

Power Source of the Future

“I have neither given or received, nor have I tolerated others' use of unauthorized aid.”

Ideas, arguments, and debates about energy sources, consumption, and sustainability continue to emerge as society moves forward. Renewability, environmental friendliness, and economics all have to be considered while accounting for the relevance of a certain energy source in any context[2]. Nuclear energy is one of the many available energy resources that is in the forefront of the renewable energy conversation. Because of the several underlying advantages associated with nuclear energy, a significant amount of time, capital, and effort is being invested in its development[3]. Though there are some people who argue against the use of Nuclear Energy due to the high mortality rate associated with it, the superior fuel efficiency of the nuclear source compared to fossil fuel, the favorable economics of the energy generation, and the environmental friendliness of the nuclear fuel all make it a potentially rewarding energy source.

According to several sources and government agencies, nuclear energy is currently the most efficient power source in terms of the fuel required for operation. When comparing fossil fuel, which generates 0.35 MWd/t (MegaWatts -days per metric tonne) of energy, to Uranium source, which burns up 800,000 MWd/t [1], this implies that one metric tonne of Nuclear source of fuel (Nuclear Fission (100% U-235)) generates around 2,715,385 more energy than fuel from coal, which is a fossil fuel. This absolute difference between the fuel used in energy production shows very high energy density for uranium when compared with coal.

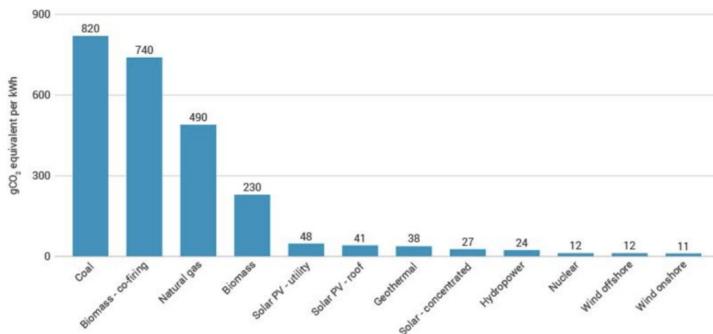


Figure 1 :Demonstration between different energy per unit KWH between different sources of energy.

However, the current open nuclear fuel cycle results in low energy efficiency, converting only 1% of the uranium energy content into electricity and producing large volumes of nuclear waste[2]. More advanced nuclear reactors, which are currently under development, are expected to allow more efficient use of nuclear energy. The Generation IV power plant focuses on selection of fuel cladding material based on many design constraints, such as neutron absorption cross section, mechanical strength, toughness, neutron radiation resistance, thermal conductivity, and chemical compatibility[3]. Gascooled, water-cooled and fast-spectrum are different types of Nuclear Power plants to be implemented in Generation IV. The pebble-bed reactor design is a special type of gas cooled power plant based on a fundamental fuel element, called a pebble, that is a billiard-ball-size graphite sphere containing about 15,000 uranium oxide particles. This small size and the general simplicity of pebble-bed reactor design increases the per unit output energy. Each power module, producing 120 megawatts of electrical output, is one tenth the size of today's central station plants, thus increasing the efficiency of new design[3]. This shows us that Nuclear Energy operates at higher efficiency than any other source of energy

like fossil fuel. In addition, the constant improvement in technology and the techniques being implemented such as fuel cladding are expected to further increase the efficiency.

Nuclear energy is a desired source of energy due to its environmental friendliness. Nuclear energy is generated by the process of fission of nuclei rather than chemical burning. During nuclear fission atoms are split apart to form smaller atoms, releasing energy. Therefore it is referred to as a “clean” energy source, unlike other fuel sources, which produce greenhouse gases, such as carbon dioxide, methane, sulfur dioxide, and nitrogen oxides. Coal-fired generation gives rise to twice as much carbon dioxide as compared to nuclear energy sources which do not directly contribute any carbon footprints.[4] If all the world's coal-fired power were replaced by nuclear power plant, electricity's carbon dioxide emissions (now at least 11 billion tonnes per year) would fall by a quarter – about 3 billion tonnes per year.[5] However there is still carbon emissions from nuclear power, and most forms of renewable energy which are small – all emitting less than 100 grams of CO₂/kWh, one-tenth of the value for today's coal plants.[6] Uranium mining facilities produce tailings that generally are disposed of in near a water body close to the mine. These tailings cause serious environmental and health risks in the form of Radon emission, leaching of contaminants including heavy metals into the water. Researchers are seeking progress in the management of the waste and risks of Uranium mining[7]. Historic strategies for treating Uranium mines have included capping to reduce radon emanation and reactions that promote leaching, and drainage systems to collect and remove harmful products. These strategies have been extremely successful thus lowering the pollution level. Switching to nuclear power eliminates the production of any greenhouse gases and the byproduct produced thus helping us to keep our environment safer.

Nuclear Energy provides energy for a long period of time with low operation cost, but has high-capital investment in deregulated markets . Since the initial cost is a substantial amount of money, there are multiple economic strategies by the Nuclear Energy Generation companies to fund the new power plant. Debt financing is one of the major strategies where a loan is provided to a project's promoters for a given portion of the expected project cost. Another option is equity financing where an investor provides funding in exchange for a stake in a project. The government and other private sectors are the biggest contributors to the project's funds, they hold the majority stake in the equity, which makes it much easier to raise cost-effective debt. An example for government investment is the Qinshan 1 nuclear power plant in China, but private investment is widely used in France, Korea, Russia, the UK, and the USA. The Nuclear Energy Agency calculated the overnight cost for a nuclear power plant built in 1990, which cost \$19000/kWe (kilo watts) and they found that the cost declined to \$3850/kWe in 2009 [7]. This highlights that even after accounting for the interest rates, the cost to produce energy per kilowatt has decreased significantly.

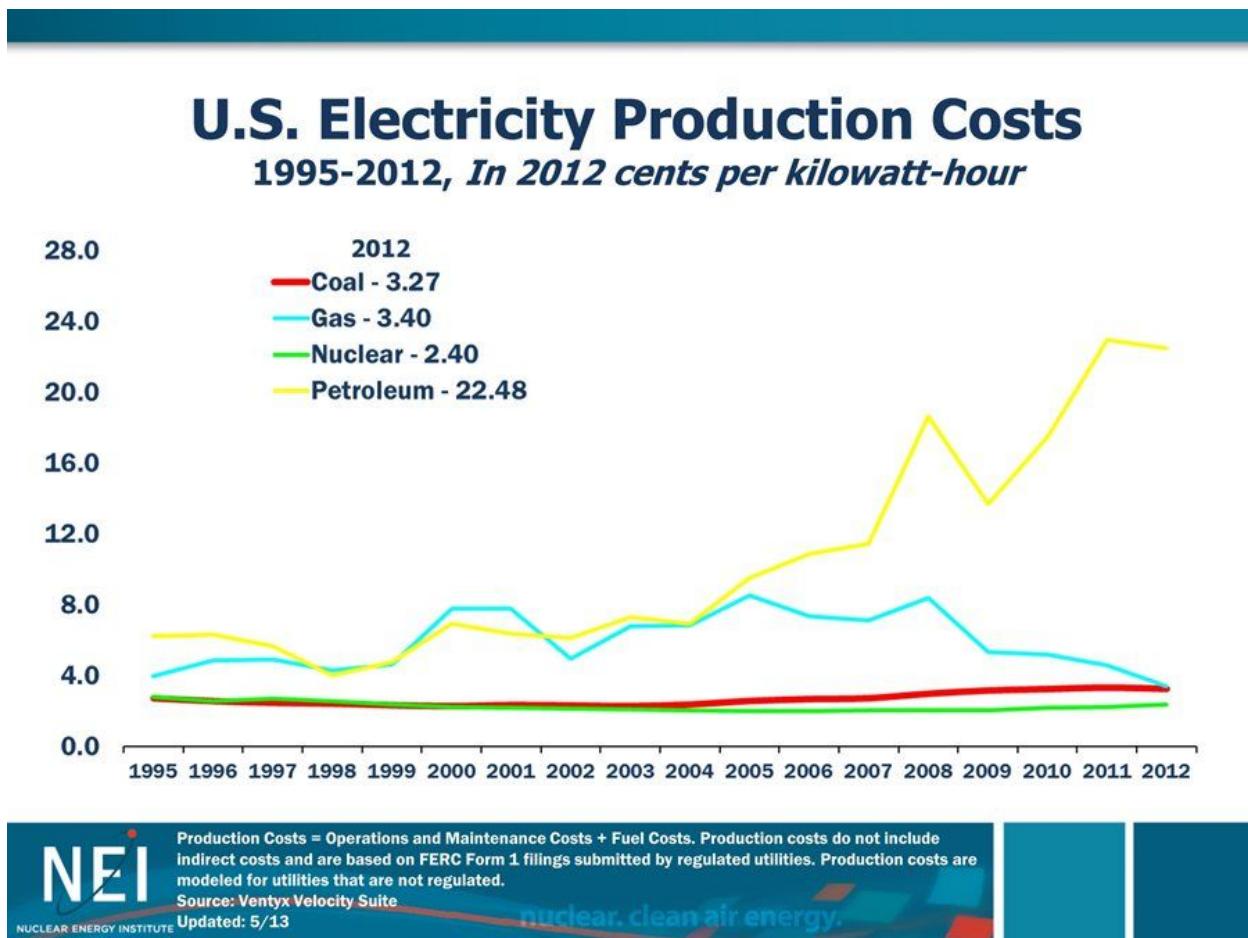


Figure 2 :Demonstration between different production costs between different sources of energy.

Another benefit of this source of energy is its price stability, doubling the price of uranium would cause only a 5–6 percent increase in the total generation cost of nuclear energy, while the same increase in price of natural gas would lead to a 65 percent increase in gas-fired costs.[8] This shows that in spite of the same fluctuation in the energy source ,the user of Nuclear fuel is impacted less as compared to the user of fossil fuel.A 2004 report from the University of Chicago, funded by the US Department of Energy, compared the levelised power costs of future nuclear, coal, and gas-fired power generation in the USA. Various nuclear options were covered, and for an initial ABWR(Advanced boiling water reactor) they range from 4.3 to 5.0 c/kWh on the basis of overnight capital costs of \$1200 to \$1500/kW, 60 year plant life, 5 year construction

and 90% capacity. Coal gives 3.5 - 4.1 c/kWh and gas CCGT (Combined Cycle Gas Turbines) 3.5 - 4.5 c/kWh, depending greatly on fuel price.[9] Therefore Nuclear power is cost competitive with other forms of electricity generation.

Due to accidents that occurred in the past many people fear Nuclear energy. The 2011 Fukushima disaster showed the world that nuclear power is fundamentally unsafe. The meltdown at the Fukushima I Nuclear Power Plant was the worst since Chernobyl in Ukraine, 25 years earlier. The earthquake and tsunami caused an accident at the Fukushima Daiichi nuclear power plant in Japan and resulted in repeated fires and three reported core meltdowns. At the latest count, the Fukushima had caused \$166 billion in damages and at least 573 immediate deaths from the evacuation, along with hundreds of future deaths related to cancer anticipated to occur [10]. The Chernobyl accident in 1986 was the result of a flawed reactor design that was operated with inadequately trained personnel [11]. The Three Mile Island Unit 2 reactor, near Middletown, on March 28, 1979 is the most serious accident in United States nuclear power plant operating history. There were small radioactive releases and had no detectable health effects on plant workers or the public. A combination of equipment malfunctions, design-related problems and worker errors led to TMI-2's partial meltdown and very small off-site releases of radioactivity[12]. The aftermath from the accidents brought about sweeping changes involving emergency response planning, reactor operator training, human factors engineering, radiation protection, and many other areas of nuclear power plant operations. It also caused the NRC(Nuclear Science Regulatory Commission) to tighten and heighten its regulatory oversight which prevent on causing any accidents in the future. When we compare the mortality rate among all the sources of energy, nuclear energy is at 4% while the two other sources of energy is coal at 29% and oil at 31%. Now looking at a few accidents over the past 50 years Three Mile Island

(USA 1979) had no adverse health or environmental consequences, Chernobyl had fire killed two people initially plus a further 28 from radiation poisoning within three months, and had significant health and environmental consequences, Fukushima (Japan 2011) and no deaths or serious injuries due to the accident. To future make this resource an safest form of energy the The national regulator is responsible for operation and checking of Nuclear power plants. Introduction of new reactor designs on a more international basis since the 1990s, has helped greater design standardisation and regulatory harmonization in this industry. Reports from OECD Organisation for Economic Co-operation and Development and NEA(Nuclear Energy Agency) in 2010 talked the theoretically-calculated large frequency of radioactivity from a nuclear power plant leading to accident has reduced by a factor of 1600 between the early Generation I reactors and the Generation III/III+ plants being built today[13]. Nuclear energy is the safest source of energy and the people involved in this industry are further working to have a strict guideline and constantly improving to provide a clean ,reliable and efficient energy without any compromisation in our health.

Therefore, the superior fuel efficiency of the nuclear source compared to fossil fuel, the favorable economics of the energy era, and the environmental friendliness of the nuclear fuel all make it a possibly fulfilling energy. Because of the aforementioned advantages associated with nuclear energy, I believe there should be more time, capital, and serious efforts invested on the development and expansion of the current nuclear energy research and development. With an ever growing human population and the need to sustain ambitious human endeavors, energy optimization is an issue that should be in the midst of our energy related debates and policies.

Citation

[1]“Fossil fuels continue to account for the largest share of U.S. energy - Today in Energy - U.S. Energy Information Administration (EIA),” Eia.gov. [Online]. Available:

- <https://www.eia.gov/todayinenergy/detail.php?id=41353>. [Accessed: 10-Sep-2020]
- [2]“Nuclear Energy Agency - Sustainable development,” Oecd-nea.org. [Online]. Available: <https://www.oecd-nea.org/sd/>. [Accessed: 10-Sep-2020]
- [3]“Nuclear Energy Agency - Sustainable development,” Oecd-nea.org. [Online]. Available: <https://www.oecd-nea.org/sd/>. [Accessed: 10-Sep-2020]
- [4]F. I. T. Petrescu et al., “Environmental protection through nuclear energy,” Am. J. Appl. Sci., vol. 13, no. 9, pp. 941–946, 2016.
- <https://www.world-nuclear.org/focus/climate-change-and-nuclear-energy/climate-change-the-science.aspx>.
- [5]K. Vaillancourt, M. Labriet, R. Loulou, and J.-P. Waaub, “The role of nuclear energy in long-term climate scenarios: An analysis with the World-TIMES model,” Energy Policy, vol. 36, no. 7, pp. 2296–2307, 2008.
- [6]Global warming and climate change - the science - world nuclear association,” World-nuclear.org. [Online]. Available: <https://www.world-nuclear.org/focus/climate-change-and-nuclear-energy/climate-change-the-science.aspx>.
- [7]C. Arnold, "Once Upon a Mine: The Legacy of Uranium on the Navajo Nation," Environ. Health Perspect. 122, A44 (2014).
- [8] “The Economics of Nuclear Power,World-nuclear.org.” [Online]. Available: <http://www.world-nuclear.org/uploadedFiles/org/info/pdf/EconomicsNP.pdf>
- [9]“Safety of nuclear reactors - World Nuclear Association,” World-nuclear.org. [Online]. Available:<https://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/safety-of-nuclear-power-reactors.aspx>.
- [10]U. S. Epa and OAR, “Radioactive waste from uranium mining and milling,” 2018
- [11]“Chernobyl,” World-nuclear.org. [Online]. Available: <https://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/chernobyl-accident.aspx>. [Accessed: 01-Oct-2020].
- [12]“Backgrounder on the Three Mile island accident,” Nrc.gov. [Online]. Available: <https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html>. [Accessed: 07-Nov-2020].
- [13]“Global warming and climate change - the science - world nuclear association,” World-nuclear.org. [Online]. Available: <https://www.world-nuclear.org/focus/climate-change-and-nuclear-energy/climate-change-the-science.aspx>. [Accessed: 16-Nov-2020]