

What if Chernobyl had been a coal-burning power plant?

Putting nuclear energy fears into perspective.

Dr. Jesús Pineda, [Guido Núñez-Mujica](#), Carl Page, D J LeClear, Brian Bramlett

What if Chernobyl had been a coal-burning power plant?

Putting nuclear energy fears into perspective.

Dr. Jesús Pineda, Guido Núñez-Mujica, Carl Page, D J LeClear, Brian Bramlett

Abstract: We compare the death toll of the 1986 Chernobyl disaster with a counterfactual “Coal Chernobyl”: a Soviet-era coal plant generating the same electricity as Chernobyl, operating continuously from 1977 to 2023. Our findings show that such a plant would have caused far more premature deaths, primarily from respiratory illness due to fine particulate pollution. Counterintuitively, it would have released more radioactive material over a much longer timespan than the actual Chernobyl accident. Even history’s worst nuclear disaster caused less harm to human health than decades of coal-fired power from the same period.

Nuclear energy is increasingly recognized as essential for clean, reliable power. Yet it continues to face stigma, much of it rooted in the traumatic legacy of the 1986 Chernobyl disaster (Midden & Verplanken, 1990).

We place the Chernobyl disaster in perspective by examining a counterfactual: what if the Soviet Union had built a coal plant instead of a nuclear one? Our analysis shows that this “Coal Chernobyl” would have caused at least 33,728—and possibly up to 106,002—excess deaths, far exceeding the 50 to 5,000 attributed to the actual disaster. Most of these deaths would stem from respiratory disease caused by coal pollution. Counterintuitively, although the real Chernobyl released about three times more radioactive material than a coal plant would have, the radionuclides from “Coal Chernobyl” would have half-lives up to 20 billion times longer.

THE ACTUAL DISASTER

The health impact of Chernobyl remains contested, with death-toll estimates varying widely. Ritchie (2017) argues that as few as 50 deaths can be directly attributed to the disaster. In contrast, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the International Atomic Energy Agency (IAEA) place the toll at up to 5,000 deaths (United Nations, 2011).

This divergence stems from different assumptions about the geographic scope of exposure, the effects of low-dose radiation (at or below background levels), and the risk factors used in health calculations. Ritchie (2017) counts only 49 deaths: 2 plant workers killed in the explosion, 28 of the 134 emergency workers who died from acute radiation exposure in the following weeks, and 19 others who survived Acute Radiation Syndrome but died by 2006 of various causes, most not directly attributable to radiation. By contrast, UNSCEAR includes those 50 deaths, nine children who died of thyroid cancer possibly linked to contaminated milk, and an estimated 3,940 lifetime cancer and leukemia deaths across 200,000 emergency workers (1986–1987), 116,000 evacuees, and 270,000 residents of the most contaminated areas of Ukraine, Belarus, and Russia, projected over 95 years.

Regarding the projected cancer deaths, UNSCEAR notes that increases beyond emergency workers are difficult to detect and questions the use of models such as linear no-threshold to estimate dose–response in radiation epidemiology.

Several projections of the health consequences of the Chernobyl accident based on the linear non-threshold model have been conducted by various groups. However, there is a limit to the use of the data derived from epidemiological studies. Below doses of about 0.1 Sv, the experimental evidence for radiation-induced health effects is ambiguous and risk coefficients become more uncertain. Therefore, any radiation risk projections in the low-dose area should be considered as extremely uncertain, especially when the computation of cancer deaths is based on collective effective doses involving very small additional exposures to very large populations over many years. It is inappropriate to use collective effective dose for risk projections because the biological and statistical uncertainties are too great. [(United Nations. Scientific Committee on the Effects of Atomic Radiation & United Nations, 2011 §§D279)].

METHODS

We estimate the emissions from a coal plant matching Chernobyl’s capacity, operating continuously since January 1, 1977. This “Coal Chernobyl” would have replaced the full output of the actual Chernobyl complex, which was designed for four reactors—one at 800 MW and three at 1,000 MW—with two additional 1,000 MW reactors planned, assuming a 70% capacity factor (International Atomic Energy Agency, 2025).

Reactor	Date of Grid Connection	Capacity (Mwe)
Unit 1	1977-09-26	800
Unit 2	1978-12-21	1000
Unit 3	1981-12-03	1000

Reactor	Date of Grid Connection	Capacity (Mwe)
Unit 4	1983-12-03	1000
Unit 5	(planned for) 1988-01-01	1000
Unit 6	(planned for) 1994-01-01	1000

Our “Coal Chernobyl” reflects the design and efficiency typical of the late 1970s: a pulverized-coal plant equipped with dust-control systems averaging 92% efficiency in the USSR by 1990. In practice, this meant that about 18% of generated fly ash was released into the atmosphere. Because emissions vary with coal composition and plant characteristics, we set lower and upper bounds for CO₂ emissions at 924 g CO₂e/kWh and 1,093 g CO₂e/kWh. Emission factors for lead, mercury, and cadmium are taken from estimates of Soviet coal plants of similar design and vintage (Gromow & Ginzburg, 1998).

RESULTS

Lifetime estimated generation for each reactor is given in Table 1, for the entire power plant complex we find an estimated total generation of 1376.65 Twh.

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Total
Lifetime generation (Twh)	222.2	270.18	252.07	239.48	214.77	177.95	1376.65

A “Coal Chernobyl” would have emitted between 1.27 and 1.50 gigatons of CO₂ over its lifetime—roughly a thousand times the 2023 emissions of Cabo Verde (1.23 Mt) and Palau (1.50 Mt) (Crippa et al., 2024).

For health impacts, we estimate deaths, serious illnesses, and minor illnesses under three scenarios. As a best case, we use health impact factors from current European hard-coal plants, which employ extensive controls to limit carbon, particulate, and heavy-metal emissions (Markandya & Wilkinson, 2007). As a mid-tier scenario, we draw on data from European lignite plants, which better approximate the Soviet coal mix. Even with modern controls, lignite plants produce emissions of similar composition, though in smaller amounts (Gromow & Ginzburg, 1998). Finally, for a worst case, we use estimates from current Chinese coal plants: 77 deaths, 975 serious illnesses, and 18,000 minor illnesses per TWh (Kharecha & Hansen, 2013).

Including the Chinese case illustrates the impact of higher population density and different regulatory standards.

Table 2 presents our health impact results. After subtracting the 50–5,000 deaths attributed to the actual nuclear disaster, a coal-fired Chernobyl would have caused excess deaths ranging from 28,728 to 33,678 in the best-case scenario (modern European hard coal plant), 39,879 to 44,829 in the mid-tier scenario (modern European lignite plant), and 101,002 to 105,952 in the worst case (Chinese coal plant).

	Deaths	Serious Illness	Minor Illness
Hard coal	33,728	309,746	18,292,910
Lignite	44,879	410,241	24,333,650
Chinese CPP	106,002	1,342,233	24,779,684

Heavy metal emissions are also an important risk factor arising from coal power plants. Following the assessment of emissions for Russian coal power plants in 1990 estimating lead, mercury and cadmium emissions in air of 1.08 Kg / Kwh, 4.57 µg / Kwh and 45.7 µg / Kwh respectively (Gromow & Ginzburg, 1998). In table 3, we show our estimates for heavy metal emissions for the lifetime of our hypothetical “Coal Chernobyl.”

	Lead	Mercury	Cadmium
Contaminants (t)	1486.78	6.29	62.91

MERCURY

Mercury is associated with neurocognitive defects, damage to hearing and speech, neuromuscular damage, fetal defects and death. Extreme cases of Mercury poisoning are known as Minamata Disease, in reference to the set of neurological conditions first discovered in Minamata, Kumamoto Prefecture, Japan in 1956 due to exposure to high quantities of mercury in wastewater [(Wexler, 2023)].

Coal power plants emit mercury that deposits in soils, plants and nearby water sources nearby, resulting in risk of exposure from inhalation, drinking water and food. Most of the mercury from modern coal power plants deposits within 15 Km of the plant [(Rodríguez & Nanos, 2016)]. According to the Emissions Database for Global Atmospheric Research, our estimate for the total lifetime emissions for Coal Chernobyl is comparable to about 6 times the yearly mercury emissions from Panama, totalling 6.46 t [(Muntean et al., 2024)].

In our counterfactual scenario, mercury poisoning yield calls for an exclusion zone for mercury exposure around a Chernobyl coal power plant. This zone would be of around half the radius of the actual Chernobyl exclusion zone. However, had Chernobyl used the lower-performing mercury-abatement technology in use in the Soviet Union at the time, it's likely a larger radius would have been necessary.

CADMIUM

Cadmium is a heavy metal pollutant commonly released by coal burning power plants. Acute cadmium exposure results in fever, chills, cough, and respiratory distress, while long-term cadmium exposure is associated with permanent excess protein in urine due to deteriorated renal function, osteomalacia (bone softening) in postmenopausal women, neurologic dysfunction and cancer (Koons & Rajasurya, 2023).

Our lifetime estimate for cadmium emissions is comparable to half of the entire output for Spain from all sources in 1979: 62.91 t for our model compared with 126 t for Spain according to (Pacyna et al., 1984). Cadmium deposits from the emissions of coal power plants contemporary with our hypothetical Chernobyl coal power plant have been found to reach background levels at a distance of close to 30 Km from source [cf. (Meema, 1987) and references therein], leading to a safety area comparable to that of the Chernobyl exclusion zone.

LEAD

Lead poisoning affects nearly all human bodily functions. Acute exposure to lead can lead to delirium, cognitive deficits, hallucinations, and convulsions while long-term exposure manifests in gastrointestinal conditions as nausea, abdominal pain; neurologically as, numbness in the extremities, headaches, stupor, slurred speech, and memory loss, and hemodynamically as anemia and breakdown of other bodily functions. Furthermore, exposure to lead in childhood is well documented to have drastic effects in mental and physical development (Halmo & Nappe, 2023). These manifold negative effects to human health led to a worldwide effort to remove sources of exposure to lead to humans, mainly in the form of removal of lead from gasoline (Angrand et al., 2022).

Our estimates show that if Chernobyl had been a coal power plant, given the composition of coal emissions usual in the Soviet Union at the time, it would have released some 1,500 t of lead throughout the lifetime of the power plant. This would put the lead emissions of our Coal Chernobyl plant between the all-cause lead emissions of Greece and Finland for 1979, which were 1,303 t and 1,621 t respectively. These amounts of lead emissions have been linked to lead in blood concentrations of 32.3 µg/dL in Greek children and of 6.7 µg/dL in Finnish children (Drossos et al., 1982), (Taskinen et al., 1981). Without any of the emissions from our “Coal Chernobyl” plant, values of lead content in the blood for Ukrainian children in 1998, already vary between 0.7–22.7 µg / dL (Friedman et al., 2005). One would expect that the excess emissions from our hypothetical coal plant would have made this result trend undesirably upwards.

According to the World Health Organization lead in blood levels at or above 5 µg/dL require an investigation to identify the source of contamination, while levels at or above 10 µg/dL have been associated with neurological toxicity in children leading to lower cognitive performance (World Health Organization, Chemical Safety and Health Unit, 2007).

A BRIEF COMMENT ON RADIOISOTOPES

In addition to heavy metals and particulates, coal plants also release radionuclides that damage health and the environment. The Chernobyl disaster released an estimated 50 t of radioactive material—mainly isotopes of Kr, Xe, Cs, and I—along with about 6 t of nuclear fuel, over a ten-day period (OECD et al., 2003).

Life-cycle assessments place the ionizing radiation from hard-coal power at roughly 9.07 g ²³⁵Ueq per kWh, most of it from extraction; burning coal accounts for about 5% (0.454 g ²³⁵Ueq) (UNECE, 2022). On this basis, our counterfactual plant would have emitted ~624 kt ²³⁵Ueq over its lifetime, or ~44.2 t ²³⁵Ueq per day.

Isotopic composition is critical to health effects and persistence. At Chernobyl, the most significant were ¹³⁷Cs (30-year half-life), ⁹⁰Sr (29 years), and ¹³¹I (8 days). Coal emissions, by contrast, are dominated by ²²⁶Ra (7.4 min), ²²⁸Ra (1.08 min), ²²⁸Th (1.9 years), ²¹⁰Pb (22.3 years), ²³⁸U (4,468 Myr), and ²³⁵U (704 Myr) (Pacyna, 1980).

Expressed in ²³⁵U-equivalent terms, radionuclide emissions from a “Coal Chernobyl” exceed those from the actual accident, mainly because of its decades-long operation and the extreme half-lives of coal-derived isotopes. However, without robust models of ash transport and human exposure, the health impact of these radionuclides cannot be reliably quantified.

The tables below report lifetime equivalent emissions for both Chernobyl-type isotopes and those typical of coal combustion.

Chernobyl isotopes	Equivalent emissions (g)	Equivalent emissions (t)
Cs137	15,607,759	15.6
Sr90	9,573	0.0096
I131	10,858	0.0109

Coal isotopes

Ra226	1,349,860	1.3499
Ra228	4,945	0.0049
Th228	1,643	0.0016
Pb210	17,525	0.0175
U238	3,901,939,849,500	3,901,939.85

DISCUSSION

We have estimated the health and environmental impacts of a counterfactual “Coal Chernobyl” – that is, a coal-fired power plant of the same scale as Chernobyl. In this counterfactual, there is no meltdown. Instead, the plant continues generation uninterrupted until 2023, with no upgrades or unit shutdowns.

We use emission factors for coal power plants of that period, when available, to estimate CO₂, heavy metals and radionuclide equivalent emissions and estimate deaths, serious and minor illnesses associated with those emissions.

We find that the estimated excess deaths just due to carbon and particulate emissions, to be between 28,728 and 105,952. The lower bound assumes that the health impacts from our theoretical Coal Chernobyl would be comparable with a modern European coal plant and then assumes the maximum number of victims from the Chernobyl accident, 5000. The higher estimate assumes health impacts comparable to Chinese coal plants, minus the lower estimate of victims of the actual accident, 50.

These are far above the range of between 50 and 5,000 estimated for the actual Chernobyl disaster by official sources.

The worst nuclear plant disaster in history cost far fewer lives than the normal operation of a similarly sized coal plant.

Comparison with contemporary emissions of heavy metals allows us to add detail to the massive impact that our counterfactual Coal Chernobyl would have had.

The substantial emissions of Pb, Hg and Cd emitted by coal power plants at the time lead to well documented deleterious health effects for populations around said plants, even at a distance comparable to the current Chernobyl exclusion zone. Our hypothetical Coal Chernobyl, over its lifetime, would have single-handedly produced about as much heavy metal pollution as entire nations, reverting a full year's worth of heavy metal controls.

Radionuclide emissions from burning coal also contribute to the danger of our hypothetical power plant: we see that while these emissions can be broadly smaller in quantity than those of the Chernobyl Nuclear Plant, when put in terms of the isotopes emitted by the disaster, the isotopes emitted due to the isotopic profile of coal have far longer half-lives and longer decay chains, which is of concern. However, lacking a model for isotope transport and for human exposure, we cannot truly assess the radiological health impacts of our coal power plant. This could prove to be an interesting avenue for further research.

A more thorough approach using epidemiological methods could further show the damage heavy metal emissions could have caused in health outcomes for those exposed (especially in children born under chronic exposure since conception) and radiological estimates could further show how the radioisotope emissions of our counterfactual coal plant could impact solid mass cancers and leukemia outcomes in exposed populations. These deeper research programs, while lying beyond our current scope, could show even more clearly how the terrible cost of the worst nuclear reactor disaster in history is dwarfed by the consequences of eschewing nuclear energy in favor of dirtier and more dangerous energy sources like coal.

REFERENCES

- Angrand, R., Collins, G., Landrigan, P., & Thomas, V. (2022). Relation of blood lead levels and lead in gasoline: an updated systematic review. *Environmental Health*, 21(138).
<https://doi.org/10.1186/s12940-022-00936-x>
- Chestney, N. (2025, May 6). EU power grid needs trillion-dollar upgrade to avert Spain-style blackouts. Reuters. Retrieved June 11, 2025, from
<https://www.reuters.com/sustainability/climate-energy/eu-power-grid-needs-trillion-dollar-upgrade-avert-spain-style-blackouts-2025-05-05/>
- Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., Schaaf, E., Monforti-Ferrario, F., Becker, W. E., Quadrelli, R., Riquez Martin, A., Taghavi-Moharamli, P., Köykkä, J., Grassi, G., Rossi, S., Mello, J., Oom, D., Branco, A., San-Miguel, J., Manca, G., ... Pekar, F. (2024). GHG Emissions of All World Countries. Publications Office of the European Union.
- Drossos, C., Mavroidis, K., Papadopoulou-Daifotis, Z., Michalodimitrakis, D., Salamalikis, L., Gounaris, A., & Varonos, D. (1982, Oct). Environmental lead pollution in Greece. *American Industrial Hygiene Association Journal*, 43(10), 796-798.
<https://doi.org/10.1080/15298668291410594>
- Fairlie, I., & Sumner, D. (2006, April). THE OTHER REPORT ON CHERNOBYL. Berlin, Brussels, Kiev:Greens/EFA in the European Parliament.
<http://www.chernobylreport.org/torch.pdf>
- Friedman, L. S., Lukyanova, O. M., Kundiev, Y. I., Shkiryak-Nizhnyk, Z. A., Chislovska, N. V., Mucha, A., Zvinchuk, A. V., Oliynyk, I., & Hryhorczuk, D. (2005). Predictors of elevated blood lead levels among 3-year-old Ukrainian children: A nested case-control study. *Environmental Research*, 99(2), 235-242.
<https://doi.org/10.1016/j.envres.2004.12.006>
- Gromow, S., & Ginzburg, V. (1998). Estimation Of Heavy Metal Emissions From Coal- Fired Power Plants In Russia. *WIT Transactions on Ecology and the Environment*, 28, 10.
10.2495/AIR980581
- Halmo, L., & Nappe, T. (2023, July 4). Lead Toxicity - StatPearls. National Library of Medicine. Retrieved June 11, 2025, from <https://www.ncbi.nlm.nih.gov/books/NBK541097/>
- International Atomic Energy Agency. (2025, 06 11). Power Reactor Information System (PRIS) - Ukraine. Retrieved 06 11, 2025, from
<https://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=UA>
- Kharecha, P. A., & Hansen, J. E. (2013). Prevented mortality and greenhouse gas emissions from historical and projected nuclear power. *Environmental science & technology*, 47(9), 4889–4895. <https://doi.org/10.1021/es3051197>
- Koons, A. L., & Rajasurya, V. (2023, Aug 14). Cadmium Toxicity - StatPearls. National Library of Medicine. Retrieved June 11, 2025, from <https://www.ncbi.nlm.nih.gov/books/NBK536966/>

REFERENCES

- Markandya, A., & Wilkinson, P. (2007). Electricity generation and health. *Lancet*, 370(9591), 979–990. [10.1016/s0140-6736\(07\)61253-7](https://doi.org/10.1016/s0140-6736(07)61253-7)
- Meema, K. M. (1987). Lead, mercury, cadmium and arsenic in the environment - SCOPE 31 (T. Hutchinson, Ed.). John Wiley & Sons.
- Midden, C., & Verplanken, B. (1990). The stability of nuclear attitudes after chernobyl. *Journal of Environmental Psychology*, 10(2), 111-119. [https://doi.org/10.1016/S0272-4944\(05\)80122-7](https://doi.org/10.1016/S0272-4944(05)80122-7)
- Muntean, M., Crippa, M., Guizzardi, D., Federico, P., William, B., Manjola, B., Edwin, S., & Andrea, S. (2024). EDGAR v8.1 Global Mercury Emissions. European Commission, Joint Research Centre (JRC). <https://doi.org/10.2905/83b507d7-5218-4dc5-95f9-0ec36f073204>
- Organisation for Economic Co-operation and Development, OECD Nuclear Energy Agency, & Nuclear Energy Agency. (2003). Chernobyl: Assessment of Radiological and Health Impacts: 2002 Update of Chernobyl: Ten Years On. OECD Publishing. https://www.oecd-neo.org/jcms/pl_13598
- Pacyna, J. (1980). Radionuclide behavior in coal-fired plants. *Ecotoxicology and Environmental Safety*, 4(3), 240-251. [https://doi.org/10.1016/0147-6513\(80\)90026-3](https://doi.org/10.1016/0147-6513(80)90026-3)
- Pacyna, J., Semb, A., & Hanssen, J. (1984, jan). Emission and long-range transport of trace elements in Europe. *Tellus B: Chemical and Physical Meteorology*, 36(3), 163-178. <https://doi.org/10.3402/tellusb.v36i3.14886>
- Ritchie, H. (2017). What was the death toll from Chernobyl and Fukushima? Published online at OurWorldinData.org. <https://ourworldindata.org/what-was-the-death-toll-from-chernobyl-and-fukushima>
- Rodríguez, J. A., & Nanos, N. (2016, May 05). Soil as an archive of coal-fired power plant mercury deposition. *Journal of Hazardous Materials*, 308, 131-138. <https://doi.org/10.1016/j.jhazmat.2016.01.026>
- Siegel, J., & Stabin, M. (2012). RADAR COMMENTARY: USE OF LINEAR NO-THRESHOLD HYPOTHESIS IN RADIATION PROTECTION REGULATION IN THE UNITED STATES. *Health physics*, 102(1), 90–99. <https://doi.org/10.1097/HP.0b013e318228e5b4>
- Taskinen, H., Nordman, H., Hernberg, S., & Engstöm, K. (1981). Blood lead levels in Finnish preschool children. *Science of The Total Environment*, 20(2), 117-129. [https://doi.org/10.1016/0048-9697\(81\)90058-9](https://doi.org/10.1016/0048-9697(81)90058-9)
- United Nations. Economic Commission for Europe. (2022). Carbon Neutrality in the UNECE Region: Integrated Life-cycle Assessment of Electricity Sources. UN. <https://doi.org/10.18356/9789210014854>

REFERENCES

- United Nations. Scientific Committee on the Effects of Atomic Radiation & United Nations. (2011). Sources and Effects of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation : UNSCEAR 2008 Report to the General Assembly, with Scientific Annexes. UN.
https://www.unscear.org/unscear/en/publications/2008_2.html
- Weber, W., & Zanzonico, P. (2017, January). The Controversial Linear No-Threshold Model. *Journal of Nuclear Medicine*, 58(1), 7-8. <https://doi.org/10.2967/jnumed.116.182667>
- Wexler, P. (Ed.). (2023). *Encyclopedia of Toxicology*, 4th Edition, 9 Volume Set. Elsevier Science.
<https://doi.org/10.1016/B978-0-12-824315-2.00459-0>
- World Health Organization, Chemical Safety and Health Unit. (2007, May). Blood lead levels in children. European Environment and Health Information System. Fact sheet No. 4.5.