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The Nuclear Anthropocene and the Myth of Containment in the U.S.

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Abstract

International expert agencies and the nuclear industry concur that nuclear technology is necessary to solve both energy and climate crises. This argument is based on the still-alive ideology of containment, a set of discursive and material practices that aim at isolating nuclear technology from the environment. Based on a brief discussion of recent nuclear decommissioning cases, the article argues that containment is a myth invented to expand commercial nuclear applications. It describes the emergence of containment strategies through the illustration of three strategic regulatory turns in the US: the Price-Anderson Act, the development of siting criteria, and the establishment of radioprotection standards.

Keywords: Containment; Nuclear Decommissioning; Cold War; Environment; Climate Change.

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1 The Nuclear Anthropocene and the Myth of Containment in the U.S.

On April 13, 2021, the Japanese government announced plans to release contaminated water from the Fukushima Nuclear Power Plant into the Ocean. In the aftermath of the 2011 accident more than one million gallons of water were used to cool down the melted reactors. That water has been collected and stored in steel tanks, and now is being treated with a filtration system (ALPS: Advanced Liquid Processing System) to remove most of the radioactive elements contained in it, except for tritium and carbon-14, two radionuclides that are easily absorbed by living organisms. To lower this risk, the treated water is further diluted before being discharged into the Ocean.[1] To demonstrate the safety of the sea dumping solution, TEPCO (Tokyo Electric Power Company) started a public experiment to grow fish in both uncontaminated and contaminated seawater, with the supervision of the International Atomic Energy Agency (IAEA).[2] The decision of the Japanese government, with the endorsement of the IAEA, which has declared the discharge operations to be "consistent with relevant international safety standards,"[3] has encountered criticism from sectors of the scientific community and neighboring countries of the Pacific area.[4]

The Fukushima decommissioning process might appear exceptional, given the dramatic circumstances that caused it, but other nuclear power plants and facilities around the world pose similar environmental problems both during routine operations and at the end of their useful life. For example, the Pilgrim Nuclear Power Station near Plymouth, Massachusetts, was shut down in 2017 and is currently in an active decommissioning status. There, too, concerned local communities and expert agencies, including the Massachusetts Department of Environmental Protection, are opposing the site owner's request (HOLTEC Decommissioning International) to discharge high volumes of radiocontaminated water into Cape Cod Bay.[5] HOLTEC asserts that in addition to being the least expensive solution, dumping treated water into the Ocean is safe and in line with U.S. Nuclear Regulatory Commission and Environmental Protection Agency's regulations, as demonstrated by routine effluent discharges performed over decades at all nuclear facilities.[6]

I mentioned the above examples to show that nuclear plants do not simply end their lives after reactors shut down: their legacies and socioecological implications extend well beyond power production, whether after severe accidents or under programmed phaseout. Yet, public discourses concerning the costs, and the health and environmental implications of nuclear power most of the time focus on nuclear reactor safety and accident prevention and mitigation, leaving nuclear decommissioning at the margins. During my research I came to realize that this emphasis on reactor safety is not just a reflection of public catastrophic imaginations, but is the result of a seventy-year-long effort by industry, developers, and regulators to build and reinforce the idea that nuclear technology can be effectively isolated from the environment.

Despite the pretense of containment, nuclear power plants are a porous technology. The construction and operational life of reactors depend on and establish an osmotic relationship with the surrounding environment and beyond, for obvious reasons. First, and maybe most clearly, nuclear power plants need water for their functioning; in fact, it would be possible to draw a hydrographic map of nuclear power plants' sites by following the course of rivers, coastlines, and lakes.[7] Second, both

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[1] https://www.iaea.org/topics/response/fukushima-daiichi-nuclear-accident/fukushima-daiichi-alps-treated-water-discharge/faq.

[2] https://www.tepco.co.jp/en/decommission/progress/watertreatment/breedingtest/index-e.html.

[3] *IAEA Comprehensive Report on the Safety Review on the ALPS-Treated Water at the Daiichi Nuclear Power Station*, 2023, https://www.iaea.org/sites/default/files/iaea_comprehensive_alps_report.pdf.

[4] Bianca Nogrady, "Is Fukushima Wastewater Release Safe? What the Science Says," *Nature* 618 (2023): 894–895.

[5] Public hearings on Massachusetts Department of Environmental Protection initiative to prohibit contaminated water discharge from the Pilgrim Nuclear Power Plant were held on August 24, 2023. Recording of the event is accessible here: https://www.youtube.com/watch?v=Cuxk2sro21c.

[6] HOLTEC, "Letter to Stakeholders, Elected Officials, Advocacy Groups and Community Members", January 27, 2022, https://www3.epa.gov/region1/npdes/pilgrim/1-27-22-Holtec-Letter-Trice-to-Stakeholders.pdf

[7] Historian of energy Per Högselius has recently emphasized this nuclear-water nexus by stressing the hydraulic essence of nuclear technology. Per Högselius, "Atomic Shocks of the Old: Putting Water at the Center of Nuclear Energy History,"

during routine operations and at decommissioning (and, of course, after severe accidents), nuclear power plants release effluents (gaseous and liquid) into the environment, by design. Thinking about siting, the installation of a nuclear power plant is a vast reordering of socioecological relations. Land occupation, water sources for reactor cooling and controlled effluent discharges, waste management on site and transportation off-site, roads, river dams, cooling towers: these are just a few examples of how nuclear site operations transform spaces through time. In addition, the installation of nuclear sites brings deep socioeconomic transformations associated with the development of new services, different cultural and professional identities, and new perceptions and experiences of the natural and the built environment.[8] In one word, we can say that nuclear siting is a form of place-making, and therefore of meaning-making. This is clearly visible at the decommissioning stages, when the status of nuclear power plants shifts from *being the place* to *being out of place*.[9]

Moving through different scales of analysis, from the biography of specific nuclear sites to the technopolitical arrangements of national and global nuclear regulatory regimes,[10] the logic of containment looks much like a process of sociotechnical co-production.[11] *Atoms for Peace* was designed to disentangle the military origins of nuclear power exploitation from the future commercialization of nuclear energy. To do so, the Eisenhower Administration and nuclear developers alike had to invest and organize (mostly) public and private resources to make the economic benefits of nuclear power appear worth the health and environmental risks that society would run inevitably. During this effort, the discursive and material practices of containment were essential.

Following the insight of Schoot and Mather, I would like to mobilize the original meaning of the Latin verb *contineo*, which indicated the act of keeping or holding things together.[12] The history of expert practices and public discourse over nuclear technology in fact shows that containment had not only the material function of isolating, keeping inside radioactive elements that should not be dispersed into the environment. Containment was also, and more importantly, a technopolitical device, an ensemble of regulatory strategies to represent and enact nuclear technology's isolation and confinement, and therefore to make nuclear energy manageable, and ultimately socially and environmentally acceptable.[13] In what follows, I will briefly review three pillars of this strategy in the United States: the Price-Anderson Act, nuclear plant siting regulations, and the regulation of radiation exposure.

Technology and Culture 63, 1 (2022): 1–30.

[8] Gabrielle Hecht, "Peasants, Engineers, and Atomic Cathedrals: Narrating Modernization in Postwar France," *French Historical Studies* 20, 3 (1997): 381-418; Françoise Zonabend, *The Nuclear Peninsula* (Cambridge: Cambridge University Press, 2010); Christine Wall, "'Nuclear Prospects': The Siting and Construction of Sizewell A Nuclear Power Station 1957-1966," *Contemporary British History* 33, 2 (2019): 246–273.

[9] Martin Pasqualetti, *Nuclear Decommissioning and Society: Public Links to a New Technology* (London: Routledge, 1990); Martin Pasqualetti, "Introducing the Geosocial Context in Nuclear Decommissioning: Policy Implications in the U.S. and in Great Britain," *Geoforum* 20, 4 (1989): 381–396.

[10] Soraya Boudia, "Global Regulation: Controlling and Accepting Radioactivity Risks," *History and Technology* 23, 4 (2007): 389–406; Gabrielle Hecht, *The Radiance of France: Nuclear Power and National Identity after World War II* (Cambridge, MA: MIT Press, 1998).

[11] Sheila Jasanoff, *States of Knowledge: The Co-production of Science and the Social Order* (London: Routledge, 2006).

[12] Ignace Schoot and Charles Mather, "Opening Up Containment," *Science, Technology, & Human Values* 47, 5 (2022): 937–959.

[13] The literature is abundant. Here I only cite works that highlight the systemic buildup of containment culture during the Cold War and address specifically its material entanglements with nuclear power. George T. Mazuzan and Samuel J. Walker, *Controlling the Atom: The Beginnings of Nuclear Regulations 1946-1962* (Berkeley: University of California Press, 1984); Samuel J. Walker, *Containing the Atom: Nuclear Regulation in a Changing Environment 1962-1973* (Berkeley: University of California Press, 1992); Brian Balogh, *Chain Reaction: Expert Debate and Public Participation in American Commercial Nuclear Power, 1945-1975* (Cambridge: Cambridge University Press, 1991); Alan Nadel, *Containment Culture: American Narratives, Postmodernism, and the Atomic Age* (Durham: Duke University Press, 1995); Paul N. Edwards, *The Closed World: Computers, and the Politics of Discourse in Cold War America* (Cambridge, MA: MIT Press, 1996); William J. Kinsella, "Nuclear Boundaries: Material and Discursive Containment at the Hanford Nuclear Reservation," *Science as Culture* 10, 2 (2001): 163–194; Sheila Jasanoff and Sang-Hyung Kim, "Containing the Atom: Sociotechnical Imaginaries and Nuclear Power in the United States and in South Korea," *Minerva* 47 (2009): 119–146.

2 The Price-Anderson Act

In 1957, three months before the first commercial power reactor went critical at Shippingport, Pennsylvania, the U.S. Congress approved the Price-Anderson Nuclear Industries Indemnity Act (known as the Price-Anderson Act), "to provide financial protection against public liability claims for bodily injury or property damage caused by a nuclear incident."[14] Given the safety uncertainties of a new technology, U.S. legislators offered reluctant power companies an exceptional compensation for developing a risky business (fixing a limited accident liability), while reassuring the public that even in case of a catastrophic accident the U.S. government would intervene to mitigate the damage. Site owners had to demonstrate the capacity to provide sixty million dollars, while the government would disburse the exceeding amount, up to a maximum of five hundred million dollars. To guarantee that such amounts of money would be available to nuclear companies, before approval of the Price-Anderson Act, several insurance companies formed the American Nuclear Insurers, adopting a so-called pooling technique to spread risk over many actors.[15]

The Price-Anderson Act withstood repeated challenges both in court and in public debates. In the context of the energy crises of the 1970s, anti-nuclear movements denounced the Act as an undue subside to the nuclear industry that contributed to hide the real costs of nuclear power production.[16] A relevant example was the case of the West Valley reprocessing plant in the State of New York.[17] In 1976, the owner of the facility, Nuclear Fuel Services, Inc. (NFS)—a subsidiary of Getty Oil—decided to renounce its license and return the site to the State of New York because the costs for expanding and refitting the plant—to match newly introduced safety requirements—would put the operator out of business. In the meantime, during only six years of fuel reprocessing (1966-1972) NFS had produced a considerable amount of liquid and solid radioactive waste, which was stored on site, while providing only four million dollars for their indefinite custody, for which the State of New York was responsible according to the original agreements. Due to the technical difficulties of shipping the waste to a federal repository, several expert agencies estimated clean-up costs to be potentially higher than six hundred million dollars.[18] Who should be responsible for cleaning up the site, and who should pay for it? Several congressional committees took up these questions while starting a thorough review of the government energy policy, and especially of nuclear energy and its associated costs. Nuclear decommissioning came under the radar of citizens, legislators, and regulators for the first time, as several nuclear power plants approached the end of their life and military nuclear waste continued to accumulate inside plutonium production facilities all over the country.[19]

3 Nuclear siting

The second pillar of the nuclear containment strategy in the U.S. was the effort to limit environmental contamination. In a paper presented in 1955 at the International Conference on the Pacific Uses of Atomic Energy, U.S. ecologist Eugene Odum wrote:

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[14] Richard Jones, "The Price-Anderson Act," in *Proceedings of the International Conference Nuclear Option in Countries with Small and Medium Electricity Grids, 19-22 June 2000*, Dubrovnik, Croatia, 699, https://www.osti.gov/etdeweb/servlets/purl/20110976#page=698.

[15] ANI's website provides information about the financial mechanisms of insurance pools in the nuclear sector: https://www.amnucins.com/

[16] U.S. Congress, Committee on Government Operations, *Nuclear Power Costs: Hearings Before a Subcommittee of the Committee on Government Operations, House of Representatives, Ninety-fifth Congress, First Session pt. 1*, Washington, DC, 1977, https://babel.hathitrust.org/cgi/pt?id=purl.32754076878127&seq=3.

[17] Gene I. Rochlin, et al., "West Valley: Remnant of the AEC," *Bulletin of the Atomic Scientist* 34, 1 (1978): 17–26.

[18] United States Comptroller General, *Cleaning Up the Remains of Nuclear Facilities: A Multibillion Dollar Problem*, Report to Congress, June 16, 1977, https://babel.hathitrust.org/cgi/pt?id=uiug.30112057895440&seq=3.

[19] U.S. Congress, Committee on Science and Technology, *Decommissioning and Decontamination of Nuclear Facilities Report, Prepared for the Subcommittee on the Environment and the Atmosphere of the Committee on Science and Technology, U.S. House of Representatives, Ninety-fifth Congress, Second Session,* Washington, DC, 1977, https://babel.hathitrust.org/cgi/pt?id=uc1.a0000675496&seq=1.

> It is generally conceded that environmental contamination with its current dangers of genetic damages, stands as the most important limiting factor in the large-scale use of atomic energy in the immediate future. This prospect is rapidly transforming ecology from a rather obscure and ill-defined member of the biological family into a more organized and coherent division, which will be expected to provide the basic answers necessary for solving practical problems.[20]

Studying the relationship between nuclear technology and the environment appeared to be one of the most crucial preconditions for the expansion of the nuclear industry while ensuring that the effects of radiation on ecosystems were understood and contained. To this effect, nuclear installations like the Savannah River's plutonium production plant, and nuclear test sites became ecological laboratories for mapping radiocontamination pathways and accumulation processes.[21] Since the 1960s, the concept of environmental receptivity connotes the compatibility between the presence of a nuclear plant (or facility) and the environmental characteristics of a given site.[22] Seismology, hydrology, soil composition, atmospheric conditions, population density, land use, and other variables shape complex pictures of nuclear sites, in which the environment figures as an ambivalent active agent: a potential threat but also an asset. For example, earthquakes and floodings can disrupt routine operations of nuclear technology, with clear safety implications. A river with an irregular or insufficient water flow can compromise reactor operations. For this reason, most rivers that serve as water sources for nuclear power units underwent massive works of embankment and regimentation through the construction of dams, canals, and artificial ponds.[23]

To assess the bio-ecological effects of radiation, radioecology emerged in the early Cold War as a multidisciplinary field concerned with the observation, measurement, and modeling of radiocontaminants dispersion and absorption into the environment. But how did early nuclear experts and developers perceive and represent the "environment" and the environmental entanglements of nuclear technology? Siting policies are an eloquent example of the nuclear-environment nexus: on the one hand, site selection depends on the assessment of its environmental characteristics; on the other hand, the environmental entanglements of nuclear facilities must be controlled through a series of rhetorical and material devices to make nuclear technology appear sealed off and isolated from the external environment. The vocabulary of containment is quite rich: nuclear island, exclusion area, buffer zone, low population zone, population center distance, biological shield, and other such concepts delineate degrees of isolation of nuclear technology from the surrounding living environment.

The history of nuclear siting debates and practices suggests that both conceptualizations of the environment and of its relationships with nuclear technologies changed over time. Nuclear facilities built for the Manhattan Project (Hanford, Oak Ridge, Los Alamos, etc.) were sited in scarcely populated areas for both security and safety reasons. The isolation criteria persisted for about ten years. Small experimental reactors in fact often lacked containment and biological shielding structures, so in case of accidental releases the dispersion of radioactive elements would put nearby communities at risk and could immediately affect reactor operators. According to authors like Andrew Blowers and Françoise Zonabend, placing nuclear facilities in "remote" locations also reflected a design to limit and contain local resistance. Far from urban centers, experts and technocrats could sell the benefits of nuclear technology more easily, while downplaying its associated risks. The map of nuclear plant

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[20] Eugene P. Odum, "Ecology and the Atomic Age," *ASB Bulletin* 4, 2 (1957): 27–29.

[21] Scott Kirsch, "Ecologists and the Experimental Landscape: The Nature of Science at the Department of Energy's Savannah River Site," *Cultural Geographies* 14, 4 (2007): 485–510.

[22] Davide Orsini, "Taking Samples: An Envirotechnical Account of Radioecology in the Mediterranean Sea during the Cold War," *Annali dell'Istituto storico italo-germanico in Trento, Jahrbuch des italienisch-deutschen historischen Instituts in Trient* 2 (2020): 153–179. For a broader analysis of radioecology and its early development in the U.S. see: Joel Hagen, *An Entangled Bank: The Origins of Ecosystem Ecology* (New Brunswick, NJ: Rutgers University Press, 1992); Rachel Rothschild, "Environmental Awareness in the Atomic Age: Radioecologists and Nuclear Technology," *Historical Studies in the Natural Sciences* 43, 4 (2013): 492–530.

[23] Sarah B. Pritchard, *Confluence: The Nature of Technology and the Making of the Rhone* (Cambridge, MA: Harvard University Press, 2011); Högselius, "Atomic Shocks of the Old."

siting corresponded to a strategy to shape a geography of power resulting in an unequal distribution of risk.[24]

In the early phase of nuclear siting practices, it became obvious that siting nuclear reactors came with the drawing of exclusion zones, areas where no human activity was allowed. The rule of thumb for the establishment of exclusion zones was expressed by the formula 0.01 x √Kw thermal.[25] At this stage, representations of the environment at nuclear facilities and power plants were perfectly symbolized by the iconic concentric circles surrounding the reactors, indicating exclusion zones, low population zones, and distance from urban centers. The anthropocentric spatial ideologies of early nuclear siting practices resulted in representations of environmental variables as intervening factors. Meteorological conditions were especially monitored to calculate the effects of accidental discharges of gaseous effluents.

In the mid-1950s the U.S. Atomic Energy Commission, solicited by the Joint Committee on Atomic Energy (JCAE), started to address siting in relation to the commercial exploitation of nuclear power generation, as envisioned by the *Atoms for Peace* program.[26] The development of commercial nuclear power plants for energy production raised new problems for the definition of siting criteria. For economic reasons, power companies were inclined to request siting permits near urban centers that could absorb their energy production and where loading and transmission costs would be lower. The exclusion zone criterion appeared quite too strict. If the rule of thumb were to be followed, only a few sites in the United States would be suitable for the installation of power reactors. It is in this context that new technical solutions intervened to reshape in part the discussion over reactor safety. How to reconcile reactor safeguards with economic priorities?

In a paper delivered in June 1959, during the Sixth International Congress and Exhibition of Electronics and Atomic Energy in Rome, Clifford Beck of the U.S. AEC Licensing and Regulation Division spelled out the difficulties of defining absolute siting criteria since site selection must be considered jointly with the technical characteristics of reactors. Most importantly for this discussion, Beck described the emergence of containment as the ultimate safeguard against accidental radioactive releases:

> Examination of the possibilities under which radioactivity might be released from the reactor facility, the characteristics of dispersion and the biological consequences of exposure to radioactive materials, lead to two basic criteria which must be satisfied by the reactor-site combinations.
>
> 1. The design of the plant and its location must be so chosen so that the radioactivity released in normal effluents of plant operation (to air, water, earth) will not result in levels beyond the site boundary in excess of maximum permissible levels for continuous exposure.
>
> 2. The radioactivity which might be released from any likely accident, even from the worst accident whose occurrence is considered credible would not result in exposures beyond the site boundary in excess of permissible emergency exposures.
>
> [...] Where accidental release of significant amount of fission products from a particular reactor is judged to be a credible possibility, it has become customary to provide some sort of external containment structure around the assembly as a barrier of last resort. [It] offers a unique protection, completely independent of all other safety devices and engineering safeguards and its dependability is unaffected by errors in safety analyses and judgement of the reactor assembly. It stands as a visually obvious and intuitively attrac-

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[24] Zonabend, *The Nuclear Peninsula*; Andrew Blowers, *The Legacy of Nuclear Power* (London and New York: Routledge, 2017).

[25] David Okrent, *Nuclear Reactor Safety. On the History of the Regulatory Process* (Madison: The University of Wisconsin Press, 1981).

[26] Okrent, *Nuclear Reactor Safety.*

> tive bulwark against the possible consequences of errors in reactor design, malfunctions and misoperation which are admittedly present in every human undertaking.[27]

Containment technologies were developed as a response to uncertainty regarding early reactors' safety boundaries and the difficulty to elaborate a system of risk assessment to determine the probability and severity of reactor accidents.[28] The design of containment vessels and biological shields increased the possibility to think about siting in less isolated areas. Thus, containment promised to reduce isolation. The tension between safety and economy though would not be solved so smoothly. While some members of the AEC and the JCAE pushed to advance a set of standard calculable criteria that could be applied across different cases, private companies preferred general guidelines to allow decisions on a case-by-case basis. Their argument was that a more flexible siting policy would be more realistic and effective because more sensible to variables such as reactor type and power, containment design, and environmental conditions.

At the beginning of the 1970s, when U.S. regulators struggled with admitting to the possibility that a loss-of-reactor-coolant accident (or LOCA) could potentially lead to a core meltdown (popularly termed China Syndrome), the emphasis on containment solutions shifted toward accident prevention. The response of industry representatives and promoters of nuclear technology consisted in implementing more technological fixes: more containment measures, more redundant safety systems.[29] But the porousness of nuclear technology re-emerged with the wave of anti-nuclear and environmental movements concerned with the effects of routine radioactive releases of nuclear power plants and the question of thermal pollution. Encouraged by the introduction of the National Environmental Protection Act (NEPA, 1969) and the institution of the Environmental Protection Agency, local communities opposed to nuclear power siting organized a legal resistance based on litigations in which petitioners affirmed that the new environmental legislation required that each federal agency should enact appropriate measures to guarantee environmental protection. Most famously, the *Calvert Cliff* nuclear power plant case forced the Atomic Energy Commission to include an environmental impact evaluation (Environmental Impact Statement) for each license proposal.[30] Thermal pollution caused by the discharge of reactor cooling water into lakes, rivers, and Ocean bays also became a controversial topic, which widened the conflict between industry, regulators, and popular anti-nuclear movements.[31]

4 Radiation Exposure

Connected with the environmental concerns raised by the nuclear commercial expansion of the 1960s was the question of the health effects of ionizing radiation. Already by the mid-1950s, the debate over radiological safety was very much influenced by the Fallout controversies. The radiological effects of nuclear weapon tests—it was discovered—were not confined to remote areas of the Pacific Ocean or to the Nevada desert. Radioactive elements circulating through the atmosphere spread globally, exposing the public to the risks of radiogenic illnesses. In the U.S., biochemist, and Nobel Prize winner, Linus Pauling led a fierce battle for a nuclear weapon test ban, which had a substantial echo both within

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[27] Clifford Beck, "Safety Factors To Be Considered in Reactor Siting," *Proceedings of the Sixth International Congress and Exhibition of Electronics and Atomic Energy, Rome, Italy, June 1959, U.S. Papers*, U.S. Atomic Energy Commission, 45–46, 50.

[28] International Atomic Energy Agency, "Containment and Siting of Nuclear Power Plants," *Proceedings of a Symposium*, Vienna, April 3-7, 1967*; Thomas R. Wellock,* Safe Enough? A History of Nuclear Power and Accident Risk* (Berkeley: University of California Press, 2021).

[29] Okrent, *Nuclear Reactor Safety*.

[30] Walker, *Containing the Atom*.

[31] Samuel J. Walker, "Nuclear Power and the Environment: The Atomic Energy Commission and Thermal Pollution, 1965-1971," *Technology and Culture* 30, 4 (1989): 964–992. Dorothy Nelkin, *Nuclear Power and its Critics: The Cayuga Lake Controversy* (Ithaca: Cornell University Press, 1971).

the scientific community and in public debates over the effects of low-level radiation exposure.[32] Pauling's scientific publications on the perils of radioactive fallout through the intake of strontium-90 and carbon-14 in human and animal tissues became the topic of widespread controversies also over the civilian uses of nuclear energy and the cost-benefits balance in view of the commercial expansion of the nuclear program.[33] At stake was the validity of the threshold model, which assumed that only above a certain limit of radiological exposure human beings would be harmed.

Between 1956 and 1962, congressional hearings over the fallout controversy featured high-rank AEC officers, medical experts, and scientists, but revealed inconclusive as to establishing the validity of exposure models and converging toward a set of radioprotection standards applicable under different circumstances. Even the possibility to assess radiation effects on different human body parts and for different categories of nuclear workers and the public was put into question.[34] During the Hearings of the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy in November 1960, several testimonies admitted the difficulty of achieving an agreed-upon definition of radioprotection standards and at the same time expressed the need to formulate a synthesis between safety and economic demands to make nuclear energy applications practically possible.[35]

At the beginning of the 1970s, another round of controversies over low-dose exposure—this time concerned with routine nuclear power plant effluent emissions—provoked an acceleration of the Nuclear Regulatory Commission's efforts to arrive at a workable regulation of radiation exposure. The outcome was the famous ALARA (As Low As Reasonably Achievable) principle, which established that licensees were required to keep radiation releases as low as reasonably achievable

> taking into account the state of technology, and the economics of improvements in relation to benefits to the public health and benefits, and other societal and socioeconomic considerations, and in relation to the utilization of atomic energy in the public interest.[36]

As Shannon Cram has aptly observed,

> By identifying federal dose limits as the upper boundaries of acceptability, ALARA lends authority to what remains an uncertain metric for safe exposure [...] As such, ALARA has achieved what the 1960 Special Subcommittee on Radiation thought impossible: it has transformed an inherently imprecise and uncertain definition of nuclear safety into a broadly accepted regulatory imperative.[37]

5 Conclusions

Since the early 1950s, the myth of containment has played a crucial role in the effort to represent nuclear technology as harmless and isolated from the natural environment. Containment-attempted solutions embodied a compromise between public safety and the economic demands of the industry, pushing for more liberal siting regulations that would allow building power plants closer to urban centers, where the loading capacity and distribution of electricity would be easier and cheaper. As we

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[32] Christopher J. Jolly, "Linus Pauling and the Scientific Debate over Fallout Hazards," *Endeavor* 26, 4 (2002): 149–153. Samuel J. Walker, *Permissible Dose: A History of Radiation Protection in the Twentieth Century* (Berkeley: University of California Press, 2000).

[33] Barclay Kamb and Linus Pauling, "The Effects of Strontium-90 on Mice," *Proceedings of the National Academy of Sciences* 45 (1959): 54–69; Linus Pauling, "Genetic and Somatic Effects of Carbon-14: This By-product of Nuclear-weapon Testing May Do More Genetic and Somatic Damage Than Has Been Supposed," *Science* 128, 3333 (1958): 1183–1186.

[34] Shannon Cram, "Living in Dose: Nuclear Work and the Politics of Permissible Exposure," *Public Culture* 28, 3 (2016): 519–539.

[35] *Radiation Protection Criteria and Standards: Their Basis and Use: Hearings Before the United States Joint Committee on Atomic Energy*, Special Subcommittee on Radiation, Eighty-Sixth Congress, Second Session, on May 24-26, 31, June 1-3, 1960, https://babel.hathitrust.org/cgi/pt?id=umn.31951d02097609g&seq=1.

[36] Cited in Walker, *Permissible Dose*, 62.

[37] Cram, "Living in Dose," 528.

have seen through this brief exploration of nuclear industrial and military expansion, the idea of containment, impermeability, and isolation from the external environment is really a fiction. It became a technopolitical solution enabling the industry, regulatory agencies, and sectors of the political elites to continue developing nuclear reactors in the face of safety uncertainties.

Rather than an accomplished technological fix, containment is a probabilistic concept, a goal that in the realm of public relations must be presented as an absolute certainty. Indeed, the entire life of the nuclear industry depends on the public acceptance of containment as an absolute certainty. But, if containment is conceived of as a matter of degree rather than a binary variable, its real working possibility resides in controlling discharges of effluents, in preventing and mitigating accidents, and in establishing that certain levels of radiological exposure are socially acceptable in light of nuclear power's benefits.

Over the past few years, a renewed interest in nuclear power has emerged. International expert agencies, and of course the nuclear industry concur that nuclear technology is necessary to support future energy demands in a clean and sustainable way.

This view is quite simplistic because it focuses only on reactor safety and neglects unresolved environmental questions that emerge during the life of nuclear facilities, as during decommissioning, for example. The idea that nuclear power can offer clean energy with the objective of decarbonizing the world economy is once again predicated on the assumption that nuclear technology can be safely isolated from the environment.

While the myth of containment and isolation is still alive, the effects of climate change remind us that nuclear power might not be a solution, but a problem to solve. In March 2023, the French Court de Comptes issued a report titled *The Adaptation of the Nuclear Reactor Fleet to Climate Change*, which underlines the need to consider the potential effects of extreme climate events and new environmental conditions such as air and water warming, droughts, sea level rising, and so on, while planning maintainance and expansion of current nuclear power installations.[38] The Anthropocene explodes the myth of containment and puts into question the possibility to reiterate its use to solve the problem of climate change and energy demands.

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[38] The original title is: *L'Adaptation au Changement Climatique du Parc de Réacteurs Nucléaires*, https://www.ccomptes.fr/system/files/2023-03/20230321-Adaptation-du-parc-de-reacteurs-nucleaires-au-changement-climatique_0.pdf.