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A STUDY ON NUCLEAR ENERGY: SUSTAINABLE SOLUTION FOR ENSURING ENERGY SECURITY OR EMERGING FUTURE THREAT

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ABSTRACT

Sustainability is characterized by the environmental friendly process best fitted for eco-systems and the capacity to maintain a process smoothly indefinitely. Maintaining sustainability in every aspect is the key for continuing human race in the long run. Recent energy insecurity problem and global climate change has led the concerned to take a fresh look at the benefits and risks of nuclear power for better future and find out a sustainable solution. Risk from fatal accident and radioactive waste management for a long period of time surely diminish the benefits of nuclear power, such as no green house gas emission and significant amount of power supply with minimum infrastructural development. As nuclear power is all about balancing the benefit and the risk, therefore this paper summarizes the benefit and risk causing from nuclear power to find out a sustainable choice for future energy demand.

Keywords: Nuclear energy, climate change effects, radioactivity, energy demand, sustainable development.

1. INTRODUCTION

Modern age is passing an energy deficient time and the coming days will definitely be starved for energy. About 1.4 billion people (20% of the global population) do not have access to electricity and 2.7 billion people (40% of global population) rely on traditional biomass for basic energy needs such as cooking and heating [1]. Increasing global energy demand combined with the need to minimize Green House Gas (GHG) emission will require the diversification of energy sources, while still ensuring that the bottom 2 billion people- those who live on less than USD 2.5 per day have access to modern energy services. Achieving the goal set in April, 2010 by the UN Advisory

Group on Energy and Climate Change (AGECC) for universal access to modern energy by 2030 [2] is a daunting prospect, given the intertwined challenges to tackle natural resources security, energy insecurity and climate change impact. At present, nuclear power appears to be the best choice for many nations. However, integrating nuclear power into a country's energy infrastructure is not without challenges. It has a great prospect of supplying sufficient amount of energy with creating less impact to the environment but in the long run there still remains a doubt about its sustainability.

2. Sustainable Development

Human beings are said to be at the centre of concerns for sustainable development. We are entitled to a healthy and productive life in harmony with nature. States are seen

as having the right, within the principles of international law, to exploit our own resources and the responsibility to ensure that any activities within our jurisdiction do not cause damage to the environment or other States. In addition, the right to development must be fulfilled so as to equitably meet the developmental and environmental needs of present and future generations. Eradication of poverty is seen as a required element of sustainable development. Climate change is a pressing threat to the sustainability of life on earth [3]. It is a highly complex problem that is unpredictable, reflecting an intricate interaction of organizational production processes, government management and regulation, natural forces, and individual behaviour [4]. It is generally held that sustainable development requires attention to the following things:

- Food availability and protection.
- Water availability in adequate quantities.
- Disease prevention and medical treatment.
- Steady and abundant supply of energy specifically, electricity.
- Sewage treatment.
- Infrastructure development such as schools, factories and transportation.

3. Global Climate Change Effects

In recent years, dramatic environmental changes have caused extraordinary climate changes around the globe. This has made countries all over the world to focus on greenhouse effect issue and consider it seriously [5]. It is an important problem that can't be ignored because the greenhouse effect causes global warming [6, 7]. In the past century, research and literature has concluded that carbon dioxide (CO₂) concentration increased by 28%

following the industrial revolution [8]. The global average temperature has increased by 0.3°C to 0.6°C, and the sea level rose 10 to 15 cm in the past 100 years. If greenhouse gas (GHG) emissions continue to increase at the present rate, it is predicted that the average global temperature will increase by about 1°C by the year 2025 and by 3°C at the end of the century [9]. The increase of atmospheric GHG concentration results to a large extent from human activities [10, 11]. Scientists predict if no effective protection policies for the environment are put into place, the global temperature will increase by 1°C to 3.5°C, and the sea level will increase by 15 to 95 cm. This will make many countries uninhabitable by 2100 [12]. The second assessment report of Inter governmental Panel on Climate Change (IPCC) stated that the CO₂ concentration in the atmosphere rose from 280 to 358 ppm in 1994 [13]. The World Meteorology Organization (WMO) also pointed out in greenhouse gas annual report in 2007 that the CO₂ concentration had already raised to 383 ppm [14]. CO₂ is the main GHG emitted from various sources and power sector is solely responsible for 30% emission of CO₂ throughout the world [15].

4. Nuclear Energy: An Emerging Source

The star, of which our sun is one, relies on nuclear fusion for their output of heat, light and other radiations. If one believes in the Big Bang Theory, then the Earth may be considered as a fragment of the Sun. Fusion reaction is exactly what is happening on the Sun. Energy from fission reaction is derived from a nuclear reaction involving uranium or plutonium as the fuel which originally comes from the fragment of the Sun. Nuclear reactors are either the slow thermal kind using moderators or the fast

breeder type using purer fuels and able to generate or 'breed' new fuel form which is useful in the context of renewability. It is projected that world primary energy demand will increase by 45 percent between 2006 and 2030, an average annual rate of growth of 1.6 percent slower than the average growth of 1.9 percent per year from 1980 to 2006 [16]. The International Atomic Energy Agency (IAEA), the most authoritative

international source of information on nuclear energy, predicted in August 2009 that global nuclear power capacity would be doubled by 2030, from the current 372 gigawatts electric (GWe) to 807 GWe. Today, about thirty countries are harnessing nuclear energy in about 440 commercial reactors. Table I. shows the list of countries with their respective nuclear programme.

Table I. The list of countries with their respective nuclear programme [17].

Nuclear Programme	Countries
Contracts signed, legal and regulatory infrastructure well-developed	United Arab Emirates, Turkey.
Committed plans, legal and regulatory infrastructure developing	Vietnam, Jordan, Belarus, Bangladesh.
Well-developed plans but commitment pending	Thailand, Indonesia, Egypt, Kazakhstan, Poland, Lithuania, Chile.
Developing plans	Saudi Arabia, Israel, Nigeria, Malaysia, Morocco, Kuwait.
Officially not a policy option at present	Australia, New Zealand, Portugal, Norway, Ireland.

5. Problems With Nuclear Energy

The disadvantages of nuclear energy include: the storage and management of dangerous high level radioactive waste, the possibility of proliferation of nuclear materials and potential terrorist applications, the high cost of building nuclear facilities and the possibility of accidents. Common people awareness is another issue that may also regard as a bar for nuclear energy programme. These disadvantages are listed below with respective description.

5.1 Radioactive Waste

High-level radioactive waste is very dangerous. It lasts for tens of thousands of years before decaying to safe levels. It is highly radioactive and is a major barrier for the expansion of nuclear power. More than fifty years of commercial nuclear energy use has left the world with a legacy of tens of thousands of tons of highly radioactive

waste that will last for tens of thousands of years [18]. On average, uranium ore contains only 0.1% uranium. Most nuclear reactors require one specific form of uranium, uranium-235 (U-235). This form represents only 0.7% of natural uranium. To increase the concentration of U-235, the uranium extracted from ore goes through an enrichment process, resulting in a small quantity of usable 'enriched' uranium and huge volumes of waste. If nuclear power production expands substantially in the coming decades, the amount of waste requiring safe and secure disposal will also significantly increase. High-level nuclear waste can last for thousands of years before being safe again, so this is a major hurdle which must be overcome before nuclear power can expand. Radioactivity can be turned out fatal for human body. Table II. shows major problems caused by radioactivity.

Table II. Human tissues and organs ranked by sensitivity to radiation induced cancer

High Risk	Moderate Risk	Low Risk
Bone Marrow Breast (premenopausal) Thyroid (child) Lung	Stomach Ovary Colon Bladder Skin	Brain Bone Uterus Kidney Esophagus Liver

5.2 Proliferation

Some forms of nuclear reactor, known as "breeder" reactors produce plutonium, which can, conceivably, be used to make nuclear weapons. This is a conventional explosive mixed with radioactive material with the intention of spreading the material across a wide area to do even more damage. As modern world politics is circling to grab more power and get share of energy of any rival country, therefore any nuclear power generating project could be turned into nuclear weaponry production project at any time.

5.3 Fuel Supply

Nuclear fuels are, physically, even rarer than fossil fuels. Fossil fuels at least are made on Earth, albeit over millions of years. Heavy elements like Uranium are only made as stars die, in supernovas. Our solar system actually formed from the

remains of another star, at which point heavier elements were made. Essentially, once they're gone, they are well and truly gone. Only in particle accelerators can heavier elements be made. Therefore the type of fuel required for nuclear power programme is not abundant at all.

5.4 Changing Perception of Common People

Common people always possess a doubtful mind regarding nuclear energy. They feel free considering its capability to deliver huge power but become fearful when they consider its adverse effects. Table III. and IV. are showing the drastic change of the perception of common people and the reflection of doubtful mind setup about nuclear energy programme.

Table III. Global Views about Nuclear Energy before the Japan Earthquake (Fukushima Nuclear Power Plant Tragedy) in 2011 [19].

Condition	Globally (%)	Japan (%)
Favourable	57	62
Unfavourable	32	28
No Response	11	10

Table IV. Global Views about Nuclear Energy after the Japan Earthquake (Fukushima Nuclear Power Plant Tragedy) in 2011 [19].

Condition	Globally (%)	Japan (%)
Favourable	49	39
Unfavourable	43	47
No Response	8	14

This changing mind setup of common people create dilemma among decision makers to take any major decision about launching nuclear power programme.

5.5 Accidents Happened So Far

Nuclear power generating programme have been caused for some fatal accidents so far. To judge the severity of those accidents International Nuclear Events Scale (INES)

has been introduced starting from 0 to 7. Table V. lists these accidents with respective INES scale and International Atomic Energy Agency (IAEA) description.

Table V. Nuclear power station incidents since 1952 with respective INES level and IAEA description [20].

Year	Incident	INES level	Country	IAEA description
2011	Fukushima	5	Japan	Reactor shutdown after the 2011 Sendai earthquake and tsunami; failure of emergency cooling caused an explosion.
2011	Onagawa		Japan	Reactor shutdown after the 2011 Sendai earthquake and tsunami caused a fire.
2006	Fleurus	4	Belgium	Severe health effects for a worker at a commercial irradiation facility as a result of high doses of radiation.
2006	Forsmark	2	Sweden	Degraded safety functions for common cause failure in the emergency power supply system at nuclear power plant.
2006	Erwin		United States	Thirty-five litres of a highly enriched uranium solution leaked during transfer.
2005	Sellafield	3	United Kingdom	Release of large quantity of radioactive material, contained within the installation.
2005	Atucha	2	Argentina	Overexposure of a worker at a power reactor exceeding the annual limit.
2005	Braidwood		United States	Nuclear material leak.
2003	Paks	3	Hungary	Partially spent fuel rods undergoing cleaning in a tank of heavy water ruptured and spilled fuel pellets.
1999	Tokaimura	4	Japan	Fatal overexposures of workers following a criticality event at a nuclear facility.
1999	Yanangio	3	Peru	Incident with radiography source resulting in

Year	Incident	INES level	Country	IAEA description
				severe radiation burns.
1999	Ikitelli	3	Turkey	Loss of a highly radioactive Co-60 source.
1999	Ishikawa	2	Japan	Control rod malfunction.
1993	Tomsk	4	Russia	Pressure build up led to an explosive mechanical failure.
1993	Cadarache	2	France	Spread of contamination to an area not expected by design.
1989	Vandellos	3	Spain	Near accident caused by fire resulting in loss of safety systems at the nuclear power station.
1989	Greifswald		Germany	Excessive heating which damaged ten fuel rods.
1986	Chernobyl	7	Ukraine (USSR)	Widespread health and environmental effects. External release of a significant fraction of reactor core inventory.
1986	Hamm-Uentrop		Germany	Spherical fuel pebble became lodged in the pipe used to deliver fuel elements to the reactor.
1981	Tsuruga	2	Japan	More than 100 workers were exposed to doses of up to 155 millirem per day radiation.
1980	Saint Laurent des Eaux	4	France	Melting of one channel of fuel in the reactor with no release outside the site.
1979	Three Mile Island	5	United States	Severe damage to the reactor core.
1977	Jaslovské Bohunice	4	Czechoslovakia	Damaged fuel integrity, extensive corrosion damage of fuel cladding and release of radioactivity.
1969	Lucens		Switzerland	Total loss of coolant led to a power excursion and explosion of experimental reactor.
1967	Chapelcross		United Kingdom	Graphite debris partially blocked a fuel channel causing a fuel element to melt and catch fire.
1966	Monroe		United States	Sodium cooling system malfunctions.
1964	Charlestown		United States	Error by a worker at a United Nuclear Corporation fuel facility led to an accidental criticality.
1959	Santa Susana Field Laboratory		United States	Partial core meltdown.
1958	Chalk River		Canada	Due to inadequate cooling a damaged uranium fuel rod caught fire and was torn in two.
1958	Vinča		Yugoslavia	During a subcritical counting experiment a power build up went undetected - six scientists received high doses.
1957	Kyshtym	6	Russia	Significant release of radioactive material to the environment from explosion of a high activity

Year	Incident	INES level	Country	IAEA description
				waste tank.
1957	Windscale Pile	5	United Kingdom	Release of radioactive material to the environment following a fire in a reactor core.
1952	Chalk River	5	Canada	A reactor shutoff rod failure, combined with several operator errors, led to a major power excursion of more than double the reactor's rated output at AECL's NRX reactor.

6. Nuclear Energy: Sustainable Solution or Future Threat

Nuclear energy is clean and has a potential to guarantee the world to serve with an everlasting supply of fuel without affecting resources sorely needed for other applications. However, so far little has possibly been known about the damages associated with nuclear power generation. The valuation of damages is further complicated because they are likely to occur only after several decades. Therefore it is difficult to estimate the benefit of nuclear energy avoiding its risk. Nuclear power generation is seemingly profitable. However when real costs are taken into account, nuclear is often more expensive than fossil fuels. For instance, nuclear energy takes a long time to produce. The process of permitting, environmental

impact studies and the length of time from planning to design and construction of the nuclear infrastructure typically last no less than several decades. Plus nuclear waste is still considered to be more controversial than fossil fuel emission, often requiring large underground storage facility. Despite these obvious hurdles, perhaps the most important challenge for this industry is about the risk of fatal accident and spreading radiation. Because casualty and fearful damage from such accident is not that so easy to handle by sending emergency rescue team and providing immediate shelter or medicine, the brutal effects of this type of damage pass from one generation to another through radioactivity and can be caused of an everlasting suffering for human race.

Table VI. Cost of electricity estimated by Massachusetts Institute of Technology (MIT) and University of Chicago report.

Electricity Generation Type	MIT report (2003)	University of Chicago report (2004)
	Cost (cents per kWh)	
Coal	4.2	3.3 to 4.1
Natural Gas (Combined Cycle Gas Technology)	3.8 to 5.6	3.5 to 4.5
Nuclear	6.7	6.2

7. CONCLUSION

The authors of this paper evaluated one of the key debatable issues influencing the achievement of energy security both at present and in the foreseeable future. The facts have raised from neutral point of view considering their future impacts. The present trend of switching source of energy from classic fossil fuel to nuclear energy for countries is seemingly attractive for the long run of sustainability due to its reduction in global warming, climate change, and improvement in energy security. But energy security is such a issue that must be addressed considering an energy policy include: security of supply, environmental impact, national competitiveness and social concerns. Nuclear energy definitely has its potential to meet worldwide increasing energy demand but when security and safety issue comes into account then it becomes a tough situation to take it as a potential alternative of energy. Therefore it can not be said that nuclear energy is the only alternative and utmost solution for future. Continuous research and development programmes should carried out on this regard to make it best fitted for future and alternative options should put under microscope to find their feasibility for meeting the energy demand in a sustainable way.

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