NAYGN Advocacy Starter Kit

The purpose of this is to try and collect resources together all in one place to help when you are going to build a presentation, go to a rally, do a speech, or write an article. The goal is to put the most impactful information together while striving to have the data from reputable sources (IPCC, WNA, UN, etc.). Put together by Matthew Mairinger in March 2020 – if you want additions/changes please email Canada@naygn.org as this should be a living document.

Fundamentals

- Energy is the ability to do work, power is the rate of change of energy (energy divided by time).
- Chemical energy in one gallon of gasoline equals ~10 kWh.
- Most energy that people use is derived from nuclear power (fossil fuels come from ancient carbon beings which received energy from the Sun, which is powered by nuclear fusion; biofuels and solar power also are the same; wind power is the result of differences in air density caused by unequal solar heating; geothermal energy results from radioactive decay of heavy elements such as uranium and thorium) (Nuclear Energy, C. Ferguson).
- Burning fossil fuels releases chemical energy in which the chemical bonds holding the atoms together are broken. On a per-mass basis nuclear reactions release more than 1 million times more energy than chemical reactions. Nuclear fusion releases 3 times more energy than nuclear fission. (Nuclear Energy, C. Ferguson)

Electricity

- In 2017, fossil fuels generated 64.5% of worldwide electricity, compared with 61.9% in 1990. WNA
- Burning carbon-based fuels produces large amounts of carbon dioxide, which drives climate change. These plants also produce other pollutants, such as oxides of sulphur and nitrogen, which cause acid rain. WNA
- Currently one in seven people in the world has no access to electricity. WNA
- Hydropower: the accident with the highest death toll was the collapse in 1975 of the Banqiao Dam in China's Henan province, which resulted in 171,000 direct and indirect fatalities according to official estimates. WNA
- Methane (natural gas) leaks, especially at the well but also along the pipeline system. A ton of unburned methane has more than 80 times more warming effect than a ton of CO2. In LA in 2015, a massive leak at an underground methane-gas storage facility led to health problems and evacuation of a whole neighbourhood. During the four months it took to control the leak,

around 100,000 tons of methan went into the atmosphere (equivalent to several months of CO2 emissions from the whole LA basin). - (A Bright Future, Goldstein & Qvist)

- Because electricity cannot be easily stored, renewables have to be backed up by other forms of electricity generation. WNA
- Biomass: The energy required can be greater than the energy value in the final fuel, and the greenhouse gas emissions can be as high, or even greater, than those from equivalent fossil fuels. Additionally, it can take more than 100 years for the emitted carbon dioxide to be absorbed, which leads to a short-term emissions increase WNA

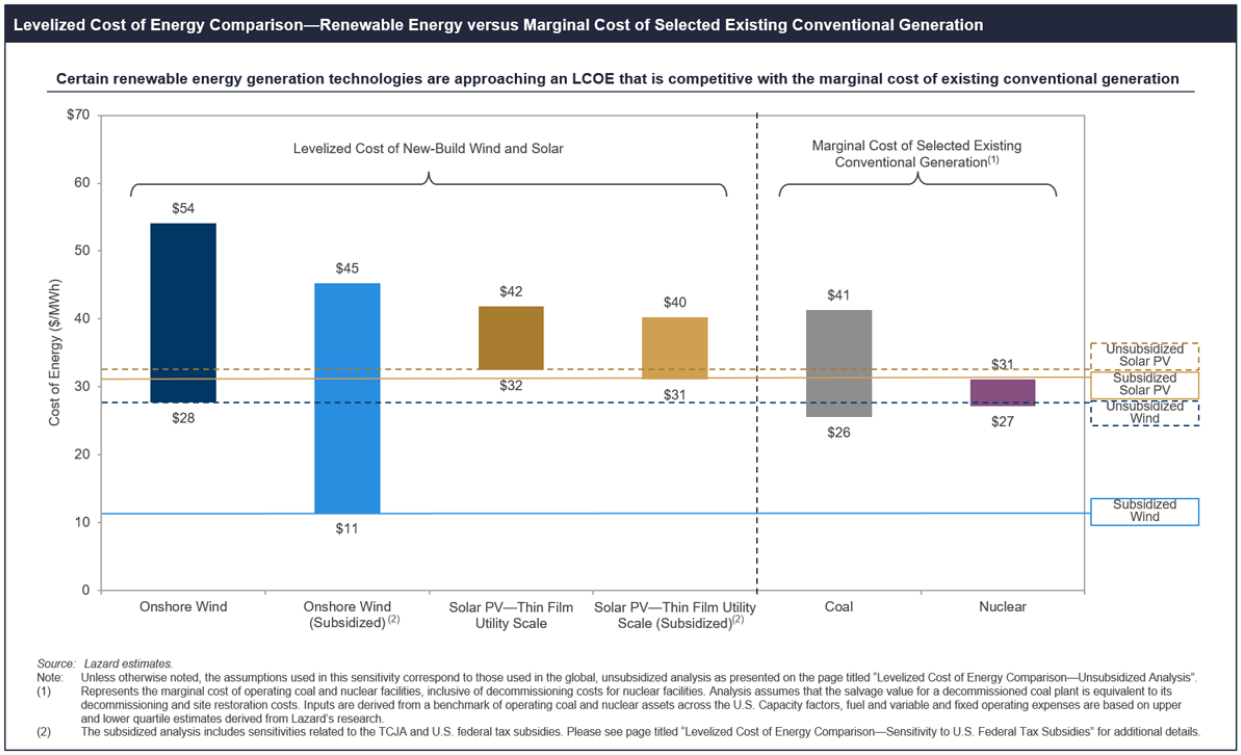


Figure 1: Source Lazard

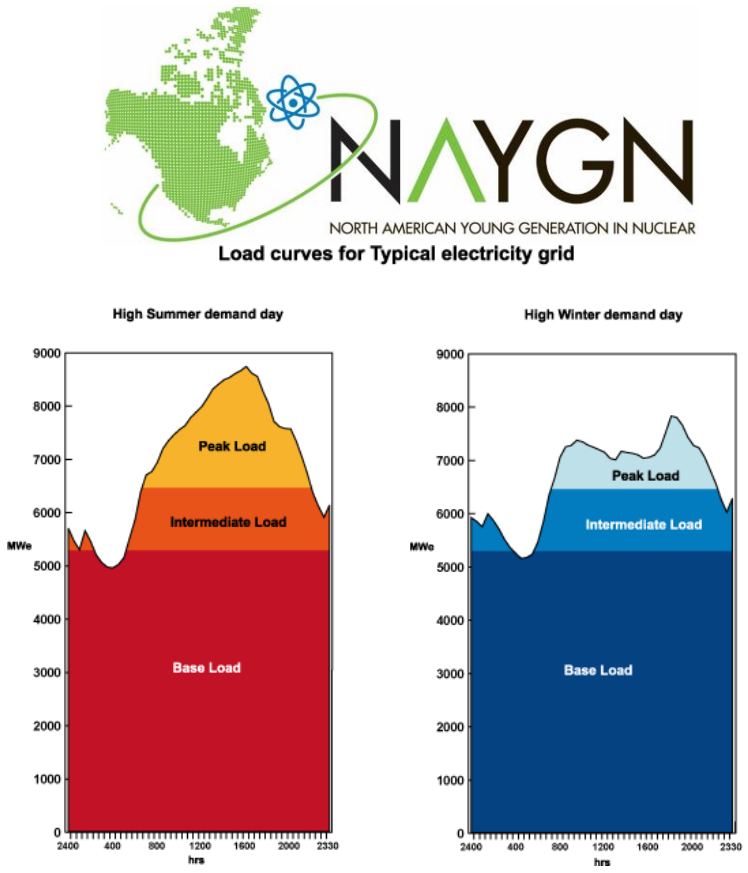


Figure 2: Load Curves for Typical Electricity Grid. Source [WNA]

Quotes

"Nuclear power is a potential safety threat, if something goes wrong. Coal-fired power is guaranteed destruction, filling the atmosphere with planet-heating carbon when it operates the way it's supposed to." – Bill McKibben

"In thinking about nuclear power safety, one should always ask, "Compared to what?" And the answer is: compared to coal – the world's dominant and fastest-growing fuel, the lauding cause of climate change, the fuel that kills a million people a year. Compared to *that*." - (A Bright Future, Goldstein & Qvist)

"A long half life means that it takes a long time for half the number of atoms in a particular sample to decay. To put it another way the half-life tells you how rapidly the nuclear is breaking apart […] the longer the half-life, the less radioactive the sample, because the rate of disintegrations is slower – the fewer the number of rays and particles emitted per minute or hour." Rip Anderson (Power to Save the World by Gwyneth Cravens).

Smoking "two packs a day [of cigarettes] adds up to 16,000 to 20,000 millirem [1600 to 2000 mSv] per year to the lining of the lungs" (Power to Save the World by Gwyneth Cravens).

"Curiously, I discovered that the same environmental activists who implicitly believe in the models of global climate disruption that have been derived from probabilistic risk assessment nevertheless distrust that same methodology when it is applied to nuclear safety." (Power to Save the World by Gwyneth Cravens).

Climate Change / Air Quality

- Almost all proposed pathways to achieving deep decarbonisation suggest an increased role for nuclear power, including those published by the International Energy Agency, Massachusetts Institute of Technology Energy Initiative, US Energy Information Administration, and World Energy Council.
- Air pollution kills an estimated seven million people worldwide every year. WHO data shows that 9 out of 10 people breathe air containing high levels of pollutants. WHO
- In Europe, more than 22,000 people die prematurely each year because of air pollution caused by coal power, a recent report by various environmental organizations concludes (Europe's Dark Cloud, 2016).
- According to Europe's Dark Cloud, the health costs in Europe alone are between 32 and 62 billion euros per year, depending on the value used for loss of life. If these costs would be internalized in the costs of coal burning, the price of coal-powered electricity would rise by roughly 3 to 6 cents per kilowatt hour.
- Projected worldwide consumption of all types of energy thirty years from now is about 50% higher than today. - (A Bright Future, Goldstein & Qvist)

Renewables

- In 2017, more than 100 times that year, Germany (who integrated wind and solar more heavily into the grid), had electricity prices that went negative (meaning grid operators paid large consumers as much as 6 cents/kWh to take power to avoid overloading the grid). Sometimes this occurred for more than a day at a time – (A Bright Future, Goldstein & Qvist)
- Over the past decade, the world has spent $2 trillion on wind and solar power but has seen almost no progress towards decarbonisation. – (A Bright Future, Goldstein & Qvist)
- While the reductions in [wind and solar] costs continue, their rate of decline has slowed, especially for onshore wind. Costs for utility-scale solar have been falling more rapidly (about 13 percent per year) compared to onshore wind (about 7 percent per year) over the past five years. Lazard

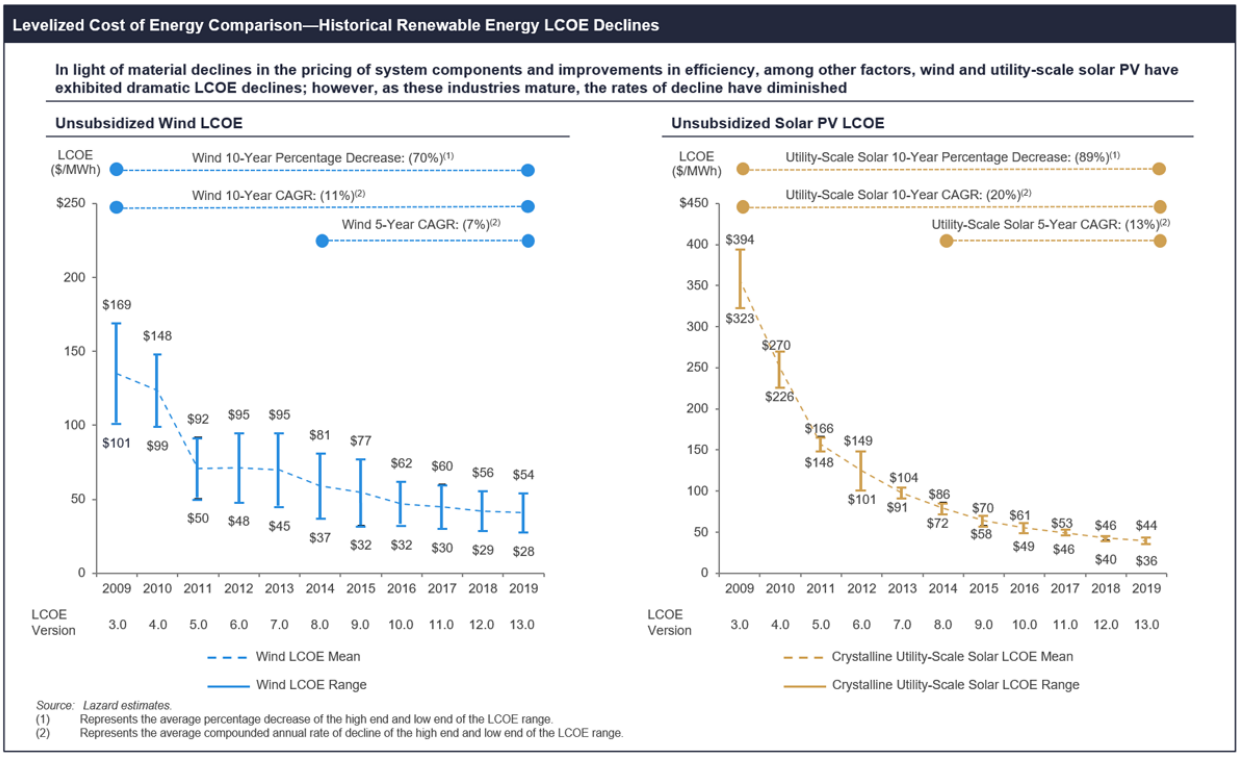


Figure 3:Solar and Wind Price Drops. Source Lazard

Wind

- Total world wind capacity was 514 GWe at the end of 2017, with tens of thousands of turbines installed. However, all this has to be backed up with dispatchable generating capacity, due to low utilization and intermittency WNA
- Offshore wind farms generally are supposed to last for twenty-five years, but there is some evidence that shorter life spans than expected may add to the ultimate price. – (A Bright Future, Goldstein & Qvist)
- More often, rather than vent steam from a coal plant, electric grids "curtail" wind or solar power, wasting their potential output rather than letting it on the grid. This has particularly affected China's massive wind farms, where curtailment has recently caused a reduction of about 20% in wind-power generation in the country. – (A Bright Future, Goldstein & Qvist)
- IRENA 2017 statistics showed that the 416 GWe of wind installed in 2015 produced 826 GWh, (an average capacity factor of 22.7%).WNA
- Harnessing power from wind (or any fluid in open flow) is subject to Betz's law, which says that no turbine can capture more than 59.5% of the kinetic energy in the wind (or water). Utility-scale wind turbines today achieve at peak flow up to 80% of the Betz limit. WNA

Solar

- IRENA 2017 statistics had 296 GWe of solar capacity in 2016 (up from 225 GWe in 2015), which produced 256 GWh (an average capacity factor of 13%). Of the 2016 total, 291 GWe (98%) was solar PV. WNA
- A serious grid integration problem with solar PV is that cloud cover can reduce output by 70% in the space of one minute. Various battery and other means are being developed to slow this to 10% per minute, which is more manageable. The particular battery system required is designed specifically to control the rate of ramp up and ramp down. System life is ten years, compared with twice that for most renewable sources. WNA
- IRENA in 2016 estimated that there were about 250,000 tonnes of solar PV waste, and that the total could reach 78 million tonnes by 2050. Recycling solar PV panels is generally not economic, and there is concern about cadmium leaching from discarded panels. WNA
- California has had to force curtailments on its solar production – 15 percent of the time in 2015 growing to 30 percent in 2017. Because solar is decentralized and hard to control, especially for rooftops, California still regularly ends up with too much production and, to avoid overloading the grid, pays Arizona to take some of it. This is called "negative pricing". -(A Bright Future, Goldstein & Qvist)
- The hidden costs of integrating solar onto the grid adds about 50 percent to the stated cost of solar power, according to Sivaram.
- Unlike for nuclear power, the cost of decommissioning solar farms is not usually included in the price. – (A Bright Future, Goldstein & Qvist)

Storage

- In 2015 battery storage costs were around $400/kWh, and 1.6 GWe was installed or planned. WNA
- Used on a grid scale, battery storage adds about 30 cents/kWh to the cost of electricity, whereas "behind the meter" commercial and residential use, the cost is 85 cents to $1.27/kWh. Lazard
- A recent comprehensive analysis found that the cost of adding just ten hours of storage would nearly double the cost of electricity. – (A Bright Future, Goldstein & Qvist)

Radiation:

- On average, we all receive between 2 and 3 millisieverts (mSv) of radiation every year, but this varies considerably around the world due to factors such as altitude and the composition of the ground. WNA
- Ionization means that the radiation's energy can produce ions (charged atoms) by knocking negatively charged electrons off of neutral atoms – alpha, beta, gamma radiation is ionizing radiation. Longer wave length, lower frequency waves (heat and radio) have less energy than shorter wave length, higher frequency waves (X and gamma rays). Not all electromagnetic (EM)

radiation is ionizing. Only the high frequency portion of the electromagnetic spectrum which includes X rays and gamma rays is ionizing.
    - Alpha particles and beta particles are considered directly ionizing because they carry a charge and can, therefore, interact directly with atomic electrons through coulombic forces (i.e. like charges repel each other; opposite charges attract each other).
    - The neutron is an indirectly ionizing particle. It is indirectly ionizing because it does not carry an electrical charge. Ionization is caused by charged particles, which are produced during collisions with atomic nuclei.
    - The third type of ionizing radiation includes gamma and X rays, which are electromagnetic, indirectly ionizing radiation. These are indirectly ionizing because they are electrically neutral (as are all electromagnetic radiations) and do not interact with atomic electrons through coulombic forces. WHO
- No deterministic effects would be expected below an absorbed dose of 100 mGy (above the natural background exposure), and thresholds for most effects are much higher. ICRP
- The ICRP estimates that 200 mSv raises the risk of fatal cancer by 1 percent. ICRP

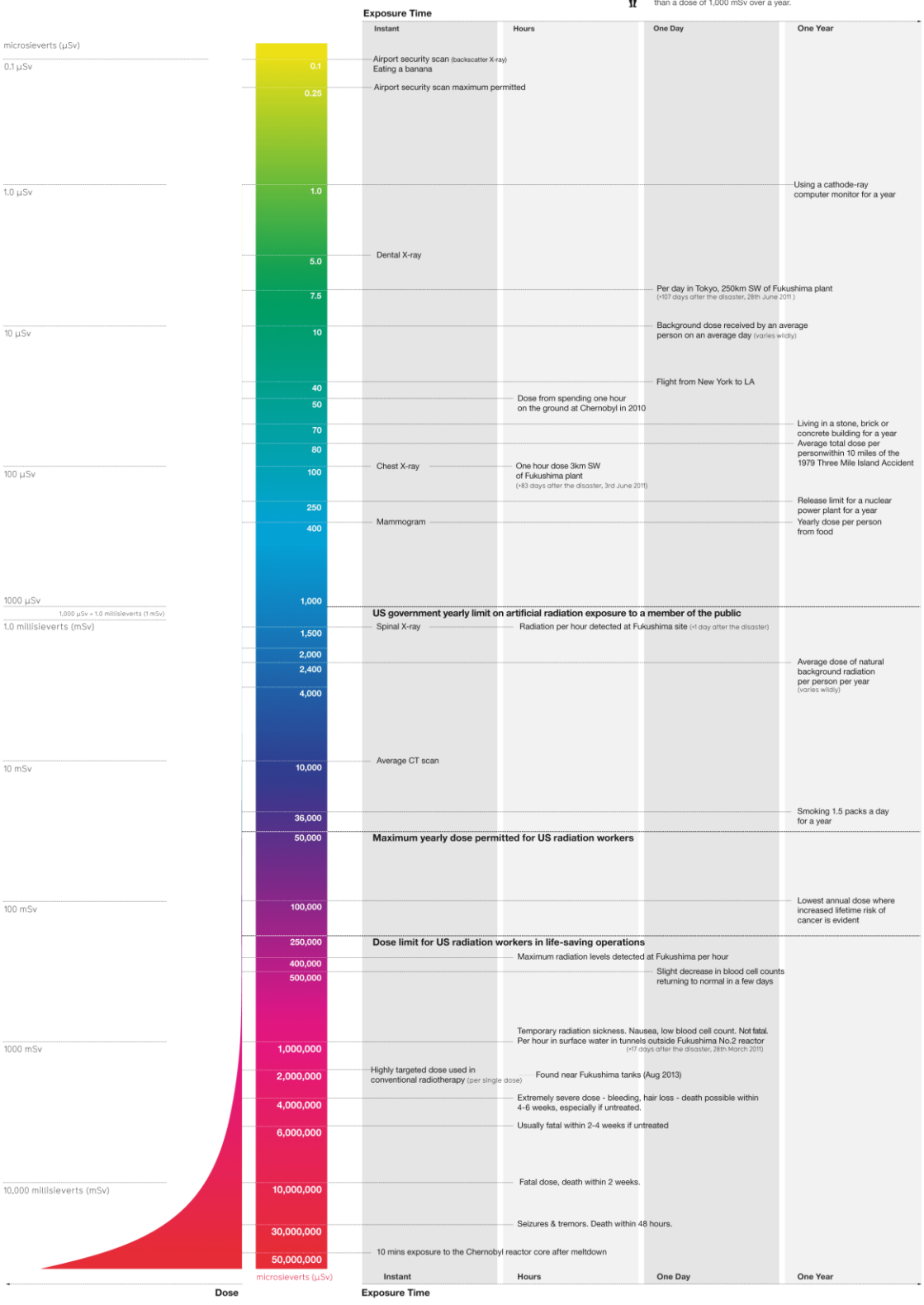
NAYGN

NORTH AMERICAN YOUNG GENERATION IN NUCLEAR

Radiation Dosage Chart

Risk of harm is dependent on both the **dose** and the **dose rate** (the time the body is exposed to that dose).

So a dose of 1,000 mSv over an hour is considerably more damaging than a dose of 1,000 mSv over a year.



David McCandless, Matt Hancock // v.2.02 //Aug 2013

InformationIsBeautiful.net

source: BBC, Guardian Datablog, Mayo Clinic, XKCD
data: bit.ly/RadiationChart (case sensitive)
note: logarithmic scale & average dose used

- In Ramsar (Iran), residents can receive doses of up to 260 mSv per year, about 100 times the global average, due to naturally occurring radioactive elements. However, there is no evidence of any adverse health effects in these areas. Many of these areas actually have higher radiation levels than many parts of the evacuation zones around Chernobyl and Fukushima. WNA
- Since the accident in 1986, Chernobyl also resulted in about 6500 thyroid cases – which would have been prevented if the authorities had stopped contaminated foodstuffs from entering the food chain. These cases have, to date, resulted in 15 deaths. In comparison, air pollution from the use of coal kills about 80 people - every hour - in China alone.
  Neither of the accidents at Three Mile Island nor Fukushima Daiichi – the only other civil nuclear power plants that have suffered accidents resulting in a noteworthy release of radioactive material into the environment – resulted in any radiation-induced health effects. WNA

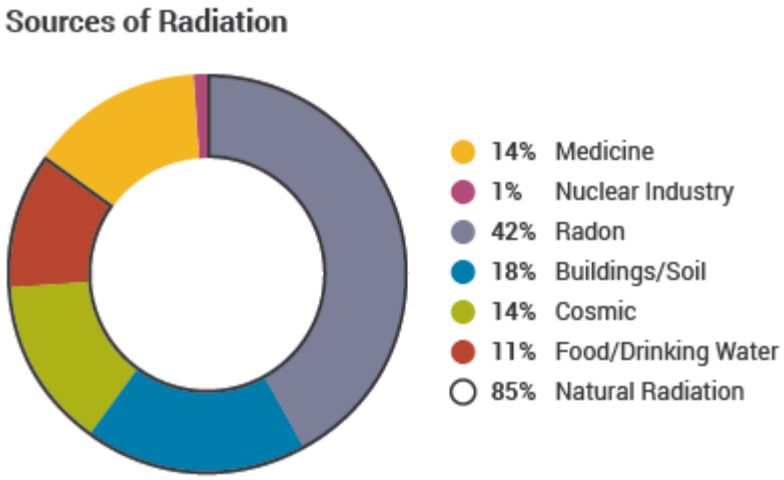


Figure 4: Source WNA

Hiroshima and Nagasaki

- It is uncertain what proportion of these 103,000 deaths, or of the further deaths in military personnel, were due to radiation exposure rather than to the very high temperatures and blast pressures caused by the explosions – 15 kilotons at Hiroshima and 25 kilotons at Nagasaki. From the estimated radiation levels, however, it is apparent that radiation alone would not have been enough cause death in most of those exposed beyond a kilometre of the ground zero below the bombs. Most deaths were from blast injuries or burns rather than the radiation. There was an increase in leukaemia beginning about two years later and peaking at four to six years later, and other cancers beginning about ten years later. There was no evidence to suggest an increase in leukaemia at less than 500 mSv acute dose. At an acute dose of 100 mSv, an increased cancer risk of 1.05 times normal was calculated. WNA

Doses from Atmospheric Atomic Weapons Testing

- There were 545 nuclear weapons tested atmospherically up to 1963.
- The most important radionuclides remaining from weapons testing are now carbon-14, strontium-90 and caesium-137. The global average dose from these is about 0.005 mSv/yr, compared with a peak of 0.113 mSv average in 1963. WNA

Nuclear for Non-Power Uses

- Radioisotopes, which can be produced by nuclear reactors, are used as 'tracers' in positron emission tomography (PET) scans, one of the most accurate means of detecting and evaluating most cancers. WNA
- Exploration of our solar system is enabled by nuclear technology through the use of radioisotope thermoelectric generators (RTGs), which rely on the decay of radioactive isotopes to power satellites for deep-space exploration where solar panels cannot be used. RTGs have been one of the main power sources for space work and have powered numerous American, Russian and Chinese space vehicles' exploration of space. WNA
- At least 20% of harvested food spoils before it can be consumed. Irradiation – a process which kills microbes, without making the produce radioactive – can delay the ripening of fruit and vegetables, increasing their shelf-life significantly and reducing wastage. It can also control pests and prevent transmission of foodborne illnesses, reducing required quarantine periods – factors that have proved decisive for the more than 60 countries that have introduced regulations allowing food irradiation. WNA

Nuclear Power

- Nuclear energy comes from transforming matter into energy. An individual neutron or proton always has greater mass outside a nucleus than inside. The mass difference comes about because when the neutrons and protons bind together, a tiny fraction of their masses is transformed into energy – binding energy.
- Fusion works by overcoming the attractive strong force overcoming the repulsive electrical force.
- Nuclear fission either can use uranium, plutonium or thorium (via breeder reactors to make U-233)
- Humans have used uranium oxide since at least 79 C.E. (Nuclear Energy, C. Ferguson).
- The average nuclear plant is around 1000 Megawatts electric, and can generate the electricity demands for about 600,000 people.
- There are 441 operable plants (391,565 MWe) around the world, 54 under construction, 109 planned and 330 proposed WNA

- The most common power reactor types use water, with more than 90% of the world's reactors being water-based. WNA
- A single pellet contains as much energy as there is in 1000 kg of coal. WNA
- In 2018, 11.2 GW of additional nuclear capacity were connected to the grid, the largest increase since 1989. IEA
- Under current trends, nuclear capacity in 2030 would amount to 497 GW, compared with 542 GW under the Sustainable Development Scenario (SDS). At least a doubling of the annual rate of capacity additions is therefore required. IEA
- Overall, global investment in nuclear capacity remains insufficient, as testified by the low number of new projects being launched. According to the World Energy Outlook, USD 1.5 trillion in investment would be required between 2018 and 2040 to get on track with the SDS. In 2017, investments in nuclear decreased to USD 17 billion. IEA

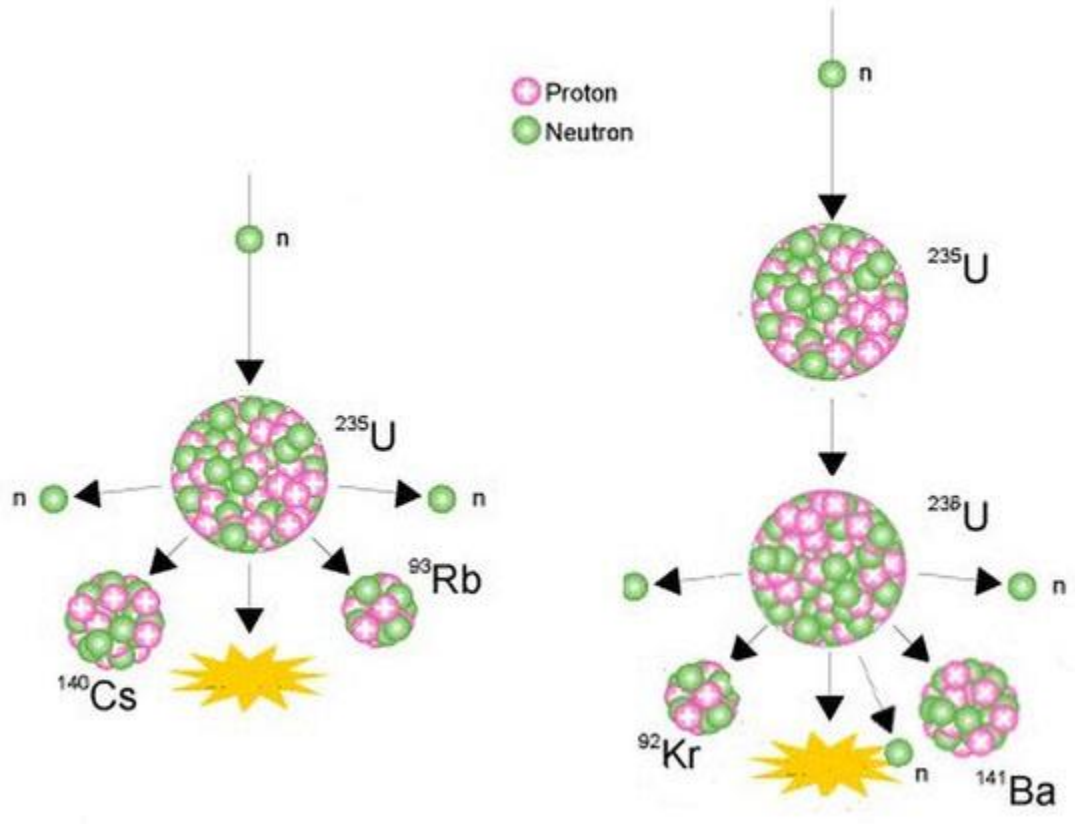


Figure 5 Nuclear Fission. Source: WNA

Figure 6: Nuclear Fuel Pellets. Source: WNA

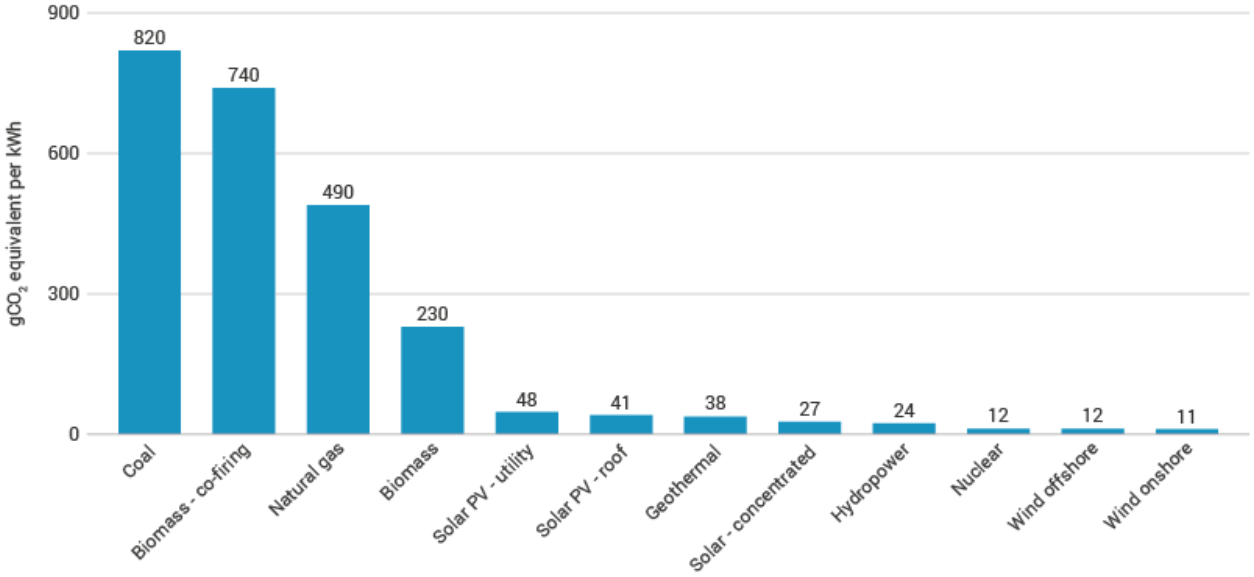


Figure 7: Average life-cycle CO2 equivalent emission. Source: Source: IPCC, Climate Change 2014: Mitigation of Climate Change, Annex III3

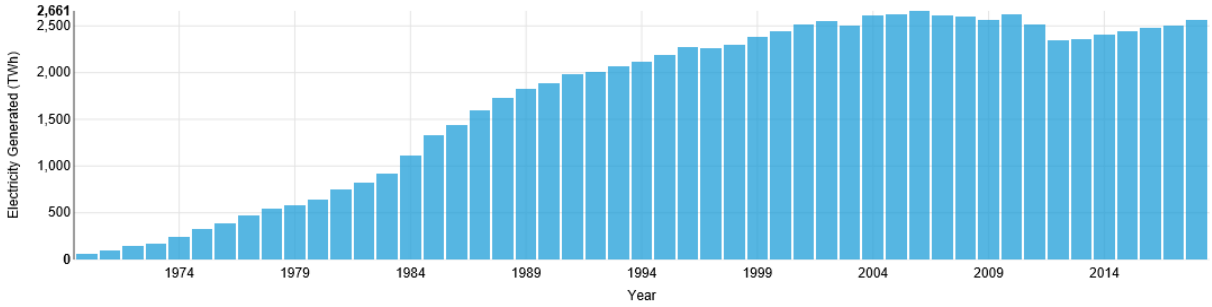


Figure 8: Global Nuclear Generation. Source [WNA]

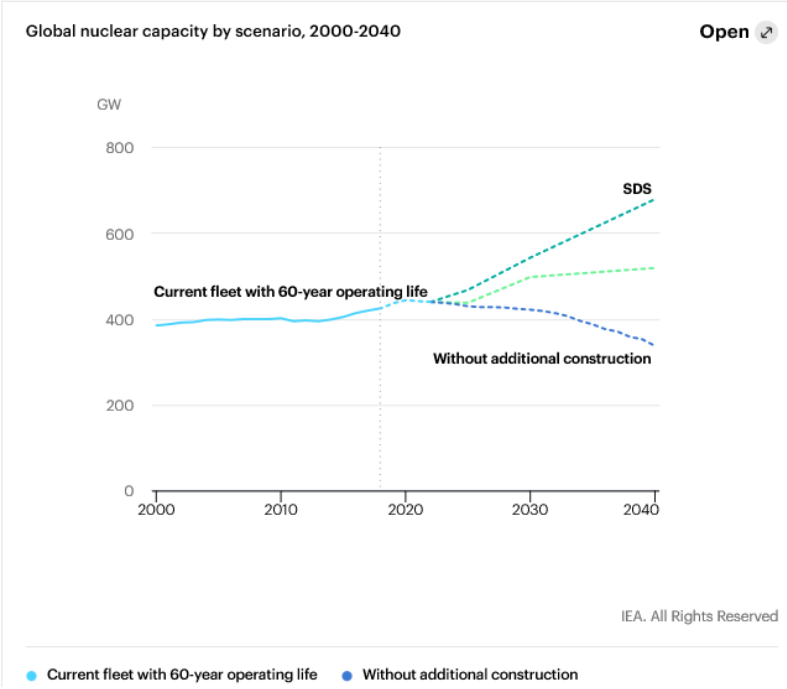


Figure 9: Source [IEA]

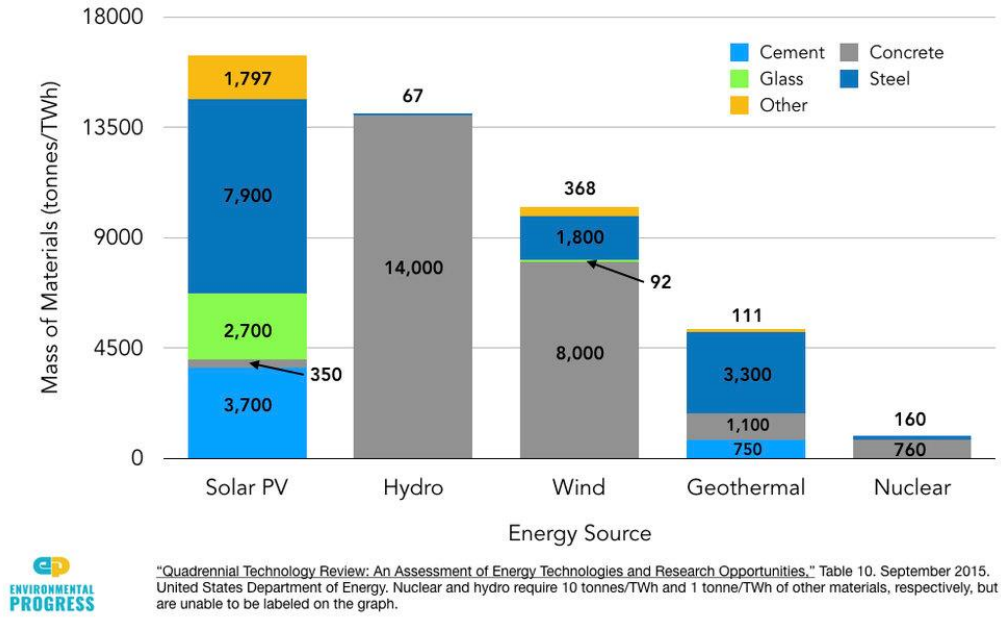


Figure 10: Source [Environmental Progress]

GenIV Nuclear

- https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/advanced-nuclear-power-reactors.aspx

Small Modular Reactors (SMRs)

- https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx

Chernobyl

- Chernobyl accident in 1986 was the result of a flawed reactor design that was operated with inadequately trained personnel.
- The resulting steam explosion and fires released at least 5% of the radioactive reactor core into the atmosphere and downwind.

- UNSCEAR says that apart from increased thyroid cancers, "there is no evidence of a major public health impact attributable to radiation exposure 20 years after the accident."
- The conclusions of this 2005 Chernobyl Forum study (revised version published 2006) are in line with earlier expert studies, notably the UNSCEAR 2000 report which said that "apart from this [thyroid cancer] increase, there is no evidence of a major public health impact attributable to radiation exposure 14 years after the accident. There is no scientific evidence of increases in overall cancer incidence or mortality or in non-malignant disorders that could be related to radiation exposure."
- A particularly sad effect of the accident was that some physicians in Europe advised pregnant women to undergo abortions on account of radiation exposure, even though the levels concerned were vastly below those likely to have teratogenic effects. The foetal death toll from this is likely very much greater than directly from the accident. WNA
- According to an UNSCEAR report in 2018, about 20,000 cases of thyroid cancer were diagnosed 1991-2015 in patients who were 18 and under at the time of the accident. The report states that a quarter of the cases 2001-2008 were "probably" due to high doses of radiation, and that this fraction was likely to have been higher in earlier years, and lower in later years. However, it also states that the uncertainty around the attributed fraction is very significant – at least 0.07 to 0.5 – and that the influence of annual screenings and active follow-up make comparisons with the general population problematic. Thyroid cancer is usually not fatal if diagnosed and treated early; the report states that of the diagnoses made between 1991 and 2005 (6,848 cases), 15 proved to be fatal
- Conifers in about 10 square kilometres of forest close to the plant were killed by the high radiation levels, but regeneration got underway from the following year. The net environmental effect of the accident has been much greater biodiversity and abundance of species. The exclusion zone has become a unique sanctuary for wildlife.
- Almost 6000 people worked at the [Chernobyl unit 3] plant every day [until December 2000], and their radiation dose has been within internationally accepted limits. A small team of scientists works within the wrecked reactor building itself, inside the shelter WNA

Fukushima Daiichi

- Following a major earthquake, a 15-metre tsunami disabled the power supply and cooling of three Fukushima Daiichi reactors, causing a nuclear accident on 11 March 2011. Three of the six reactors on site were suspected to have partial nuclear meltdowns within the first three days.
- Three Tepco employees at the Daiichi and Daini plants were killed directly by the earthquake and tsunami, but there have been no fatalities from the nuclear accident. WNA
- Tepco figures submitted to NRA for the period to end January 2014 showed 173 workers had received more than 100 mSv (six more than two years earlier) and 1578 had received 50 to 100 mSv. This was among a total of 32,024, 64% more than had worked there two years earlier. Since April 2013 none of the 13,154 who had worked on site had received more than 50 mSv,

and 96% of these had less than 20 mSv dose. Early in 2014 there were about 4000 on site each weekday.

No radiation casualties (acute radiation syndrome) occurred, and few other injuries, though higher than normal doses were being accumulated by several hundred workers on site. WNA

- United Nations Scientific Committee for the Effects of Atomic Radiation: Adults living in the city of Fukushima were estimated to have received, on average, an effective dose of about 4 mSv. No discernible increased incidence of radiation-related health effects are expected among exposed members of the public or their descendants. Annual exposure in the region from radiation sources is about 2.1 mSv
- WHO Report: indicated that the residents of the area who were evacuated were exposed to so little radiation that radiation induced health impacts are likely to be below detectable levels.
- Japan's regulator, the Nuclear & Industrial Safety Agency (NISA), estimated in June 2011 that 770 PBq (iodine-131 equivalent) of radioactivity had been released, but the Nuclear Safety Commission (NSC, a policy body) in August lowered this estimate to 570 PBq. The 770 PBq figure is about 15% of the Chernobyl release of 5200 PBq iodine-131 equivalent. Most of the release was by the end of March 2011.

	Unit 1	Unit 2	Unit 3
Loss of AC power	+ 51 min	+ 54 min	+ 52 min
Loss of cooling	+ 1 hour	+ 70 hours	+ 36 hours
Water level down to top of fuel*	+ 3 hours	+ 74 hours	+ 42 hours
Core damage starts*	+ 4 hours	+ 77 hours	+ 44 hours
Reactor pressure vessel damage*	+11 hours	uncertain	uncertain
Fire pumps with fresh water	+ 15 hours		+ 43 hours
Hydrogen explosion (not confirmed for unit 2)	+ 25 hours service floor	+ 87 hours suppression chamber	+ 68 hours service floor
Fire pumps with seawater	+ 28 hours	+ 77 hours	+ 46 hours
Off-site electrical supply	+ 11-15 days		
Fresh water cooling	+ 14-15 days		

Figure 11: Event Sequence at Fukushima. Source WNA

Safety/ Risk

- Death footprint (deaths/trillion kWh) – Forbes
  - Coal (global average) 100,000
  - Oil 36,000
  - Biofuel 24,000
  - Gas 4,000
  - Hydro (global) 1,400
  - Solar 440
  - Wind 150
  - Nuclear (global) 90

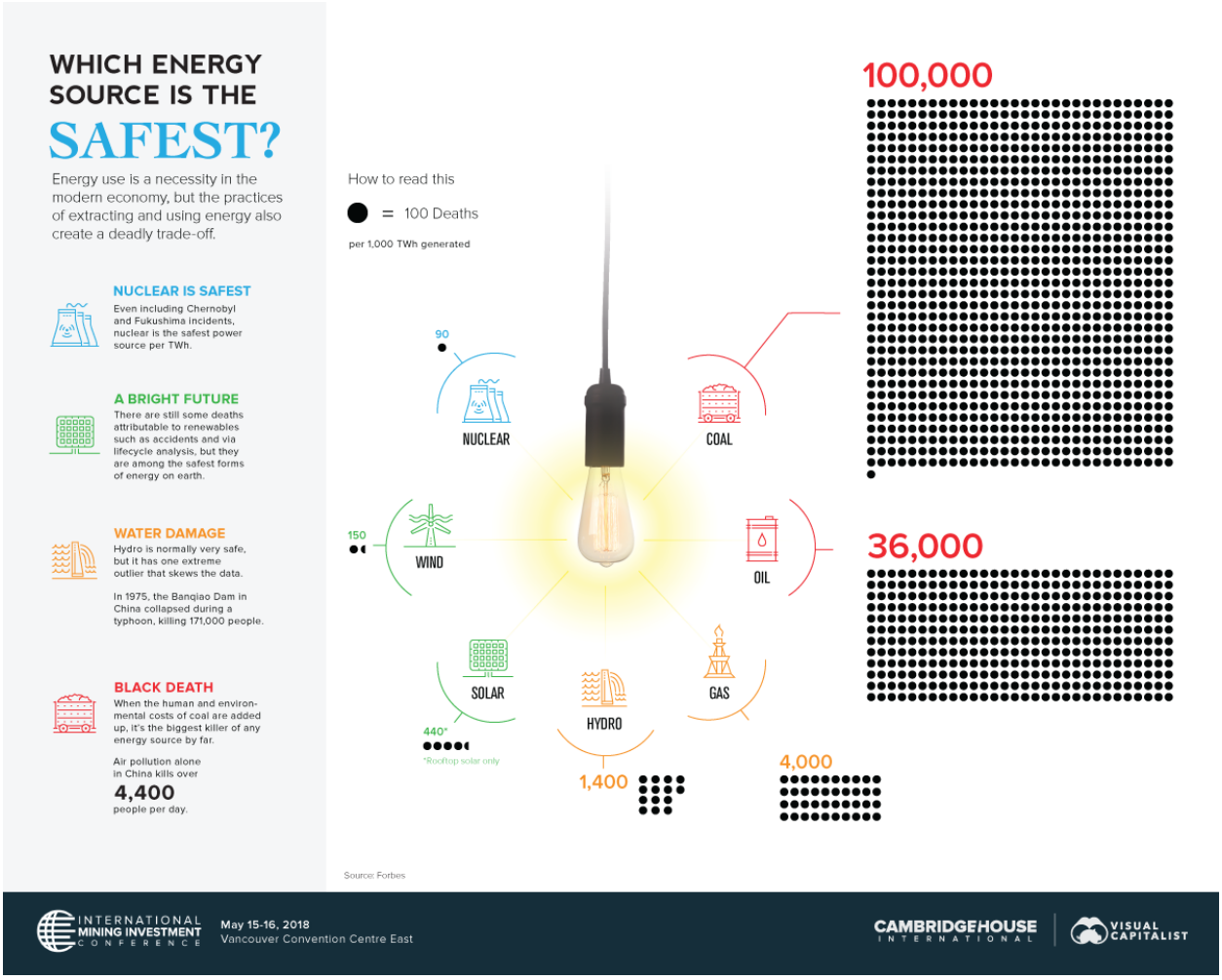


Figure 12: Source Visual Capitalist

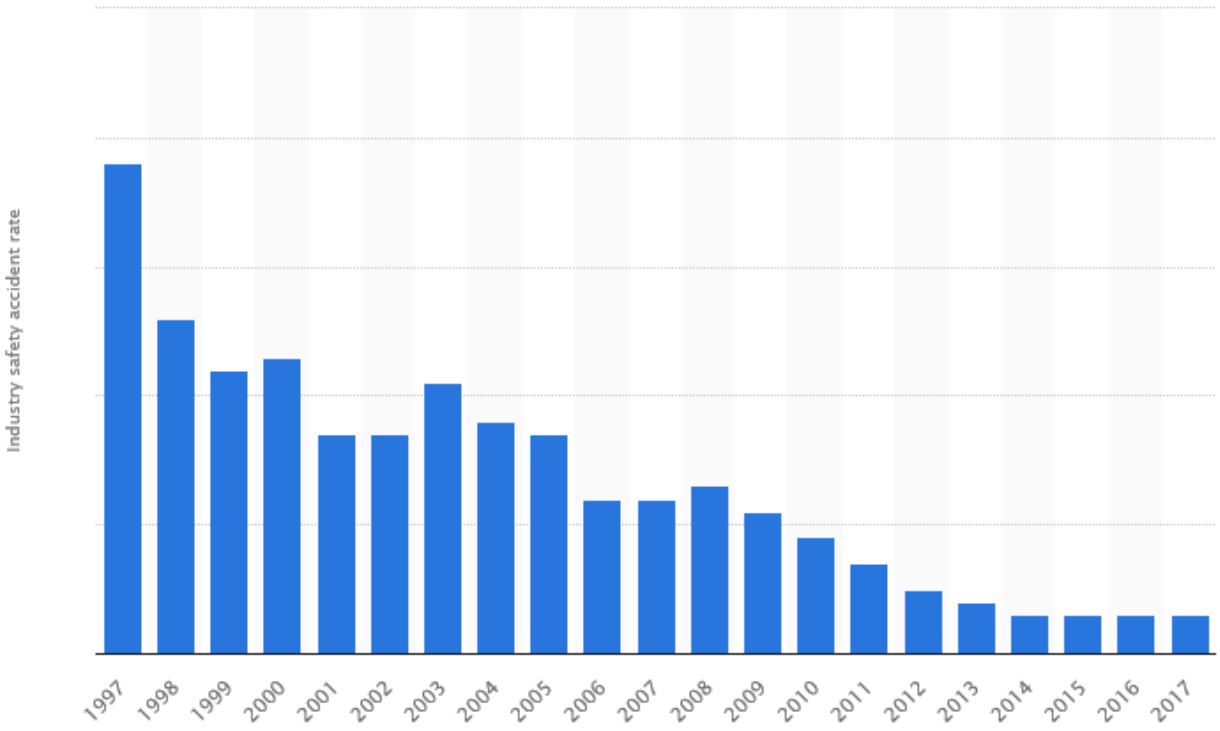


Figure 13: Industry safety accident rate of the nuclear sector in the United States from 1997 to 2017. Source

- This statistic above provides the industry safety accident rate (ISAR) for the nuclear energy sector in the United States between 1997 and 2017. In 2017, the ISAR was 0.03, equivalent to 0.03 accidents that resulted in lost or restricted work or fatalities per 200,000 worker hours.
- Data compiled by the U.S. Bureau of Labor Statistics shows that it is safer to work at a nuclear power plant than in the manufacturing sector, leisure and hospitality industries, and financial sectors. NEI

Liability for Nuclear Damage

- Operators of nuclear power plants are liable for any damage caused by them, regardless of fault. They, therefore, normally take out insurance for third-party liability, and in most countries they are required to do so. WNA
- The potential cross boundary consequences of a nuclear accident require an international nuclear liability regime, so national laws are supplemented by a number of international conventions. WNA

- Liability is limited by both international conventions and by national legislation, so that beyond the limit (normally covered by insurance) the state can accept responsibility as insurer of last resort, as in all other aspects of industrial society. WNA
- The international Convention on Supplementary Compensation for Nuclear Damage (CSC) has entered into force, and will largely replace other conventions. WNA

Nuclear Waste

Radioactive waste is not unique to the nuclear fuel cycle. Radioactive materials are used extensively in medicine, agriculture, research, manufacturing, non-destructive testing, and minerals exploration. Unlike other hazardous industrial materials, however, the level of hazard of all radioactive waste – its radioactivity – diminishes with time. – WNA

A spent fuel assembly will approximately consist of, by weight, 95.6% uranium, 0.9% plutonium, 0.1% minor actinides, 3.4% fission products. (Nuclear Energy, C. Ferguson).

If nuclear power was used to supply a person's electricity needs for an entire year, only about 5 grams of highly-radioactive waste would be produced, which is the same weight as a sheet of paper. WNA

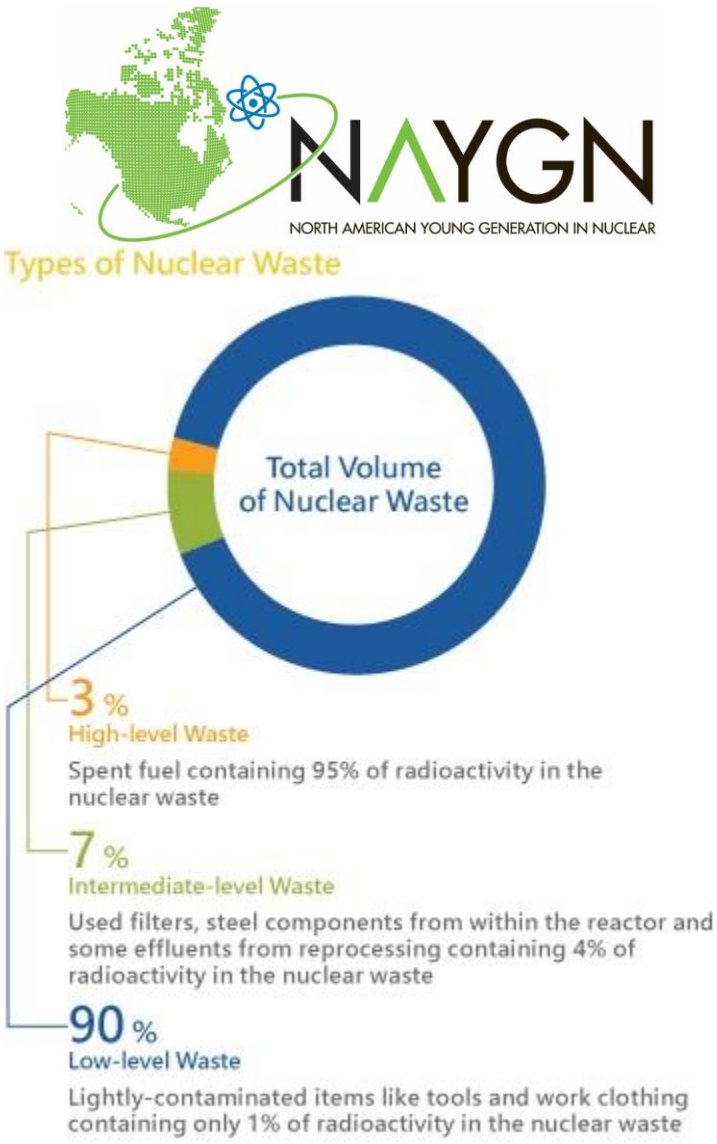


Figure 14: Nuclear Waste Composition. Source WNA

Low Level Waste:

- It comprises paper, rags, tools, clothing, filters, etc., which contain small amounts of mostly short-lived radioactivity. To reduce its volume, LLW is often compacted or incinerated before disposal. LLW comprises some 90% of the volume but only 1% of the radioactivity of all radioactive waste. – WNA

Intermediate Level Waste:

- ILW typically comprises resins, chemical sludges, and metal fuel cladding, as well as contaminated materials from reactor decommissioning. Smaller items and any non-solids may be solidified in concrete or bitumen for disposal. It makes up some 7% of the volume and has 4% of the radioactivity of all radioactive waste. – WNA

High Level Waste:

- HLW arises from the 'burning' of uranium fuel in a nuclear reactor. HLW contains the fission products and transuranic elements generated in the reactor core. HLW accounts for just 3% of the volume, but 95% of the total radioactivity of produced waste. There are two distinct kinds of HLW:
    - Used fuel that has been designated as waste.
    - Separated waste from reprocessing of used fuel. – WNA

Reprocessing Used Fuel:

- Several European countries, as well as Russia, China, and Japan have policies to reprocess used nuclear fuel. – WNA
- This process allows some 25-30% more energy to be extracted from the original uranium ore, and significantly reduces the volume of HLW (by about 85%).– WNA
- In addition, the remaining HLW is significantly less radioactive – decaying to the same level as the original ore within 9000 years (vs. 300,000 years). – WNA
- Electrometallurgical – often called pyroprocessing since it happens to be hot. With it, all actinide anions (notably uranium and plutonium) are recovered together. Whilst not yet operational, these technologies will result in waste that only needs 300 years to reach the same level of radioactivity as the originally mined ore. – WNA

Storage/Disposal of LLW/ILW

- Most LLW and short-lived ILW are typically sent to land-based disposal immediately following packaging. This means that for the majority (>90% by volume) of all of the waste types, a satisfactory disposal means has been developed and is being implemented around the world. – WNA

Storage/Disposal of long lived ILW and HLW

- There is a strong technical incentive to delay final disposal of HLW for about 40-50 years after removal, at which point the heat and radioactivity will have reduced by over 99%. Interim storage of used fuel is mostly in ponds associated with individual reactors, or in a common pool at multi-reactor sites, or occasionally at a central site. At present there is about 250,000 tonnes of used fuel in storage. Over two-thirds of this is in storage ponds, with an increasing proportion in dry storage. WNA
- After being buried for about 1,000 years most of the radioactivity will have decayed. The amount of radioactivity then remaining would be similar to that of the naturally-occurring uranium ore from which it originated, though it would be more concentrated. WNA
- Nuclear power is the only large-scale energy-producing technology that takes full responsibility for all its waste and fully costs this into the product. Financial provisions are made for managing

all kinds of civilian radioactive waste. The cost of managing and disposing of nuclear power plant waste typically represents about 5% of the total cost of the electricity generated. WNA

Volume of HLW

- The IAEA estimates that the disposal volume of the current solid HLW inventory is approximately 22,000m3. For context, this is a volume roughly equivalent to a three metre tall building covering an area the size of a soccer pitch. WNA
- Comparison: in the UK: 200 million tonnes of conventional waste is produced **annually**, of which 4.3 million tonnes is classified as hazardous. WNA

Coal Nuclear Waste

- The largest Tenorm waste stream is coal ash, with around 280 million tonnes arising globally each year, carrying uranium-238 and all its non-gaseous decay products, as well as thorium-232 and its progeny. This ash is usually just buried, or may be used as a constituent in building materials. WNA

Mining

- Nearly half the world's mines now use a mining method called in situ leaching . This means that the mining is accomplished without any major ground disturbance. Groundwater with a lot of oxygen injected into it is circulated through the uranium ore, extracting the uranium. The solution with dissolved uranium is pumped to the surface. WNA

Website Resources:

https://www.world-nuclear.org/

http://energyforhumanity.org/en/

https://www.iea.org/reports/tracking-power-2019/nuclear-power#abstract

https://www.who.int/health-topics/radiation#tab=tab_1

Book Resources:

A Bright Future – Joshua S. Goldstein & Staffan A. Qvist

Campaigning for Clean Air – Meredith Angwin

Nuclear Energy: What Everyone Needs to Know – Charles D. Ferguson

Power to Save the World, the truth about nuclear energy – Gwyneth Cravens

Whole Earth Discipline – Stewart Brand