REVIEW AND ANALYSIS OF ENVIRONMENTAL IMPACTS OF DIFFERENT ENERGY TECHNOLOGIES: CLEAN ENVIRONMENT FROM NUCLEAR ENERGY

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ABSTRACT

No form of energy production or use is without environmental impact. The principal environmental impacts associated with nuclear power and sustainable development is air pollution/green-house gas (GHG) emissions and radiation. Nuclear energy plants do not emit pollutants or greenhouse gases when they generate electricity. Nuclear power plants in normal operation emit fewer radioactivities than coal power plants. Nuclear energy has one of the lowest impacts on the environment of any energy source because it does not emit air pollutants, isolates its waste from the environment and requires a relatively small amount of land. Handling, storage and disposal of low and medium-level nuclear waste pose no serious problem. No reason to worry about the management of nuclear wastes from the Rooppur nuclear power plant. As nation's demand for electricity grows, we must find a way to produce it without damaging our environment. Nuclear energy can help us meet this challenge-safely, cleanly, economically. This paper describes the environmental aspects of the major sources of different energy technologies.

Key Words: Environment, air emissions, Impact, energy technologies, nuclear energy, radiation hazards.

1.0 INTRODUCTION

The people of the world will be unwilling to face a future that diminishes lifestyles or expectations much below those enjoyed at present. One third of the world's current population lives in poverty, without access to commercial energy. Hence, world demand for energy will continue to grow as population grows and countries develop and expand their economies. It is essential to provide energy, particularly electricity, to a world population approaching 10 billion people in the next 50 years. All energy sources have some impact on our environment. The exact type and intensity of environmental impacts varies depending on the specific technology used, the geographic location, and a number of other factors. Fossil fuels –coal, oil, and natural gas - do substantially more harm than renewable energy sources by most measures, including air and water pollution, damage to public health, wildlife and habitat loss, water use, land use, and global warming emissions. Generating electricity from renewable energy rather than fossil fuels offers significant public health benefits. The air and water pollutants emitted by coal and natural gas plants are linked to breathing problems, neurological damage, heart attacks, and cancer. Replacing fossil fuels with renewable energy has been found to reduce premature mortality and lost workdays, and it reduces overall healthcare costs[1]. In USA, the aggregate national economic impact associated with these health impacts of fossil fuels are between $361.7 and $886.5 billion, or between 2.5 percent and 6 percent of gross domestic product (GDP)[1].

Wind, solar, and hydroelectric systems generate electricity with no associated air pollutants emissions. While geothermal and biomass energy systems emit some air pollutants, total air emissions are generally much lower than those of coal- and natural gas-fired power plants. It is still important, however, to understand the environmental impacts associated with producing power from renewable sources such as wind, solar, geothermal, biomass, and hydropower. Increasingly, Bangladesh has become a nation of electricity users. At the same time, our nation is committed to preserve the environment. We must protect our clean air, environment, lakes and streams while providing ample supplies of energy. We must look to energy sources that are good for the environment-that don't cause urban smog or acid rain or emit the "greenhouse" gases that may cause global warming [2-5]. Nuclear power is a part of the solution that has the advantage of avoiding the wide variety of environmental problems arising from burning fossil fuels—coal, oil, and gas. Without nuclear power, the long-term future of the global ecosystem is at risk. It is not claimed that an extended use of nuclear power would be the only solution for avoiding global warming or other environmental damages originating from electricity production. It is asserted that nuclear power offers a significant contribution to a global energy balance with low emission of gases that cause climate change and that it should be used in a well-balanced combination with energy conservation and renewable sources so that emissions of greenhouse gases can effectively be reduced [6,7].

Nuclear energy has one of the lowest impacts on the environment of any energy source because it does not emit air pollution, isolates its waste from the environment and requires a relatively small amount of land. Nuclear energy plants do not emit pollutants or greenhouse gases when they generate electricity[8-9]. At present 437 commercial nuclear power units with total capacity of about 375 GW (e) are operated in the world (nearly 11 percent of the world's electricity as of July 2016, (http://www.world-nuclear.org/information-library/ facts-and-figures) and 66 new nuclear power plants (total capacity: 66029 MWe) are under construction in 15 countries. In 2015, 13 countries[9] relied on nuclear energy to supply at least 30% of their total electricity, such as France (76.9%), Slovakia (56.8%), Hungary (53.6%), Ukraine (49.4%), Belgium (47.5%), Sweden (41.5%), Switzerland (37.9%), Slovenia (37.2%), Czech Republic (35.8%), Finland (34.6%), Bulgaria (31.8%), Armenia (30.7%), and South Korea (30.4%). Bangladesh is introducing nuclear energy as a safe, environmentally benign and economically viable source of electrical energy to meet the increasing electricity needs of the country. The government has taken practical steps to build the first nuclear power plant (NPP) of the country, the Rooppur NPP with net output capacity 2000 MWe by 2024-25 to ensure energy security for inclusive development of the country [10-12]. The objective of this study is to analyze the environmental impacts from different energy technologies.

Table-1: Typical emissions from plants of different technologies based on 1 GWe/yr. (Source: http://www.nei.org/Issues-Policy/Protecting-the-Environment/Life-Cycle-Emissions-Analyses)

Energy Technologies	Emissions to Air or Water	Non-emission wastes
Coal: combustion at power plant	CO^2, NO^2, SO^2, Hg, waste heat, other metals, and organic chemical emissions to air	~3 x 10^5 t of bottom and fly ash containing trace metals (arsenic, lead, nickel, etc.) and GBq quantities of radionuclides, such as ^{228}Th, ^{230}Th, ^{232}Th, ^{226}Ra, and ^{228}Ra. Some of the boiler wash waste may need to be treated as hazardous waste.

Oil: Combustion at power plant	CO^2, NO^2, SO^2, Hg, waste heat, other metals, and organic chemical emissions to air through flue gas waste heat and boiler-wash waste emissions to water	Solid/ash wastes are less than for coal, unless flue gas desulfurization is employed, in which case total mass can be similar
Gas: Combustion at power plant	Flue gas emissions including CO^2, NOX, various organic chemicals and particulates waste heat and boiler-wash waste emissions to water	Some of the boiler wash wastes may need to be treated as hazardous wastes. Amounts are small compared with coal or
Power plant operation	Gaseous and liquid releases of radionuclides	Spent fuel LLW associated with plant operation

2.0 ANALYSIS OF ENVIRONMENTAL IMPACTS

2.1 Power plant emissions

Most electrical energy derived from coal is obtained by direct combustion of coal, including fluidized bed combustion and coal gasification. The major air emissions for direct combustion of coal are listed in Table 1. Listed in this table are major air and water emissions, other waste streams, and estimates of waste amounts from oil combustion at power plants. Also listed in this table are major air and water emissions and descriptions of other waste streams from gas combustion at power plant. Typical air emissions and other waste streams from the nuclear power plants are also shown in Table 1.

The environmental impact of nuclear power results from the nuclear fuel cycle, operation, and the effects of nuclear accidents. The routine health risks and greenhouse gas emissions from nuclear fission power are small relative to those associated with coal, but there are "catastrophic risks": the possibility of over-heated fuel releasing massive quantities of fission products to the environment, and nuclear weapons proliferation. The public is sensitive to these risks and there has been considerable public opposition to nuclear power. The 1979 Three Mile Island accident and 1986 Chernobyl disaster, along with high construction costs, ended the rapid growth of global nuclear power capacity[13]. In March 2011 an earthquake and tsunami caused damage that led to explosions and partial meltdowns at the Fukushima Nuclear Power Plant in Japan.

The principal environmental impacts associated with nuclear power and sustainable development is air pollution/green-house gas (GHG) emissions and radiation. Nuclear power plants produce electricity by the fissioning (Fig. 1) of uranium, not the burning of fuels. The most commonly used nucleus in nuclear power reactors is Uranium-235 or ^{235}U for short. The diagram below is a summary of what happens when a neutron collides with a ^{235}U nucleus and causes it to fission. The red balls are neutrons, the blue are ^{235}U, and the green are the smaller nuclei the ^{235}U splits into fission fragments. In a nuclear reactor, billions of fission events occur every second, so as a whole, a reactor can give us a lot of heat energy which we can then put to useful work. As a result, nuclear plants do not pollute the air with sulfur oxides, nitrogen oxides, and dust or green-house gases like carbon dioxide. Nuclear energy has helped to create a cleaner environment throughout the world (Fig. 2).

The main benefits of nuclear power are that is it more efficient than burning fossil fuels as the amount of energy released from uranium per gram is much more than that of fuels such as oil or coal; approximately 8,000 times more efficient in fact.

Nuclear energy plants eliminate 5 mil tons of sulfur oxides each year that would result if we produced that power by burning fossil fuels.

Nuclear energy plants also eliminate 2 million tons of nitrogen oxide (NOx) emissions each year. NOx contributes to the formation of urban smog as well as acid rain. Among the alternatives for generating electricity, fossil fuelled technologies (coal, oil and natural gas) have the highest CO_2 emission rates and create the majority of energy related GHG emissions[3-5]. The GHG emissions data have been analyzed[14] and are shown in Figures 3-5 based on literature data (http://www.nuclearfiles.org/menu/key-issues/nuclear-energy/issues/health environment/moens_nuclear_power_environment.html).

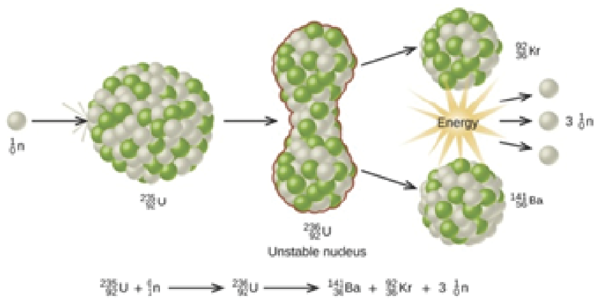


Fig. 1: Fission process of ^{235}U

(Source: ttp://chem.libretexts.org/Textbook_Maps/General_Chemistry_Textbook_Maps/Map%3A_Chemistry%3A_The_Central_Science_(Brown_et_al.)/21%3A_Nuclear Chemistry/21.7%3A_Nuclear_Fission)

2.2 Life-Cycle Emissions

The World Nuclear Association published a study in 2011 that compiled and analyzed 21 different life-cycle emissions studies and made the following observations[14, 15]:

- Greenhouse gas emissions of nuclear power plants are among the lowest of any electricity generation method and on a lifecycle basis are comparable to wind, hydroelectric and biomass.
- Lifecycle emissions of natural gas are 15 times greater than nuclear.
- Lifecycle emissions of coal generation are 30 times greater than nuclear.

Fig. 2: Nuclear energy plants preserve vital natural resources- like clean environment

(Source:http://www.triplepundit.com/special/energy-options pros-and-cons/nuclear-energy-pros-and-cons/#)

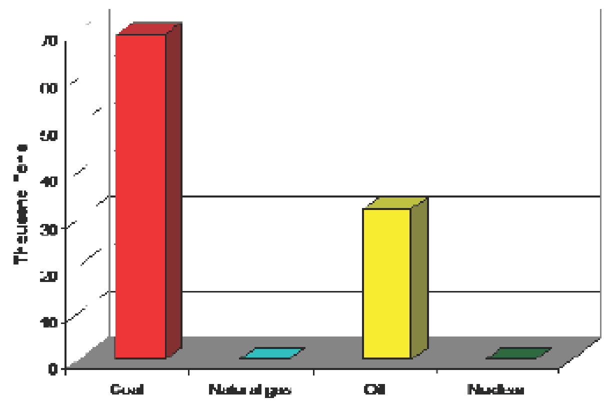


Fig. 3: Sulfur oxide emissions from 1000 MW plant per year

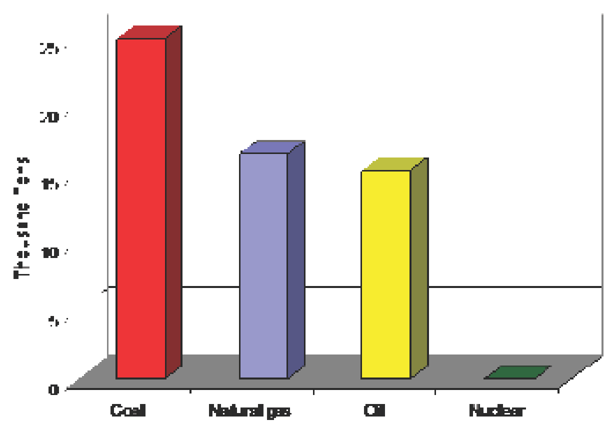


Fig. 4: Nitrogen oxide emissions from 1000 MW plant per year

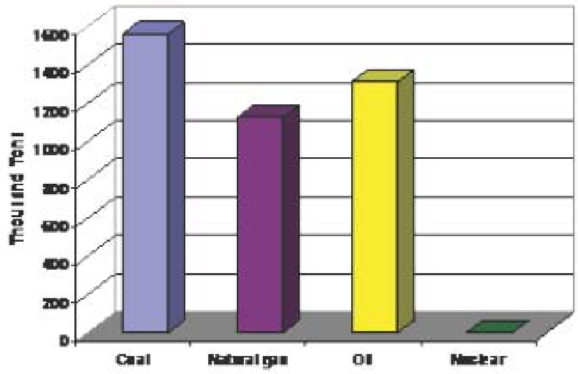
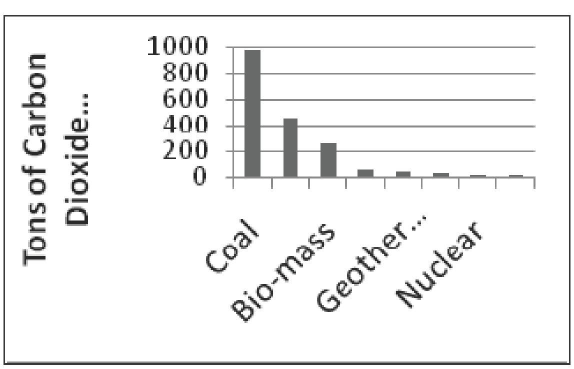


Fig. 5: Carbon dioxide emissions from 1000 MW plant per year

Independent studies have assessed nuclear energy's life-cycle emissions and found them to be comparable to wind, solar, geothermal and hydroelectric generation. In 2014, the United Nations Intergovernmental Panel on Climate Change found that nuclear power has the lowest lifecycle emissions of any electric generating technology, except for wind energy. The International Atomic Energy Agency in 2007 released a report titled: Guide to Life-Cycle Greenhouse Gas (GHG) Emissions from Electric Supply Technologies[15, 16]. The report states the following about nuclear:

> *"From a GHG emission perspective, nuclear power plants (i.e. LWR) are very attractive since they have a huge GHG life-cycle reduction potential when displacing fossil fuel fired power plants, as well as the ability to provide energy services similar to most fossil fuel based energy technologies. On average LWRs has the second lowest life-cycle GHG emissions of all assessed technologies."*

A comparison of life-cycle emissions from different energy technologies is shown in Fig. 6.



2.3 Radioactive Effluents and Wastes

The total amount of radioactivity released through this method depends on the power plant, the regulatory requirements, and the plant's performance. Atmospheric dispersion models combined with pathway models are employed to accurately approximate the dose to a member of the public from the effluents emitted. Effluent monitoring is conducted continuously at the plant. Radioactive wastes are wastes that contain radioactive material. Radioactive wastes are usually by-products of nuclear power generation and other applications of nuclear fission or nuclear technology, such as research and medicine. Radioactive waste is hazardous to most forms of life and the environment, and is regulated by government agencies in order to protect human health and the environment[17-20].

Radioactivity diminishes over time, so waste is typically isolated and stored for a period of time until it no longer poses a hazard. The period of time waste must be stored depends on the type of waste. Low-level waste with low levels of radioactivity per mass or volume (such as some common medical or industrial radioactive wastes) may need to be stored for only hours, days, or months, while high-level wastes (such as spent nuclear fuel or by-products of nuclear reprocessing) must be stored for thousands of years. Current major approaches to managing radioactive waste have been segregation and storage for short-lived wastes, near-surface disposal for low and some intermediate level wastes, and deep burial or transmutation for the long-lived, high-level radioactive wastes.

High-level radioactive waste

Around 20–30 tons of high-level wastes are produced per month per nuclear reactor. The world's nuclear fleet creates about 10,000 metric tons of high-level spent nuclear fuel each year. Several methods have been suggested for final disposal of high-level waste, including deep burial in stable geological structures, transmutation, and removal to space. So far, none of these methods have been implemented. There is an "international consensus on the advisability of storing nuclear waste in deep underground repositories", but no country in the world has yet developed such a site.

Other radioactive waste

Moderate amounts of low-level radioactive waste are produced through chemical and volume control system (CVCS). This includes gas, liquid, and solid waste produced through the process of purifying the water through evaporation. Liquid waste is reprocessed continuously, and gas waste is filtered, compressed, stored to allow decay, diluted, and then discharged. The rate at which this is allowed is regulated and studies must prove that such discharge does not violate dose limits to a member of the public. Solid waste can be disposed of simply by placing it where it will not be disturbed for a few years. Nuclear power is characterized by the very large amount of energy available from a very small amount of fuel. The amount of waste is correspondingly very small. However, much of the waste is radioactive and therefore must be carefully managed as hazardous waste.

Radioactive wastes comprise a variety of materials requiring different types of management to protect people and the environment. They are normally classified as low-level, medium-level or high-level wastes, according to the amount and types of radioactivity in them. Another factor in managing wastes is the time that they are likely to remain hazardous. This depends on the kinds of radioactive isotopes in them, and particularly the half-lives characteristic of each of those isotopes. (The half-life is the time it takes for a given radioactive isotope to lose half of its radioactivity. After four half- lives the level of radioactivity is 1/16th of the original and after eight half- lives 1/256^{th,} and so on.). The various radioactive isotopes have half-lives ranging from fractions of a second to minutes, hours or days, through to billions of years. Radioactivity decreases with time as these isotopes decay into stable, non-radioactive ones. The rate of decay of an isotope is inversely proportional to its half-life; a short half- life means that it decays rapidly. Hence, for each kind of radiation, the higher the intensity of radioactivity in a given amount of material, the shorter the half -lives involved. The composition of radioactive wastes from nuclear power plants is shown in Table 2. High level wastes make just 3% of the total volume of waste arising from nuclear generation, but they contain 95% of the radioactivity arising from nuclear power. Low level wastes represent 90% of the total volume of radioactive wastes, but contain only 1% of the radioactivity.

Table-2: Typical radioactive wastes from nuclear power plant[18]

	By Volume	**By Radioactive Content**
High Level Waste	3%	95%
Intermediate Level Waste	7%	4%
Low Level Waste	90%	1%

All radioactive waste facilities are designed with numerous layers of protection to make sure that people remain protected for as long as it takes for radioactivity to reduce to background levels. Low-level and intermediate wastes are buried close to the surface. For low-level wastes disposal is not much different from a normal municipal landfill. High-level wastes can remain highly radioactive for thousands of years. They need to be disposed of into deep underground in engineered facilities built in stable geological formations. While no such facilities for high-level wastes currently operate, their feasibility has been demonstrated and there are several countries now in the process of designing and constructing them.

Most low-level radioactive wastes can be handled by humans without any measurable biological effects. Nevertheless, good handling practices of all radioactive materials and waste should be the goal to provide optimum protection to humans and the environment. Raw radioactive waste is produced in nuclear power plants through cleaning of the cooling circuit, air and water from control areas and cleaning of the system. Spheroidal resin and filter cartridges are used to clean the cooling circuit, e.g. in pressurized water reactors. Evaporation drying systems, centrifuges and ion-exchange filters are used to clean the waste water. The air is cleaned with filters. Combustible and compactable waste in particular is produced during cleaning of the system. The raw waste is either treated directly in the nuclear power plant or in an external waste conditioning plant. Procedures such as drying, compacting or burning result in a considerable volume reduction. The annual volume of radioactive waste produced through the operation of a 1,300 MWe nuclear power plant with a pressurized water reactor amounts to:

- Ion-exchanger resins 2 m^3,
- Evaporator condensate 25 m^3,
- Metal parts, insulating material 60 m^3,
- Paper, textiles, plastics 190 m^3.

The annual volume of radioactive waste produced through the operation of a 1,300 MWe nuclear power plant with a boiling water reactor amounts [30] to:

- Ion-exchanger resins 8 m^3,
- Evaporator condensate 35 m^3,
- Filter auxiliaries, sludges 90 m^3,
- Paper, textiles, plastics 300 m^3.

All the spent fuel produced to date by commercial nuclear power in USA could fit within a single football field and be only about three feet deep. That's a remarkably small amount when it compare to the millions of tons of other industrial wastes accumulating each year. The small volume of high-level waste makes it highly controllable, compared to the wastes of other kinds of industrial activity. In USA, more than 5000 spent fuel elements have already been shipped over the past two decades in specially designed casks without a single accident causing a harmful release of radiation. A typical large 1000 MWe nuclear reactor produces 25–30 tons of spent fuel per year. If the fuel were reprocessed and vitrified, the waste volume would be only about three cubic meters per year, but the decay heat would be almost the same. Handling, storage and disposal of low and medium-level nuclear waste pose no serious problem. No reason to worry about the management of nuclear wastes from the Rooppur nuclear power plant[16].

Table-3: Volume and activity of LILW generated annually by 1 GWe nuclear power plant[18]

Reactor type	Volume (m^3)	Activity (TBq)
ABWR	500	500
AGR	650	600
BWR	500	500
FBR	500	500
GCR	5000	1000
RBMK	1500	1000
PHWR	200	100
PWR	250	100
VVER	600	600

A summary of the amounts of radioactive wastes and management approaches for most developed countries are presented and reviewed periodically as part of the International Atomic Energy Agency (IAEA) Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management[18]. Most used fuel from nuclear power plants is stored in steel-lined concrete pools filled with water, or in airtight steel or concrete-and-steel containers as pictured above. In France, for example, where nuclear power supplies about 80% of the total electricity generation in the country, the production of wastes of all kinds is 3000 kg per inhabitant and year. Of this, 100 kg per inhabitant and year (3.3%) are toxic industrial wastes (Fig. 7). About 99% of these toxic industrial wastes are chemical wastes, some of which are non-degradable (mercury, lead, cadmium, stable chemical compounds, etc.) and only 1% are radioactive wastes, i.e., 1 kg per inhabitant and year. Summarizing, only about 0.03% of the total production of wastes in France are radioactive wastes, and from these only 9.5% are highly radioactive wastes.

2.4 Radiation Hazards

Most commercial nuclear power plants release gaseous and liquid radiological effluents into the environment as a byproduct of the Chemica Volume Control System, which are monitored by the operators and the national regulatory authorities. In USA, civilians living within 50miles of a nuclear power plant typically receive about 0.1μSv per year [6]. For comparison, the average person living at or above sea level receives at least 260 μSv from cosmic radiation[6]. The total amount of radioactivity released depends on the power plant, the regulatory requirements, and the plant's performance. Atmospheric dispersion models combined with pathway models are employed to accurately approximate the dose to a member of the public from the effluents emitted. Effluent monitoring is conducted continuously at the plant.

Fig. 7 presents a worldwide comparison, based on data from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), showing, on a logarithmic scale, that the average radiation dose from nuclear power production is one ten-thousandth of the dose from natural background sources.

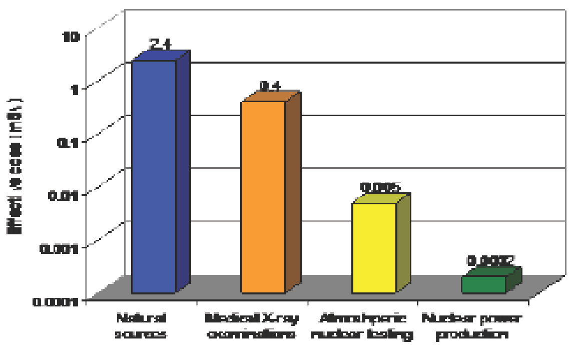


Fig. 7: Worldwide average annual per capita dose from natural and anthropogenic radiation (www.unscear.org/docs/publications/2000/UNSCEAR_2000_Report_Vol.I.pdf).

2.5 Comparison to coal-fired generation

In terms of net radioactive release, the National Council on Radiation Protection and Measurements (NCRP) estimated the average radioactivity per short ton of coal is 17,100 millicuries/4,000,000 tons. In terms of dose to a human living nearby, it is sometimes cited that coal plants release 100 times the radioactivity of nuclear plants. This comes from NCRP Reports No. 92 and No. 95 which estimated the dose to the population from 1000 MWe coal and nuclear plants at 4.9 man-Sv/year and 0.048 man-Sv/year respectively (a typical Chest x-ray gives a dose of about 0.06 mSv for comparison). The Environmental Protection Agency estimates an added dose of 0.3 μSv per year for living within 50miles of a coal plant and 0.09 μSv for a nuclear plant for yearly radiation dose estimation[8]. Nuclear power plants in normal operation emit less radioactivity than coal power plants[7, 8].

Fission and corrosion products are in the primary coolant of nuclear reactors in a variety of concentrations. Some of these trace radionuclides present in the primary and/or secondary coolant loops may be released in several ways, including, for example, pressurizers, steam valves, seals, and pipes. The atmosphere of the nuclear reactor containment vessel retains the gaseous and volatile radionuclides. When one assumes that a fraction of one percent of the fuel fails, and a leak occurs at a small rate across the heat exchanger, trace amounts of fission and corrosion products find their way to the steam generator (or the secondary system). Some of these trace radionuclides present in the primary and/or secondary coolant loops may be released in several ways, including, for example, pressurizers, steam valves, seals, and pipes. The atmosphere of the nuclear reactor containment vessel retains the gaseous and volatile radionuclides, while the liquid ones go to floor drains and retention tanks. A system of radioactive waste treatment and retention, the Rad waste system, is design to work in such a way that most of the radionuclides in the containment vessel and in the retained tanks are not released. However, small amounts are released in accordance with the ALARA principle. This means that releases are to be made in a way "to ensure that the magnitude of the individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received, are all kept as low as reasonably achievable (ALARA), economic and social factors being taken into account."

A universally accepted system of dose limitation is used to control public exposure for the case of routine releases of radioactive effluents during power generation in nuclear power plants. Such system, based in a tripod which includes justification of a practice, optimization of protection of the public, and dose limits for public exposure. Moreover, the ALARA criterion (as low as reasonably achievable, economic and social factors taken into account) is adopted for the actual routine releases of radioactive effluents into the environment. This assures that, in the case of nuclear power generation, the magnitude of the individual doses, the number of people exposed, and the likelihood of incurring exposures are all kept ALARA. By and large, annual averages of the effective dose equivalent received due to nuclear power generation in the world are of the order of 0.1 μSv/y, while the annual dose limits adopted for light water reactors (LWRs) lie between 0.10 and 0.25 mSv/y. This means that the world annual averages are less than one thousandth the adopted limits for nuclear power generation. Moreover, the International Commission on Radiological Protection (ICRP) recommends that the limit for public exposure should be 1 mSv/y.

2.6 Risk of cancer

There have been several epidemiological studies that claim to demonstrate increased risk of various diseases, especially cancers, among people who live near nuclear facilities. A widely cited meta-analysis by Baker et al. was published in the European Journal of Cancer Care[19]. It offered evidence of elevated leukemia rates among children living near 136 nuclear facilities in the United Kingdom, Canada, France, United States, Germany, Japan, and Spain. However this study has been criticized on several grounds - such as combining heterogeneous data (different age groups, sites that were not nuclear power plants, different zone definitions), arbitrary selection of 17 out of 37 individual studies, exclusion of sites with zero observed cases or deaths, etc. Elevated leukemia rates among children were also found in a 2008 German study[21] that examined residents living near 16 major nuclear power plants in Germany. This study has also been criticized on several grounds. The 2007 and 2008 results are not consistent with many other studies that have tended not to show such associations[22-23]. The British Committee on Medical Aspects of Radiation in the Environment issued a study in 2011 of children under five living near 13 nuclear power plants in the UK during the period 1969-2004. The committee found that children living near power plants in Britain are no more likely to develop leukemia than those living elsewhere[12].

3.0 NUCLEAR POWER SAVES LIVES

According to a study [2] global use of nuclear power has prevented about 1.84 million air pollution-related deaths and release of 64 billion tons of greenhouse gases that would have resulted from burning coal and other fossil fuels. The Table-5 shows the CO_2 emissions from each process in the nuclear power life cycle.

Table-5: CO_2 emissions from each process in the

gCO_2e/kWh	Front End	Construction	Operation	Back End	Decommis-	Total
Minimum	0.58	0.27	0.1	0.4	0.01	1.36
Maximum	118	35	40	40.75	54.5	288.25
Mean	25.09	8.2	11.5	9.2	12.01	66.08
N	17	19	9	15	13	

Source: http://www.nirs.org/climate/background/sovacool_nuclear_ghg.pdf

Pushker A. Kharecha and James E. Hansen of Columbia University[3] state that nuclear power has the potential to help control both global climate change and illness and death associated with air pollution. That potential exists, they say, despite serious questions about safety, disposal of radioactive waste and diversion of nuclear material for weapons. Concerned that the Fukushima accident in Japan could overshadow the benefits of nuclear energy, they performed an analysis of nuclear power's benefits in reducing carbon dioxide emissions and air pollution deaths [24-26].

4.0 DISCUSSIONS

Every source of electrical power has advantages. In the case of nuclear power, those advantages are clean and environmentally friendly operation, affordability, safety over its entire supply chain, and round-the-clock reliability. It is the only source of energy that can replace a significant part of the fossil fuels (coal, oil and gas) which massively pollute the atmosphere and contribute to the greenhouse effect.

Clean: Nuclear energy stations do not emit criteria pollutants or greenhouse gases when they generate electricity. Nuclear energy produces almost no carbon dioxide, and no sulfur dioxide or nitrogen oxides whatsoever. These gases are produced in vast quantities when fossil fuels are burnt[14]. The life cycle emissions from nuclear energy are comparable to other non-emitting sources of electricity like wind, solar and hydropower. When the whole life-cycle of power generation is taken into account, nuclear power is one of the cleanest forms of energy, behind only hydroelectric and wind power.

Nuclear waste: Nuclear power is of course the densest form of energy harnessed yet by humankind. A ton of nuclear fuel used in a light-water reactor contains more than 200,000 times more energy than a ton of coal, making nuclear five orders of magnitude more energy dense than fossil fuels. Nuclear waste is correspondingly about a million times smaller than fossil fuel waste, and it is totally confined. In the USA and Sweden, spent fuel is simply stored away. Elsewhere, spent fuel is reprocessed to separate out the 3% of radioactive fission products and heavy elements to be vitrified (cast in glass) for safe and permanent storage. The remaining 97% –plutonium and uranium – is recovered and recycled into new fuel elements to produce more energy[18]. The volume of nuclear waste produced is very small. Nuclear waste is to be deposited in deep geological storage sites; it does not enter the biosphere. Its impact on the ecosystems is minimal. Nuclear waste spontaneously decays over time while stable chemical waste, such as arsenic or mercury, lasts forever. Most fossil fuel waste is in the form of gas that goes up the smokestack. We don't see it, but it is not without effect, causing global warming, acid rain, smog and other atmospheric pollution.

Safe: Nuclear power is safe, as proven by the record of half a century of commercial operation, with the accumulated experience of more than 12,000 reactor-years. There have been only three serious accidents in the commercial exploitation of nuclear power: i) Three Mile Island in 1979 (in Pennsylvania, USA), ii) Chernobyl in 1986 (in the Soviet Union, now in Ukraine) and iii) Fukushima accident in 2011.

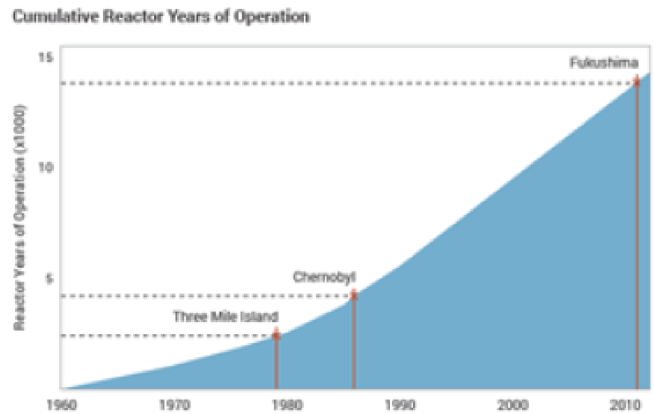


Fig. 8. Cumulative reactor years of operation.

(Source: http://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/safety-of-nuclear-power-reactors.aspx)

TMI was the worst accident one can imagine in a western power reactor. The core of the reactor melted down and much of it fell to the bottom of the reactor vessel. The radioactivity released was almost entirely confined within the reinforced concrete containment structure, the air-tight silo-like building which housed the reactor – it was designed for that purpose. The small amount of radioactivity, which escaped was quite innocuous. As a result, no one at TMI was seriously irradiated nor did anyone die. In fact, Three Mile Island was a real success story for nuclear safety. The worst possible accident occurred, a core meltdown, and yet no one died or was even injured.

Chernobyl was different. The reactors at Chernobyl had no containment structure. The reactor's faulty design made it unstable and Chernobyl was operated that night in a way known to be dangerous. In the execution of a test, all the security systems were deliberately bypassed. An uncontrollable surge in power occurred leading to a steam explosion. The 600-ton graphite moderator then caught fire and burned for several weeks. Chernobyl was the perfect example of what not to do with a nuclear reactor: a faulty design, an unstable reactor, operated in an experiment with all security systems disconnected, followed by a panicked response by the civil authorities. The incident at the Fukushima-Daiichi power plant was caused by an immense natural disaster involving a massive earthquake and a huge tsunami. The meltdown at Fukushima did not kill anyone or destroy large swaths of land. Some people died from the stress of the disaster, and others from being abandoned in nearby hospitals or retirement homes when their staff fled the buildings unnecessarily. But no one died from radiation exposure. The events at Three Mile Island and Fukushima, however, were different matters altogether. These incidents were testaments not to the danger but to the safety of nuclear power plants. Zero people died as a result of the problems at these plants. Despite the Chernobyl accident, there is no industry in the world that can present the same excellent record of safety performance as the nuclear industry. Worldwide nuclear power is the third most used source of energy for electricity production, after coal and hydropower[24].

Public Opinion: NEI-sponsored research provides a unique database on attitudes toward nuclear energy. It is the only source of long-term trend data on a wide variety of questions that are needed to measure and fully understand public opinion about nuclear energy. Latest public opinion data shows an upward trend in public's favorable attitudes toward nuclear energy (http://www.nei.org/Knowledge-Center/Public-Opinion). In Bangladesh, we conducted a limited survey on public acceptance/awareness about nuclear power programme that clearly described the unique public acceptance level of the Rooppur nuclear power plant project[27,28] based on the generic questionnaire under the FNCA project[27].

Reliable: Nuclear energy is the most efficient and reliable source of large-scale, around-the-clock electricity, meaning it is available on the grid at all times. Nuclear power plants are designed to operate continuously, which is ideal for utilities that need a dependable baseload source of electricity at all times of the day and night. Nuclear power plants generate electricity 24/7 at a 92 percent capacity factor. This is more efficient than other types of energy—combined-cycle natural gas, with a 56 percent capacity factor; coal-fired at 55 percent; and wind at 33 percent (http://www.nei.org/News-Media/News/News-Archives/Nuclear-Power-Plants-Set-Records-for-Safety,-Opera). This makes nuclear energy one of the most reliable sources of electricity in the world. Nuclear energy plants maintain an average reliability of 85-90 percent. Most reactors are designed for a life of 40 years; many are reaching that age in good condition and extensions of 20 years have usually been granted[9].

Competitive: Nuclear power is cost competitive with other forms of electricity generation, except where there is direct access to low-cost fossil fuels. The cost of nuclear power is competitive[29] and stable. The cost of nuclear fuel is a small part of the price of a nuclear kiloWatt-hour, whereas fossil fueled power, especially oil and gas, is at the mercy of the market. Nuclear plant operations, maintenance, and fuel costs are the lowest among the major sources (nuclear, coal, gas, and petroleum) for power generation in the world. On average, it costs just over two cents per kilowatt-hour to generate electricity with nuclear power. This equates to low-cost clean energy for consumers and businesses that drive the economic engine (http://www.world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx). As one of the most price-stable energy sources due to little fluctuation in production costs and average fuel costs, nuclear energy is the lowest-cost producer of base load electricity, making it one of the most efficient energy sources throughout the world.

Inexhaustible: There are uranium deposits around the world, and only a small amount of uranium is needed to generate electricity in a nuclear power plant. Uranium is found everywhere in the crust of the Earth – it is more abundant than tin, for example. Major deposits are found in Canada and Australia. It is estimated that increasing the market price by a factor ten would result in 100 times more uranium coming to market. Enough uranium resources are available to last well into the future, and to support growth of the global nuclear industry. Existing technology to reuse spent uranium fuel rods could further extend the life of uranium resources (http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/canada-uranium.aspx).

Compact: Nuclear fuel is so compact that only two grams of natural uranium, about the weight of two paperclips, would fuel 100 percent of an average British person's energy needs for a day, according to Cambridge University Professor David Mackay (http://www.withouthotair.com/c24/page_161.shtml). Nuclear energy produces more electricity on less land than other carbon-free technologies (http://www.nei.org/Issues-Policy/Protecting-the-Environment/Ecology). A nuclear power station is very compact, occupying typically the area of a football stadium and its surrounding parking lots. Solar cells, wind turbine farms and growing biomass, all require large areas of land.

5.0 CONCLUSIONS

Nuclear energy has one of the lowest impacts on the environment of any energy source because it does not emit air pollution, isolates its waste from the environment and requires a relatively small amount of land. Global use of nuclear power has prevented about 1.84 million air pollution-related deaths and releases of 64 billion tons of greenhouse gases that would have resulted from burning coal and other fossil fuels, according to a paper in *Environmental Science & Technology*[3]. Handling, storage and disposal of low and medium-level nuclear waste pose no serious problem. Bangladesh Atomic Energy Commission has the necessary expertise and experience to manage such waste and, in fact, has been doing so since the construction of its research reactor in 1986 at the Atomic Energy Research Establishment (AERE) at Savar. There is, therefore, no reason to worry about the management of low and intermediate level nuclear wastes (except spent fuel-the spent fuel will be taken back to Russia) from the Rooppur nuclear power plant[30]. As our nation's demand for electricity grows, we must find a way to produce it without damaging our environment & health. Nuclear energy can help us meet this challenge-safely, cleanly, and economically. The Fukushima accidents will serve to develop even safer and more affordable nuclear-generated electricity. The review of what occurred in Fukushima and the lessons drawn from the disaster will further help prevent accidents.

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