Circular Economy Lab & Observatory

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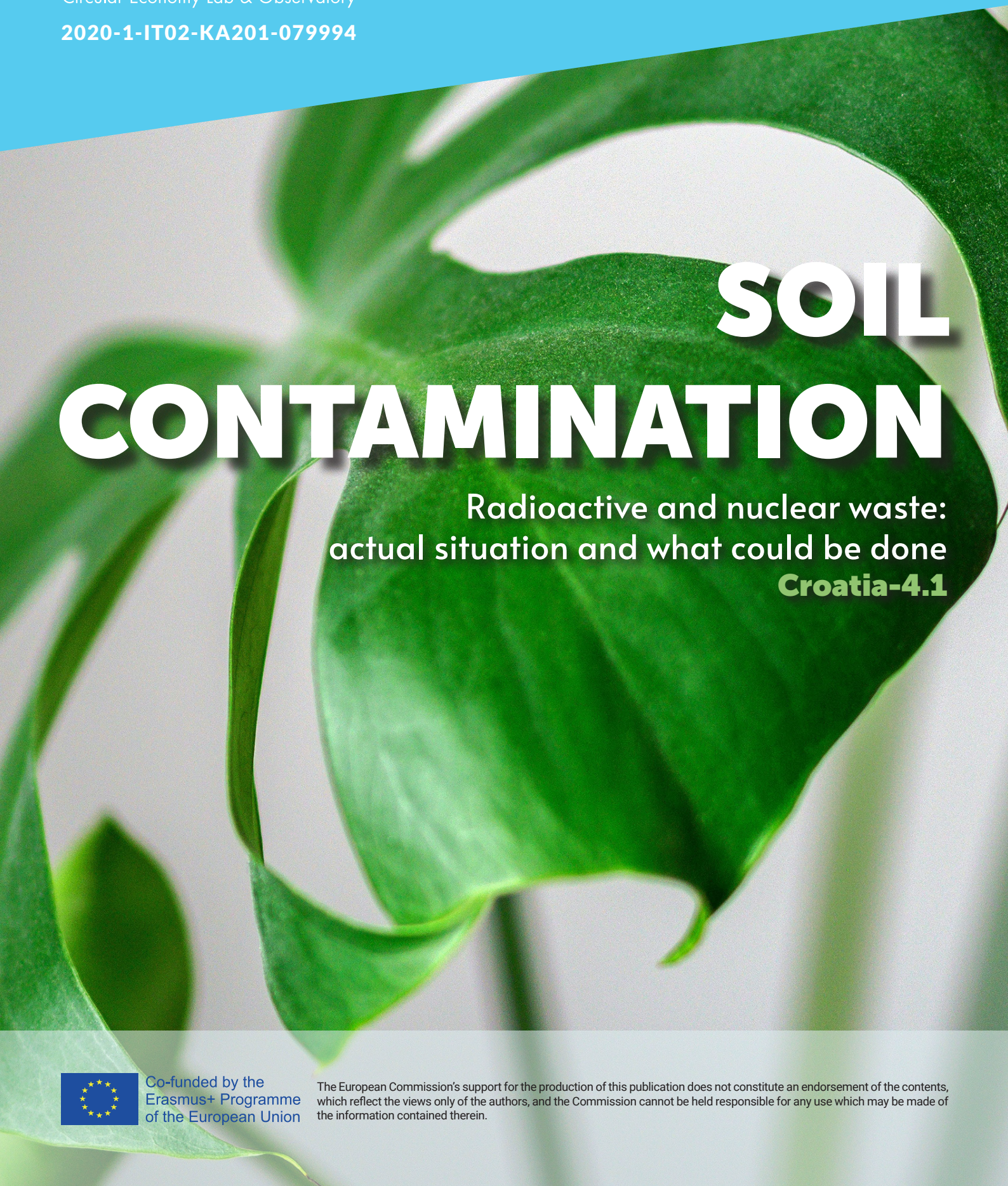

SOIL CONTAMINATION

Radioactive and nuclear waste: actual situation and what could be done

Croatia-4.1

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Radioactive and nuclear waste: actual situation and what could be done

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Radioactive and nuclear waste is waste that contains natural or artificial radioactive nuclides that have no practical application [1]. A nuclide is a set of atoms characterized by the structure of the nucleus, i.e., the number of electrons, protons, and neutrons.

Radiation symbol (Image by Elias from Pixabay https://pixabay.com/users/JamesQube-6733902/ on Pixabay https://pixabay.com/photos/nuclear-power-plant-nuclear-power-6798207/)

Nuclides with the same atomic number make up a chemical element, and if a nuclide has several members with the same atomic number but different mass numbers, they are called isotopes. They are divided into stable and unstable [2]. Radionuclides are unstable nuclides that spontaneously decay and emit radiation [3]. There are about 1500 of them in nature, and 800 of them have been artificially produces (e.g., when testing nuclear weapons). They are used in determining the age of archaeological finds etc. If it not treated properly, it endangers the environment and human health.

This waste is generated by processing coal, oil, gas, and minerals containing radionuclides or by using them for therapeutic purposes in health institutions, as in radiography, PET scans (Positron Emission Tomography) etc. It is created in smaller quantities in industries and scientific research institutions. There are four categories of radioactive waste: very low, low, intermediate, and high radioactive waste. Very low radioactive waste is not dangerous for the environment and human health, so it can be disposed of as ordinary municipal waste.

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Low-level radioactive waste contains a small proportion of radionuclides with a long half-life and is generated in medical institutions and industry.

When transporting and handling this waste, it is not necessary to wear any special protection that will protect us from nuclear radiation. In order to reduce its volume, this kind of waste is burned and then disposed of by dumping it in a surface landfill, i.e., it is buried shallowly.

When handling intermediate radioactive waste, it is necessary to use protection against nuclear radiation. Such waste is generated during the decommissioning of nuclear power plants.

Hazmat suits (Photo from https://www.howitworksdaily.com/wp-content/uploads/2018/11/Untitled-design.png)

The decommissioning of a nuclear power plant is the procedures and works that are necessary for the nuclear power plant to cease to be a nuclear facility [4].

All nuclear power plants have a lifespan of 40 to 60 years.

Radioactive material is removed completely, and that space can be used for other purposes or partially, so that space must be under supervision. The waste is then solidified into concrete, and the final disposal depends on the half-life of the radionuclide. If the waste contains radionuclides with a short half-life, then it is disposed of in a surface disposal repository.

If the waste contains radionuclides with a long half-life, then it is disposed of in deep underground repositories [5]. Highly radioactive waste contains a large proportion of radionuclides that are created in the rector's core. A nuclear reactor is a device in which a controlled nuclear chain reaction takes place [6]. In the rector's core, nuclei are split, which produces neutrons that participate in the splitting of new nuclei.

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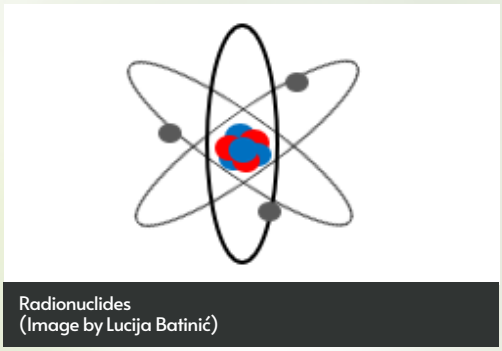
This waste also generates a large amount of heat, so it needs to be cooled for years before being disposed of. This kind of waste appears in two forms: as spent fuel that is not processed or as fission products that are created by processing spent fuel. Nuclear fission is a process in which the nucleus of an atom splits into two parts of similar mass, and part of the mass is converted into energy [7].

To cool the spent fuel and to reduce radioactivity, it is stored temporarily (20-50 years) in the area of the nuclear power plant in a pool for spent fuel and in dry concrete or iron tanks. The fission products are converted into a solid form by being embedded in a special type of borosilicate glass, and then stored in temporary storage facilities for cooling. Borosilicate glass is made of boron oxide and silicon oxide, which make the glass resistant to extreme temperature changes [8]. Finally, they are disposed of in landfills at a depth of 500 to 1000 m.



Radionuclides
(Image by Lucija Batinić)

When radioactive material is deposited on a person or an object, that's what we call radioactive (or nuclear) contamination. It can contaminate water, air, surfaces, people, animals etc.

One of the things it can also contaminate is, of course, soil. Nuclear wastes are thrown away in large pits in the ground. That is one way how soil can be contaminated.

Soils contaminated with radionuclides can no longer produce healthy, good quality crops and they can be classified as degraded. Radionuclides are nuclides that have excess nuclear energy, making them unstable. Every chemical element can exist as a radionuclide. Radionuclides are used in several scientific fields including biology, nuclear medicine, physics and geology. Any material that is either radioactive by nature or is contaminated by radioactivity, and is of no further use is called radioactive waste.

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Most of that waste is produced by nuclear power production, so it's been given another name – nuclear waste. Most of the releases of those materials are accidental, and they happen when radionuclides are being processed, being disposed of, transported or segregated (a process of separating molecules from one another).

Less typically, nuclear fallout is caused by a nuclear explosion. [15] In a 1983 article, Carl Sagan, an American astrophysicist, stated that a smaller nuclear war could release enough particles to lower the temperature on the entire globe and cause animals, as well as crops, to disappear across the planet. He named that effect nuclear winter.

Some of the biggest nuclear accidents are the events that happened in Chernobyl (Ukraine, 1986) and Fukushima (Japan, 2011). They caused global contamination of air, water, living organisms and soil.

Fukushima Daiichi Nuclear Power Plant (Photo by JamesQube https://pixabay.com/users/JamesQube-6733902/ on Pixabay https://pixabay.com/photos/nuclear-power-plant-nuclear-power-6798207/)

Massive amounts of radioactive materials were released into the environment, especially 131I (an important radioisotope of iodine present in nuclear fission products), 137Cs (a radioactive isotope of cesium and a common product of nuclear fission of 235U) and 90Sr (a radioactive isotope of strontium, a product of nuclear fission). Around 40% of Europe has been exposed to Chernobyl's 137Cs.

The radioactive contamination in the soil after the Chernobyl accident was 3500 times higher than the level before.

One of the more recent and, to us, closer problems regarding nuclear waste is the waste from the Krško power plant, a power plant whose energy is used by two countries – Slovenia and Croatia. Until now, all low- and medium-level radioactive waste from Krško, an annual amount of about 30 cubic meters, was stored in a temporary disposal site within the vicinity of the nuclear plant itself.

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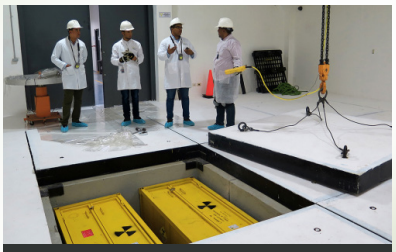
It is a storage facility that was supposed to be in operation only for the first five years of the nuclear plant's operation, but over three decades have passed since then, and the waste is still there. As the capacity of that "temporary" storage facility is almost full, the waste is being sent to Sweden, and as of recently to France too, from where it's returned as ash, equally as radioactive, but of a much smaller volume. Another important accident worth mentioning is the Fukushima Daiichi accident.

Although nuclear facilities are usually designed so that other external events, for example earthquakes or tsunamis, can't endanger the safety of the plant, sometimes accidents happen. On March 11, 2011, a magnitude 9.0 earthquake hit Japan and triggered a massive tsunami. That event led to three nuclear power plants in the area being damaged. The plant that received the most damage was Fukushima Daiichi Nuclear Power Plant.

The earthquake and tsunami knocked out power at the plant causing a triple meltdown that led to the release of large amounts of radioactive material into the air, water, and soil. The nuclear facility is an example that nuclear power is not a secure option, even though it's safer generally than other energy sources. [16]



Example of effective nuclear waste management (photo by IAEA https://www.iaea.org/sites/default/files/styles/width_555px_6_units_16_9/public/status-and-trends-spent-fuel-management-1140x640.jpg?itok=A8i2AOBc)

Nuclear waste is dangerous because of its radioactive nature. Because of that, it needs to be processed to make it as safe as possible for disposal.

It must be collected, sorted, reduced in volume, changed in chemical and physical composition and lastly, conditioned in immobilized state and carefully packed before storage and disposal. To make a good selection of waste processing strategy, it's important to understand the waste source, rate of waste generation and characteristics of the waste.

By characterization we can find out information about physical, chemical and radiological properties of the waste, which we can later use to deduce the best processing option as well as proper safety requirements.

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Not only can this analysis help us with processing, but also with storage because we can look up compatibility and compliance with accepted storage and disposal criteria as well. The processing of nuclear waste consists of three main steps: pre-treatment, treatment and conditioning. Pre-treatment is the process of preparing the waste for later stages.

Usually it includes sorting and separating contaminated items from non-contaminated ones. However, it may also include reducing the size of the waste to optimize it for further processing. It's done by cutting or shredding the sizeable waste. This step also minimizes the cost of waste disposal by using decontamination techniques to reduce the amount of waste requiring treatment. Once all of this is done and the waste is properly prepared, we move to the next step.

Treatment is done to increase the waste's safety and minimize the costs of further stages of storage and disposal. It separates out the radioactive component form bulk waste to decrease volume of radioactive waste. This process often changes the waste's composition. Based on the nature of the waste and its acceptance requirements of the chosen disposal site, a great spectrum of waste treatment processing steps are available to use.

Two most frequently used treatment techniques are incineration of solid waste and evaporation of liquid waste. The third and final step in the processing of nuclear waste is conditioning. It maneuvers the waste into a stable, safe and manageable form so it can be transported, stored and disposed.

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Disposal facility Onkalo (photo by Posiva Oy https://www.iaea.org/sites/default/files/styles/width_555px_6_units_16_9/public/onkalo-disposal-facility-1140x640.jpg?itok=7CJGwrbC)

To accomplish that , the waste is often encapsulated or solidified in cement, bitumen or glass, or overpacked into special containers. The main goal of conditioning techniques is to slow down the release of radionuclides from the disposed waste into the environment. After all three steps of processing are completed, the nuclear waste is stored in designated areas that provide for its isolation and confinement, but also which allow its easy retrieval at the end of the storage period.

The final step in the management of nuclear waste is disposal. Its aim is to ensure safety by providing placement for waste in facilities designed for appropriate levels of containment and isolation. These facilities are made and maintained to enclose both natural and engineered barriers for sufficient radiation protection of people and environment over long periods of time.[18] Nuclear industries must be careful of and control what they release into the environment to keep air, water and land clean and safe from pollution.

The best way to do that is by closely following these protocols and rules for the nuclear waste management and making sure that the chosen disposal areas are fit for storing the amount and level of contamination of the nuclear waste. Finland is the country that is the most dependent on nuclear energy. That's why they're investing in nuclear solutions for climate change and long-term ways to manage nuclear waste. Recently they succeeded and built the first licensed deep disposal site for high level nuclear waste, called Onkalo.

It's located on Olkiluoto island, around 450 meters below ground level. There the fuel will be safely kept in corrosion-resistant canisters and embedded in clay for hundreds of thousands of years. But Finland is not the only one, other countries are also making progress towards safe waste disposal solutions.[19]

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One of the things it can also contaminate is, of course, soil. Nuclear waste is thrown away in large pits in the ground. Soil contamination can cause a number of unwanted effects, like an increased risk of cancer in all organisms living in the contaminated area, as well as making the contaminated soil unfit for agriculture for a number of years.

There have been many quarrels over the years over storage site locations for nuclear waste, as it always poses a risk of leaking and contaminating the area. An example close to us is the storage of nuclear waste from the Krško Powerplant, which has caused political tensions between the Croatian and Slovenian governments over the location site of the nuclear waste produced by the Krško Powerplant.

The topic of nuclear waste usually comes up with the topic of nuclear energy.
The nuclear waste produced in theproduction of nuclear energy is the main concern for the safety of nuclear energy, especially in the aftermath of many critical disasters (i.e., Chernobyl, Fukushima).

While that is a valid concern, in reality the numbers don't addup, as the number of indirect deaths caused by the burning of fossil fuels far outweighs any danger that nuclearwaste from nuclear energy produces.

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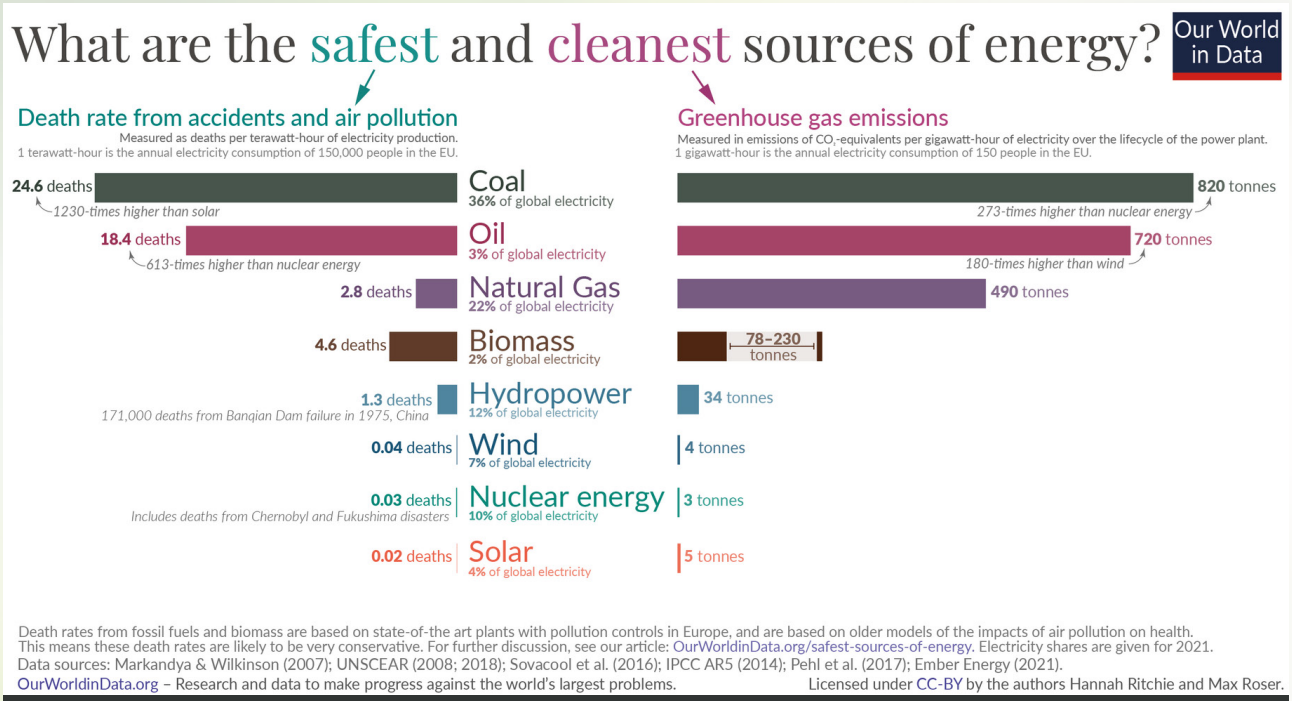

Bar chart of deaths and greenhouse gas emissions caused by different types of energy sources (Graphic by Hannah Ritchie and Max Roser, from OurWorldinData.org)

It's worth noting as well that the burning of coal in coal powerplants alsoproduces radioactive nuclides that go into the air (as coal contains trace amounts of radioactive nuclides).

Nuclearwaste is a negligible threat to public safety as long as it is treated safely and correctly. And so, over the years, there have been an increasing number of regulations put to the nuclear industry to make it safer.

Which has made the nuclear energy industry incredibly safe, but has also had the side effect of forcing nuclear powerplants to constantly invest money into achieving those new safety requirements. That adds a big cost to the nuclear energy industry, making it less viable and cost-effective compared to other means of getting energy.

On the topic of lowcost safety measures, there has been some innovation, as with one company, DeepIsolation. As DeepIsolation has an idea for a low-cost and safe solution for the disposal of nuclear waste, it proposes to bury it in deep underground boreholes, like those used in drilling for oil.

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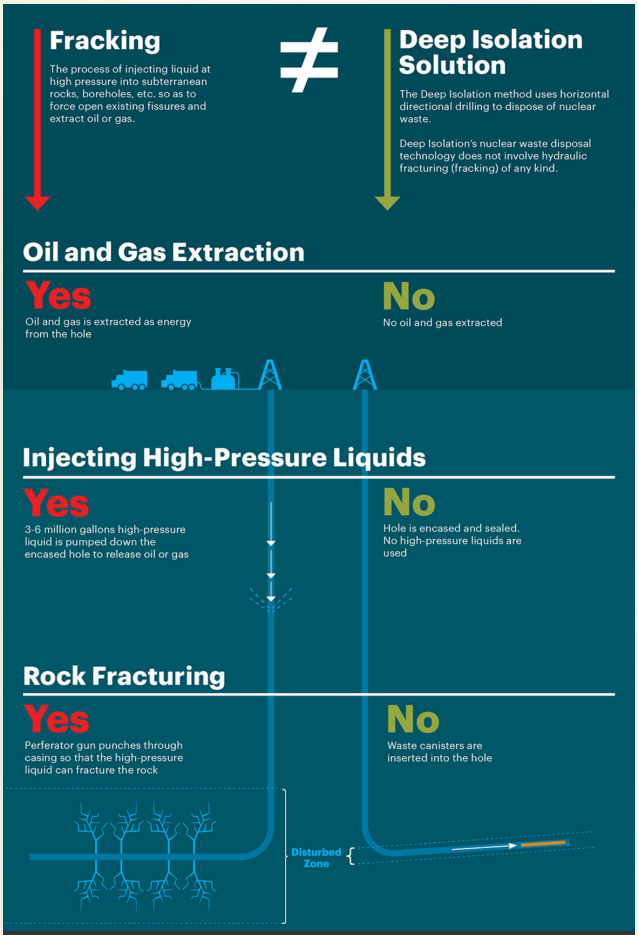
And so the public image of nuclear energy has recently changed, especially in the context of the recent political climate surrounding energy resources as well as the global economic recession.

Those factors have made people reconsider nuclear energy in a new light.

That can, for example best be seen in the renewed interest of the Japanese government in the reopening of nuclear powerplants in Japan.

As Japan has previously been extremely anti-nuclear ever since the Fukushima disaster.

Although it is always worth remembering that there may be unforseen problems with nuclear energy, as in the case of the Fukushima disaster, where even though the Fukushima nuclear power plant was earthquake-proof, the tsunami that followed the earthquake destroyed it and caused a major nuclear disaster.



Graphic showing DeepIsolation\'s method of storing nuclear waste and how it differentiates from controversial fracking methods (Graphic from https://www.deepisolation.com/deep-isolation-does-not-frack/)

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