

Introduction:

Nuclear energy:

Nuclear energy is energy in the nucleus (core) of an atom. Atoms are tiny particles that make up every object in the universe. Nuclear energy can be used to make electricity. But first the energy must be released. It can be released from atoms in two ways: nuclear fusion and nuclear fission. In nuclear fusion, energy is released when atoms are combined or fused together to form a larger atom. This is how the sun produces energy. In nuclear fission, atoms are split apart to form smaller atoms, releasing energy. Under certain circumstances (in this case struck by neutron), the nucleus of a very large atom can split in two. In this process, a certain amount of the large atom's mass is converted to pure energy following **Einstein's famous formula $E = MC^2$** . where M is the small amount of mass and C is the speed of light (a very large number). Nuclear power plants use the energy from nuclear fission to produce electricity.

Unlike other energy sources, nuclear power plants do not release carbon or pollutants like nitrogen and sulfur oxides into the air as no fossil fuels are used. So this is a source of clean energy.

The benefits of nuclear energy extend far beyond carbon-free electricity too. Nuclear powers space exploration, sterilizes medical equipment, provides potable water through desalination, supplies radioisotopes for cancer treatment and much more.

Principle of a nuclear reactor:

- Steam is required to run turbine to produce electricity in a conventional power plant. Nuclear power plant uses the energy of a fission reaction, rather than burning a fuel, to create that steam. In this process uranium atoms, the fuel, are disintegrated to release energy. To split a uranium atom, it is hit with neutron, which releases more neutrons and heat. Those neutrons will hit other uranium atoms causing them to split and continue the process, generating more neutrons and more heat. This chain reaction occurs in a pressure vessel called nuclear reactor.
- Nuclear reactors are designed to sustain an ongoing chain reaction of fission; they are filled with a specially designed solid uranium fuel rod surrounded by moderator, which keep the speed of neutron in a moderate range suitable for hitting another uranium. A number of control rods are used to control the fission reaction through absorption of neutrons, thereby control the heat as well as power generated.
- The heat is carried out of the reactor by a coolant, which is most commonly just plain water. The coolant heats up itself or a secondary water coolant to steam and that steam goes off to a turbine to spin a generator for producing electricity.

Establishment of Fukushima nuclear reactor:

After world war ii, nuclear power offered new possibilities with few of its own natural resources like gas or oil. For japan, it was a way to avoid relying on other countries for electricity. By 1954 japan had budgeted 230 million yen for nuclear energy and it began to build nuclear plants faster than any other nation in the world. In 1967 tokyo electric power company built its nuclear plants in Fukushima, which is a region in the northeastern of Japan and the Fukushima Daiichi plant became one of the largest operational nuclear power stations on the planet.

Structure of Fukushima nuclear reactor:

The nuclear reactor at the Fukushima was boiling water reactors called BWRs we say reactor because the heat in the core is produced by fission reactions. This water that removes the heat from the core turns into steam and the steam goes directly to the turbine. The turbine drives the generator that produces electricity. Afterwards the steam is condensed with the help of a seawater cooling system and returned to the core. A boiling water reactor has only one single system combining feed water and steam. The core is composed of fuel assemblies containing uranium. It is controlled by control rods introduced from the bottom that can stop the fission reactions in case of an emergency. Fission of uranium nuclei produces radioactive atoms that in turn produce heat and this continues to occur even after reactors shut down this is called residual heat. Keeping the fuel confined and cooled is a major safety issue. The fuel is isolated from the environment by different containment barriers. A first barrier is the fuel cladding of zirconium alloy and second barrier is the steel reactor vessel in combination with steam and water cooling systems. Finally the third barrier is the containment building in concrete with a leak tight steel liner. The fuel is kept under water in the reactor as well as in the adjacent pool where the spent fuel is unloaded. The pool is located at the top of the reactor vessel to facilitate the transfer of fuel under water. The reactor 2 and 3 has a turbo pump that feeds water into the reactor and it is operated by the steam produced in the reactor. The steam is condensed in the wet suppression pool. In reactor 1 there was no turbo pump but a heat exchanger which condensed steam from the reactor vessel. The condensed water was reintroduced into the reactor vessel by gravity. There were suppression pool which helps to trap the radioactive elements from the steam in case of emergency venting. The water was continuously cooled down by the water driven by the pump. The chimney of the

What really happened:

1. Monday, March 7th 2011: In a move that will prove to be eerily prophetic, the Tokyo Electric Power Company submits a report to Japan's nuclear safety

agency highlighting the vulnerability of the plant to tsunami forces. The plant's sea wall is nearly six meters high, and the report highlights a 1897 tsunami with 10.2 meter waves which devastated the location the plant sits at today. Officials take note and make plans to review the strengthening of the sea walls at a future date.

2. Friday, March 11th:

- i. 2:46 pm: A 9.1 magnitude earthquake tears through the seafloor off the coast of Honshu Island at a depth of 15 miles (24 km) in the earth's crust. At the Fukushima nuclear plant, emergency safety systems automatically kick on upon being struck by the first tremor, and reactors 1, 2, and 3 are automatically shut down. Reactors 4, 5, 6 are currently undergoing maintenance and not operational.
- ii. 2:47 pm: The tremor is severe enough to have cut off the power plant from the national electricity grid. On site, backup diesel generators start up- their job is to continue circulating cooling water into the nuclear reactors which while shut down, are still incredibly hot and will take a long time to cool. Without this cooling water circulating around the reactor core, the core will overheat just like in Chernobyl, causing a massive steam explosion.
- iii. 2:52 pm: Reactor 1's emergency cooling system, a safety relief valve, automatically opens in response to rising pressure from inside the reactor vessel. The valve is designed to vent dangerous buildups of steam in order to prevent an explosion. For the next hour the valve will open and close automatically as it regulates the buildup of pressure inside the reactor- this one safety system is likely responsible for averting a catastrophic explosion.
- iv. 3:27 pm: The first tsunami strikes the 19 foot (5.7 meter) high sea wall, but the wall holds and protects the plant from major flooding.
- v. 3:30 pm: Steam continues building to dangerous levels inside reactor no.1. The safety relief valve prevents an explosion but the temperature of the steam is steadily climbing as the emergency condenser system meant to cool the steam fails. Workers are extremely concerned, but as long as the safety relief valve remains operational the reactor vessel should not explode. Many believe that the worst is over, and that the first tsunami was the only one they would have to deal with.
- vi. 3:38 pm: One of the backup diesel generators stops running. The rest continue running, but because all but one of the generators are located underground there is concern of serious flooding from additional tsunami waves.
- vii. 3:46 pm: A 46 foot (14 meter) tsunami crashes into the seawall and overtops it, flooding the entire Fukushima facility. The diesel generators are

- all flooded and shut down, and their fuel tanks are washed away by the roaring waves. Now all power has been lost in the facility, and all but the mechanical safety systems meant to operate without power are offline. Temperatures begin to rise inside the reactors, and only the remaining safety systems are keeping any check on the temperature rise- though they alone will not be enough to prevent a major disaster.
- viii. 4:00 pm: The Nuclear and Industrial Safety Agency of Japan begins post-disaster emergency procedures and convenes an emergency headquarters. Personnel contact all nuclear power plants in Japan in an attempt to ascertain their condition. The news from Fukushima is grim, but so far the exterior plant sensors have not detected any release of radioactivity into the surrounding environment.
 - ix. 6:00 pm: Inside reactor 1 water levels have fallen so low that the top of the nuclear fuel rods are now exposed to dry air inside the reactor vessel. Without water to radiate their heat onto, the temperature inside the reactor immediately begins climbing again.
 - x. 6:18 pm: Workers restore power to Reactor 1's emergency cooling system and water once more begins circulating. Workers however are unaware of the massive boil off of water inside the reactor.
 - xi. 7:02 pm: Prime Minister Naoto Kan declares a nuclear emergency. The declaration is followed by announcements that no radiation leaks have been detected and is merely a cautionary measure.
 - xii. 7:30 pm: Fuel rods inside reactor 1 are now fully exposed to air as water levels continue to drop. The incredible buildup of heat causes the rods to begin melting and pooling at the bottom of the reactor vessel as a molten slag heap of highly radioactive metal.
 - xiii. 9:00 pm: Workers fear that the dropping water levels inside Reactor 1 are inevitably going to lead to a Chernobyl-like steam explosion. The government issues an emergency evacuation order to all residents within two miles (3km) of the plant. Residents within 6.2 miles (10km) are told they can remain in their homes but they should be prepared to evacuate nonetheless. Inside Reactor no.1 the pressure is at twice normal levels and climbing. Older power plant workers offer to take the place of the younger men on-duty at the plant, knowing that disaster may be inevitable and preferring to place themselves at risk to radiation poisoning over the younger workers.
3. Saturday, March 12th
- i. 2:44 am: Emergency battery power for the high pressure core-flooder system, the main emergency cooling method for reactor no.3, runs out. Water begins boiling off inside the reactor vessel.

- ii. 4:15 am: Inside reactor 3, the dropping water levels expose the fuel rods and temperature immediately skyrockets.
- iii. 5:30 am: The situation inside reactor 1 is critical- extremely high pressure threatens to explode the containment vessel at any moment. Officials have been arguing all night over a proposed and extremely risky maneuver which could cause a large explosion, and yet if not attempted the vessel is guaranteed to explode. At last it's agreed to vent steam from directly inside the reactor, and the workers hold their breath as a large volume of steam is allowed to vent into the air above the plant. Not only is the steam slightly radioactive, but there is a large possibility of hydrogen having been formed inside the containment vessel due to the high pressure and temperatures, and it's feared that it could ignite after combining with oxygen. The venting is successful and there is no explosion.
- iv. 5:50 am: More emergency power is restored, allowing plant workers to pump fresh water into reactor 1 in an attempt to cool the fuel rods.
- v. 6:50 am: Although workers do not realize it, the entire core of reactor no.1 has completely melted and fallen to the bottom of the pressure vessel. With temperatures reaching over 2190 degrees (1200 C), the zirconium in the fuel rods splits the hydrogen from the water vapor in the steam inside the vessels. This causes a buildup in dangerous hydrogen gas.
- vi. 10:58 am: Pressure inside Reactor no.2 reaches critical levels, and once more workers gamble by venting off some of the radioactive steam to avoid an explosion.
- vii. 3:30 pm: Residents within 6 miles (10km) are now being evacuated. All fear a Chernobyl-style explosion at the power plant.
- viii. 3:36 pm: Hydrogen gas buildup inside the containment vessel of reactor no.1 reaches critical levels and there is a massive explosion, cracking open the containment vessel but leaving the reactor core intact. Four workers are injured and the concrete building that surrounds the reactor vessel collapses.
- ix. 7 pm: Workers begin pumping seawater directly into reactor no.1 in an attempt to keep the core cool.
- x. 7:25 pm: In a bid to limit how much water becomes contaminated, Tokyo Electric Power Company orders that the seawater injection be halted. Plant boss Masao Yoshida orders his workers to continue

pumping in seawater though, ignoring TEPCO- he fears a meltdown more than the release of contaminated water.

- xi. 9:40 pm: The evacuation zone is extended to 12.4 miles (20 km).

4. Sunday, March 13th:

- i. 2:42 am: the high pressure coolant injection system inside reactor no.3 fails, and water levels immediately begin falling as the water is boiled off by the intense heat of the fuel rods.
- ii. 5:10 am: Fukushima Unit 1 is declared an International Nuclear and Radiological Event Scale level-4 event, signifying an accident with local consequences.
- iii. 7:00 am: Water levels inside reactor no.3 have dropped so low that the top of the fuel rods are now exposed.
- iv. 9:00 am: Reactor no.3's fuel rods begin to melt, causing a buildup in hydrogen gas.
- v. 1:00 pm: Workers believe that reactor no.3 has suffered a partial meltdown, and reactors 1 and 3 are once more vented in order to relieve the growing pressure. The reactor containment vessels are refilled with water and boric acid, which absorbs neutrons and helps prevent more nuclear reactions from the fuel inside the reactors. Reactor no.2 has low water levels and high pressure, but is believed to be stable.

5. Monday, March 14th:

- i. 11:01 am: Hydrogen gas buildup inside the containment vessel at reactor no.3 leads to an explosion, collapsing the building housing the container and injuring six workers. TEPCO announces no release of radioactive material but the blast damages the water supply helping keep unit 2 cool.
- ii. 1:15 pm: Reactor 2's cooling systems fail, and water levels immediately begin falling.
- iii. 3:00 pm: A large chunk of molten fuel inside reactor no.3 drops to the bottom of the pressure vessel and pools there.

- iv. 6:00 pm: Water levels inside reactor no.2 now reach the top of the fuel rods, and the temperature climbs as the exposed rods overheat.
 - v. 8:00 pm: Reactor 2 now also enters a meltdown state, as its fuel rods begin to melt from the extreme heat. Hydrogen gas once more builds as the zirconium strips hydrogen away from the water vapor.
6. Tuesday March 15th
- i. 11:00 am: A second explosion due to hydrogen gas buildup rocks reactor number 3, which damages the cooling systems of reactor no.2.
 - ii. 8:00 pm: Reactor no.2 is now in worse condition than the other two reactors, and is in a full blown melt down as most of the nuclear fuel drops to the bottom of the reactor pressure vessel. An explosion causes damage to unit 2's containment system and radiation levels rise significantly but quickly fall once more. Workers would go on to bravely battle the rising temperatures inside the stricken reactors and fuel rod storage pools. Ultimately the Fukushima disaster would lead to a permanent quarantine zone around the stricken power plant which lasts to this day, and to massive protests across the country over nuclear power. Yet the plant used reactors that were over forty years old, and lacked many of the safety features of modern reactors. Additionally, in the years since the disaster, workers have come forward to state that much of the plant suffered from poor maintenance, and that many of the safety cooling systems had not been tested since the reactors were first installed forty years ago.

A ten years have passed in Japan but time has stood still frozen at 2:46 pm the exact moment a massive earthquake struck northeastern Japan and led to one of the worst nuclear disasters of all time. On the 11th of March 2011 a magnitude 9.1 earthquake struck which caused a tsunami killing more than fifteen thousand people and led to a meltdown at Fukushima Dai-ichi nuclear power plant. The earthquake that Japan encountered this time was the strongest that Japan had seen for a thousand years even bigger than the Great Kanto earthquake of 1923. It was so powerful that Japan's coastline moved eight feet to the east and sank three feet down. It set off aftershocks around the world. Tremors were felt as far as Beijing, United States and Cuba. The tsunami flooded the nuclear power plant results massive overheating and reactors one two and three suffered meltdowns. When the power supply failed operators lost control of the plants and a hydrogen explosion blew the roof and walls off reactor 4. Chernobyl was an explosion inside the reactor core but Fukushima was different in that it was an explosion in the reactor building there was a partial meltdown. Hydrogen gas was vented out of the core and then it was that hydrogen gas that exploded. So the radioactivity we see in the environment from Fukushima is volatile elements that came out of the reactor as it was overheating and melting down. Japan classified the event as a level seven the same as Chernobyl meaning it was a major release of radiation with

widespread health and environmental effects. Following the explosion, the government set up an exclusion zone prohibiting residents from living within 20 kilometers of the plant.