Nuclear Energy through a Double Lens of its Genesis and as an Energy Option **Prakash Burte**
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ABSTRACT

The first part of the paper deals with the story of nuclear energy begins with an accidental discovery of X-rays. It prompted the then scientists of Europe and later of the USA to work with cathode ray tubes and later to look into an atom to explain its observed chemical and spectral properties. That opened the doors wide open of a new world of knowledge in the march of modernity. It had inherited a culture of modernity to accept ignorance and overcome it step by step through continuous collective and cooperative efforts. That gave birth to a new form of energy: Nuclear energy.

The second part of the paper discusses the Manhattan project, its successes and the mass destruction in Japan, the reasons behind it etc. The other prominent use of nuclear energy is generation of electricity, the highly efficient, transportable and easy to use form of energy. The paper later analyses these two forms. The context of the Treaty of Prohibition of nuclear weapons, while the environment and harm to human well being is the context for the power reactors. Here a historical fact speaks volumes. The fact is first application of the nuclear energy was as the weapons of mass destruction of two Japanese cities and perhaps the second large scale application of this energy was for generation of electricity, perhaps for washing the universal blot of unparalleled brutality on the of USA the then president Eisenhower might have given a call of the 'Atom for the peace.' The purpose of the paper is to see the historicity of that period, to learn a few lessons for the future.

Key words: Nuclear Energy, Manhattan Project; Radioactivity; Einstein; Modernity; Nuclear Reactors

This paper titled "Nuclear Energy through a Double Lens of its Genesis and as an Energy Option"tries to objectively evaluate Nuclear energy. For this the speech by Prof. Joseph Rotblat should be read to serve the purpose of an introduction.

On 5th November, 1999 Sir Rotblat received the Jamanalal Bajaj award for promoting the Gandhian values. On the same day he spoke in Dr. Homi Bhabha auditorium of TIFR, Colaba, Mumbai. Prof. Rotblat was a citizen of the kingdom of Poland. When Adolf Hitler attacked Poland, young Rotblat gathered courage and escaped to the UK. He became a natural citizen of Britain. He had shared a Nobel Prize for Peace with the Pugwash Conferences for the year 1995. Prof. Rotblat was heading that organisation then. This section of the paper analyses (as now can be described as) his personal involvement and his priorities of that turbulent period of WWII as a scientist.

At the Jamnalal Bajaj award ceremony Professor Rotblat was 90 years old. He narrated his career graph with a clear voice, good memory and tremendous alertness. He had worked under the guidance of Prof James Chadwick for the doctorate and completed it in 1938. Incidentally Prof. Chadwick had discovered in 1932 the existence of neutrons in the centre of atoms. Rotblat had returned to Warsaw and was working there. In the same year, Otto Hahn who had worked with Lise Meitner and a chemist Fritz Strassmann in Germany had experimented with bombardment of uranium by neutrons. The trio analysed the products of the nuclear reaction and declared the discovery of a nuclear fission of uranium atom into two parts. The name nuclear fission was given based upon the similarity of the well-known fission process of a unicellular microorganism creating two organisms. In the fission process, uranium atoms also emitted some neutrons apart from two fission fragments. When checked it was found that the fission fragments had kinetic energy. These experiments opened the doors to a new source of energy called nuclear energy. Many countries including the US, Germany, UK, etc. had taken up this work expecting that they would possess nuclear weapons. UK had a project with a fictitious code name called "Tube Alloys" that was busy making the atomic bomb. The young Rotblat then having worked under Chadwik, moved to UK and take part in this effort simply because he thought that nuclear weapons will be a good deterrent to the Nazi Germany's bomb. Later when "Tube Alloys" was merged with the Manhattan project, he worked in Los Alamos laboratories for a few months. When it became clear that Germany is not making atom bomb, sizable number of scientists approached the authorities to pack up this project. The authorities and the US government were firm about carrying the project on. Rotblat was the first scientist to resign from the project and some more followed him later. Though not mentioned in his talk, the obituary written by Jones (Jones_2005) and published in 'The Guardian' is worth taking note of. It says 'while working at Los Alamos laboratory, Rotblat had been shocked to hear General Leslie Groves, director of the Manhattan Project, making remark quite casually that the real purpose, of course, was to subdue the Soviet Union. When Rotblat decided to leave the project, a determined but highly incompetent attempt had been made to "fit him up" as a Russian spy.'

In the later years he worked for world peace and took a lead in establishing an organisation later named 'Pugwash Conferences on Science and World Affairs' or in short Pugwash Conferences. He dedicated his remaining entire life to it. The inspiration for this work was the Russell- Einstein manifesto issued on 9th July 1955 in London. Professor Joseph Rotblat was the youngest scientist as a signatory to that manifesto. He ended the speech by telling the audience to remember their humanity. Then it was time for a question-answer.

After a few questions, I gathered some courage and asked a question: Prof. Rotblat, imagine for a moment that you are of the same age when you decided to work for Manhattan project, but your maturity is that of your present age. Please also imagine that Hitler has once again appeared on horizon as deterrence US starts Manhattan project to make atom bomb. My question to you is 'whether you will still join a project like the Manhattan project? He took a pause of hardly 10 seconds and said, 'Perhaps I might take the same decision.' There was low volume laughter in some corners of the auditorium. He continued, 'Wait for a moment; I am Gandhiyan but not Gandhi. I might commit the same mistake again. To avoid such a situation only I have been working for peace till today after resigning from the Bomb making project.' The auditorium was silent for a few seconds and then there were many claps. My respect for him grew many folds.

Later I collected some biographical information on Professor Rotblat and the Pugwash conference. His parents being Jew, his father incurred great loss in the business after WW I. Joseph was the 5th child born in 1908 in Warsaw, Poland. That time Poland was part of the Russian empire. This boy from age 5 used to stand in a queue to get some ration and had to face physical violence sometimes. The Jews throughout Poland were finding it difficult to educate their kids. His study in school was often on and off. He on his own learnt Polish, Russian and English languages. Being a voracious reader, he developed interest in science and wished to become a scientist. It was his determination even in the odd circumstances that could fulfil his dream. He completed a doctorate under the guidance of British physicist James Chadwik who discovered neutrons. He had married to a girl known to him since 1930 named Tola Gryn. It was a sad story. She got trapped by the Germans after army of Adolf Hitler occupied Poland and later, she was murdered in a Belzec concentration camp in Poland itself. Joseph Rotblat never saw her again. After WWII he could meet his parents. This jolt of Nazi Holocaust was a personal as well as of social situation. The Holocaust has killed in between 5.5 to 6 million Jews, was very saddening to him. He pledged to work for making a peace-loving world without any kind of hatred and dedicated his entire remaining life for the cause.

He was one of the founding members of the Pugwash Conferences on Science and World Affairs. The objective of the organisation is to bring scientific insight and reason to bear on the catastrophic threat posed to humanity by nuclear and other weapons of mass destruction. He died in 2005.

The Precursors of Manhattan Project:

This section of the paper discusses precursors for genesis of Manhattan project. Adolf Hitler was named chancellor of Germany on Jan 30, 1933 and he ruled absolutely until his death by suicide in April 1945. In those years the anti-Jew campaign got a brutal boost. Many well to do Jews migrated to either liberal European countries or to the United States of America. Ordinary Jews started getting killed in the camps. Their livelihoods were at stake. Like other European powers, Hitler also wished for a share of colonial cake. One of the important reasons behind the Second World War (WWII) was also that. The clouds of WWII were getting thicker, darker and closer to the ground.

1. **The scientific Precursors:** A long series of scientific events acted like a precursor for the Manhattan project. As a result, the course of the world had changed forever from 1890 to 1940. The initial scientific discoveries and inventions were born out of the sheer curiosity about the concept of an atom and were sometimes due to certain accidental coincidences. After the discovery of fission of Uranium in 1938, the possibility of nuclear weapons was felt to be an achievable one in the given political situation of Europe. Let us list a few such initial events as precursors to the Manhattan project. Let us see them briefly.
   1.1. **Radioactivity** Based on an accidental discovery of radiation in uranium ore by French physicist **Henri Becquerel (1852-1908)**, the research topic of Marie Curie was to see which other elements also emit such radiations. Within a few days **Marie Curie (1867-1934)** realised that the naturally occurring element thorium also emits similar radiation. In the course of her study Curie couple (Marie & Pierre) isolated a new element called Radium and in 1898 discovered another one from uranium ore that Marie Curie named Polonium after her country name ‘Poland’. During these decades Marie Curie supplied radium to many scientists for research.
   1.2. **Atoms are no more indivisible**: The German scientist **Wilhelm Roentgen (1845- 1923)** accidentally discovered new rays. He named them as ‘X-rays. **J. J. Thomson (1856 - 1940)** from the UK discovered electrons in 1897 during the study of cathode rays. **Ernest Rutherford (1871–1937)** born in New Zealand and worked in the UK discovered two types of rays in the emission of Uranium. He named them as alpha rays and more penetrating ones as beta rays. He discovered artificial radioactive isotopes, suggested an atomic model like that of the solar system in which electrons rotate around the positively charged nucleus and he also expected some particles without any electrical charge (**James Chadwick [1891-1974]** discovered the predicted particles without any electrical charge in 1932. He named them as neutrons that are present in the nucleus to be part of the nucleus). **Fredrick Soddy (1877–1956)** observed spontaneous disintegration of radioactive elements into its variants. He called them ‘isotopes’. All isotopes of an element show the same chemical properties[1]. **Niels Bohr (1885-1962)** has improved the model based on quantum mechanics 8) Erwin Schrodinger (1887-1961) and others improvised the model with four types of quantum numbers.

[1] After the discovery of neutrons in 1932, it was found that all the isotopes of an element have same number of protons but they differ in number of neutrons in the nucleus. The number of protons in the nucleus is equivalent to the atomic number of the element but the mass number is a sum of the protons and neutrons in the nucleolus. For example, the element Uranium has only two naturally occurring radioactive isotopes and no stable isotope of uranium exists. Both have 92 protons and have 143 and 146 neutrons respectively. Since both protons and neutrons have more or less similar masses (≈ 1 Atomic Unit) the mass numbers of these isotopes of uranium are 92+143= 235 and 92+146= 238. These two isotopes are normally represented as ${}_{92}U^{235}$ and ${}_{92}U^{238}$ or as U-235 and U-238 assuming the readers know atomic number of uranium.

1.3. **Mass- energy equivalence**: Albert Einstein (1879 –1955) published the special theory of relativity in 1905. In that he talks about the mass-energy equivalence. The meaning of this equivalence is that both mass and energy can get converted into the other under special conditions. The mathematical equation is $E= mc^2$, where m is the mass in kilograms, c^2 is the square of velocity of light in metres/second in vacuum and E is energy released in the process of mass converting into energy in the units of Joules. This energy was responsible for the binding of all the positively charged protons and charged neutral neutrons together in the nucleus. In most of the nuclear reactions part of this 'Binding energy' gets released in the process of radioactive decay[2]. In comparison with the spontaneous decay of radioactive isotopes, the nuclear fission and fusion type of reactions, far larger mass gets converted into energy so releases tremendous energy [3]. In addition if that conversion is in very short time enormous energy can be made to get released leading to an explosion i.e. a possibility of making an atom bomb. Under the lead scientist Lise Meitner (1878- 1968), her nephew Otto Frisch, Otto Hahn and Fritz Strassmann had worked on the nuclear fission of U-235. However, the credit has finally gone to Hahn- Strassmann. It was later found that in the fission of the uranium nucleus apart from two fission products with high kinetic energy and 2-3 neutrons are emitted. With good design these neutrons can cause fission in other U-235 atoms leading to a sustained chain reaction of fissions in the entire mass of U-235. The minimum required mass essential for a sustained chain reaction is called critical mass.

1.4. **Szilard-Einstein Letter:** The evolution of the atom bomb began one hot summer day in Long Island, New York on July 16th, 1939. The dramatic setting was of the beautiful summer home of Albert Einstein. The actors were Germany's Albert Einstein a Jew by birth and the other was Hungary's Leo Szilard, also a son of middle class Jewish parents (1898–1964). He had conceived the nuclear chain reaction in 1933. He also had taken a patent of a nuclear fission reactor in 1934. Both the actors having Jewish ancestry had left their country and settled as refugees in the US. The US had given refuge to many Jews with a warm welcome. On 16th July of 1939 Szilard was carrying a well drafted letter for a signature of Einstein, to be handed over to the president Roosevelt of US then. Though Szilard was a well-known nuclear physicist in the circle of scientists, he was not known outside it. On the other hand, Einstein was an eminent personality amongst the community of scientists and also amongst the political circle then. Einstein was in great dilemma and Szilard was seriously making an effort using all

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[2] This "Binding energy" gets released in the nuclear reactions where alpha, beta particles are emitted. Alpha particles (α) are positively charged and made up of two protons and two neutrons from the atom's nucleus. Alpha particles come from the decay of the heaviest radioactive elements, such as uranium, radium and polonium. Even though alpha particles are very energetic, they are so heavy that they use up their energy over short distances in air and are unable to travel very far from the atom. But if α-emitting material enters the human body it is very dangerous. Beta particles (β) are small, fast-moving particles with a negative electrical charge that are emitted from an atom's nucleus during radioactive decay. These particles are emitted by certain unstable atoms such as hydrogen-3 (Tritium), carbon-14 and strontium-90. Gamma rays (γ) are pure energy. Gamma rays are similar to visible light, but have much higher energy. Gamma rays are often emitted along with alpha or beta particles during radioactive decay. All the above three radiations are ionising and so dangerous to health.

[3] Fission reaction: Specific isotopes of heavier elements like uranium and plutonium when bombarded with neutrons (slow or fast) can fission into two very unstable nuclei with tremendous kinetic energy and 2 to 3 neutrons. Just to give an idea if every atom of 1 gram of U-235 undergoes fission reaction it gives out 1MWd energy.

his skills to convince Einstein. Finally, Einstein yielded and soon the Manhattan Project got moving. This letter of Einstein had changed the world for how long one can only guess.

2. **The Manhattan Project:** The mandate of the Manhattan project was to produce the first atomic bomb of the world during WW II before Hitler's Nazi Germany makes it. The project was led by the United States with allies like the United Kingdom and Canada. From 1942 to 1946, the project was under the direction of Major General Leslie Groves. Robert Oppenheimer was in charge of the scientific side. On the progress of the project, it absorbed the British project code named 'Tube Alloys' in which Prof. Joseph Rotblat had worked. The Manhattan Project began modestly in 1939, but grew to employ more than 1,30,000 people and cost nearly US$2 billion then (that will be equivalent to $30.2 billion dollars in 2020). Over 90% of the cost was for building factories and producing the fissionable materials, with less than 10% for development and production of the weapons. When the Tube Alloys project in the UK got merged into the US project named Manhattan Project Prof. Rotblat had worked for that project as well.
Great achievements of Manhattan project: In the short period from 1942 to 1946, the Manhattan project has made two atom bombs, named 'Little Boy' (U-235 based) and the other 'Fat Man'. It had set up two reactors at Oak Ridge and Hanford, Washington to produce plutonium for 'Fat Man' type bombs and tested one extra plutonium based bomb under the code name 'Trinity nuclear test' on July 16, 1945. The Military Policy Committee of the Manhattan project had decided the future target as Japan for the nuclear weapons on May 5, 1943. This might be perhaps a retaliation of the Japanese attack on Pearl Harbour in December, 1941. Roosevelt had died on April12, 1945 and Harry Truman was named the 33rd president of the USA. In spite of the change in the highest political person in power, the future target cities of Japan were also fixed to be two cities from this list of four cities: Kokura, Hiroshima, Niigata and Kyoto. Looking at these achievements one is really amazed by the efficiency, the secrecy maintained and completing the mandate of the project. The Manhattan Project was formally replaced by the Atomic Energy Commission in 1947. In the words of Alex Wellerstein (Wellerstein_2019) 'the project is commonly regarded as one of the most successful megaprojects bringing together scientific expertise, industrial production, and military coordination to create an entirely new industry, and new form of weaponry, in an unusually compressed timescale. The role of the thousands of academic scientists in hundreds of centres of the project, who participated in the weaponisation of a new scientific discovery to facilitate the project as a prototype of future military-industrial-academic collaborations.'

Number of A-bombs and nuclear Reactors: Two types of atomic bomb were developed during the WW II. A relatively simple gun-type of atom bomb was made using only Uranium-235 a fissionable isotope. In this design a special trigger fires a sub critical projectile of U235 into another subcritical U-235 target. Both together make the total mass more than the critical mass leading to an explosion[4] releasing tremendous energy.

The other nuclear bomb making had used two nuclear reactors with natural uranium as a fuel to produce element Plutonium. Two such plutonium (${}_{94}Pu^{239}$ having atomic number 94 and mass number 239) producing reactors were constructed at Oak Ridge and Hanford, Washington. The plutonium bomb had an altogether different problem, which did not allow using gun type

[4] However, the requirement of this design is to raise the naturally occurring percentage of U-235 (which is 0.7%), to more than 90%. This is a gigantic task. This process to raise the percentage of U-235 is called the uranium enrichment process.

technique[5]. So a practical technique called implosion technique was used for plutonium based atom bomb. Both the design and construction procedures were developed in a concerted effort at the project's principal research and design laboratory in Los Alamos, New Mexico.

The Bombing of Hiroshima and Nagasaki: Out of the four potential city targets selected (Kyoto, Hiroshima, Yokohama, and Kokura), Hiroshima was the number one target. That is because Hiroshima was a major army base. It was an important port of south Japan. Seventy-five years ago on August 6, 1945 The B-29 bomber Enola Gay commanded by Paul Tibbets of US air force was carrying the "Little Boy". Enola Gay was accompanied by two other B-29 bombers carrying scientific and photography instruments. At 8:15 am the "Little Boy" was released from the plane from a height of around 10,000 metres. That boy, made up of roughly 8-10 kg of U-235 exploded at very low efficiency (below 2%) from about half km height over Hiroshima. The fire mushroom, thundering sound, heavy wind that carried vehicles, burnt many people to gases, the ones at more distance to charred black bodies, boiling waters, heavy sea waves, still further away from the location where the bomb exploded skin pealed individuals running around. The US had shot the video perhaps as a proof of her military might and scientific 'cruelty'. The Geneva Convention disapproves treating the city civilians as targets. Here the whole city was a target. That 'little boy' instantly and then immediately killed between 80,000 to 1,50,000 up to the end of the year 1945. Three days later there was a similar demonstration at the cost of Nagasaki killing immediately around 70,000 people. Those who died were lucky. From the surviving others nobody could get medical help, simply because there was no medical staff, no hospitals and no medicines. `The scene of the city was something like this: nothing to eat in close by areas, the nights quite dark because of no lamps in most of the areas, no immediate humanitarian help. There was no emergency because the surviving people were freely left over to die on their own.

There is a US version of why were the A-bombs used on two Japanese cities one after the other? It is this: A difficult decision to use A-bombs on two Japanese cities was taken to shorten the war with Japan and so to save the lives of thousands of US armed forces. However, it is a simplistic answer to a complex question.

The decision to use two A-bombs on two cities had given birth to not only the age of nuclear energy but it kindled the desire of stockpiling of nuclear weapons in the minds of many nations as groups or as single nations. That lead to a MAD (Mutually Assured Destruction) race for nuclear weapons amongst US-USSR, NATO states Vs the then Warsaw Treaty Organisation, Israel-Palestine and India-Pakistan, and also among the single nations like N. Korea, South Africa before being independent, doubtfully Iran and Japan.

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[5] In any reactor there are always neutrons of low to high kinetic energy around, Pu-239 isotope by absorbing one neutron becomes Pu-240 some of the thus formed Pu-240 further absorbs second neutron and becomes isotope Pu-241. Since all the isotopes of every element have the same chemical properties, separated plutonium contains all the isotopes of plutonium. Of the four isotopes, only Pu-239 isotope is fissionable by slow neutrons. The Pu-240 isotope on the other hand has a secondary decay mode called spontaneous fission, which can start a premature chain reaction. As a result a gun-type bomb cannot be made, instead implosion technique is used. In this technique many subcritical plutonium projectiles are simultaneously fired by explosive chemical reaction to the centre of the bomb. That creates the required critical mass to sustain the fission chain reaction causing a big energy release in a fraction of second- that is explosion.

The controversy surrounding the decision to bomb two Japanese cities touches many complex questions having many possible answers. To Mark 75th anniversary of the atomic bombings of Hiroshima and Nagasaki in August 1945, US National Security Archive had published (Burr_2020) a posting of "A Collection of updated Primary Sources" under the title, "The Atomic Bomb and the End of World War II". It carries a list of 14 questions that historians attempted to answer.

A list of the 14 questions

1. Were the atomic strikes necessary primarily to avert an invasion of Japan in November 1945?
2. Did Truman authorize the use of atomic bombs for diplomatic-political reasons- to intimidate the Soviets--or was his major goal to force Japan to surrender and bring the war to an early end?
3. If ending the war quickly was the most important motivation of Truman and his advisers, to what extent did they see an "atomic diplomacy" capability as a "bonus"?
4. To what extent did subsequent justification for the atomic bomb exaggerate or misuse wartime estimates for U.S. casualties stemming from an invasion of Japan?
5. Were there alternatives to the use of the weapons? If there were, what were they and how plausible are they in retrospect? Why were alternatives not pursued?
6. How did the U.S. government plan to use the bombs? What concepts did war planners use to select targets? To what extent were senior officials interested in looking at alternatives to urban targets? How familiar was President Truman with the concepts that led target planners chose major cities as targets?
7. What did senior officials know about the effects of atomic bombs before they were used? How much did top officials know about the radiation effects of the weapons?
8. Did President Truman make a decision, in a robust sense, to use the bomb or did he inherit a decision that had already been made?
9. Were the Japanese ready to surrender before the bombs were dropped? To what extent had Emperor Hirohito prolonged the war unnecessarily by not seizing opportunities for surrender?
10. If the United States had been more flexible about the demand for "unconditional surrender" by explicitly or implicitly guaranteeing a constitutional monarchy would Japan have surrendered earlier than it did?
11. How decisive was the atomic bombings to the Japanese decision to surrender?
12. Was the bombing of Nagasaki unnecessary? To the extent that the atomic bombing was critically important to the Japanese decision to surrender would it have been enough to destroy one city?
13. Would the Soviet declaration of war have been enough to compel Tokyo to admit defeat?
14. Was the dropping of the atomic bombs morally justifiable?

Apart from the controversies surrounding the purpose/s of American use of nuclear weapons against Japanese cities in August 1945, one fact is beyond any doubt. That is President Harry Truman had insisted to use the bomb but it was not he, who issued the order to that effect. It was Secretary of War, Henry Stimson (Sean_2009) who authorised the delivery of the "first special bomb as soon as weather will permit visual bombing after about 3 August 1945." This directive was almost certainly discussed with the president before its approval. Truman never signed this or any other order with respect to the use of the atomic bomb against Japan. It raises a question "why"?

The first US president who visited Hiroshima was Barack Obama after 71 years of bombing. US President Barack Obama gave a speech (Obama_2016) at Hiroshima peace memorial on May 27, 2016 at 5:45 local time. He said, "Seventy-one years ago, on a bright, cloudless morning, death fell from the sky and the world was changed. A flash of light and a wall of fire destroyed a city and demonstrated that mankind possessed the means to destroy itself. He further asked a rhetorical question, "Why do we come to this place, to Hiroshima? We come to ponder a terrible force unleashed in a not so distant past. We come to mourn the dead, including over 100,000 Japanese men, women and children; thousands of Koreans; a dozen Americans held prisoner. Their souls speak to us. They ask us to look inward, to take stock of who we are and what we might become." It is difficult to believe that the same President, who spoke with such a beautiful human sensitivity, is a person in the position of president who agrees to spend (Ewing_2016) trillion dollars in upgrading the US nukes. What is this quality of people in power called?

2.1. The Culture of the Manhattan Project: By now we know that the Manhattan Project had built both the Nuclear Weapons and the basic nuclear reactors though not for power but for breeding plutonium to procure nuclear weapons with ease. Weapons required 8-to 10 kg of fissile material, a trigger that will bring segregated subcritical masses together and the material becomes critical if the container does not allow most of the neutrons escape the container, then maximum amount of fissionable material fissions in few nanoseconds. The container should be strong enough to withstand the high pressure and temperature for at least 60-65 generations of neutrons and then explode. On the other hand the purpose of that Manhattan project time nuclear reactors was to irradiate the uranium of the load of fissile material and convert U-238 isotope into Plutonium-239 and U-235 isotope to sustain the fission chain reaction for a few months. Due to fission chain reaction the generated heat if not taken out, the core of the reactor can melt. One has to shut down the reactor so that the isotope of plutonium-239 percentage wise is more than 90%. If the reactor is running for longer times, part of this the Plutonium-239 gets converted into Plutonium-240 and subsequently Plutonium-241by absorbing one later one more neutron.

During the war period the prime purpose of the Manhattan Project was to make nuclear weapons, it was perhaps expected that the research work will be inundated with all round secrecy, spying, doublespeak, threats of new weapons and targeting the vulnerable countries as a dry run. The circumstances of the time also indicate by the post-hand sight that the US had other allied purposes like nuclear diplomacy, improvisation of world status, etc. However, when scientists of high standing from many nation states were working together, it is humanly difficult to maintain secrecy. After the August 1945 A-bombing two Japanese cities Hiroshima and Nagasaki the details of its inhuman effect also spread world over and criticism on this act started pouring in US. Even till today that is the single use of nuclear weapons.

When Eisenhower was declared President of the US he concentrated on maintaining world peace. He watched with pleasure the development of his "atoms for peace" program–the loan of American uranium to "have not" nations (Freidel_2006) for peaceful purposes. That may be because of his trait to "negotiate peace from military strength". He tried to reduce the strains of the Cold War. In 1953, the signing of a truce brought an armed peace along the border of South Korea. The death of Stalin the same year caused shifts in relations with Russia. Thus, Eisenhower concentrated on maintaining world peace.

The spread of Nuclear Weapons: The weapons are for destruction and mass killing. So, a few kilograms of fissile material is enough to start a fission chain reaction and it has to explode within a few nanoseconds after trigger, whereas the purpose of a reactor is to supply the controlled amount of heat energy to the turbine to convert the heat energy into electrical energy. This electrical energy has to be carried through a grid to the variety of consumers. That demands a safe sustained fission rate through the core design of the fuel distributed in a number of tubes, good heat transport to generate first high temperature flow of coolant into the generator of high temperature steam in the turbines. This peaceful function was carried to many nations through the “the atoms for peace”. The duality of negotiating peace from military strength existed from the presidential periods of Eisenhower to till this day. This hidden hypocrisy reappeared in many international treaties except in the case of the TPNW (Treaty for Prohibition of Nuclear Weapons).

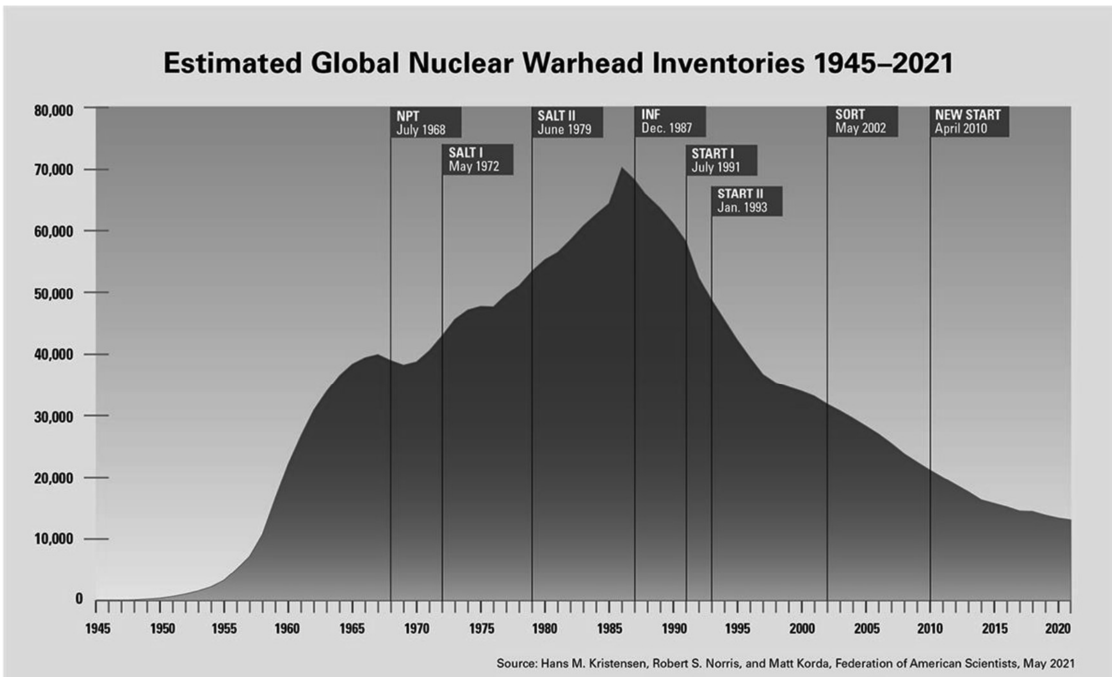


Fig. 1: Shows the temporary effects of various initiatives at different times on the global nuclear warheads as an indicator of world peace.

And the Table 1 below elaborates when and how many nuclear weapons stockpiled the nine weapons states of today as the years pass by.

Table 1: 1945-2010 Abridged Global Nuclear Weapons Inventories (of Stockpiles)										
For the advanced Years the entries are from other sources mentioned against them										
http://journals.sagepub.com/doi/pdf/10.2968/066004008										
Year	**USA**	**USSR/ Russia**	**UK**	**France**	**China**	**Israel**	**India**	**Pakistan**	**N. Korea**	**Total**
1945	2	-	-	-	-	-	-	-	-	2
1946	9	-	-	-	-	-	-	-	-	9

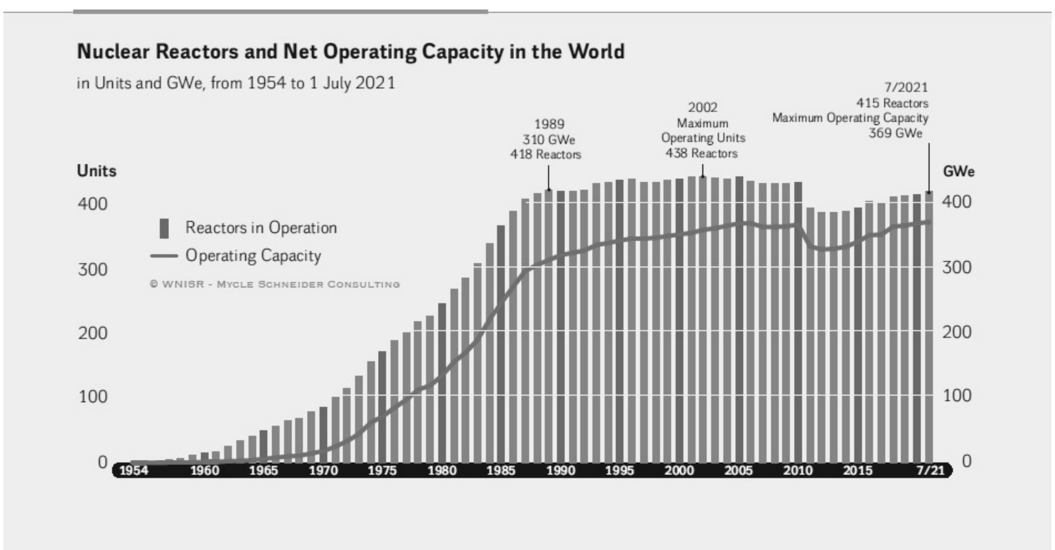
1947	13	-	-	-	-	-	-	-	-	13
1948	50	-	-	-	-	-	-	-	-	50
1949	170	1	-	-	-	-	-	-	-	171
1950	299	5	-	-	-	-	-	-	-	304
1955	2,422	200	14	-	-	-	-	-	-	2,636
1960	18,638	1,605	42	-	-	-	-	-	-	20,285
1965	31,139	6,129	436	32	5	-	-	-	-	37,741
1970	26,008	11,643	394	36	75	8	-	-	-	38,164
1975	27,519	19,055	492	188	180	20	-	-	-	47,454
1980	24,104	30,062	492	250	205	31	-	-	-	55,144
1984	23,459	37,431	380	280	249	40	-	-	-	61,839
1985	23,368	39,197	422	360	243	42	-	-	-	63,632
1986	23,317	45,000	422	355	230	44	-	-	-	69,368
1987	23,575	43,000	422	420	230	47	-	-	-	67,694
1988	23,205	41,000	422	410	240	49	-	-	-	65,326
1989	22,217	39,000	422	410	238	51	-	-	-	62,338
1990	21,392	37,000	422	505	232	53	-	-	-	59,604
1995	10,904	27,000	422	500	234	63	-	-	-	39,123
2000	10,577	21,500	281	470	232	72	14	13	-	33,159
2005	8,360	17,000	281	350	235	80	44	38	-	26,388
2006	7,853	16,000	281	350	235	80	50	43	-	24,892
2007	5,709	15,000	225	350	235	80	60	50	-	21,709
2008	5,273	14,000	225	300	235	80	70	60	-	20,243
2009	5,113	13,000	225	300	240	80	80	70	-	19,108
2010	5,000 a	12,000	225	300	240	80	80	70	-	17,995
2013 b	4,650	4,480	225	300	250	80	110	120	n/a	10,215
2017 c	6,800	7,000	215	300	270	80	120-130	130-140	10-20	14,935
2021 d	5 550	6 255	225	290	350	90	156	265	40-50	13 080
Year	**USA**	**USSR/ Russia**	**UK**	**France**	**China**	**Israel**	**India**	**Pakistan**	**N. Korea**	**Total**
a	**The U.S. column only includes warheads in the Defence Department stockpile, which was declassified in May 2010. Several thousand additional retired but intact warheads are awaiting dismantlement, probably 3,500-4,500 as of August 2010.**									
b	**From Bulletin of the Atomic Scientists. https://journals.sagepub.com/doi/pdf/10.2968/066004008**									
c	**SIPRI Yearbook Summary 2017; Page No 18, Total no of warheads 4,150.**									
d	**SIPRI Yearbook Summary January 2021, Vol 2, Chapter 10, Page 19. Table 'world nuclear forces'. https://sipri.org/sites/default/files/2021-06/sipri_yb21_summary_en_v2.pdf**									

Both the graph and the table ignore the ever increasing strengths of nuclear weapons, their types and many more specialities. This table shows only one side, the other side of the reality is the peace talk followed by the international treaties officially initiated through UNO. The main hypocrisy was that the five nation states having Veto rights, namely US, USSR, UK, France and China can have, can produce, can threaten and can also make use of nuclear weapons, but not the member states. Apart from Non Proliferation Treaty (NPT), Partial Test ban treaty (PTBT), Cumulative Test Ban treaty (CTBT) had this element of duality. They all name who can and who are banned to share the NUC technology, possess N-weapons etc. The divide between the weapons state and the others is clear cut amongst the member states of the UNO. Of course, it is a "democratic grace" that there exists a freedom to be a member of the treaties or not to be a member. Not only that, a member of any treaty can resign from it. If a non-weapons state wants to possess or develop N-weapons there are many options like do whatever you want but do not declare, don't become a member of the treaty and if you are already a member of say NPT resign from it and behave like the rogue superpowers. Don't you worry; UNO does not have teeth for any action.

However, in 2017 under the umbrella of UNO a new treaty had taken place. It called "The Treaty on the Prohibition of Nuclear Weapons (TPNW)". It includes a comprehensive set of prohibitions on participating in any nuclear weapon activities. It has entered in to force since January 22, 2021. From this day onwards possessing, helping to possess, threatening with or using the Nuclear weapons is illegal for the members of the treaty. It is obvious that the nine weapons states are not members of this treaty. These states are rogue states in the eyes of the majority of nations and also of UNO. January 21, 2021 was a critical milestone (ICAN_2021) towards the total elimination of nuclear weapons.

Taking note of the above data one feels that in a war between any two weapon's states, if the enemy country is driven to the wall, the probability of that country using the A-bomb increases many folds. Should any country indulge in a serious war? Secondly, when two countries opt for the option of risking a nuclear war, is it not correct to say that the heads of these states are bad statespersons, incompetent politicians and are not fit for their job? There exists a good possibility that some other weapons states might indulge in as the allies of the two countries in such a situation. Are we blind to learn from history? In reality after every large scale war and massive damages and death tolls there in, genuine efforts are made for lasting peace. One can see such a trend right from the epic of '*Mahabharat*' (*Stree Parva* and *Shanti parva* soon after the war ends), WW I (League of Nations), WWII (Russell-Einstein manifesto, formation of UNO) etc. Unfortunately, the initiative for peace efforts is taken by the winners of the wars. Perhaps the peace effort may be towards maintaining an upper hand? The peace organisations stand on the financial support of the winners so they listen to the strongest winner and act in its favour. Other winners start feeling uneasy. That eventually makes the peace initiatives short lived and makes the peacekeeping organisations ineffective. As a result, the leaders of the next generations start preparing for the wars. Do civilians wish for wars? Let us ponder over with a cool head on such drawbacks of our leaders and next generation citizens supporting the leaders. Thirdly, when two countries cannot solve their problem through good negotiations, is it not true that the citizens had either tolerated or supported a bunch of individuals ignorant and short sighted for their jobs as statesmen and leaders? Think about the ways out of such recurring *Chakravyuha*. Also remember when A-bombs are dropped from sky, the effects are not similar to a heavenly shower of flowers in the honour of such leaders? It is better to remember our own humanity.

The Spread of Nuclear Power Reactors: One should admit that Eisenhower's "Atoms for peace" program is more successful than the treaties to ban the spread of N-weapons. The proof is data in the form of a graph in Fig. 2 below. This is a copy of a graph taken from (Schneider_2021) a "World Nuclear Industry Status Report-2021(Wnisr-2021)" The x-axis starts from the year 1954 because that is the year a first power reactor, built by USSR, went critical and started supplying electricity to consumers. The blue vertical bars show the year-wise number of operating reactors, while the brick colour line shows the year-wise cumulatively used operating power of the working reactors. It is interesting to know that the total number of operating reactors was above 400 units till the year 2010, maximum being of 438 reactors in 2002 and the level dropped from around 430 operating reactors, it suddenly dropped to the number roughly around 380 reactors. Normally, a power station consists of around 4-6 reactors. That helps build common systems for all the plants in the station. One has seen the flip side during the major accidents of Chernobyl and Fukushima Daiichi power stations; nearly all the reactors of the power station got affected simultaneously, of course, to a different extent. The Fig.2 graph points a finger at a very serious nuclear accident year 2011 (on March 11, 2010) at the Japanese Fukushima Daiichi power plant site having six reactors. The graph indicates that the cumulative operating power maxima (369 GW level) of the 415 reactors took place in the month of July 2021.



Sources: WNISR, with IAEA-PRIS, 2021

Note
Changes in the database regarding closing dates of reactors or LTO status slightly change the shape of this graph from previous editions. In particular, the previous "maximum operating capacity" of 2006 (overtaken in July 2019) is now at 367 GW.

Fig.2: World nuclear reactors Fleet from 1954 to 2021

As of 1 July 2021, worldwide 415 reactors were operating. In the same year there were 196 closed reactors in the various stages of decommissioning. Their total capacity was 90.4 GW. This WNISR-2021 report has depicted all the world reactors by age. Here that graphic image is reproduced from page no 59.

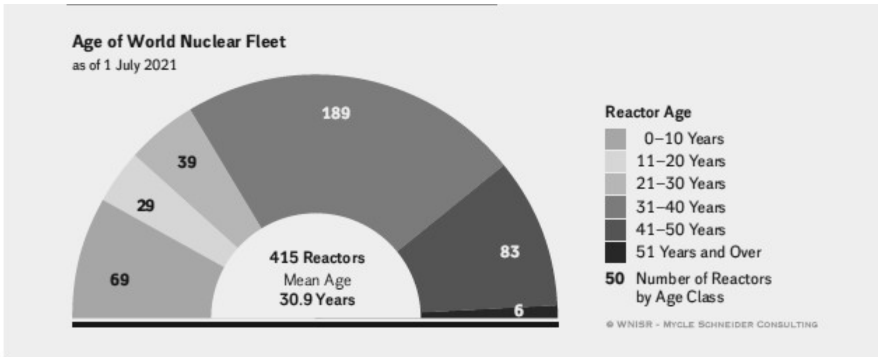


Fig.3: World nuclear reactors by age for the year 2021

Is nuclear power an option for Energy? Since Global Warming is talked about very often, most of us have heard that the increase in the concentration OF Greenhouse Gases (GHGs) in the atmosphere is responsible for trapping the heat in the atmosphere and thereby causing Global Warming. The Intergovernmental Panel on Climate Change (IPCC) has proven that Global Warming is anthropogenic that is made through human activities. Meaning that the global warming is because of the increasing emission of the Green House Gases, namely CO2, water vapour, Methane, nitrous oxides etc. after industrial revolution. Not only that, IPCC has also warned all the citizens of the planet about the rise of temperature beyond 1.5^{O} C above the pre-industrial revolution (IPCC_2018), it is going to be too dangerous for the entire population of the planet. And perhaps half the global population may get wiped out by 2050. To mitigate this global warming, it is advised to reduce the emission of CO_2 by using alternate technologies that have less carbon footprints. So naturally the Nuclear power advocates have started arguing that their favoured Nuclear Energy would be the indispensable option. Their rationale is that nuclear energy provides continuous power generation, compared to the intermittent solar and wind renewable energy with net-zero GHGs emissions. For example, the International Atomic Energy Agency's (IAEA) Director labelled nuclear power (Jeffrey_Donovan_2021) as "present solution" to curbing emissions. He is wrong on at least two counts, 1) he does not consider the entire fuel cycle and the natural life cycle of nuclear power plants. He is talking as if a nuclear reactor directly falls from heaven without any prior to start-up stages and without after close-up any posterior stages. To understand this blunder, consider two IAEA publications titled 1) a simple brusher (IAEA_2020) of 12 pages. This brusher gives very brief information of the total eight stages. Electricity generation is the fifth stage. Possessing the right kind of and right quantity of fabricated fuel is not sufficient to generate electricity. The fuel has to be in a specially selected type of a nuclear reactor that is operating smoothly. 2) The other IAEA technical document (IAEA_TECDOC_2002) talks of nine stages of a nuclear power plant starting with Design to Decommissioning. As a result, one must consider the carbon footprint of all these 8 plus 9 that is all the 17 stages together of these documents to certify nuclear energy any quantum of carbon footprints. Perhaps Dr. Grossi should order his staff to come up with a report that considers all the available options with their respective cradle to graveyard stages. So that he and other curious lay people can study that future report and talk like a knowledgeable individual. Let us move on to the second consideration on which IAEA Director General is not right in making the statements he made. 2) Most of the energy sources including nuclear electricity are vulnerable to climate change, the resulting extreme weather events that affect the transmission grid spread over huge geographic areas. This causal chain is common to many energy sources. As a result, higher ambient temperature levels definitely lead to greater transmission and distribution losses. Not only that when climate change causes wildfires, which could lead to cutting off users. Similarly, all the thermal power stations including nuclear electricity generation have common component units like steam generators, turbines and generators (Fig. 3). As a result, when the ambient temperature rises, the temperature gap between the steam and coolant water diminishes, reducing the efficiency. Nuclear energy is not an exception. The Wnsr-2021 has provided the analyses of the 56 French nuclear reactors for the year 2020. In that year, the total duration of no output of the French reactors reached 6,465 reactor-days. The reactor performance averaged to an outage ratio of 115.5 days per reactor for the year 2020.

The nuclear power advocates, while parroting the views of their bosses without taking any cognisance of the complexity involved in the issue are doing a disservice to the world human society in general.
Some research works of the analysis of emission levels of the entire nuclear fuel and reactor life cycle have been published. They arrive at different conclusions than IAEA, which is part of the United Nations System. The IAEA in spite of having a mandate to seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity, it does not engage in a dialogue with those researchers who do not agree with it. The first such reference is (Lenzen_2008) and the second is (Benjamin_2008). As a result, until the IAEA takes cognisance of such research, we need not get persuaded with the favoured energy option of IAEA, the 'Nuclear energy'. Because of such an attitude they are harming the integrity of the organisation itself. Few other reasons are as follows: (i) Electricity from nuclear sources is costlier than the renewable sources like hydro, wind and solar. (ii) There is no solution for a permanent site where the long lived radio-active waste can be stored for

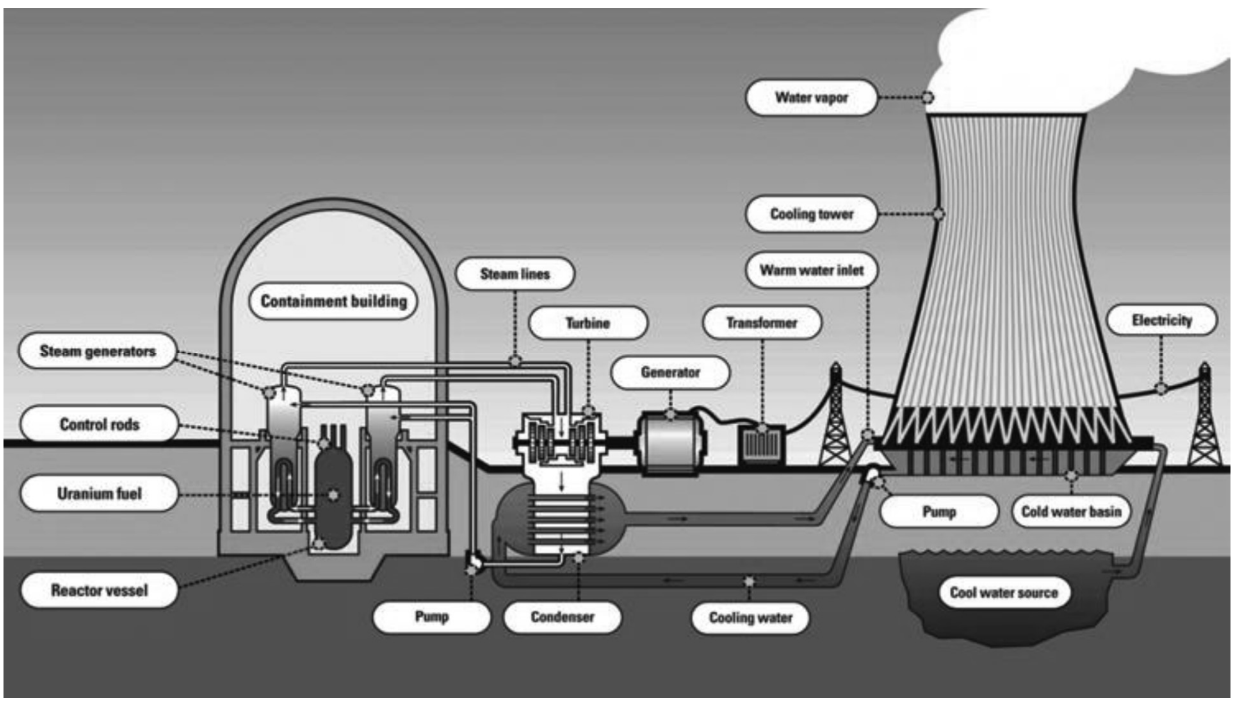


Fig. 4: Nuclear thermal energy is converted in to electrical energy through heat exchanger
https://www.foronuclear.org/en/updates/in-depth/what-are-the-different-components-of-a-nuclear-power-plant/

many hundreds of years and the once reactor sites can be used for normal purposes. (iii) Soon after a nuclear reactor is closed and cooled for prescribed time, it is not taken for decommissioning as soon as possible. However, being a costly and risky venture of decommissioning many times takes longer time than the services given by it. (iv) As a result, there is an international tendency to extend its working for more years beyond its stipulated age. This is a risky affair because some systems related to the electricity generation might have gotten weakened and relatively a small trigger for accidents becomes sufficient. (v) Though in the last 62 years only two major accidents at the sites of Chernobyl and Fukushima Daiichi exist, there exists a long list of minor mishaps of radio-active leakages are more common. (vi) A part of the radioactive waste is very long lived one (a few centuries duration), in that period the political world map may change many times. The recent example being that of the collapse of the USSR and many smaller nations are formed. The state of Russia and that of Ukraine are at war in the year 2022. The Russian head of the state, Mr Putin, had placed many nuclear weapons on high Alert mode. Such an act during war periods is an irresponsible one. However, leaders of many prominent states in the world are not competent enough to solve the interstate issues through dialogue. (vii) Apart from the regular nuclear power reactors, there exist many enriched uranium fuel based small reactors for a plethora of purposes in nearly all the countries using nuclear power reactors with different names like experimental reactor, research reactor, etc.

We have seen that such reactors produce isotopes like plutonium-239, plutonium-240 and plutonium-241. The neutron density is low in such reactors, and so the fuel burn-up is also, producing plutonium in which plutonium-239 is more than 90%. Such plutonium is an easily fissionable material just like uranium-235 enriched to the level of more than 90%. It is an easier pathway for nuclear weapons. So, nuclear reactors are a double edged device useful to generate Electricity, as research reactors can be equipped with many facilities, neutron activation analysis and production of new isotopes for a variety of purposes on one side. On the other side if political leaders are for nuclear weapons, a nation can make Nagasaki type plutonium based A-bombs.

Conclusions:

Considering all these related issues the first conclusion is: one should not use power reactors for electricity generation at all. All reactors should be research reactors and there should be a ban on a plutonium plant for all the nations. The used reactor fuel should be centrally processed only by IAEA or under the supervision of IAEA and the plutonium should be used for peaceful uses only. Finally, such facility stations should be transparent for visitors on a fixed day of a week.

The other conclusions this plenary is going to put forth are related to the cultural changes that are needed in the academic and research institutions. This plenary also appeals to this august audience to discuss the suggested cultural changes in our Indian institutions, additions/ deletions in that and the ways to set in the processes for such a s change. For such a purpose, perhaps study of history of such changes that have taken place in the world history might be useful. For example, in ancient times in the South Asian subcontinent there must have been some thoughts that inspired the kings and wealthy people to set up those famous universities like (i) Valabhi University (an important centre of Buddhist learning 600 CE and 1400 CE. The city Valabhi, present day Vallabhipur, was the capital of the Maitraka Empire and an important port for international trade located in Saurashtra, Gujarat. (ii) Nalanda University, which was a renowned Buddhist monastic university in ancient Magadha, modern-day Bihar, located near the city of Rajagriha (now Rajgir) and about 90 kilometres from Pataliputra or present-day Patana. It was operating from 427 to 1197 CE. Nalanda was established during the Gupta Empire. (iii) The University of Ancient Taxila was located in the city of Txila (तक्षशिला) present-day Pakistan on the eastern bank of the Indus River. Like Nalanda, Taxila was also an institute of higher learning. It became the capital of the Achaemenid or the First Persian Empire founded by Cyrus the Great in 550 BC in north-western Indian Subcontinent around 515 BCE. That culture shaped the brilliant people like Varah Mihir, Araybhat I, etc. Again, in the ancient times Alexandria in present day Egypt became the world known centre for study and in Greek city states creative people like Socrates, Archimedes, Euclid etc did foundational work. Later in the business people who came to the Indian subcontinent were curious to collect and translate works in Arabic and Farsi languages. It is the same people who preserved the work of famous people from Greek city states. We will have to study such periods to search for the inspirations that human history has witnessed.

Now few suggestions regarding the desirable cultural changes for our future generation:

1) In the plenary we talked about what is Modernity. That sort of modernity is desirable in our institutions. Science and meta-science should not be mixed. That was a departure from the ancient times. Also we should guard against the mistakes like spread of colonialism that Europe did that time. Let us remember that inputs in academic institutions are to initiate the desirable cultural change. So first of all, the curiosity of the children has to be aroused, they should help to search, invent for the answers for their questions. In short we

have to change pedagogy of education in all our schools, irrespective of medium of communication and rural and city conditions.

2) We have met some scientist while listing them under the precursor to Manhattan project. Some young students had poor economic background, they were helped. Some European kingdoms had banned education in science and mathematics for girls. Other European kingdoms not only welcomed them gave good opportunity to them to good research work. That culture we have to imbibe.

3) We should be critical of the Manhattan project culture that was cluttered with secrecy. As a result, a Taylor System where the work under completion of the Mandate is broken in to pieces and carried out. And few individuals in a central place put the pieces together so as to make complete picture. For such a system a military like hierarchy was used in Manhattan project. We have to keep it away.

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