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# Nuclear Energy: Is it the Answer to the Problem of Climate Change?

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***Abstract:*** ***For too many environmentalists concerned with global warming, nuclear energy is today's Devil's excrement. They condemn it for its production and use of radioactive fuels and for the supposed problem of disposing of its waste. Their condemnation of this efficient, low-carbon source of base load energy is misplaced. Far from being the Devil's excrement, nuclear power can be, and should be, one major component of our rescue from a hotter, more meteorologically destructive world. Like all energy sources, nuclear power has advantages and disadvantages. This paper seeks to provide a foundation of what nuclear energy actually is, what are its feasibilities both in terms of economy and environment, followed by an econometric model that studies the positive impacts of nuclear energy at the aggregate level. The penultimate section of the paper focuses on major nuclear attacks and disasters that have occurred during the course of human history.***

**Keywords:** Nuclear Energy Climate Change Quantitative Modeling Efficient fuel

## 1. Introduction

### 1.1 Nuclear Power

Nuclear power is the use of nuclear reactions that release nuclear energy to generate heat, which most frequently is then used in steam turbines to produce electricity in a nuclear power plant. Nuclear energy can be harnessed in 3 ways:-Nuclear fission, Nuclear decay, Nuclear fusion.

Despite the fear that it leakages can create global emergency situations ,this form of energy has created the least fatalities when compared to the other form of energies and it is believed that nuclear energy since its commercialization has prevented around 1.84 billion deaths and 64 billion tonnes of carbon dioxide equivalents.

#### 1.1.1 Nuclear Fission

Nuclear fission is a process in which the nucleus of the atom split into two or more smaller, lighter nuclei. The process has show to release a large amount of energy. Nuclear fission of heavy elements was discovered by the German scientist Otto Hann and his assistant Fritz Strassman. The amount of free energy contained in nuclear fuel is millions of times the amount of free energy contained in a chemical fuel of similar mass such as gasoline, making nuclear fission a very dense source of energy. The products of nuclear fission, however, are on average far more radioactive than the heavy elements which are normally fissioned as fuel, and remain so for significant amounts of time, giving rise to a nuclear waste problem.

Concerns over nuclear waste accumulation and over the destructive potential of nuclear weapons are a counterbalance to the peaceful desire to use fission as an energy source.

Nuclear fission is the process that is used in both the reactors and in weapons except the fact that in weapons there is a chain reaction in an uncontrolled manner.

#### 1.1.2 Nuclear Fusion

It is the process of combining the nuclei of two or more atoms to create one or more atom nuclei and subatomic particles such as neutrons and protons. It is something that occurs at stars that causes them to keep on producing their own energy and emit their own light something that is not found in celestial bodies like planets.

If we consider sun then the atoms of deuterium and tritium combine to form helium, protons, and neutrons. Nuclear fusion is something that at present at earth is not possible on a large scale.

#### 1.1.3 Nuclear Decay

Nuclear decay or Radioactive decay is the process through which an unstable atomic nucleus loses its energy by radiation. A material containing unstable nuclei is considered radioactive. 3 types of nuclear decay are the most prominent: - alpha decay, beta decay and gamma decay.

#### 1.1.4 Nuclear fission: - The feasible way

Despite fusion being a better source of energy it does not produce a chain reaction and it also does not produce large amount of radioactive waste it is an ideal source of energy but still is not possible to harness till date on large scale

For fusion to occur on Earth, you need a temperature of at least 100 million degrees Celsius—six times hotter than the core of the sun. The sun is a natural fusion reactor which makes up for its measly 15 million degrees with the intense pressure created by its core's gravity. Currently, here on Earth the amount of energy you'd need to put in to produce that kind of heat or pressure is much higher than what you get out in usable energy. In spite of several methods of nuclear decay calculations, it is impossible to predict when the atom is going to decay. One of it is The Radioactive Formula where N0 = the initial quantity of the substance and N is the quantity still remaining and not yet decayed and T is the half-life of the decaying quantity and e is the Euler's number equal to 2.71828. The computation is given by N0 = $N.e^{-\lambda t}$

### 1.2 Working of Nuclear Reactors

Nuclear reactors work on the principle of chain reaction where the chain reaction turns water into steam and the pressure of the steam turns the generator that produces electricity. Here instead of using fossil fuels to produce heat, nuclear fission (splitting of atoms) takes place. Nuclear fission is a process in which the nucleus of the atom is slit into two or more smaller, lighter nuclei. Nuclear fission is the process that is used in both the reactors and in weapons except the fact that in weapons there is a chain reaction in an uncontrolled manner.

#### 1.2.1 Elements used in Reactors

Uranium-233, Uranium-235, Plutonium-239 are used in nuclear fission in reactors.
Plutonium-238 is used to produce small amount of nuclear power by radioactive decay in atomic batteries.

For fission reactors, the fuel (typically based on uranium) is usually based on the metal oxide; the oxides are used rather than the metals themselves because the oxide melting point is much higher than that of the metal and because it cannot burn, being already in the oxidized state. An oxide is a chemical compound that contains one oxygen atom and one other element in its chemical formula.

#### 1.2.2 Thorium Based Reactor:-The ideal reactor

Nuclear based thorium reactors are created by the nuclear fission of isotope uranium233 produced from element thorium has been described as the most safest fuel for reactors since its discovery by the US after world war-II through an experimental molten salt reactor using uranium-233 by bombarding thorium with neutrons and 1968 the Nobel laureate Glen Seaborg declared that the reactors were full developed and capable But over the years the reactors were shut down as the thorium breeding ratio was insufficient to produce fuel to develop a commercial nuclear industry. Despite its shortcoming the reactor is the safest form of producing energy as the reaction can be stopped at any point of time and the reaction does not takes place under extreme pressure

India leads in thorium based reactors as it has a quarter of thorium reserves and lacks uranium reserves. The main issue with the world going for uranium rather than the thorium based reactors is the fact that the thorium dioxide has a boiling point of 3300 degrees Celsius which is the highest among the oxides. But since commercialization of the nuclear energy and mans greed the thorium based reactors have been neglected in favor of uranium isotopes that creates a large amount of radioactive waste which needs to be disposed off carefully.

### 1.3 Positives of Nuclear Energy

#### 1.3.1 Cost competitiveness

The initial construction costs of nuclear power plants are large. On top of this, when the power plants first have been built, we are left with the costs to enrich and process the nuclear fuel (e.g. uranium), control and get rid of nuclear waste, as well as the maintenance of the plant. The reason this is under advantages is that nuclear energy is cost-competitive. Generating electricity in nuclear reactors is cheaper than electricity generating from oil, gas and coal, not to speak of the renewable energy sources.

#### 1.3.2 Flexible Base Load

Nuclear power plants provide a stable base load of energy. This can work synergistic with renewable energy sources such as wind and solar. The electricity production from the plants can be lowered when good wind and solar resources are available and cranked up when the demand is high.

#### 1.3.3 Thorium

Reports show that with the yearly fuel consumption of today's nuclear power plants, we have enough uranium for 80 years. It is possible to fuel nuclear power plants with other fuel types than uranium.

**Table 7.1:** Dataset for regression; *Y variable-mortality from exposure to ambient PM 2.5; **X variable- Nuclear energy generation in the United States

| Year | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y variable (per million people)* | 372.67 | 373.71 | 362.28 | 340.54 | 306.29 | 316.75 | 298.24 | 291.06 | 277.73 | 276.34 | 259.24 | 263.23 |
| X variable (Mega watt hours)** | 567.86 | 673.4 | 753.89 | 781.98 | 806.96 | 790.2 | 769.33 | 789.01 | 797.16 | 797.17 | 805.69 | 804.94 |

Thorium, which also is a greener alternative, has lately been given an increased amount of attention. China, Russia and India have already plans to start using thorium to fuel their reactors in the near future.

It looks like nuclear fuel is of good availability if we combine the reserves of the different types together. In other words, hopefully enough time for us to find cost-competitive greener ways of harnessing energy.

#### 1.3.4 Sustainable

Is nuclear energy renewable or non-renewable? This is a good question. By definition, nuclear energy is not a renewable energy source. As mentioned above, there is a limited amount of fuel for nuclear power available.

On the other hand, you could argue that nuclear energy is potentially sustainable by the use of breeder reactors and fusion reactors. Nuclear fusion is the holy grail of harnessing energy. If we can learn to control atomic fusion, the same reactions as those that fuel the sun, we have practically unlimited energy. At the moment, these two methods have serious challenges that need to be dealt with if we are to start using them on larger scale.

#### 1.3.5 High energy density

It is estimated the amount of energy released in a nuclear fission reaction is ten million times greater than the amount released in burning a fossil fuel atom (e.g. oil and gas). Therefore, the amount of fuel required in a nuclear power plant is much smaller compared to those of other types of power plants.

**1.4 Studying the numbers behind nuclear energy (econometric analysis)**

In order to study the positive impacts of nuclear energy on environment, a somewhat different variable has been taken under study. This is the mortality rate from ambient PM 2.5, which is the most common source of pollution from the conventional sources of energy.

The other variable is the nuclear energy generation in the United States. While the former variable has been taken to be the dependant variable, the latter is the independent variable because clearly the line of reasoning is: - as there is more and more dependence on nuclear energy, there is expectation of a much lower mortality rate from exposure to ambient PM 2.5. (Table-7.1). There are 2 reasons why US statistics have been chosen. One, they are readily available. Two, US is one of the largest nuclear energy generators in the world.

**Table 7.2:** ANOVA output

| Regression Statistics | Value |
|---|---|
| Multiple R | 0.76391 |
| R Square | 0.58357 |
| Adjusted R square | 0.541927 |
| Standard error | 28217149 |
| Observations | 12 |

Having a look at figure 7.2), one can easily conclude that the study is of no empirical use since the r-square is too low. However, it must be noted from figure 7.3 that the x variable i.e. nuclear energy generation has a very large and negative t-statistics which points to the statistical significance of the variable.

A close analysis of the regression results reveals that the x-variable is significant even at a confidence level as high as 96%, as revealed by a p-value of 0.038.

As far as the low value of r-square is concerned, the reasons can be manifold. One, it could be due to the fact that very few observations are used in the analysis. Two, it could be possible that there are many other factors leading to a decline in mortality from PM 2.5, besides expansion of nuclear energy. Better healthcare, better enforcement laws prohibiting pollution and increased awareness among the public could well be the additional factors driving down the ambient PM 2.5 levels during the period between 1990 and 2017 in the United States.

Notwithstanding the limitations, the conclusion is simple and clear- an expansion in the nuclear energy around the globe has a great potential in terms of reviving the environment by means of reducing the mortality rate by ambient PM 2.5 levels.

**Table 7.3:** Regression results

| Variable | Coefficients | Standard error | t-stat | p-value | Lower 95% | Upper 95% |
|---|---|---|---|---|---|---|
| Intercept | 663173176.3 | 94293527.7 | 7.033 | 3.57E-05 | 453074104.5 | 873272248 |
| Nuclear Energy Generation | -461373.9235 | 123247.293 | -3.743 | 0.038246 | -735986 | -186761.84 |

## 2. Major risks associated with nuclear energy

The main risk with nuclear energy is associated with power plant meltdowns. Any nuclear power plant process a high amount of energy. Despite having international safety standards, lack of implementation in developing countries raises the risk of meltdowns. A meltdown leads to leakage of high levels of radiations into the environment due to which nearby area of plant become inhabitable.

The second risk associated with the energy is wars. Nuclear energy was primarily developed for use in weapons. World has seen only one instance of nuclear war till now. The use of nuclear weapons is disastrous. A larger access to the energy can increase the risk of use of nuclear weapons.

Also, there is no method of decomposing the waste generated by nuclear plants. The waste remains radioactive for thousands of years. This creates risk of leakage in the waste containers. Lastly, nuclear power plants can be an easy target for terrorist groups. This can lead to meltdown problem.

## 3. How Nuclear Accidents and Wars affect Environment

Any nuclear disaster starts with a blast or thermal radiation. Temperature of the spot rises to 1-2 million degree Celsius. Any person within the range of blast immediately dies because of heat. After that radiation starts leaking into environment. It increases the risk of casualties due to exposure to acute radiations and skin cancer. This radioactive material then fallout into the environment like water bodies and farm land. It come back into the human food chain and increases the risk in the medium term. Finally, it also increases the risk of mutation which leads to increase in birth of abnormal babies.

Any area affected by nuclear energy remains inhabitable for many because of the stated reasons. It makes the nuclear energy extremely risky. Any human error can affect the millions of people.

## 4. Nuclear attacks and major disasters

### 4.1 Little Boy and Fat Man

Little boy and fat man were the code names of two bombs used in 1945 atomic attack on Japan. The United States detonated two nuclear weapons over the Japanese cities of Hiroshima and Nagasaki on August 6 and 9, 1945, respectively, with the consent of the United Kingdom, as required by the Quebec Agreement.

The two bombings killed between 129,000 and 226,000 people, most of whom were civilians, and remain the first and only uses of nuclear weapons in armed conflict. 92% of the building structure got destroyed in Hiroshima.

Although bomb used on Nagasaki was more powerful. Destruction in Nagasaki was comparatively less than Hiroshima mainly because Nagasaki is surrounded by the mountains which helped in limiting the impact of attack.

This is the only nuclear attack in history and since this attack was done at a time when this technology was limited to America the impact was only faced by Japan. Any future nuclear war can have even more dangerous consequences because now many countries have access to nuclear weapons.

### 4.2 Chernobyl Disaster

The Chernobyl disaster was a nuclear accident that occurred on Saturday 26 April 1986, at the No. 4 nuclear reactor in the Chernobyl Nuclear Power Plant, It is considered the worst nuclear disaster in history and is one of only two nuclear energy disasters rated at seven—the maximum severity—on the International Nuclear Event Scale. The accident started during a safety test on an RBMK-type nuclear reactor, which was commonly used throughout the Soviet Union. A combination of unstable conditions and reactor design flaws caused an uncontrolled nuclear chain reaction instead. A large amount of energy

was suddenly released, vaporizing superheated cooling water and rupturing the reactor core in a highly destructive steam explosion. This was immediately followed by an open-air reactor core fire that released

considerable airborne radioactive contamination for about nine days that precipitated onto parts of the USSR and Western Europe, before being finally contained on 4 May 1986. The reactor explosion killed two of the reactor operating staff. In the emergency response that followed, 134 station staff and firemen were hospitalized with acute radiation syndrome due to absorbing high doses of ionizing radiation. Of these 134 people, 28 died in the days to months afterward and approximately 14 suspected radiation-induced cancer deaths followed within the next 10 years. Model predictions with the greatest confidence values of the eventual total death toll in the decades ahead from Chernobyl releases vary, from 4,000 fatalities when solely assessing the three most contaminated former Soviet states, to about 9,000 - 16,000 fatalities when assessing the total continent of Europe. It is approximated that about 400 times more radioactive material released from Chernobyl than the Hiroshima and Nagasaki bombing. More than 5 million lives were affected because of disaster.

### 4.3 Fukushima Daiichi Disaster

Fukushima Daiichi is the only other nuclear disaster to be given level 7 event classification on International nuclear event scale, after Chernobyl. The accident was started by the Tōhoku earthquake and tsunami on Friday, 11 March 2011. On detecting the earthquake, the active reactors automatically shut down their fission reactions. The earthquake generated a 14-meter-high tsunami that swept over the plant's seawall and flooded the plant's lower grounds around the Units 1–4 reactor buildings with sea water, filling the basements and knocking out the emergency generators. The resultant loss-of-coolant accidents led to three nuclear meltdowns, three hydrogen explosions, and the release of radioactive contamination in Units 1, 2 and 3 between 12 and 15 March. In the days after the accident, radiation released to the atmosphere forced the government to declare an ever larger evacuation zone around the plant, culminating in an evacuation zone with a 20-kilometer radius. All told, some 154,000 residents evacuated from the communities surrounding the plant due to the rising off-site levels of ambient ionizing radiation caused by airborne radioactive contamination from the damaged reactors. Large amounts of water contaminated with radioactive isotopes were released into the Pacific Ocean during and after the disaster.

While there has been ongoing controversy over the health effects of the disaster, a 2014 report by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and World Health Organization projected no increase in miscarriages, stillbirths or physical and mental disorders in babies born after the accident. An ongoing intensive cleanup program to both decontaminate affected areas and decommission the plant will take 30 to 40 years, plant management estimate.

## 5. Way Forward

Nuclear energy is environment friendly and can be a great substitute for conventional source of power generation but radioactive properties of energy also make it a very risky alternative. World can adopt the new source of energy but need to take some precautions before using it. World must promote nuclear deals to increase civil use of energy. These deals can help developing world to obtain the necessary technology and raise the required fund, since the initial cost required for constructing a nuclear power plant is very high. Also we need to promote the role of IAEA (International Atomic Energy Agency) at international level. IAEA must set the safety standards and enforce them on all nations to minimize the risk.

Also, steps needs to be taken by developed world to restrict the use of atomic energy for military purpose. For example, US imposing restrictions on Iran is a good step to discourage nations to obtain nuclear weapons. Also we need a comprehensive plan to manage the waste created by nuclear plants. As these waste can be very hazardous, if came back into environment.

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