

How Nuclear Power powers the Bomb

The interdependence of military and civilian nuclear industries

The military origins of nuclear technology

The discovery of the atomic chain reaction in 1938 paved the way for the military use of nuclear technology. Throughout the Second World War, Germany, the UK, the Soviet Union and the US were involved in a race to construct the first atomic bomb. In the end, it was the US with its Manhattan project who succeeded. The first atomic detonation took place in Alamogordo, New Mexico in July 1945. Less than a month later, Hiroshima was attacked with a uranium bomb, and Nagasaki with a plutonium bomb. The combined death toll by the end of 1945 was about 200,000.

The civilian use of nuclear power began with the “Atoms for Peace” speech by US President Eisenhower before the UN General Assembly in 1953 in which he said “The United States knows that peaceful power from atomic energy is no dream of the future” and announced that nuclear fission, which will forever be associated with the horrendous bombings of Hiroshima and Nagasaki, could be a blessing and solve all mankind’s energy problems through the use of nuclear power plants.¹ Governments and the nuclear industry have carefully concealed and denied any links between civil and military nuclear programmes, implying that there are two, carefully separated nuclear production cycles—a military one and a civil one.

A closer look at the global nuclear industry shows a different picture: nuclear-weapon states dominate current investments in nuclear energy. China is leading the way, while the other nuclear weapon states Russia, India, Pakistan, France, the UK and the USA also have active nuclear power plant projects.² Russia also has plans to build, finance and operate nuclear power plants in Belarus, Bangladesh, Turkey and Hungary, while France is constructing nuclear power plants in Finland and the UK.

Only a few states without nuclear weapons programmes operate substantial civil nuclear energy programmes: Japan, South Korea, Canada, Sweden, Germany, Belgium, Taiwan and Switzerland. However, these countries have had military nuclear programmes in the past (such as Sweden, Taiwan or Switzerland), kept the

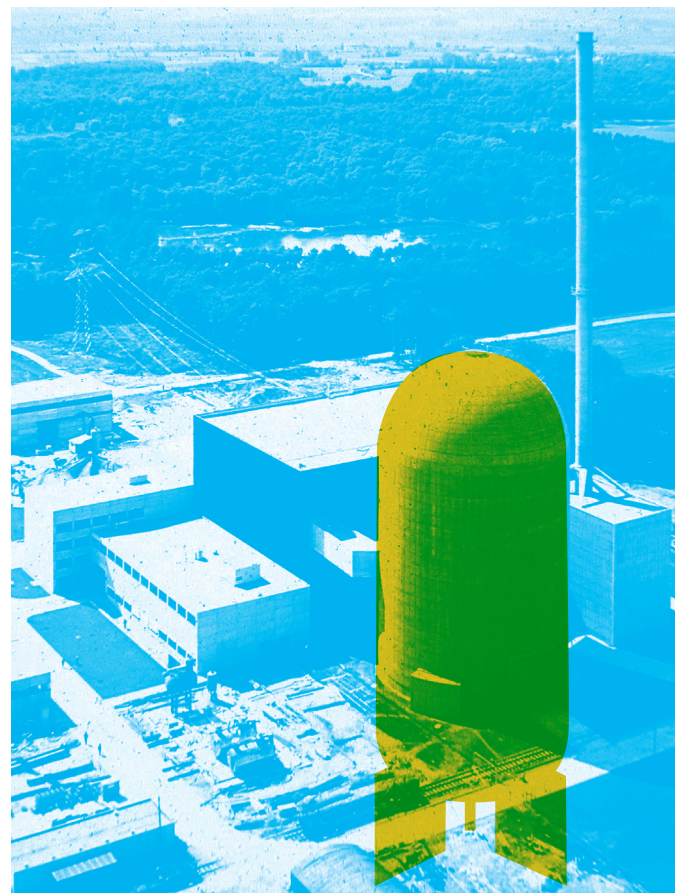


Photo: Nuclear Power Plant Gundremmingen, 1966. edited version of the original by Viola Somans, CC BY 3.0

door towards military nuclear programmes open (such as Germany, South Korea or Japan) or are de facto nuclear-weapon states under the nuclear-sharing agreement of NATO and closely involved with the nuclear industries of other NATO states (such as Belgium).

Of the 25 countries that are currently building or officially planning to build nuclear reactors, 23 either have nuclear weapons or have shown an interest in their development. Only Finland and Hungary had no ambitions to build nuclear weapons and yet invested in civil nuclear energy, while states with nuclear ambitions such as Saudi Arabia, the United Arab Emirates, Turkey or Iran are su-

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spected of pursuing civil nuclear programmes with the main aim to develop military nuclear capabilities.

Saudi crown prince Mohammad bin Salman announced in an interview with Reuters in 2018: “If Iran has a nuclear bomb, we will develop a nuclear bomb as soon as possible”.³ In view of the termination of the nuclear agreement with Iran and Iran’s current announcement to resume uranium enrichment, this could mean a dangerous escalation of the rivalry between Iran and Saudi Arabia.

Nuclear energy as a solution to the energy problems of the 21st century?

Supporters of nuclear energy often argue that only nuclear power can meet the energy needs of the 21st century and at the same time offer a solution to the impending climate catastrophe by replacing fossile fuels. Since the 1950’s, nuclear technology has been aggressively marketed as a solution to all energy problems. “Energy too cheap to meter” was the initial sales motto of the nuclear industry. Today, 60 years later, we know that these promises have never been fulfilled and that nuclear power is, in fact, the most heavily subsidised form of energy. Nuclear power plants cannot hold their own without massive state intervention—even without considering the lack of adequate insurance payments and the costs of renaturalization of uranium mining sites, the decommissioning of nuclear power plants or the treatment, storage and safeguarding of the massive amounts of nuclear waste for hundreds of thousands of years.^{4,5}

Since the nuclear catastrophes of Three Mile Island in 1979, Chernobyl in 1986 and Fukushima in 2011, the civil nuclear industry has been in decline worldwide. The disproportionate safety risks can no longer be denied and the human rights violations and ecological damage caused by uranium mining can no longer be concealed. Studies have shown that even without major accidents, the risk of radiation-related illnesses to workers in nuclear facilities increases.⁶ It is well established that nuclear power is not competitive on the free market in light of the rise of renewable energy generation and that the costs of nuclear waste management will continue to burden future generations of taxpayers.

The 2018 press release from the World Association of Nuclear Operators, which claims substantial ‘new build’ progress, was punctured significantly by independent researchers, largely on the cultural background of the commercial thinking which tends to favour operational profits and negate safety considerations.^{7,8}

While new technologies usually become more efficient and cheaper over time, the opposite trend has emerged for nuclear power: the production of one watt of energy by solar or wind power has become continuously cheaper in recent years, while the production of one watt of energy by nuclear power has become more expensive over the same period—in part due to increased safety regulations after the three major civil nuclear disasters. Moreover, solar and wind power have long since overtaken nuclear power in terms of installed capacity and produce only half and one-sixth of the CO₂ emissions of nuclear power plants, considering the entire life cycle of the plants and fuels.⁹

In 2018, human civilization generated about 26,600 TeraWatt hours or 2,300 megatonnes of oil equivalent (mtoe) of electricity each year. About 10 % of this comes from nuclear energy, 16 % from hydroenergy and 9 % from renewables, with combustibles (mainly natural gas and coal) making up the remaining 65 %. But the world’s total annual energy demand is about 14,000 mtoe, nearly 80 % coming from carbon-generating combustibles. Nuclear, at 230 mtoe, meets only 1.5 % of total energy demand.¹⁰ In order to play a more substantial role in mitigating climate change, electricity generation would have to be vastly expanded. MIT scientists calculated that in order for nuclear power to make a relevant contribution towards addressing the climate catastrophe, two nuclear power plants would have to be connected to the grid every month for the next 50 years.¹¹ This is a wholly unrealistic proposal, considering that the number of operating nuclear reactors has stayed fairly constant since 1989 and major nuclear countries like France, the UK or the US are currently constructing only 1 new reactor each, while other nuclear countries like Germany, Japan or South Korea have stopped construction of any new nuclear projects. An expansion of renewable energies on this scale is entirely feasible, however.

Compared to nuclear energy, renewables offer far greater flexibility and cost advantages, with new technologies such as wave



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and geothermal energy generation waiting in the wings. Nuclear advocates state that technological breakthroughs are possible, pointing especially to the development of small modular reactors (SMR) based on the designs of naval military reactors, but the problems of waste and security remain—as starkly shown by the eight decommissioned UK Royal Navy nuclear submarines waiting in Devonport docks to be defueled, some since the mid-2000s, while another 11 which are defueled are still significantly contaminated by residual radioactivity.¹²

But despite the lack of effects on the climate crisis, economic disadvantages, detrimental ecological and health effects and staggering safety issues, a number of states are sticking to nuclear energy and are even investing in the development of new generations of nuclear reactors. Why do they do this?

The obvious answer is the capacity to develop military nuclear capabilities. For states which do not yet have nuclear weapons, promoting a civilian nuclear energy programme in order to acquire nuclear weapons makes sense. But why do states like France, the UK and the USA, which already have several hundreds or thousands of nuclear weapons and substantial quantities of fissile materials such as highly enriched uranium and plutonium still need civilian nuclear energy programmes?

To answer this question, it is necessary to take a closer look at the close links between the civil and military use of nuclear technology:

Common nuclear infrastructure

Both nuclear weapons and nuclear power plants need the same fissile materials—primarily enriched uranium—and the technologies to extract and process them. From uranium mining to the chemical processing of uranium ore, uranium enrichment, trans-

portation, storage and safeguarding, both civil and military nuclear industries rely on the same nuclear infrastructure. In most nuclear countries, it is therefore the same state companies, authorities or ministries that uphold and develop this infrastructure—most often both for military and civil nuclear programmes.

The expansion of an extensive nuclear infrastructure for civil nuclear energy programmes makes it much easier and, above all, cheaper for a country to pursue military nuclear programme. Already in 1946, an official report by the US government warned that the infrastructure for civilian and military nuclear technology was largely interchangeable and interdependent, posing a substantial risk for the proliferation of nuclear weapons through the development of a nuclear energy infrastructure.¹³

In the end, the main difference between civil and military nuclear programmes lies in the degree of uranium enrichment: since the high-energy isotope uranium-235 is only contained to a very small extent in uranium ore (0.7%), a higher proportion of uranium-235 must be achieved in order to enable a nuclear chain reaction. This requires enrichment, usually in centrifuges. For atomic fuel rods, uranium needs to be enriched to a proportion of 3–5% of uranium-235. For an atomic warhead, an enrichment degree of 90% is required. The technical step from a civilian to a military nuclear program is thus ultimately a question of the number and the performance of centrifuges. With a functioning civilian nuclear programme, the essential steps towards constructing a nuclear bomb have already been achieved.

Historical developments of the nuclear industry

The nuclear age began with the race to construct a super-weapon for world domination. Thus, uranium was used to produce weapons-grade plutonium. The enormous amounts of energy gene-

rated by the fission of uranium was secondary and only at a later point in time, this ‘nuclear energy’ was used to improve the image of nuclear technology in the public eye. Under the marketing slogan “Atoms for Peace”, the first civilian nuclear power plants were built in the 1950’s: Calder Hall at Windscale in England was a ‘dual use’ reactor, primarily producing military plutonium and, from 1956 onwards, civilian electricity. One year after Calder Hall was commissioned, the UK tested its first hydrogen bomb. Later UK nuclear reactors were also designed to produce weapons-grade plutonium.¹⁴

In its report from July 2019, the German Institute for Economic Research (DIW) concluded that “nuclear power plants were primarily designed to be plutonium factories with appended electricity production”. The DIW further states that, regarding the investments in a civilian nuclear infrastructure, “the driving force was military developments and interests, primarily generating weapons-grade plutonium and, especially in the U.S. in the 1950s, developing pressurized water reactor technology to power submarines.”¹⁵

In 1958, the USA connected its first civilian nuclear reactor to the power grid—13 years after the atomic bombs were dropped over Hiroshima and Nagasaki. Gradually, other countries developed civilian nuclear programs, some of which were used to develop nuclear weapons. In the Soviet Union, as in the USA, the civilian use of nuclear power developed from military origins. As early as 1954, five years after the first Soviet atomic bomb was dropped, the country’s first civilian nuclear reactor in Obninsk was connected to the grid.

Michael Shellenberger of the nuclear-friendly lobby organisation ‘Environmental Progress’, one of the world’s most influential lobbyists for nuclear energy, praises the central importance of the civil nuclear industry for nuclear deterrence and writes that “national security is synonymous with the contribution of nuclear weapons, often the most important factor for a state to enter into peaceful nuclear energy.”¹⁶ He lists 20 states that have pursued civil nuclear energy programmes for military purposes: Argentina, Australia, Egypt, Germany, Brazil, France, Italy, India, Iran, Iraq, Israel, Japan, Yugoslavia, Libya, Norway, Romania, South Africa, Sweden, Switzerland, Taiwan and the Federal Republic of Yugoslavia. He fails to mention China, the UK, North Korea, Pakistan, Russia and the USA, which also invested in civil nuclear energy programmes in order to develop nuclear weapons.¹⁷

A new nuclear arms race

We are currently seeing efforts in all nuclear weapon states to comprehensively renew and expand nuclear weapon systems. In the Nuclear Posture Review of 2018, for example, the US government decided to replace all strategic systems, to procure new nuclear warheads with low explosive power, to increase the range of airborne cruise missiles and to arm sea-based systems with nuclear weapons. Russia and China are also renewing and de-



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Photo: U.S. Department of Energy

veloping their nuclear systems, the UK and France are launching multi-billion modernisation programmes for their nuclear submarines and North Korea, Israel, India and Pakistan are expanding their nuclear arsenals as well. At the same time, restrictions imposed by international arms control treaties such as the ABM treaty or the INF treaty are being shaken off. A new nuclear arms race is currently under way and the risk of nuclear war is rising.

Importance of nuclear submarines for the military strategy of nuclear weapon states

Russia and the USA have a so-called triad of nuclear weapons: land-based intercontinental nuclear missiles, long-range aircraft with atomic bombs and nuclear-powered submarines equipped with nuclear missiles. Most other nuclear weapon states also have at least two of these components. Military experts have repeatedly pointed out that the greatest strategic importance lies with the flexible submarine-based weapon systems. Their ability to remain underwater for up to three months without surfacing, to travel for long distances at high speed, to emerge at virtually any location around the globe and their ability to fire up to 20 nuclear missiles, each with a dozen individually steerable nuclear warheads, has given nuclear submarines a central role in the nuclear war doctrines of all five official nuclear-weapon states (USA, Russia, the UK, France and China). India also has nuclear submarines and Israel is in the process of creating the necessary technological conditions for their development—with substantial aid from Germany.¹⁸

The propulsion units of these submarines are small nuclear reactors, usually operating on highly enriched uranium (HEU) with enrichment levels of over 20%. Depending on the reactor type, it is also possible to use uranium enriched to less than 20%. Uranium, which is enriched to just under 20% is called HALEU

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(high assay low enriched uranium) and is to be produced by the civilian nuclear industry in the near future. This would be much cheaper and uncomplicated for the military than being dependent on the HEU enriched to over 20%, which is subject to strict controls and regulations. In the future, enrichment plants of the German-Dutch-British nuclear company URENCO in the USA are to produce HALEU for the US military.¹⁹

HALEU and SMR

In order to divert attention from the military utilization of HALEU, the nuclear industry has, for quite some time, presented plans to produce so-called small modular reactors (SMR), which could be used to generate electricity for civil consumption. URENCO UK, together with other nuclear companies, recently founded the consortium “U-Battery”²⁰. This consortium is working on developing small modular reactors (around 4 MW) with the support of the UK government. Common to all SMR projects are the unresolved issues of safety, disposal of nuclear waste as well as concerns about the proliferation of nuclear technology to states or non-state actors who could manufacture weapons from the fissile material contained in the reactors. While it is often stressed that these reactors could help developing countries provide power to remote areas, the only known locations where SMR are to be installed are small towns in Alaska, Idaho and Tennessee (USA), and Wales and Northern England (UK).^{21,22} Much more credible are speculations that the development of SMR is actually a hidden subsidy of research and development funds from the civil nuclear industry for modern propulsion forms of nuclear submarines and the power supply of the military in war zones. SMRs could be useful in military scenarios in remote combat areas. The advertisement states that they could be transported by truck or plane, would be independent of fossil fuels and would only need to be reloaded with nuclear fuel rods every 5–10 years and transported back home.^{23,24}

Civilian subsidies for military nuclear programmes

The maintenance, servicing, repair and modernisation of nuclear weapons arsenals and in particular of nuclear submarine fleets require major expenses and personnel, not least for the research and development of new forms of propulsion or safety technologies. The nuclear expert Mycle Schneider sees this as the most fundamental link between civil and military nuclear industries: “The civil-military overlap is primarily about mutual dependencies of the civil-military nuclear complex: the military uses the same

pool of engineers, specialists and so on as the civil nuclear industry. The competencies at stake, security and concept studies, material and ageing problems are all the same.”²⁵

Leaders from politics and industry in the US now openly admit that they depend on the civilian use of nuclear energy to build nuclear weapons: “The entire US nuclear enterprise—weapons, naval propulsion, non-proliferation, enrichment, fuel services and negotiations with international partners—depends on a robust civilian nuclear industry”.²⁶ Former US Secretary of Energy Ernest Moniz also confirms this connection: “A strong domestic supply chain is needed to provide for nuclear Navy requirements. This supply chain has an inherent and very strong overlap with the commercial nuclear energy”.²⁷ In the USA, the Department of Energy is responsible for both civil nuclear energy and the development, testing and production of nuclear weapons. Only recently, high-ranking US military, politicians, entrepreneurs and former heads of the nuclear regulatory authority NRC recommended in a letter to the current US Secretary of Energy Rick Perry to acknowledge the important role of civil nuclear power for the national security of the USA and to take concrete steps to stabilize the nuclear power plants in their inventory.²⁸

Situation in the UK

Hidden subsidies from civil nuclear programmes also play a role in the UK’s nuclear weapons programme. In the course of planning for the proposed reactors at Hinkley Point C, many critics questioned why the UK government invested so heavily in an overpriced nuclear power plant project, which would significantly increase the price of electricity for consumers over several decades and make the UK energy supply dependent on countries such as France and China²⁹. A study by the University of Sussex revealed that for reasons of “national security” there is an urgent need in the UK for subsidies for nuclear infrastructure, above all for the training of engineers, research and development. In order to maintain its status as a nuclear weapon state, the UK needs to modernise the nuclear-powered submarines of the Trident programme. In order to hide the immense costs for this overhaul, UK energy consumers and taxpayers are chipping in with the overpriced electricity price at Hinkley Point C. A major part of these hidden subsidies is played by the Nuclear Skills Strategic Plan, which calls for an increase in the number of people employed in the nuclear industry from 78,000 (2015) to 111,000 (2021).³⁰ Another issue that deserves mention is the Technical Outreach programme of the UK military, with its significant influence on scientific research at British universities. The Ministry of Defence

alone distributed funding to more than 50 UK universities. This collaboration between the military and the universities helps provide a pool of potential recruits for staff posts at the nuclear weapons program.³¹

The support for Hinkley Point C despite serious economic and safety issues can be explained by the need to fund Trident modernization, with hidden subsidies disguised as investments in nuclear energy development. Similar considerations may be behind the massive state subsidies for the civil nuclear industry in France, China and Russia. The enormous financial losses of nuclear companies like Areva or EDF due to the disaster with the European Pressurised Reactor (EPR) in Olkiluoto, Finland, and in Flamanville, France, were paid for with taxpayers' money so that construction continues at both sites and, despite all the setbacks with this type of reactor, a third and fourth EPR are to be built at Hinkley Point C. It is important to point out that it is irrelevant for the military, whether these nuclear reactors are ever actually connected to the grid or produce energy—the investments in nuclear infrastructure, the training of nuclear scientists and engineers and other collateral benefits for the military nuclear programme are the real driving factor behind these projects.

Situation in Germany

In Germany, the connections between civil and military nuclear industries is often ignored by the media and politicians. The connections are particularly striking at the Karlsruhe Institute of Technology (KIT), where research is being carried out on thorium molten salt reactor technology within the framework of the EU-funded SAMOFAR programme. Officially, the technology is to be used in small modular reactors (SMR) in the future. Thorium molten salt reactors date back to the 1950's and were not pursued due to safety issues. Thorium-232 has the extraordinarily long half life of 14 billion years and is converted in neutron-producing reactors to uranium-233, which can then be extracted for use in nuclear weapons, although with difficulty and at considerable occupational radiation risk.

Another example of civil-military synergies in the nuclear industry is the German-Dutch-British nuclear firm URENCO, which currently produces about 10 % of the world's supply of enriched uranium. The governments of the UK, the Netherlands and Germany are involved in the supervision of the company through a so-called Joint Committee. URENCO has four production sites: Gronau (Germany), Almelo (Netherlands), Capenhurst (UK) and Eunice (USA). The operators of the Gronau uranium enrichment plant are the German energy groups RWE and EON. Since URENCO's enrichment centrifuges are also capable of producing weapons-grade uranium, URENCO is subject to a control system under the Almelo Treaty of 1970.

URENCO currently has supply contracts with the infamously damaged nuclear power plants in Doel and Tihange in Belgium, as well as with Cattenom in France and several German, Swedish

and Ukrainian nuclear power plants. In 2017 it became known that URENCO supplies enriched uranium to the Tennessee Valley Authority (TVA), in charge of the Watts Barr nuclear reactor, which is used to produce tritium for the US nuclear weapons program. While there is no definite proof that URENCO enriched uranium is actually used in Watts Barr, it has not been ruled out despite numerous requests for clarification to the TVA, the US Energy Department and URENCO, stoking concerns that enriched uranium from Germany is used to aid the US nuclear weapons program in clear contradiction of existing laws on both sides of the Atlantic.³²

Even more worrying, however, is the delivery of enriched uranium to the United Arab Emirates, where the four nuclear reactors of the Bakkarah nuclear power plant are to be connected to the grid at the end of 2019. The situation regarding the planned 16 nuclear power plants in Saudi Arabia remains unclear.³³ It is striking that Saudi Arabia has so far refused to allow UN inspectors into the country for non-proliferation control purposes.³⁴ The escalating conflict between Iran and Saudi Arabia on the one hand and the termination of the nuclear agreement with Iran by the US government on the other show how urgent an international policy of nuclear arms control is and how closely the future plans of the nuclear weapons industry are linked to those of civil nuclear energy use.

Conclusions:

- » Without a "robust" civil nuclear industry and the associated nuclear infrastructure, nuclear weapons programmes would not be sustainable due to the high costs, risks and need for trained personnel.
- » In all nuclear weapon states, the military utilizes the civilian nuclear industry through hidden subsidies regarding human resources, research funds and investments in dual-use nuclear infrastructure.
- » The modernisation of nuclear arsenals in nuclear weapon states is driving the development of new small modular reactors (SMR).
- » Although allegedly intended for civilian use, SMR are used primarily for military purposes, in particular for the propulsion of nuclear submarines, which have become the most important component of the nuclear weapons doctrines of the major nuclear powers.
- » If nuclear propulsion units of submarines can be operated with HALEU (enrichment level of 5–20 %) instead of HEU (enrichment level of > 20 %), the civilian nuclear industry can provide relatively cheap and uncomplicated nuclear fuel for nuclear submarines.

- » A further field of application for SMRs is the electricity supply of the military in remote combat zones.
- » Since the beginning of the civil nuclear industry in the 1950's, its advertising slogans must be met with extreme caution. Nuclear energy does not reduce electricity prices but actually drives them up. Nuclear energy also offers no answer to the climate catastrophe.
- » The German Institute for Economic Research comes to a clear conclusion in its 2019 report: "The lack of economic efficiency goes hand in hand with a high risk with regard to the proliferation of weapons-grade materials and the release of radioactivi-

ty, as shown by the accidents in Harrisburg (1977), Chernobyl (1986), and Fukushima (2011). For all these reasons, nuclear energy is not a relevant option for supplying economical, climate-friendly, and sustainable energy in the future."³⁵

- » The peace movement, ICAN and the anti-nuclear movement should work much more closely together in view of the evident connection between civil and military nuclear industries.

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Hibakusha Worldwide

An interactive map on health and environmental issues related to the nuclear chain

www.hibakusha-worldwide.org

This website shows the environmental and health effects of the nuclear chain: from uranium mining and enrichment to civil nuclear accidents, nuclear weapons testing, military nuclear accidents, nuclear bombings, all the way to nuclear waste and depleted uranium munition. It is dedicated to the millions of people whose lives have been affected by the nuclear industry: the indigenous people whose homes have been turned into nuclear wastelands by uranium mining, the Downwinders of more than 2,000 nuclear weapons tests, the survivors of the bombing of Hiroshima and Nagasaki, and the people affected by radioactive fallout from civil and military nuclear accidents. All of them would have had better lives, if the uranium had been left in the ground.

Hibakusha Worldwide
An interactive map on health and environmental issues related to the nuclear chain

The exhibition Locations Contact

Categories

- Accident
- Atomic bombing
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- Nuclear facility
- Nuclear Weapons Test Site
- Uranium mining

Satellite map
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Mayak/Kyschtym, Russia
Nuclear facility

Through a series of accidents and spills, the Russian nuclear facility at Mayak contaminated more than 15,000 km² with highly radioactive waste. In 1957, the so-called Kyshtym accident alone made large parts of the Eastern Urals uninhabitable. Thousands of people had to be relocated and, to this day, the region affected by nuclear fallout is considered one of the most contaminated places on earth.

Photo: Cows grazing beside the contaminated Techa River. Until 2005, no signs warned of radioactivity here. Between 1949 and 1956, 100 Peta-Becquerel of radioactive waste was dumped in the Techa river system – including strontium-90, cesium-137, plutonium, and uranium. Photo: © Ecodefense/Henrich Boell Stiftung Russia/Sapozokaya/Nikulina

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History

The Mayak Production Association (MPA) was the first and largest nuclear facility in the Soviet Union, covering an area of about 200 km² between the cities of Ekaterinburg and Chelyabinsk. Initially built to provide plutonium for Soviet nuclear weapons, five nuclear reactors were constructed in the city called Chelyabinsk-40 (now renamed Ozyorsk) between 1945 and 1948. The facility was continually expanded until the production of weapons-grade plutonium was stopped in 1987 and the facility was gradually downsized. Between 1949 and 1956, 100 Peta-Becquerel (Peta = quadrillion) of radioactive discharge, containing strontium-90, cesium-137, plutonium, and uranium was released into the Techa river system. By comparison, radioactive emissions from the Fukushima nuclear disaster into the Pacific Ocean have been estimated at 78 PBq. At least eight large-scale accidents took place at Mayak. In 1967, for example, dispersion of radioactive dust from the Karachay radioactive waste dump contaminated 1,800 km² with cesium-137.

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