Kurokawa,

The Chairman of the committee nominated by the National Diet

“Message from the Chairman”

“This was a disaster Made in Japan” and

“The fundamental causes are to be found in the ingrained conventions of Japanese culture: our reflexive obedience; our reluctance to question authority; our devotion to ‘sticking with the program’; our groupism; and our insularity”

One of the government committee members

Three elements to be considered separately and independently
to prepare for imminent accidents of nuclear power stations;

first “The nuclear power system” to prevent any failure,

secondly “Support systems in case of an accident”
such as communications and transportations, and

thirdly “Preparations for residents and their evacuations”.

All three investigation reports emphasized the complete lack of the first element

But **the more serious:** the total lack of any meaningful measures for the second and the third elements

Every decision with regards to the nuclear energy policy
→only by the inner-circle people,
completely shrouded from the outside world.

↓

"Residents in Gensiryoku-mura (a village where residents are all associated with nuclear energy)"

“The security myth surrounding nuclear energy”

They had treated nuclear power stations as “absolutely safe, because those are protected by many layers of safety measures”

They insisted this argument to the extent to have had behaved as if telling a possibility of any severe nuclear accident to happen be a false and instead used to tell that Chernobyl-type accident would never happen in Japan because the reactor type be completely different

These reasoning and arguments naturally lead to almost complete negligence of or being very reluctant to prepare for the above second and third elements

Actions and reactions worldwide

Three groups

The first group: Germany, Italy, Sweden and Switzerland

The second group: includes most other industrialized countries
such as USA, France and Britain

The third group consists: emerging economies, such as China and India

Japan ?

The International Atomic Energy Agency (IAEA)

“accelerating and enlarging the contribution of atomic energy to peace, health and prosperity throughout the world since its foundation in 1957”

The Action Plan for defining a program of work to strengthen the global nuclear safety framework: September 2011

12 main actions were listed, such as assessments of the safety vulnerabilities of the nuclear power stations in the light of the accident and strengthening of safety standards and their implementations

After more than three years.

still about 140,000 persons evacuated from their homes of residence

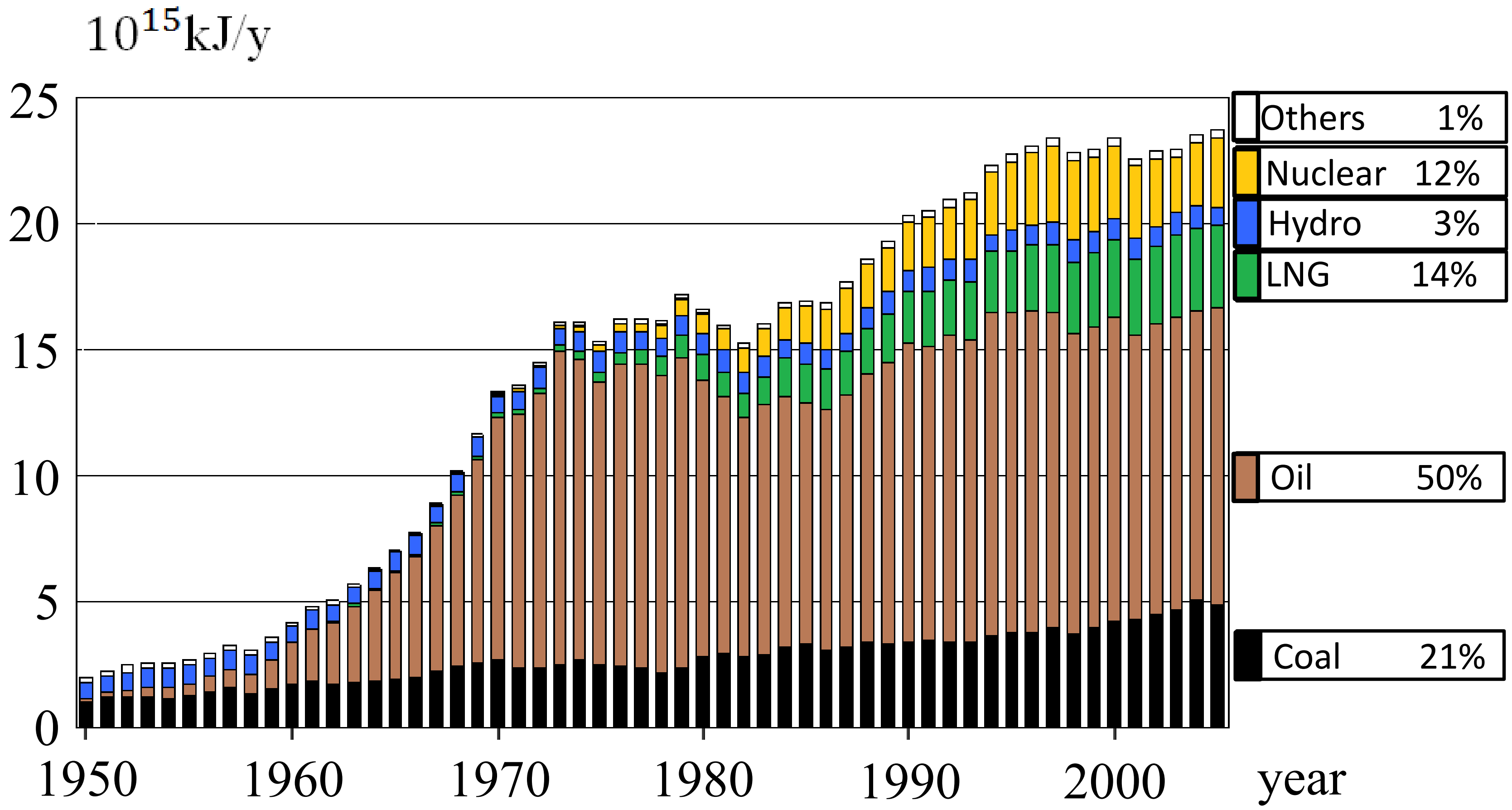
There was no loss of life due to radiation exposure during and after the 3.11 accident,
but there have been about 30 workers on site whose radiation level exceeded 100 mSv and about 90 residents who needed cleaning up of their contamination by radiation.

In addition, there has been death of about 60 people, mostly elderly, due to stress during evacuation in temporary housing.

↓

Let’s look back the past Japanese energy policies

3. The Japanese energy policy before 2011.3.11



The Japanese policy on nuclear energy : “Long-range plans”
at several stages of pivotal importance.

The plan of 1982: just after the two oil crises
“90 GW of nuclear power by the year 2000”

The plan of 1987: just after the Chernobyl accident
“100 GW of nuclear power by the year 2030”
→ reaffirmed in the plan of 1994

⇳

more than double the nuclear capability at the time of
the Fukushima Dai-ichi nuclear accident of 2011
with the capacity of about 49 GW from 54 nuclear reactors

Statement by Prime Minister Yukio Hatoyama
at the United Nations Summit on Climate Change

22 September 2009
New York

Mr. Secretary-General,
Excellencies,
Distinguished Delegates,
Ladies and Gentlemen,

It is my great pleasure to address this timely meeting of the United Nations Summit on Climate Change. I was appointed as Prime Minister of Japan six days ago, in a historic change of government achieved through the will of the people at the recent elections.

Climate change affects the entire globe and requires long-term and international efforts. Thus, it is imperative for all countries to address the issue under the principle of "common but differentiated responsibilities". With the change of government, as Prime Minister of Japan, I will now seek to unite our efforts to address current and future global climate change, with due consideration of the warnings of science.

[Reduction targets]

Allow me to touch upon the issue of reduction targets for greenhouse gas emissions.

Based on the discussion in the Intergovernmental Panel on Climate Change (IPCC), I believe that the developed countries need to take the lead in emissions reduction efforts. It is my view that Japan should positively commit itself to setting a long-term reduction target. For its mid-term goal, Japan will aim to reduce its emissions by 25% by 2020, if compared to the 1990 level, consistent with what the science calls for in order to halt global warming.

"With the change of government, as Prime Minister of Japan,
I will now seek to unite our efforts to address current and future global climate change, with due consideration of the warnings of science"

CO_2 reduction in 2020 by 25% compared with that for 1990

4. Turmoil in the Japanese energy policy after 2011.3.11

Japan has been experiencing the "Lost 20 years" since the burst of the economic bubble in the year 1990

political situations were very turbulent with changes of governments one after another

Because all government measures to stimulate economy to try to get out from the slump had turned out to be fruitless with the resultant mounting deficit of staggering more than double the Japanese GDP (the deficit of about 10 trillion US$, which is on average 80,000 US$/person)

Then came the fateful date of 2011.3.11 !

The above political turmoil was “well” matched by that of the energy policy of Japan during the three years after the 3.11 accident

before 2011.3.11: defined the energy policy of Japan to 2020 and beyond by being heavily dependent on nuclear energy

it was swiftly thrown away after the Fukushima accident to say that all nuclear reactors should terminate operation by the 2030’s !

this policy had a lifetime of only about one year, when the government was badly beaten at the Lower House election in December 2012

The newly formed government has since been very careful
to say anything provocative to people and
to try to conceal their real intentions

“Nuclear reactors are to be abolished as soon as possible”

“Resumptions of reactor operations as soon as
the Nuclear Regulation Authority declares their decision
of meeting their safety standards
combined with agreement of the local government of
each reactor”

“Top-sales by the prime minister
to market nuclear power stations
to various countries, such as Turkey or Vietnam”

In their "Fundamental Energy Plan",
approved on 11th April 2014 by its cabinet meeting,
the nuclear energy was labelled as "Bearing the base load
of electricity production"

Also, the fast-breeder reactor (FBR) project called "Monjyu",
the operation of which has been stopped since 1995
due to sodium leakage with subsequent various negligence
of regulations and which was almost being slashed
by the previous government, has been kept in this Plan
with more emphasis on nuclear transmutation of long-lived
radio-activities in addition to plutonium breeding

the present government must be behaving like this
in order to try to buy time

so heavily dependent on imports (96 %) of primary energy sources

fossil fuels would have to be almost completely eliminated in the next few decades

PV and wind energies be so limited for this over-populated country and so unreliable because of their intermittent character

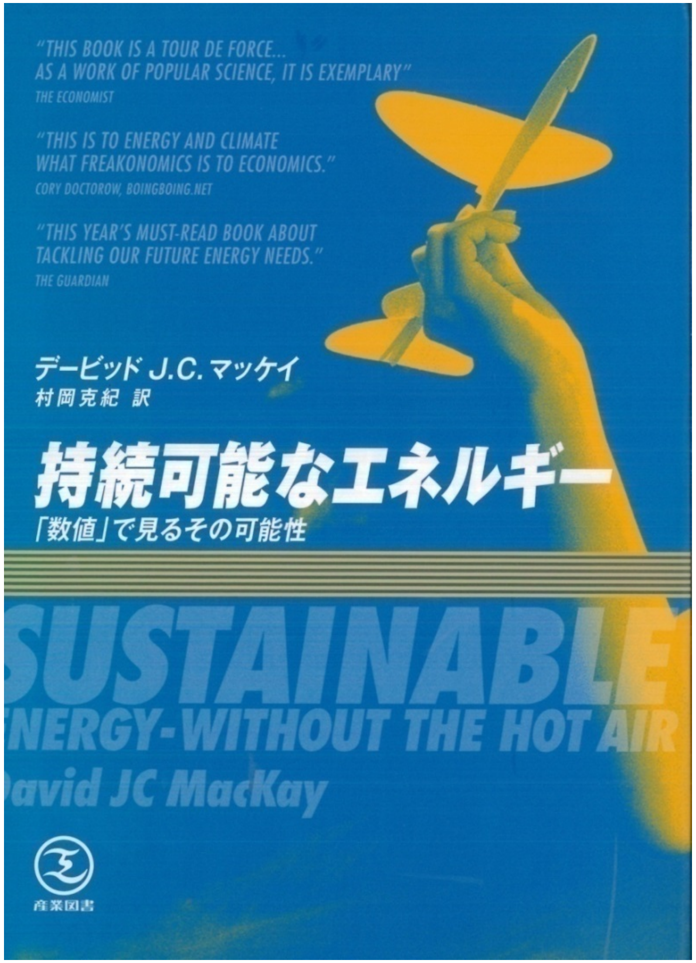
↓

this discussion will be focused on in the next Chapter

5. A personal projection of energy sources for Japan to 2050

we have to first realize the present situation regarding energy on which one may be able to chart everyone's future using "Numbers" for relevant quantities

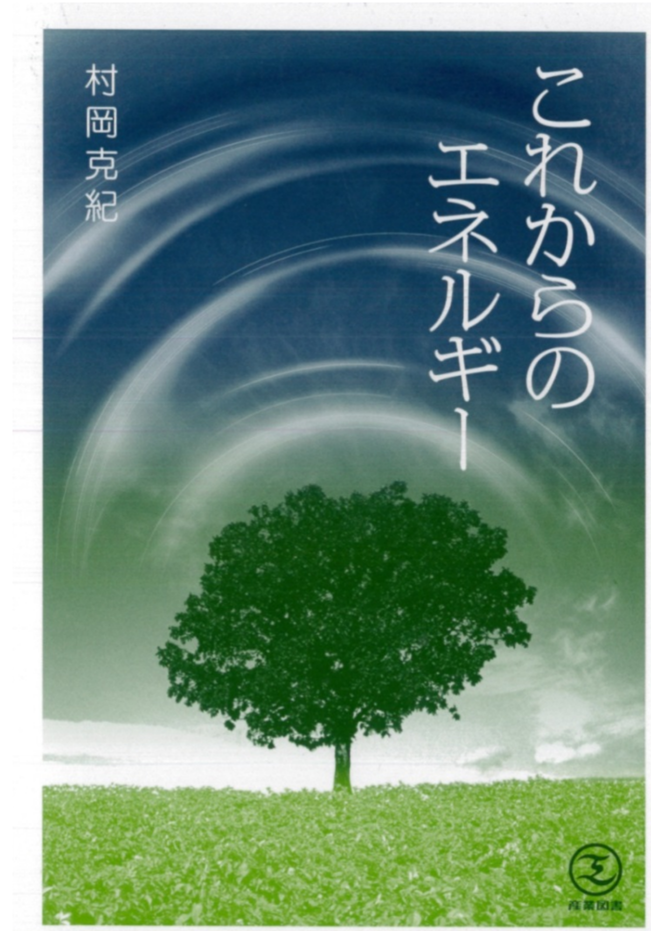
5·1. *The approach.* —



translation 2010
[kWh/person/day]

→

2011.3.11



Energies for the coming Age for Japan, 2012

Japan consumed 1.4×10^{19} Joule/y
just after 2011.3.11

↓

$$1.4 \times 10^{19} / (1.3 \times 10^{8} \times 365) / (3.6 \times 10^{6})$$

= 83 [kWh/person/day]

----

cf: France (87 [kWh/person/day]), Germany (85 [kWh/person/day]) the UK (63 [kWh/person/day]), China (43 [kWh/person/day]) and India (13 [kWh/person/day])

The distribution of 83 [kWh/person/day] for Japan
among various sectors

43% for industry (36 [kWh/person/day]),
14% for household (12 [kWh/person/day]),
20% for offices/services (17 [kWh/person/day]) and
24% for transportation (20 [kWh/person/day])

the population change (the Japanese population to decrease by about 30 % by 2050):
the unit [kWh/person/day] is not directly affected by the population change

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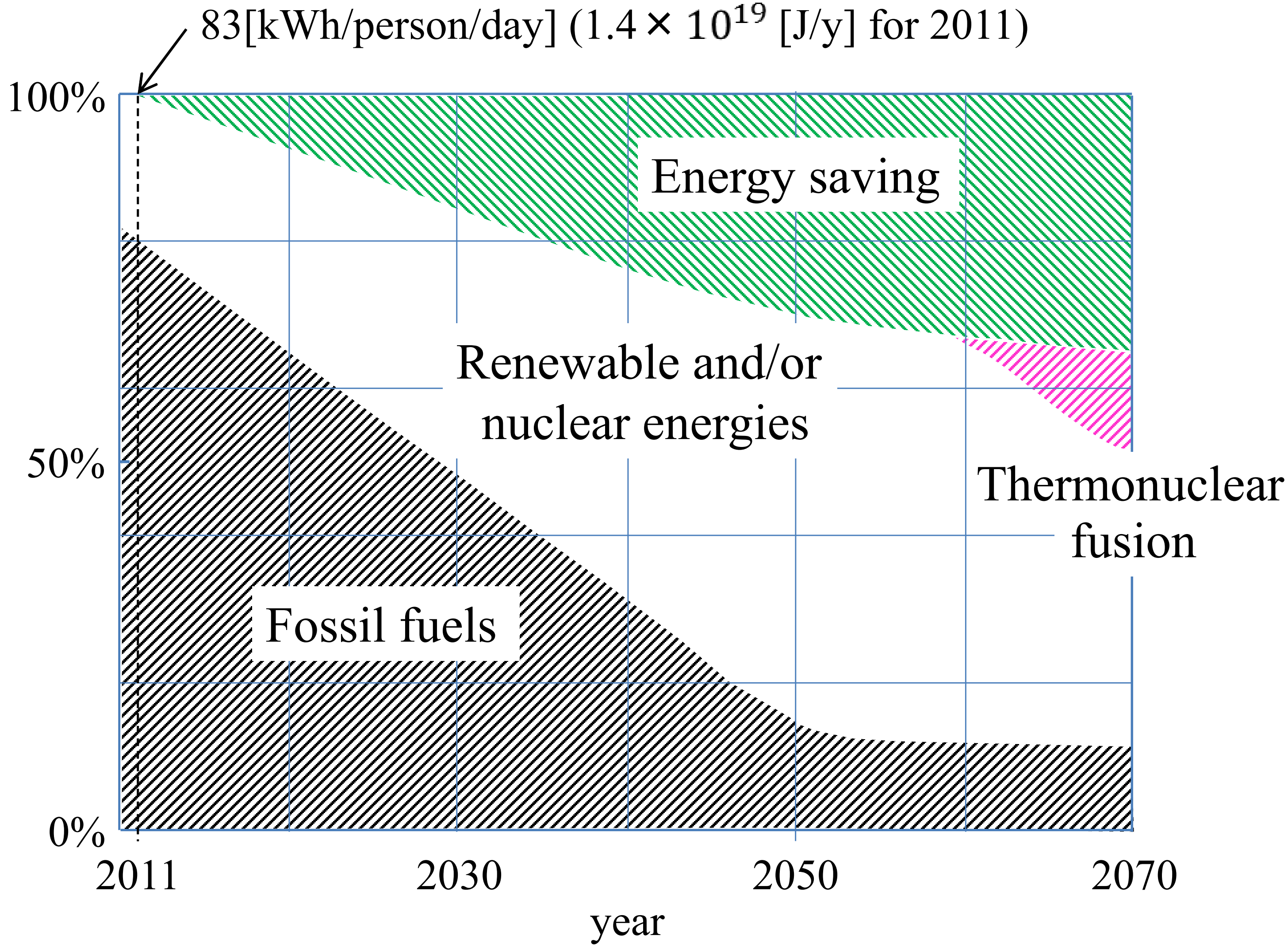
5·2. *The present Japanese status and a projection to 2050*

Just before 2011
fossil fuels: 83 %
nuclear: 11 %,
hydroelectricity: 3 %
others: 3 %



A possible scenario of the Japanese energy consumption to 2050 [16].
"Thermonuclear fusion" is described later in Section 5·7.

(1) Energy saving → the author's estimate: 30% reduction

(to 58 [kWh/person/day])

the author assumed

◎much reduction in industry and transportation,
expecting efficiency improvements
(eg, increased use of electric vehicles)
and other means,

◎household and service sectors to keep almost the present values
bearing in mind that increased energy needs
in ever aging society will match efficiency improvements
(eg, electrical appliances)

The resulting distribution among sectors:

38% for industry (22 [kWh/person/day]),
19% for household (11 [kWh/person/day]),
26% for offices/services (15 [kWh/person/day]) and
16% for transportation (9 [kWh/person/day])

(2) Reduction of fossil fuels → From 83 % to less than 10%

(to 8 [kWh/person/day])

----

60 % of 83 [kWh/person/day]=50 [kWh/person/day]
to be covered using renewable and nuclear energies

How big is 1 [kWh/person/day] ?

1 [kWh/person/day]x1.3x10^8x365=47 TWh/y:
1/83=1.2% of the total energy consumption, and
5 % of the present electricity production of 1.1x10^{12} kWh/y

1 [kWh/person/day]x1.3x10^8/24=5.4 GW
5 units of an electric power station having an output of 1 GW each

5·3. *Renewable energies* 1

Hydroelectricity: 3 [kWh/person/day]. no further exploitation

Geothermal energy: 0.1 [kWh/person/day]

potential in future 2 [kWh/person/day]

Biomass from plants and use of waste energies: hopeless

Future wave and tide energies: not exceed 5 [kWh/person/day]

↓ Combined

10 [kWh/person/day].

→ Remaining 40 [kWh/person/day]

Potential of PV and wind

the biggest hopes of renewable energies in any country

the limiting factors for Japan: limited land area (3.8×10^{11} m^2)
against large population (1.3×10^8)

PV: 15 [W/m^2]

2,950 [m^2/person]

↓ 100% of land

1,060 [kWh/person/day]

↓ 4% of land

40 [kWh/person/day]

Wind: 2 [W/m^2] from onshore and
3 [W/m^2] from offshore

↓ 11 % of her combined land and ocean area
40 [kWh/person/day]

Reasonable estimates of PV and wind to 2050

At the end of 2012：PV 5.5×10^6 kW and wind 2.6×10^6 kW

1.2% of the annual electricity production of 1.1×10^{12} kWh→ still "primordial"

PV and onshore wind parks to 1 %→ 11.4 [kWh/person/day]
offshore wind parks to 5 %→ 11 [kWh/person/day]

↓ combined
23 [kWh/person/day], 58 % of 40 [kWh/person/day]

5·4. *Nuclear energy*

A district court ruling on 21st May 2014:

not to allow operations for the two reactors,
because the assumed acceleration of 700 Gal (7 m/s^2) due to an earthquake be groundless in the light of the experience of the Fukushima Dai-ichi nuclear accident

---

6 [kWh/person/day] before the 2011.3.11

The most optimistic in 2050 : double the above12 [kWh/person/day]

The opposite side: no reactors

Concerns for nuclear waste treatments

already piled-up wastes
+ for decommissioning
+ low active wastes

5·5. *Possible scenarios to 2050*

the maximum possible
23 [kWh/person/day] (PV and wind) +
12 [kWh/person/day] (nuclear)=35 [kWh/person/day]
↓
below 40 [kWh/person/day]

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(1) Necessary investments for PV and wind

stresses on grids and the surplus power
⇕
storage of electrical energy

FIT

(2) Uncertainties surrounding the nuclear energy

5·6. *Possible remedies to save the situation*

More energy saving

→drastic changes in the way of life for all average citizens

more fossil fuels

CCS (Carbon Capture and Storage) ?

5·7. *A possible role that fusion energy may play*

ITER (International Thermonuclear Experimental Reactor): 2021 ~ 2040

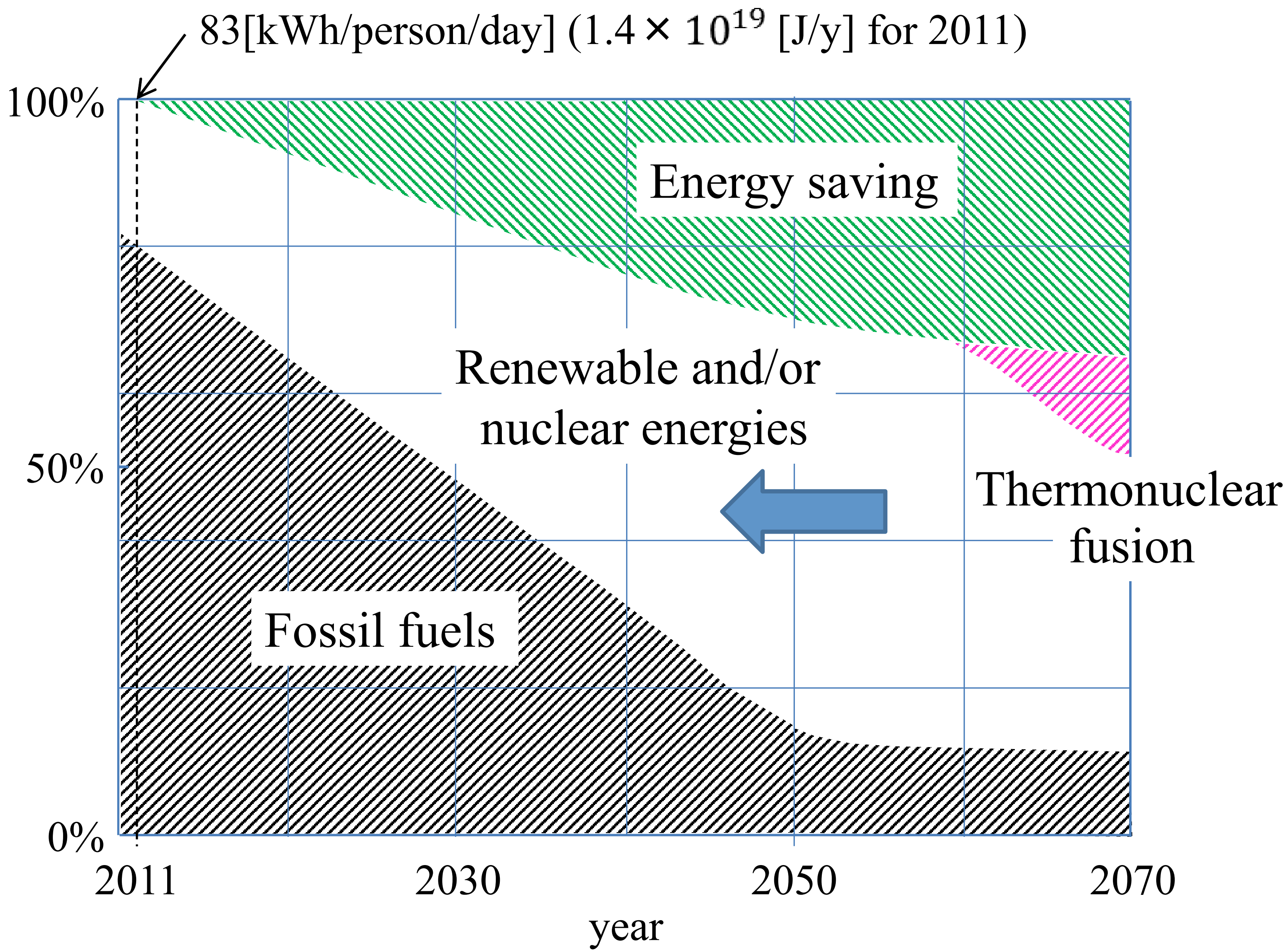
Demonstration Power Reactor (DEMO): 2045 ~ 2060

Power to grids: 2060 ~

⇕

"Fusion will be there when society needs it"

by L Artsimovich



83[kWh/person/day] (1.4 × 10^19 [J/y] for 2011)
100%
50%
0%
Energy saving
Renewable and/or nuclear energies
Thermonuclear fusion
Fossil fuels
2011
2030
2050
2070
year

7. Summary

Two messages

(1) the background, the event and the resultant casualties of the 2011.3.11 nuclear accident, and

(2) to draw possible charts for energy options for Japan from present to future

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Civilian control