Slide 1: My name is Nirupama Sensharma and I am a PhD student from the University of Notre Dame. The talk I am about to give today is a part of an initiative that I have started. The name of the initiative is Nuclear Energy – The Better Energy. Through this talk, I hope to be able to convince you all that we do need this initiative and now Is the best time to actively participate in something like this.

Slide 2: I will start with talking about why did I need to start this initiative in the first place. Read points.

Slide 3: This slide shows the three major challenges that we as Nuclear scientists face while addressing the general public about the benefits of Nuclear energy. The first and most difficult challenge is the (read first point). Then, of course there is lack of knowledge. Both of these lead to a fear of radiation and (read middle point).

Slide 4: This shows examples of how media frenzy occurred after some of the nuclear accidents like Chernobyl and Fukushima. Read some of the headlines. These are perfect examples of how media has time and again mislead the public into believing that nuclear power has caused more damage than what actually happened. For example, people in Fukushima died due to the hasty evacuation procedure started by the Govt., nobody died of radiation poisoning. But no media ever reported that. What happened at Chernobyl was the classic example of the worst reactor design, worst operational practices and the truth that Chernobyl-type accidents can not occur in the present day reactors. Misrepresentations and use of provocative language is a very big barrier that we as scientists have to deal with while convincing the society about the benefits of Nuclear power.

Slide 5: Marie Curie said, “Quote” This served as the motivation for starting this initiative.

Slide 6: So where did we start with this initiative?
We needed a platform that serves as an easy-to-approach resource and it needs to be clear, accurate, credible and interesting.

Slide 7: So, I started with designing a website *thebetterenergy.net*. The website has been designed in a user-friendly and easy to understand language. The aim is to be able to use this website as an educational and informational resource for anyone over the age of 15. To attract more people and get more traffic on the website, it has been linked to a Facebook page of the same name – Nuclear Energy – The Better Energy.

Slide 8: The website has been divided into five sections. The first three are – read the sections. Each of these three sections, currently has three articles each. The fourth section involves a detailed explanation of the Indian nuclear power program. This was done because to get people from India also involved in this initiative. Also, the nuclear power programs of India and US are very different. It was imagined that the public would benefit and develop a better understanding of the programs of two major countries. Finally, a fun quiz section has been included with questions from the above four sections. And the website has also been linked to the US NRC for authenticity.

Slide 9: The implementation of the initiative involved organizing various outreach events for for primary and middle school students to introduce them to the concepts of Nuclear physics through demonstrations. I also delivered lectures to high school students about working of nuclear power plants and their safety features. Additionally, I have organized a platform to interact with parents and answer their questions about radiation and nuclear safety.

Slide 10: **Before we start,** it is important to know that the motive of this talk is to open a platform for dialogue about Nuclear science amongst specialists in the field and the general public so as to remove any misconceptions and irrational fears that the society has about nuclear science.
And to be able to do that, it is important that the concepts be explained in a non-specialist way i.e., in a language that can be easily understood by the general public.

Slide 11 and 12: Time for pop quiz 1. Read both slides.

Slide 13: Talking about creating awareness amongst the general public about Nuclear energy, we need to look at all the aspects one by one. We start with the **Availability of fuel**. Now, one of the very first problems that we solve while taking a class in nuclear fission is to calculate to amount of energy released by burning 1 kg of U. So, what we get tells us that The amount of energy produced by 1kg of Uranium is the same as that from burning 2,750 tons of coal.
Moreover, According to the US Energy Information Administration (EIA) estimates, we have enough Uranium to last for 500 years. With reprocessing techniques and use of Fast Breeder reactors, we can convert Nuclear energy into a renewable source of energy and then we don’t have to worry about running out of fuel.
Finally, It must also be remembered that electricity generation is not the sole purpose of coal. It also needs to be preserved for some other industries like steel and fertilizer.

Slide 14: Coming next to the **Environmental effects.** It is no longer a secret that burning fossil fuels emit huge amount of greenhouse gases like CO_2, CO, SO_2, SO_3, NO_2 etc. This leads to global warming and result in environmental pollution, reduced rainfall, melting of polar ice-caps, drying of rivers, sea level rising and inundating low-lying coastal areas, acid rains that pollute different drinking water sources, lung diseases and whatnot.
Whereas, uranium burning does not produce any carbon dioxide. The only CO_2 that U burning releases is during the mining phase.
And most importantly, all the radiation generated in a nuclear power plant is safely contained within the reactor building by thick lead and concrete shielding (containment structure) all around it.

Slide 15: Talking about **Accident Statistics,** if safety is the prime concern, then this table tells us that Nuclear should be our top priority. The data in this table reflects the statistics given by IAEA. We clearly see that while coal, nat gas and hydro have caused 18,000, 1,000 and 30,000 deaths of workers and public respectively, Nuclear has resulted in only 31 deaths.

Slide 16: These accident statistics brings us back to the challenges that Nuclear power faces. Before proceeding, I would like to ask you all, read questions.
The 31 people to die were fire fighters who helped dousing the flames after the blast of a reactor at Chernobyl by flying in a helicopter to the top of the reactor building.
Whereas, some of you might have heard about the Bhopal Gas tragedy where a gas leak incident occurred in 1984 at a pesticide plant in Bhopal, India. This accident resulted in 2,259 direct deaths, 558,125 injuries, including 38,478 temporary partial injuries and approximately 3,900 severely and permanently disabling injuries.

Slide 17: Another aspect of why Nuclear is better than other energy sources is because of its long **Lifetime and small land requirements.** The designed life-time is 40 years and above for nuclear power plants whereas for thermal power plants, it is limited to 30 years. Because of various reasons like corrosion and erosion, life extension may not be possible for thermal power plants. However with better choice of materials and good maintenance practices, an extension of 10 to 15 years is usually possible for nuclear power plants. As a result, the generation cost beyond the lifetime of the plant will only include the running cost and hence also makes Nuclear energy cheaper.
Coming to LAND REQUIREMENT,
For thermal power plants, the land requirement is about 0.5 to 1.2 acres per MWe. However, for nuclear power plants this is just 0.20 to 0.25 acres per MWe. A 1 km radius is usually required for the construction of a nuclear power plant. However, the actual plant occupies only a small percentage of this area. In the remaining area, agriculture and common human activities can go on as usual.

Slide 18: However, the most challenging aspect that hinders the future of Nuclear power is the fear of Radiation. As nuclear scientists, we need to be able to make the general public understand what exactly is radiation and how it affects our day-to-day lives.
Google will simply tell you that **Radiation** is the emission or transmission of energy in the form of waves or particles through space.

We never worry about any exposure that we receive by say sitting under a light bulb for 12 hours or listening to radio all night long or heating our food in a microwave. The reason is because there is a subcategory that any kind of radiation can be divided into – ionizing and non-ionizing. Radiation like α- β- γ- rays and X-rays that can possibly do harm to living tissues by ionizing atoms or knocking off electrons from atoms are ionizing. Whereas, radio waves, microwaves and visible light that are on the lower frequency end of the Electromagnetic spectrum, cannot ionize atoms and are unable to cause any potential damage to the living tissues are non-ionizing radiation.

Slide 19: People often worry about the **Radiation exposure** that they would be receiving if more nuclear power plants are built in their cities or close to habitations. I like to tackle this question by asking a simple question.
So, we know that...read the first two lines.
Ask question. The answer is No.
Radiation has been a part of human life since the beginning of time. There are two sources of radiation emission - (i) Natural sources of radiation (Background radiation and (ii) Artificial sources of radiation. We will look at each one individually.

Slide 20: Let's start with **Natural sources of Radiation** that can be divided into three categories: Cosmic rays, Terrestrial radiation and internal radiation.

Slide 21: Cosmic Rays
Cosmic rays are immensely high-energy radiation, mainly originating outside the Solar System. They may produce showers of particles that penetrate and impact the Earth's atmosphere and sometimes even reach the surface. Cosmic rays are composed primarily of protons and alpha particles (99%), with a small amount of heavier nuclei (~1%). When cosmic rays enter the Earth's atmosphere they collide with atoms and molecules, mainly oxygen and nitrogen. This interaction produces a cascade of lighter particles that rains down on everything on the surface of the Earth.
The exposure received by Cosmic radiation differs for different regions depending upon their elevation. The average dose as received from from cosmic radiation is 0.04 rem per year (rem is a unit of radiation dose applied to humans).

Slide 22: Consequences of radiation from cosmic rays
Few people realize that taking an inter-continental flight exposes them to radiation far greater than what they receive from the nuclear fuel cycle. The exposure on such flights is due to the exposure from cosmic rays which increases with altitude. The longer you are on a flight, the more radiation you receive and the higher you are in altitude, the higher the dose of radiation. Annual jet travel can add up to 10 mrem of radiation dose to humans.

Slide 23: Terrestrial Radiation
The Earth that we live on is in itself a source of radiation. Radioactive materials like Uranium, Thorium and their decay products occur naturally in rocks, soil, water and vegetation. The most harmful of all these decay products is Radon. Radon is a gas and can be inhaled. On reaching our lungs, Radon further decays to solid daughter products that can get stuck in the respiratory system causing harm.
The exposure received by Terrestrial radiation also differs for different parts of the world depending upon the uranium/thorium content of the soil of that area. The average dose from terrestrial radiation is 0.2 rem per year.

Consequences of Terrestrial Radiation

Slide 24: Radon accumulation

Radon is a radioactive gas that is the decay product of Uranium and Thorium. Since both uranium and thorium are found in rocks and soil in small quantities, radon is released in the environment from these sources. Radon does not have any smell or taste but can create problems due to its radioactive nature. Radon can enter buildings or houses through openings in floors, walls or through construction joints and can get trapped if enough air circulation is not possible. Hence, radon accumulation mostly occurs in basements and enclosed spaces within buildings.

The average dose received by a person from radon in the atmosphere is 200 millirem. Radon poisoning accelerates if the person is a smoker.

Slide 25: Drinking water

Drinking water in our homes usually come from rivers and lakes. Radiation can enter the water stream from natural sources rocks and soil. In the United States, the levels of radiation in drinking water is very low. The average annual radiation dose received by a person in the U.S. is about 5 millirem.

Slide 26: Internal Radiation

All living beings on Earth have Potassium-40, Carbon-14 and Lead-210 in them from the time of their birth. These are radioactive elements that get absorbed by the body and keep getting replenished over time. The exposure received by an average man in the United States by Internal radiation is an effective dose of about 0.03 rem each year.

Slide 27: Consequences of internal radiation

Sitting next to a person

Just by sitting next to a person would expose you to radioactivity arising from the internal radiation emitted from that person’s body. As we saw in the last slide, all living beings on Earth have Potassium-40, Carbon-14 and Lead-210 in them from the time of their birth. These may arise due to the consumption of food, drinking water or simply inhaling air containing radioactive elements. These elements are absorbed by the tissues and bones in our bodies and keep getting replenished over time by simple processes like ingestion and inhalation. The radiation received via this process is called Internal radiation.

The exposure received by an average man in the United States by Internal radiation is an effective dose of about 0.03 rem each year.

Slide 28: Now coming to the artificial sources of radiation. This can also be further subdivided into three categories: Nuclear Medicine, Consumer products and the nuclear fuel cycle.

Slide 29: Nuclear Medicine

The most radiation exposure as received by the general public from man-made sources, at present is by medical procedures such as X-rays, radiation therapy to cure cancer and medical imaging wherein a radioactive material is injected in the body to check for various diseases. Any patient undergoing such a procedure will receive a radiation dose. The radiation doses delivered to a patient in such an investigation is generally accepted to present a very small risk of inducing cancer. For example, the effective doses can range from 0.006 rem to 3.7 rem for a non-specific tumor imaging procedure. A typical chest X-ray can expose you to about 0.002 rem of radiation dose while a chest CT-scan can result in up to a dose of 0.2 rem.

Slide 30: Consumer Products

Let's talk about the various consumer products that expose us to radiation on a daily basis.

Slide 31: Smoke Detector

Most smoke detectors use a small amount (about 1.0 microCurie) of Americium-241 (241Am), a radioactive material to detect smoke. 241Am is an alpha-emitting radioactive source i.e., it decays by emitting alpha (helium-4) particles.

A typical smoke detector has three major components – the ionization chamber, a radioactive source and a battery. The ionization chamber consists of two metal plates held at different voltages. The 241Am source emits alpha particles that interact with the air molecules in between the two plates. This interaction causes the air molecules to ionize i.e., it breaks down to positive and negative ions which are then attracted to the negative and positive plates respectively. This flow of charges results in an electric current.

If there is smoke in the air, the smoke particles stick to the ionized air molecules and obstructs their flow to the metal plates. This obstruction leads to a decrease in the electric current. It is this decrease in current which is detected and triggers the smoke alarm.

Modern smoke detectors emit around 37,000 alpha particles per second. However, the americium is encased in ceramic and foil and therefore very few of them can exit the detector. The energy of the alpha emitted by 241Am is about 5.4 MeV, which can be stopped by a piece of paper or a few centimeters of air and cannot penetrate the human skin. Unless directly inhaled or ingested, 241Am in the smoke detector does not pose any threat.

Slide 32: Building materials

Sandstone, brick, concrete, gypsum and granite contain naturally occurring radioactive elements like radium, uranium and thorium and act as sources of radiation. Radiation dose from building materials largely depend on the type and amounts of material used. However, the level of radioactive materials in such building materials is very low and does not pose any threat to human health. Living in a concrete building adds only up to 7 millirem per year to the annual radiation dose of a person.

Slide 33: Smoking

Tobacco has a property to absorb radon from the atmosphere. Radon along with the smoke is inhaled by the smoker. Now, radon is a gas which decays into solid radioactive products like polonium and lead. Gaseous radon enters the respiratory tract and soon decays into solid radioactive products. These solids can then get stuck in the respiratory tract and lungs and stay there for a very long time continuously decaying into other radioactive products. Over the years, this accumulation can prove seriously dangerous and often times even fatal.

This will not only just affect the smoker but also anyone and everyone near the smoker who is knowingly/unknowingly inhaling the contaminated smoke.

Smoking can add up to 1.3 rem/year to your average annual radiation dose.

Slide 34: Fiestaware

If you were born before 1972 and ever used the orange-red colored Fiestaware, it must be brought to your notice that back in the day, that special orange-red color was derived from Uranium oxide. Researchers estimate that one such plate would have contained approximately about 4.5 grams of uranium. That being said, if you ate off that dinnerware daily, you would have almost 0.21 grams of uranium ingested per year. But not to worry, Fiestaware manufactured after 1972 is not radioactive.

Slide 35: Television

If you still use your old television set, the cathode ray tube in the machine exposes you to about 1 millirem of X-ray radiation per year. The FDA monitors all TV sets sold in the U.S. to be tested to make sure they do not exceed a safe level of X-ray emission. Flat-screen TVs and computers don't use cathode ray tubes, so they don't produce X-rays.

Slide 36: Nuclear Fuel Cycle

This is the last category of man-made sources of radiation.

Surprisingly enough, the source that everyone is most scared of is in fact the least contributing factor of all the sources of radiation seen so far. The entire procedure involved in a Nuclear fuel cycle, right from the mining of Uranium to power production exposes the general public to a much lesser radiation dose. To be specific, the average dose equivalent to the US population from the fuel cycle is only about 0.05 millirem per year which is much less than the dose received by any of the natural sources of radiation. It is also much less than any consumer products that we have just seen and of course much much less than what typical X-rays or CT-scans expose you to.

Slide 37: Banana

I say that bananas are controversial because very few people realize that if they had a banana for breakfast, they actually exposed themselves to radioactivity. A typical banana contains about 0.5 gram of potassium of which 0.012% is radioactive 40K. This roughly amounts to a radiation dose of 0.01 mrem.

Now here's a fun fact: The radioactivity from a truck full of bananas can cause false alarms when passing through a radiation detection device setup to check on the smuggling of radioactive elements!

Slide 38 and 39: Now is the time for our pop quiz 2. Read both slides.

Slide 40 and 41: Pop Quiz 3. Read both slides.

Slide 42: NRC Dose calculator
Before talking about this, I should tell you a little about NRC. The NRC is an independent agency of the US Government that looks after and protects the public health and safety related to Nuclear energy. There is a wonderful application on the U.S.NRC website, also called the Personal Annual Radiation Dose Calculator. It allows you to convert your fear factor into an actual number by answering a few simple questions. This number is the total annual radiation dose that you have received depending on where you live, your lifestyle and adds that to the average background radiation that you are ought to receive on Earth.
Now, The annual average dose per person from all natural and man-made sources is about 350 mrems. However, it is possible for any of us to receive more than that each year (largely due to medical procedures). The U.S. Nuclear Regulatory Commission (NRC) has established standards that allow exposures of up to 5,000 mrem per year for those who work with and around radioactive material, and 100 mrem per year for members of the public (in addition to natural background radiation).

Slide 43: This is what the dose calculator looks like. It shows radiation from cosmic rays, asks your altitude, area of residence (unfortunately only gives estimate for people living in and around the US) Varies from place to place. For ex. If you live in Kerala, you get more radiation due to monazite which is a mineral present in the sand and is very rich in Thorium. It also looks at the type of building you live in, radiation from food and water and any air travel that you might have done.

Slide 44: It will then ask you to select out of all these options, whether you, read the options.

Slide 45: So my personal dose came out to be around 330 mrem which is less than the annual average dose per person from all natural and man-made sources of about 350 mrem (as mentioned on the U.S.NRC website). Of course, if you have undergone a medical procedure lately, you dose will come out to be a greater number. But the point here is that you don't have to be living near a nuclear power plant or you don't have to be working as a Uranium miner to receive a radiation dose. This calculator, more than anything, makes clear that everyone living on this planet receives a radiation dose, albeit the number might vary depending on your lifestyle and other natural factors.
Another very interesting thought that I came across on the same web page goes something like this;
"The reduction in life expectancy from a dose of 1 mrem is about 1.2 minutes. This is equivalent to the reduction in life expectancy from crossing the street three times, taking three puffs on a cigarette, or consuming 10 extra calories (for a person who is overweight)."

Slide 46: Now coming back to where we started from:

1. The idea is to not get scared but to gain better understanding of what radiation is & how it affects our day-to-day lives.

2. We saw clear examples of bananas and inter-continental flights. So bananas are radioactive. Does it mean you need to stop eating them? No! It provides a vital need for your body – potassium. Same goes for taking long trans-continental flights that expose us to radiation from cosmic rays. If you need to go to Japan, you have to take a flight. The subtle point here is that the human body has been subjected to radiation (from background and other sources) ever since it came into existence. Depending on where we live and our lifestyle, the amount of radiation that we receive might vary. But, the important part is that our body knows how to handle it. It has been handling radiation and keeping us safe for all this time. To receive a fatal or a potentially dangerous dose (greater than about 1000 rem) of radiation, you need to receive a lot of it; certainly a lot more than what you receive from the background or from the Nuclear industry at present.

Fear always comes as a by-product of ignorance. Now is the time to shed that ignorance about radiation and its ill-effects and accept Nuclear power for all the benefits it can offer.
And this is the reason behind the initiative that I have started – Nuclear energy – the better energy.

Slide 47: **Quickly looking at the progress report:** So far, this initiative has garnered up to 176 followers and about 300 unique visitors per month. Efforts would be continued for the progress of this initiative and if anyone of you are interested, I would be happy to collaborate, get volunteers for field work and just to extend the website beyond what it is currently delivering.

Slide 48: I wound **End** with this quote from my website:
85 years of scientific experience and the nucleus has still managed to keep the entire mankind baffled. Such is the enigma of Nuclear Power. The immense energy that it releases can not only light your bulbs but can also provide you medical assistance. It is something that stays inside your body, gets replenished every time you eat and breathe. You cannot escape it. You need it. Coal, Petroleum and Natural Gas won't last for your great grandchildren, but Nuclear Power will. Not necessarily the last resort but, a greener, safer and a better one.

Thank you!

BACKUP

Other direct comparisons

Mineral oil and Natural Gas – Whatever reserves of mineral oil and natural gas the world has is better to be used for transport and domestic purposes. Also, it is an equally potent source as coal for environment pollution and emission of greenhouse gases leading to global warming.

Hydel power plants – These plants are environment friendly which however is achieved at the cost of large areas of fertile land being submerged in water. Hydel power plants also create a lot of disturbance in the ecosystem of the surrounding area. Aquatic life as well as any other habitation settled around rivers need to be forcefully displaced.

Wind power – Another environment friendly source of power but is a huge contributor of noise pollution. Also since in most areas, sufficient winds are not available and therefore utilizing wind power for commercial purposes is usually not favorable.

Solar power – Also environment friendly but amounts to a very high cost of electricity. Also putting up commercial solar cells require vast areas of land for maximum exposure to sunlight to be able to produce enough power.

Absorbed dose is the concentration of energy deposited in tissue as a result of an exposure to ionizing radiation.
Equivalent dose is an amount that takes the damaging properties of different types of radiation into account.
Effective dose is a calculated value, measured in mSv, that takes three factors into account:

- the absorbed dose to all organs of the body,
- the relative harm level of the radiation, and
- the sensitivities of each organ to radiation.

Rem – roentgen equivalent man
The **roentgen equivalent man** is a CGS unit of equivalent dose, effective dose, and committed dose which are measures of the health effect of low levels of ionizing radiation on the human body.