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Nuclear Energy, Environmental Protection and Sustainable Development

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Abstract. Nuclear energy is a proven technology for large scale base load electricity generation which can reduce dependence on imported gas and carbon dioxide (CO_2) emission, less vulnerable to fuel price changes than coal- and gas-fired power plants. With the discoveries of fertile Thorium fuel cycles that offer attractive features, including lower level of waste generation, less dangerous, less expensive, more accessible and more environmentally friendly option for nuclear fuel supply- this is against Uranium fuel cycle that most of the present reactors were built on. Furthermore, with the latest innovation of fast breed reactors (FBR) which offer more efficient use of uranium resources and the ability to burn actinides which are otherwise the long-lived component of high-level nuclear wastes. In this submission, we will also look at environmental protection in line with sustainable development and how nuclear energy is in conformity with the environmental protection.

Keywords: Nuclear, Environmental Protection, Sustainability, Ozone Layer and Global Warming.

1. Introduction

Many countries are currently facing energy crisis because the electricity required to grow the economy and drive local development is inadequate [1]. The growth, prosperity and security of any country depend, to a large extent, on the adequacy, efficiency and functionality of its electricity industry. Therefore, unreliable power supply constitutes a major challenge to economic growth and development More so, the traditional energy solution has relied heavily on fossil fuel for power generation which is becoming unsustainable. Increasing frequency of global warming induced extreme events such as droughts and floods are undermining the generation capacity of hydropower generation, which has also come under pressure because of its negative impacts on people and ecosystems. Energy plays the most vital role in the economic growth, progress, and development, as well as poverty eradication and security of any nation. Accordingly, uninterrupted energy supply is a vital issue for all countries today because future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible, and environmentally friendly. Also security, climate change, and public health are closely interrelated with energy. Energy is an important factor in all the sectors of any country's economy. The standard of living of a given country can be directly related to the *per capita* energy consumption. The recent world's energy crisis is due to two reasons: the rapid population growth and the increase in the living standard of whole societies. The *per capita* energy consumption is a measure of the *per capita* income as well as a measure of the prosperity of a nation. Similarly, energy is essential for human development and energy systems are a crucial entry point for addressing the most pressing global challenges of the 21st century, including sustainable economic, and social development, poverty eradication, adequate food production and food security, health for all, climate protection, conservation of ecosystems, peace, and security [2]. Yet, more than a decade into the 21st century, current energy systems do not meet these challenges.

2. Issues on Environmental Degradation

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Environmental degradation is the deterioration in environmental through depletion of resources such as air, water and soil, the destruction of ecosystems and the extinction of wildlife [3]. Generally it can be referred to as any change or disturbance to the environment perceived to be deleterious or undesirable. Environmental degradation has many forms and can occur naturally or through human processes.

However, environmental problems can be regional (such as acid rain or forest fires), international (such as climate change or ozone layer loss) or national (such as overfishing, deforestation, overgrazing, soil erosion, over mining, biodiversity loss, and the loss of cultural heritage) in character. Consequently, severe environmental degradation can affect a country's macroeconomic performance over the long run. If not dealt with appropriately and early, environmental problems could eventually impose a heavy burden on an economy and hamper growth [4].

Topical issues on environmental degradation are as follows:

2.1. Ozone Layer

The ozone layer is responsible for absorbing the ultraviolet rays and thereby preventing them from passing through the atmosphere of Earth. Ozone is a molecule containing three oxygen atoms (O_3). It is blue in color and has a strong odor. Normal oxygen, which we breathe, has two oxygen atoms and is colorless and odorless. Ozone is much less common than normal oxygen. Out of each 10 million air molecules, about 2 million are normal oxygen, but only 3 million are ozone [5]. However, even the small amount of ozone plays a key role in the atmosphere. The ozone layer absorbs a portion of the radiation from the sun, preventing it from reaching the planet's surface. Most importantly, it absorbs the portion of ultraviolet type B light called UV-B. UVB has been linked to many harmful effects, including various types of skin cancer, cataracts, and harm to some crops, certain materials, and some forms of marine life. This means that the effects of ozone depletion are not limited to humans only, as it can affect animals and plants as well. Therefore, ultraviolet rays of the Sun are associated with a number of health and environmentally related issues. According to Ref [6] chlorofluorocarbon (CFC) contains chlorine, fluorine and carbon atoms. UV radiation breaks oxygen molecules (O_2) into single oxygen atoms and the chlorine atom is then free to attack another ozone molecule again. Therefore, the chain reaction continues as shown in the following equations.

$$CFCl_3 + \text{UV Light} \Longrightarrow CFCl_2 + Cl$$
$$Cl + O_3 \Longrightarrow ClO + O_2$$
$$ClO + O \Longrightarrow Cl + O_2$$

However, the overall effect is a decrease in the amount of ozone.

2.2. Acid Rain

Acid rains is a broad term referring to a mixture of wet and dry deposition (deposited material) from the atmosphere containing higher than normal amounts of nitric and sulfuric acids [7]. Accordingly the precursors of acid rain formation result from both natural sources, such as volcanoes and decaying vegetation and man-made sources such as fossil fuel combustion with the primarily emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x). Therefore, acid rain occurs when these gases react in the atmosphere with water, oxygen, and other chemicals to form various acidic compounds. The result is a mild solution of sulfuric acid and nitric acid.

2.3. Global Warming

Global warming is the gradual increase in the average temperature of the Earth's atmosphere and its oceans, a change that is believed to be permanently changing the Earth’s climate [8]. The scientific consensus on climatic changes related to global warming is that the average temperature of the Earth has risen between 0.4 and 0.8 ℃ over the past 100 years. The increased volumes of carbon dioxide and other greenhouse gases released by the burning of fossil fuels, land clearing, agriculture, and other human activities, are believed to be the primary sources of the global warming that has occurred over the past 50 years. Scientists from the Intergovernmental Panel on Climate carrying out global warming research have recently predicted that average global temperatures could increase between 1.4 and 5.8 ℃ by the year 2100. Changes resulting from global warming may include rising sea levels due to the melting of the polar ice caps, as well as an increase in occurrence and severity of storms and other severe weather events.

2.4. Consequences of Radioactive Waste Management

One of the most difficult problems associated with nuclear power is the disposal of wastes produced during mining, fuel production, and reactor operation [9]. Accordingly, how these wastes are managed may ultimately be the overriding obstacle to nuclear power.

3. Sustainable Development

Sustainable development is the development which meets the needs of the present without compromising the ability of future generations to meet their own needs [10]. The concept that was clearly articulated in 1987 through the publication of a United Nations report our "common future", known also as the Brundtland report. Although the ''Brundtland'' report has identified critical objectives for the environment and development, the concept of Sustainable Development needed strengthening by an international legal framework. Fortunately, this was accomplished in June, 1992 in Rio-De-Jeneiro, Brazil under the United Nations Conference on Environment and Development also known as the Earth Summit.

3.1. Sustainability in Fast Breed Reactors (FBR) and High Temperature Reactors (HTR)

Fast reactors use the uranium-238 as well as the fissile U-235 isotope used in most reactors [11]. If they are designed to produce more plutonium than they consume, they are called Fast Breeder Reactors (FBR). The FBR can also burn long-lived actinides which are recovered from used fuel out of ordinary reactors. Therefore, several countries have research and development programs for improved FBR. There has been progress on the technical front, but the economics of FBRs still depends on the value of the plutonium fuel which is bred and used, relative to the cost of fresh uranium. Also there is an international concern over the disposal of ex-military plutonium, and there are proposals to use fast reactors as burners for this purpose. In both respects the technology is important for long-term considerations of world energy sustainability. According to Ref [12], fast reactors operating in a closed fuel cycle would be able to provide energy for thousands of years as well as easing concerns about waste. More so, fast reactors are versatile and flexible technology that promises to create or breed more fuel by converting nuclear waste into fissile material. The High Temperature Reactor (HTR) innovation concept is also an advanced reactor concept that can meet the energy and environmental needs of future generations [13]. HTR is suitable for burning Plutonium most effectively, as well as to minimize the amount of it to be disposed and even with the use of a Thorium based fuel cycle would produce a small amount of toxic fuel waste or long-lived radiotoxic waste, both of which contribute substantially to anxieties about disposal of nuclear waste.

3.2. Sustainability in Coal- And Gas-Fired Power Plants

There is no perfect energy source. Each and every one has its own advantages and compromises [14]. No doubt the least destructive form of clean coal is underground coal gasification (UCG). This is where the coal is left in the ground and converted to gas by chemical means and then sucked up to the surface where it is burned. Most of these projects include capturing the CO_2 and then sequestering it. According to Ref [15] coal plays a vital role in electricity generation worldwide. For instance, coal-fired power plants currently fuel 41% of global electricity and 85% in Republic of South Africa [16] coal. In as much as it is in abundant supply with concentration in industrialized countries, relatively inexpensive with high load factor and mature industry, it has a lot of demerits to the environment [17]

3.3. Underground Coal Gasification

UCG is a method of converting coal that is still in the ground into a combustible gas which can be used for industrial heating, power generation or the manufacture of hydrogen, synthetic natural gas or diesel fuel [18], [19]. The basic UCG process involves drilling two wells into the coal mine, one for injection of the oxidants (water/air or water/oxygen mixtures) and another well some distance away to bring the product gas to the surface and the coal at the base of the first well is then heated to temperatures that would normally cause the coal to burn. According to Ref [18], through careful regulation of the oxidant flow, the coal does not burn but rather separates into the syngas. The syngas is then drawn out of the second well. Therefore, UCG turns this resource into high value products by providing clean power, liquid fuels, syngas, fertilisers and other chemical feedstocks.

3.4. Carbon Capture Storage (CCS)

CCS is a set of technologies that can greatly reduce CO_2 emissions from new and existing coal- and gas-fired power plants and large industrial sources [20]. CCS is a three-step process that includes, capturing the carbon dioxide (CO_2) from power plants or industrial processes, transporting the captured and compressed CO_2 (usually in pipelines), and underground injection and geologic sequestration (also referred to as storage) of the CO_2 into deep underground rock formations. These formations are often a mile or more beneath the surface and consist of porous rock that holds the CO_2. Overlying these formations are impermeable, non-porous layers of rock that trap the CO_2 and prevent it from migrating upward. After capture, however, carbon dioxide (CO_2) is compressed and then transported to a site where it is injected underground for permanent storage also known as sequestration. It is commonly transported by pipeline, but it can also be transported by train, truck, or ship. According to Ref [21], CCS uses established technologies to capture, transport and store carbon dioxide emissions from large point sources, such as power stations. It also has an important role to play to ensure manufacturing industries, such as steel and cement, can continue to operate, without the associated emissions. CCS is a key tool in tackling climate change, providing energy security, creating jobs and economic prosperity. Similarly, the principal rationale behind any effort to sequester carbon is to mitigate the progression and further impact of climate change. Given its high mitigation potential, CCS technology is often regarded as particularly relevant to our three case countries, which along China are seen as critical actors in any global mitigation scenario. India and Brazil are already the world's fifth- and seventh-largest emitters in absolute terms, respectively; while South Africa has one of the highest emissions rates per capita [22].

4. Conclusion

The importance of electricity cannot be overemphasized and improving access to electricity worldwide is critical to alleviating poverty. However, the environmental resources available to man, animals, plants and the entire ecosystem are very vulnerable and require strategic planning to carter for our generation and subsequent ones. And to imbibe this concept of sustainable development and sustainable energy, we will require a return to a clean energy that is sustainable: that does not contribute to environmental degradation. But, for nuclear energy to significantly contribute to sustainable energy development we cannot depend on burner reactors that will quickly use earth's uranium resources. Instead research and development of safer breeder reactors and increase on the research on HTR which is an advanced reactor concept that can meet the energy and environmental needs of future generations will be necessary. To avoid large stockpiles of weapons-grade plutonium, which is being inevitably accumulated, one alternative for the management of Plutonium is to incinerate it in the reactors with a thorium based fuel cycle in the HTR which is suitable for burning Plutonium most effectively, as well as to minimize the amount to be disposed. A Thorium based fuel cycle would produce small amount of toxic fuel waste or long-lived radiotoxic waste, both of which contribute substantially to anxieties about disposal of nuclear waste. Similarly, the global contribution of using fossil as a source of fuel in generating electricity is very high but, the control system of underground coal gasification (UCG) and sequestering is a welcome finding to sustainable development. However, with soaring oil and natural gas prices coupled with worries about global warming due to fossil fuel, nuclear scientist still believe that nuclear energy is a better option as it offers competitively priced, base load electricity which is essentially free of greenhouse gas emissions combined with enhancement of energy supplies security.

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