Understanding Risk

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Presentation Objectives

- In November 2006, Time Magazine featured the question

"Why we worry about the things we shouldn't and ignore the things we should"

- In this presentation, we will discuss:
  - What we mean when we say something is unsafe.
  - The relationship between safety and risk.
  - The major health risks are that we face in our daily lives.
  - The character and magnitude of nuclear power plant accident risk.

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Safety

- *Is it safe to cross the street?*
- What could happen to you?
  - You could be injured.
  - You could die.
  - Nothing.
- You look both ways and assess the likelihood of being hit.
- Safety is not just a question of the potential size of the hazard, it also depends on the likelihood.

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Risk

- Definition of risk

  "Risk is the potential for some unwanted event to occur. Risk is a function of the likelihood of the unwanted event and its consequences."

  National Infrastructure Protection Center

- Risk always has some element of (unwanted) consequence and some element of likelihood
- Simple measure of risk:
  - Probability of an event times its consequences.
- Risk assessment is a tool that we use to quantify safety.

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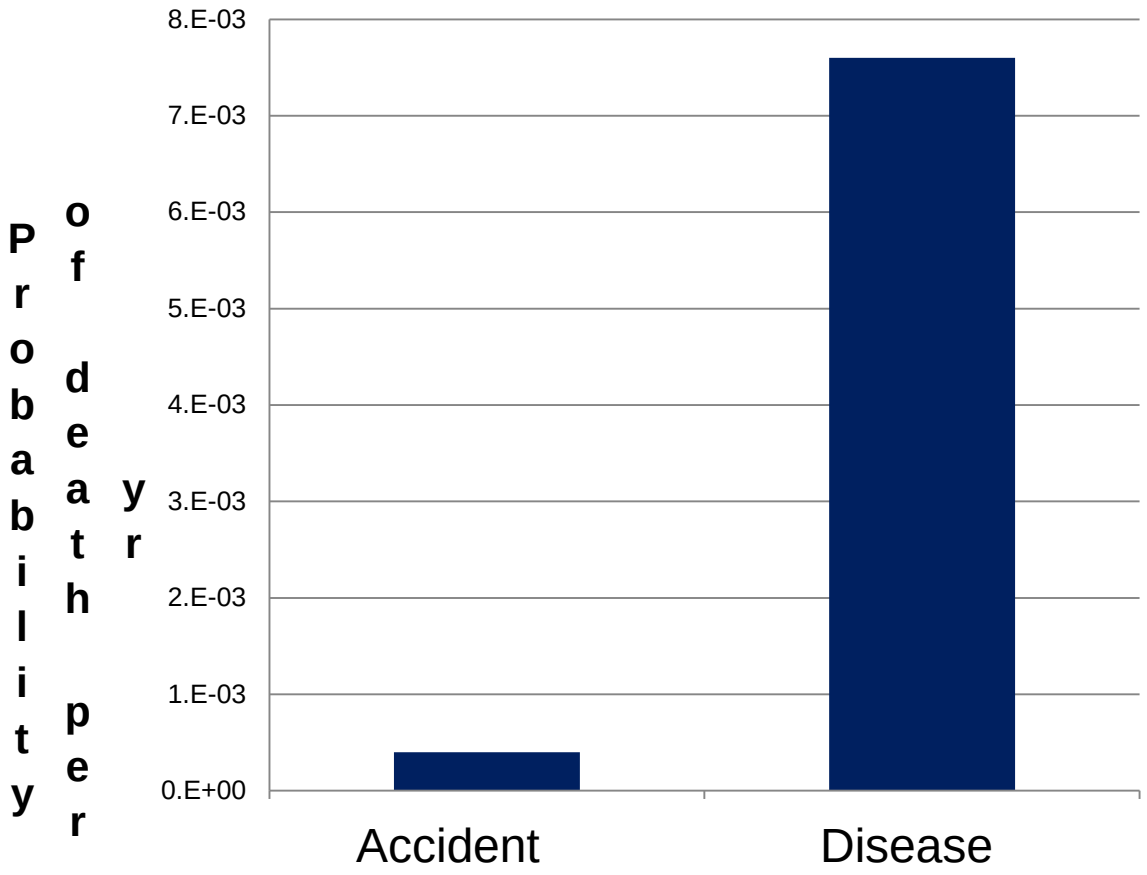
Disease Risks Dominate Personal Risk



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Accident Risks

Type	Annual Fatalities (2010)
Transportation (motor vehicles)	37,961
Falls	26,009
Poisoning	33,041
Drowning	3,782
Fire/Smoke	2,782
Other	17,284
Total	120,859

- Risk per year = 120,859/309 million = 0.0004/yr

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Disease Risks

Type	Annual Fatalities (2010)
Total	2,350,000
Heart	600,000
Cancer	575,000
Respiratory	138,000
Cerebrovascular	129,000
Alzheimers	83,000
Diabetes	69,000
Other	755,000

- Risk per year = 2,350,000/309 million = 0.0076/yr

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Odds of Dying

- Average ~ 8/1,000 per yr
- Accident risk – 4/10,000 per yr
- Only period of life in which accident risk is as large as health risk ~1/1000 per yr
  - Men in the period 18 to 20 yr due to automobile accidents
- Cars kill 100 people per day
- Smoking kills 1,200 people per day

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What Is the Health Risk of a Nuclear Power Plant Accident?

- Extremely small.
  - Even for a person living next door to a nuclear power plant, the risk of dying prematurely from cancer from an accident is approximately 1/100,000 th the risk of dying from other causes of cancer.
  - Based on risk assessment models developed from severe accident research and 15,000 reactor years of world-wide operating experience.
- But health risk is not the dominant risk of nuclear power plant accidents.
  - I will explain.

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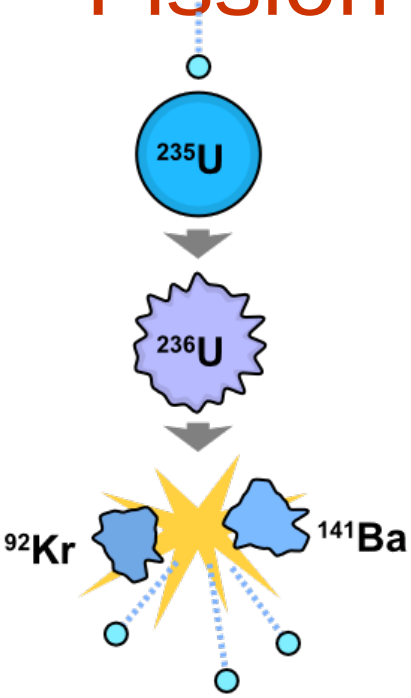
Nuclear Power Basics - Fission

- Two isotopes of uranium
  - $^{238}U_{92}$ – Not readily fissionable
    99.3% of natural uranium
  - $^{235}U_{92}$ – Fissionable
    0.7% of natural uranium
- Fission results in
  - Radioactive fission products
  - Neutrons
  - 200 MeV of released energy
- The concentrated nature of nuclear energy is what limits its environmental footprint relative to competitive sources of energy



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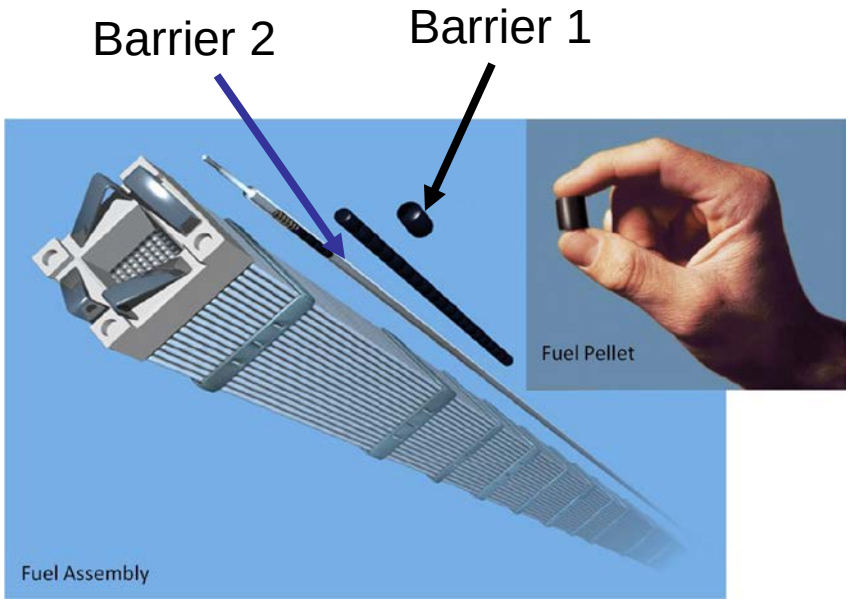
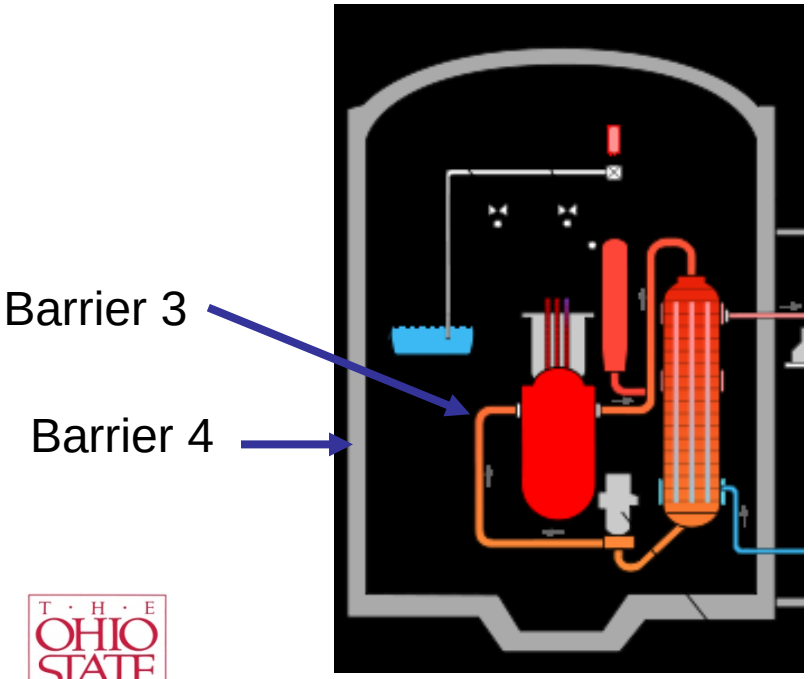
Fission Products and Reactor Safety

- All reactor safety problems are associated with the radioactive fission products.
  - Because they are radioactive, they produce heat (decay heat) that must be continually removed to prevent fuel melting.
  - Because they are radioactive (emit radiation), if they are release to the environment people can be exposed to the emitted radiation and their health can be affected.

Defense in Depth

- Multiple Barrier Concept
  1. Fuel matrix (uranium dioxide)
  2. Cladding (zirconium alloy)
  3. Reactor Coolant System (steel)
  4. Containment (steel boundary)





- Although very unlikely, a severe accident can result in the failure of all of four barriers as happened at Fukushima.

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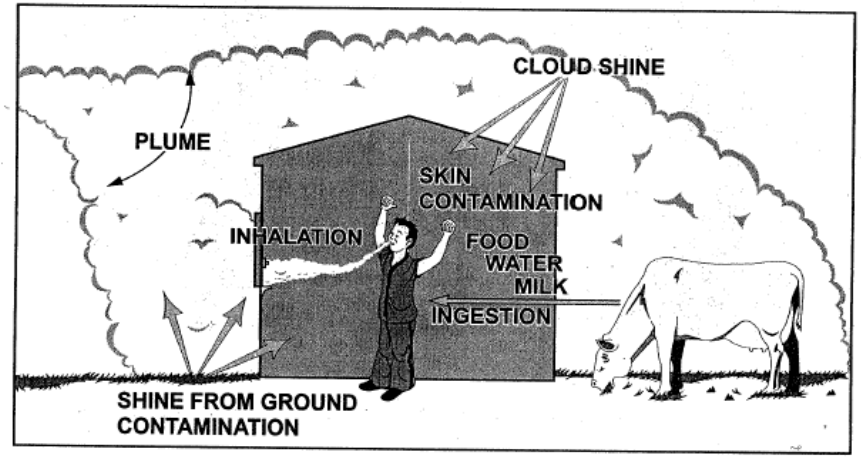
Safety Concern of Severe Accident

- Accident in which ability to cool the fuel is lost.
- Fuel melts and penetrates the reactor coolant system resulting in release of fission products to the air in the containment building.
- Containment building fails leading to an airborne release of radioactive material.
- People are exposed:

  external, inhalation or

  ingestion



Radiation dose pathways

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Measuring Human Exposure to Radiation

- Ionizing radiation damages cells.
- Rem is a unit of measure that determines the biological effect of radiation exposure
  - It is independent of the type of radiation.
- Sievert is the SI unit (=100 rem) but historically rem has been more commonly used in the U.S.

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Health Effects of Exposure – High Dose

- Radiation sickness (high doses)
- LD50/30 is the “lethal dose for 50 percent of the population within 30 days without medical intervention”.
- Lethal dose LD50/30 = 450 rem (some variability with age)
- Signs of radiation sickness ~100 rem
- In risk assessments with modern models, risk to public of early fatality effectively non-existent

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Health Effects of Exposure – Low Dose

- Cancer possible at lower doses
- Random behavior – radiation can increase probability of getting cancer but can't say who will get cancer
- Appear with some delay in time (latency period).
- Typically described in terms of mrem (1 millirem = 0.001 rem)

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Background Radiation

- Humans are unavoidably exposed to radiation that arises from cosmic rays and the decay of naturally occurring radioactive materials.
- Average exposure
  - Natural sources of radiation (cosmic rays, house construction) – 320 mrem per year
  - Medical procedures – 320 mrem per year

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Low Dose Issue

- Does a high background dose of radiation increase the incidence of cancer in a population?
  - We don't know.
  - There is no evidence that people living in Denver with a higher background dose of radiation have a higher incidence of cancer than people in Columbus?
  - The effect is so small, it is very difficult to measure.

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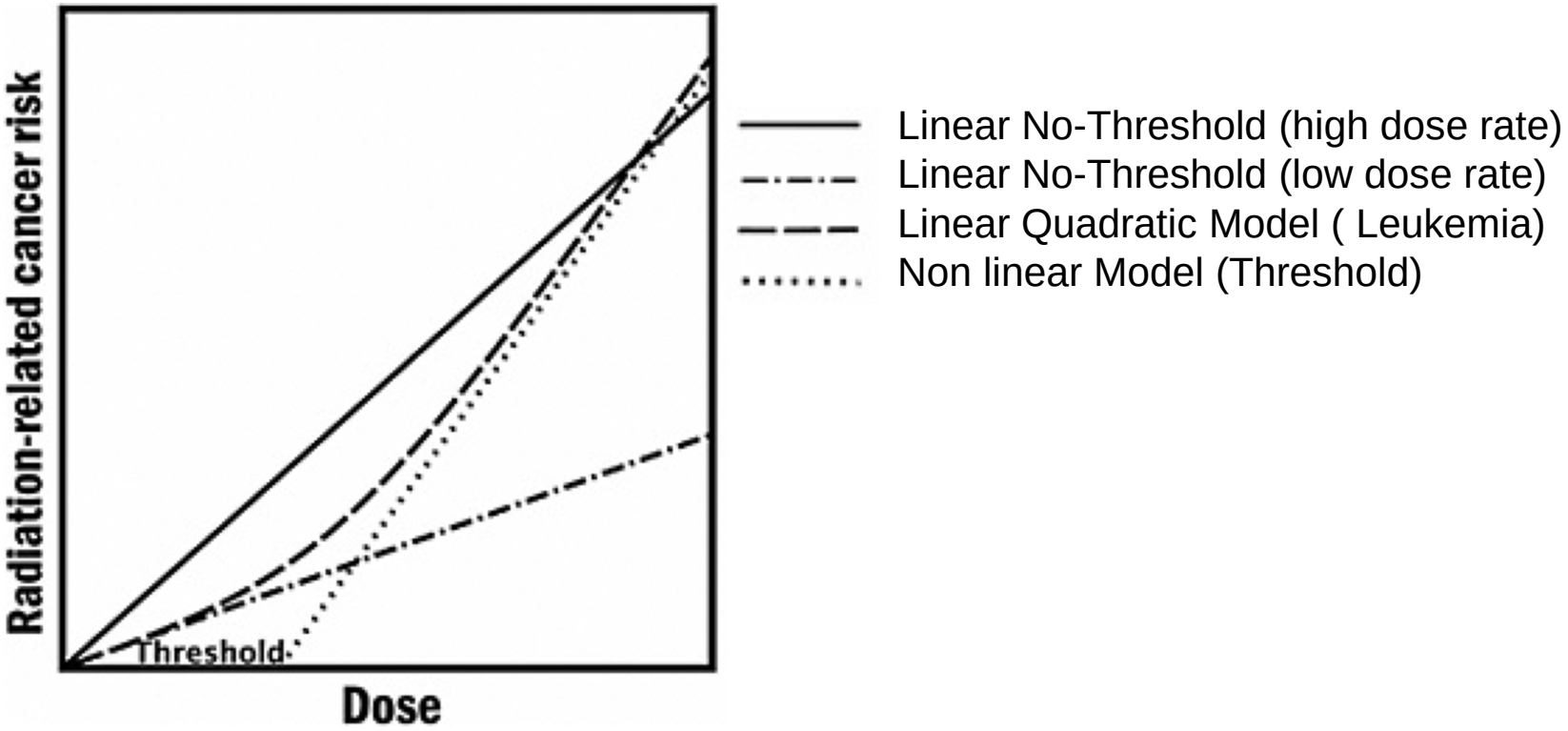
Dose-Response: Linear no Threshold (LNT) Versus Threshold Model



- The estimation of cancer risk at very low doses (near background) is highly controversial.
- But can be used in establishing conservative regulations.

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Terrestrial and Cosmic Sources

- Radioactive minerals in the soil
  - Potassium - 40
  - Decay products of uranium and thorium
  - Average of 28 mrem/year (not including radon)
- Cosmic radiation
  - Shielded by the atmosphere
  - Exposure in Denver is about twice as high as in Ohio
  - Flying in an airplane at high altitude increases exposure
  - Average of 27 mrem/year

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Internal Radiation
We are Naturally Radioactive !

- Potassium-40 enters the body through the food chain
  - A natural and necessary nutrient
  - Is ~ 0.01% of all potassium
- Carbon makes up about 23% of our body weight
  - Carbon-14 is produced in the atmosphere by cosmic radiation
  - It enters our body through the food chain and by breathing
- Average of ~40 mRem/year from internal radiation

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Radiation And Our Body

- *Radioactive material in the body produces approximately one-half million decays per minute.*
- Plus, it is exposed to radiation from the environment and cosmic rays.
- *Billions of our cells are hit each day.*
- Nearly all the trillions of cells are hit each year, many more than once.
  - Cells have effective repair mechanisms.
  - Cancer is primarily a disease of the aged.
- However, cancer CAN begin with disruption of the DNA of a single cell → minimize radiation exposures

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Public Exposure in Actual Accidents - Chernobyl

- Chernobyl was not the same type of reactor as operated in the U.S. and did not have the same level of defense-in-depth.
- The release of fission products involved a large fraction of the reactor inventory.
- Extensive land contamination occurred.
- The only measurable increase in cancer was thyroid cancers in children.
  - These consequences would have been avoided if the FSU had admitted that the accident was happening.

Public Exposure in Actual Accidents – Three Mile Island

- Extensive fuel damage occurred and release of fission products from the fuel to the reactor containment building.
- Containment maintained its integrity – as is expected in a severe accident.
- Only very small doses to the public.
- No radiation-related health effects.

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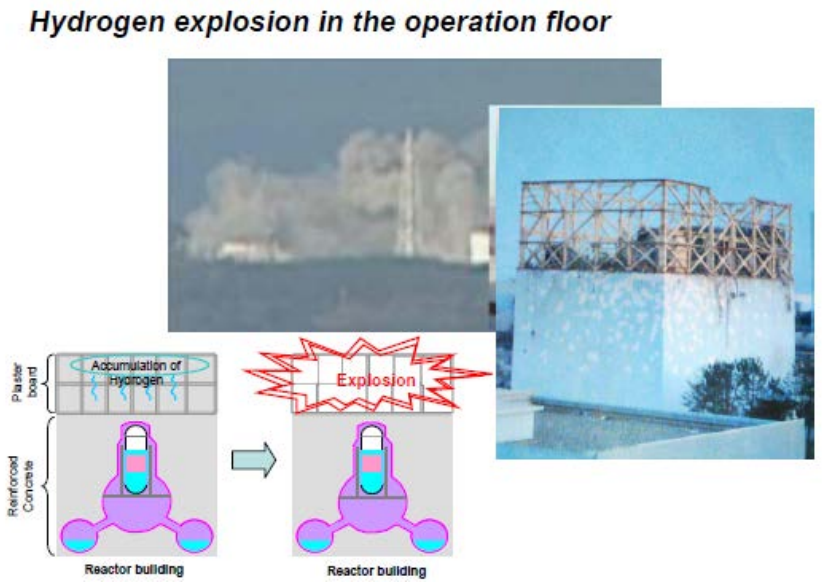
Public Exposure in Actual Accidents – Fukushima

- Loss of capability to remove heat from the reactor resulting from damage caused by tsunami.
- Extensive fuel melting and release of fission products to containment .
- Containment failure of three reactors.



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Public Exposure in Actual Accidents – Fukushima

- Substantial release of fission products but much less than at Chernobyl.
- Contamination of a large area and the need to relocate a large number of people.
- However, the maximum actual exposures will be similar to background radiation.
  - No member of the public has received or is likely to receive a dose that would significantly increase their likelihood of incurring cancer.
  - Confirmed by WHO and UNSCEAR.

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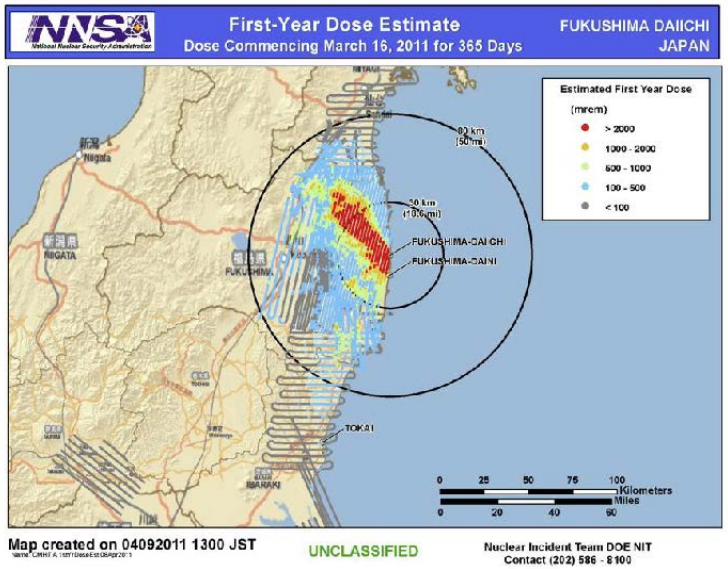
The Real Risk of Nuclear Power Plant Accidents

- The risk of radiation-related health effects to members of the public in a reactor accident is extremely small.
- The real risk is a societal risk associated with land contamination, the need for relocation of people, loss of produce, loss of land use, and the cost of decontamination.
- It is a significant but manageable risk.



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Why Bother?

- Why accept any risk? Why don't we just use a safe alternative?
- All forms of energy generation have associated health risks: mining deaths, drilling deaths, natural gas explosions, respiratory deaths.
  - Must consider the entire life cycle: mining (drilling), transportation, operations, waste disposal.
- Per unit of energy produced, nuclear energy is the safest mode of energy production.

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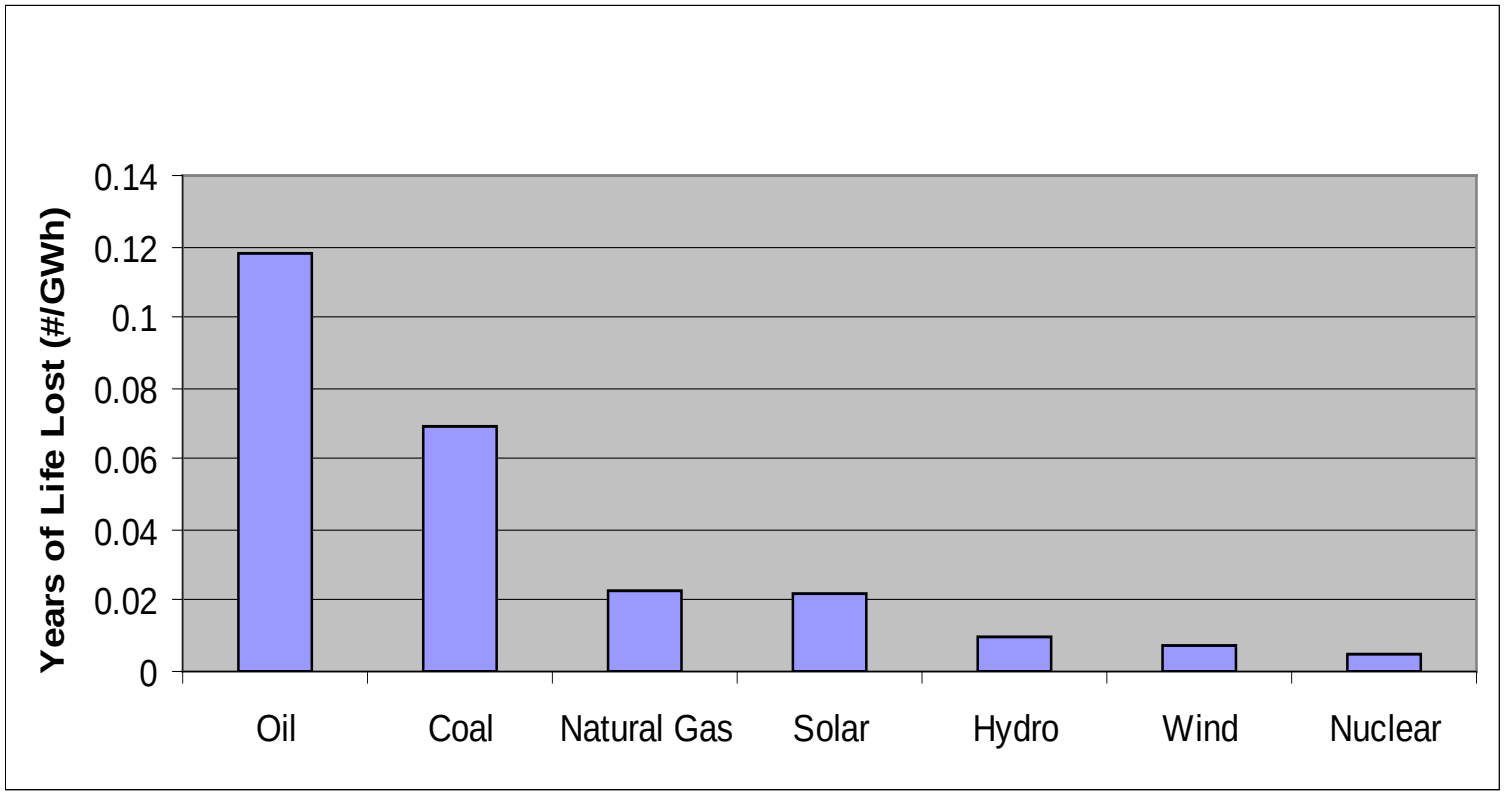
Total Life Cycle Impacts – Years of Life Lost per GWh



– Paul Sherrer Institute (German data on emissions)

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The Need

- Within the lifespan of the children that we teach, the world will face four converging crises: global warming, inadequate fresh water supply, loss of arable land (and food supply), and the need to replace fossil fuels as an energy source.
- Renewables will only be capable of satisfying a fraction of the total energy need.
- Nuclear must be a major component of the energy mix.

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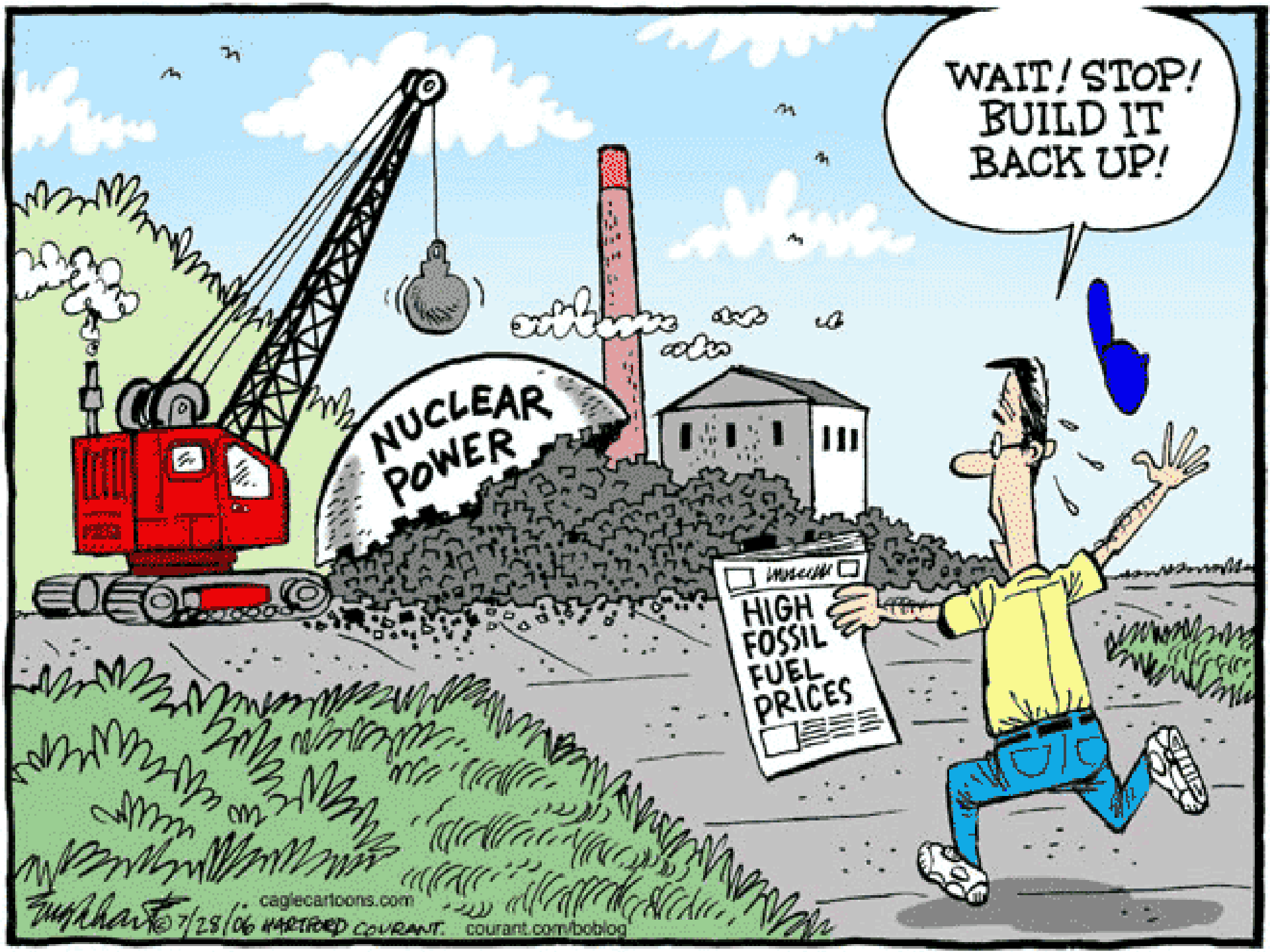
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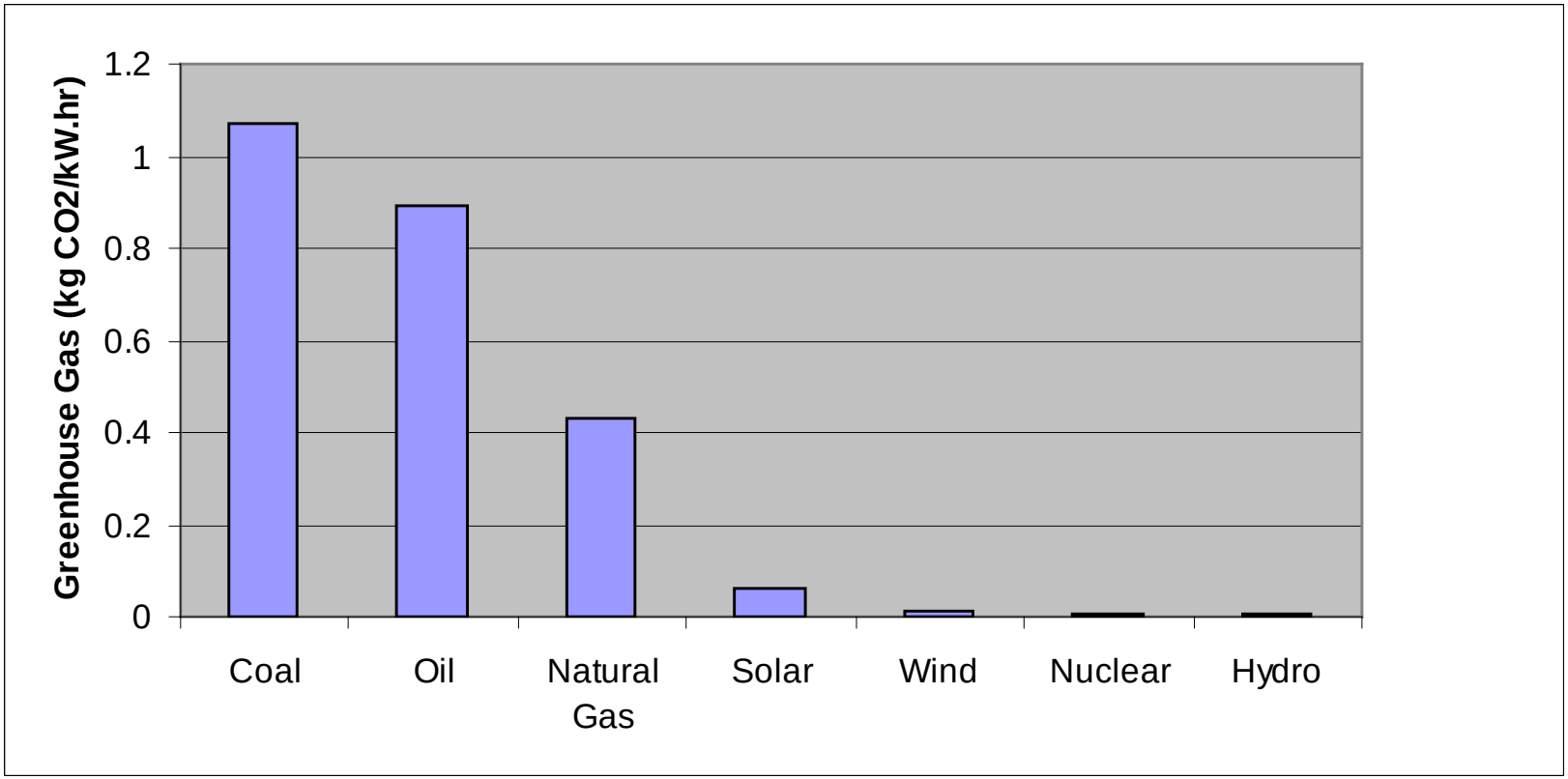
Total Life Cycle Impacts – Greenhouse Gas Released



NEA Report, Risks and Benefits of Nuclear Energy

Pressurized Water Reactor