

Protecting Citizens Against Radiation in the Aftermath of the Fukushima Nuclear Accident in Japan

從日本福島核災談民眾輻射防護

國立清華大學
台灣新竹
2013年9月10日

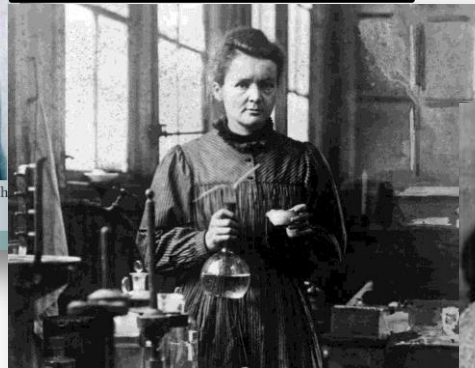
陳士友博士
美國伊利諾理工學院

歷史及背景: 幅射線和我們的日常生活

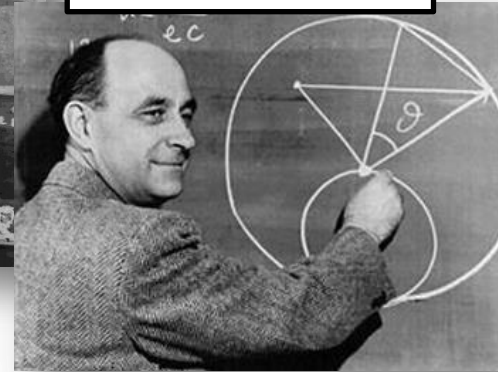
1895 – Discovery of X-Ray (Wilhelm Roentgen)



1898 – Radioactivity (Marie Curie)



1943 – Atomic Pile (Enrico Fermi)



Signing the Atomic Energy Act of 1954. President Eisenhower, at his desk, August 30, 1954, after signing the Atomic Energy Act (see excerpts on page viii). Seated: President Eisenhower, Rep. Sterling Cole (R-NY), Atomic Energy Commission (AEC) Chairman Lewis Strauss. Back: Military Liaison Commission Chairman Herbert B. Langer, Sen. Edwin C. Johnson (D-CD), Rep. Carl Hinchey (R-CA), Rep. James E. Van Zandt (R-PA), Rep. Melvin Price (D-IL), Rep. Carl T.

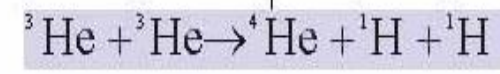
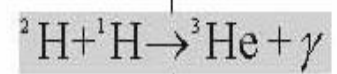
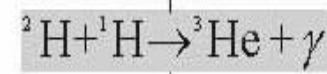
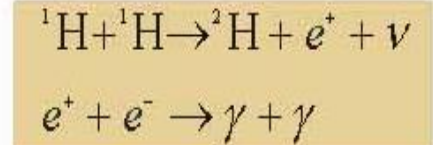
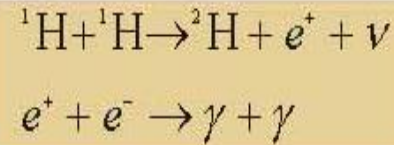
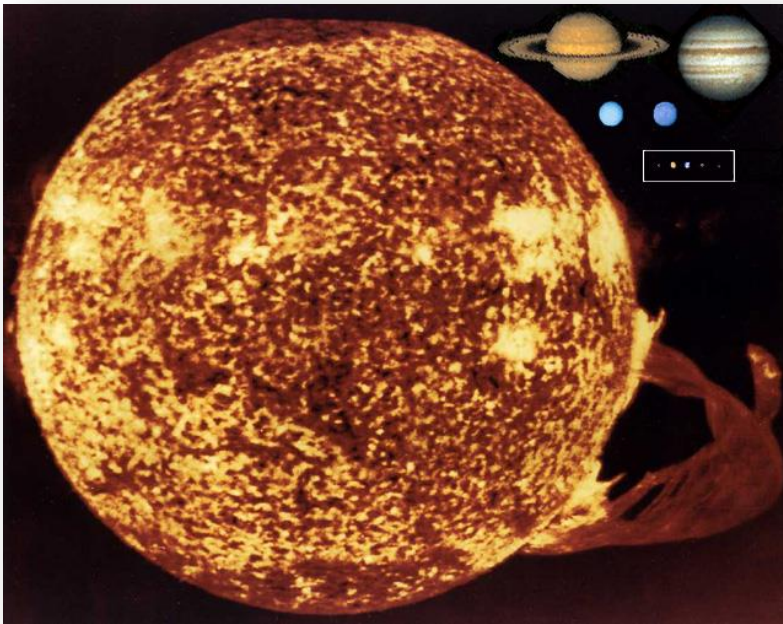
1954 - Atoms for Peace (Dwight Eisenhower)



Atomic power will make
electricity “too cheap to meter”
– Glenn Seaborg, Chair, USAEC

The Sun: Nature's Nuclear Power Plant

Thermonuclear Fusion Reactions Continue to
Power the Energy of the Sun



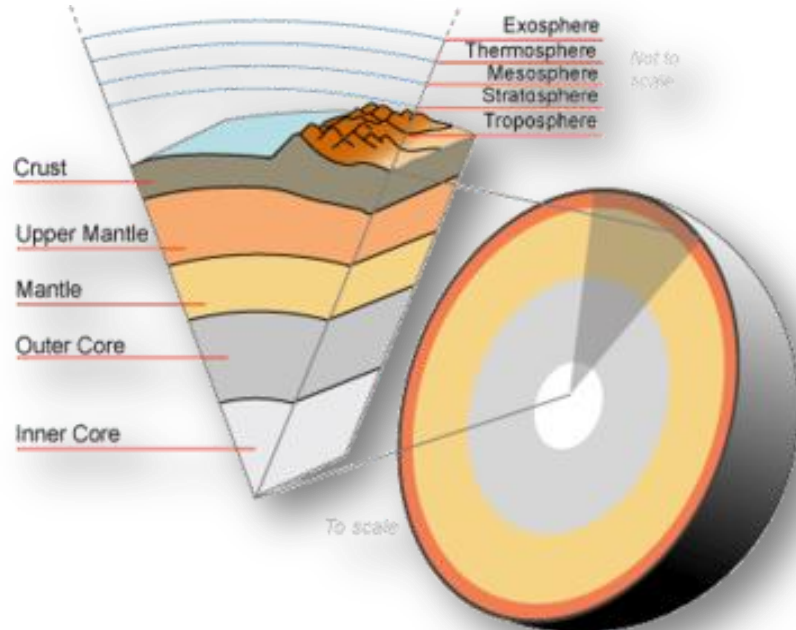
Fusion cycle of the Sun

The Sun's energy output is 3.86×10^{26} Joule/s, or equivalent to about 2×10^9 large A-Bombs.

(This cycle releases 26.7 MeV of energy, 5 million times greater than 5 eV released by 4H-2O chemical reaction)

Naturally occurring materials are prevalent radioactive decay powers heat in Earth

The decay heat of naturally occurring radionuclides helps sustain the geothermal energy on the Earth: of 44 TW ($1 \text{ TW} = 10 \times 10^{12} \text{ W}$) of energy produced by Earth about **50% (20 TW)** is generated by **radioactive decay heat**.



Earth Internal Heat Sources

- 20% from planetary accretion
- 80% from natural radioactive decay
- Earth heat is replenished at a rate of 30 TW (annual world power consumption rate: 16 TW)

Natural Radioactivity Near Surface

- About 10^{15} Ci in Earth's crust (within 10 Km thick)
- **Estimated Age of the Earth = 4.5 billion years**

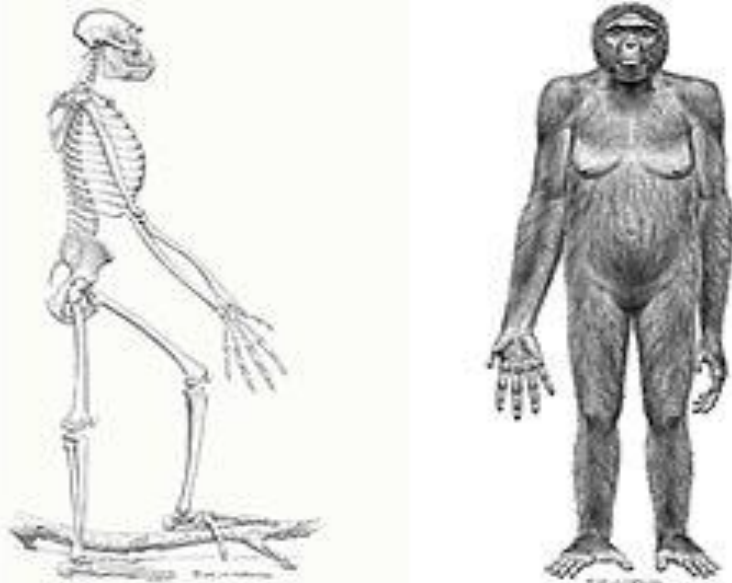
There are equivalent of **more than 3,000 nuclear power reactors** (at 3,000 MW) continuously generating heat in the Earth by **radioactive decay**.

Mankind has been living with radiation since its existence for several million years

- It took Mother Nature a long while (about 4.5 billion years) to provide a friendly environment to humans)
- Spontaneous mutations helps the evolution process
- Human body contains about 5,000 Bq (or 0.1 μ Ci) of K-40
- Our diets contain natural radioactivity

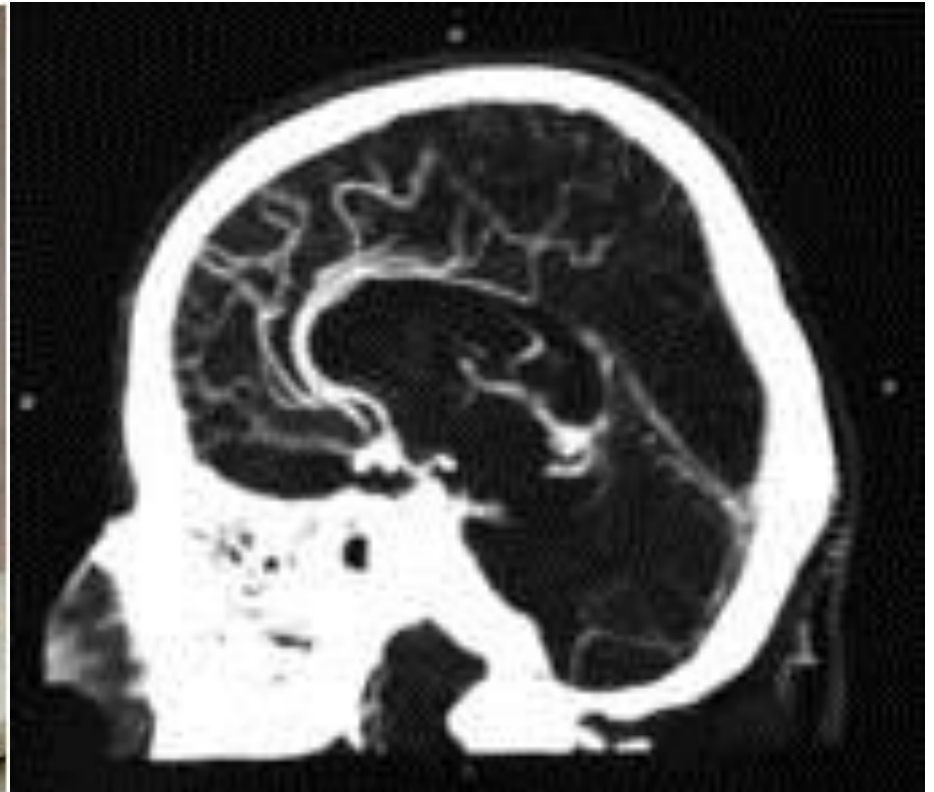
“Ardi” the Earliest Human Found

- 4.4 Million Years Old
- Humans having been living with radiation for a long time



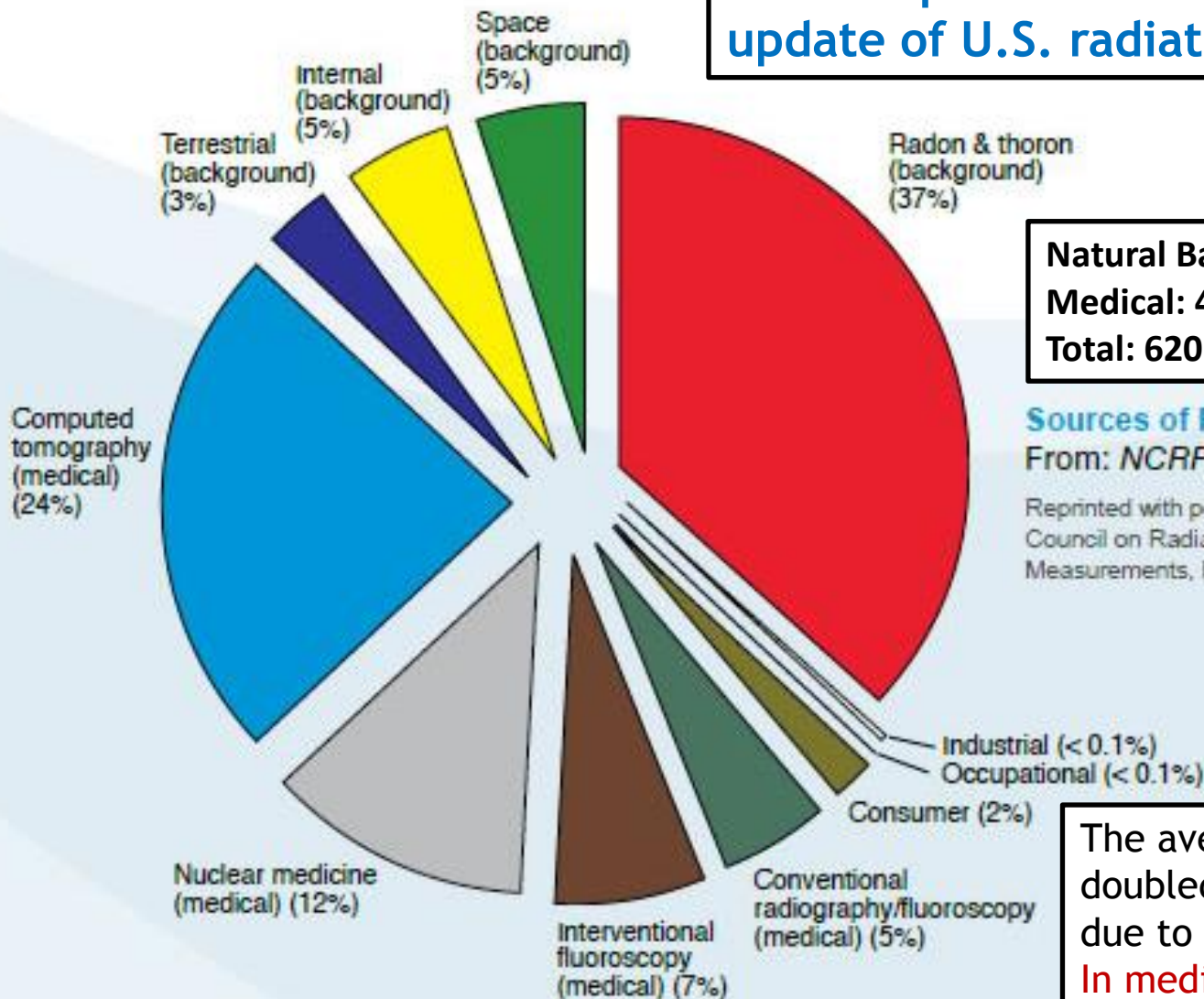
Modern nuclear medicine & technology offers a new approach to diagnostic and treatment

CT (Computed Tomography) Scan: 62 million procedures with average annual growth rate > 10% (ICRP Report 160)



From X-Rays to Gamma Radiations to Electrons, Neutrons and Protons

NCRP Report 160: update of U.S. radiation exposure



Natural Background: 50%
Medical: 47%
Total: 620 mSv/y

Sources of Radiation Exposure
From: *NCRP Report No. 160*

Reprinted with permission of the National Council on Radiation Protection and Measurements, <http://NCRPonline.org>

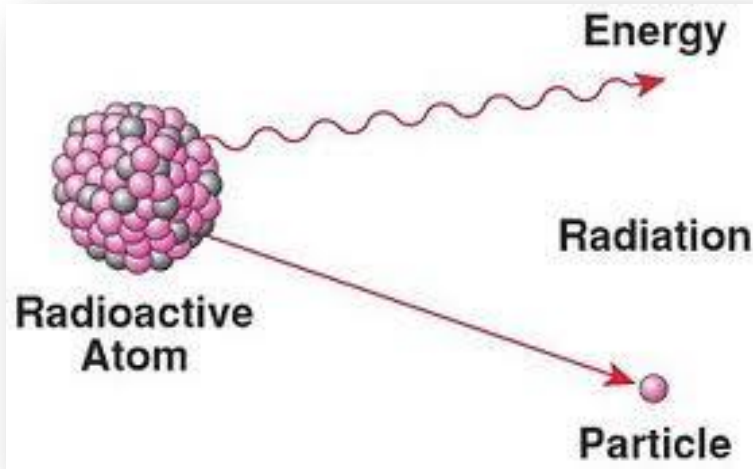
The average dose has doubled in 20 years due to a **6-fold increase** in medical exposure.

Figure reprinted with permission of the [National Council on Radiation Protection and Measurements](http://NCRPonline.org).

輻射線的特性及防護

| Group → ↓ Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---------------------|----------|----------|---|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|-----------|------------|-----------|------------|------------|
| 1 | 1 H | | | | | | | | | | | | | | | | | 2 He |
| 2 | 3 Li | 4 Be | The Periodic Table of Chemical Elements | | | | | | | | | | 5 B | 6 C | 7 N | 8 O | 9 F | 10 Ne |
| 3 | 11 Na | 12 Mg | | | | | | | | | | | 13 Al | 14 Si | 15 P | 16 S | 17 Cl | 18 Ar |
| 4 | 19 K | 20 Ca | 21 Sc | 22 Ti | 23 V | 24 Cr | 25 Mn | 26 Fe | 27 Co | 28 Ni | 29 Cu | 30 Zn | 31 Ga | 32 Ge | 33 As | 34 Se | 35 Br | 36 Kr |
| 5 | 37 Rb | 38 Sr | 39 Y | 40 Zr | 41 Nb | 42 Mo | 43 Tc | 44 Ru | 45 Rh | 46 Pd | 47 Ag | 48 Cd | 49 In | 50 Sn | 51 Sb | 52 Te | 53 I | 54 Xe |
| 6 | 55 Cs | 56 Ba | | 72 Hf | 73 Ta | 74 W | 75 Re | 76 Os | 77 Ir | 78 Pt | 79 Au | 80 Hg | 81 Tl | 82 Pb | 83 Bi | 84 Po | 85 At | 86 Rn |
| 7 | 87 Fr | 88 Ra | | 104 Rf | 105 Db | 106 Sg | 107 Bh | 108 Hs | 109 Mt | 110 Ds | 111 Rg | 112 Cn | 113 Uut | 114 Fl | 115 Uup | 116 Lv | 117 Uus | 118 Uuo |
| Lanthanides | | | 57 La | 58 Ce | 59 Pr | 60 Nd | 61 Pm | 62 Sm | 63 Eu | 64 Gd | 65 Tb | 66 Dy | 67 Ho | 68 Er | 69 Tm | 70 Yb | 71 Lu | |
| Actinides | | | 89 Ac | 90 Th | 91 Pa | 92 U | 93 Np | 94 Pu | 95 Am | 96 Cm | 97 Bk | 98 Cf | 99 Es | 100 Fm | 101 Md | 102 No | 103 Lr | |

Radioactive decay

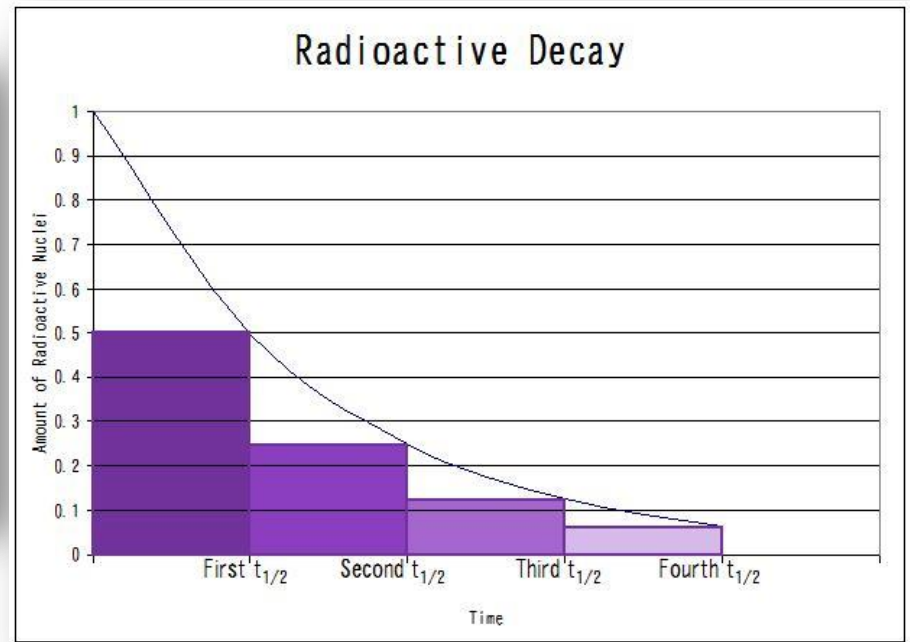


Release from decay

Alpha particle α

Beta particle β

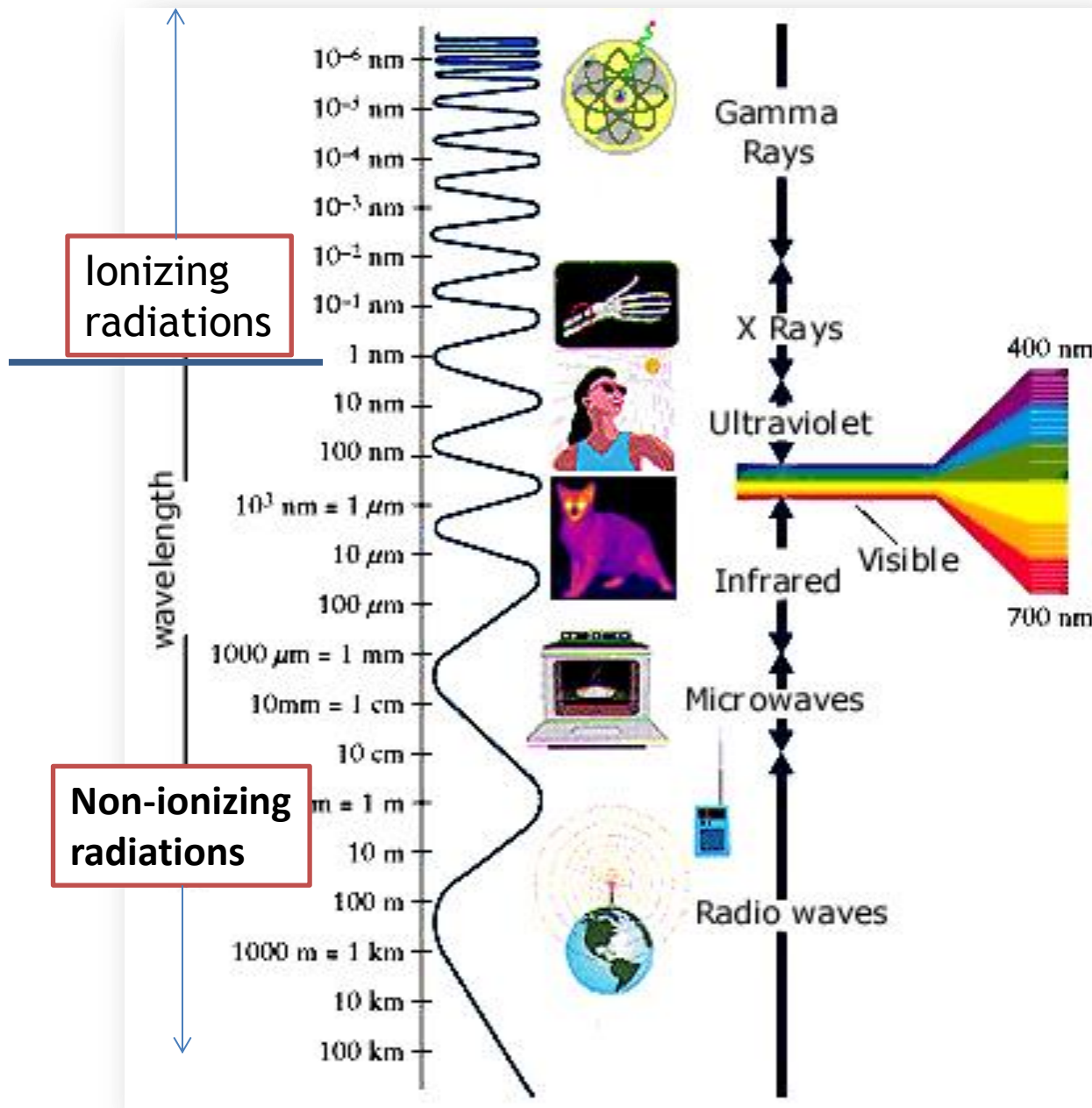
Gamma ray γ



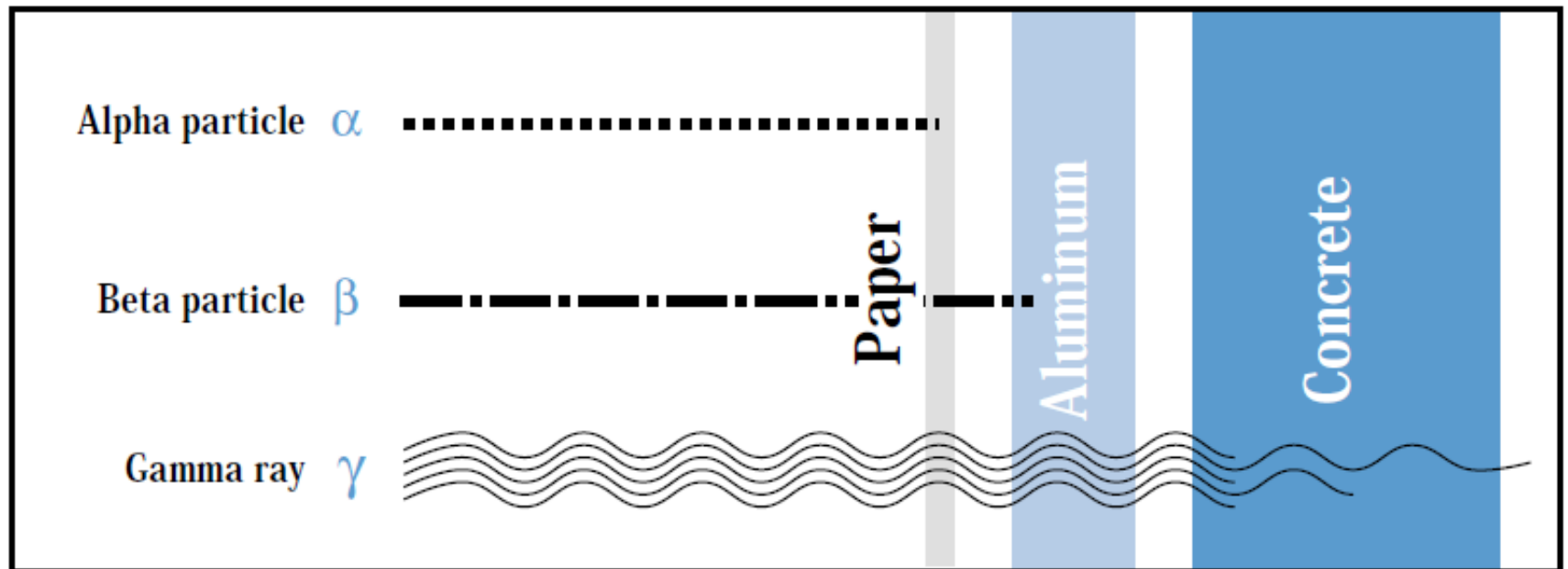
| Radioisotope | Half Life (Years) |
|--------------|-------------------|
| K-40 | 1.3×10^9 |
| U-238 | 4.5×10^9 |
| Co-60 | 5.3 |
| Cs-137 | 30 |

(By comparison, life of the Earth is 4.5×10^9 years)

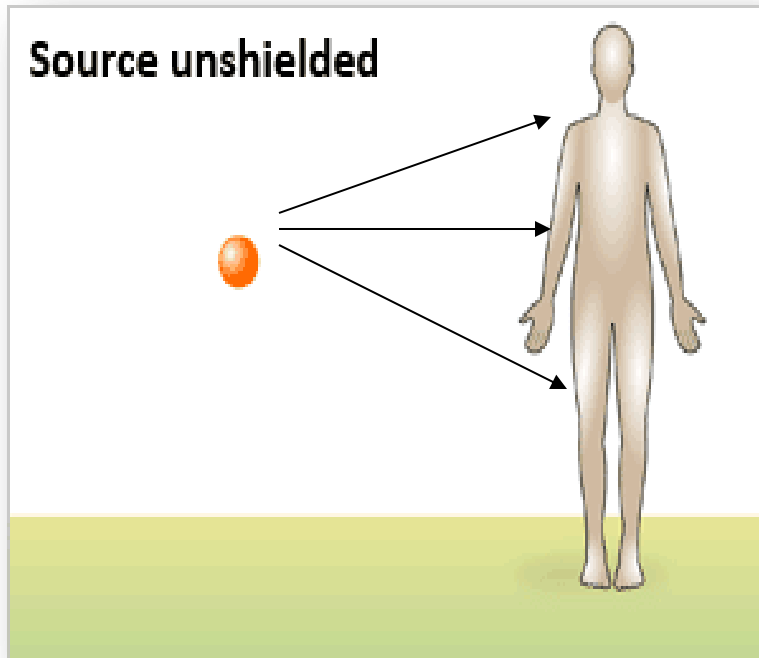
Spectrum of photons



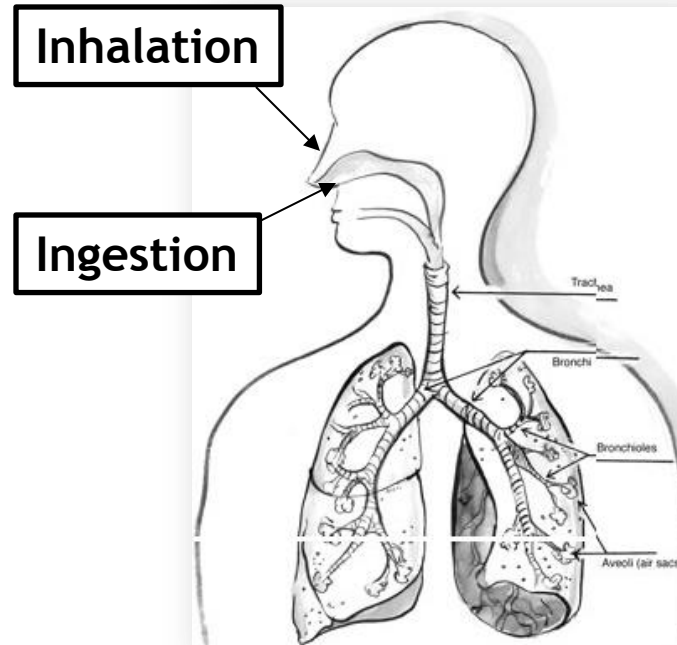
Radiations and shielding



Primary exposure pathways to humans are via external & internal exposures



External Exposure (Direct Shine)



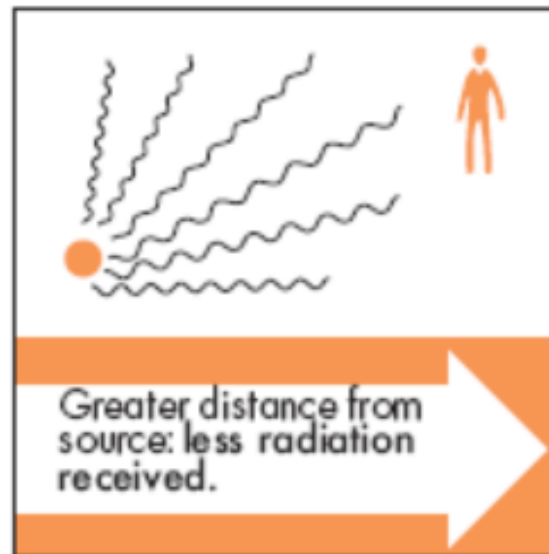
Internal Exposure

(Other Modes of Exposure: Dermal Absorption and Intake through Wounds)

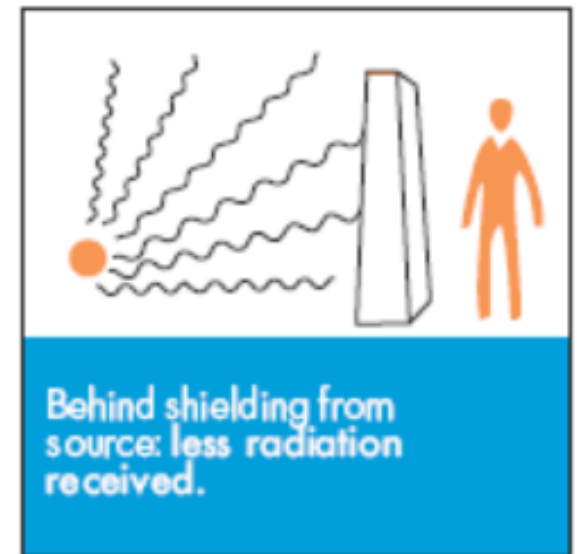
Radiation protection methods against external radiations (X- or γ -Rays)



Time

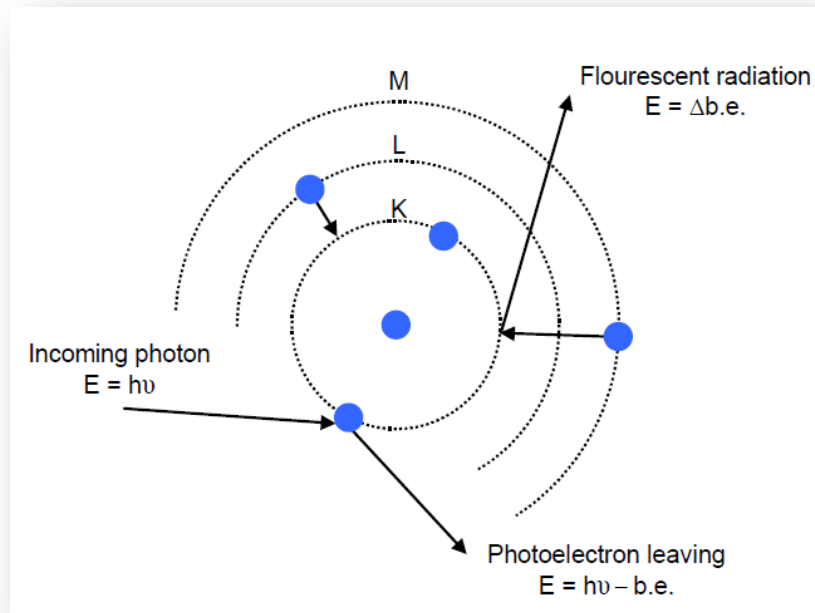


Distance



Shielding

幅射線計量及其健康效應



Ionization by photon interaction



Radiation interacting with tissues

Radiation dose & units

Radiation dose is measured by **energy absorbed**

Absorbed Dose (D)

1 rad = 100 erg/g

1 Gray = 1 Joule/kg = 100 rad

Radiation health effect is measured by **absorbed dose plus biological effects**

Effect Dose (H)

= Absorbed Dose x Biological Weighting Factors (WTs)

1 rem = 1 rad x (WTs)

1 Sievert (Sv) = 1 Gray x (WTs)

Radiations & health effects

❑ Acute Exposure (High Dose Range >100 s mSv)

- Somatic Effects (impairing organ functions; dose thresholds exist)
 - Nausea
 - Hair Losses
 - Skin Burns (*Cutaneous Syndrome*)
 - Damage to Blood Forming Organ (Bone Marrow) (*Hematopoietic syndrome*)
 - Damage to Digestive System (*Gastrointestinal Syndrome*)
 - Damage to Lung (*Pulmonary Syndrome*)
 - Damage to Nervous and Circulatory Systems (*Neurovascular Syndrome*)

❑ Chronic Exposure (Low Dose Range <100 s mSv)

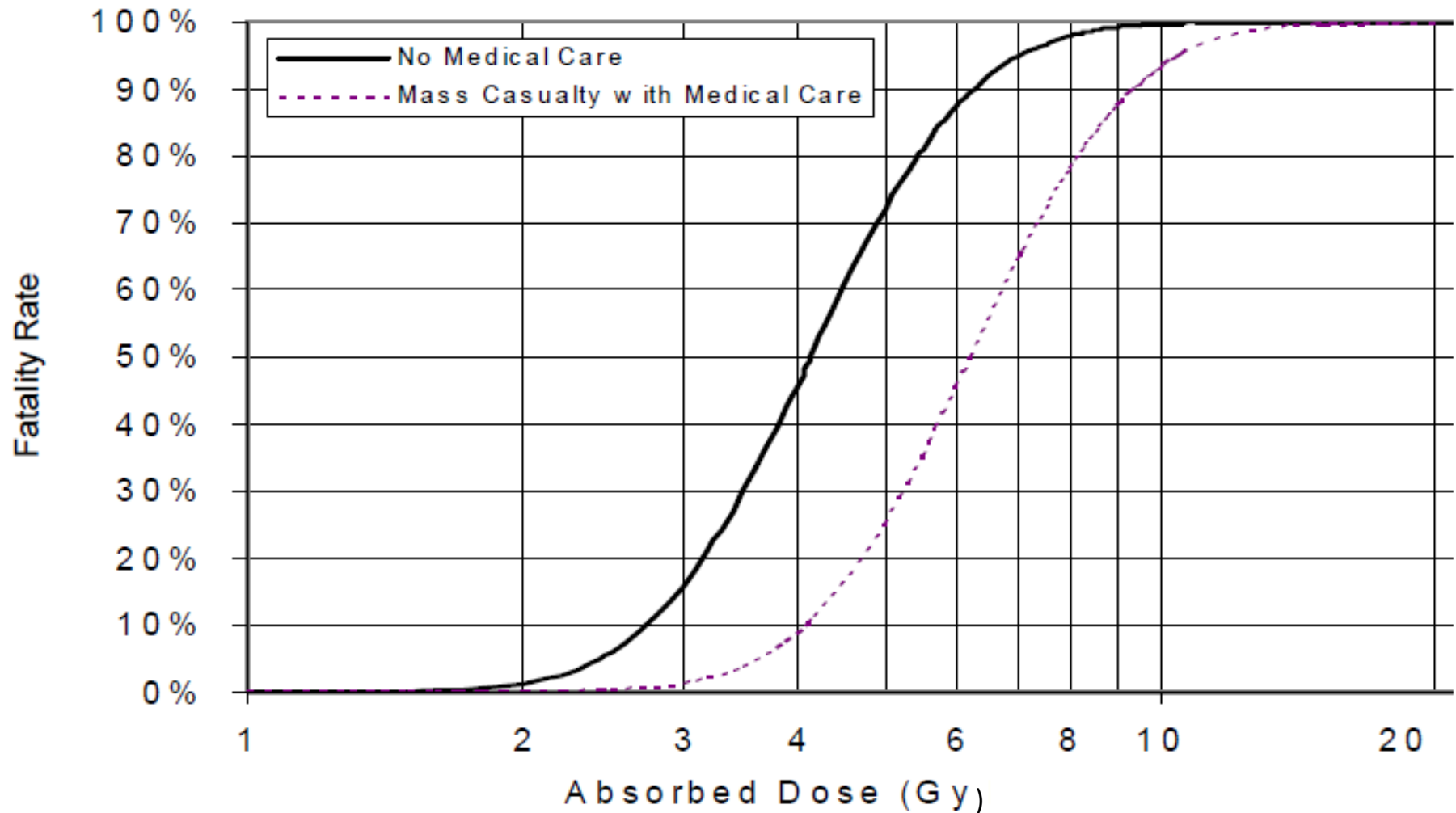
- Stochastic Effects (effects are linearly proportional to dose)
 - Latent Cancers
 - Genetic Effects

Acute radiation syndrome (ARS)

Radiation sickness, known as **acute radiation syndrome (ARS)**, is a serious illness that occurs when the entire body (or most of it) receives a high dose of radiation, usually over a short period of time. Many survivors of the Hiroshima and Nagasaki atomic bombs in the 1940s and many of the firefighters who first responded after the Chernobyl Nuclear Power Plant accident in 1986 became ill with ARS.

The first symptoms of ARS typically are **nausea, vomiting, and diarrhea**. These symptoms will start within minutes to days after the exposure, will last for minutes up to several days, and may come and go. Then the person usually looks and feels healthy for a short time, after which he or she will become sick again with loss of appetite, fatigue, fever, nausea, vomiting, diarrhea, and possibly even seizures and coma. This seriously ill stage may last from a few hours up to several months.

Radiation acute fatality rate



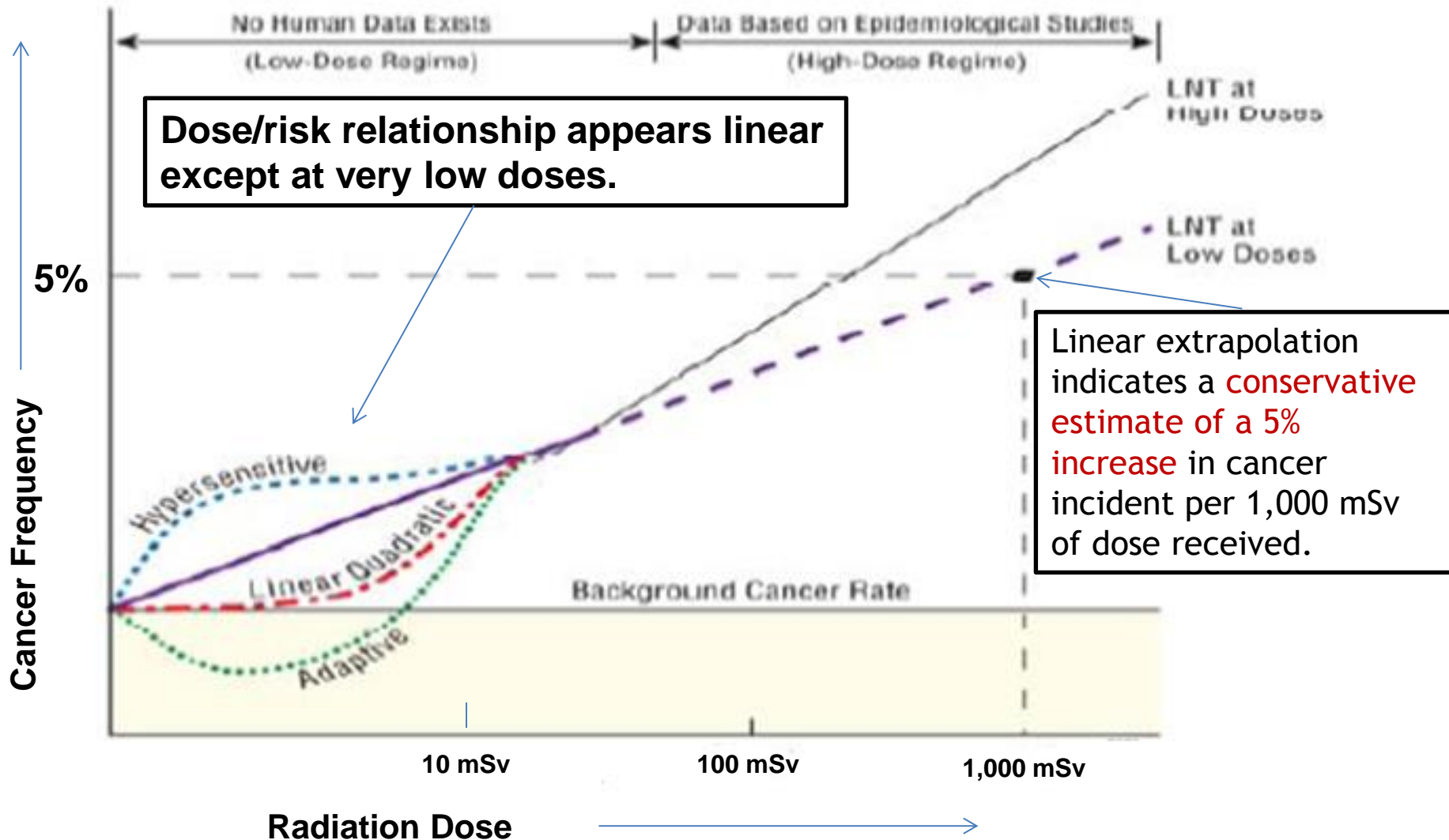
No known radiation casualty in the Fukushima nuclear accident

Approximately 134 plant workers and firefighters battling the fire at the **Chernobyl** power plant received high radiation doses – 80,000 to 1,600,000 mrem (**800 to 16,000 mSv**) – and suffered from acute radiation sickness (ARS). Of these, **28 died** within the first three months from their radiation injuries. Two more patients died during the first days as a result of combined injuries from the fire and radiation.

In contrast, **no one** has died of ARS from **Fukuhsima** nuclear accident by far.

Health response model at low doses

Radiation Dose–Response Models



Latent health effects (cancers) for Chernobyl and Fukushima accidents

For Chernobyl accident, a substantial increase in thyroid cancer incidence has occurred in Belarus, Ukraine, and the four most affected regions in the Russian Federation, since the Chernobyl accident among those exposed as children or adolescents. Among those under the age of 18 y in 1986, **6,848 cases of thyroid cancer were reported** between 1991 and 2005.

For the Fukushima accident, a recent WHO report (2013) suggested that **slight increases in lifetime cancer risk** might occur in any heavily exposed subgroups of the population.

Background information

U.S. cancer instance and mortality

Cancer Incident

The age-adjusted incidence rate was 463.0 per 100,000 men and women per year. These rates are based on cases diagnosed in 2006-2010 from 18 SEER geographic areas.

Cancer Mortality

The age-adjusted death rate was 176.4 per 100,000 men and women per year. These rates are based on patients who died in 2006-2010 in the US.

Source: U.S. National Institute of Health (NIH)

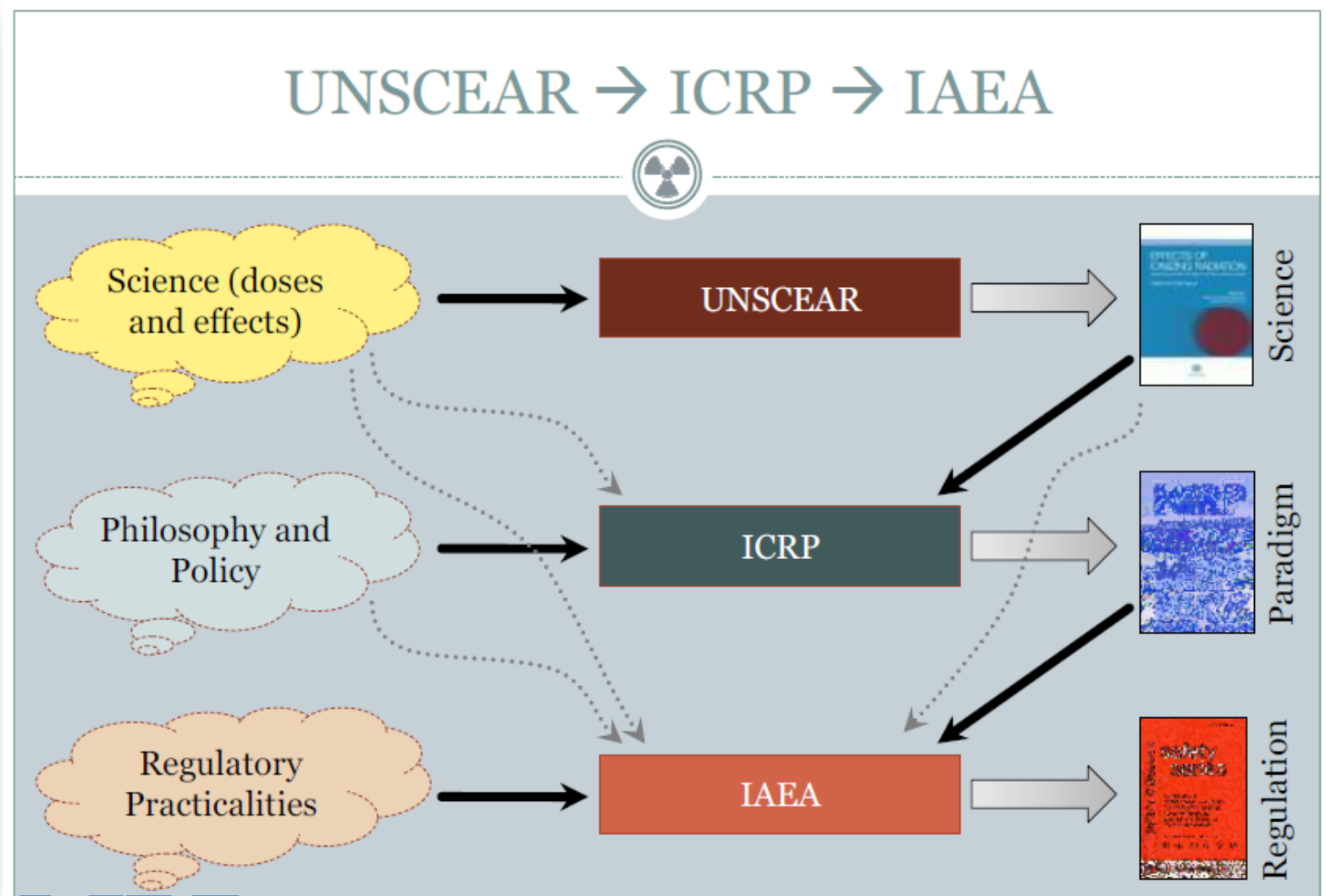
幅射線防護的基本原理, 標準及溝通方式

The Three Principles of Radiation Protection (ICRP 103)

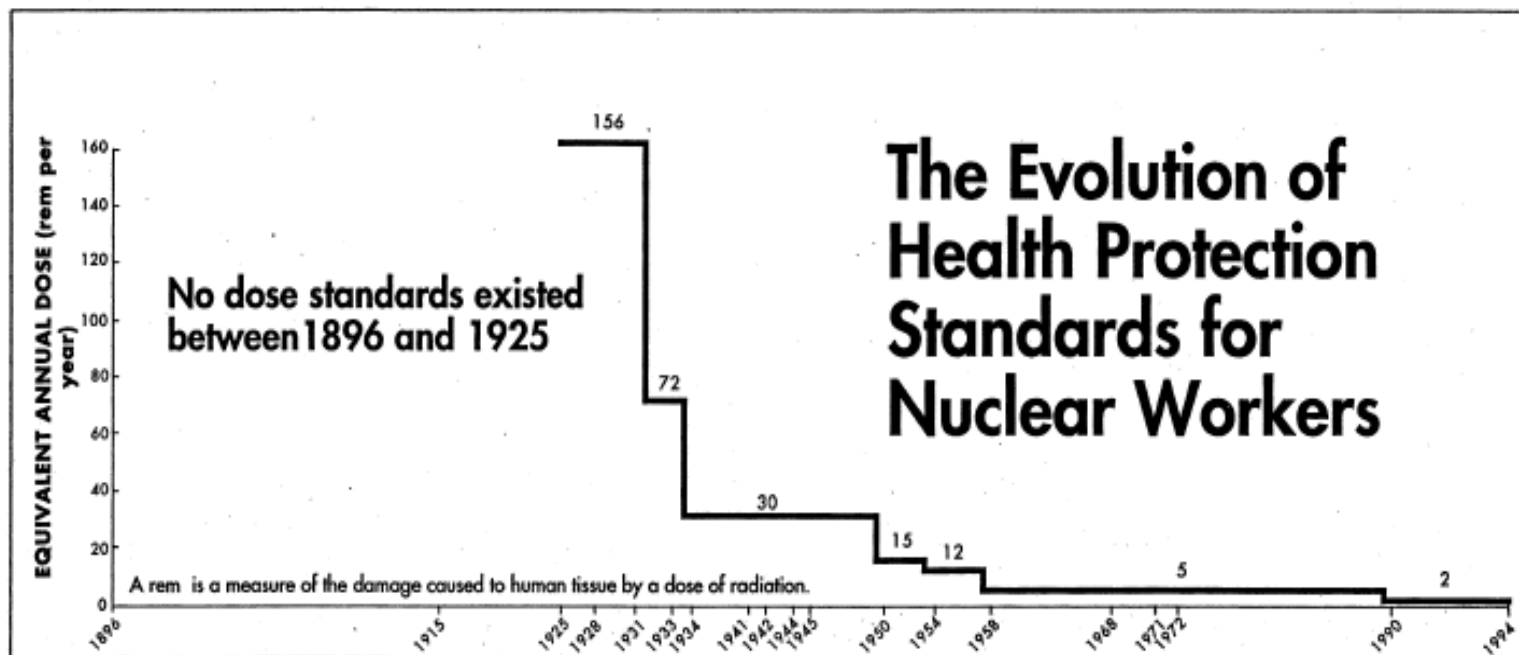
- ☐ Justification
- ☐ Optimization
 - As Low As Reasonably Achievable (ALARA)
- ☐ Protection of Individuals
 - Additional Requirement
 - Protection of the Environment (ICRP 103)

Note: In recent years the **ALARA Principle** has dominated the **radiation protection practices** that renders the individual protection limits nearly obsolete - the average annual dose to a **U.S. public is about 2 mrem (or 0.01 mSv), way below the regulatory limit of 100 mrem (or 1 mSv).**

International Guidance and Standards



Radiation standards have decreased over the past few decades due to evidence of health effects



Stages Leading to Evolution of Protection (Moeller, 1989):

1. Avoidance of Acute Effects (1900-1930)
2. Concern for Chronic Effects (1930-1950)
3. Concern for Genetic Effects (1950-1960)
4. Concern for Somatic Effects (Primarily Leukemia) (1960-1970)
5. Concern for Somatic Effects (Primarily Solid Tumors) (1970 - Present)
6. Application of Risk-Based Approach (1980-Present)

Current dose limits (ICRP 103, 2007)

| Type of Limit | Occupational | Public |
|------------------------------|---|-------------------------|
| Effective Dose | 20 mSv/y (2 rem/y), averaged over 5 yrs* | 1 mSv/y (100 mrem/y) |
| Annual Equivalent Dose | | |
| Lens of the eye | 150 mSv (15 rem) | 15 mSv (1.5 rem) |
| Skin | 500 mSv (50 rem) | 50 mSv (5 rem) |
| Hands and Feet | 500 mSv (50 rem) | N/A |

Dose chart: how to communicate dose?



| Effective Dose | Equivalent in Daily Life |
|----------------|---|
| 0.01 mSv | Watch TV with CRT Technology |
| 0.1 mSv | A Chest X-Ray |
| 1 mSv | Annual Limit for Public |
| 10 mSv | Annual Limit for Radiation Workers (20 mSv) |
| 100 mSv | Maximum for an Emergency Worker |

Radiation Exposure in Daily Life

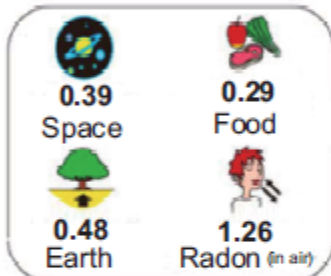
Natural Radiations

250,000 $\mu\text{Sv}/\text{year}$

(10 mSv/yr)

10,000 $\mu\text{Sv}/\text{year}$

Guarapari Beach, Brazil



(2.4 mSv/yr)

2,400 $\mu\text{Sv}/\text{year}$
Natural Radiation per person/year

World average

(0.4 mSv/yr)

400 $\mu\text{Sv}/\text{year}$

Domestic Natural Radiation variation (Gifu - Kanagawa)

200 $\mu\text{Sv}/\text{roundtrip}$

Tokyo - New York flight
(radiation varies depending on the flight altitude)

Evaluation of radioactive emission from nuclear reprocessing plant

22 $\mu\text{Sv}/\text{year}$

10 $\mu\text{Sv}/\text{year}$

Clearance level
(estimated value)

Man-Made Radiations

100,000 $\mu\text{Sv}/\text{year}$

(100 mSv/yr)

Maximum permitted for staff working in emergency cases

50,000 $\mu\text{Sv}/\text{year}$

(50 mSv/yr)

Maximum permitted for Radiation workers and Disaster management workers (Policeman and Firemen)

6,900 $\mu\text{Sv}/\text{tomography}$

Chest X-Ray computed tomography (one time)

(6.9 mSv/CT)

1,000 $\mu\text{Sv}/\text{year}$

Regular public space
(except medical area)

(1 mSv/yr)

Annual dose limit for public

600 $\mu\text{Sv}/\text{radiograph}$

(0.6 mSv)

Abdominal X-Ray for health checkup (one time)

50 $\mu\text{Sv}/\text{radiograph}$

(0.05 mSv)

Chest X-Ray for health checkup (one time)

50 $\mu\text{Sv}/\text{year}$

(0.05 mSv/yr)

Nuclear Power Plant area
(Light Water Reactor) (estimated value)

Sv (sievert) = constant of biological effects of radiation * x Gy (Gray)

(*) X-Ray, γ -Ray = 1

核子事故的背景資訊及應對法則

Chernobyl Nuclear Accident
in Ukraine (1986)

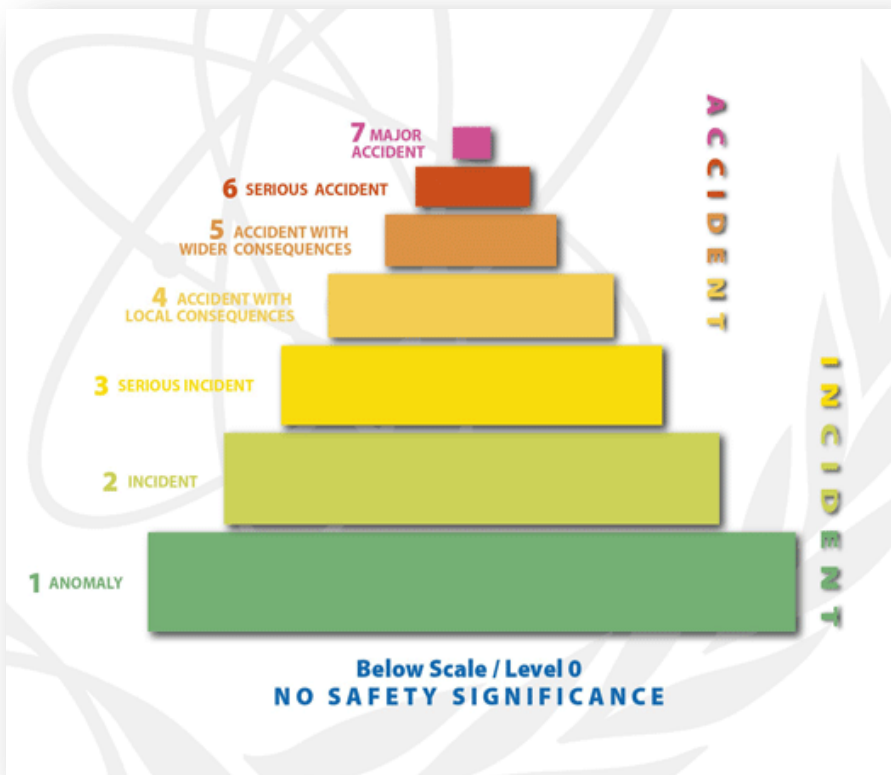


Fukushima Event in Japan (2011)



- 9.0 Richter Scale earthquake
- Followed by over 45-foot high tsunami

Past experiences offer valuable lessons



International Nuclear and Radiological Event Scale (INES) System

Level 7 : Major Accident

Large offsite release with widespread health and environmental effects.

Examples: Chernobyl Event (1986), Ukraine;
Fukushima Event (2011), Japan.

Level 6 : Serious Accident

Significant offsite release requiring full implementation of planned countermeasures.

Example: Kyshtym event at Mayak (1957), former Soviet Union.

Level 5 : Accident with Wider Consequences

Limited offsite release requiring partial implementation of planned countermeasures.

Examples: Three Mile Island (1979), US;
Goiania Source Incident (1987), Brazil.

Level 4: Accident with Local Consequences

Minor release of radioactive material unlikely to result in implementation of planned countermeasures other than local food controls.

Example: Tokaimura Nuclear Accident (1999), Japan

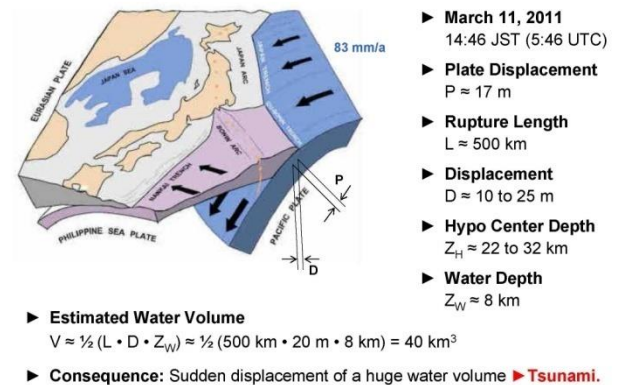
Fukushima nuclear accident: event initiation

March 11, 2011

- ❑ About 14:46, a 9.0 magnitude earthquake struck (Plant design basis earthquake: 8.2)- Plant safety systems reportedly function satisfactorily.
- ❑ Units 1,2 & 3 Scram & Unit 4 has 100 day old core offloaded into Unit 4 Spent Fuel Pool
- ❑ ~ 15:45, a tsunami 14 meters high inundated the site, whose design basis was 5.7 meters - the reactors and backup diesel power sit roughly 10 to 13 meters above sea level
- ❑ The tsunami & earthquake impacts up and down the northeast coast resulted in tragic loss of 20,000+ lives, damage, and destruction of infrastructure.



Subduction Fault

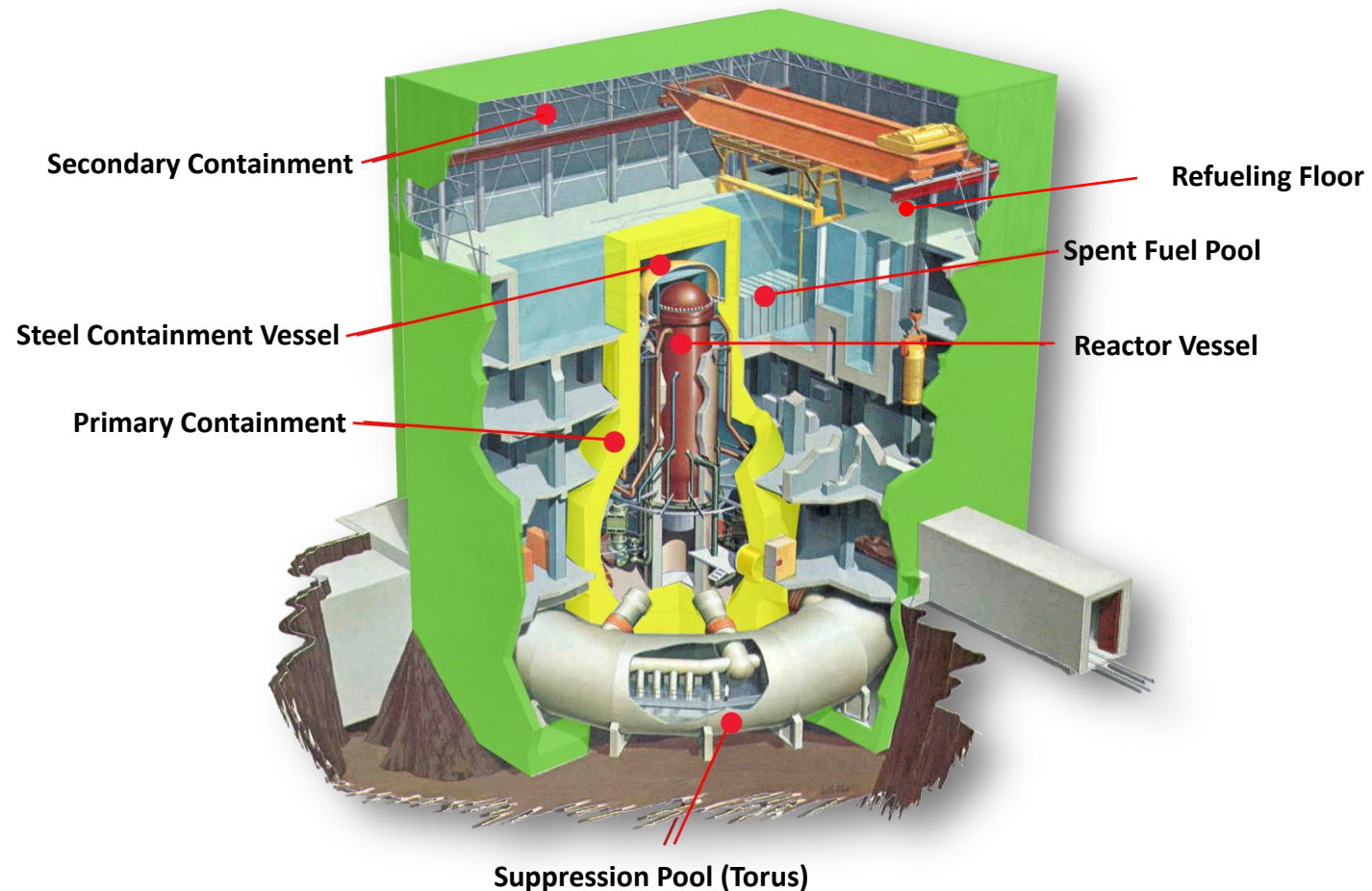


Fukushima Daiichi nuclear power station



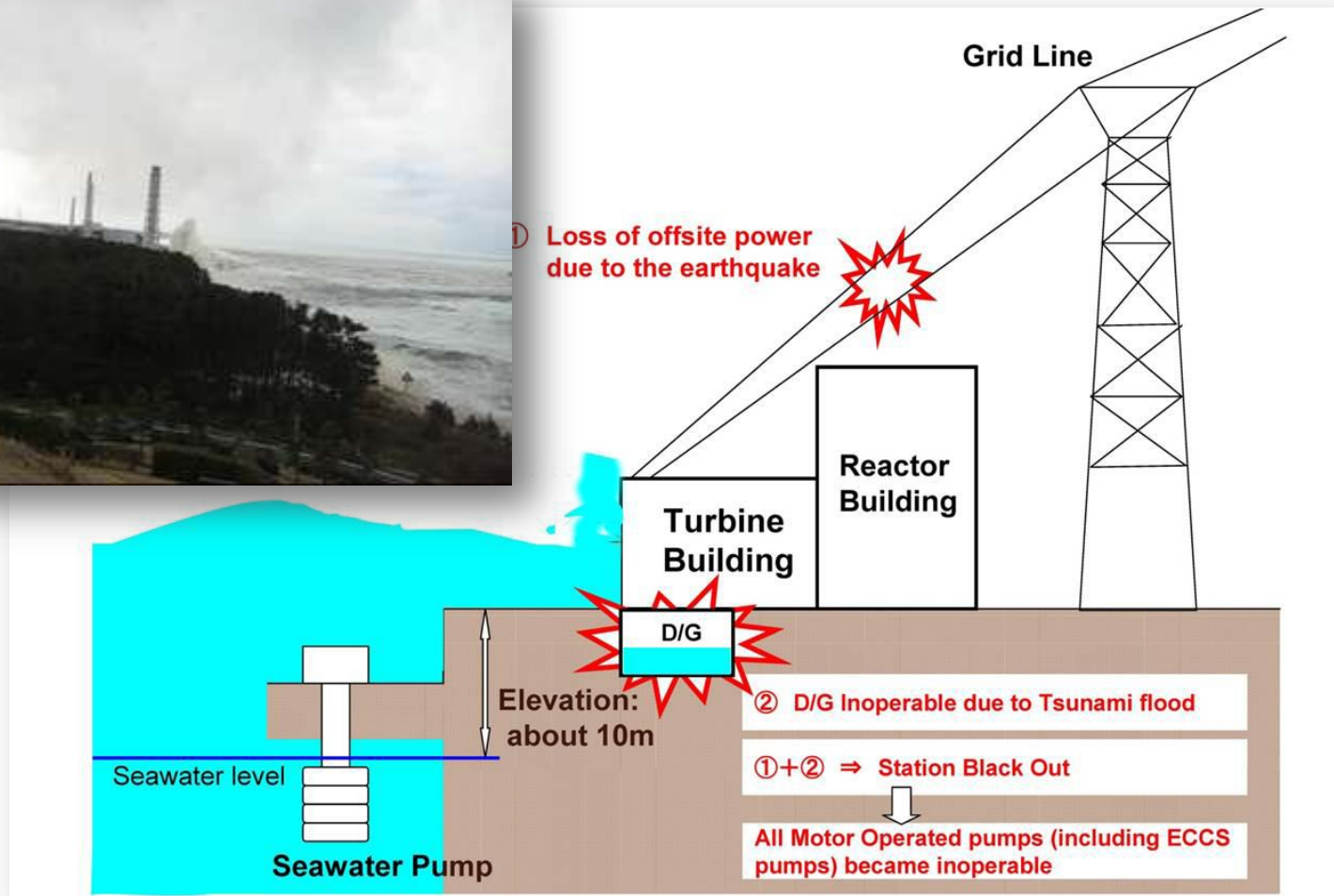
GE Mark I reactor building

Boiling Water Reactor Design At Fukushima Daiichi

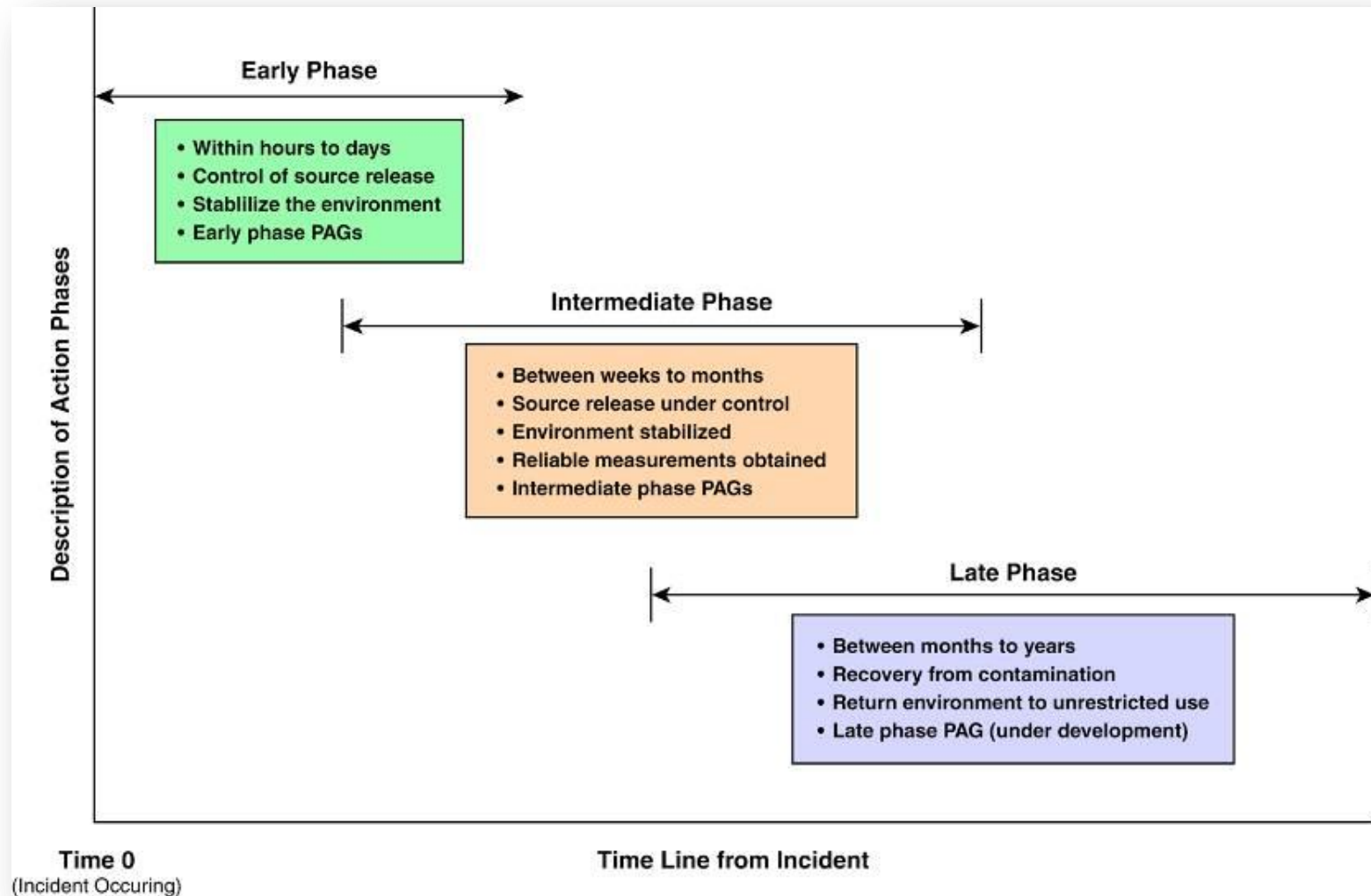


Tsunami size: main safety factor

3/11 15:45



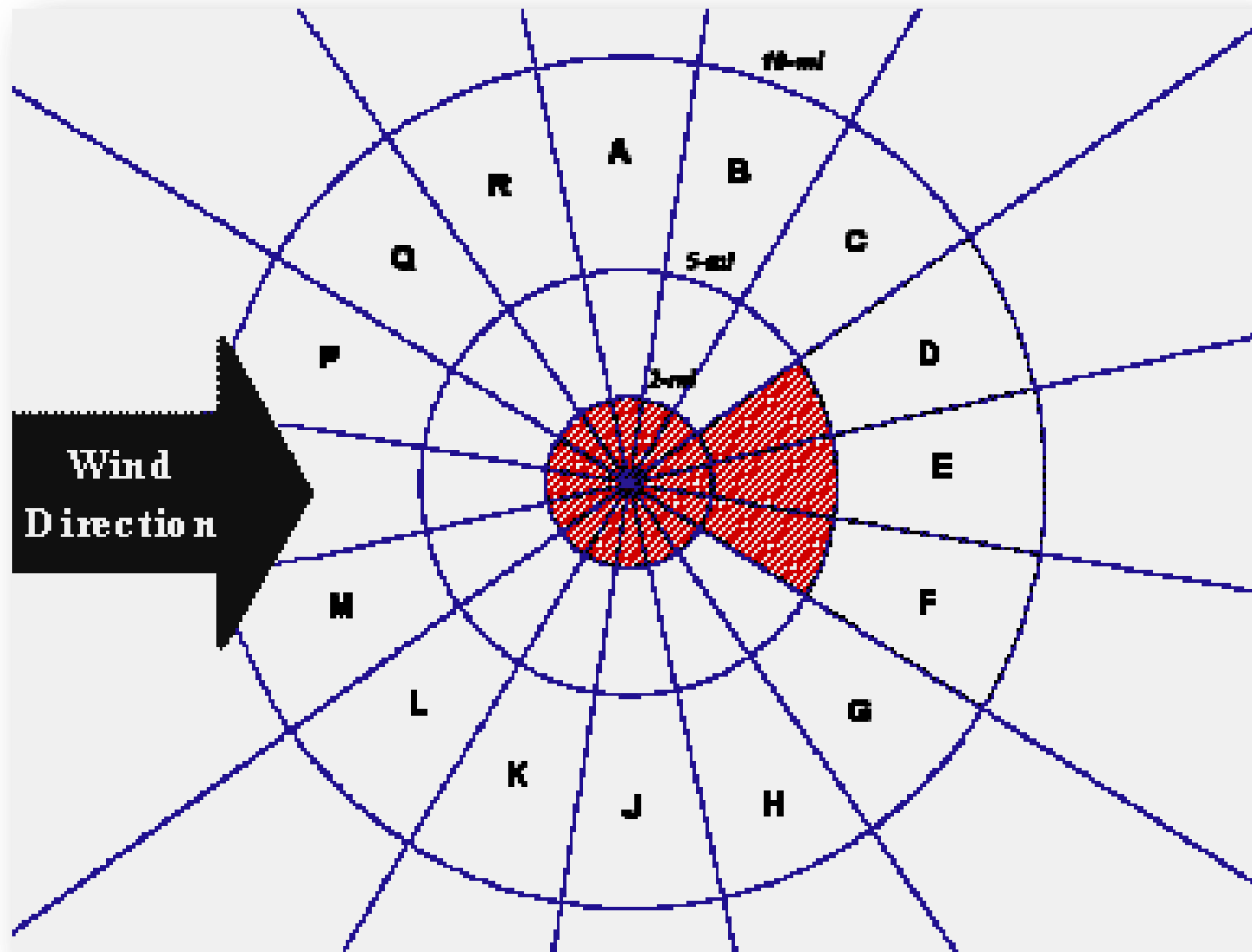
Three sequential phases for radiological response and management



Planning Guidance and Protective Action Guides for Radiological Incidents

| Phase | Protective Action Recommendation | Protective Action Guide or Planning |
|--------------|--|--|
| Early | Sheltering-in-place or evacuation of the public ^a | 1 to 5 rem (10 mSv to 50 mSv) projected days ^b |
| | Administration of prophylactic drugs KI ^c | 5 rem (50 mSv) projected child thyroid from radioactive iodine |
| | Limit emergency worker exposure | 5 rem (50 mSv)/year (or greater under exceptional circumstances) ^e |
| Intermediate | Relocation of the public | 2 rem (20 mSv) projected dose first year Subsequent years, 0.5 rem (5 mSv)/year projected dose |
| | Food interdiction ^f | 0.5 rem (5 mSv)/year projected dose, or (50 mSv)/year to any individual organ, whichever is limiting |
| | Limit emergency worker exposure | 5 rem (50 mSv)/year ^b |
| | Reentry | Operational Guidelines ^g (Stay times and concentrations) for specific activities |
| Late | Cleanup | Brief description of planning process |
| | Waste Disposal | Brief description of planning process |

Emergency evacuation



What are the 10-mile and 50-mile emergency planning zones?

Two emergency planning zones (EPZs) around each nuclear power plant help plan a strategy for protective actions during an emergency. The plume exposure pathway EPZ has a radius of about **10 miles from the reactor**. Predetermined protection action plans are in place for this EPZ and are designed to avoid or reduce dose from potential exposure of radioactive materials. These actions include **sheltering, evacuation, and the use of potassium iodide** where appropriate. The ingestion exposure pathway EPZ has a radius of about **50 miles from the reactor**. Predetermined protection action plans are in place for this EPZ and are designed to **avoid or reduce dose from potential ingestion of radioactive materials**. These actions include a **ban of contaminated food and water**.

Emergency rescuing effort in early phase reducing casualties

Emergency Rescue



Medical Triaging



Dose guidelines constraint the stay time for the responders

Turn-Back Exposure Rates and Dose Guidelines

| Activities | Suggested Turn-Back Exposure Rates | Guidelines for Total Accumulated Dose | Increased Cancer Risk ^{4,5} |
|--|--|---|--------------------------------------|
| Emergency worker dose limit | Follow Radiation Safety Officer instructions | 5,000 mrem ¹ | 0.4 % |
| Non-lifesaving activities (major critical property protection) | 10,000 mR/hr | 10,000 mrem (stay time = 1 hr) | 0.8 % |
| Lifesaving activities | 200,000 mR/hr ² Extreme Caution | 50,000 mrem ³ (stay time = 0.25 hr) | 4 % |

¹ Note that the 5000 mrem dose guideline represents the standard occupational dose limit for one year.

² Specific approval and controls required to exceed this turn-back exposure rate.

³ The 50,000 mrem dose guideline is a level where minor effects from short-term radiation exposure are possible. Note that this guideline applies to a once-in-a-lifetime event.

⁴ Increased lifetime risk of a fatal cancer. It does not mean that the person will get cancer. *For more information see Appendix 7.*

⁵ NCRP Commentary 19, NCRP 138

(Source: CRCPD Publication 06-6)

Monitoring the population protection of citizens following a nuclear accident

Monitoring Individuals

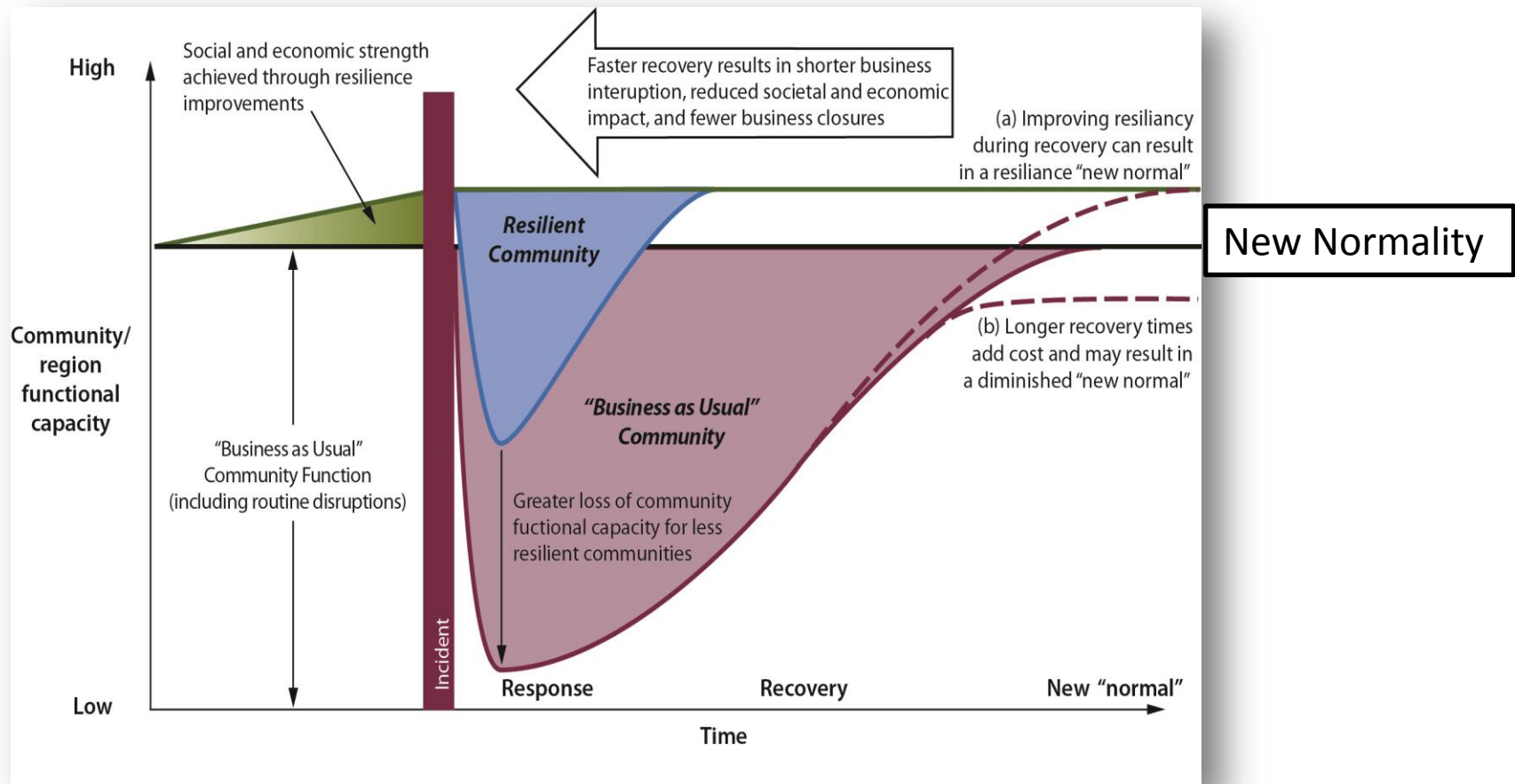


Officials in protective gear check for signs of radiation on children who are from the evacuation area near the Fukushima Daiichi nuclear plant in Koriyama, March 13, 2011. Kim Kyung-Hoon/Reuters

Controlling Contamination

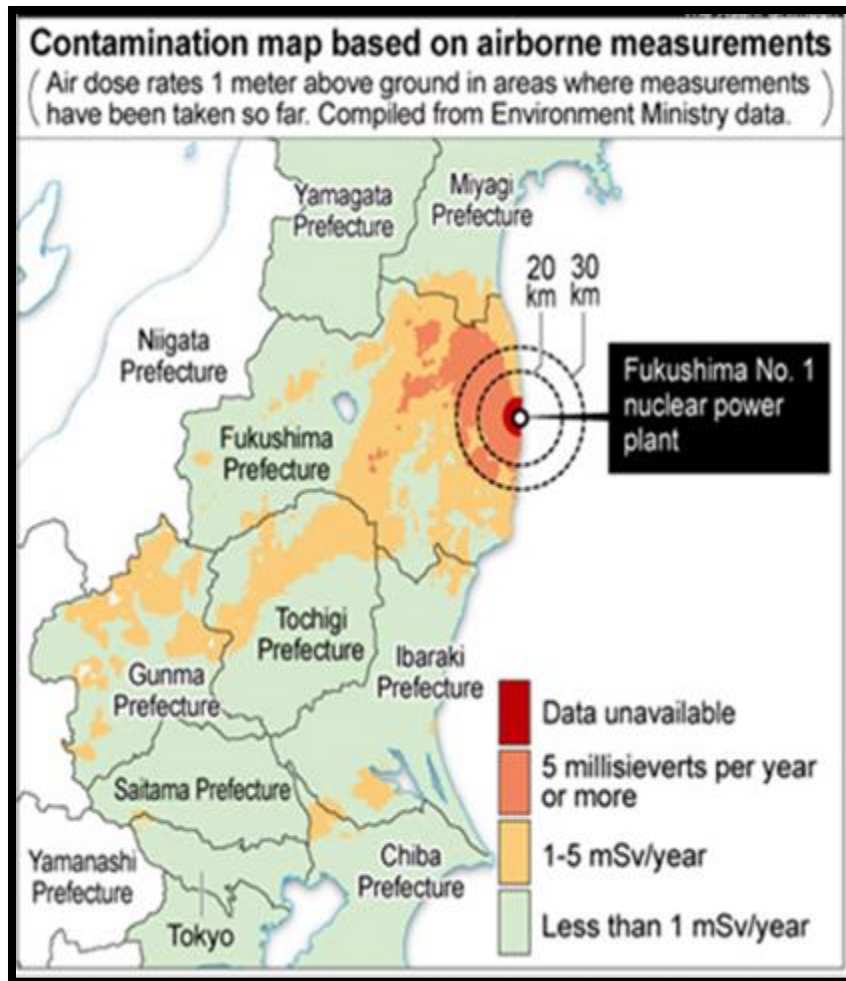


災後重建的原則及方針



The objective of recovery is to return the community back to a near normal condition.

Addressing wide-area contamination: the unprecedented impact



Cleanup level at 1 mSv/y:

- 13,000 km², or
- 3% of Japan's land mass, or
- About the size of Connecticut
- Costs at \$15.6 B

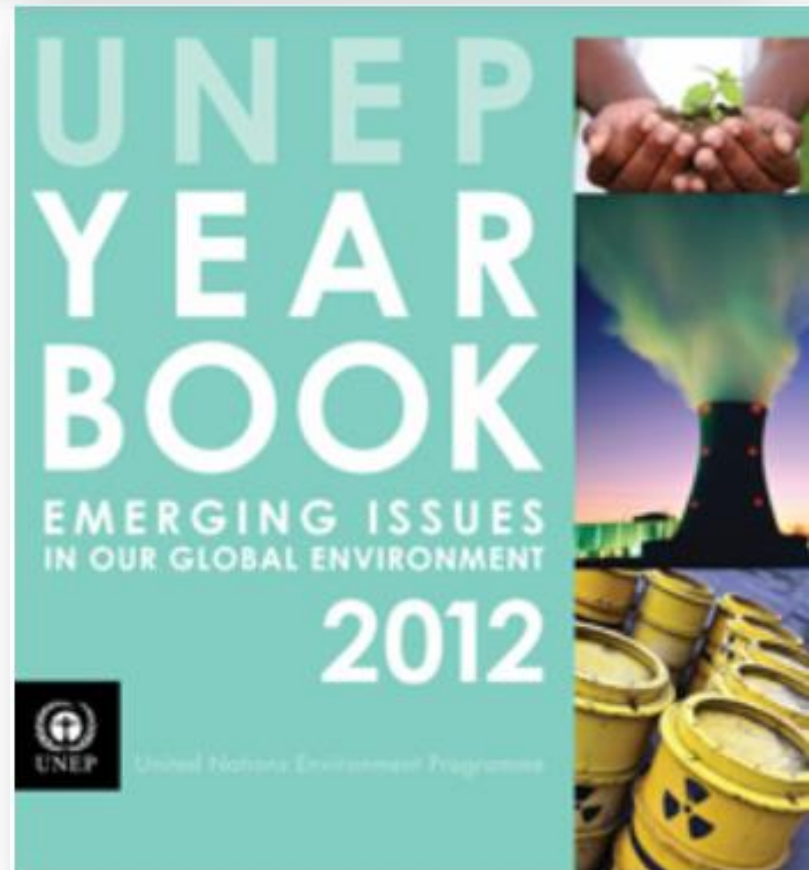


**Contaminated area is about
the size of 1/3 of Taiwan**



United Nations Environment Programme
environment for development

With huge economic damage, this event is considered not only tragic in terms of its human toll; it is the **most economically devastating disaster in history** - United Nations Environmental Programme (UNEP 2012).



DECISION MAKING FOR LATE-PHASE RECOVERY FROM NUCLEAR OR RADIOLOGICAL INCIDENTS

2013



S.Y. Chen,
Chairman SC 5-1

Illinois Institute of
Technology, Chicago, IL

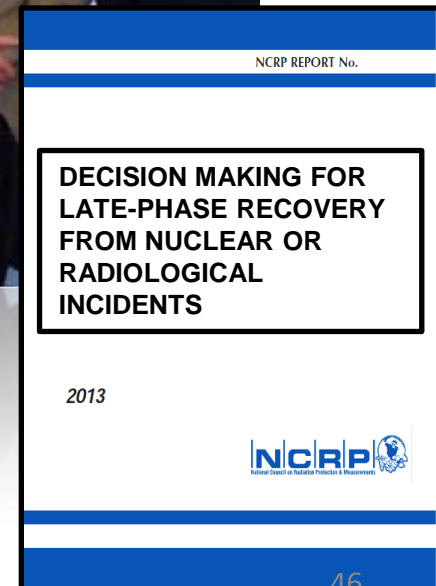
In 2008, DHS issued Protective Action Guides (PAGs) for Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) incidents, providing recommendations for protection of public health in the early, intermediate, and late phases of response to an RDD or IND incident.

The current Report, expanded to include nuclear reactor accidents, provides **detailed approaches to implementing and optimizing decision making during late stage recovery for large-scale nuclear incidents**

SC 5-1: Decision Making for Late-Phase Recovery from Nuclear or Radiological Incidents

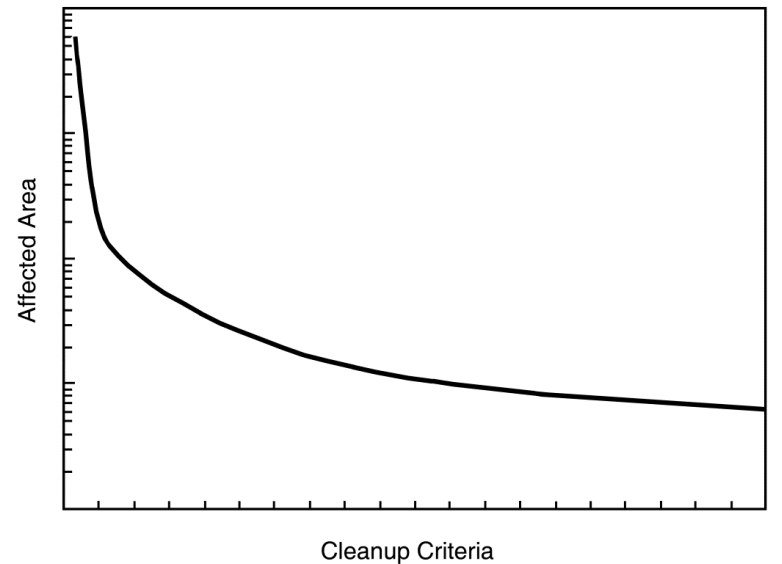


Standing: B Buddemeier (LLNL), J MacKinney (DHS, Consultant), M Noska (FDA, Consultant), D Allard (PA, Advisor), A Wallo (DOE), K Kiel (Holy Cross), J Edwards (EPA, Advisor), A Nisbet (HPA, Advisor), J Cardarelli (EPA, Consultant), D Barnett (JHU), & S Frey (Staff Consultant) **Seated:** V Covello (CRC), SY Chen (IIT, Chairman), H Grogan (Cascade, Advisor), J Lipoti (NJ), & D McBaugh (Dade Moeller)



Weighing the difficulty options: cleanup vs. waste generation

Estimated radioactive waste volume from cleanup of nearby prefectures surrounding Fukushima NPP is $29 \times 10^6 \text{ m}^3$, or about 1 million ft^3 . This amount has far exceeded the US commercial LLW disposal capabilities combined. **Some adaptive management strategy is needed.**



Among the major challenges: radioactive waste management



Small-holder farming systems in the Fukushima prefecture: An area-wide landscape approach is crucial (Gerd Dercon, NAFA, IAEA).



Concrete box for temporary storage of contaminated material




Temporary storage of contaminated material – examples from clean-up demonstration tests

(Source: Fukushima, Japan)

**Waste storage and disposal issues
can be contentious**

Cleaning up the contamination requires many different technologies


Examples of Decontamination Method
--Decontamination of **Housing Land and Structures** (1)--



Roof: Wash off with hot water or high-pressure hot water.
Solar panels or a damaged portion of the **roof:** Wipe off with sponges with an enhanced cesium-adsorption property

Balcony: Wash off with hot water or high-pressure hot water

Gutters: Remove accumulations; wash off with hot water or high-pressure hot water



Interlocking bricks: Electric planer / wash by high-pressure water

Garden trees: Trim or remove them.

Garden soil: Remove the surface. (Then, bring in earth from other places)

Shed: Wash off with hot water or high-pressure hot water

Turf: Remove it. (Then, bring in earth from other places)

Concrete surface: Wash off with hot water or high-pressure hot water.

Gravels: Comb out and wash off. (Then, bring in earth from other places)

Key to stakeholders outreach: risk management and communication

- Risk communication is as important as the risk assessment itself.
- Even when radiation doses are low, risk communication and outreach are essential to help the public, media, authorities.
- Scientists must be willing to communicate their work to other scientists, regulators, and the public.
- Be available
- Town meetings
- Focus Groups
- Dialogues
- Engage, Empower



After Fukushima: families on the edge of meltdown

Two years after the Fukushima nuclear disaster, a new phenomenon is on the rise: **atomic divorce**. Abigail Haworth reports on the unbearable pressures and prejudices being faced by those caught in the radiation zone. The Observer, Sunday, February 24, 2013



'Each anniversary we will be thinking, "Is this the year one of our daughters will get sick?"' Kenji and Aiko Nomura with Sakura, 3, and 15-month-old Koto. Photograph: Panos Pictures/Eric Rechsteiner

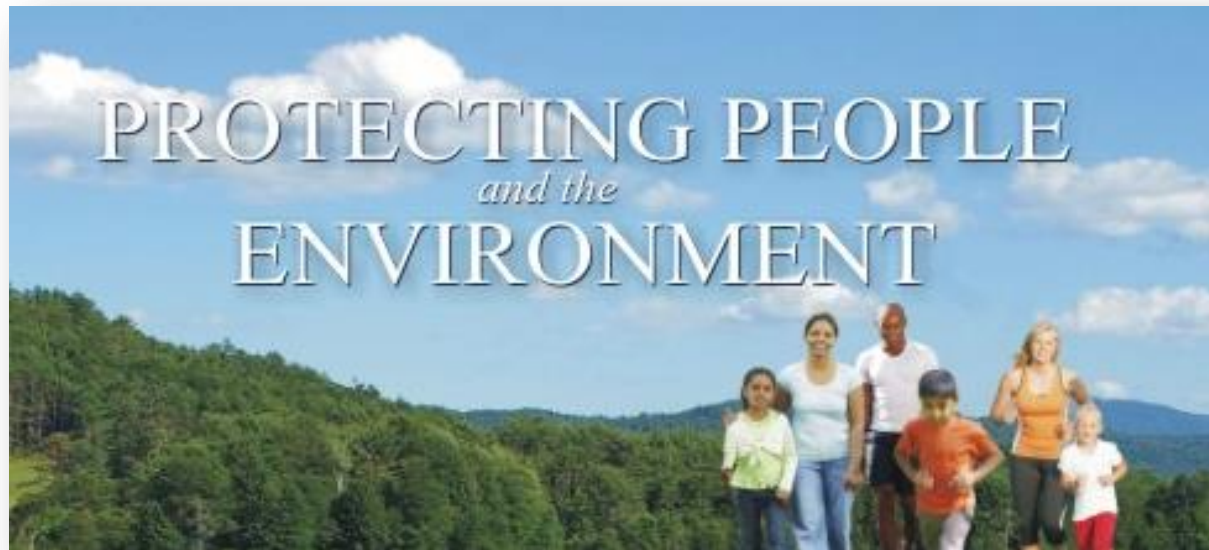
Marital discord has become so widespread that the phenomenon of couples breaking up has a name: ***genpatsu rikon*** or "atomic divorce".

Preparing response to recovery the “Whole Community” approach

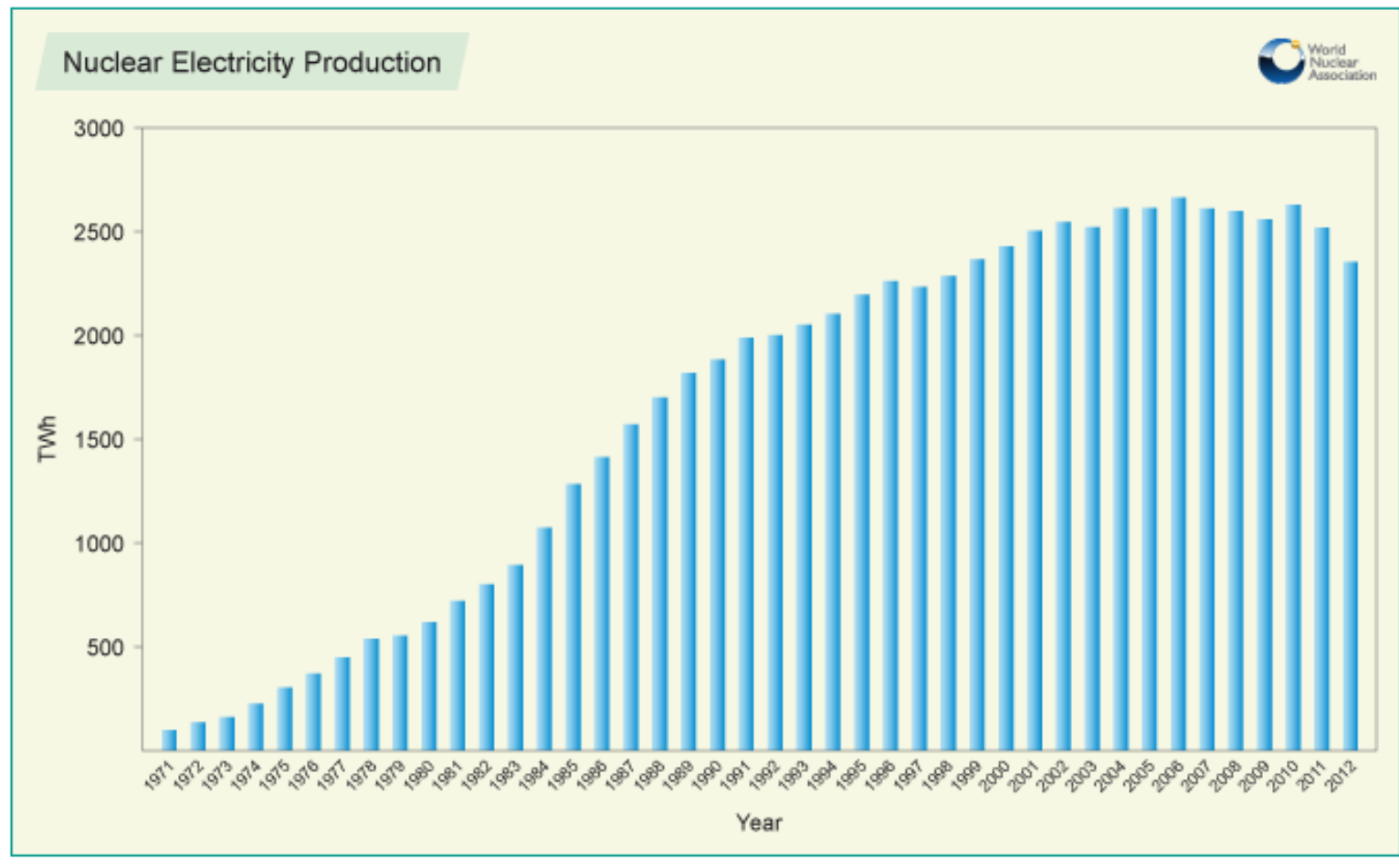
- Adaptation to a “new normality”
- A community-centered recovery effort
- Stakeholders involve in decision making
- Response planning needs to focus on re-establishing the local economy
- Recovery is conditioned on an expedited cleanup of contaminated areas
- Acquire and manage available resources
- Combat stigma through education and better communication

展望未來：能源與環境的平衡和抉擇

**Making Technology Work for Mankind:
Always Learning Lessons from the Past**

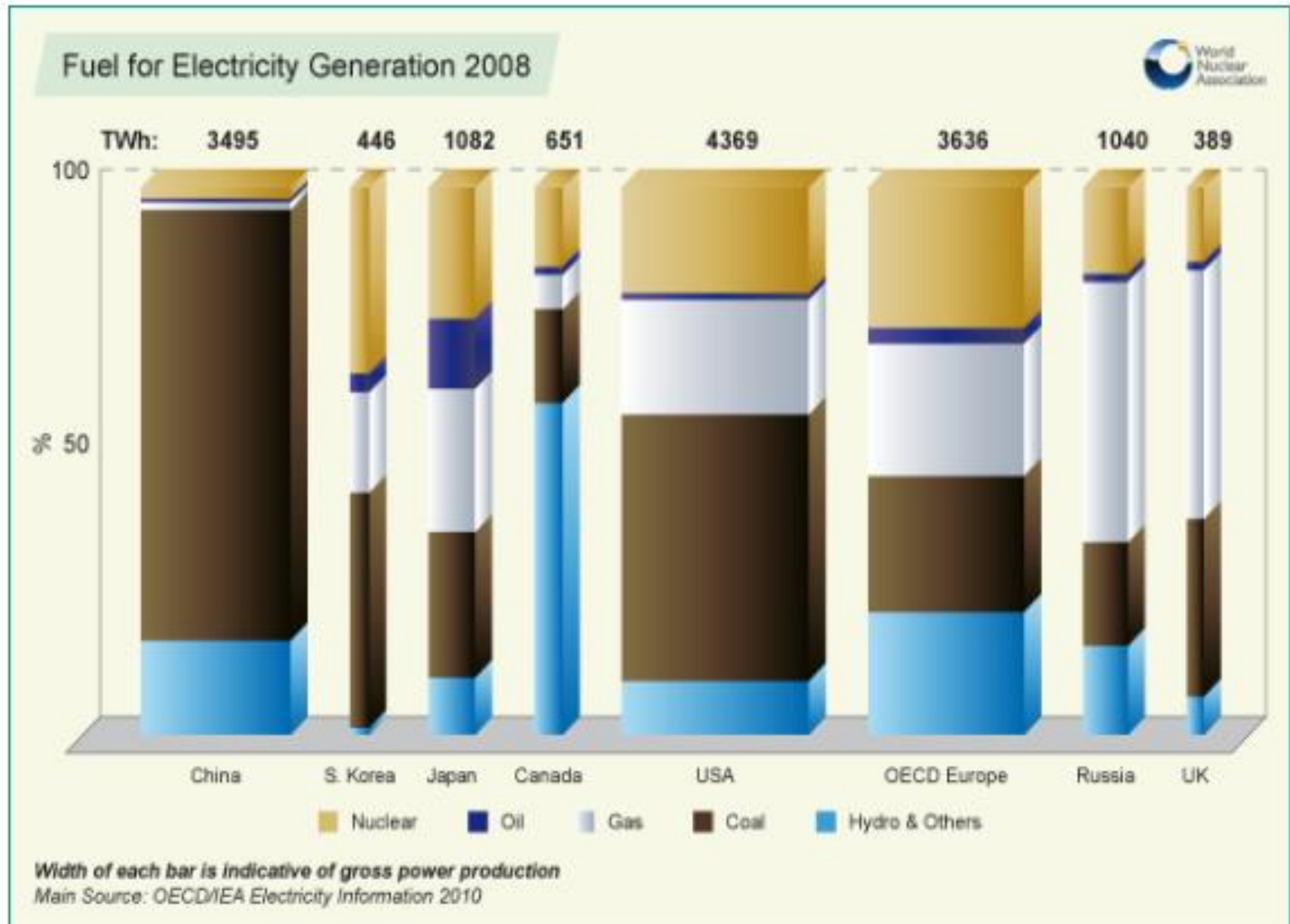


Economic Development Depends on Electric Power Production



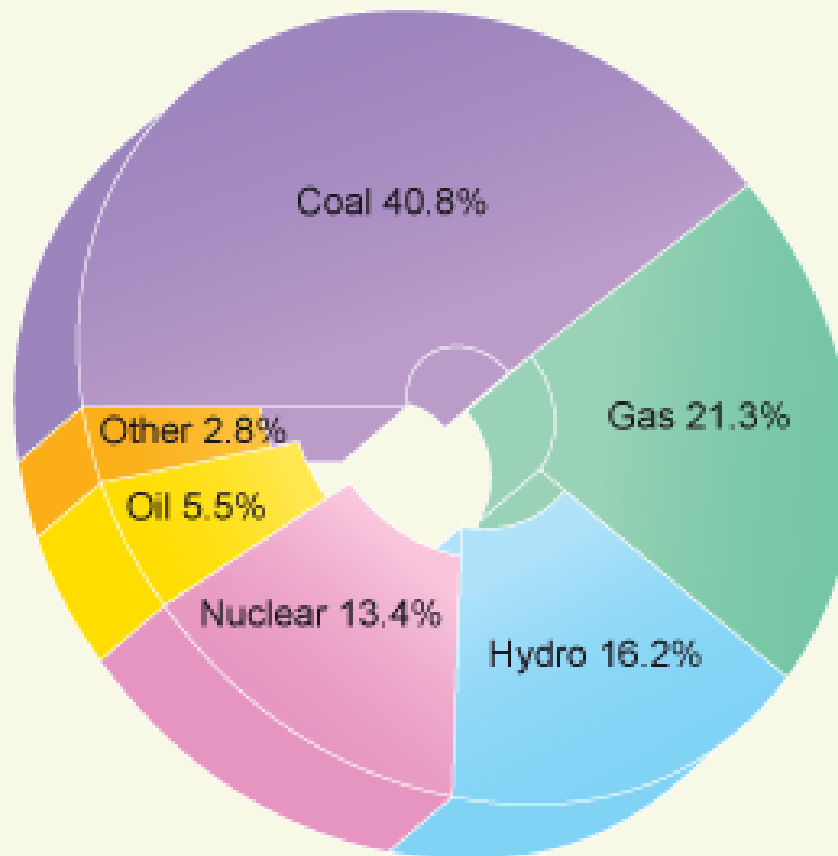
There are now over 430 commercial nuclear power reactors operating in 31 countries, with 372,000 MWe of total capacity.

A Balanced Energy Strategy Consists of A Right Mix of Options



**Development of
Viable Energy
Options Takes
Decades of Efforts**

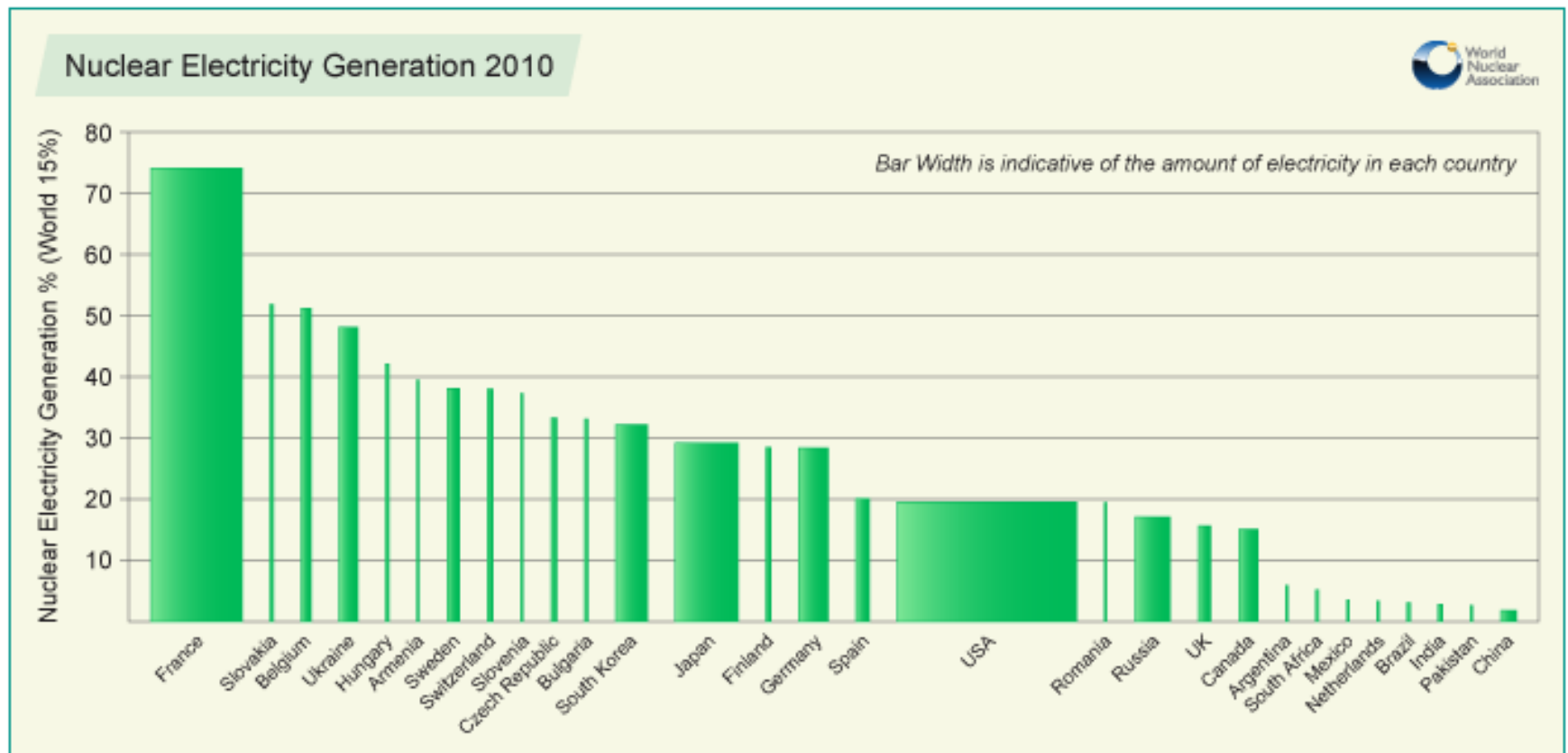
World Electricity Production 2008



Total: 20,269 TWh

Source: IEA Electricity Information 2010

Replacing Nuclear Power Would Face Considerable Technological and Policy Challenges

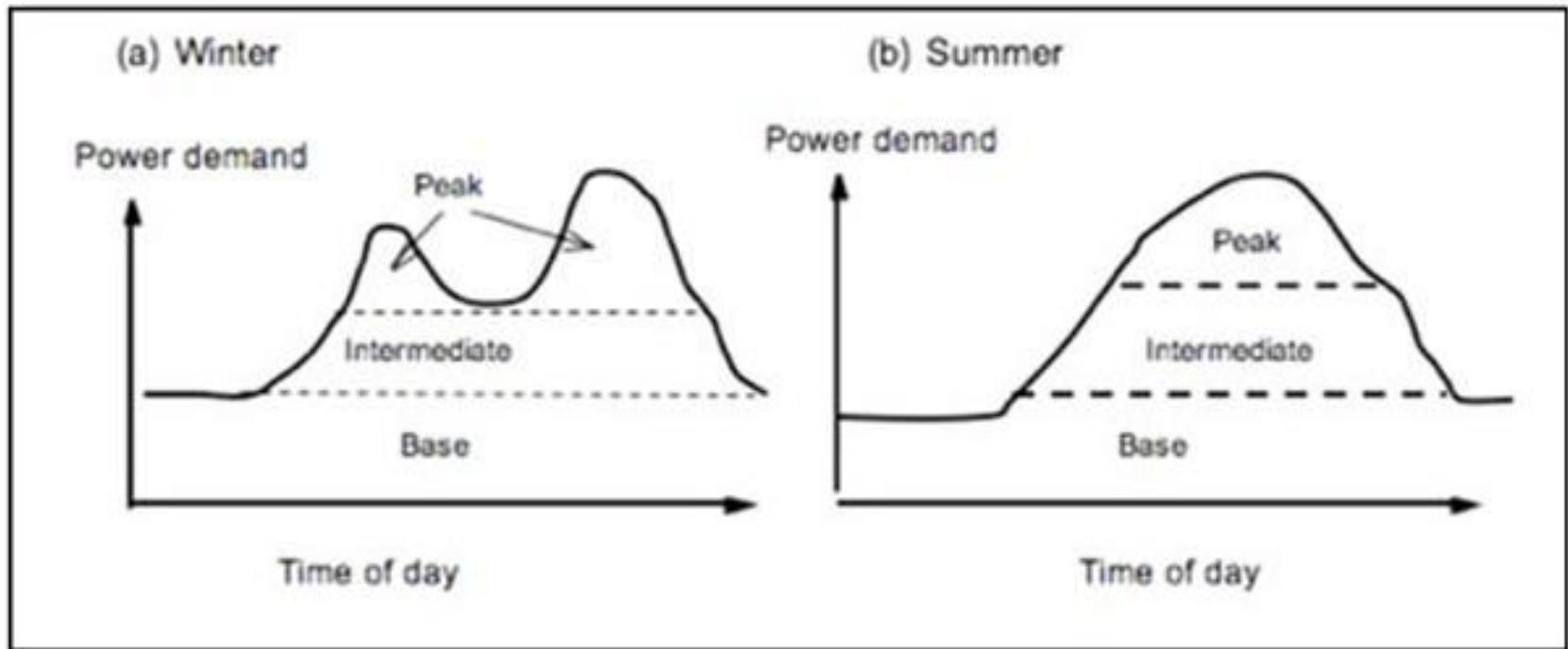


Note: Taipower uses nuclear energy to generate 22% of electricity on the island of Taiwan.

Nuclear Power Provides **BASE LOAD** Energy Source

Base Load: Minimum energy required to meet the demand of the customers.

Daily Base Load Power Variations by Season



Some plants, like coal-fired and nuclear power plants, put out base load power. Others, like solar and most gas-fired power plants, generate "peaking" power.

A Modern Wind Energy Farm Would Take up about 100 Times of Land Compared to Nuclear Energy

Arkansas Nuclear One Station

- ❑ Power Output: ~**1,800 Megawatts**
- ❑ Number of Reactors: **2**
- ❑ Land Use: **1,100 acres¹ (1.7 square miles)**

Modern Wind Power

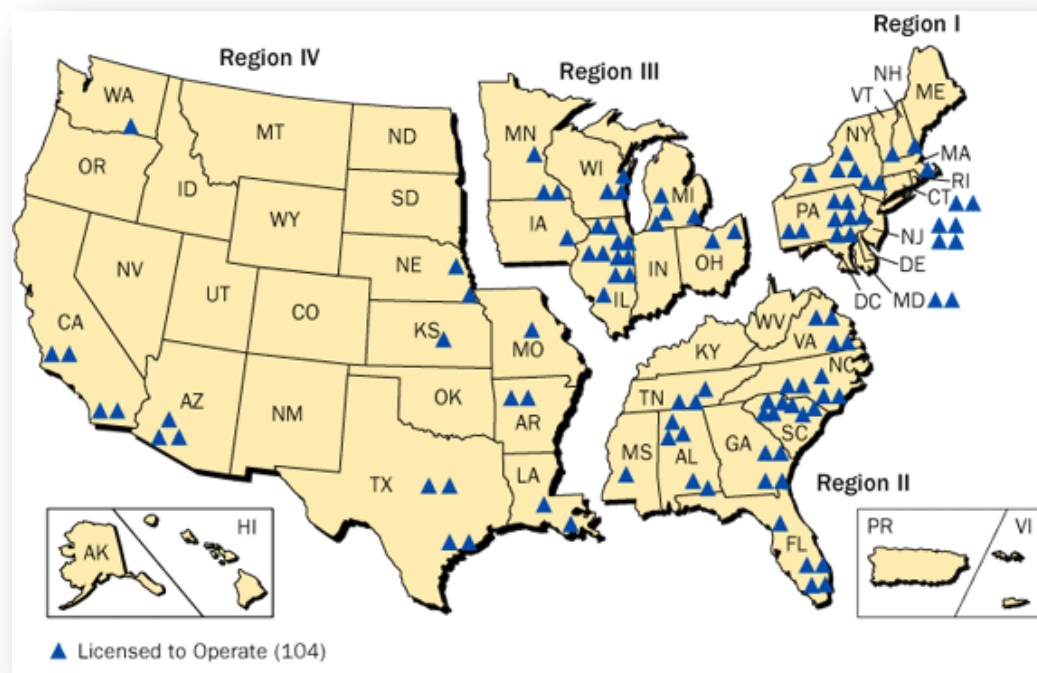
- ❑ Power Output: Above Average Wind Turbine Generates **2.5 Megawatts/turbine**
- ❑ Number of 2.5 MW Turbines Needed to Generate 1,800 Megawatts: **720**
- ❑ Average Acres Per Megawatt⁵: **60**
- ❑ Land Use: **108,000 acres (169 square miles)**

Modern Solar Power

- ❑ Power Output: **1 Megawatt per 7.4 acres of photovoltaic solar panels⁶**
- ❑ Land Use: **13,320 acres (21 square miles)**

US commercial nuclear power operations over 95% of the plants have opted for license renewal

The current operating reactors (104 units; 69 PWRs & 35 WBRs) **supply about 20%** of the US electricity capacity.



Nearly 95% have completed license renewal or under application. As of 2013 more renewal applications are pending. A total of **new reactors with ONLY 4 units at two new power stations** (Vogtle Unit 3 & 4, and V.C. Summer Units 2 & 3 new reactors) have been licensed by NRC so far.

Japan: looking to a brighter future



“Following a statement by the World Health Organization on the low predictive rate for cancer in Fukushima, Japan, Prime Minister Shinzo Abe was quoted Thursday pledging his goal to restart Japan’s inactive nuclear power plants”.

日能源白皮書 未出現零核電目標



◀ 1/1 ▶

點選放大 🔍

新頭殼newtalk 2013.06.14 黃沛瑜/綜合報導

根據日媒共同社報導，日本政府於今(14)日在內閣會議上通過2012年版的《能源白皮書》，此白皮書橫跨前執政黨民主黨與現任的自民黨政府，從2012年8月到2013年3月，但卻不見白皮書中記載民主黨政府於去年9月決定的「零核電目標」的表述。

日本政府今天通過2012年度的《能源白皮書》，白皮書就新能源與環境戰略指出，將以儘早實現不仰賴核電的社會、實現綠色能源革命、及能源的穩定供應為三大核心。而民主黨政府曾提出將投入所有政策資源，以爭取到2030年達成零核電目標，白皮書中則未提及。

Weighing benefits against the disadvantages

反核四聲浪高 核廠延役成選項

中央社-2013年08月03日 上午09:42

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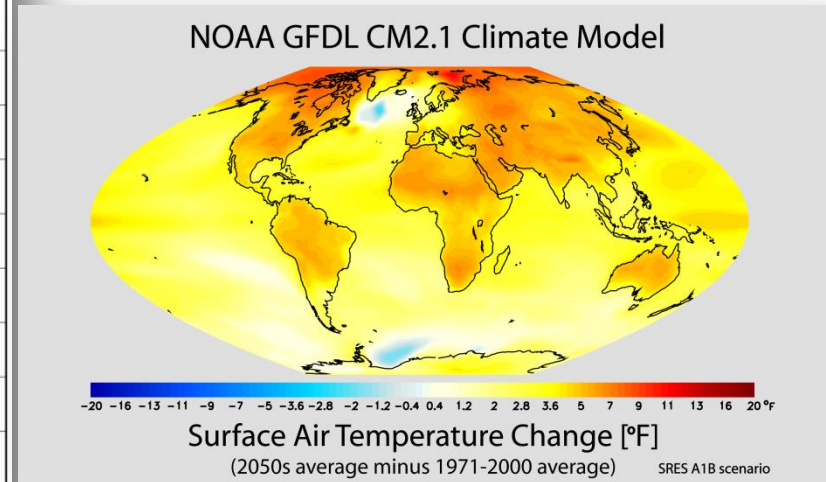
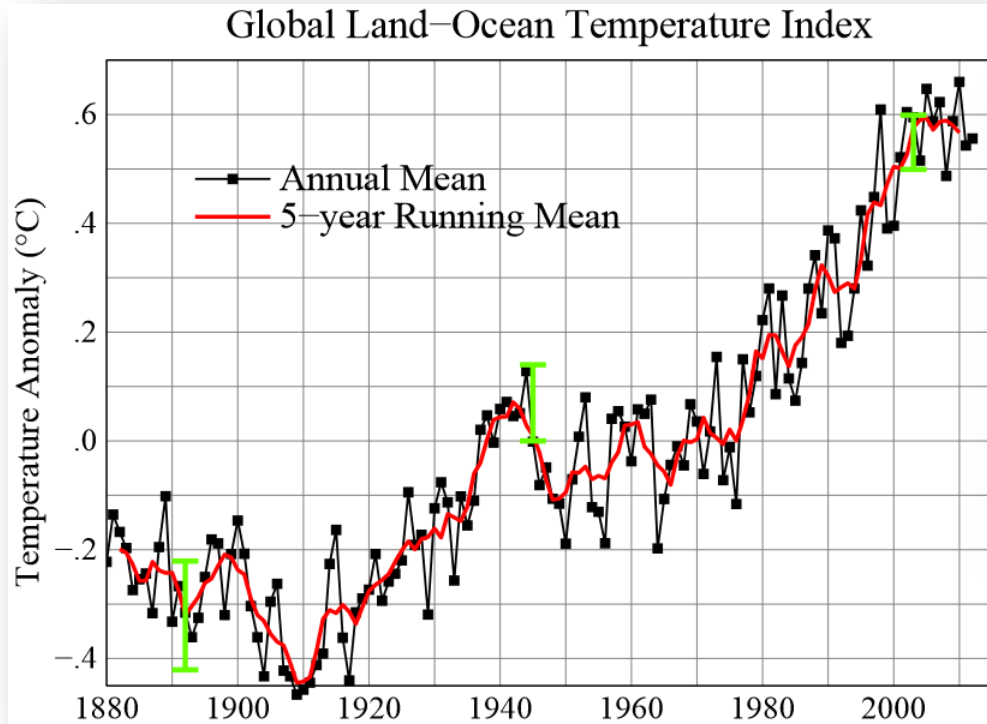
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（中央社記者林孟汝台北 3日電）核一二三廠延役在反核四的聲浪下異軍突出，在非核家園願景，及需要電力支撐台灣產業競爭力考量下，核一、二、三廠延役，或許是最大公約數。

Balancing the economic growth and the risks of ever increasing energy demand



Future disasters: waiting to happened anytime



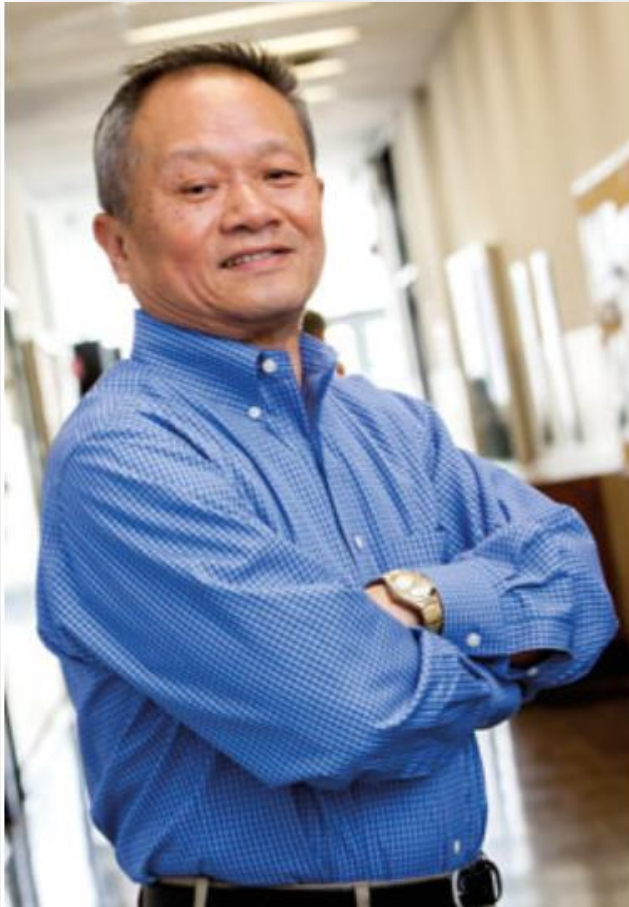
Climate change - the ultimate disaster to the humanity



總結

- ❑ 人類和幅射線有切身的關係 – 我們自古以來就與幅射線共存; 對幅射線要有認知而不是恐懼
- ❑ 幅射線科技給人類帶來前所未有的福祉, 也可能帶來重大的災難; 所以要處處小心不可大意
- ❑ 尖端科技(包括核能及醫學)的發展端視社會的需求, 不可因噎廢食; 人類將需仰賴科技以求生存及發展
- ❑ 國家的能源政策需有長期的規劃包括所有替代方案及可行性 – 任何方案都有其正負面; 維持平衡的政策才能確保穩定及永續的能源發展
- ❑ 社會經濟的發展必需以民眾之安全及環境之保護為前題; 國家的重大計畫也必需以此為優先考量

謝謝各位!



我們必須善盡責任以確保
民眾安全及維護環境!

Vanguards of Advanced Technology

ILLINOIS INSTITUTE
OF TECHNOLOGY

