Indian Institute of Technology Madras
Present

NPTEL
NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING

NUCLEAR REACTOR AND SAFETY
AN INTRODUCTORY COURSE
Module 01 Lecture 01
Energy Sources

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Good morning, students. Today, we'll be talking about the different sources of energy. You know, we normally take electricity for granted. We think about it only when it is not there and electricity, need for electricity has become a part and parcel of our lives without which our daily life becomes very difficult. So how do we get this electrical energy from? What are the sources? Let us have a look at the sources.

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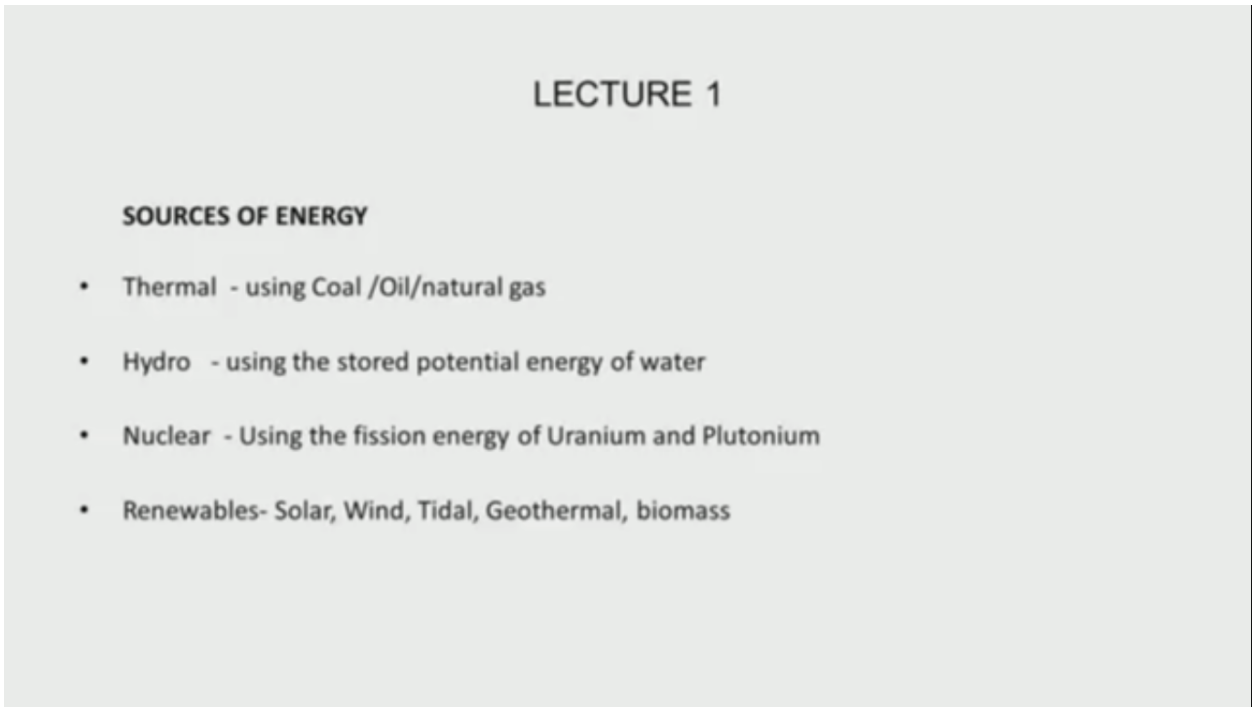

One, you have the thermal energy wherein we burn coal or oil or natural gas and the heat that is produced is used to convert water into steam and that steam rolls a turbine and the turbine runs a generator and that's how you get electricity.

What is the other one is the hydro. As the name suggests, it uses water. This water is collected in dams and these dams water is poured from a great height and the water falls on a turbine and runs a turbine and again, which moves a generator and produces electricity.

What is the third largest one is the nuclear. Here we use the energy which is coming out of the fission of some of the nuclei like Uranium and Plutonium and the heat produced is a gain used to convert water into steam, which runs a turbine generator. If you look at the major power sources, thermal, hydro and nuclear are today the major power sources.

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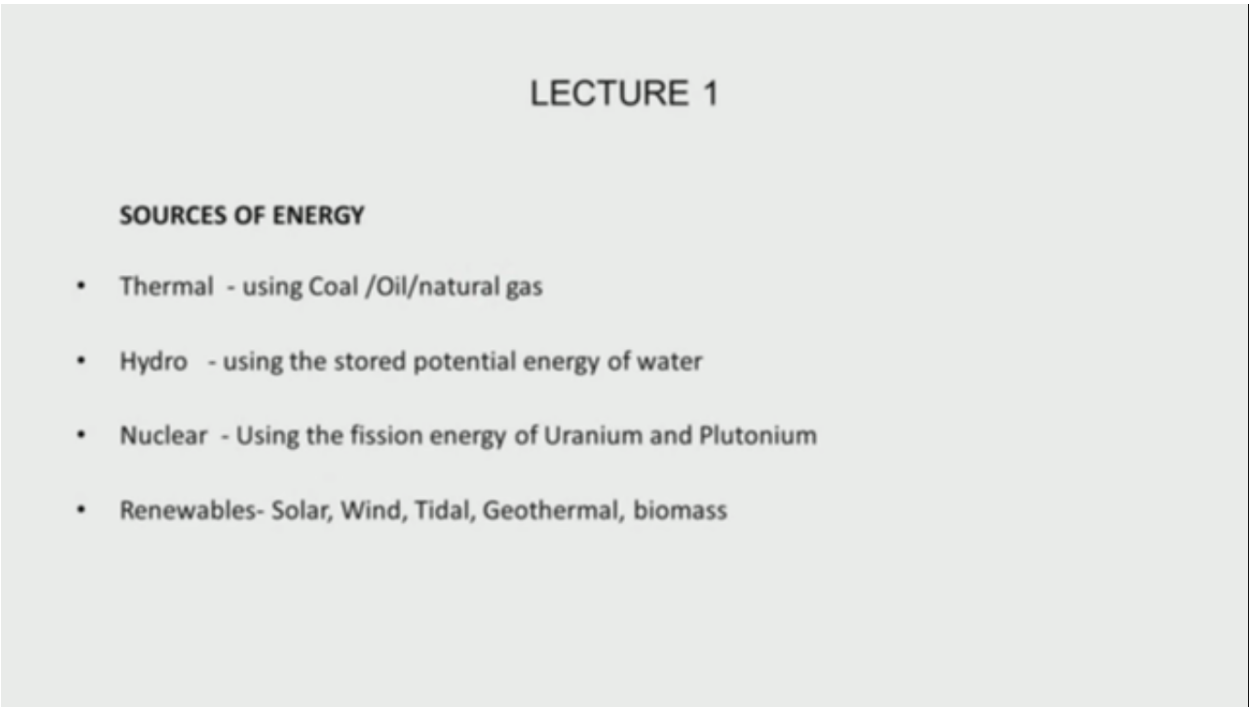

Last but not the least, we are to talk about renewables. You have got the solar energy. You have got the wind energy. We have got the tidal energy. We have got the geothermal energy and biomass. Yes, solar has been able to contribute a reasonable amount of power, but not to a very large scale. Wind energy has been really useful in the coastal areas where wind is present most of the year; tidal on to a lesser level; geothermal and biomass to still lesser levels, but if you look at the major sources, we have thermal, hydro and nuclear.

Now let us look at each one.

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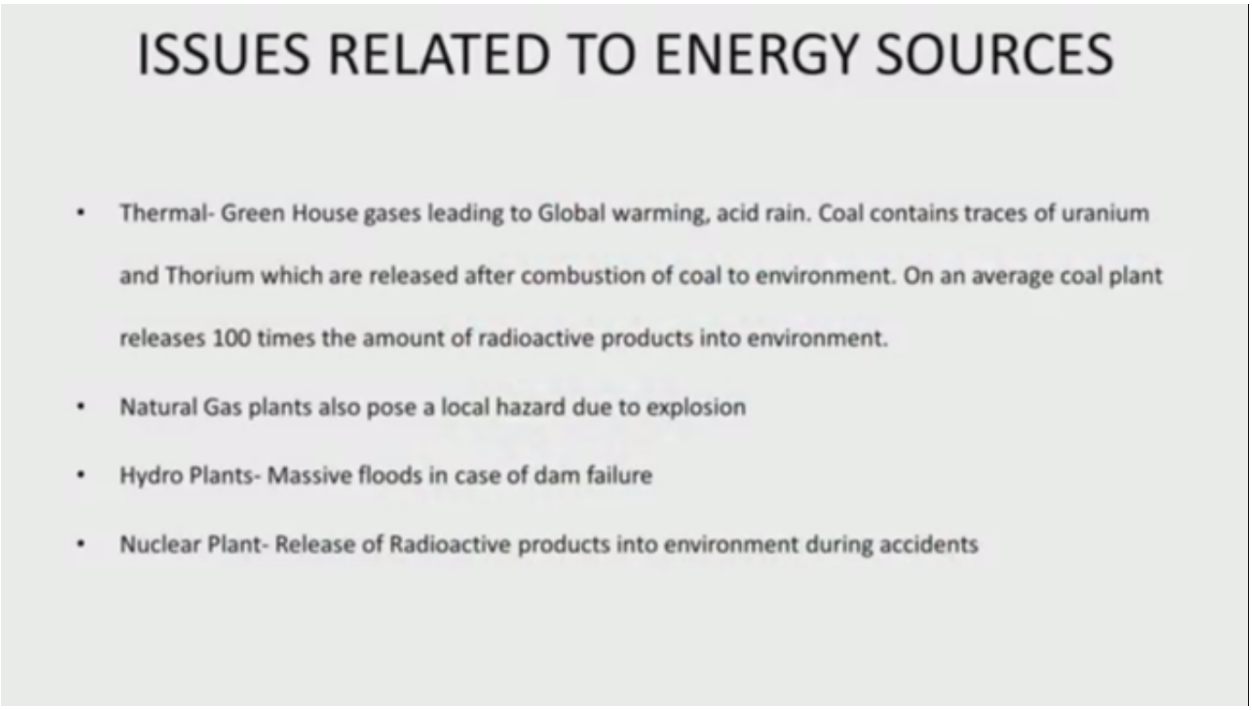

Yes, the positive thing is from the thermal power plants we get lot of electricity. Most of the power within our country is from the thermal power plants, which burn coal or oil. Now is there -- are there any problems with these plants? Why should we think about other type of electricity generation? If you look up whenever you go near Coal fired plant, you see smoke from the chimney coming out and this smoke contains Sulfur Dioxide, Nitrous Oxide.

Now what does this do? This sulfur dioxide goes into the atmosphere, gets into the moisture, becomes Sulfuric Acid. The Nitrous Oxide becomes Nitric Acid and when this rain water falls, vegetation is destroyed. Also in the process of smoke release, you would be surprised that lot of radioactivity is also released, but where does Coal get the activity from?

You know, Uranium and Thorium are the two important naturally found materials, which are used in the nuclear arena and Uranium exists in the form of powder, but it is scattered throughout so it is not in a single place. So Uranium is found everywhere and natural Uranium contains 0.7% of Uranium-235 and rest 99.3% is Uranium-238.

Now this Uranium-235 is one of the materials which is -- which are directly fissionable by neutrons in a reactor. So this Uranium, traces of Uranium get into -- are in the -- present in the coal. However, there is no realization that coal contains Uranium particles and after the combustion, these particles are released to the atmosphere and on an average it appears a coal-fired power plant releases about 100 times the amount of radioactive products into the environment compared to a nuclear power plant. It is really surprising, but it is a fact.

Now I can tell you some examples in India itself. There was a survey, environmental survey, which was carried out in the state of Maharashtra. One was the Tarapur Power Plant, which has got four nuclear reactors and the other was the Nasik Thermal Power Plant.

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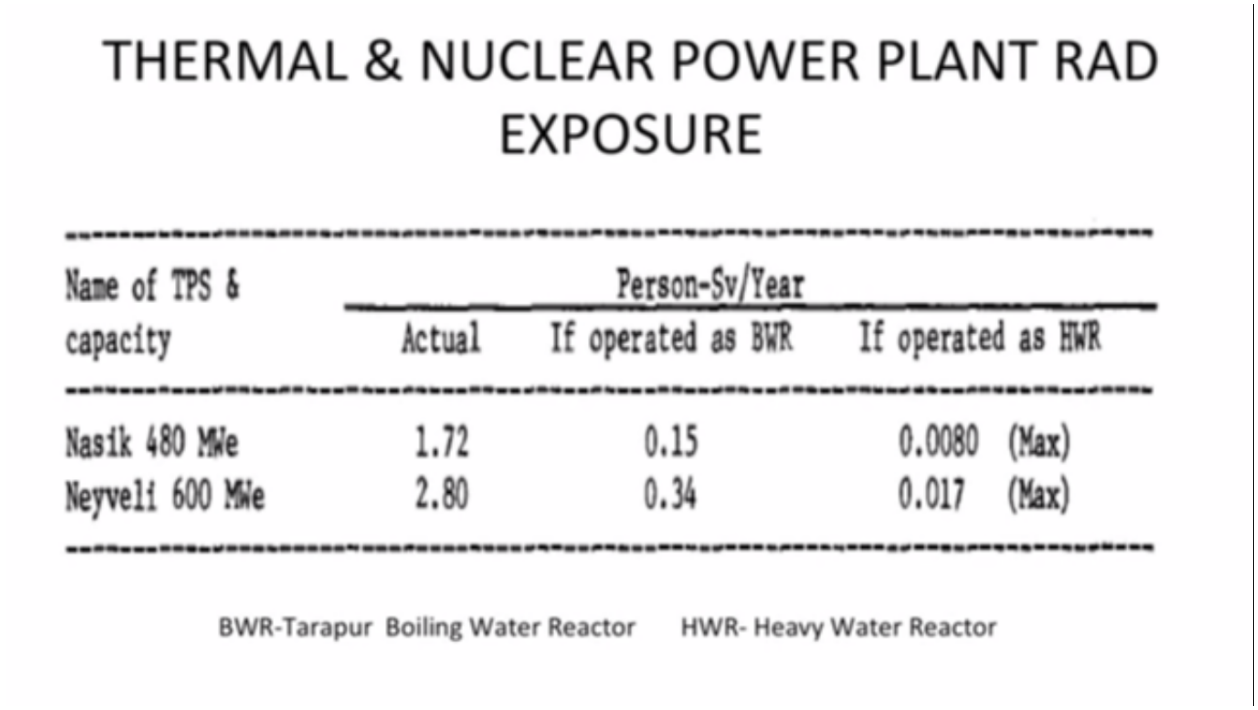

And people went from some of the university researchers had gone. They did a survey in both places and it was surprising to see that the ash pond in the Nasik Thermal Power Station had a much higher level of radioactivity than the Tarapur plant. This only shows that there needs to be an awareness that Uranium and Thorium are present and these need to be monitored in any plant. So we look at the problem which this thermal power generation is giving us, but anyway, we have been living with it for many years.

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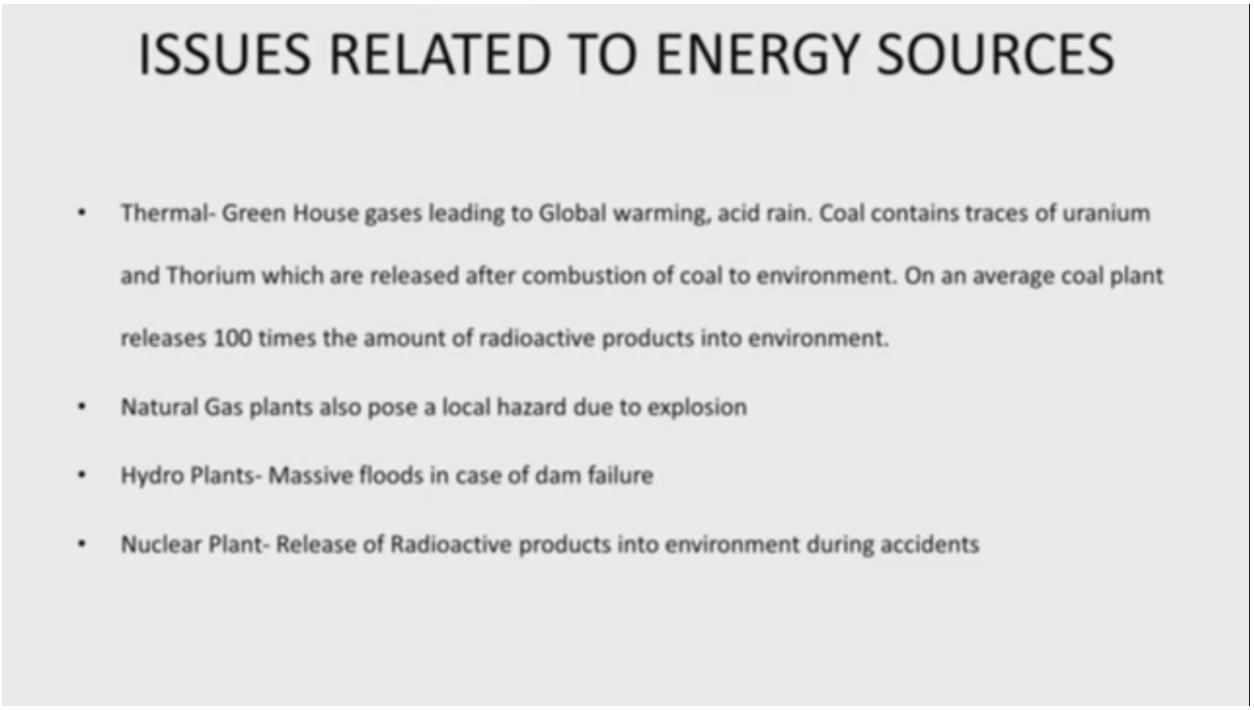

Coming to natural gas, we don't have that many natural gas plants in India. USA has got natural gas and is having lot of many number of plants in USA, but again, natural gas has an issue that it can cause an explosion. So just because it causes an explosion doesn't mean that I won't use natural gas. It is available plenty. We use it. We have to take care.

Coming to hydropower plants, you might have seen many times in the media that some of the politicians and they say that we don't want a hydro power plant to be built here because it will displace a lot of people. Then the other issue starts. In case a dam fails, surely, it will fled a large amount of area and people will be put to hardship. You can see what is happening today in the Jammu and Kashmir with lot of floods. So it is an issue to be kept in mind. So that doesn't mean you should not have hydro. You must not have thickly populated areas around these plants.

Coming to the nuclear power plant, one very important and point that you have to note even before we started enjoying the fruits of electricity from nuclear power, we knew what are its bad points? The use of nuclear material in the Hiroshima and Nagasaki bombings showed us what all devastation it can occur, but it was a blessing in disguise I should say for the nuclear community right from day one when we developed nuclear power as an alternative source of energy, we took precautions that the radioactivity must not be affecting the people who are working. So right from the beginning, we set up rules, which would be followed and later these rules combined came under a single agency called as an International Atomic Energy Agency and it is not surprising to see that all countries follow the guidelines of the International Atomic Energy Agency.

But then, why should still we be worried? The public should be worried? Very simple. You have heard about the three accidents which happened: the Three Mile Island reactor accident in the USA in the '79, and then the Chernobyl reactor accident in Russia, and last in 2011 in Fukushima. So there is a fear that because of the release of these radioactive products into the environment, people, and vegetation, and so many things could be affected, and which could affect the health. So if you see every energy source has a plus point. It has got a minus point.

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CARBON FOOT PRINT FROM DIFFERENT ENERGY SOURCES

Source	CO_2 Emission(g/kWh)	Source	CO_2 Emission(g/kWh)
Coal	900	Wind	65
Oil	700	Solar Photovoltaic	40-200
Gas	450	Concentrating Solar	50-90
Nuclear	65	Geothermal	20-140
Hydro	45-200	Biomass	35-85

Many of you might think when we talk about Carbon Dioxide emission, okay, coal, coal is carbon. So we burn it. We get Carbon Dioxide. So coal is anyway is a big carbon emitting source. Oil, okay, it contains many hydrocarbons. Surely, carbon is there. It will also burn. Natural gas also.

But hydro, from where this carbon footprint comes? I myself was very surprised when I went through. When you look at the hydropower plants after all in the hydropower plants, we take a part of the river. We -- the water comes and is stored in a big reservoir and in the reservoir, when it comes, it brings in lot of vegetation and all these settle in the reservoir and here in the reservoir, these react. Organic things, they react. They produce Methane and when this water falls from a great height onto the turbine, this Methane breaks. It comes out and Carbon Dioxide is getting released into the atmosphere.

Then not only that, when you look at Carbon Dioxide emission from different sources, you must remember that every component of any power plant is after all manufactured and during the manufacturing process, you may use a heat treatment for which you may use a coal, or oil, or

gas, some sort of heat treatment. So in that process there is a Carbon Dioxide emission related to every energy source. So if you just compare the numbers, coal emission is about 900 grams per kilowatt hour. Oil is a bit less, 700 grams per kilowatt hour and gas you see 450 grams per kilowatt hour. Nuclear is only about 65. Even this 65 is basically due to the processing of the fuel wherein we use chemicals etc., and also the transportation of the components which takes place.

Coming to hydro, it varies from a small dam or small hydroelectric power plant to a large hydroelectric plant from things like 45 to 200 grams per kilowatt hour. The wind energy, yeah, is relatively less. Carbon Dioxide emission is only 65 grams per kilowatt hour.

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CARBON FOOT PRINT FROM DIFFERENT ENERGY SOURCES

Source	CO_2 Emission(g/kWh)	Source	CO_2 Emission(g/kWh)
Coal	900	Wind	65
Oil	700	Solar Photovoltaic	40-200
Gas	450	Concentrating Solar	50-90
Nuclear	65	Geothermal	20-140
Hydro	45-200	Biomass	35-85

Solar photovoltaic, again, it is in the similar nature of hydro. Here again, lot of emission of the Carbon Dioxide is there in the manufacturing process of this solar photovoltaic cells, but when it come to a concentrating that is where you have a parabolic reflector and then you concentrate the solar heat, there you find only about 50 to 90 grams per kilowatt-hour of carbon emission. Geothermal, of course, this data, the statistics is much less today, but it is also quite low, 20 to 140 and biomass is still less. So this gives you that there is nothing free of Carbon dioxide. If you are worried about the greenhouse effect, if you are really worried about the global warming, it is essential to reduce the Carbon dioxide emission and we need to choose those sources, which will have minimal release of Carbon dioxide.

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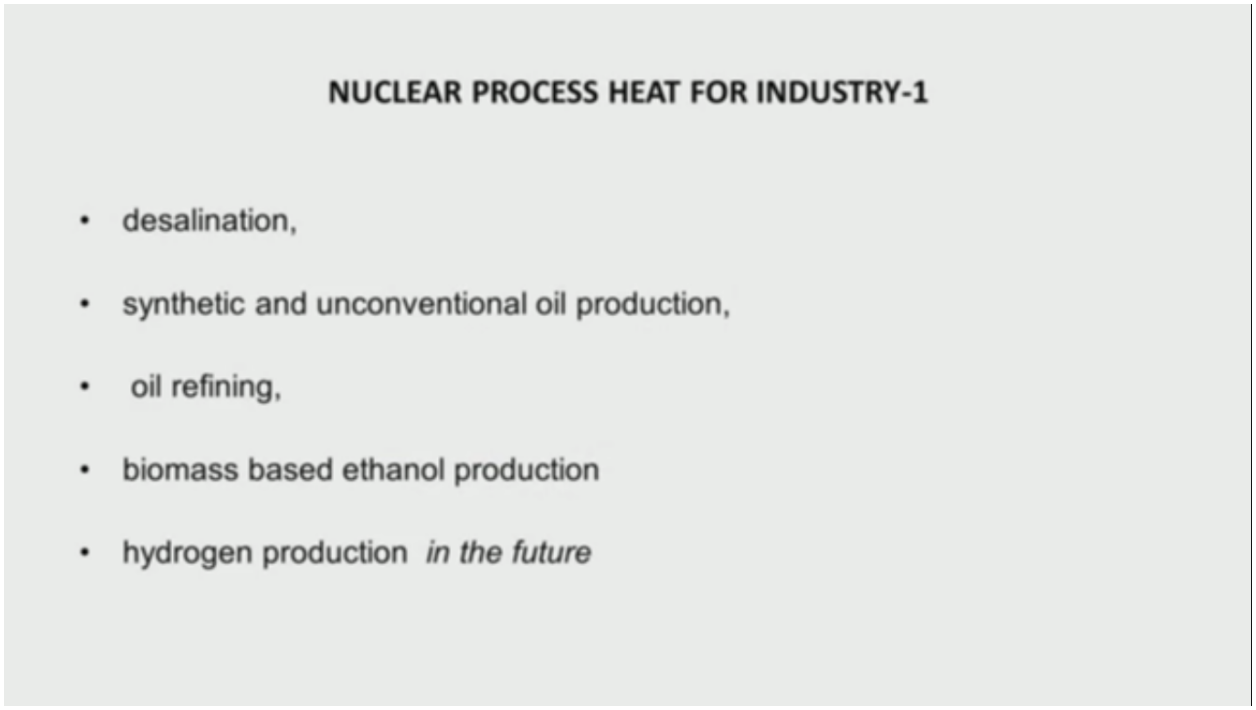

Now coming to the nuclear energy, yes, it has been used for electricity generation, but its utilization is in many areas I think which most people are not aware and through this lecture, I would like to bring to your notice, which are all the ways in which the nuclear energy has been useful in our day-to-day life.

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One of the important points is desalination. Here, basically, there is nothing nuclear about it.

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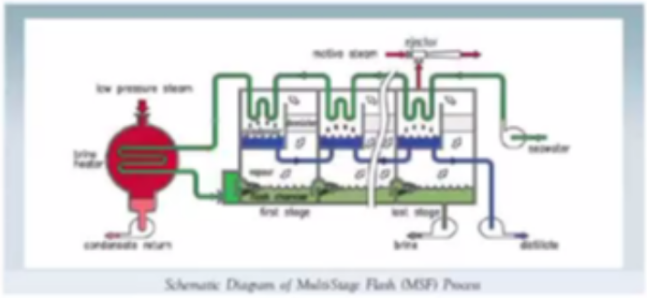

We basically use the steam from the last few stages of the turbine where it cannot do any more work, but that heat which is available in the steam is used in a multi flash distillation process wherein the salt gets separated from the water and we get desalinated water.

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In our country, at Kalpakkam, we have a desalination plant which is linked to the Madras Atomic Power Station and we get desalinated water at about 5 paisa per liter, but it is not something new that nuclear power plants have been used for desalination. There is a plant in Kazakhstan, which is a part of the former USSR, It was called as the BN-350 Nuclear Power Plant where the electricity generation was only 150 megawatt electrical. The rest corresponding to 200 megawatt electrical, that amount of heat was used for desalination. So this shows that the utilization of the process heat for desalination is one which has been going on in the nuclear power plants and this is one of the important uses.

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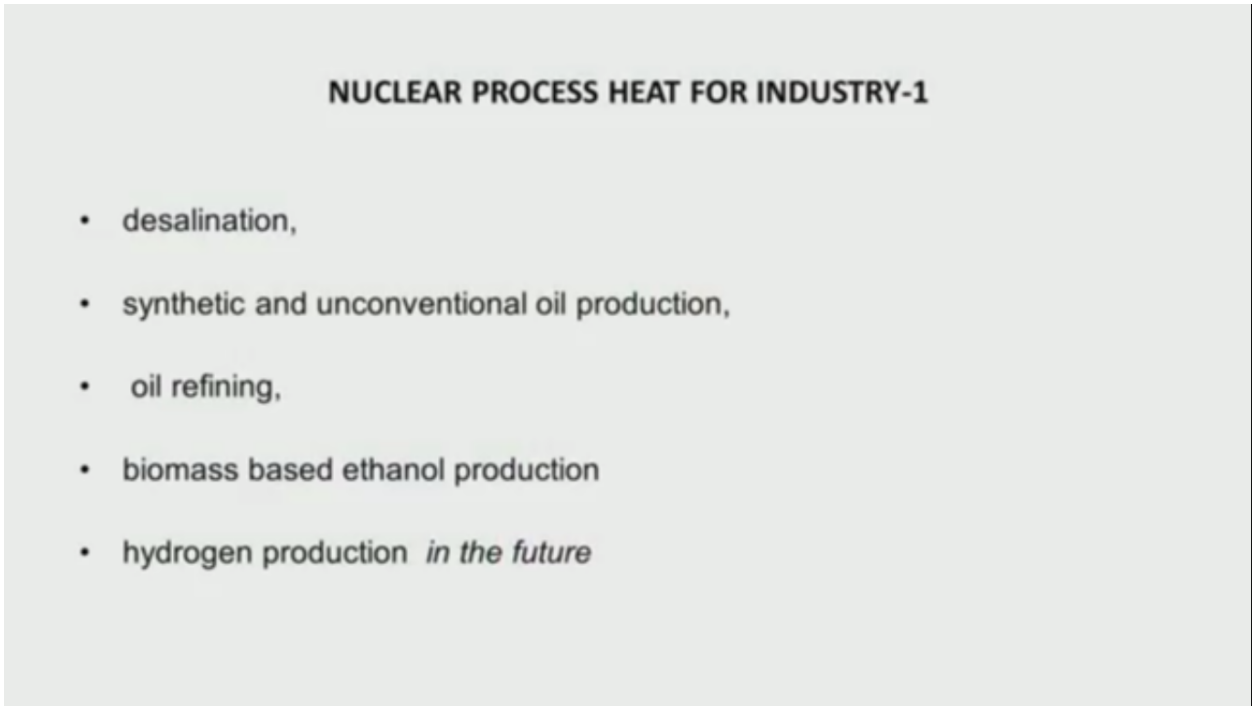

Then coming to the oil production, basically, the petroleum power production, you require lot of synthesis of the oil and here is where the steam, which you are getting from the nuclear power plants and that too the last two stages, they can be used. Oil refineries. Then biomass based ethanol production and last but not the least hydrogen production. If you know slowly hydrogen is going to be the fuel of the future. Now this hydrogen production can be very well done in high-temperature reactors and hydrogen produced and kept for the use. So here also nuclear reactors have a important place.

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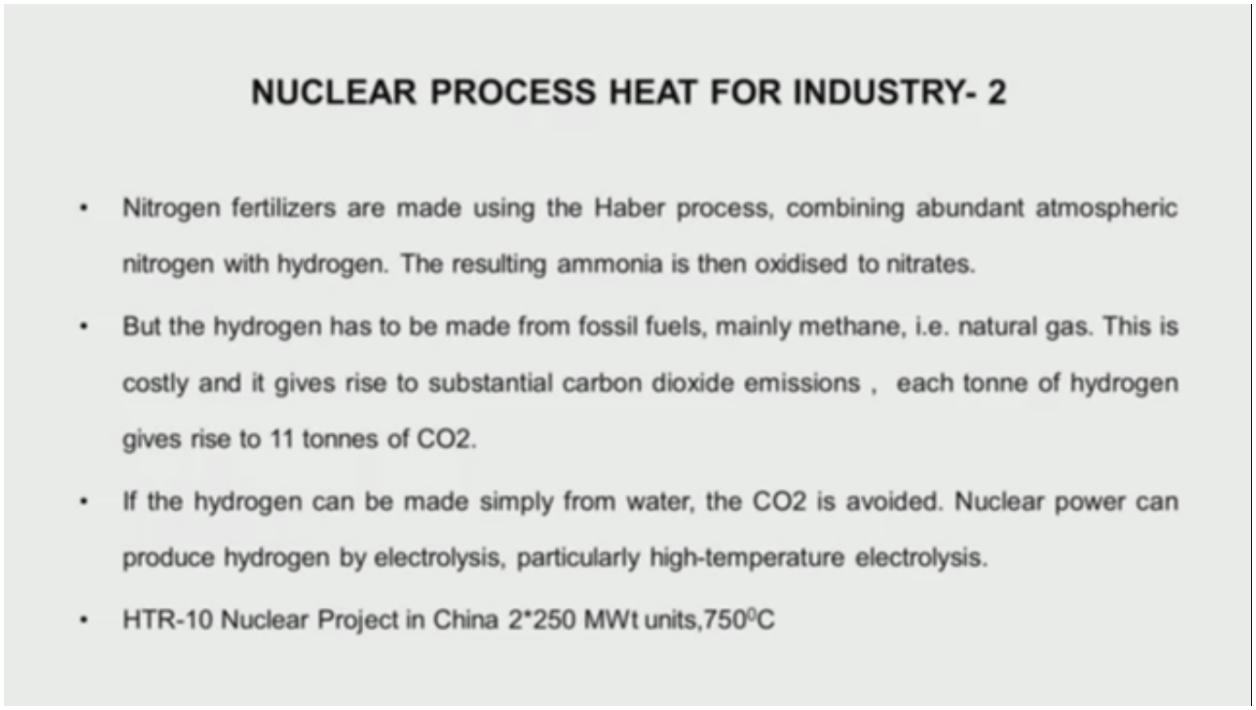

Let us look further in the field of agriculture. We require lot of fertilizers and these fertilizers are using nitrogen which are based on the Haber process, which is a well-known process so wherein we combine the atmospheric nitrogen with hydrogen and the resulting ammonia is used to make the fertilizer in the form of nitrates. Here the hydrogen that is produced is obtained from the burning of the fossil fuels say coal and oil and sometimes natural gas that is a natural gas is nothing but methane.

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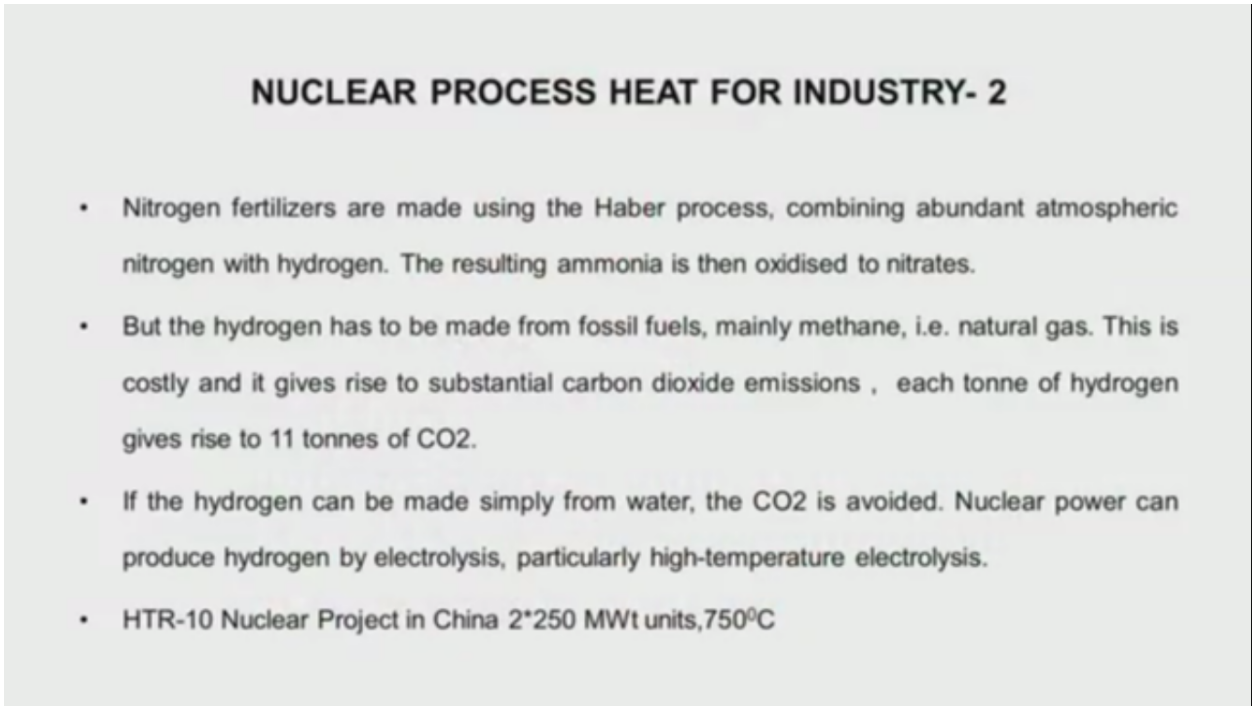

Now this is not only costly, but it also gives results in lot of Carbon dioxide emission. Just to get an idea, each ton of hydrogen gives rise to 11 tons of carbon dioxide. It is a huge number. If only this hydrogen could be made from water, then we could avoid this generation of 11 tons of carbon dioxide. So how can nuclear power play? Nuclear power can generate electricity and by electrolysis of water, it can produce hydrogen, which could be used for making these fertilizers. There is an interest in high-temperature reactors. China has gone forward.

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NUCLEAR PROCESS HEAT FOR INDUSTRY- 2

- Nitrogen fertilizers are made using the Haber process, combining abundant atmospheric nitrogen with hydrogen. The resulting ammonia is then oxidised to nitrates.
- But the hydrogen has to be made from fossil fuels, mainly methane, i.e. natural gas. This is costly and it gives rise to substantial carbon dioxide emissions , each tonne of hydrogen gives rise to 11 tonnes of CO2.
- If the hydrogen can be made simply from water, the CO2 is avoided. Nuclear power can produce hydrogen by electrolysis, particularly high-temperature electrolysis.
- HTR-10 Nuclear Project in China 2*250 MWt units,750^{0}C

It has already built two units of 750 megawatts, I'm sorry, 250 megawatt thermal units. They produce steam at a high temperature of about 750 degree centigrade and this heat has been used to generate electricity and produce hydrogen.

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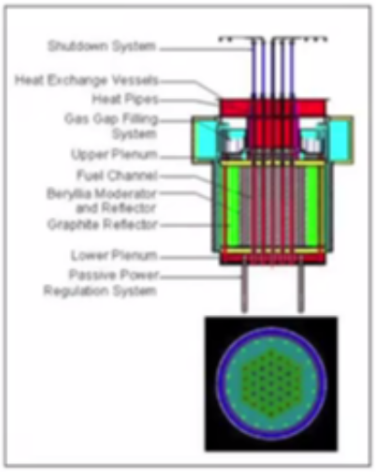
HIGH TEMPERATURE REACTOR HYDROGEN PRODUCTION



We in India also have a plan to develop compact high temperature reactors, which would produce hydrogen and we are halfway through the process.

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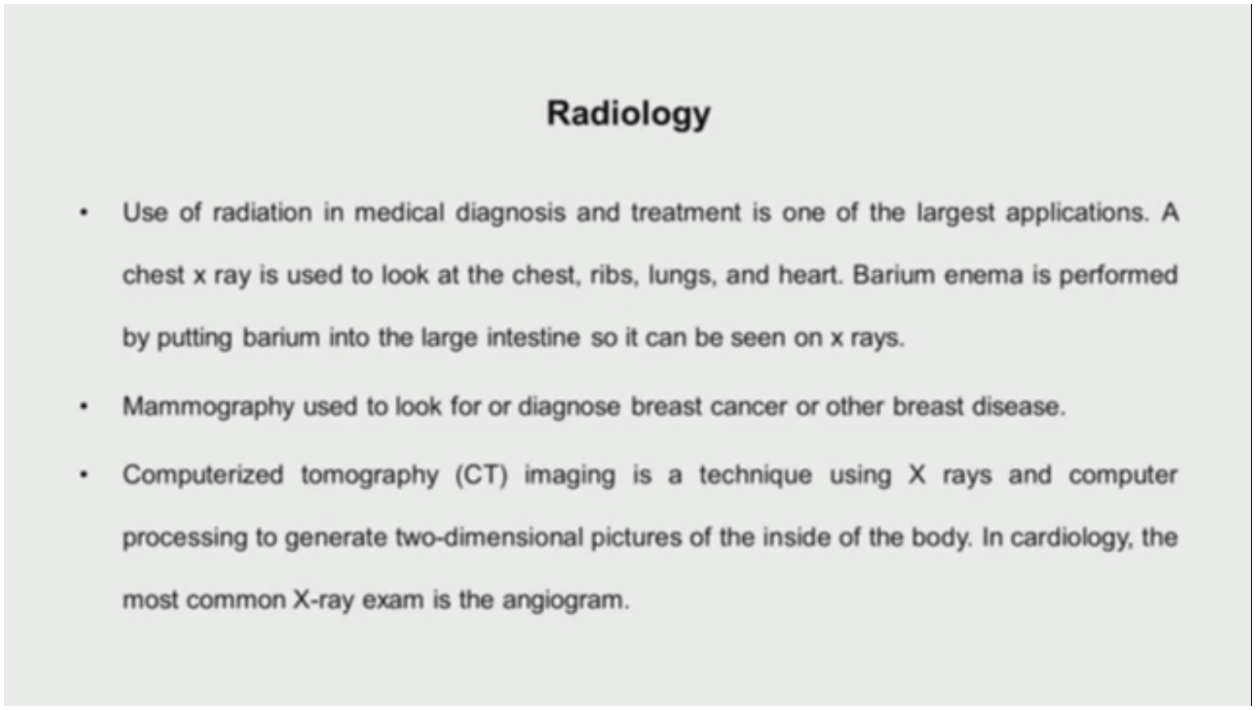

Let us look to the field of health. Does radiation have any role to play? Surely, you cannot deny that. Your use of radiation for medical imaging is one of the largest applications. You have x-ray of the chest. You have x-rays of the lungs. All is done. You go to the doctor. You say you have a chest congestion. Immediately, he says, "Okay, take an x-ray." He looks at the x-ray and finds out where the congestion is there. He is able to relate the darkness and the -- the -- what you call the difference in the shades. From that he is able to know where your chest is congested and he is able to give you a medicine. So this is a very, very widely used of -- usage of radiation.

Now you take a stomach x-ray. You know, the stomach x-ray, you are given Barium prior to taking an x-ray because the intestines as such cannot be seen, but once you put Barium inside, they become visible to the x-rays. The x-rays can go and you take a Barium meal. Then all of you who have heard of breast cancer in women and it is a disease, but it was a dreaded disease. Today we need not fear about it. Mammography is a type of x-ray, which is used for looking at the breast and assessing whether cancer is there or not.

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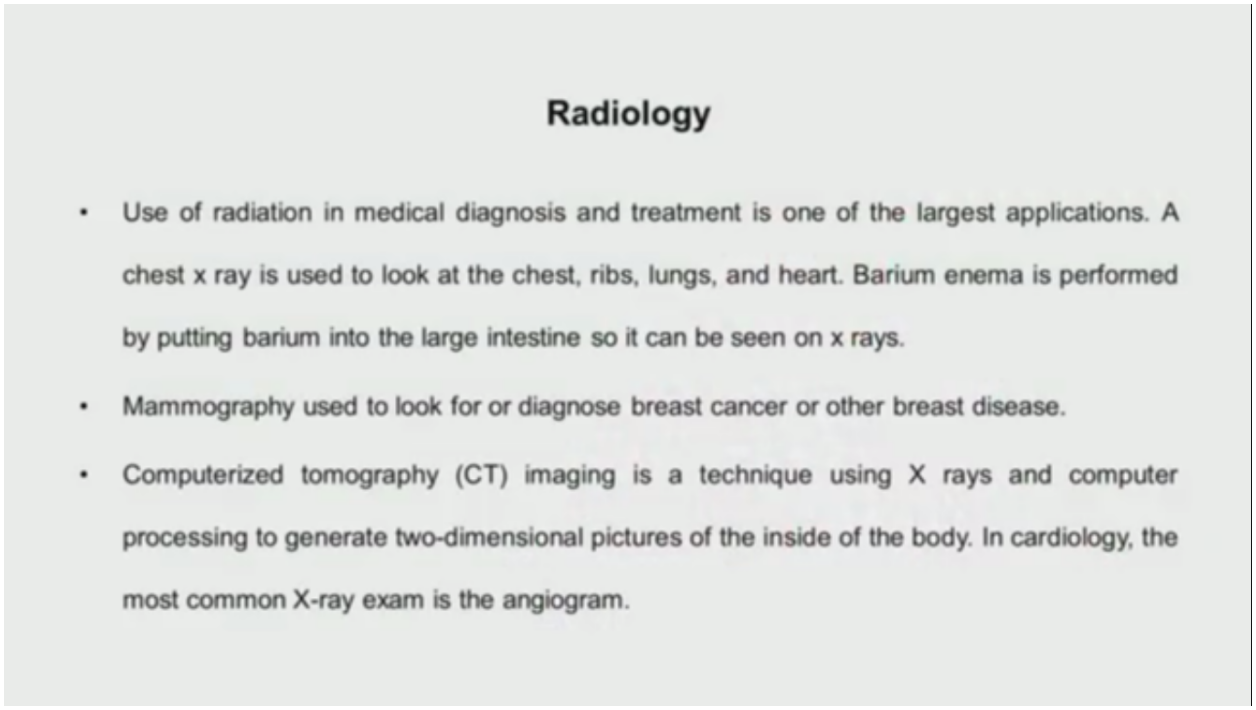

And believe it or not, more than 90% of the cancers have been cured again with radiation. Many times you might have seen, you find a person has had a brain injury and then they say, "Oh, let us take a CT scan. Let us find out what has happened to the brain." What is a CT scan? It is again using x-rays in different frames and combining these frames using image processing to develop a two-dimensional picture of the brain.

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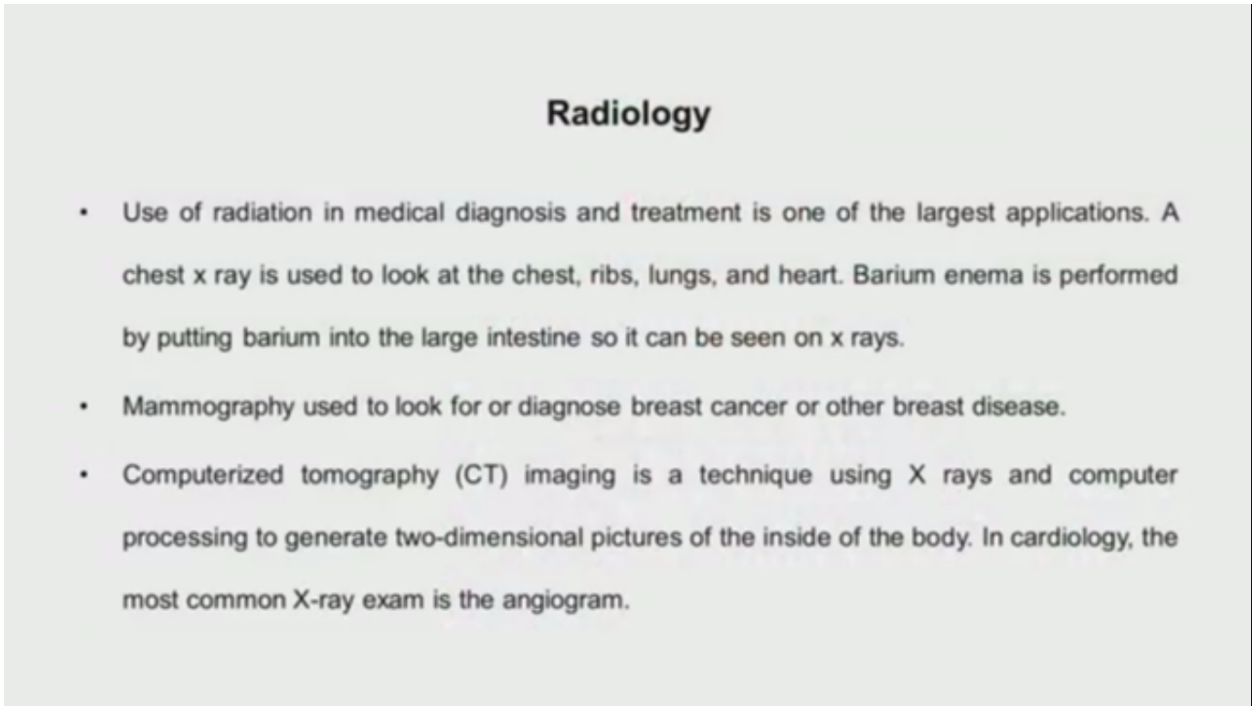

So here again, x-ray has been very widely used and today we talk about the blocking of the arteries leading blood to the heart and we take a angiogram, which tells us where the blockage is. Again, x-ray. So you really find that this science of radiation or I should say radiology has been very well useful in diagnostics.

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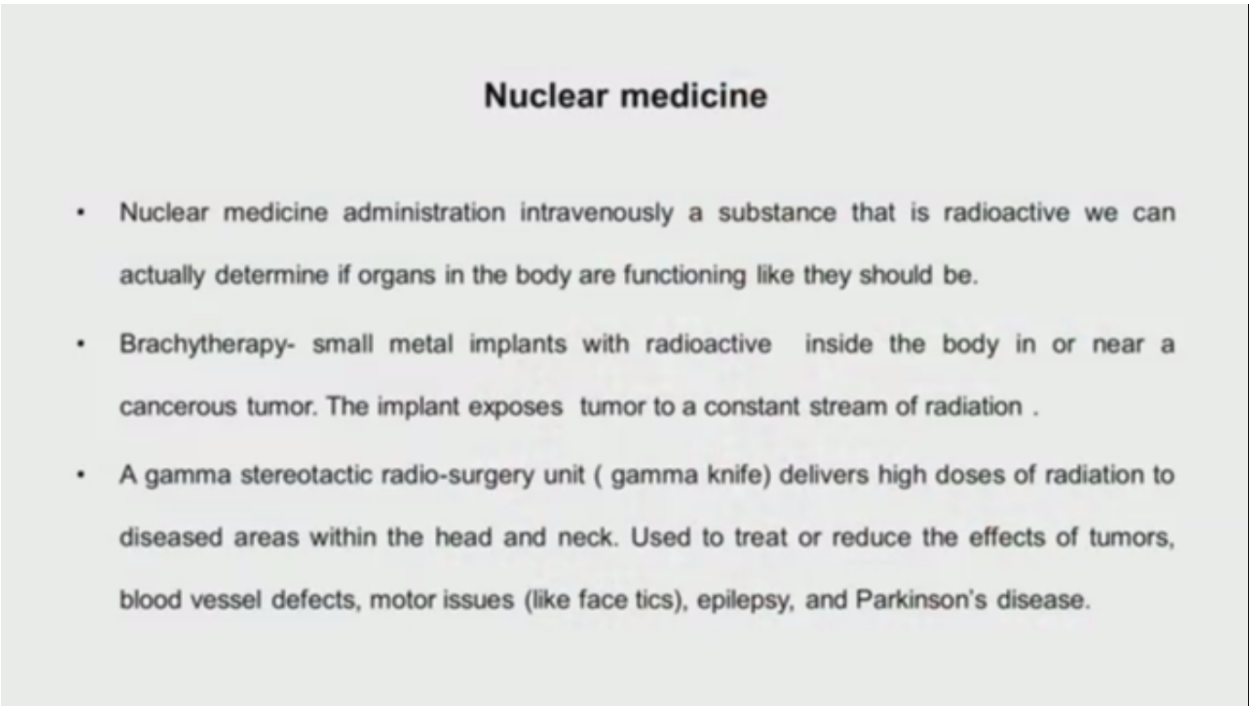

Yes, then what is this nuclear medicine? We talked about diagnostics. We use radiation to diagnose. Now as a medicine, now in many cases you have tumors inside the body.

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And you might like to kill those tumors. For that they make an implant of a radioactive substance and that implant will emit radiation which will expose the tumor to the radiation and it will kill the cancerous cells. So this is actually referred to as brachytherapy.

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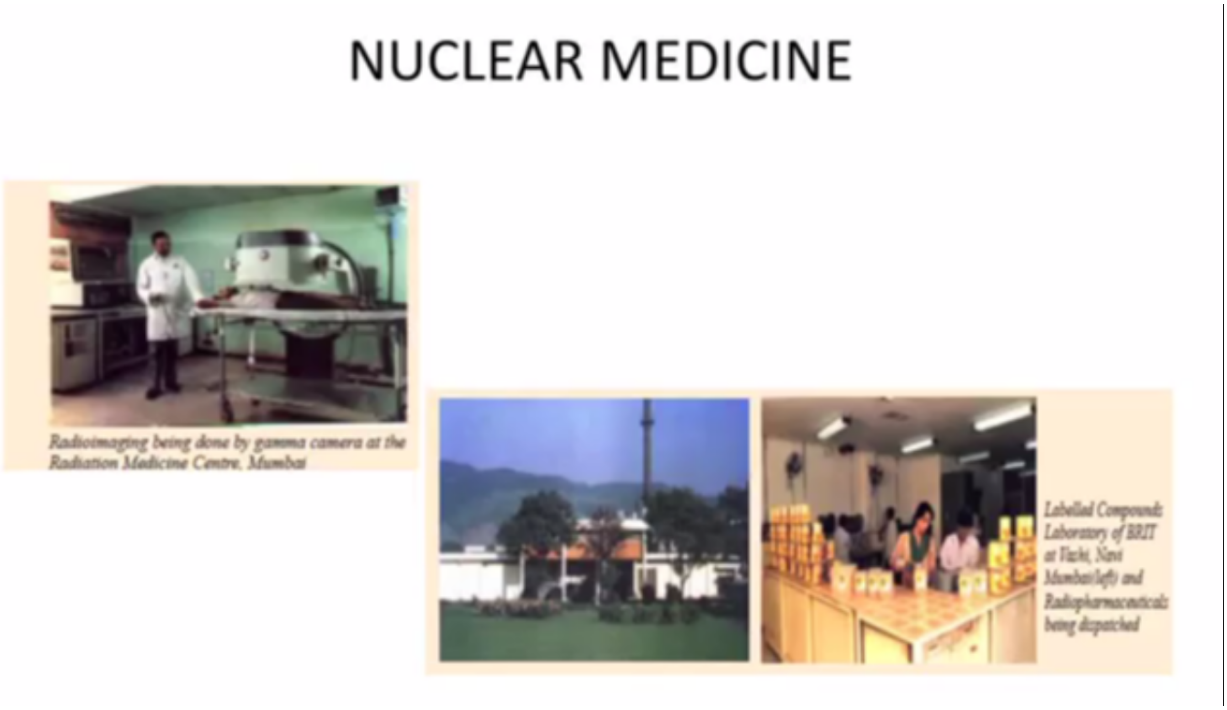

Then another one is the Gamma Stereotactic Radiosurgery also known as a Gamma Knife. So here this unit gives high doses of radiation exactly to the diseased areas, basically in the head, neck, and the head and this can treat the tumors. It can also sometimes relieve the defects in the blood vessels or tissues and it is supposed to have been useful even in Parkinson's disease. So you see we saw utilization of radiation, nuclear things first in the process heat applications, then in generation of hydrogen, then we saw radiology, then nuclear medicine.

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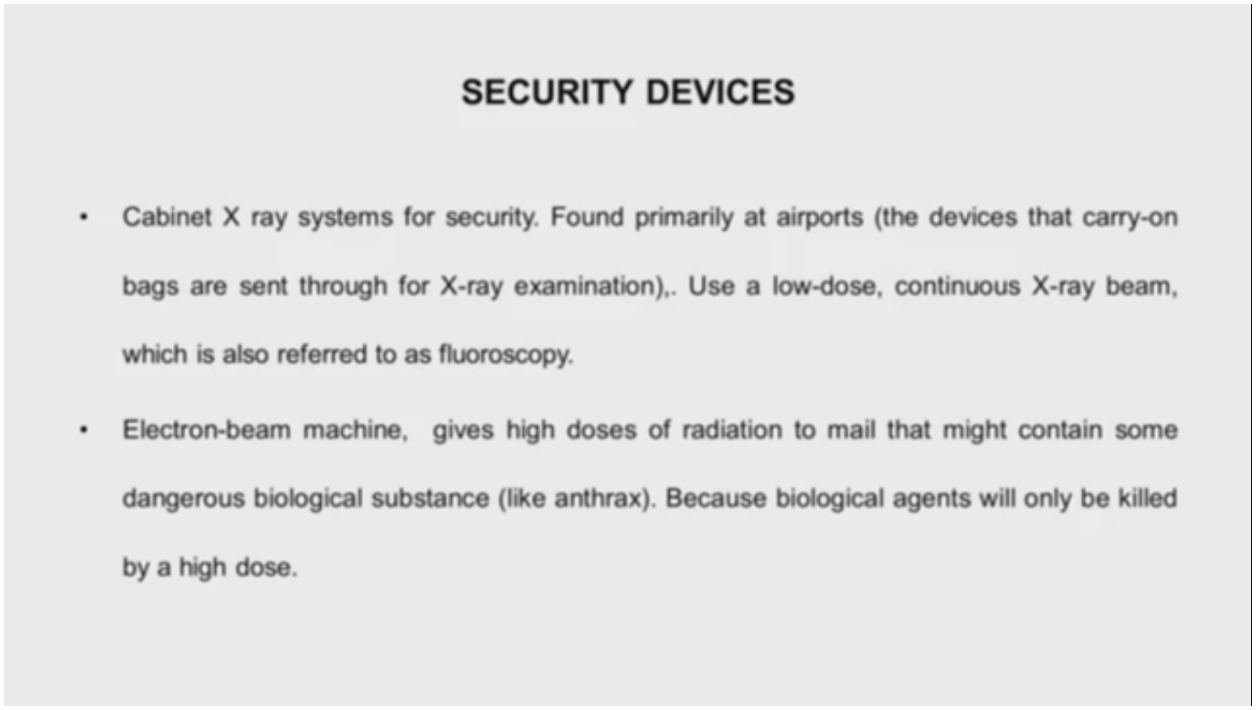

Then security devices. When you go to the airport, you have a arch like thing. You walk in through that. Then your bags are scanned. These are all nothing; they are using x-ray examination, but a very low dose. Then you have many times some fear about letter bombs. Some terrorists might have sent something, which contains lot of radioactive material, which could cause any issue in case it is open. So in such cases wherever there is a doubt, we use electron beam machine, which gives high dose of radiation and things like anthrax can be very easily identified and these agents can be destroyed by the use of this machine. So coming to our security, which we don't think about on a day-to-day thing, we have been using radiation.

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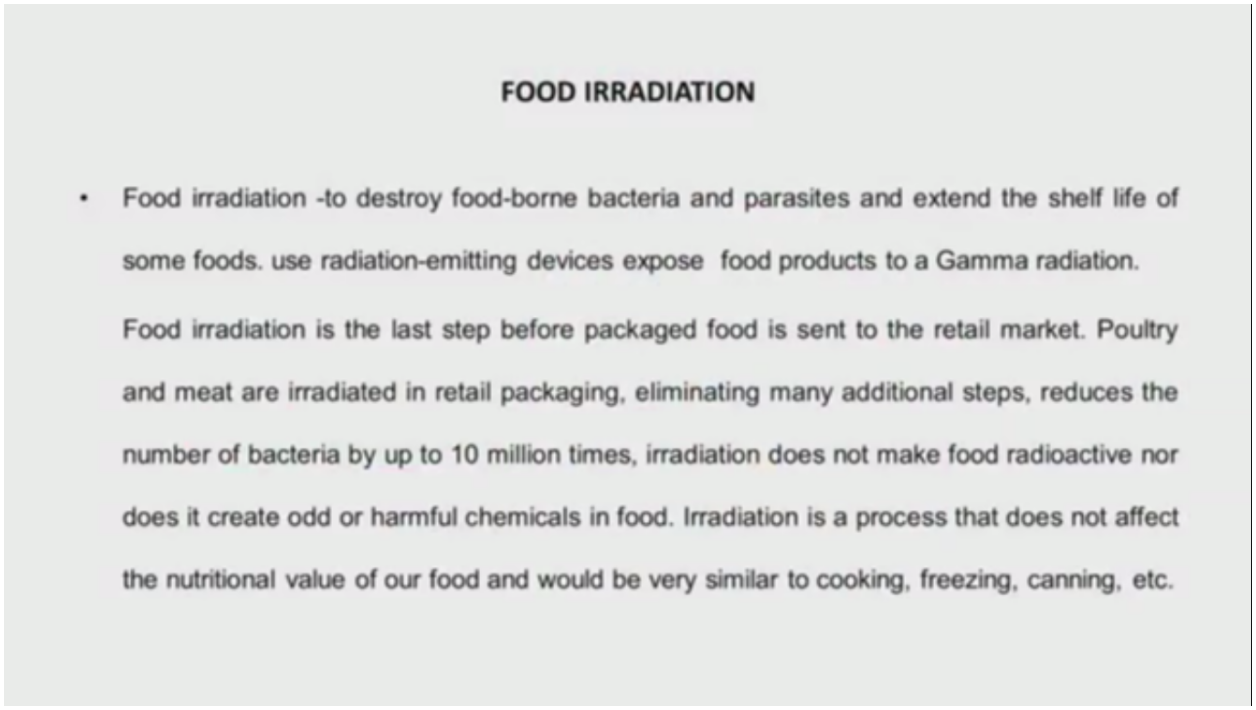

Let us look to the other areas. Food. See what -- why do you need to irradiate food? Why? We can -- we prepare the food we eat. I can give a very simple example. During the Chinese war in 1960, we found that the food, which was sent to our troops who were fighting the Chinese in the Himalayas, by the time the food was taken to them, it became stale because the food was prepared somewhere down and by the time it was taken to the place where the troops are working, it became stale. Basically, the chapattis, they became hard and it was not palatable at all. Now there was a time when our country started looking at food preservation in general and what can be done.

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In the Department of Atomic Energy, we also set up a laboratory called as Food Irradiation Laboratory. We studied, did research on what are the effects of radiation on food and we found that because of the radiation, the bacteria are killed. The parasites also are killed so that your shelf life is good and not that we are putting a very large amount of radiation, very small amount of gamma radiation.

And one advantage of in this radiation of food is you don't have -- you pack the food, pack the food as you would have normally packed it and put it to a radiator and no other steps. So it is just a passing phase and then it reduces the bacteria by nearly about 10 million times. One more thing the food is tasty. It doesn't lose its taste and it does not create any chemicals. That's why we feel that this sort of thing needs to be, you know, people have to be very much aware of such things that it doesn't lose nutritional value. It still has the same nutritional value and doesn't lose anything and it's not harmful and all this has come out of decades of research.

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Now this sort of research has also been undergone in other countries. France, Netherlands, USA, Thailand and China, they process many of the foods through radiation.

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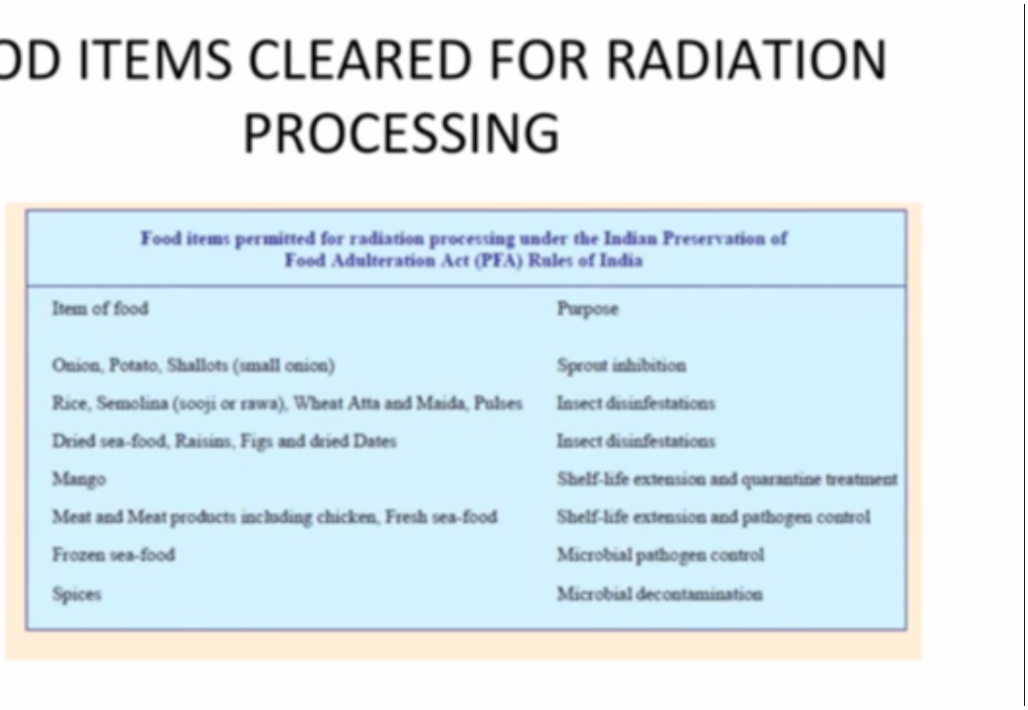

Some of the fruits, strawberries, mangoes, banana, chicken, all are sold on a regular basis. Nearly 23 countries have been irradiating food and selling. In 1994, in the Government of India approved this irradiation of onion, potatoes, spices etc., on a pilot's plant and today we have even for spices we have plants in Maharashtra.

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You might ask what this irradiation of onion and potato means? all of you must have seen if onions and potatoes are kept for some duration, they start sprouting and when we cook it, we remove the sprouts and then start cooking. In fact, these sprouts are the one which contains the nutritional value. So we are really removing. In order that it doesn't sprout, we give a small dosage of gamma radiation and then it does the managing. Here again, it is all packed. It comes in packed containers. We just give a small dose of irradiation and it remains fresh. In fact, I myself have tasted the chapattis, which were irradiated in BRC. Even after six months, it is soft. It is not hard. So there is a need that our country go on a large scale so that we need not waste food. Wasting food is really a crime just because and wherever food can be preserved, we must do and of course, surely, not at the cost of our health.

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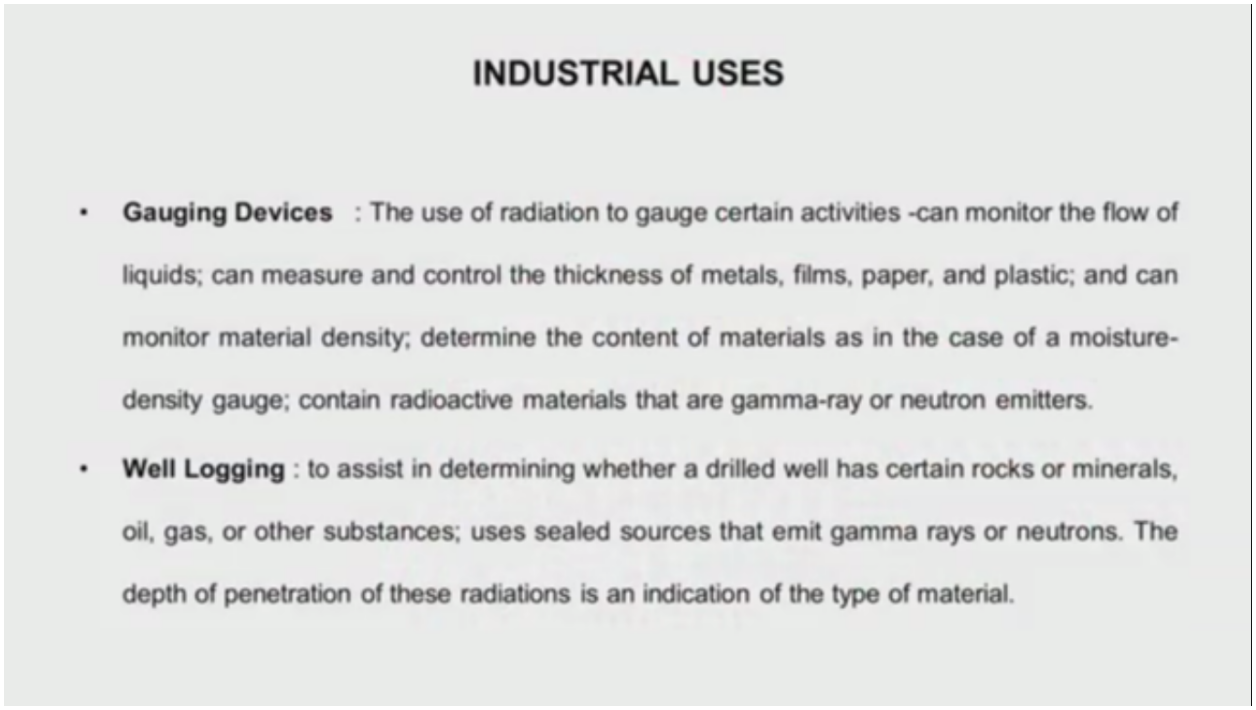

Let us move to the industry. We have looked enough at the human beings in what way nuclear radiation has been useful. You have got radiation gauges which can monitor the flow of liquids. You can find out the thickness of material. Paper thickness it can determine. You know how much of the radiation has input and how much is coming out, you can see the attenuation. We can find out. Then you can find out the moisture in the atmosphere using a radiation. So you can monitor many properties and contents of the material using radiation.

There is the other application which is called as well logging. Now when we go for exploration, we do drill some wells and then look for oil, or minerals or gas.

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So here we try to find out what materials are inside by using gamma ray sources or neutron we put inside the wells and they are able to tell us what sort of material is there. So this also shows because the radiation can penetrate well deep and give us an indication of the type of material that is present in there.

Just like I talked about x-ray for the human being, x-ray for all welds, very, very common, very, very common is the radiography. Wherever we have welds and we have to see that the welds are perfect, what we do? We take an x-ray. We keep an x-ray source. We keep a film. We look at the film to find out whether there are no blow holes.

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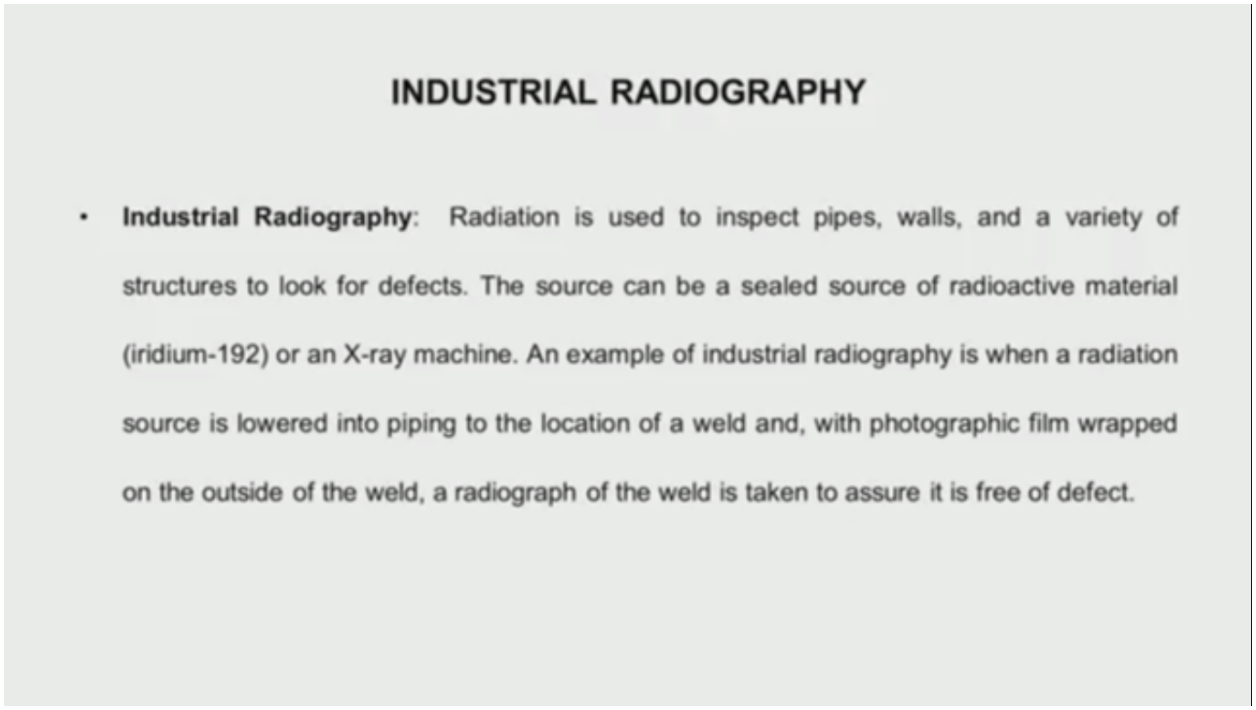

And here we use a source radioactive material mostly Indium on the x-ray machine and the photographic film is used. We can preserve it also and we can find out later in case there is a problem with that.

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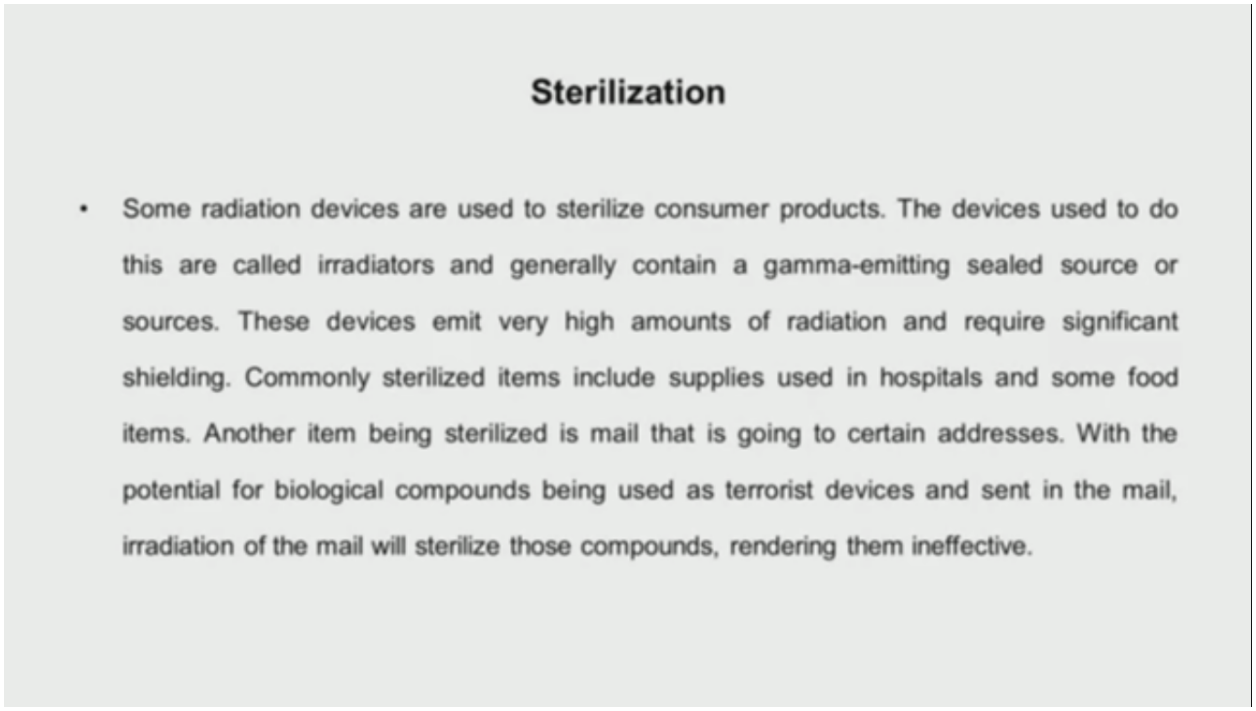

Sterilization. Yeah, I think if you look back about two decades back, when we used to go to the doctor, we used to have an injection syringe in a rectangular box. He used to put water in that, put the syringe and a needle, and then boil it on a -- put on a boiling water and then he used to use it so that that was the sterilization he did, but today when you go to the doctor, he doesn't do anything. He just takes it out of a one polythene paper cover.

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He takes it -- he don't even gives you injection and after that uses that, throws it off. What is this? You are not aware. All this is all sterilized using radiation and these units have such a utilization that it is a commercial industry. We have the Board of Radiation and Irradiation Technology in BARC, in Trombay and most of these materials used in the hospitals like gauze, then your needles, all are being irradiated and then sent.

Now as I mentioned to you earlier with this sterilization, you are achieving the same thing what would have done by boiling water, but with lesser effort and better way of doing things.

Yeah. We have seen the human being the industry and then we should also not forget about the environment.

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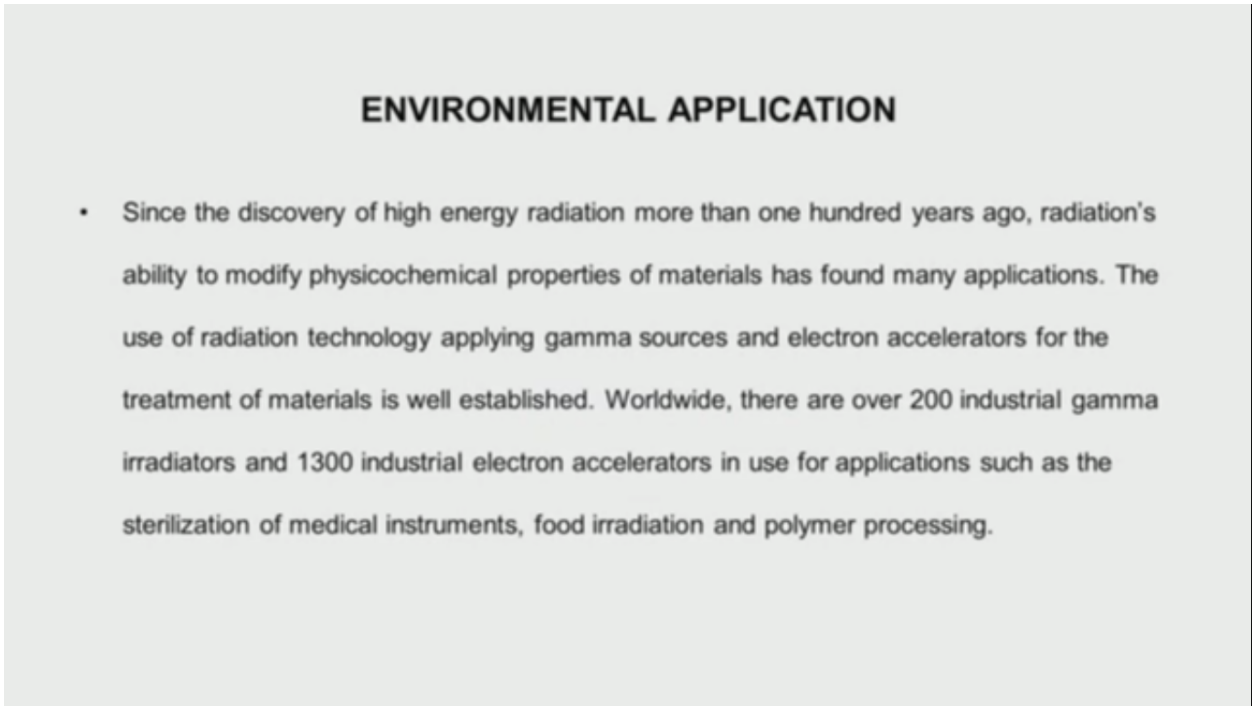

Now this use of radiation technology by applying gamma sources and electron accelerators has been used large amounts for medical instruments, food irradiation, and even polymer processing. Radiation polymerization is also one type of application where it has been widely used.

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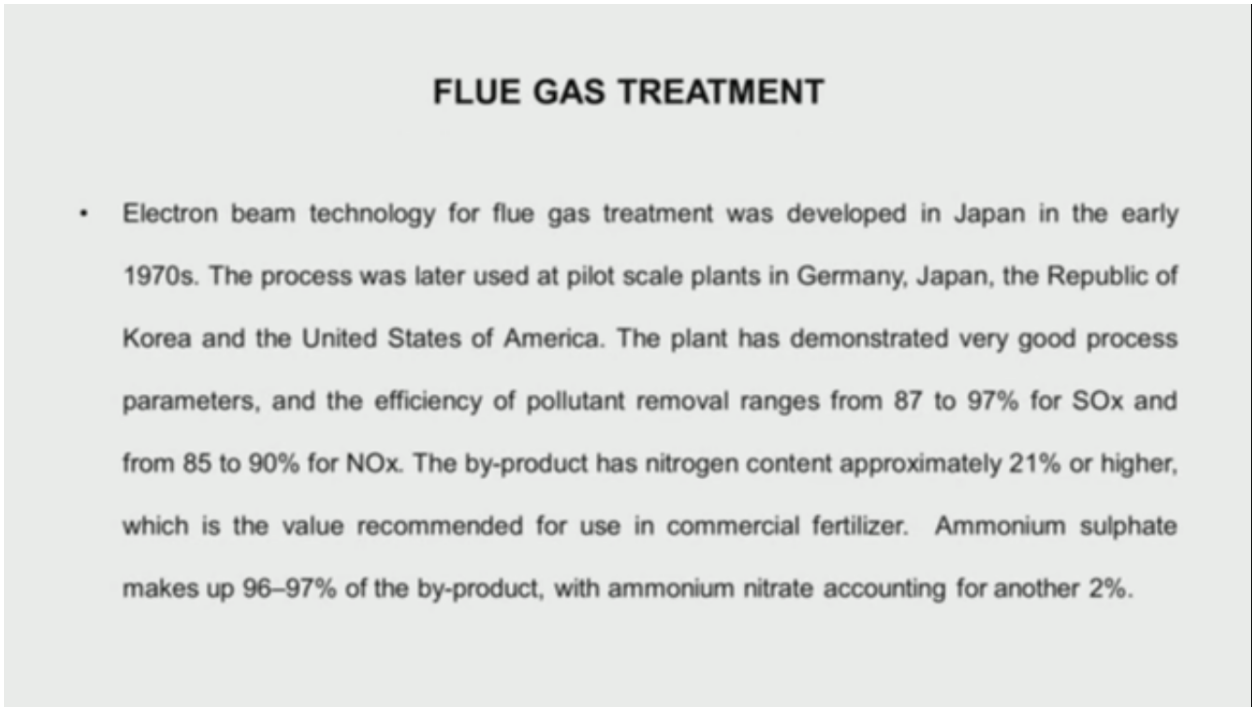

This electron beam technology has in fact found to be very useful for flue gas treatment. We saw that in a coal-fired power plant or an oil-fired power plant, we do get carbon dioxide and sulfur dioxide and surely, this, if they can be caught and put somewhere, they would not spoil the environment.

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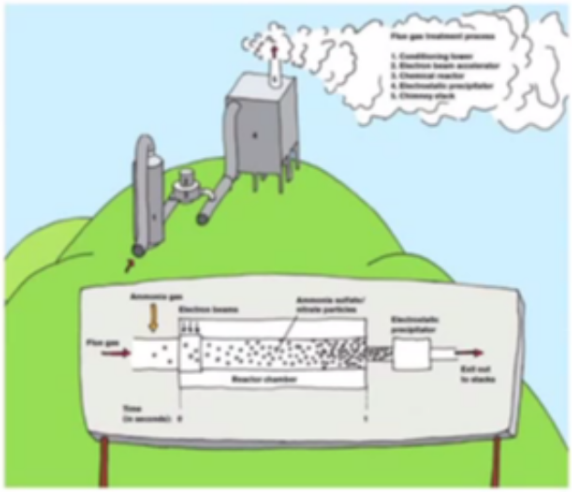
ELECTRON BEAM PROCESSING FLUE GAS



So here by the use of electron beam technology, countries like Japan, USA, and Korea, they have been able to remove as much as 87 to 97% of sulfur dioxide and 85 to 90% of nitrous oxide. They are able to absorb it in some special material and that material is used for making fertilizers because fertilizers require both nitrogen and sulfur. So ammonium nitrate -- sulfate is a byproduct of that along with ammonium nitrate. So you see how irradiation has -- is helping even to control the carbon dioxide emission from the fossil fuel plants.

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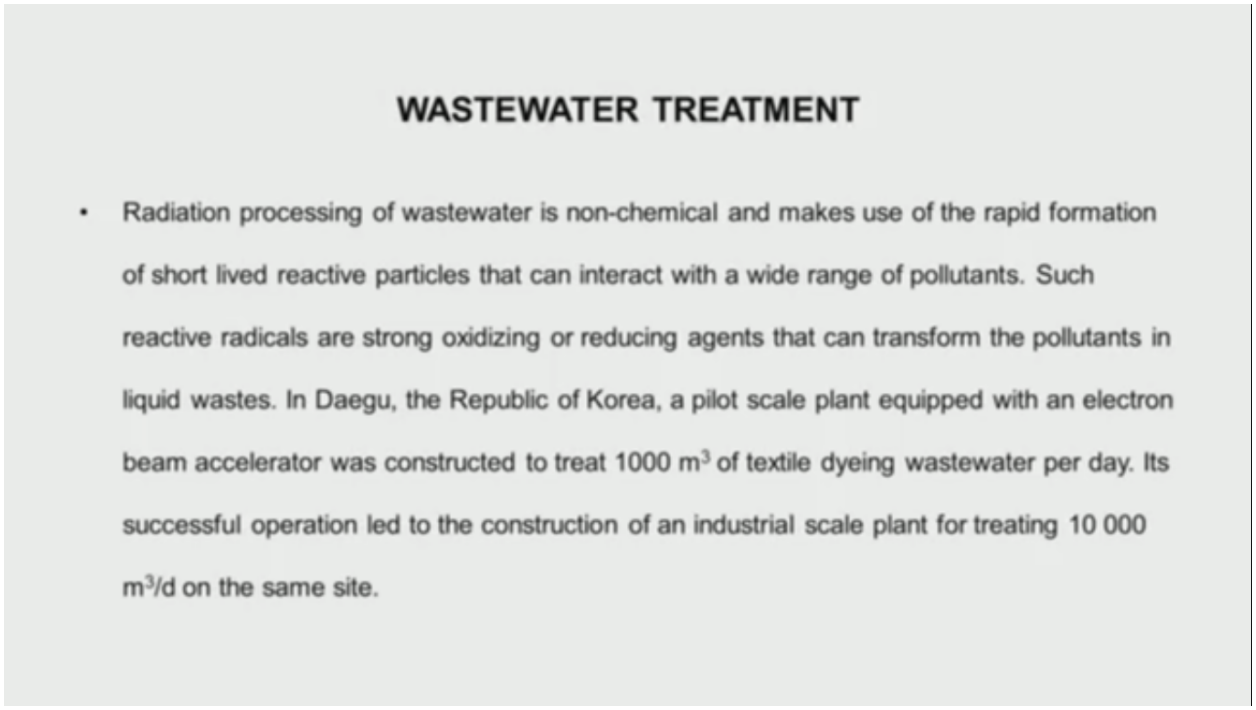

Yeah. Wastewater treatment, what is this? It is going on applications. Here again, the principle is same. Wastewater contains lot of bacteria and pollutants and these are all health hazards. If these thing, these pollutants or the bacteria could be killed without much effort, then you'll -- your water will be pure. It will be more environment friendly. So here radiation processing of water, the advantage is it is a non-chemical process. So you don't put chemicals or you don't make it into some other thing. Here it is a non-chemical process and we are able to reduce or kill this bacteria. The pilot plant has been set up in the Republic of Korea for wastewater treatment, basically, the wastewater coming from the textile industry, and work on this direction is also going on in many countries including India.

Yeah. Wastewater we have been like a place like leather industry and all this sort of wastewater treatment would have been very, very useful.

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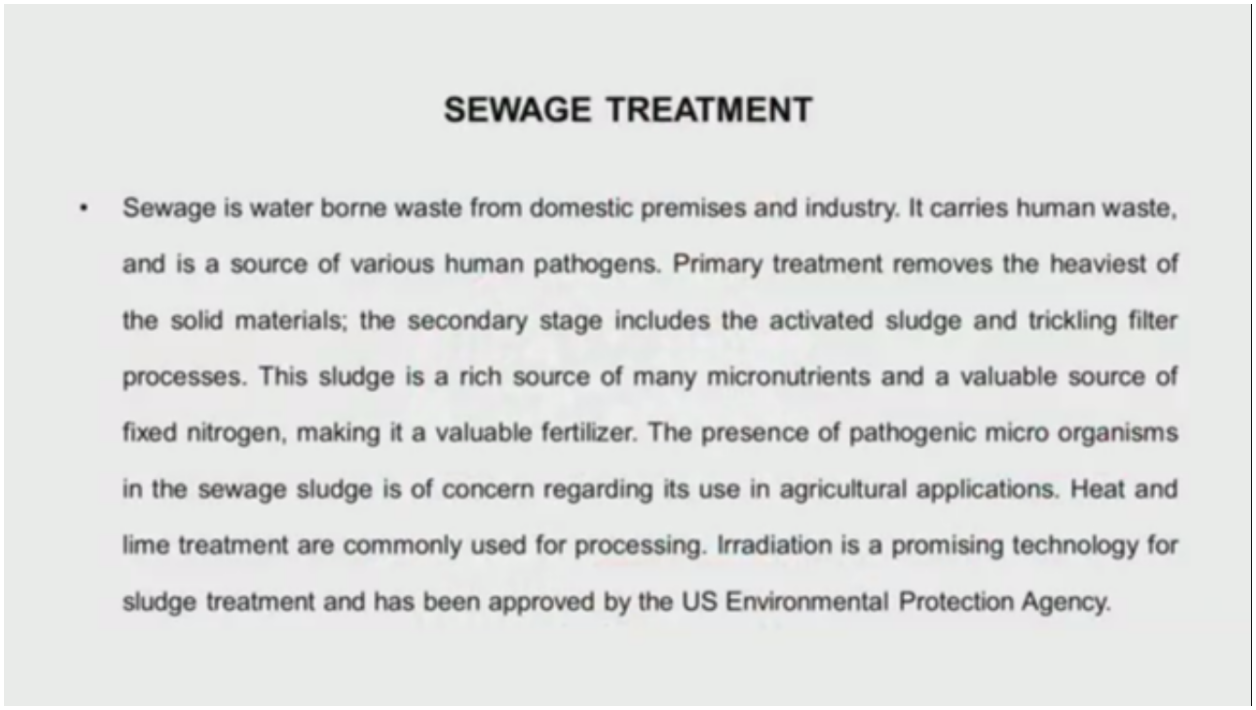

Moving further to sewage, of course, all of us know sewage, tons and tons of sewage comes out every day and this sewage all goes from different houses to the -- by -- through pipes and all to where it has to be disposed off, but this contains human waste, and it's a lot of pathogens and bacteria are all there. So what do we do? We do, of course, we do the treatment. The solid materials we remove in the first stage and the secondary stage, we have the sludge.

Now this sludge if you leave it, it is a good source of breeding for all bacterias and mosquitoes. So it becomes really a health hazard. Surely, we do nowadays we do convert it into valuable fertilizers we can make, but then if we can kill these pathogens or microorganisms in this sludge, then we would be having a better environment friendly waste. Earlier heat and lime treatment were used for processing.

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SEWAGE TREATMENT

- Sewage is water borne waste from domestic premises and industry. It carries human waste, and is a source of various human pathogens. Primary treatment removes the heaviest of the solid materials; the secondary stage includes the activated sludge and trickling filter processes. This sludge is a rich source of many micronutrients and a valuable source of fixed nitrogen, making it a valuable fertilizer. The presence of pathogenic micro organisms in the sewage sludge is of concern regarding its use in agricultural applications. Heat and lime treatment are commonly used for processing. Irradiation is a promising technology for sludge treatment and has been approved by the US Environmental Protection Agency.

But today irradiation treatment is the major thing and it has been approved by the US Environmental Protection Agency.

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VADODARA PLANT,INDIA

- A plant for liquid sludge treatment using gamma radiation from a ^{60}Co gamma source has been in operation in Vadodara, India, since 1992. The plant is designed to treat 110 m^3 of sludge from a conventional treatment plant per day. The plant's operational experience has shown that the process is simple, effective and easy to integrate into an existing sewage treatment plant, and that the radiation treated sludge can be used as a fertilizer in agriculture. The two artificial radioisotopes ^{60}Co and ^{137}Cs are widely used as gamma radiation sources. Cobalt-60 is produced by irradiating the stable isotope of cobalt (^{59}Co), while ^{137}Cs is separated from spent reactor fuel.

Okay. I talked about the US, but we are not very much behind. Already a plant has been set up at Vadodara formerly called Baroda in the state of Gujarat for sludge treatment and it uses a gamma radiation, the Cobalt-60 gamma source and this plant has been operating since 1992. It is designed to treat about 110 meter cubed of sludge from conventional plants.

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The experience so far '92 means we have now nearly completed about 22 years. We find that the operational experience is good. It is very effective and we find that the -- this sort of technology should be put to use very effectively everywhere.

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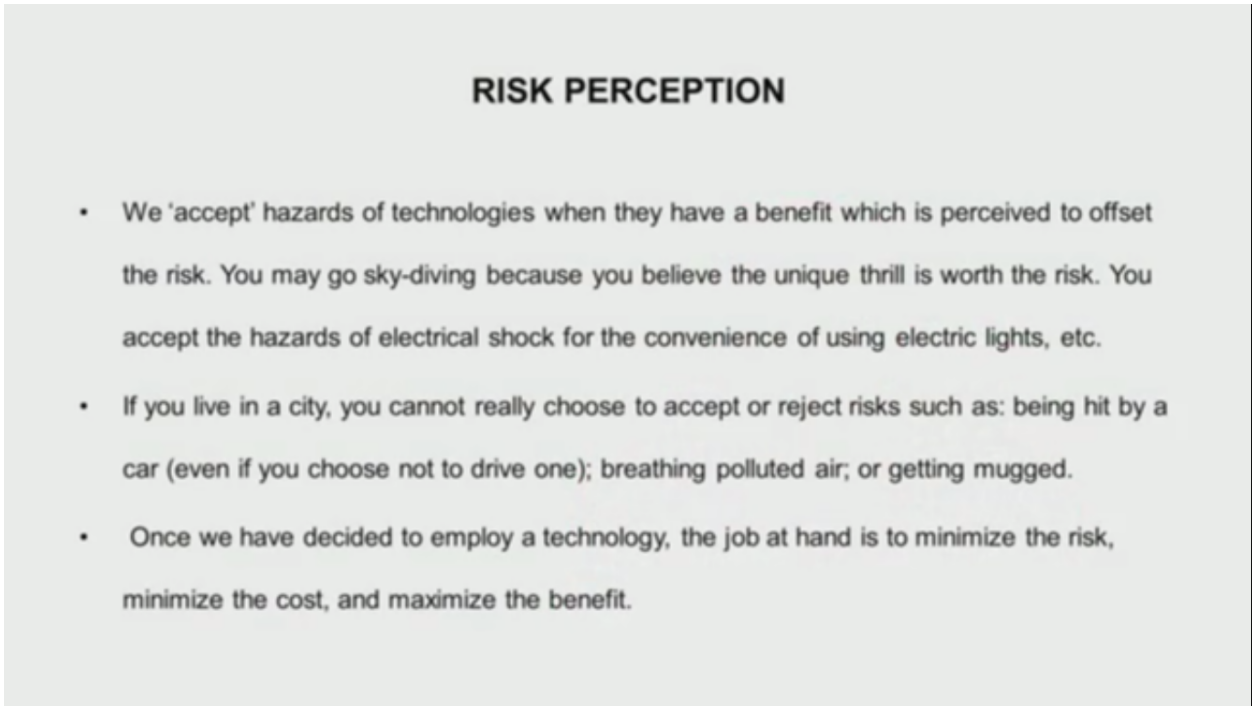

Now what is risk? Now let us say I lose -- I am going out with some money in my pocket and I find that my pocket has been picked. Maybe I lose about 100 rupees. I say, "Okay, it's all 100 rupees." So that it doesn't count as a risk for me. I go to another person. He may say, "Oh, 100 rupees. Oh, today's livelihood is lost." So the risk is a perception of a human being and coming to technologies also, we look at technologies where we benefit.

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RISK PERCEPTION

- We 'accept' hazards of technologies when they have a benefit which is perceived to offset the risk. You may go sky-diving because you believe the unique thrill is worth the risk. You accept the hazards of electrical shock for the convenience of using electric lights, etc.
- If you live in a city, you cannot really choose to accept or reject risks such as: being hit by a car (even if you choose not to drive one); breathing polluted air; or getting mugged.
- Once we have decided to employ a technology, the job at hand is to minimize the risk, minimize the cost, and maximize the benefit.

And if we find that we don't benefit we feel what you perceive, then okay, even if there is a risk, okay, I am getting benefited by it. That is more important.

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RISK WITH SKY DIVING

Now many people have the thrill of going for a sky diving. In skydiving there is a risk, but they would like to have the fun. So here again, there is a risk.

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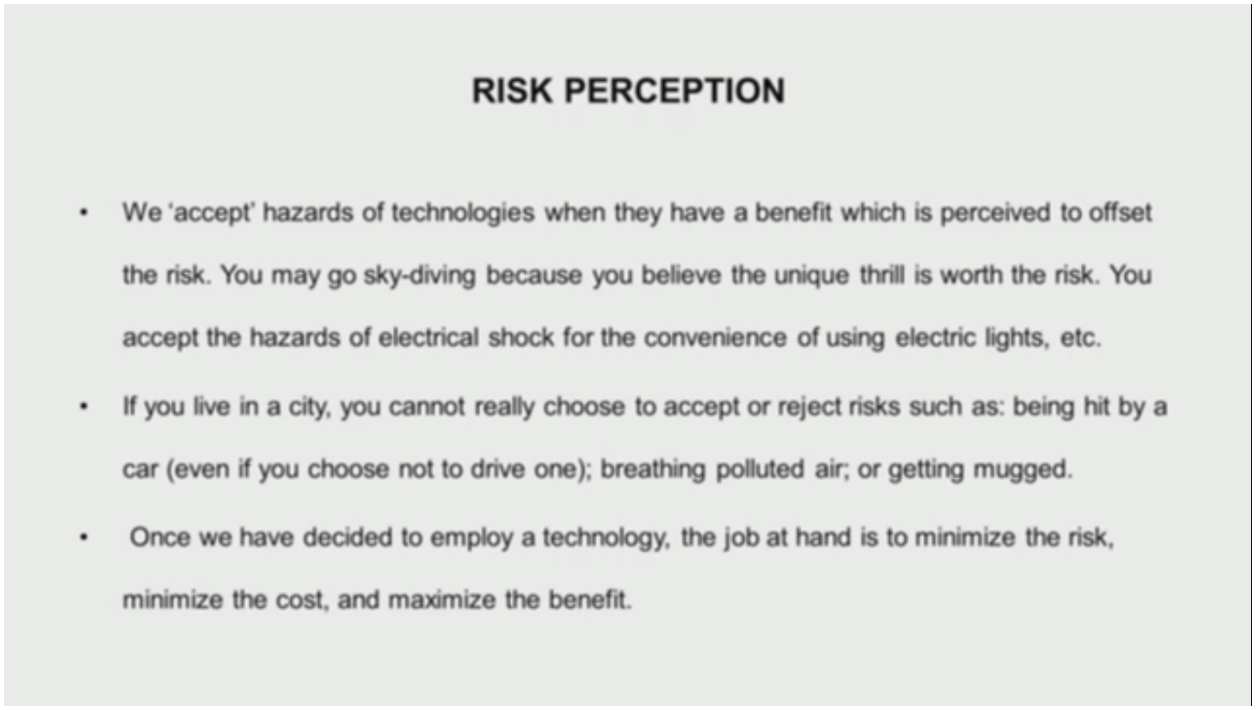

You go, you operate a electrical machine. You put on the air-conditioner. You still find that there is a chance of getting a electric shock, but again the advantage is more than what are the risks involved. So you have to decide once we employ a technology, we have to minimize the risk, minimize the cost and maximize the benefit.

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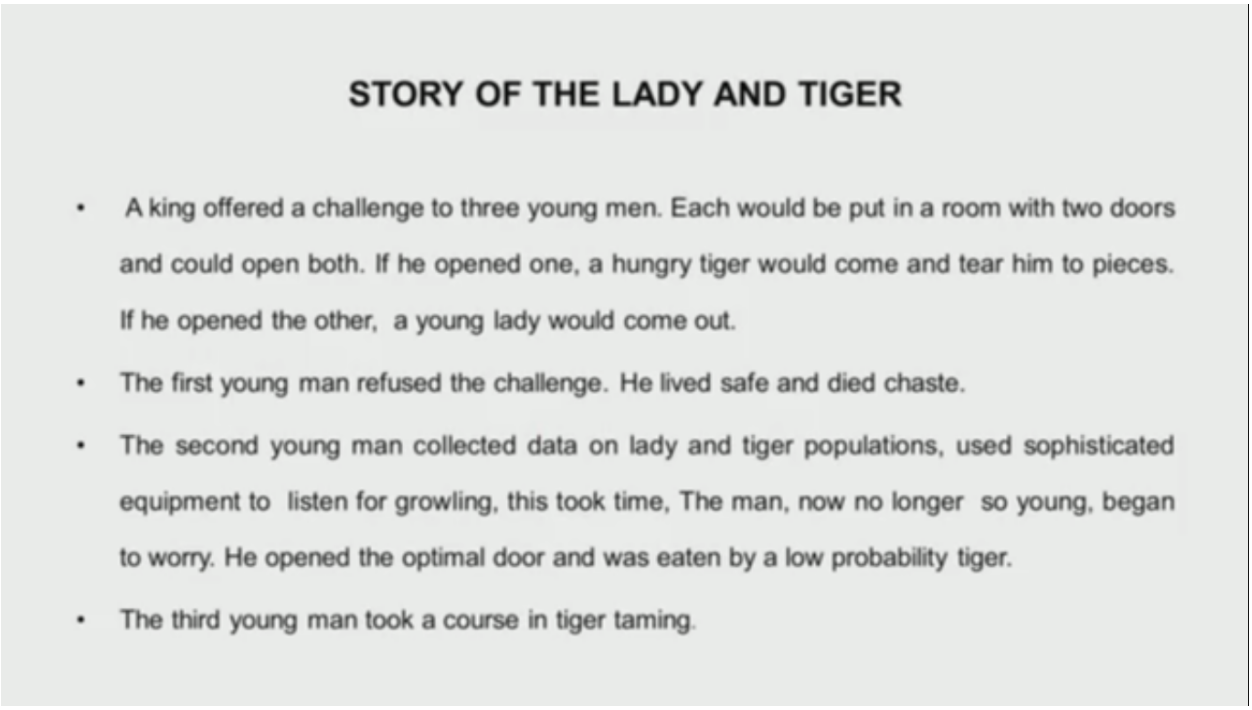

I will end this lecture with a story of the lady and tiger. There was a king. He offered a challenge to three young men. Each would be put in a room with two doors and they could open both.

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If he opened one door, a hungry tiger would be there and tear him to pieces. If he opened the other door, a charming lady would come out. The three young men sat. The first young man thought there is no point in taking any risk. He stayed there in the room. He was safe and died there.

The second young man, he thought, he appeared to -- appeared to be more a scientific person. He started collecting data on how you can detect a tiger's growling. So he engaged people to find out and get him the data, find out whether he can find out which room that tiger is and which room the lady is. He went on doing research. He had to remove the other noises from the patterns he got so much so it took so much time that he started worrying, "Arre! I will lose all my time." He opened the door and probably was eaten by a tiger.

The third young man thought, "Okay, there is nothing to worry about the lady. The tiger is important." So he learned, he undertook a course in tiger taming, opened the door, the tiger came and he was able to tame the tiger.

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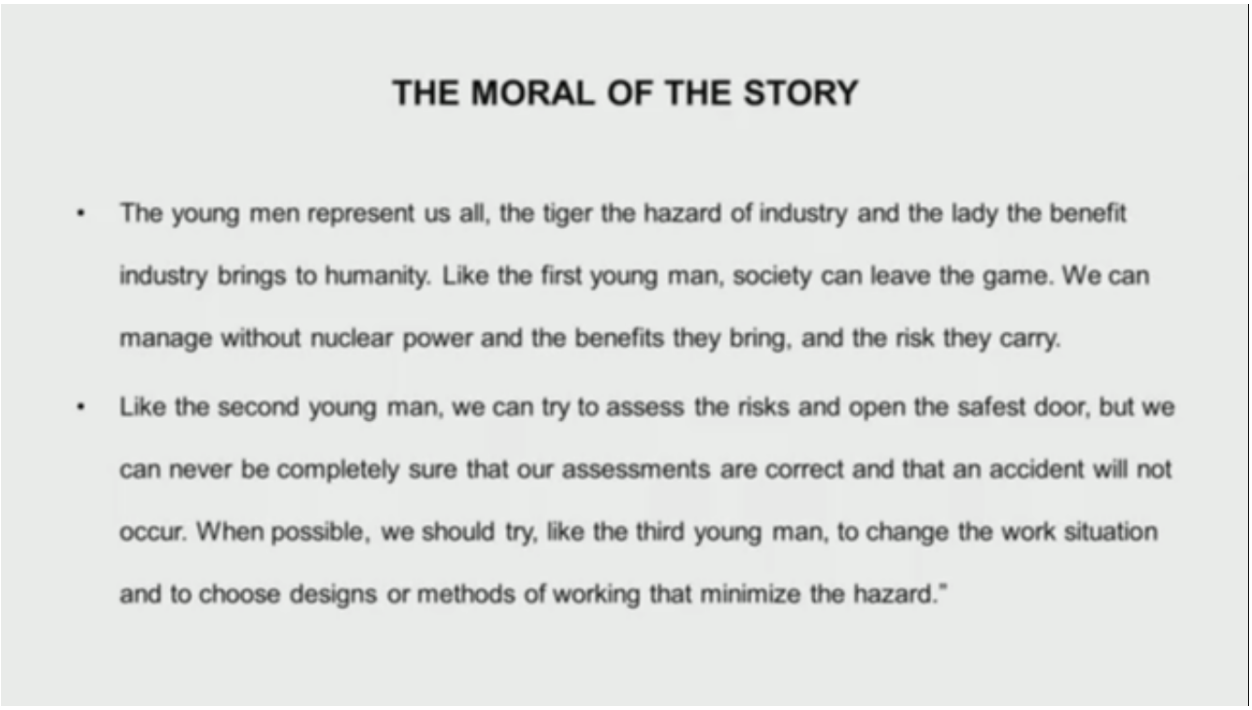

So what do we learn or the moral of the story? The young men represent we people and the tiger the hazard of the industry and the lady represents the benefit industry brings to humanity. Like the first young man, society can leave the game. We can manage without nuclear power, and benefits they bring, and the risks they carry or like the second young man we can try to assess the risks, and open the safest door, but we can never be completely sure that our assessments are correct. So when possible we should try like the third young man to change the work situation to choose designs of our methods which can minimize the hazard.

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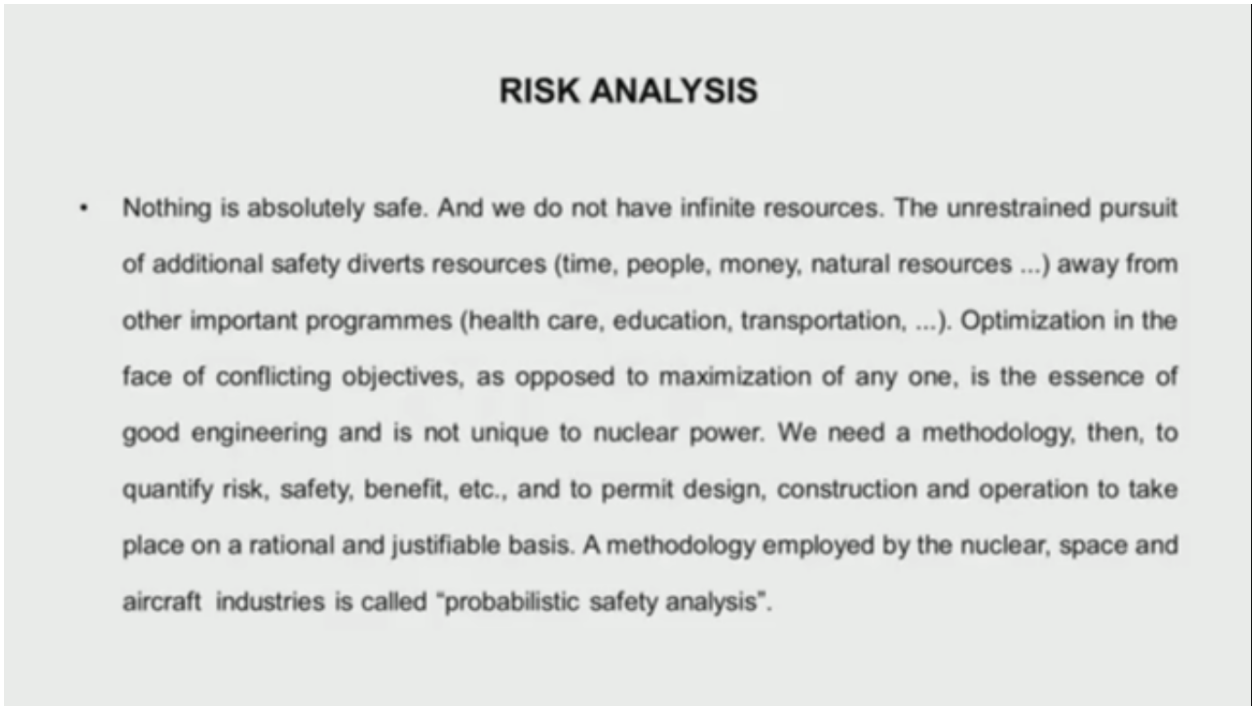

Now we talked about risk and there is nothing absolutely safe. We can keep on trying to have a protection from every type of risk, but every new element you add to the technology, it also compounds the risk because it will have one more component about which the failure of that we have to consider. So it doesn't mean that we can really take care of risks and if suppose unrestrained pursuit of this additional safety -- safety, it does divert resources, that people, time, money, etc., away from the important programs.

So what you need to do is optimization as opposed to maximization of anyone and therefore, we need a methodology.

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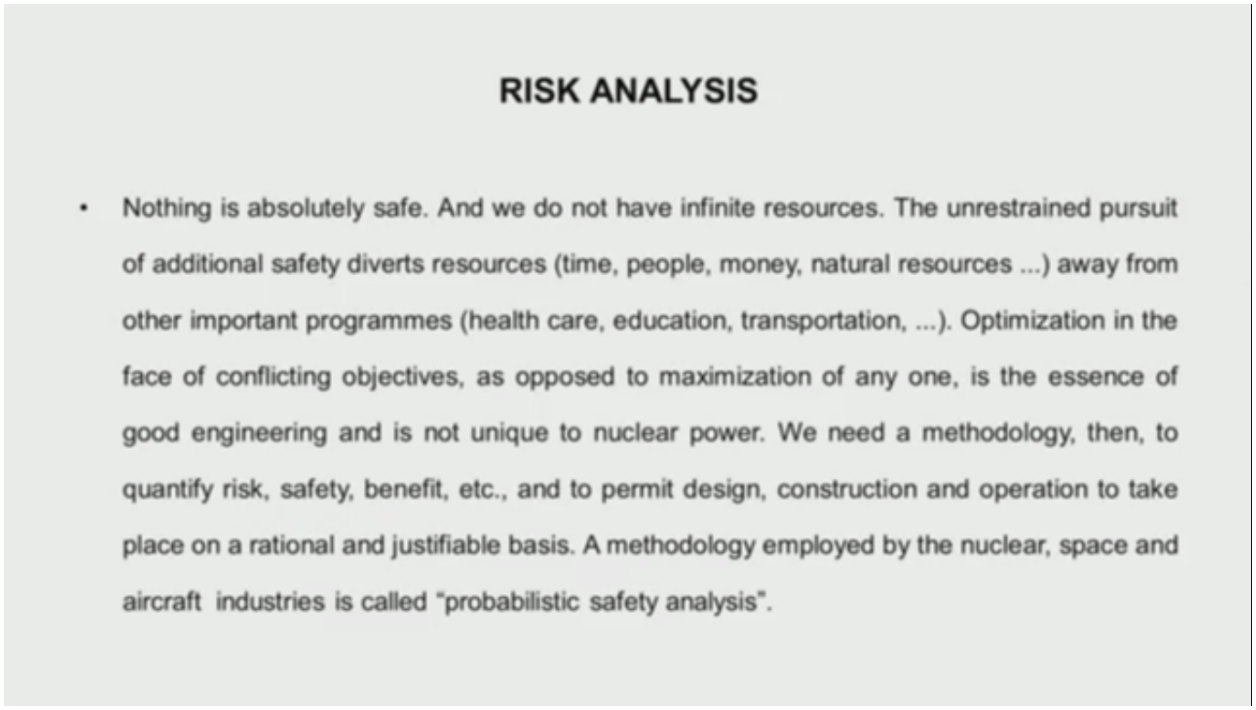

And this methodology, which is followed in all the what we call areas, in the areas of space, nuclear and art craft industries, we call this as probabilistic safety analysis wherein we consider the probability of occurrence of an event multiplied by the effect of that event and this multiplication product, this needs to be minimized. So that is being followed even in the every field and nuclear reactors really have gone ahead very much in this respect.

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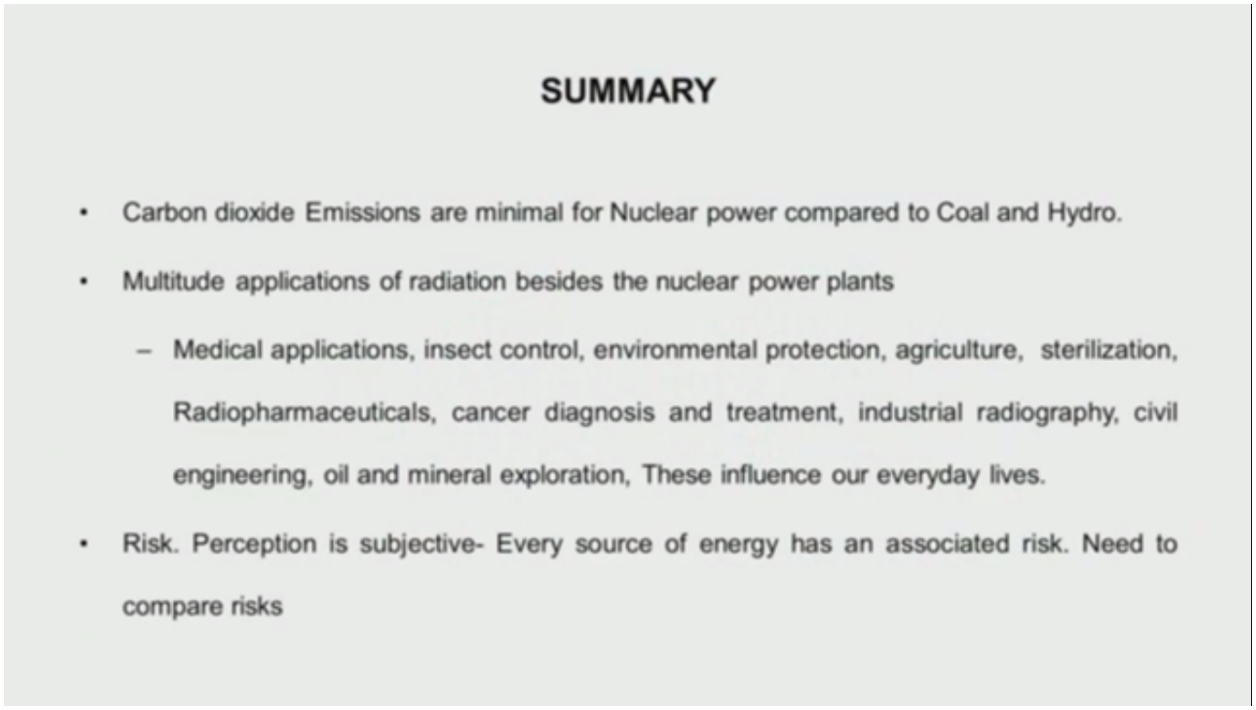

So I will just try to summarize what we have seen in the lecture today. Carbon dioxide emission is one of concern. The greenhouse effect has already started showing [indiscernible 00:52:42]. The temperatures are increasing. The weather patterns are changing. So there is need and this carbon dioxide emission is minimal for nuclear power compared to coal and hydro.

Then coming to radiation per se which is comes from this radioactive material, it has immense use for humanity in medical applications, insect control, environmental protection, agriculture, sterilization, radio pharmaceuticals, cancer diagnosis, cancer treatment, industrial radiography and whatnot. These, all these influence our day to day life and the last we saw not -- but not the least risk perception is subjective. Every source of energy has a risk associated with it. We need to compare risks and there is nothing absolutely safe. Thank you.

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