E.F. Schumacher

Small is Beautiful Economics as if People Mattered

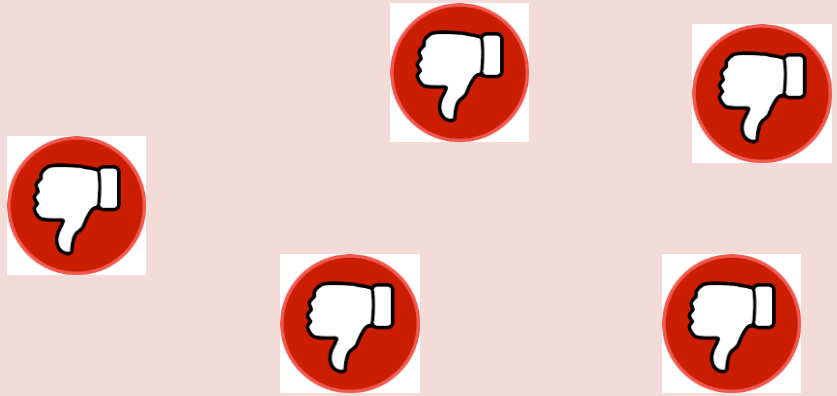
Chapter 9

Nuclear Energy – Salvation or Damnation?

A Lonergan Institute Seminar

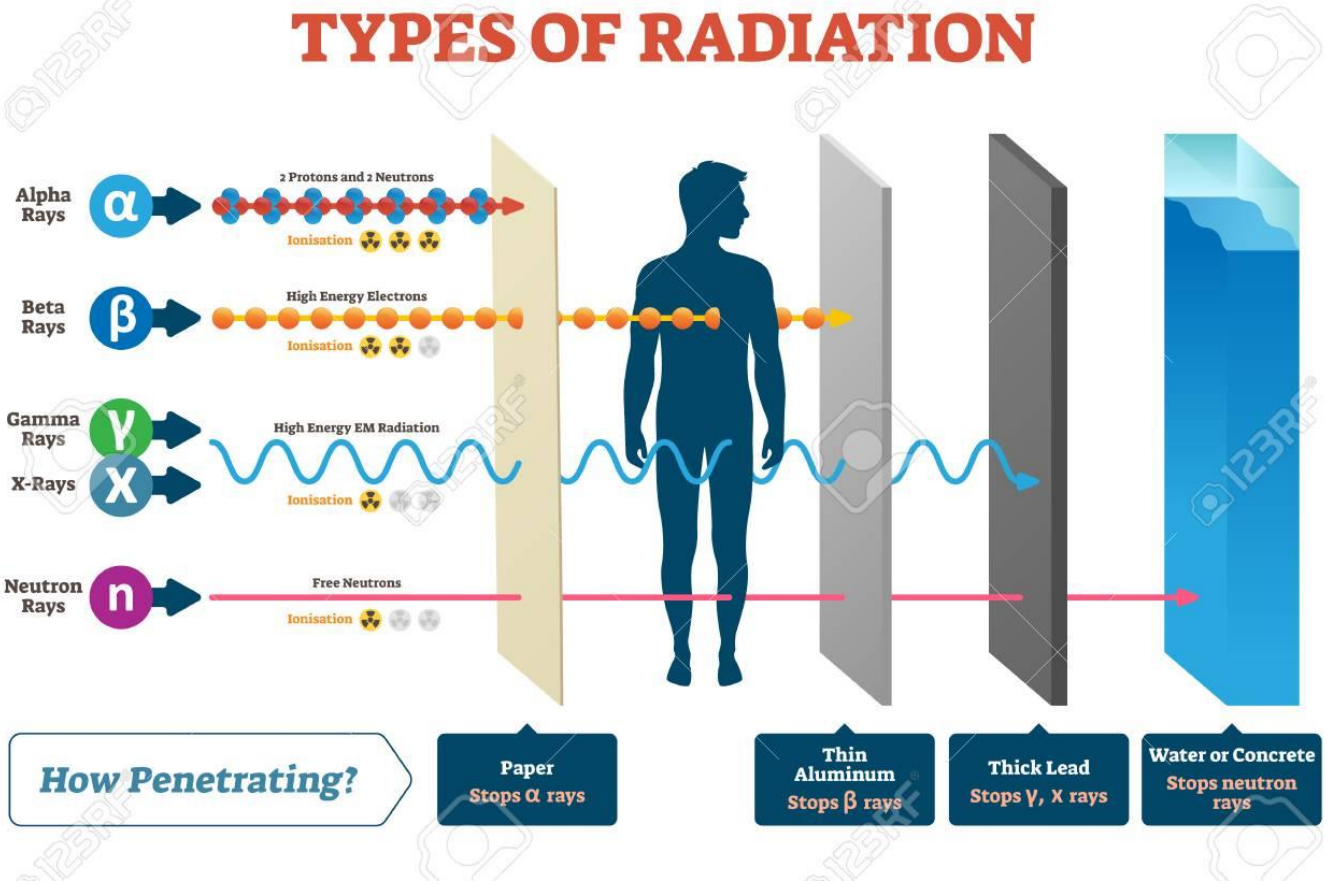
St Anselm's Abbey

Discussion Question: If you were a member of the U.S. Senate, and had to vote to approve an international treaty that bans the production of all new nuclear power plants worldwide – how would you vote?

Votes For	Votes Against
	

From Schumacher - Chapter Nine

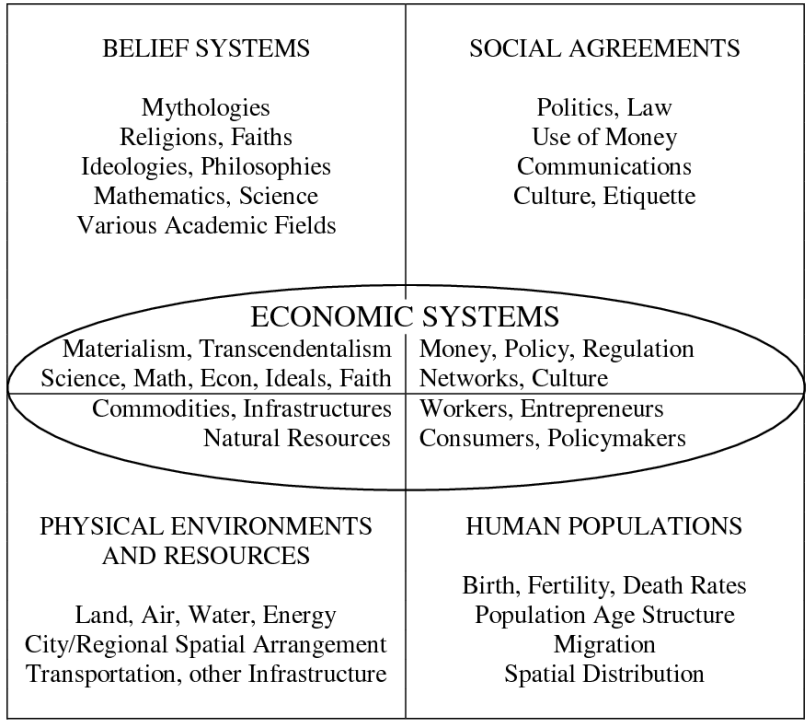
"The argument, six years ago, proceeded as follows: Of all the changes introduced by man into the household of nature, large-scale nuclear fission is undoubtedly the most dangerous and profound. As a result, ionizing radiation has become the most serious agent of pollution of the environment and the greatest threat to man's survival on earth."



From Schumacher - Chapter Nine

"The religion of economics promotes an idolatry of rapid change, unaffected by the elementary truism that a change which is not an unquestionable improvement is a doubtful blessing. The burden of proof is placed on those who take the "ecological viewpoint": unless they can produce evidence of marked injury to man, the change will proceed. Common sense, on the contrary, would suggest that the burden of proof should lie on the man who wants to introduce a change; he has to demonstrate that there cannot be any damaging consequences. But this would take too much time and would therefore be uneconomic. Ecology, indeed, ought to be a compulsory subject for all economists, whether professionals or laymen, as this might serve to restore at least a modicum of balance. For ecology holds "that an environmental setting developed over millions of years must be considered to have some merit. Anything so complicated as a planet, inhabited by more than a million and a half species of plants and animals, all of them living together in a more or less balanced equilibrium in which they continuously use and re-use the same molecules of the soil and air, cannot be improved by aimless and uninformed tinkering. All changes in a complex mechanism involve some risk and should be undertaken only after careful study of all the facts available. Changes should be made on a small scale first so as to provide a test before they are widely applied. When information is incomplete, changes should stay close to the natural processes which have in their favor the indisputable evidence of having supported life for a very long time".''

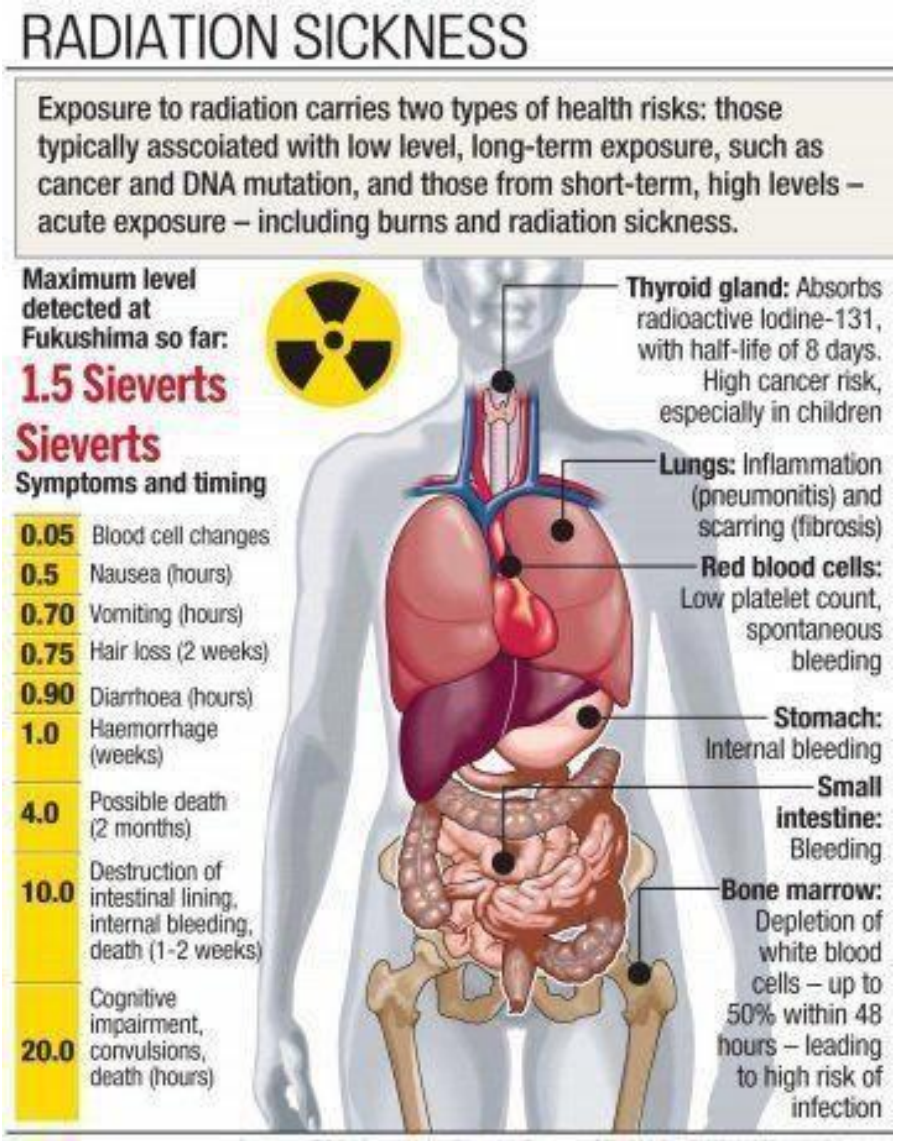
Structural Conditions in the Human Ecology



Economics exists between the intersection of all the things we know against all the things we would like to do and have.

From Schumacher - Chapter Nine

"A new 'dimension' is given also by the fact that while man now can - and does - create radioactive elements, there is nothing he can do to reduce their radioactivity once he has created them. No chemical reaction, no physical interference, only the passage of time reduces the intensity of radiation once it has been set going. Carbon-14 has a half -life of 5,900 years, which means that it takes nearly 6,000 years for its radioactivity to decline to one-half of what it was before. The half-life of strontium-90 is -twenty-eight years. But whatever the length of the half-life, some radiation continues almost indefinitely, and there is nothing that can be done about it, except to try and put the radioactive substance into a safe place. "



From Schumacher - Chapter Nine

“In fact, a prominent American nuclear physicist, A. W. Weinberg, has given some sort of explanation: 'There is.' he says, 'an understandable drive on the part of men of good will to build up the positive aspects of nuclear energy simply because the negative aspects are so distressing.' But he also adds the warning that 'there are very compelling personal reasons why atomic scientists sound optimistic when writing about their impact on world affairs. Each of us must justify to himself his preoccupation with instruments of nuclear destruction (and even we reactor people are only slightly less beset with such guilt than are our weaponizing colleagues).’ “

Advantages of Nuclear Power

- Most light water reactors that make up the world's nuclear capacity create electricity at costs of between $0.025 and $0.07 USD per kilowatt-hour dependent upon the design and requirements of each reactor and experiences many favorable variables such as government subsidies and research.
- To put into perspective, in California, the wholesale price to produce electricity from natural gas is approximately $0.05 USD per kilowatt-hour, revealing that nuclear energy may or may not be as costly as other alternatives in certain geographical areas.
- In addition, nuclear energy by far has the lowest impact on the environment since it does not release any gases like carbon dioxide or methane, which are largely responsible for the greenhouse effect.
- As a result, this differentiates nuclear energy from fossil fuels in that it does not produce negative carbon externalities as a byproduct, "though some greenhouse gases are released while transporting fuel or extracting energy from uranium."
- The factor of scarcity is not of concern when it comes to the reactors fuel source, which is primarily uranium. There are roughly 5.5 million tons of uranium in the known reserves that could be mined at $130 USD per kilogram.
- Currently, with the world's consumption of around 66,500 tons per year, there is about 80 years worth of fuel with the known reserves since the element is relatively abundant in the earth's crust.
- The main advantage to nuclear energy is that is it relatively low-cost and consistently runs on its full potential, making it the ideal source to power national grids.

Disadvantages of Nuclear Power

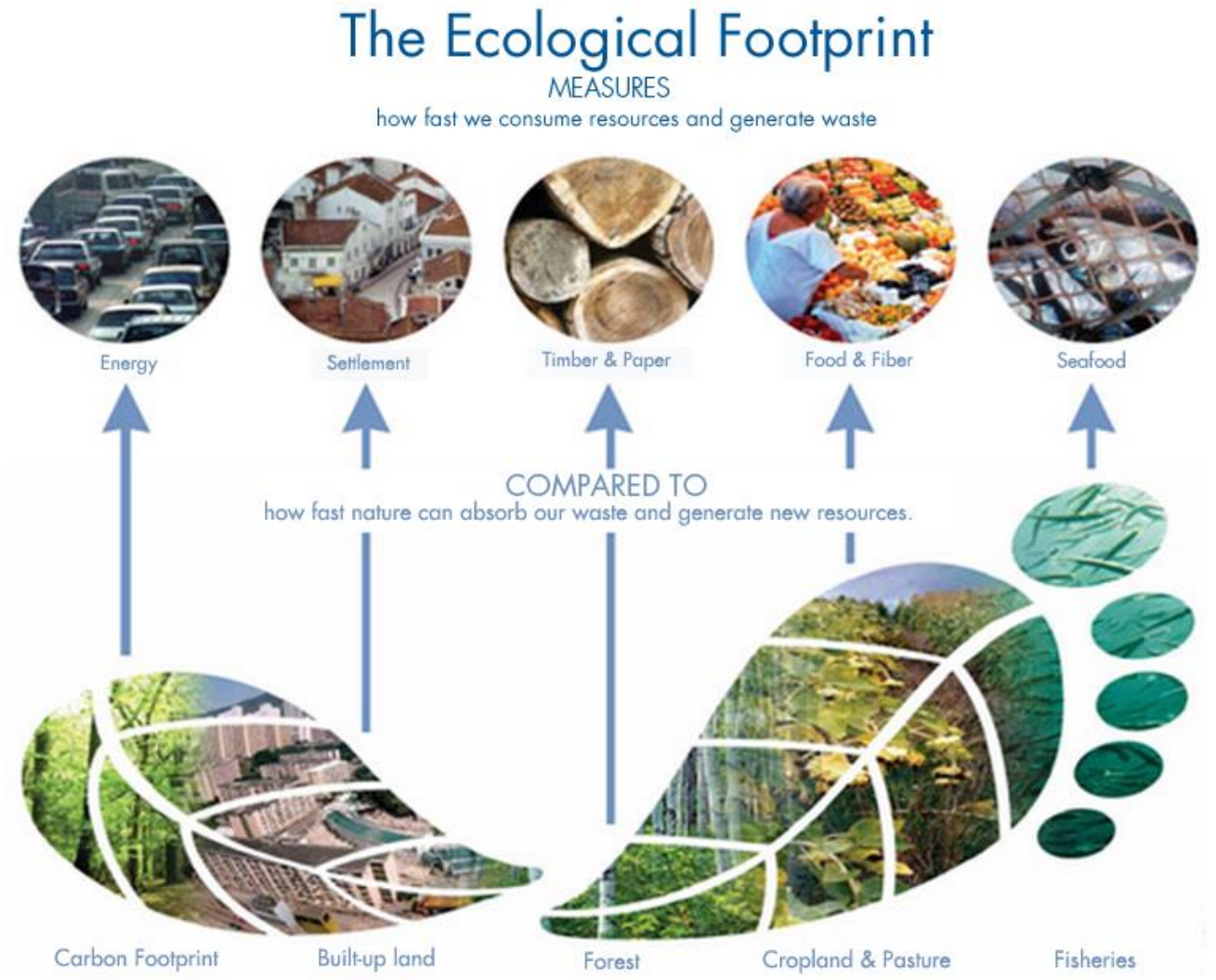
- The hindrance in the growth of nuclear energy is due to many complex reasons, and a major component is the nuclear waste.
- The further implementations of nuclear power are limited because although nuclear energy does not produce CO_2 the way fossil fuels do, there is still a toxic byproduct produced from uranium-fueled nuclear cycles: radioactive fission waste. 1 tons of fresh fuel rod waste from a nuclear reactor would give you a fatal dose of radiation in 10 seconds if placed 3 meters away.
- Plutonium is also of concern, as it increases an exposed person's potential in developing liver, bone, or lung cancer.
- There is also a negative political perception associated with nuclear plants and nuclear weapons, so expansive growth of nuclear energy is difficult to accomplish.
- In addition, nuclear power plants could also be ideal targets for terrorists due to the fissile plutonium components of the waste, which could be reused as bomb fuel.
- Also a terrorist attack on a large reactor would cause a widespread radiation catastrophe at a scale similar to Chernobyl. The final disadvantage is the plant's concentrated level of capital.
- Although the fuel cost to produce power using nuclear energy is relatively low, there is still the necessity of having highly skilled workers to build, maintain and monitor the operations to ensure the safety and process of the plant.

General Summary of Pros and Cons

Advantages	Disadvantages
Produces no polluting gases.	Waste is radioactive and safe disposal is very difficult and expensive.
Does not contribute to global warming.	Local thermal pollution from wastewater affects marine life.
Very low fuel costs.	Large-scale accidents can be catastrophic.
Low fuel quantity reduces mining and transportation effects on environment.	Public perception of nuclear power is negative.
High technology research required benefits other industries.	Costs of building and safely decommissioning are very high.
Power station has very long lifetime.	Cannot react quickly to changes in electricity demand.

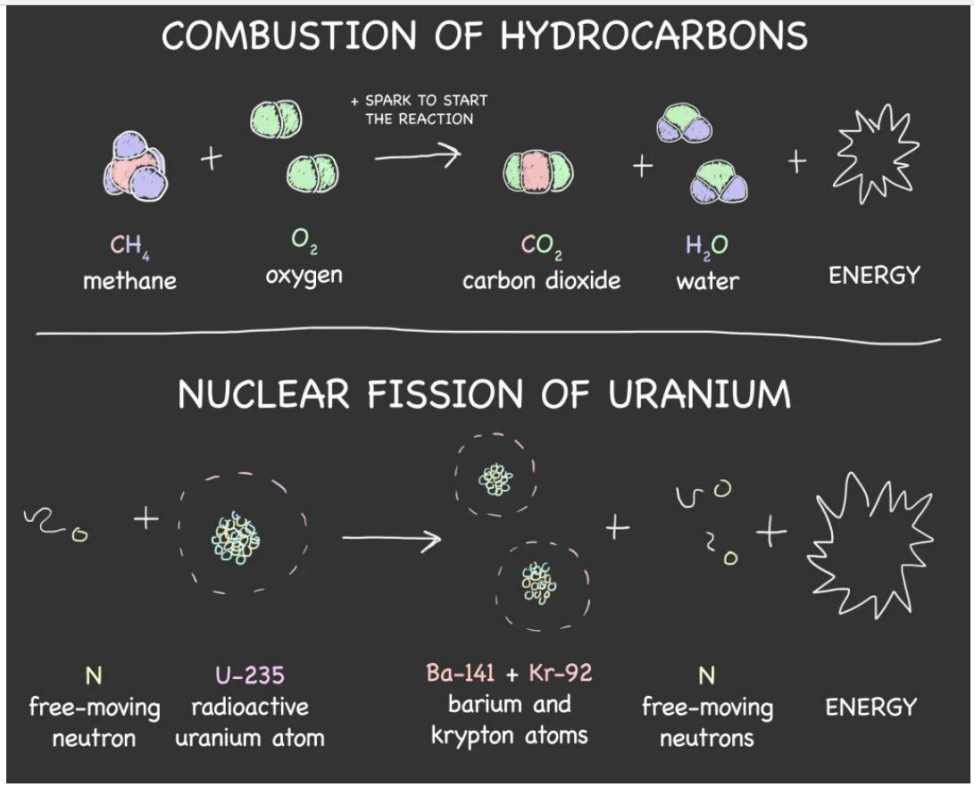
From Schumacher - Chapter Nine

"As Einstein himself said, 'almost all scientists are economically completely dependent' and 'the number of scientists who possess a sense of social responsibility is so small' that they cannot determine the direction of research. The latter dictum applies, no doubt, to all specialists, and the task therefore falls to the intelligent layman, to people like those who form the National Society for Clean Ah and other, similar societies concerned with conservation. They must work on public opinion, so that the politicians, depending on public opinion, will free themselves from the thralldom of economism and attend to the things that really matter. What matters, as I said, is the direction of research, that the direction should be towards nonviolence rather than violence: towards an harmonious cooperation with nature rather than a warfare against nature; towards the noiseless, low energy, elegant, and economical solutions normally applied in nature rather than the noisy, high-energy, brutal, wasteful, and clumsy solutions of our present-day sciences."



Nuclear Energy in the Context of Climate Change

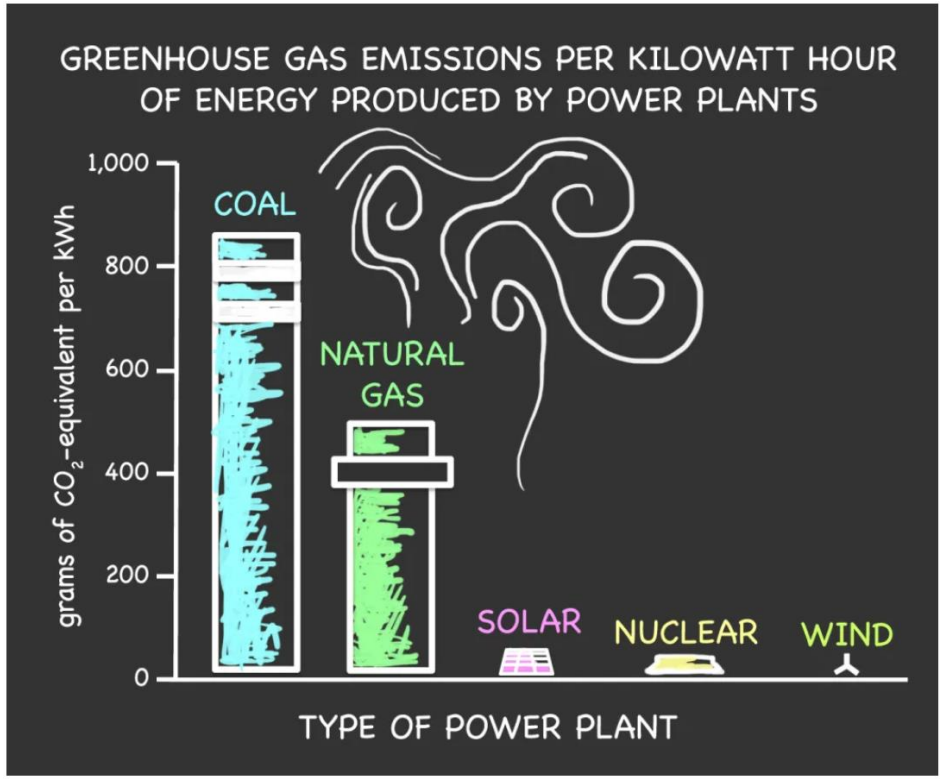
- Furthermore, the US Department of Defense has officially stated that climate change poses a serious national security threat.
- Given that, in 2015, we released 2 billion metric tons of carbon dioxide (CO_2) from electricity generation alone, and fossil fuels accounted for over 99% of these emissions
- Ideally, nuclear power may represent a source that doesn't emit CO2 and is consistently reliable; this is known as a baseload energy source.
- In this context, nuclear energy is the main alternative energy source that works.
- The US, currently the world's largest producer, relies on nuclear energy for 20% of its overall electricity generation.



Source: Reconsidering the Risks of Nuclear Energy. Harvard University

Nuclear Energy in the Context of Climate Change

- Nuclear energy and fossil fuel energy have similarities in the way they are extracted.
- The basis behind running a fossil fuel power plant is similar to a typical fire. In this instance, organic matter such as wood or natural gas is burned and converted into CO2. In this case, we change which atoms bond to each other and harvest the energy that is released when they reach a more stable configuration (as CO2).
- In a nuclear power plant, we are doing the same thing: extracting energy from atoms that ultimately gets converted to electricity. However, in a nuclear reaction, we don't just rearrange which atoms bond to which. We change the atoms themselves, and the energy released is enormous.
- In fact, the only CO2 emitted due to nuclear power plants is what's released indirectly from developing the construction materials! How does this compare to other energy sources?
- Coal power emits the equivalent of 820 g CO2 worth of greenhouse gases for every kilowatt-hour (g CO2eq/kWh) of electricity produced. (A kWh is a standard unit of energy used in billing by electrical utilities).
- Natural gas has a lower output at 490 g CO2eq/kWh. Nuclear power, though? A mere 16 g CO2/kWh



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Nuclear Energy in the Context of Climate Change

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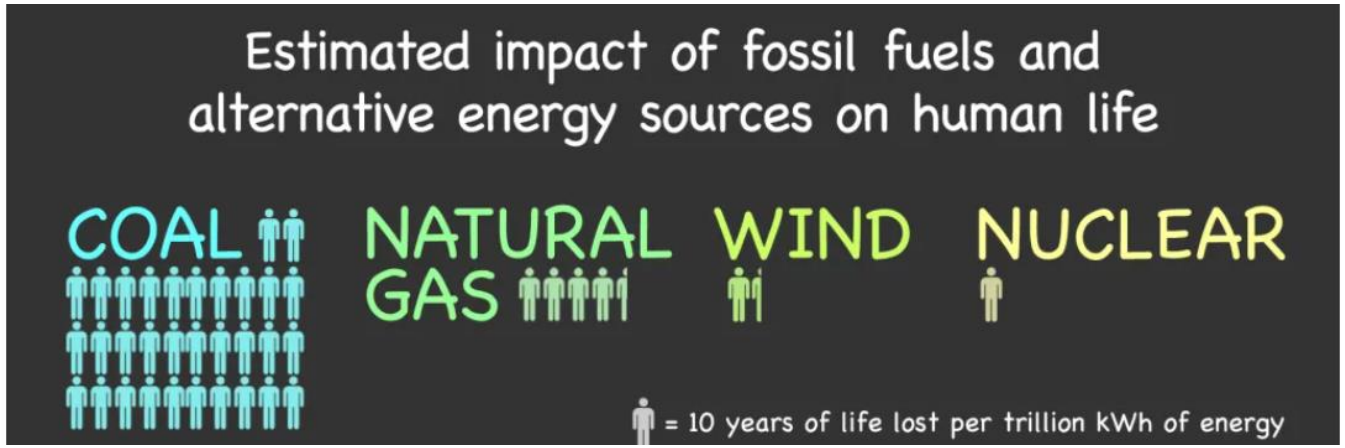
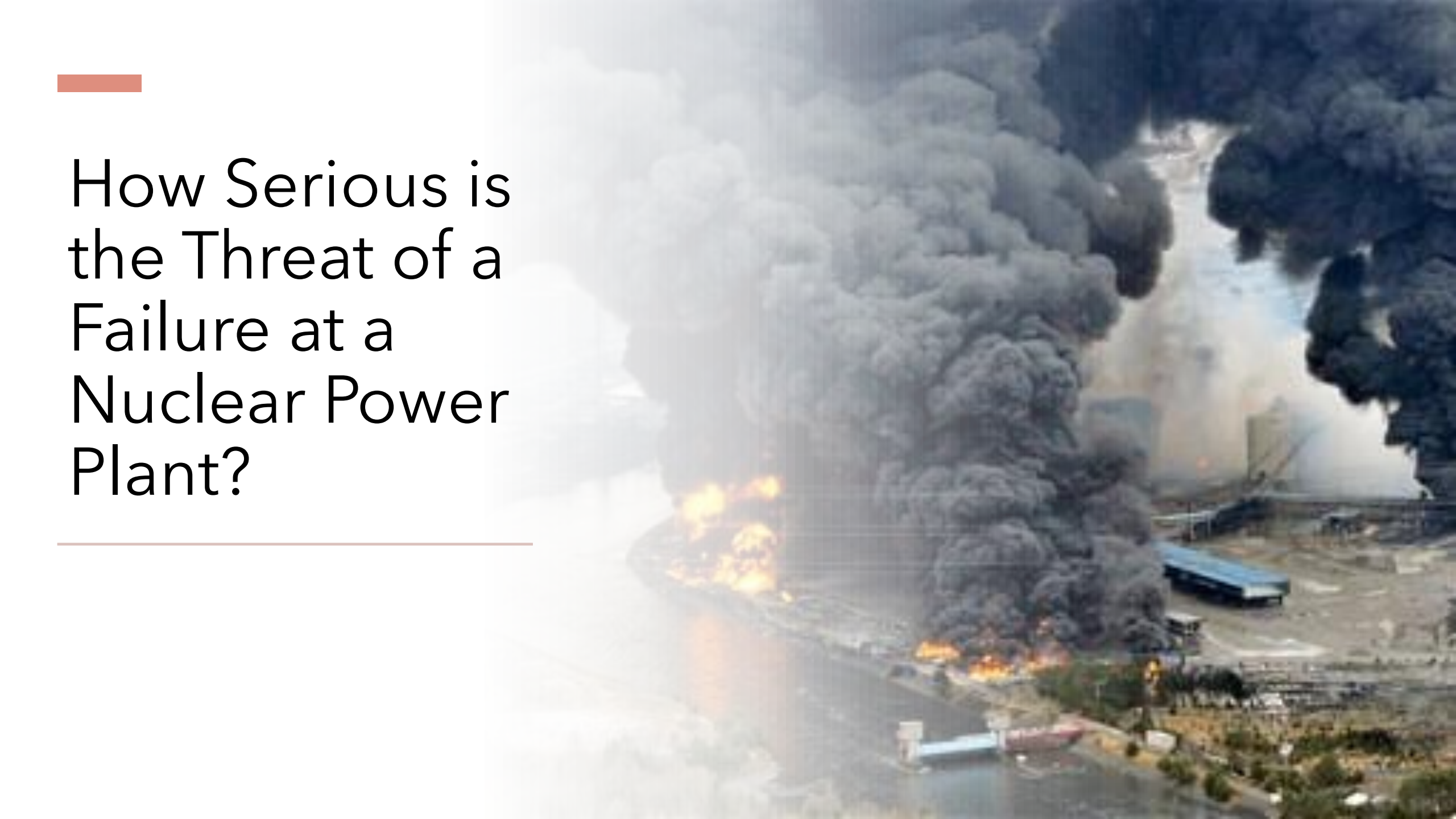


- Is nuclear energy more dangerous than other energy sources?
- The byproducts from burning fossil fuels are toxic pollutants that produce ozone, toxic organic aerosols, particulate matter, and heavy metals.
- The World Health Organization has stated the urban air pollutio7 million deaths annually, which is a mixture of all of the chemicals just described, causes or about 1 in 8 of total deaths.
- Furthermore, coal power plants release more radioactive material per kWh into the environment in the form of coal ash than does waste from a nuclear power plant under standard shielding protocols. This means that, under normal operations, the radioactive waste problem associated with one of the most mainstream energy sources in use actually exceeds that from nuclear energy.
- In fact, on a per kWh of energy produced basis, both the European Union and the Paul Scherrer Institute, the largest Swiss national research institute, found - remarkably, nuclear power is the benchmark to beat, outranking coal, oil, gas, and even wind by a slight margin as the least deadly major energy resource in application

How Serious is the Threat of a Failure at a Nuclear Power Plant?



11 Nuclear Meltdowns

Fukushima Daiichi nuclear power plant

On March 11, 2011, an earthquake measuring 9.0 on the Richter scale struck Japan, bringing a destructive tsunami along with it. One of the sites most affected by the devastation was the Fukushima Daiichi nuclear power plant, which experienced a partial meltdown two days after the quake.

The incident is being called the worst nuclear accident since the 1986 disaster at Chernobyl.

11 Nuclear Meltdowns

Chernobyl, Ukraine (1986)

On April 26, 1986, a reactor at the Chernobyl power plant in Ukraine exploded, causing the worst nuclear accident the world has seen. It sent a plume into the atmosphere with radioactive fallout that was 400 times greater than that released in the atomic bombing of Hiroshima. The plume drifted across much of the western Soviet Union. Parts of Eastern, Northern and Western Europe were also affected.

Fifty people were killed at the reactor site at the time of the accident, but the number of people across Europe who found themselves in the path of the radioactive plume is anybody's guess. A report from the World Nuclear Association (http://world-nuclear.org/info/chernobyl/inf07.html) claims that over one million people may have been exposed to radiation. However, the full extent of the damage is unlikely to ever be known.

11 Nuclear Meltdowns

Tokaimura, Japan (1999)

Until March 2011, the worst nuclear accident in the history of Japan took place at a uranium facility in Tokaimura on September 30, 1999. Three workers were attempting to mix nitric acid and uranium to form the fuel uranyl nitrate. However, the workers unknowingly used seven times the allowable limit of uranium, and the reactor couldn't stop the solution from reaching critical mass.

The three technicians were exposed to massive gamma and neutron radiation poisoning, which killed two of them. More than 70 other workers received high doses of radiation as well. After an investigation, the International Atomic Energy Agency said that the accident had been caused by "human error and serious breaches of safety principles."

11 Nuclear Meltdowns

Three Mile Island, Pennsylvania (1979)

The worst nuclear accident in U.S. history took place on March 28, 1979 at the Three Mile Island plant in Pennsylvania. A cooling system failed, causing a partial meltdown, but a full meltdown was averted and there were no fatalities. However, despite the positive outcome and despite the passage of more than 30 years, the incident remains fresh in the minds of those who are old enough to remember it.

The effect of the accident on the U.S. nuclear power industry was major. The meltdown gave many Americans second thoughts about the risks of using nuclear power, and the construction of new reactors, which had been steadily increasing since the 1960s, slowed substantially. Over 50 nuclear plant construction projects were cancelled in just four years, and the number of ongoing projects declined from 1980 until 1998

11 Nuclear Meltdowns

Goiania, Brazil (1987)

On September 13, 1987, two scavengers found the unit, carted it away in a wheelbarrow and sold it to a junkyard. The owner invited friends and family to see the glowing blue material inside, inadvertently exposing them to radiation. All of them then went their separate ways and irradiated friends and family all over the city.

In all, 245 people were exposed to radiation and four people died. According to Eliana Amaral of the International Atomic Energy Agency, one good thing came out of the catastrophe."

Before the 1987 accident… there was no awareness that sources must be controlled from 'cradle to grave' and to prevent the public accessing them. After the accident these concepts were fostered.

11 Nuclear Meltdowns

K-19, North Atlantic Ocean (1961)

On July 4, 1961, the Soviet submarine K-19 was in the North Atlantic Ocean when it developed a radioactive leak. It had no coolant system in place to stop the reactor from overheating and exploding, so with no other options, the crew entered the reactor compartment and fixed the leak, exposing themselves to levels of radiation in the process that were certain to kill them. All eight crew members who had fixed the leak died of radiation poisoning within three weeks of the incident.

The rest of the crew, the submarine and the ballistic missiles that it carried also became contaminated. When K-19 met up with the submarine that had intercepted its distress call, it was towed to base, which it contaminated. Then, as it was repaired over the course of two years, the surrounding area and the repair workers also became contaminated. Twenty of the submarine's original crew also died of radiation sickness over the next few years.

11 Nuclear Meltdowns

Kyshtym, Russia (1957)

In the years following World War II, the United States was the foremost nuclear power in the world. In an effort to catch up, the Soviet Union quickly built nuclear power plants and cut corners in order to keep pace.

The Mayak plant near the city of Kyshtym had a tank with a substandard cooling system as a result, and when it failed, the increasing temperature caused an explosion that contaminated almost 500 miles of the surrounding area.

Initially, the Soviet government didn't disclose what had happened, but one week later they had little choice. 10,000 people were evacuated from the area when some began to show signs of radiation sickness. Although the Soviet government refused to disclose any information about the accident, a study in Radiation and Environmental Biophysics estimates that at least 200 people died from exposure to radiation. The Soviet government finally declassified information about the disaster in 1990.

11 Nuclear Meltdowns

Windscale, England (1957)

On October 10, 1957, Windscale became the site of the worst nuclear accident in British history, and the worst in the world until Three Mile Island 22 years later. A facility had been built there to produce plutonium, but when the US successfully designed a nuclear bomb that used tritium, the facility was used to produce it for the UK. However, this required running the reactor at a higher temperature than its design could sustain, and it eventually caught fire.

Operators at first worried that extinguishing the flames with water would cause a hydrogen explosion, but ultimately gave in and did so as the crisis escalated. It worked, but not before a sizeable amount of radiation had been unleashed into the surrounding area. A 2007 study estimated that the incident had led to over 200 cases of cancer in the surrounding population.

11 Nuclear Meltdowns

SL-1, Idaho (1961)

The Stationary Low-Power Reactor Number One, or SL-1, was a nuclear reactor located in the desert forty miles outside of Idaho Falls, Idaho. On January 3, 1961, the reactor exploded, killing three workers and causing a meltdown. The cause was a control rod that had been withdrawn incorrectly, but even after an investigation that took two years to complete, the actions taken by the workers just prior to the accident were never discovered.

Although the accident released radioactive material into the atmosphere, it was considered a small amount, and the reactor's remote location helped to minimize damage to the neighboring population. Still, the incident is notable for being the only fatal nuclear reactor accident in US history, and for inspiring a change to the design of nuclear reactors, so that a mishap involving a single control rod would not do this kind of damage.

11 Nuclear Meltdowns

North Star Bay, Greenland (1968)

On January 21, 1968, a US Air Force B-52 bomber was running a "Chrome Dome" mission, a Cold War-era operation in which US bombers with nuclear payloads stayed in the air at all times, all with nearby targets in the Soviet Union that were to be attacked if commanded. The bomber, which was carrying four hydrogen bombs caught fire. The nearest emergency landing location was at Thule Air Base in Greenland, but there was not enough time to reach it, so the crew abandoned the bomber.

When it crashed, the nuclear payload ruptured, and the area became contaminated with radiation. The March 2009 issue of *Time* magazine classified the event as one of the worst nuclear accidents of all time. The 1968 incident caused the immediate discontinuation of "Chrome Dome" missions, and more stable explosives were eventually developed so that nuclear weapons would be less likely to explode in an accident.

11 Nuclear Meltdowns

Jaslovské Bohunice, Czechoslovakia (1977)

The Bohunice nuclear power plant was the first to be built in Czechoslovakia. The reactor was based on an experimental design that was meant to run on uranium mined in Czechoslovakia. However, the first-of-its-kind facility had multiple accidents, and it had to be shut down more than 30 times.

Two workers had been killed in a 1976 incident, but the worst mishap occurred on February 22, 1977 when a worker removed control rods incorrectly during a routine fuel change. This simple error caused a massive radioactive leak, and the ensuing accident earned a level 4 rating on the International Nuclear Event Scale of 1 to 7.

The Soviet government covered up the accident, so no reliable estimates of casualties have been released to the public. However, in 1979, the government decommissioned the plant, and it is expected to be fully dismantled in 2033.

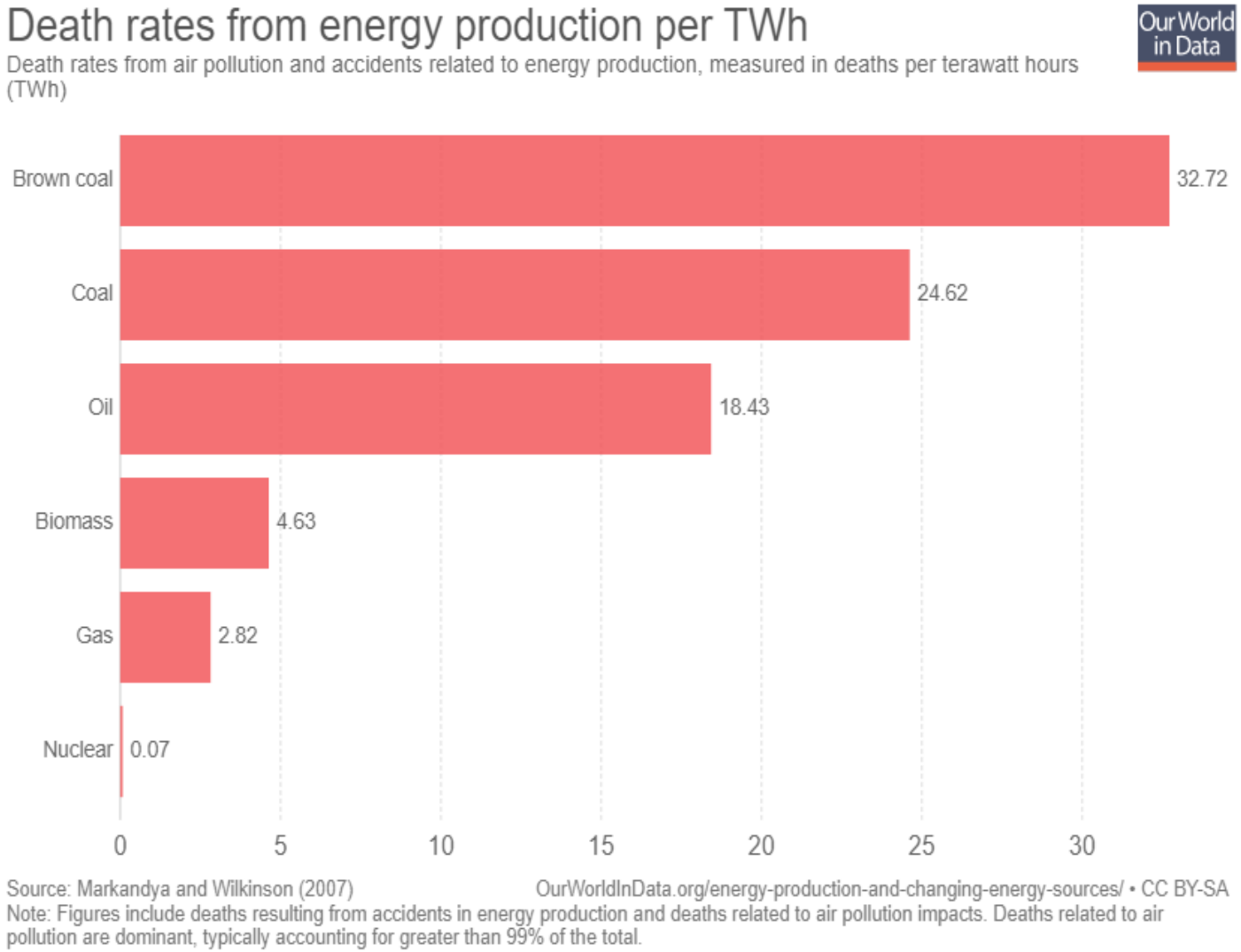
11 Nuclear Meltdowns

Yucca Flat, Nevada (1970)

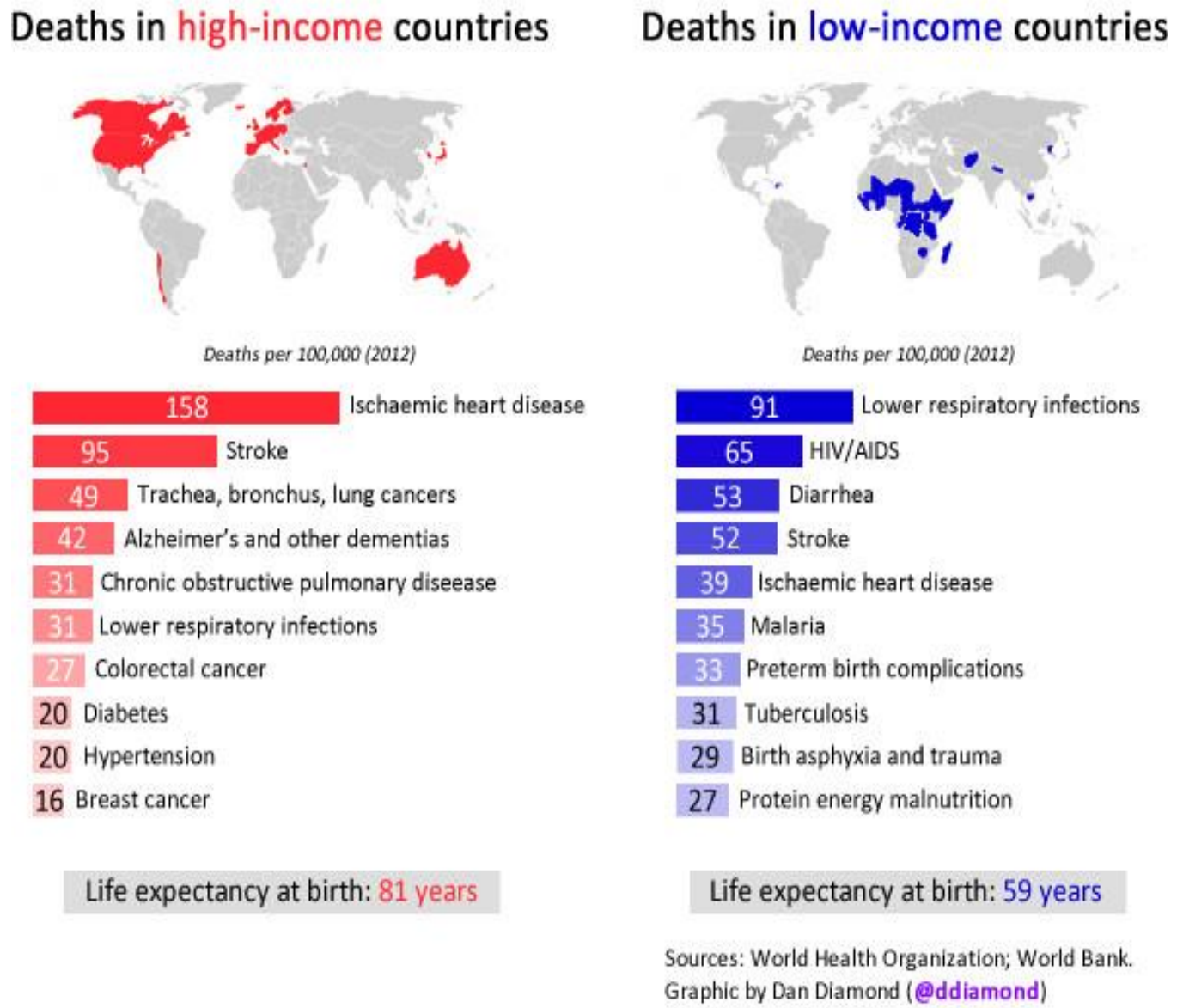
Located one hour from Las Vegas, Yucca Flat is a desert basin that has served as one of Nevada's nuclear test sites. On December 18, 1970, while detonating a 10 kiloton nuclear bomb buried 900 feet underground, the plug sealing the explosion from the surface cracked, sending a plume of radioactive fallout into the air and contaminating 86 workers who were on the site.

Apart from the radiation that fell locally, radioactive particles were carried to northern Nevada, Idaho, northern California and the eastern portions of both Washington and Oregon states. Radioactive material is also believed to have been carried into the Atlantic Ocean, Canada and the Gulf of Mexico. Two Nevada Test Site workers who had been present at the time died of leukemia in 1974.

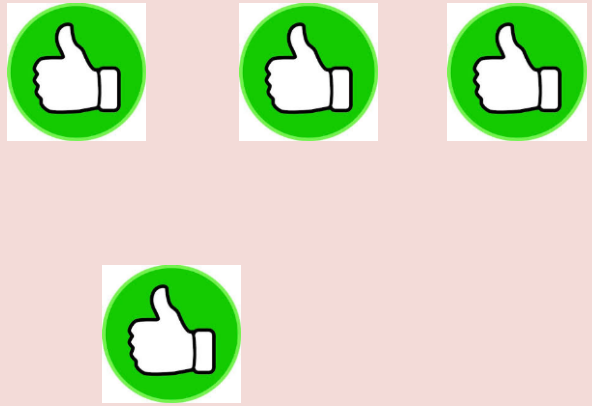
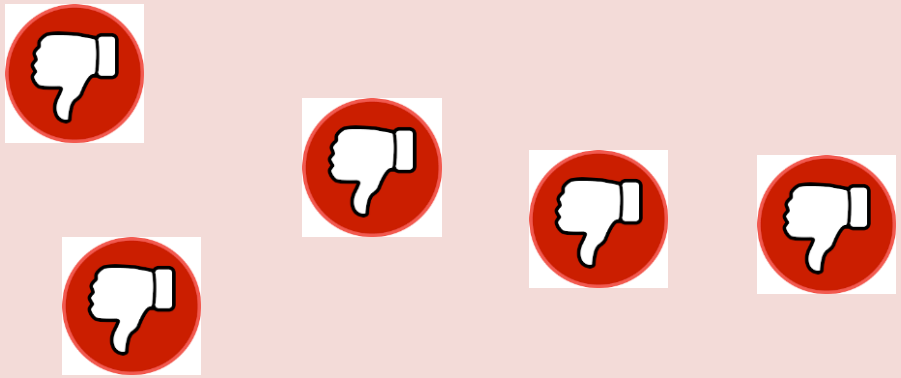
What Do People Die Of?



What Do People Die Of?



Discussion Question: If you were a member of the U.S. Senate, and had to vote to approve an international treaty that bans the production of all new nuclear power plants worldwide – how would you vote now, given our discussion tonight and after reading Chapter 9?

Votes For	Votes Against
	

THE END

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