The Decline and Death of Nuclear Power

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Nuclear power is history.

That is to say, nuclear power is deeply steeped in history. The atomic nucleus itself was found to be a heterogeneous mass of protons and neutrons in 1932, but it was only a mere 6 years after the composition of the nucleus was determined when Lise Meitner and Otto Hahn discovered that bombarding heavy elements with neutrons could crack their nuclei in two -- a process they called nuclear fission. Only 4 years after that, the first nuclear reactor, Chicago Pile-1, went critical, the first self-sustaining nuclear reaction ever.

At 1:50 PM on December 20th, 1951, in the tiny town of Arco, Idaho, Experimental Breeder Reactor I powered on for the first time. For 22 short minutes, the light bulbs above the heads of the scientists were lit not by inspiration, but by nuclear power. For the first time in history, the power of the atom was constructively harnssed. In 19 short years, nuclear chemistry had evolved from a fledgling concept to a science that altered the balance of power in the world forever.

The rapid development of nuclear chemistry was due largely to the political and economic forces that acted upon it in its formative years. Because of the unparalleled pools of energies waiting to be tapped in the nucleus, the new technology was developed not just as a tool, but as a weapon -- a fact exacerbated by the era its maturation coincided with, World War 2 and the Cold War. It is this historical baggage that holds back nuclear power today, bearing the ire of a sensationalist media and an uninformed populace, while governments refuse to relinquish the nuclear arms that continue to define warfare -- and hence international politics -- today. While fossil fuels pump our atmosphere full of greenhouse gases and we desperately scramble to find alternative-energy solutions, neglecting nuclear power as a viable energy source is an imprudent move.

The most powerful driving force behind both the growth and decline of nuclear power has always been public sentiment. When nuclear power first came into the public eye in the 1960s (and up until the mid-1970's), nuclear chemistry was a highly regarded field. Support for the construction of nuclear power plants was a 2:1 majority among the general population, especially in the context of an Arab oil embargo and the first hints of a burgeoning "energy crisis" (Rosa & Dunlap, 1994). Even in the immediate aftermath of Three-Mile Island, the first and only nuclear energy disaster on US soil, nuclear power retained a plurality of popular support. In the early 1980s, however, public opinion suddenly flipped, as voters now opposed the continued growth of nuclear power by a 2:1 ratio; support for nuclear power has never held a plurality since (Ramana, 2011). A major factor for this is the crystallization of opinion against nuclear power, a steady stream of voters going from being "unsure" or "ambivalent" about nuclear power to firmly against it. Nuclear power bottomed out at the height of the Cold War, when paranoia of global nuclear annihilation reached its peak. It is this unspoken association between nuclear weaponry and nuclear power that is responsible for much of the fear and mistrust of nuclear power, even today. Scientifically, this premise is fundamentally flawed; nuclear weaponry and nuclear power are as dissimilar as two subjects that both contain the word "nuclear" can be. Nuclear reactors in power plants are intrinsically distinct from nuclear bombs, not merely in application or even in construction, but in that they utilize completely different radioactive fuel sources; the fuel used in nuclear power plants is almost completely useless for weapons-grade radioactive material, due to the presence of adulterating Plutonium-240 that greatly impedes the ability of fissile Plutonium-239 to be weaponized (Sutcliffe & Trapp, 1997). However, this has not severed the understood connection between all things nuclear that causes the public to look with disdain upon nuclear power the more nuclear weaponry is on the world's stage. With the aid of anti-nuclear watchdog groups, nuclear power has been warped into a political talking point by people who do not fully understand the science behind it. Without public support, nuclear power loses government support, and with that goes research and expansion funding, causing nuclear power to simply fall off the energy map.

That is not to say that the disappearance of nuclear power is a foregone conclusion. Nuclear power may be dying or in decline, but it is far from dead. In the US, at least, nuclear power is at a crossroads: no new reactors have been built on US soil since the Three-Mile Island incident in 1979. At the same time, however, the US Nuclear Regulatory Committee has approved the first two nuclear reactors in 35 years, to be constructed in Georgia and expected to begin operation in 2016 (Tracy, 2012). While a majority (71%) of US citizens favor the use of nuclear power as an energy source, only a mere 43% believe that more nuclear power plants should be constructed ("The Thirty-Year Itch", 2012). Nuclear power faces intense opposition in the future, mostly due to public interest groups rooted in deep-seated misconceptions, but it is possible that in the next decade or two we may see a resurrection of the nuclear power industry in the US.

Sadly, it is not so easy to make the same claim for many other countries worldwide. In Europe, nuclear energy has been a highly competitive power source for decades, but many countries are uneasy about continued nuclear development and several have made motions to phase them out completely. Even in France, where 80% of all energy is produced by nuclear power plants, 83% of the public is opposed to the building of new reactors to meet rising energy demands. In Germany, 88% of the population voted against the renewal of nuclear power plants for 12 more years; along with Switzerland and Belgium, they have passed movements to phase out nuclear power completely in the next 10-20 years (Phillips, 2011). In Canada, a majority of the population opposes nuclear power as an energy source; the entire province of British Columbia has declared itself a nuclear-free zone. In fact, the government-owned electricity company BC Hydro has gone so far as to state that they "[reject] consideration of nuclear power in implementing [their] clean energy strategy" (BC Hydro, 2010). In Japan, every single nuclear power plant has been shut down, the result of a firestorm of anti-nuclear rhetoric in the aftermath of the Fukushima Daiichi disaster. In fact, of all the G8 countries, only the US, UK, and Russia have not made motions toward the phasing out of nuclear power as an energy source, as compared to Germany, France, Canada and Japan (Italy has no reactors, yet recently scrapped a plan to construct some). However, with the energy demands of all these countries rising, and because nuclear power provides 15% for the least of these countries' total energy supply, it is unlikely that they will be able to completely replace nuclear power with renewable sources of energy without resorting to fossil fuel sources.

While these statistics do illustrate an overlying trend in the decline of nuclear power, a majority of the more recent motions to phase out nuclear power can be traced back to the Fukushima Daiichi nuclear crisis. Prior to Fukushima, nuclear power was holding relatively steady in opinion polls -- still a minority, but, having largely faded from the public consciousness, was not a major political talking point (Ramana, 2011; Harvey, Vidal, & Carrington, 2012). When the March 2011 earthquake and tsunami hit Japan, it caused the six reactors at Fukushima Daiichi Nuclear Power Plant to shut down, while flooding prevented auxiliary generators from keeping emergency coolant pumps from running. The disaster was worsened by poor communication and general incompetence of many officials; it has been described described as

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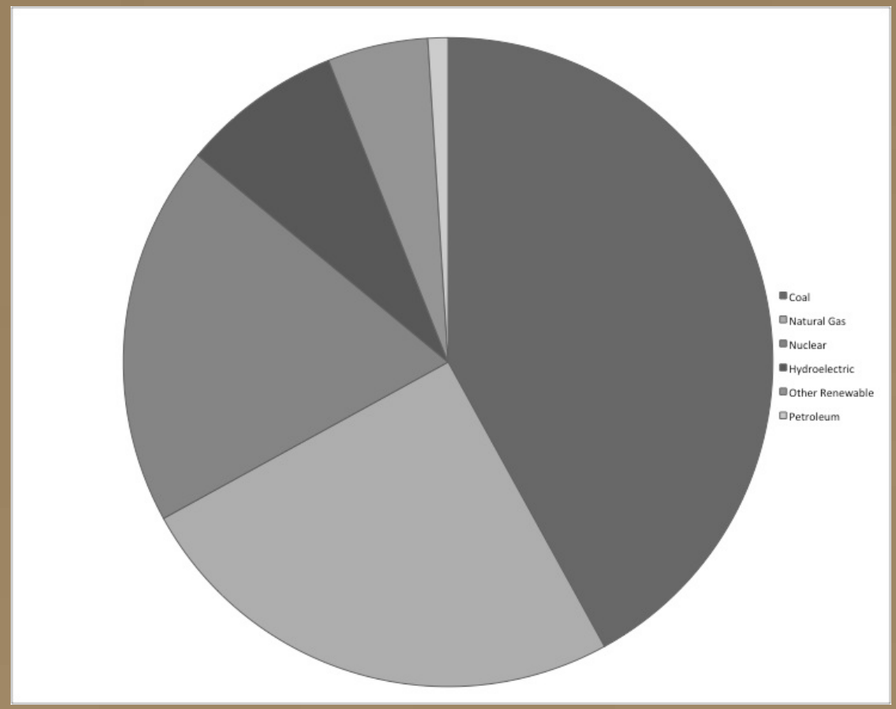

Figure 1 Nuclear power is the most-used non-fossil fuel energy source in the US, and contributes more than all forms of renewable energy combined (Energy Information Administration, 2012).

Image 1 In the aftermath of Chernobyl, hundreds of thousands of "liquidators" scoured the area around Chernobyl, isolating radiation pockets. The vehicles they used lie untouched, still dangerously radioactive.

a "snowballing disaster" with poor disaster response and characterized by a lack of government action. The plant itself was built in an unsafe region, next to the ocean on a tsunami-prone coast. When the threat of reactor meltdown was recognized, plant officials delayed a final attempt to cool the reactors by flooding them with seawater because doing so would damage them irreparably. By the time the government ordered that the plant be flooded, it was too late to prevent the reactors from melting down. After the plant itself melted down, Japanese officials consistently underestimated the magnitude of the disaster, and neglected to make the severity of the incident clear to the public or the media. When the US Department of Energy provided data on radiation levels that showed that the radiation danger zone stretched far outside the evacuation radius, Japanese officials failed to act. It was not until a week later, when the US maps were published, that the Japanese government released similar findings and expanded the evacuation efforts. Despite terrible damage control and abysmal public communication (at one point evacuees were recommended to move from an irradiated area to a zone with higher radiation levels), epidemiologists estimate on the order of only 0-100 potential radiation casualties due to the incident (Funabashi & Kitazawa, 2012). Despite the small direct damage of the event, it has led many countries to reevaluate their nuclear programs, and is the direct cause for Germany, Belgium, and Switzerland's movements to phase out nuclear power entirely.

One of the major claims by opponents of nuclear power is that nuclear power plants are inherently dangerous, releasing radioactive material into the environment and presenting a regional threat in the form of a potential nuclear meltdown. It is mostly for these reasons that the Nuclear Regulatory Commission was founded in the US, to supervise and regulate the construction and maintenance of nuclear power plants (US Nuclear Regulatory Commission [US NRC], 2012). The NRC mandates strict safety regulations regarding containment of nuclear power plants, as well as physical security to deter theft, sabotage, or acts of terror, in addition to requiring a stringent application process before any reactor construction is approved (US NRC, 2013). The best example of the success of these safety and containment protocols is the 1979 Three-Mile Island incident in Pennsylvania, when operator error and a core meltdown resulted in the release of quantities of fission byproducts to the environment via a stuck release valve. Because of the containment structures put in place, only gaseous xenon and krypton were released in any significant quantity; areas near the reactor were exposed to approximately 1.4 mrem of radiation (for context, a typical dental x-ray is about 3 mrem). The day-to-day environmental effects of nuclear power plants are not much higher, either. Studies have shown that that coal power plants, counterintuitively enough, release more radiation into the environment than nuclear power plants, due to the concentration of trace uranium and thorium in coal when it is burned -- radiation levels of crops grown near coal plants have been found to be 50-200 times higher than crops grown near nuclear power plants (Hvistendahl, 2007). Notably, neither level is high enough to biologically harmful, but the belief that nuclear reactors release significant amounts of dangerous radiation into the environment is fundamentally mistaken.

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Image 2 The Chernobyl Plant explosion released around 40 GJ of energy -- equivalent to about 10 tons of TNT (Dubasov & Pakhomov, 2009).

Image 3 While the Three-Mile Island nuclear incident resulted a core meltdown and the release of radioactive isotopes, effective control mechanisms meant that the epidemiological effects of the disaster were minimal.

The catch, of course, is that when these precautionary measures founder and a nuclear reactor does fail, the potential results are catastrophic. The prime example of a cataclysmic nuclear accident is the 1986 Chernobyl disaster in Ukraine -- mostly because it is the only disaster of that level to ever occur. Due to an engineering oversight, the control rod reactor shutdown systems did not function perfectly, and after a routine experiment they caused the reactor to overheat and explode. Radioactive fallout spread across Eastern Europe, triggering radiation alarms in nuclear power plants as far away as Sweden. The Soviet disaster response was relatively prompt: teams of volunteer "liquidators" were sent in to clear radioactive debris and a hasty concrete "sarcophagus" was erected to isolate the reactor: the total cost of cleanup came to about $37 billion today, functionally bankrupting the USSR. An estimated 200,000 people were evacuated; the nearby (and now iconic) towns of Pripyat and Chernobyl still lie abandoned as a testament to the calamitous event (International Atomic Energy Agency [IAEA], 1992). Despite their immediate and efficient actions (which doubtless saved thousands of lives), there were still innumerable casualties. Various epidemiological studies have estimated between 5,000 to 50,000 premature deaths by cancer due to the incident. To prevent further contamination, a 30 kilometer "exclusion zone" was established around the plant, which is not expected to be habitable for hundreds of thousands of years (IAEA, 2006; González, 1996). These saddening statistics underlie a simple fact about nuclear power: the potential danger a nuclear power plant poses is greater than any other source of energy, and no safety measures are perfectly preventative. In the event of a disaster, damage control can be unreliable due to the potential magnitude of the incident; as such, the best we can do is do everything we can to reduce the likelihood of a mishap, both by learning from and adapting to past mistakes, and by exercising constant vigilance in nuclear reactor maintenance and security. However, when a nuclear disaster does occur -- which it inevitably will -- even the best disaster control could leave anywhere between dozens to millions of lives up in the air.

Despite these caveats, nuclear power is certainly a viable source of energy for an advancing world. Compared to traditional fossil fuels, it is clean, sustainable, and is far less polluting on a day-to-day basis; compared to renewable energy sources, it is more efficient and has a greater maximum energy potential in regions where geothermal, wind, or hydroelectric energy is not geographically optimal. While nuclear disasters are, to say the least, catastrophic, they are few and far between. Ultimately, it is this constant fear of catastrophe that is responsible for public mistrust of nuclear power. It is common knowledge that coal power plants are filthy and polluting, but because their environmental and societal impact is not immediate, they are exposed to far less public scrutiny. Nuclear power's negative effects are not cumulative: they are short, sudden, violent, and easily headlined by the media, lingering in the public consciousness for years. By learning and adapting from past disasters, we can make nuclear power plants iteratively safer. Of the three major nuclear power disasters that have defined the science -- Three-Mile Island, Chernobyl, and Fukushima -- only Chernobyl caused significant amounts of casualties and had deep economic and environmental ramifications. Three-Mile Island and Fukushima, by comparison, were nuclear containment success stories, resulting in orders of magnitude less radiation released and hardly any radiation casualties as a result. While all three were serious radiation breaches and any loss of life is terrible, to continue to presuppose all nuclear power by a single 45-year-old worst-case-scenario is shortsighted. In the future, a movement away from nonrenewable, polluting fossil fuels to clean, sustainable alternate energy sources is inevitable; ignoring nuclear power as an important intermediary in this transition only makes such a transition more difficult and less likely. Nuclear power is the largest non-fossil-fuel source of energy in the US, producing 19% of total energy generated, while every form of renewable energy combined comprises only 13% (US Energy Information Administration, 2012). An attempt to phase out both nuclear energy and fossil fuels at the same time would take decades at the least and could overload the US energy market with unrealistic wind, solar and hydroelectric energy demands that vastly outstrip these sources' capacities. To push away from nuclear power now would only increase US dependence on unsustainable sources of energy and increase the difficulty of tackling the energy crisis.

Image 4 The Fukushima Daiichi disaster, despite being exacerbated by bureaucratic incompetence, was orders of magnitude less damaging than Chernobyl due to successful containment structure (Funabashi & Kitazawa, 2012).

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Nuclear power is history; it has been defined by its history ever since the first atom bombs were dropped on Japan. It has been slowly dying for decades, wrongly maligned for some implicit yet completely nonexisteWnt association with nuclear weaponry and preconceived notions based on a single historical worst-case scenario. Rather than learn from the past and improve upon it, there has been a push to abandon nuclear power entirely. While nuclear power is far from perfect, it is a definite improvement upon polluting fossil fuels, and a powerful ally in the transition away from them toward ultimately renewable sources like wind, hydroelectric, and solar energy. While in some countries, like Germany and France, the anti-nuclear movement has taken such a hold that its salvation is increasingly unlikely, in the US there is still a glimmer of hope for future development and research. For the first time since the Cold War, nuclear power plants are being planned and constructed. Only time will tell if these reactors will pave the way for the next generation or are merely the dying gasps of a doomed industry.

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