Overcoming the Barriers to Enable Nuclear Energy Generation

STS.032 Energy, the Environment, and Society

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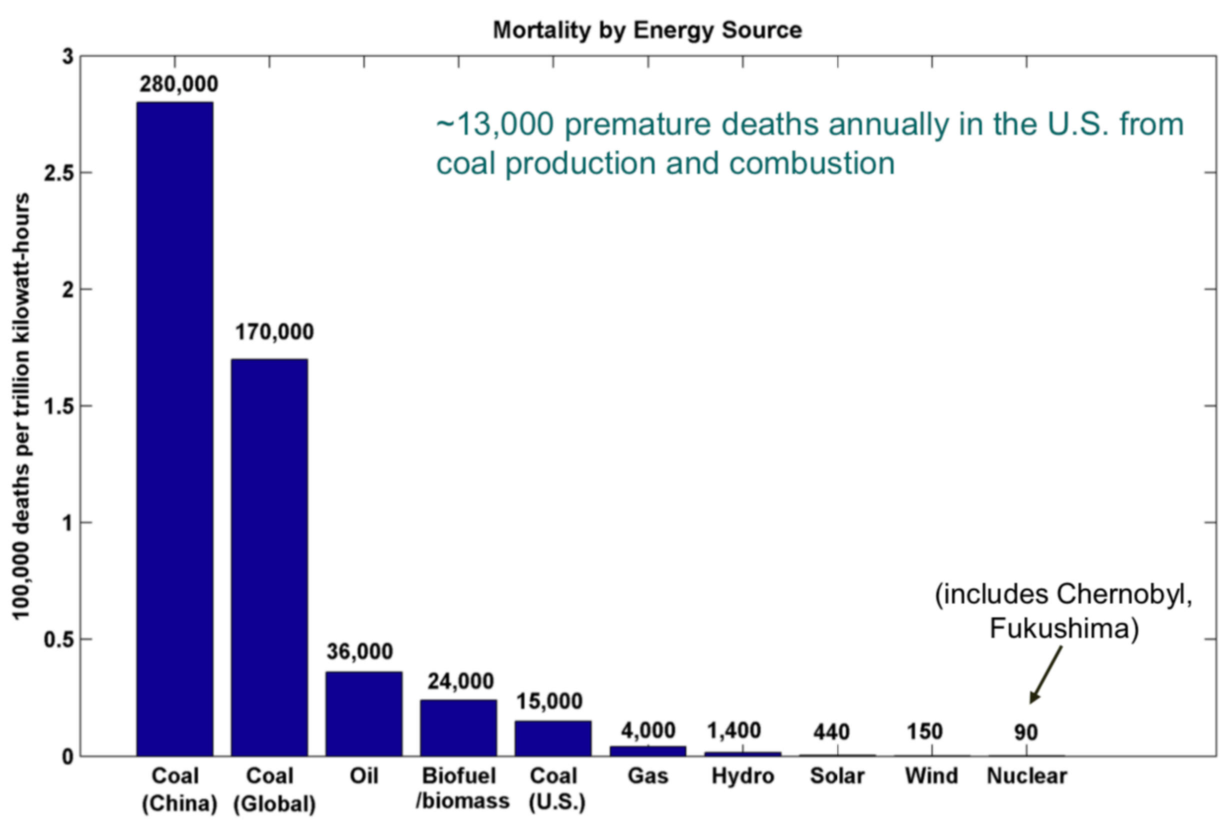
In the 1970s, the Organization of Petroleum Exporting Countries hiked the price of oil instantaneously by 400% leading many countries, the United States included, to really begin thinking carefully about energy security. Many countries turned to producing their own oil as a means for energy security, while others turned to nuclear fission power generation. Because of its density and ease of storage, nuclear energy was thought to be an indigenous energy source, or an energy source that is not subject to exoteric influences. Furthermore, the major countries that produce Uranium for nuclear fuel include the US, Australia, and Canada, which are more politically and economically stable than the major oil producing countries. Today, as many of the nuclear plants in the world begin to start their process for decommissioning, there is a new energy security issue: replacing that electric generation. In the US this means 100 gigawatts of nuclear capacity, or 20% of the US's electricity generation. While there are many alternatives like natural gas, solar, or wind, that can help in achieving this goal, it is imperative that we equally consider nuclear as part of the solution for today's energy security issues and need to decarbonize. In this white paper on nuclear energy, we discuss some of the barriers that beleaguer nuclear energy proliferation and the enabling conditions and benefits . The roadblocks to nuclear energy include public misconceptions of nuclear energy or lack of knowledge, lack of actionable plans for dealing with nuclear waste, and international opposition to the development of peaceful use of nuclear energy. We then analyze nuclear generation in the context of other popular generation mechanisms, and finish with some recommendations for how governments can work to foster a pro nuclear environment.

After polling several people at the Boston Commons, it was unsurprising to find that many people were not well informed about nuclear, and those that were had severe biases against nuclear for reasons not limited to radiation and concerns over handling waste. Much of the fear associated with radiation is tied to the nuclear bombs which were dropped on Japan and the fall outs of Chernobyl and Fukushima, and the three nuclear meltdowns of Chernobyl, Fukushima, and Three Mile Island. However, it is important to draw the distinction between nuclear weapons and nuclear energy. The energy release from the explosions that shook the world were made from nuclear fuel that is composed of more than 90% uranium 235, the isotope that undergoes fission in a chain reaction releasing energy, and 10% U-238, the more stable isotope of uranium.[1] The high concentration of U-235 allows for the catastrophic release of energy. Furthermore, the nuclear bombs were and continue to be designed for the greatest release of energy in the shortest



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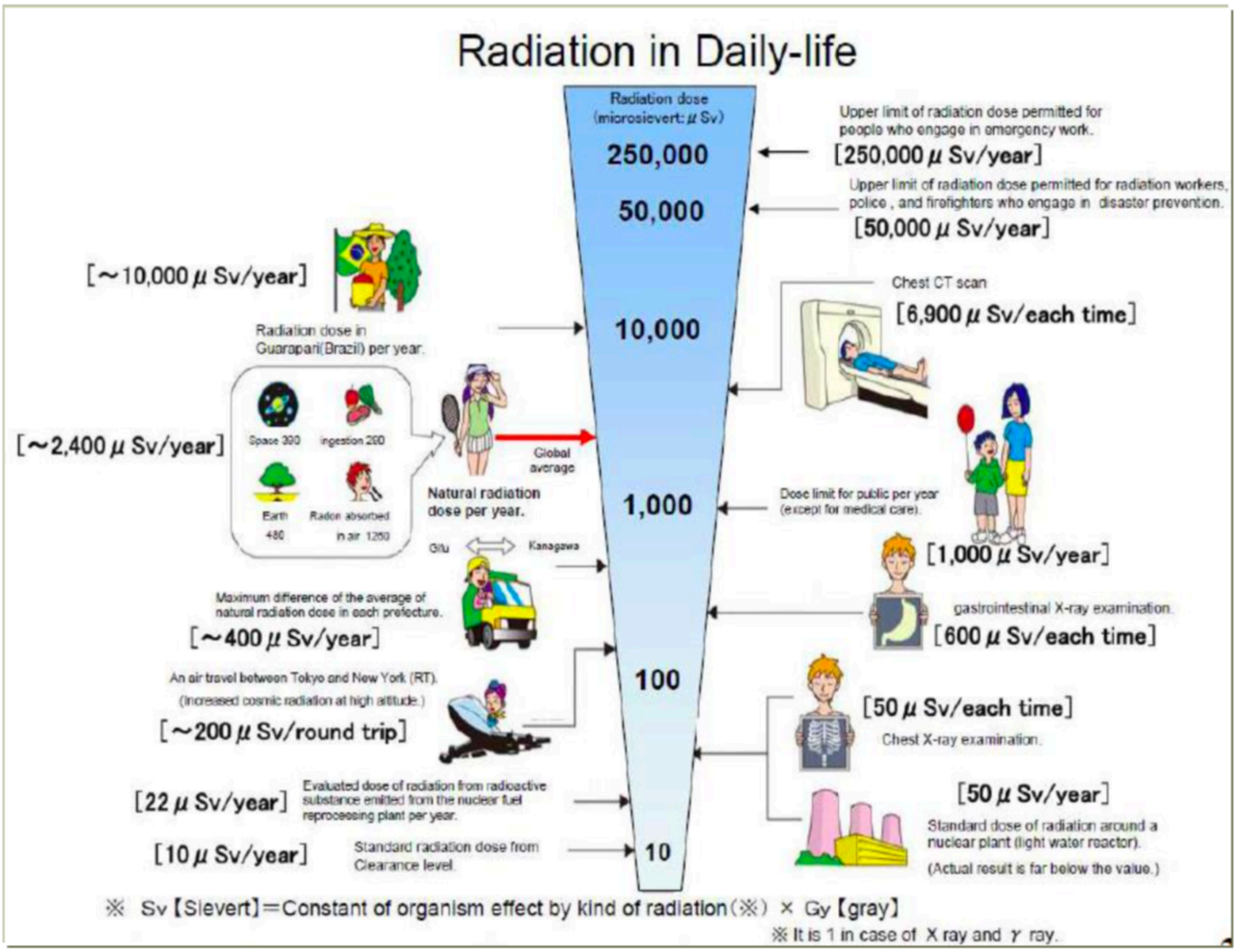
amount of time, resulting in the catastrophic events of Hiroshima and Nagasaki. In comparison, nuclear energy generators use fuel that is 4% U-235. These plants also regulate the speed of the reaction through different mechanisms—allowing for controlled production of electricity.



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A nuclear plant operating safely and correctly emits about 50 microsieverts per year. For comparison, one gets the same amount of radiation from a single chest X-ray that is a common mechanism for checking for bronchitis, and is much less than the annual radiation received from the sun.[2] Many of the misconceptions of nuclear do not stem from the proper operation, but rather the few times they have failed to operate safely. People are concerned that Chernobyl,

[2] Chernobyl at the 25th Aniversary. World Health Organization.

Fukushima, and Three Mile Island will happen again. However, the probability that someone gets fatal cancer from being exposed to 20,000 microsievers of radiation is lost in the statistical deviation that any one individual will become fatally ill from cancer. This amount of radiation is significant because it is the amount of radiation the evacuees of Fukushima would have experienced in a year had they stayed in their homes.[3] While radiation exists all around nuclear, properly operating plants pose no more of an issue than ambient radiation to locals and the radiological effects of the unfortunate meltdowns will diminish over time and plants are being designed to include passive safety mechanisms for added safety.[4]

Nuclear melt downs, as a result, are very unlikely especially when we consider the future of nuclear energy. After every nuclear meltdown, reports of the events leading up to the failure were distributed world wide, allowing for actionable steps to be taken to prevent similar issues. For example, following the Fukushima meltdown as a result of the diesel generators not coming online, all plants around the world moved their diesel generators to higher elevation to prevent their flooding in the case of a natural disaster. New generation IV reactors are being designed, so that previously active safety systems run passively, removing the possibility for system error, and simplifying these plants. The work being done on the future of nuclear power plants hopes to reduce the already low risk of nuclear fallout. In order to secure a future for nuclear energy, public awareness about the added safety of new nuclear must be promoted and presented.

Beyond the immediate issues posed by the operation of nuclear plants are the issues associated with the long term storage of radioactive spent fuel. Today spent fuel is stored first in

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[3] Slide deck provided by Dr. Jacopo Buongiorno

[4] “The Chernobyl Accident.” United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

"spent fuel pools" for an industry average of 10 years and then transferred into fuel casks which can safely store the fuel rods for almost 100 years before requiring to be transferred into a new cask.[5] These storage systems have been rated for natural disasters and are designed to be safe from acts of terrorism, as part of actions taken after Fukushima and September 11, 2001.[6] While many of these fuels are currently safely stored on site of nuclear plants, there are concerns of where to store them after old nuclear sites are decommissioned. Particularly challenging is the ability to find a suitable long term storage location. In the US, the government proposed the Yucca Mountains in Nevada as the site to store the spent fuel, but after further geological studies, active lava flow in near by regions questioned the long term sustainability of the site.[7] Since then the US has not found a suitable site, as the process has been a "political rather than a scientific choice."[8] In contrast, the Canadian government and those of Finland and Sweden have worked from the onset with scientists to locate suitable sites and with the local communities to allay concerns of hosting these long term management facilities. In Finland and Sweden, this has led to their ability to plan the opening of their deep geological repositories in the next decade.[9] Careful thought and consideration must be put into the planning of any attempt to open up long term nuclear storage facilities, but the technological feasibility exists and enables the continued use and storage of nuclear energy.

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[5] "Spent Fuel Storage in Pools and Dry Casks." *NRC*.

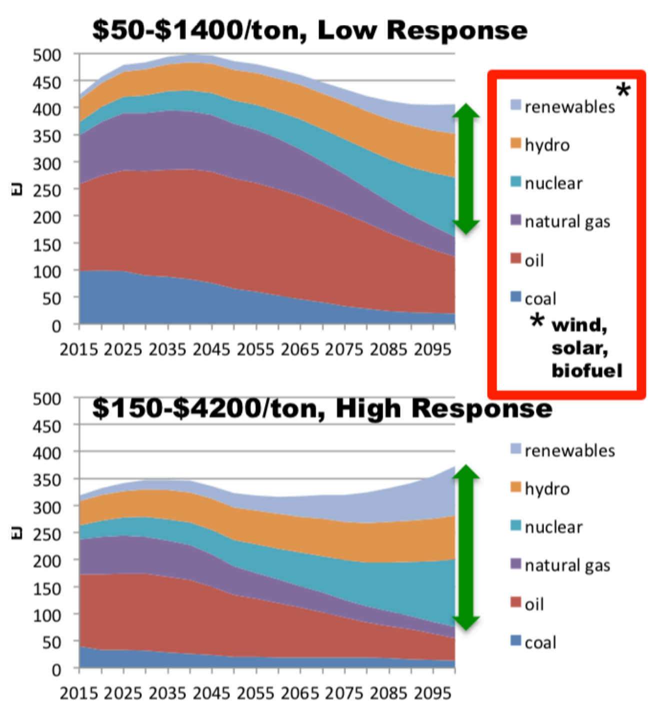
[6] Ibid.

[7] Slide deck provided by Dr. Bradford Hager

[8] "The French Approach to Nuclear Waste." *American Physical Society*.

[9] "The French Approach to Nuclear Waste." *American Physical Society*.

While the political issue of finding how to dispose of the waste plagues many countries that already have access to nuclear energy, there are many more that are prevented from even adopting the technology. Internationally, there have been efforts to stop nuclear weapon proliferation, but these same efforts have also hindered the development of nuclear power generation. Nuclear energy generation is associated by the public as a stepping stone in the process of creating nuclear weapons, yet there are pathways to nuclear weapons that do not require nuclear generation. There is a fear that the refinement process, if retuned, can be used to create nuclear weapons grade fuel instead of nuclear plant fuel. Moreover, the spent nuclear energy fuel, plutonium, can also be reprocessed to create weapons grade material. There are mechanisms that can set checks on nuclear generation that do not involve stifling the growth of nuclear energy generation, especially when it would allow increase in electricity capacity and economic output. These checks include internationally run refinement plants and accounting methods to keep track of nuclear fuel produced and used. The European Repository



Source: Slide deck Provided by Dr. Ronald Prinn

Development Organization has come together to find international repositories and manage the long term storage of the spent fuel. It is important to develop methods for checking the usage of nuclear to allay the fears of proliferation, while still enabling nuclear generation development.

This becomes especially important as we try to decarbonize the world. Developing nations already account for 63% of world emissions and are becoming even more power intensive and also carbon intensive as they become more economically productive.[10] When considering the economics of nuclear versus natural gas, natural gas is considerably cheaper. However, this story changes when the social cost of carbon is considered. Implementing a higher cost/ton of carbon emitted creates an incentive for the world to wean off of carbon intensive energy sources and replace the base load power provided by these sources. In Germany, where efforts are being made to completely phase out nuclear in favor of intermittent renewables, the Germans are being forced to turn to fossil fuels in the transition period. Moreover, the countries in Europe which have the least carbon emissions are those which have the highest concentrations of nuclear power generation not those with the highest capacity of installed renewables.[11] The major incentive for developing nuclear, and main reason for its need, is its ability to provide a reliable carbon free base load energy solution.

Nuclear generation as a technology provides benefits over other forms of generation including solar, wind, and fossil fuel generation that encourage its uptake and development. The intermittence of renewables like solar and wind prevents the complete transition off of fossil fuels. On the other hand, nuclear energy has the ability to serve as a non-variable power source.

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[10] "Energy." The New Climate Economy.

[11] Slide deck provided by Jacopo Buongiorno

This allows grid operators the ability to better be able to do supply management, or determining how many generators go online. Furthermore, nuclear energy beats out wind and solar in its site-ability and energy density.[12] Siting wind and solar requires finding large parcels of land in either windy or sunny places. Nuclear on the other hand, requires much less land than wind and solar to generate a the same amount of electricity. When considering operating and management expenses, those of nuclear and fossil fuels are much higher because of their need for fuel. The costs of nuclear fuel are much lower than those of natural gas for the same amount of electricity generated.[13] Furthermore, the volume of natural gas required to generate the same amount of electricity as a nuclear plant far outnumbers the required amount of nuclear fuel.[14] Finally, when considering these generation mechanisms in the context of water usage, nuclear takes the prize. New plants are being developed with the potential for dry cooling which would not require the use of any water. While no source of generation is perfect, we must really consider how to best implement the technology we have at our disposal to decarbonize the grid.

The role of governments in promoting the uptake of a nuclear future is nontrivial and requires active support, education, and incentives. For nuclear to gain the support of more conservative nuclear groups, solutions to long term storage must be found as well as mechanisms to control the use of refineries and waste by nations hoping to take up the use of nuclear materials. These steps would ensure the long term safety of people both from being around hazardous materials and the proliferation of nuclear weapons. Beyond these considerations, the government would need educational programs to promote the safety of nuclear energy. For the

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[12] Ibid.

[13] Ibid.

[14] Ibid.

most effective rollout of nuclear generation, governments should educate target communities where new nuclear generation is being considered. By working with and educating the people in these communities, utilities and generators will experience less local pushback. People who live closer to nuclear plants today are more supportive and knowledgable of nuclear than the general public.[15] Furthermore, increasing the general public awareness of nuclear energy would increase political favor of nuclear energy, allowing for governments to pursue nuclear energy security with less resistance.

Beyond informing the general public, the role of the government extends to incentivizing utilities and electricity generators to pursue nuclear generation. Governments can either mandate the adoption of nuclear, an option that may cause inefficient deployment of nuclear and would leave out the proper input from concerned parties, or it can become a direct purchaser of nuclear. This would include calling for request for proposals (RFPs) and funding the majority of nuclear uptake. Socially, RFPs allow for nuclear to be built in a nondiscriminatory fashion and equally weigh different projects and distribute funds. Furthermore, by being the off taker, the government could help reduce bureaucratic costs lowering the overall cost of bringing new nuclear online. Moreover, governments could favor the repurposing of old nuclear land for new modern plants, allowing for the continuity of local nuclear skilled labor and thereby protecting employment. One of the main reasons nations have not willingly turned to nuclear thus far extends beyond public perception and to its exorbitant up front capital expenditures. Nuclear technology development must take place to reduce the costs substantially, and the industry is responding with modularization and improving construction materials. However, governments

[15] "Public Opinion on Nuclear Energy: What Influences It." *Bulletin of the Atomic Scientists*

must not sit idly by and wait for the economics to work. By subsidizing the technology they will spur research that will drive costs down as has been seen in wind and solar energy and further improve the case for the adoption of nuclear.

Nuclear, was once the solution countries turned to for energy security, today, it is the technology we should heavily consider for decarbonization. Knowledge is power, yet much of the world remains uninformed and outdated on the benefits and safety of nuclear. International governments will need to make a serious effort to educate people, work together and finance a nuclear future that will enable the world to reach its 2 degree C goal.