The Risks and Benefits of Nuclear Power: Are politicians and environmentalists prematurely abandoning it?

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Table of Contents

1 Introduction to Nuclear Power, benefits, and risks:

In this paper we will discuss Nuclear power and whether or not politicians and environmental agencies are being too quick to abandon it. We will present the risks and benefits of nuclear power compared to fossil fuels in an attempt to determine the possible risks that may be making environmental agencies stray away from nuclear as a power source. We will also look at benefits that may be reasons to continue using nuclear power and reasons to replace coal power with nuclear. For this paper we will be observing fission-electric power due to its high use and extreme efficiency in generating power.

Nuclear fission is a process in which a nucleus splits into parts and releases free neutrons. This produces a large amount of energy, mainly in the form of electromagnetic and kinetic energy. This heats up the original material and is the core of what powers a nuclear power plant. Nuclear power plants work by using chunks of nuclear material called “rods”. Nuclear fission occurs in these rods which is used to heat up water until it boils into steam, this steam is then forced through turbines. These turbines are linked to electrical generators and is where the power generation happens. Problems that arise with this method of power generation is that the nuclear rods tend to get too hot and require advanced cooling. Most commonly fluoride salt, sodium, or liquid metal are used in the cooling section of nuclear power plants.

We will be exploring the benefits of nuclear power as reasons why politicians and environmental agencies who are straying away from nuclear power may be doing so prematurely. While certain politicians may have ulterior reasons to act against nuclear power, the reasons presented in this paper will objectively state that nuclear power is a future proof method of power generation. The environmental risk nuclear power presents is far less from current popular non-renewable power generation methods, despite what the media and lobbyists may be saying. Nuclear power is vastly more reliable versus coal power and other fossil fuels due to its ability to stay on for long amounts of time without need for refuel. On top of these points, nuclear power also costs less when run for a long time due to the cheap cost of the fuel and the need for minimal quantities of fuel.

Environmental agencies however may be observing the risks of nuclear power plants and determining if there should be more rules and regulations surrounding the creation and operation of Nuclear power plants. The fact that nuclear power plants have such a large concentration of nuclear resources in one specific area makes them large targets for domestic and international terrorists. With multiple examples of people breaking into these compounds to

show their vulnerabilities, an attack is clearly not outside the realm of possibility. Even if an attack does not occur, due to human error or natural disaster, accidents happen on their own and can have devastating effects on the residents surrounding these plants and the land they occupy.

With these points we will determine whether or not politicians and environmental agencies are being too quick to judge nuclear power as an alternative power source.

2. Benefits of Nuclear Power:

2.1 Environmental Impact of Nuclear power compared to coal:

Nuclear power has at least three potential forms of waste, all of which are dangerous to the environment. The question is if these streams of waste are better or worse for the environment when compared to conventional coal power generation waste streams. To compare the different power generation methods we will look at the physical environmental impact, the atmospheric impact and the impact to people living in the production location of these forms of power.

The physical environmental impact of a form of power generation is the effect the generation plant has on the local flora and fauna and the effect the power plants discharge has on local natural resources such as water and minerals. First we will look at Coal's effect on the physical environment. The by-products of coal power production include coal sludge, heavy metals, and fly ash. Coal sludge is a liquid coal waste produced in the mining stage of coal. Coal sludge is comprised of heavy metals such as mercury, arsenic, beryllium, and other metals. An estimated 13 tonnes of mercury and over 3000 tonnes of arsenic are dumped into reserves each year. These metals have a profound effect on the flora and fauna of the ecosystems around the coal generation plants.

All of these metals can have devastating effects on the local wildlife in the locations they're dumped in. Arsenic compounds can cause chronic and acute effects in animals and humans. These effects can be lethal or lead to reproductive issues due to their effect on organ development. Environments with a high concentration of arsenic tend to have limited species diversity and a lack of a large population of these species. At a certain point of concentration, only species resistant to arsenic can survive. Severe neurological effects have been observed in animals and humans when exposed to high concentrations of mercury. Significant neurological effects have also been observed in birds when exposed to concentrations as low as 0.05 to 2.0 mg/kg of mercury. At this levels, birds develop difficulties flying and other abnormal behaviour.

Compared to coal, nuclear power is a much safer alternative power method. This can mostly be attributed to the higher standard of regulation on nuclear waste by the government

and environmental agencies. A higher standardization of disposing nuclear waste means that less of it ends up in the environment. UN Nuclear Regulatory Commission splits nuclear waste into 4 categories depending on the levels of background radiation and how long it will last in the environment. The waste produced by nuclear generation plants is packed into casks that have neuron absorbers built into their cases and are insulated with inert gas. These are then stored in a ventilated storage module made of concrete and steel for redundant protection. All of this compared to the radioactive waste produced in a coal factory, known as fly ash, that is simply buried and dumped into the environment.

Compared to coal, Nuclear power is a much safer and cleaner alternative power supply. The effects of fly ash on the environment are devastating to the wildlife and plant life surrounding the plants. Comparing coal to nuclear based on the containment and effects on the local wildlife, it is sufficient to say that Nuclear power is safer than coal power.

2.2 Cost Benefits compared to Coal Power and fossil fuels:

An efficient power supply method is only beneficial if the cost for that power is relatively less expensive when compared to the less efficient alternatives. In the previous section, we examined the difference in efficiency between Nuclear power and other alternative fossil fuels such as coal and natural gas. In this section we will observe the cost difference between fossil fuels and nuclear power in terms of initial cost, and upkeep/maintenance. These two metrics make up the majority of costs of a plant during its entire lifespan and will be used to compare fossil fuel production with nuclear power production.

The initial cost of a power generation method includes purchase of land, labour, and materials to build the physical plant and the price to acquire the materials to start power generation. Due to the highly technical nature of nuclear power plants, they tend to cost more when compared to that of a traditional fossil fuel power plant. Since we can not use the direct cost of the plant itself due to the difference in power produced, we must compare the cost per kWh generated from the plant. Reports from the OCED Nuclear Energy Agency stated that in 2002 the cost of a nuclear power plant was USD $4,000/kWh, a sharp increase from the early 1960's figure of USD $1,500/kWh.[17] The reason for this increase was mainly due to newer building standards, and the increase of demand for regulation and restriction on the nuclear industry. Today the modern cost of a nuclear power plant is approximately USD $5,339/kWh. Compared to coal, which in 2005 peaked between the low values of USD $1,500/kWh and USD$1,800/kWh. Even after an increase in the past 12 years, today the cost of a power power plant is approximately USD $3,100/kWh.[17] Simply comparing the two numbers of the estimated cost for the two styles of power plants today we can clearly see that the initial cost of a nuclear power plant is significantly higher than that of a coal plant.

While nuclear power initially costs a substantial amount more than coal power, it makes up for running and maintenance costs. The running and maintenance costs are the yearly cost can split into three main categories, those are cost of the fuel, cost of physical upkeep and cost of upgrading the plant. A primary difference between the fuel cost of nuclear power versus the costs of fossil fuels such as oil or coal. The fuel costs of nuclear power account for approximately 14% of the operating costs, compared to that of coal which has a fuel cost that is 78% of the operating costs.[17] Nuclear power costs between an estimated $0.02/kWh to $0.05/kWh, which is much lower than coal power which costs between an estimated $0.04/kWh to $0.20/kWh. [17]

Comparing the two we can see that while nuclear power has significantly lower operating costs, it costs more to create the initial plant. However, due to the extreme difference in operating costs, it is sufficient to say that there exists a point in time when the total cost of a nuclear power plant will be less than that of a coal power plant.

2.3 Reliability and Power Generating Capacity of Nuclear Power:

Efficiency is a fundamental part of power generation. If you can convert 100% of the individual forms of energy from a source to electrical power, that source would be a perfect power generating method. Current nuclear power is the closest resource we have to a perfect power source. At a 92.2% efficiency it is greater to most fossil fuels by almost 40%.[19]

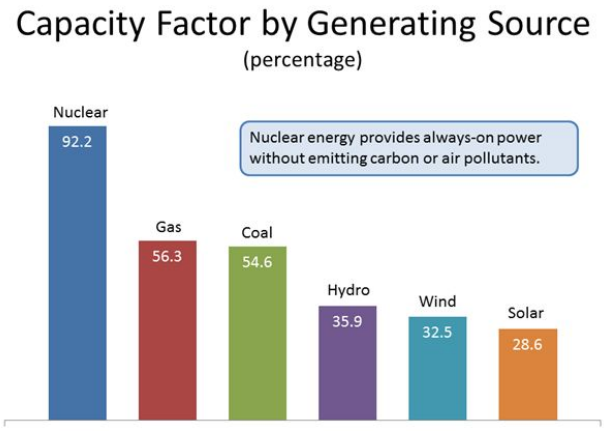

Fig. 1 - Efficiencies of popular power generation methods

Not only is the efficiency rating of Nuclear power greater than that of any other fossil fuel but the power capacity per kg of most nuclear sources are far greater than that of any fossil fuel

counterpart. According to the European Nuclear Society, 1kg of coal will produce approximately 8kWh of power where as uranium-235 can produce 24 million kWh. This substantial difference in power generation density is what makes nuclear power such an efficient resource. [19]

Nuclear power is also vastly more reliable power source due to its resilience to environmental conditions and always on capabilities. Nuclear power plants maintain around an 80 to 90 percent capacity over long periods of time. Nuclear power plants are designed to run for extended periods of time without requiring breaks except to refuel which occurs once every 18-24 months. Due to nuclear power's ability to operate in extreme conditions such as low and high temperatures, it stands to be the most reliable power supply method currently used today. One example of nuclear power's environmental resilience is that of the "polar vortex" of 2014 when natural gas supplies were greatly impacted by the extreme cold temperature. Natural gas production capacity dropped greatly below its normal capacity however Nuclear power maintained its 95 to 98 percent power generation capacity.

Due to nuclear power's high capacity and reliability, it can be said that when compared to coal power generation, nuclear power is the superior generation method for sustained power generation. On top of nuclear power's reliability due to always on capability, nuclear power also maintains no carbon emissions while producing power.

3. Downfalls of Nuclear Power:

3.1 The Potential for a Terrorist Attack or Malicious Activity:

The rising popularity of nuclear power poses many safety concerns, including that of economic disaster, contamination by waste products, and also malicious activity. Every effort should be taken in order to prevent powerful and destructive material from falling into the wrong hands. Multiple types of attacks including military attacks, sabotage, and cyber attacks have all been attempted.

Force on force exercises have been used in order to test proficiency of security protocols and personnel at nuclear facilities. This includes a planned "attack" on the plant with the intent to focus on breaching the plant, and leaving a vulnerability to a dangerous reactor meltdown or similar damage. Although force-on-force testing has been developed over time, non-operational plants are still not being tested, even though they too pose a threat of contamination.

Sabotage is a very serious threat, and not one that is easily combatted if performed from inside the plant's trusted staff. To prevent the threat, multiple personality checks are performed, depending on access level required. For non-regular employees such as maintenance crews, an escort must be assigned to them, informed with the allowances and restrictions required in

order for the servicer to perform their duties. Patrols may help deter common threats as well. Security awareness and policy is imperative to proper protection, helping the entire site respond properly.[10]

Cyber attacks have proven to be effective against nuclear stations. The computer worm Stuxnet, first identified in 2010, was programmed to cause failure in the centrifuges used to refine uranium.[11] It was largely successful in doing so; discreetly decommissioning many centrifuges, and drastically lowering productivity. Although there was no fallout as a result, this still demonstrates that nuclear reactors are at risk of cyber attack. Further costs can be incurred from the damage to the plant, or in the event of a disaster, the surrounding environment.

In 1980, the group Plowshares managed to breach a nuclear weapon manufacturing facility by snipping a fence, and harmlessly tampering with some of the warheads. One of the three intruders included an 82 year old nun.[12] Such a massive breach of security is ridiculous, and drew a lot of attention to the lack of security for such dangerous materials. In light of the breach, the responsible independent security firm issued mandatory refresher courses, however this is hardly a sufficient solution to such a massive security breach.

Theft from internal sources provides a highly dangerous threat that is difficult to prevent. Of 85 incidents of lost, theft, or misrouted material, about 75% have not been reported as reclaimed.[20] Adding more guards is not a solution either, seeing as how 41% of internal thefts from non-nuclear facilities can be attributed to guards.[13]

With the government's most dangerous materials so readily accessible, many layers of protection against a wide array of threats should be adopted. Otherwise, massive economic damage, as well as loss of life could result. As always, nuclear power proves to be a high risk if not managed properly.

3.2 Negative Economic impact of Nuclear Power plants:

Although nuclear power provides a means of very cheap, low emission energy, capital required for successful construction is large, and potential economic damage is massive.

Nuclear power plants have a history of being extremely costly to construct, no matter the savings in fuel and maintenance. A chart based on data from the Congressional Budget Office shows that the average reactor built in the United States of America cost 300% of its original projected price.[2]

When it comes down to business, nuclear power plants have potential to be cheaper than coal fired variants. However, this is based on projected costs, and does not take into account possible overrun of overnight costs. Not only is the estimated capital cost of a nuclear

plant over three times a gas plant (according to CERI), it also takes over twice as long to construct.[1] This is time spent not producing energy, and so not producing revenue.

It should be considered that if the private sector is not willing to invest in such a risky business, the government should be hesitant to pour valuable tax money into financial assistance for such a risky project.

In summary, although a nuclear plant could potentially be cost-effective, past results have shown overrun costs to average at about two hundred percent. This shows nuclear power is risky even financially.[5]

Accidental Costs

A one hundred meter steel pinwheel crashing to the ground is negligible in comparison to a disaster such as Chernobyl. The damage caused by the Chernobyl meltdown can hardly be valued in monetary terms. Damage includes:

- 2.35 billion dollar replacement seal
- Resettling of 330,000 people
- Exclusion zone of thirty (rural) kilometers

Total monetary losses valued at hundreds of billions of dollars. That's a lot of giant metal pinwheels.[3]

Nuclear power should therefore be considered a high financial risk in comparison to more traditional fossil fuel burning alternatives. Waiting for future technological improvements and pioneering may be most effective, resulting in a decreased variability of capital costs.

3.3 Difficulties in Nuclear waste Management :

Nuclear power plants are producing waste material that is sufficiently radioactive that it must be contained, as opposed to fossil fuels which are barely regulated. Due to high radioactivity, nuclear waste must be highly regulated and very securely transported. Such safety measures are necessary, and highly costly.[6] Methods of transport for nuclear waste include via ship, train, truck, and even ferry in some locations.

A reason nuclear waste has been so difficult and expensive to ship is the training personnel require in order to handle such a powerful cargo. Shipping companies have found this extremely inconvenient, and their cargo is constantly at risk for being rejected internationally due to variances in policies. Even transporting the materials has displayed high risk.

One design for a spent nuclear fuel transport ship included a double hull, redundant essential systems, and secure capsules. The hulls themselves were resilient enough to withstand a side-on collision from a moderately sized oil tanker, and the capsules include tracking capabilities in case they are submerged. Although great precautions have been successful at preventing a disaster, it is only a matter of time before an accident occurs.

After transportation of the spent fuel, it must then be disposed of. This is challenging due to the half lives of hundreds of years that some materials may have. The common method of dealing with spent fuel was either reprocessing for use in fission plants, or direct (geological) disposal by storing elements in a safe, regulated deposit location.

Fossil fuels produce approximately 400,000 tonnes of ash per year, whereas a nuclear plant would produce merely 200-350 m^3 low- and intermediate-level waste, and about twenty cubic meters of high-level waste per year per year.[7] This is an astounding difference, except nuclear waste must be stored for sometimes hundreds of thousands of years.

The current method of disposal in the USA is direct disposal, although no site has been completed as of yet. Since the waste must be contained, it is currently being held on-site of the reactors. With annual funding of 1.4 Billion USD, a Yucca Mountain repository would be scheduled to complete by at earliest 2021.[8] The repository was previously halted since the DOE(Department of Energy) discontinued Yucca Mountain license review activities. In 2013, progress was resumed, and spent fuel was being held on-site.

Track record in regards to nuclear projects show they tend to take much more than predicted time, however. If used fuel begins to be accepted by 2022, the total estimated cost to taxpayers in liability damage would be 29 Billion USD, with every additional year delayed costing 500 million.[9] This stresses the requirement of safe and responsible storage and waste management before significant nuclear potential can be achieved, otherwise significant costs are incurred.

4. Concluding Statement and Summary of Decisions:

Government bodies should be interested in promoting nuclear power due to their near zero carbon emissions, which will help reduce the impact of global warming. Since nuclear plants are highly regulated, and entirely responsible for their own emissions, they hold a significant environmental advantage over fossil fuel. There are few disadvantages until disasters occur, in which case entire tracts of land can be irradiated, restricting operations until dissipated. This is arguably better than the smog currently causing various health issues within some large asian cities. Nuclear power therefore has an overwhelmingly positive environmental

impact in comparison to fossil fuel generation. With proper regulation and safety standards, it could be a turning point against global warming.

Nuclear reactors can provide a significant advantage to a government by providing high quantities of power for a very efficient operational cost as compared to coal. They have the additional benefit of being relatively reliable in comparison to wind or hydro. Such advantages come with a high initial cost, however, which is known to be overrun. This means that in order to spur reactor construction, governments will need to provide incentives to companies. Even with such benefits, nuclear power remains a high risk alternative due to unforeseen delays and lack of modern experience to draw upon.

All substantial power generating stations would be a tempting target for malicious attacks, but nuclear power plants have a much higher potential for damage if successfully tampered with. With recent demonstrations of nuclear facility safety breaches, steps should be taken to ensure that such dangerous material is disposed of responsibly,

Nuclear generation has many advantageous aspects in comparison to popular alternatives. Governments should look into safely shepherding nuclear plant construction to eventually become the dominating power source, and put a dent in global carbon emissions.

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