Nuclear Power and the Environment Facts vs. Fiction

T.S. Gopi Rethinaraj
Lee Kuan Yew School of Public Policy
National University of Singapore

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Overview

- Resurgence of global civilian nuclear power industry after three decades of stagnation and uncertainty
- Climate change and energy security concerns have persuaded some countries to consider nuclear power as an environmentally credible option
- Does nuclear power pose unacceptable environmental risks and liability to current and future generations?
- What are the perceived environmental risks posed by nuclear power plants and fuel cycle facilities, and are they credible enough to dismiss outright the nuclear option?

Focal points

- Environmental risks of nuclear power versus other energy sources
- Health and environmental risks from normal plant operation
- Risks of reactor core meltdown and managing the consequences
- Risks from nuclear fuel cycle activities, especially managing high level radioactive wastes
- Risks to human health and environment from low level radiation
- Historical perspectives on risk management and implications for managing nuclear risks

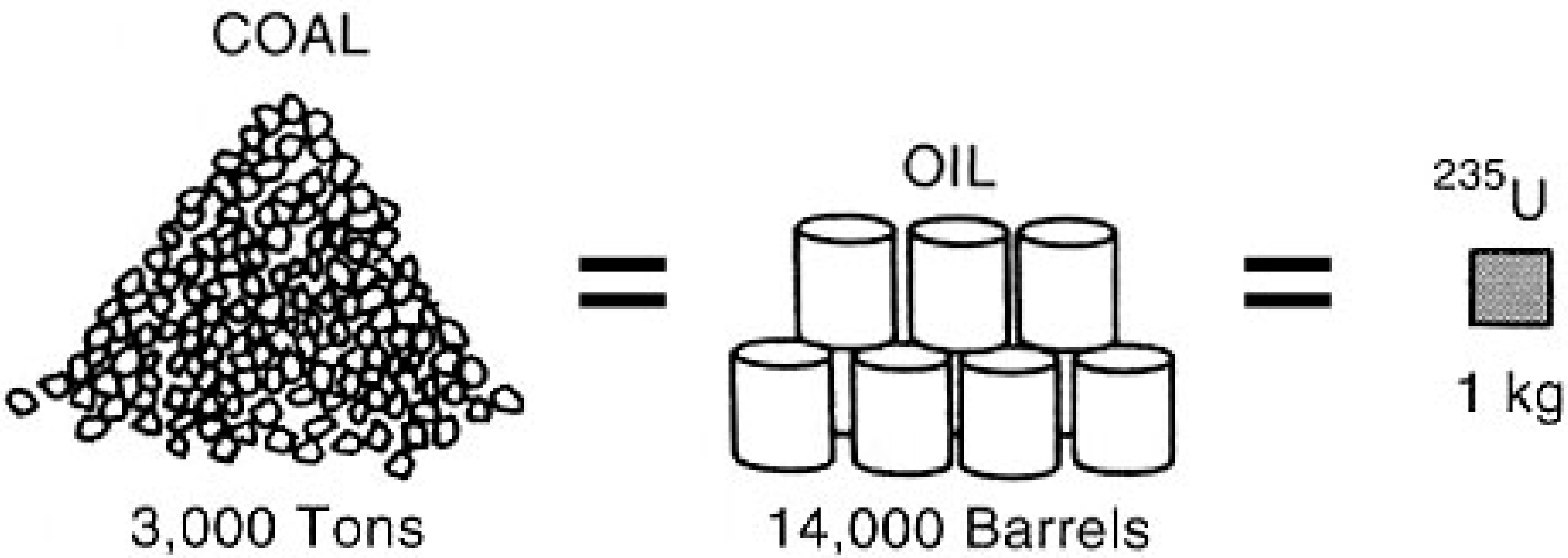
Megatons to Megawatts

- After the bomb, nuclear energy pursued for propulsion of naval reactors by US Navy, and the industry accepted the PWR design used in naval reactors.
- Basic principle of PWR suggested by Alwin Weinberg in 1944. During the war power applications were not given priority. PWRs became the foundation of U.S. naval propulsion.
- No urgency (fossil fuels were plentiful) and the knowledge was tightly guarded. Shippingport reactor was operational in 1957.
- Early enthusiasm and "too cheap to meter". Growth until mid 1970s. Reactors built before 1962 was less than 300 MWe capacity. Escalation in size due to economy of scale. Reactors up to 1600 Mwe capacity are being built.

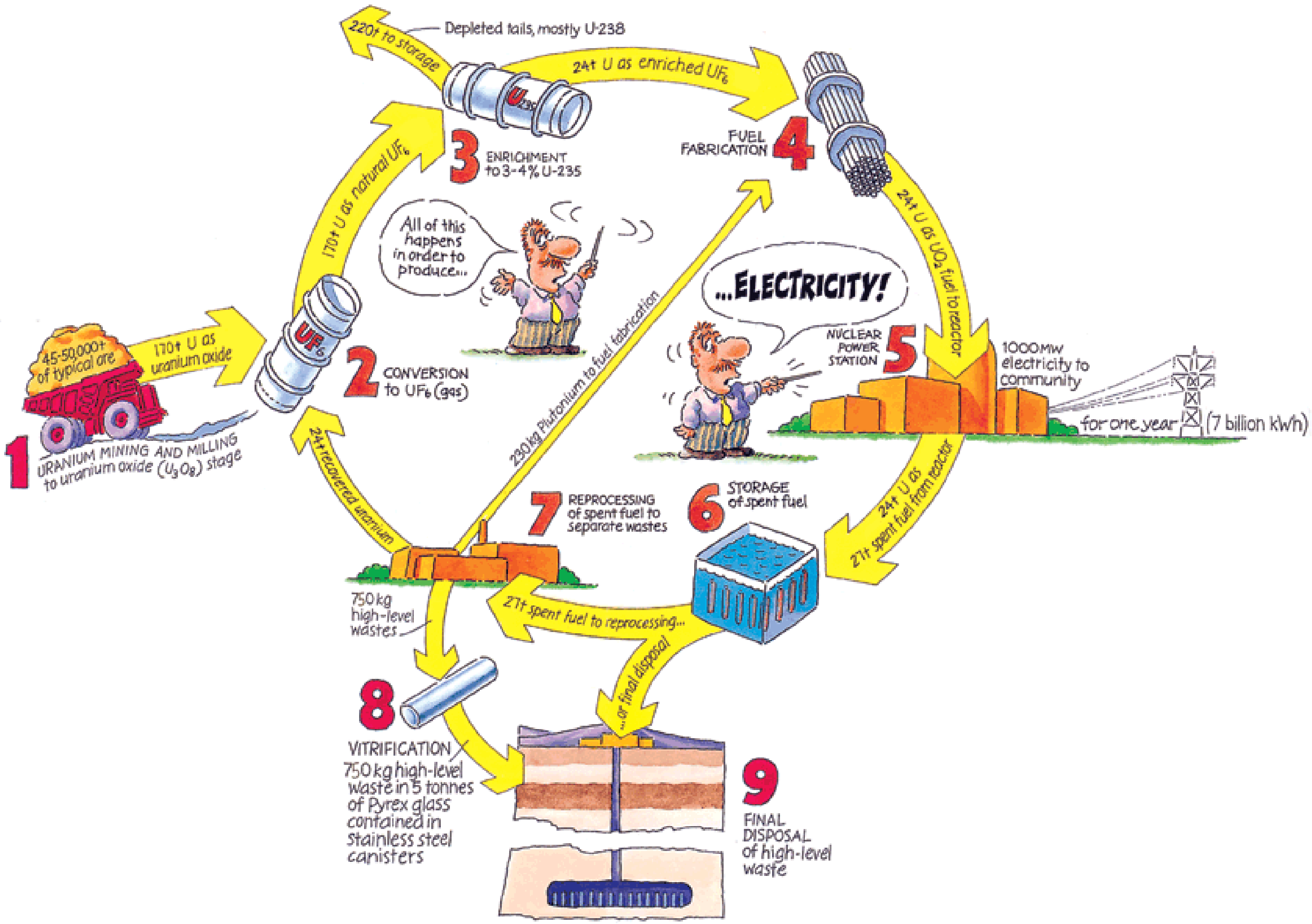
Atoms for Peace

- Atoms for Peace initiative by US to gain influence and dissuade countries from developing nuclear weapons. Former Soviet Union exported its own version to members in its sphere of influence.
- Enthusiasm about growth of nuclear power prompted programs for reprocessing spent nuclear fuel to recover plutonium.
- NPT and the grand-bargain. Choice of reactors: PWRs, PHWRs, BWRs, and others.
- Large scale government subsidies funded the early expansion of nuclear power in the West. Crumbling of protective cover and energy market deregulation reduced the charm of nuclear power.
- Three Mile Island (1979) and Chernobyl (1986) sealed the hopes of the nuclear power industry in many Western countries. Organized social resistance movements around environmental risks posed by nuclear power.

The nuclear energy appeal



Nuclear Fuel Cycle



Special nuclear materials

- Uranium-235
  - Natural uranium is 99.3% U-238 and 0.7% U-235. So it cannot be directly used for explosives. It has to be enriched (centrifuges)
  - LEU: < 20% U-235
  - HEU: > 20% U-235
  - Weapons-grade: > 80% U-235

- Uranium-233
  - This can also be used for fuelling reactors by converting Th-232, but currently not economic.

- Plutonium-239
  - Plutonium is not found in nature. It’s produced in reactors as a result of neutron absorption by U-238 followed by two successive beta decays. Favorable isotope of is Pu-239, not higher isotopes of plutonium.
    - Reactor-grade: > 19% Pu-240 and heavier isotopes
    - Fuel-grade: 7% to 19% Pu-240 and heavier isotopes
    - Weapons-grade: < 7% Pu-240 and heavier isotopes
  - Bombs can be made from reactor grade plutonium so important from the point of view of securing it from theft by terrorists.

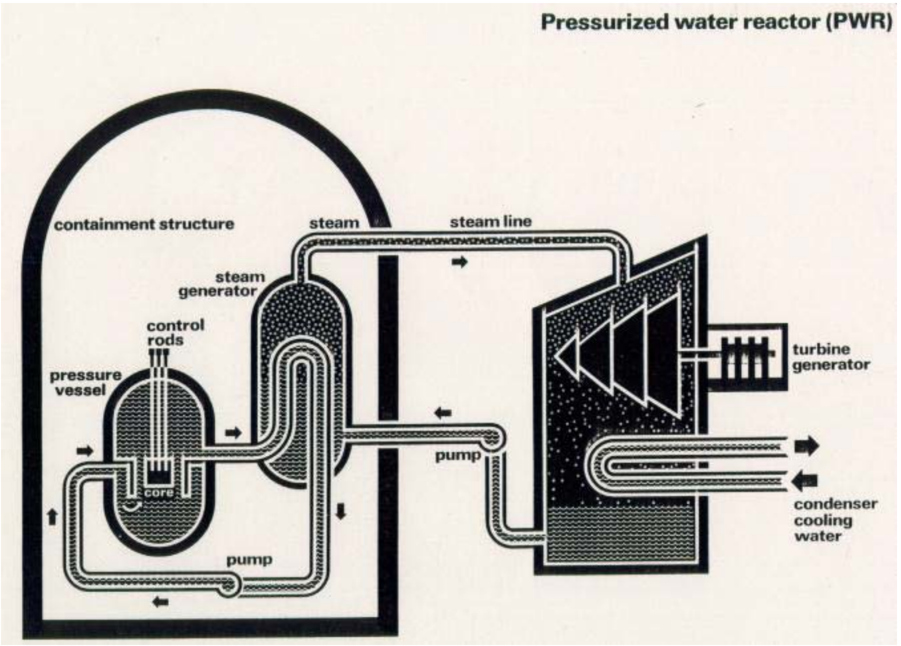
Risks from normal operation

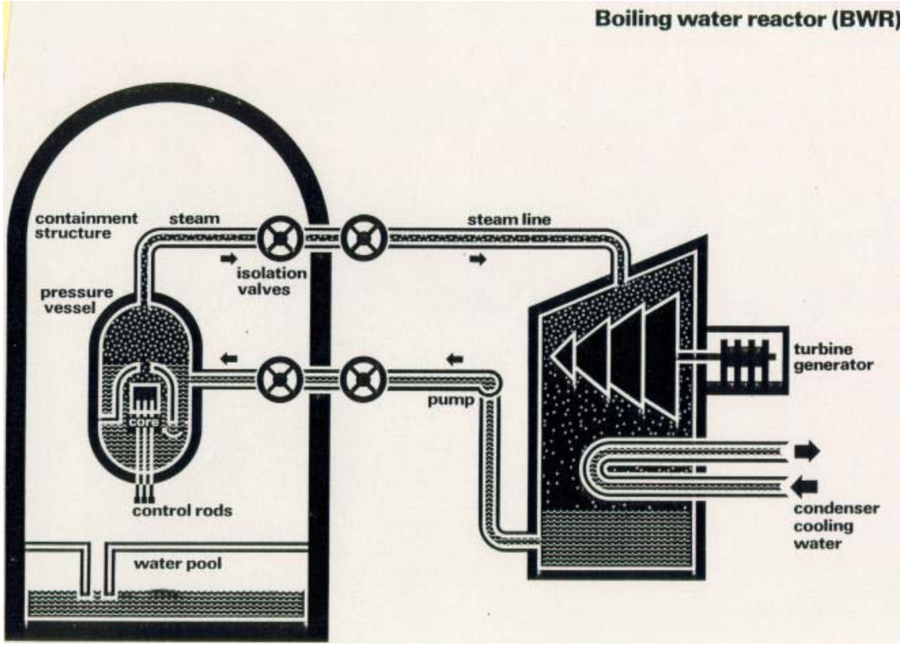
- Nothing is burned during the fission process, little fuel volume or mass is changed during nuclear power generation.
- Nuclear fuel exists under controlled conditions from the first insertion into the reactor until its removal from the reactor.
- Thermal pollution can be significant due to low thermodynamic efficiency, but they are manageable
- There is no environmental pollution during the course of normal operation.
- Occasional releases of low level radioactivity into environment doesn’t threaten public health

Risks from core meltdown

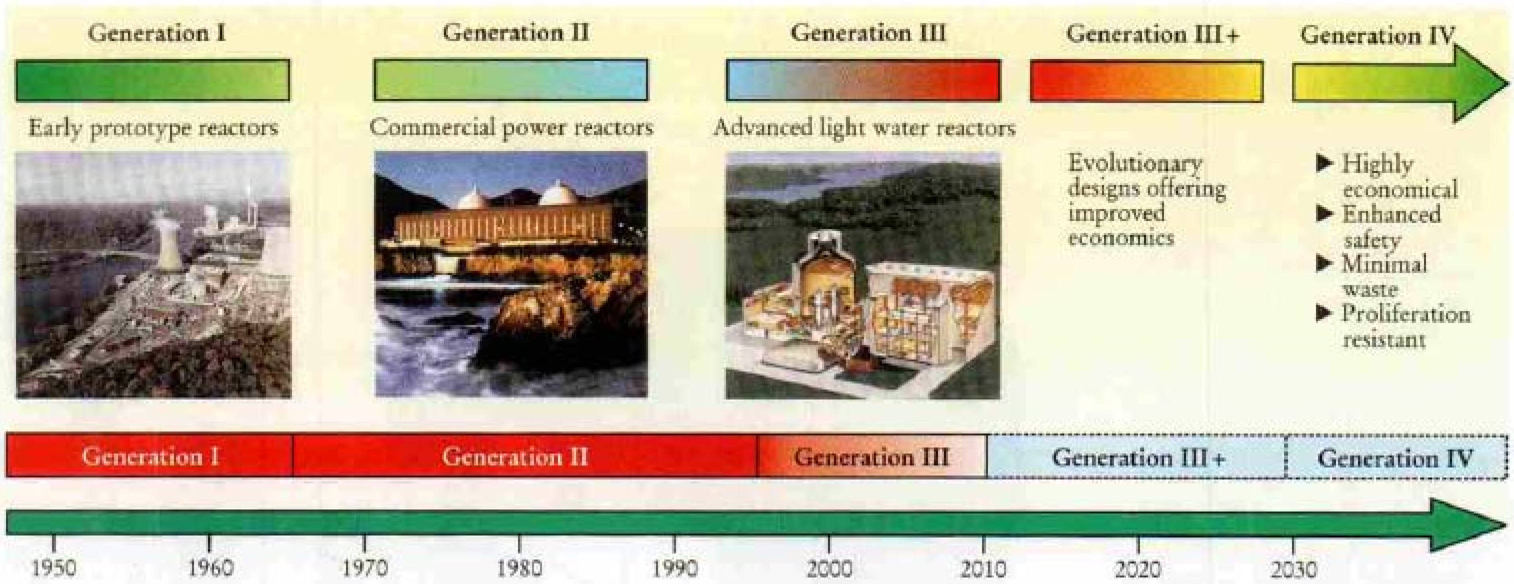
- What are the true risks of recurrence of a Chernobyl type or Three Mile Island type of nuclear accident?
- Chernobyl type accidents are not possible in modern nuclear power plants for many technical reasons
- TMI type accidents possible, but they can in the worst case scenario cause only financial damage to utility and very remotely to public health and environment
- Contrary to what many people think, nuclear reactors don’t explode like a nuclear bomb.
- The environmental effects are very different in the case of a reactor meltdown and weapon detonation.

Light Water Reactors





Evolution of Reactor Design



THE EVOLUTION OF COMMERCIAL NUCLEAR POWER PLANTS, though continuous, can be thought of as a series of generations that extends from the first prototype plants of Generation I, through the existing and planned plants of Generations II, III, and III+, to the speculative concepts of Generation IV.

Risks from nuclear wastes

- Discussions about risks from nuclear wastes are now getting further and further away from reality
- There are risks of course, but talking about inherent risks doesn’t make much sense
- Current practice of risk management in this context is very expensive and politically contentious.
- Interim storage (either on site or dedicated facilities) for a period of 50 to 100 years make economic sense instead of designing facilities to assure safety for 10,000 years to 100,000 years
- Human society doesn’t have the experience of dealing with policy planning for such a long time horizon!

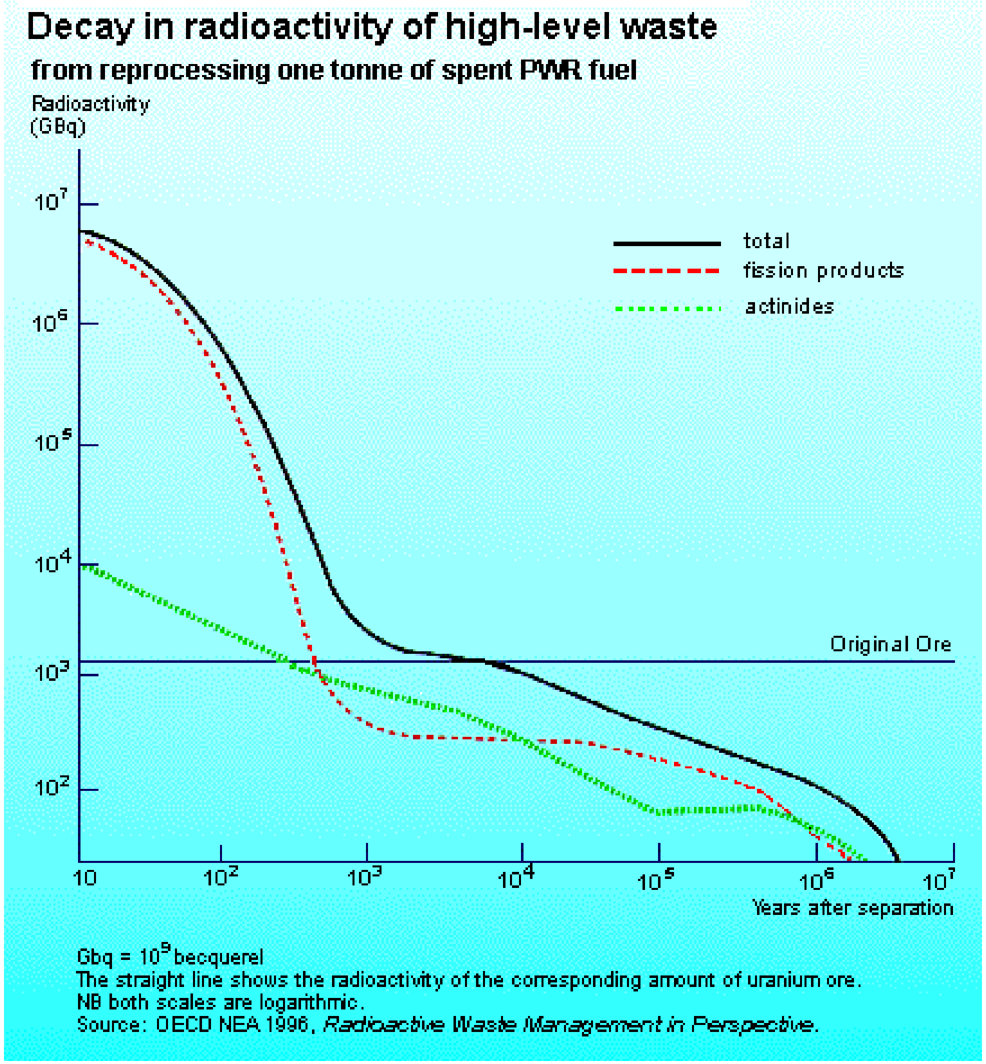
Plan D (Source: ACDIS, University of Illinois)

- Plan A. Breeding. Reprocess spent fuel, after brief underwater storage, for use in breeder reactors.
- Plan B. Prompt Deep Burial after removal from pool storage.
- Plan C. Actinide Burning. Reprocess spent fuel promptly for the purpose of deep actinide burning to reduce the deep underground storage space required.
- Plan D. Holding in Dry Casks. Holding fuel removed from wet pools in dry cask storage until it becomes clearer whether reprocessing will precede permanent disposal.
- Plan E. Elimination. Build no more reactors for nuclear electric power production and abandon spent fuel reprocessing.

Nuclear Waste Activity

Fission Products		Actinides	
Nuclide	Half-life (years)	Nuclide	Half-life (years)
^{90}Sr	28.8	237 Np	$2.1x10^6$
^{99}Tc	210000	238 Pu	89
^{106}Ru	1	239 Pu	$2.4x10^4$
^{125}Sb	2.7	240 Pu	$6.8x10^3$
^{134}Cs	2.1	241 Pu	13
^{137}Cs	30	242 Pu	$3.8x10^5$
^{147}Pm	2.6	241Am	458
^{151}Sm	90	243Am	$7.6x10^3$
^{155}Eu	1.8	144Cm	18.1
Activities (in curries) after	**10 years**	**100 years**	**1000 years**
Fission products	300000	3500	15
Actinides	10000	2200	600

Radioactivity of nuclear waste



Risks from low level radiation

- It’s abundantly clear what radiation can do in large doses (Hiroshima-Nagasaki and several accidents resulting in acute exposure).
- Risks from low level radiation is still not a settled issue because of the contentious threshold hypothesis. But we happily subject ourselves to risks from low level radiation for medical and other reasons.
- If that’s acceptable a small increase to exposure from nuclear power generation (which is going to be spread out in time and space) will become very difficult to notice.

Exposure to radioactivity

Radiation Exposure . . . Where It Comes From

NATURAL RADIATION 82%	RADON 55%
	INTERNAL 11% (INSIDE HUMAN BODY)
	TERRESTRIAL 8% (ROCKS)
	COSMIC 8% (OUTER SPACE)
MAN-MADE RADIATION 18%	MEDICAL X-RAYS 11%
	NUCLEAR MEDICINE 4%
	CONSUMER PRODUCTS 3%
	OTHER LESS THAN 1%
	OCCUPATIONAL 0.3%
	FALLOUT LESS THAN 0.3%
	NUCLEAR FUEL CYCLE 0.1%
	MISCELLANEOUS 0.1%

Natural Background Radiation . . . Where It Comes From

(Measured in millirem per year)

RADON IN BUILDINGS	200
HUMAN BODY (INTERNAL)	40
THE EARTH	28
COSMIC RAYS	27

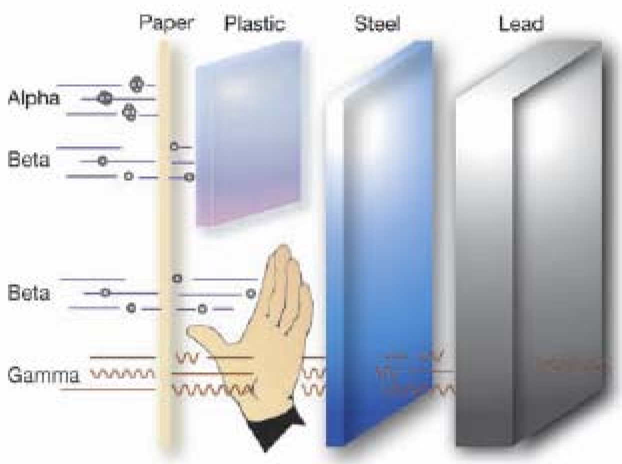
Man-Made Radiation . . . Where It Comes From

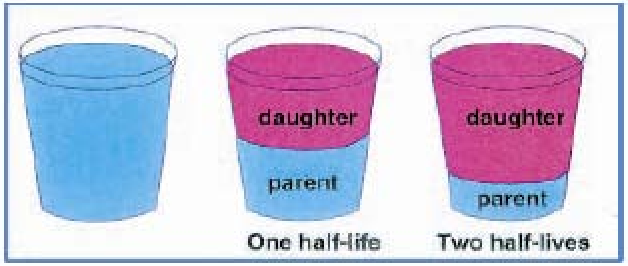
(Measured in millirem per year)

MEDICAL X-RAYS (AVERAGE AMERICAN)	45
COAST-TO-COAST ROUND-TRIP AIRLINE FLIGHT	5
COLOR TELEVISION	LESS THAN 1
LIVING NEXT TO AN OPERATING NUCLEAR POWER PLANT	LESS THAN 1

Source: National Council on Radiation Protection and Measurements.

Penetrating power of radioactivity and half life





Witches and nuclear fear

- Nuclear fear has deeper roots: fear of death from cancer is only a manifestation of a deeper socio psychological issue.
- Given the complexity and difficulty in coming to terms with the issues involved, human mind is vulnerable to easy and irrational explanations.
- Witch craft and witch hunting during the dark ages sheds lot of insight into this phenomenon.
- Witches were convenient explanations that befell various human misfortunes like crop failure, disease etc.
- Hysteria about nuclear radiation is a residual effect of this human problem.
- Better understanding will shed light on the environmental benefits of nuclear power besides helping the world manage the risks from nuclear power while continuing to enjoy the benefits of a clean energy source