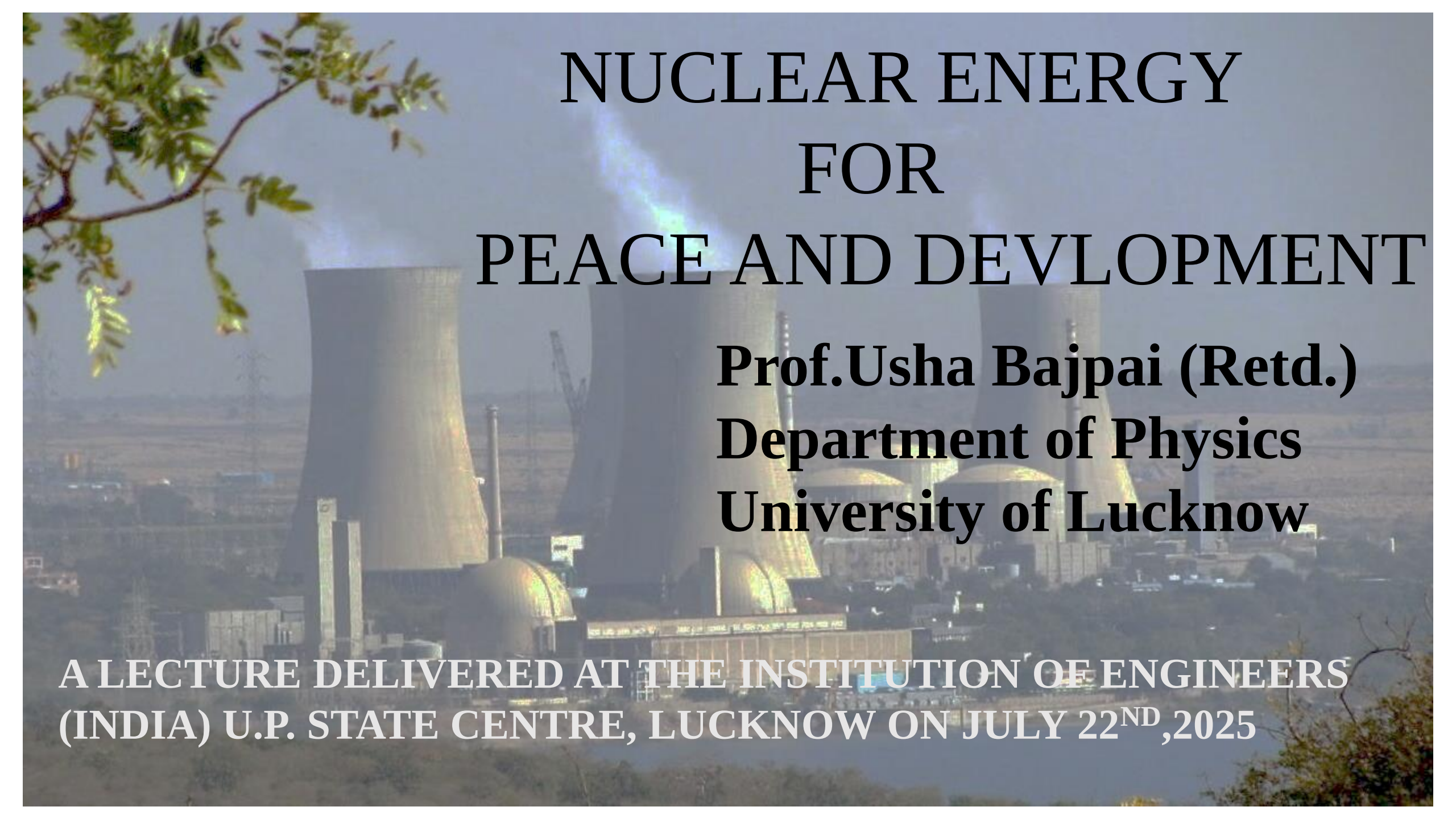




NUCLEAR ENERGY FOR PEACE AND DEVELOPMENT

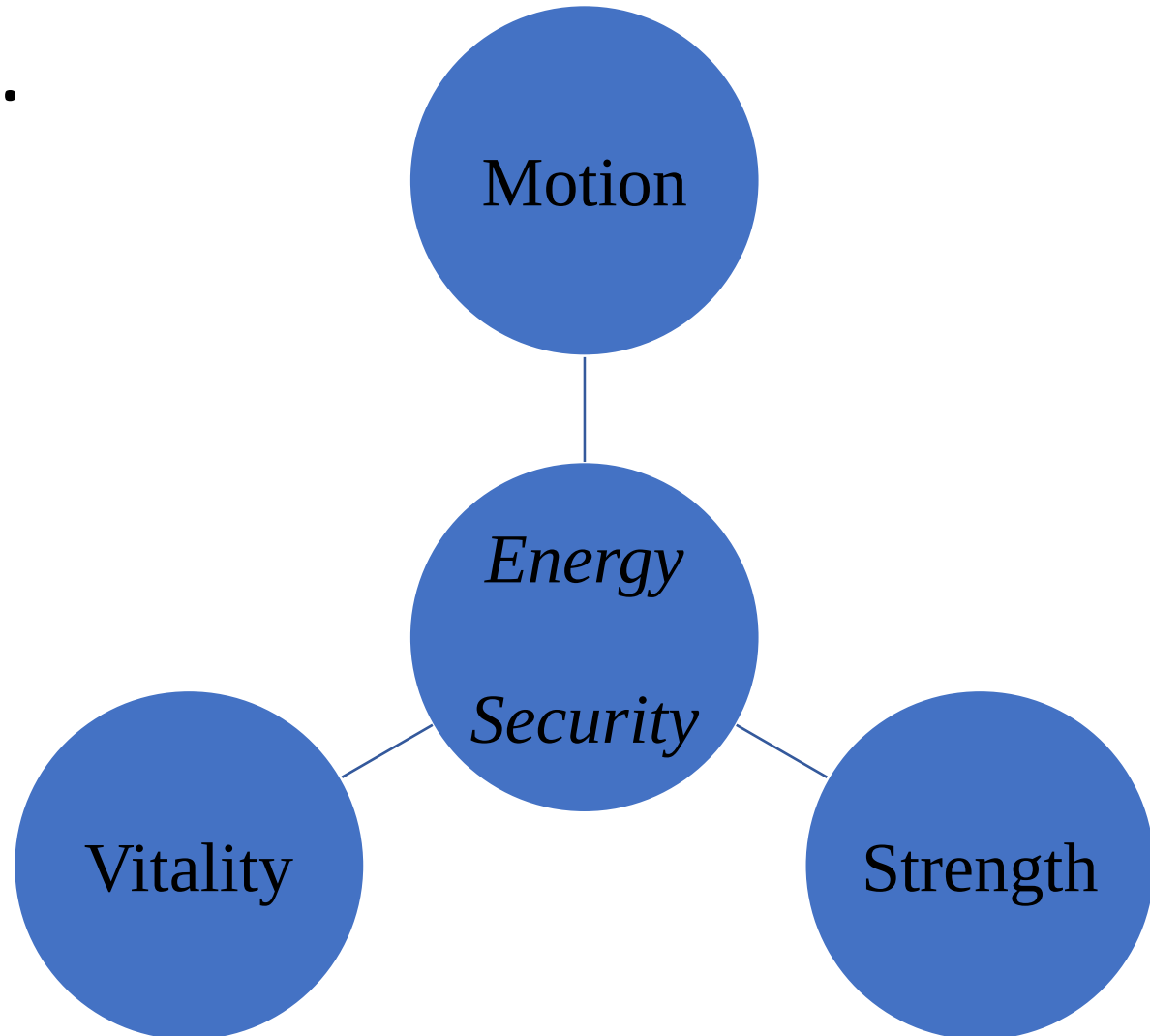
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University of Lucknow

**A LECTURE DELIVERED AT THE INSTITUTION OF ENGINEERS
(INDIA) U.P. STATE CENTRE, LUCKNOW ON JULY 22ND, 2025**

ENERGY: THE LIFE LINE ON EARTH

ENERGY SUGGESTS

- MOTION
- VITALITY
- STRENGTH



▪The demand for energy in the country has been growing rapidly.

▪The current trends indicate clearly that the country would be facing constraints in indigenous availability of conventional energy resources.

FOOD

FIRE

ENERGY

ENERGY

PRIMITIVE MAN



Primitive man derived energy from food (plants and animals) and fire



Energy demand rises with..

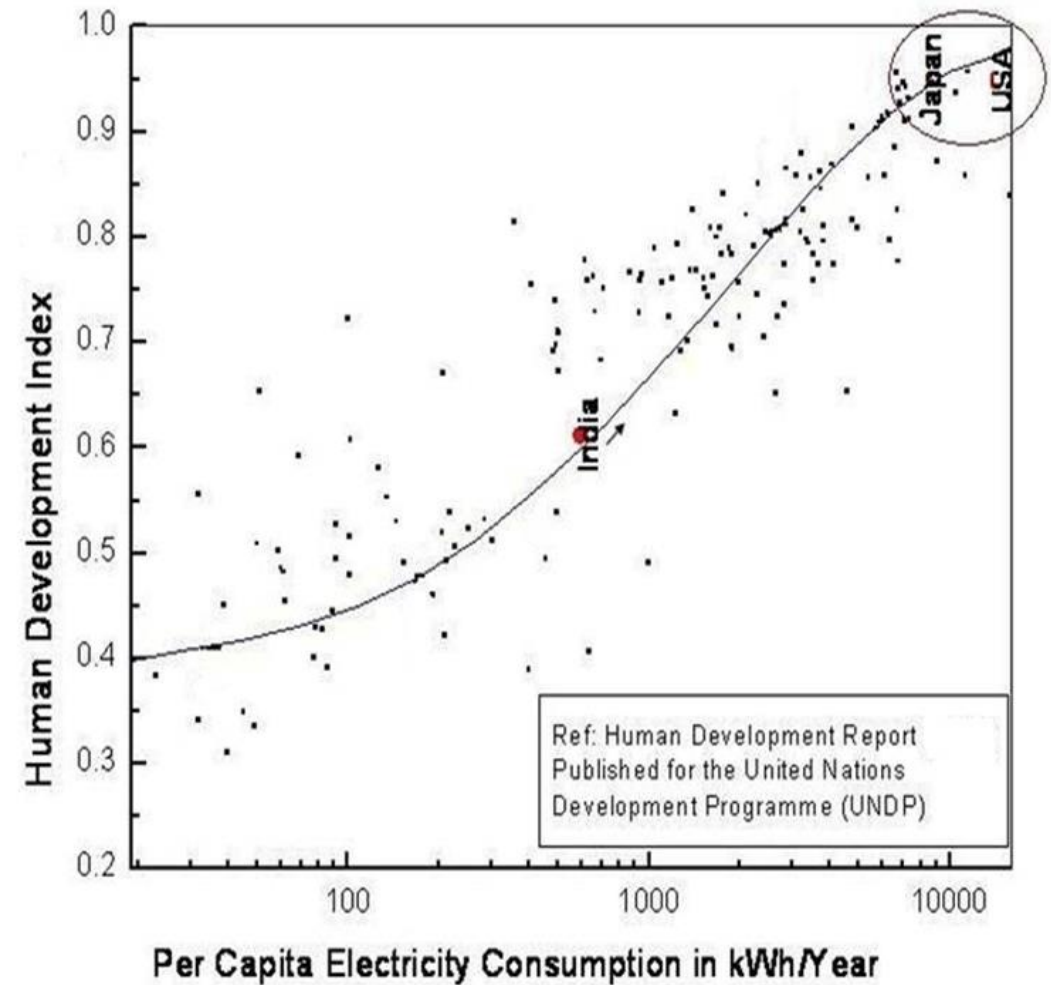
“high standards of living”



and “with increase in population”

Energy Use and Human Development

The strong positive correlation between energy use and human development is well recognized. It is obvious that India needs to substantially increase its per capita energy consumption to provide a minimally acceptable level of well being to its people



GLOBAL ENERGY POSITION

Energy demand of the world in TW-Yr (MBDOE) from 1980 through 2080 is estimated to be as follows per year:

	1980	2000	2020	2040	2060	2080
All fossil Fuels	9	11.4	13.8	16.2	18.6	21 TW-Yr
Total	10	17	27	42	54	60 TW-Yr

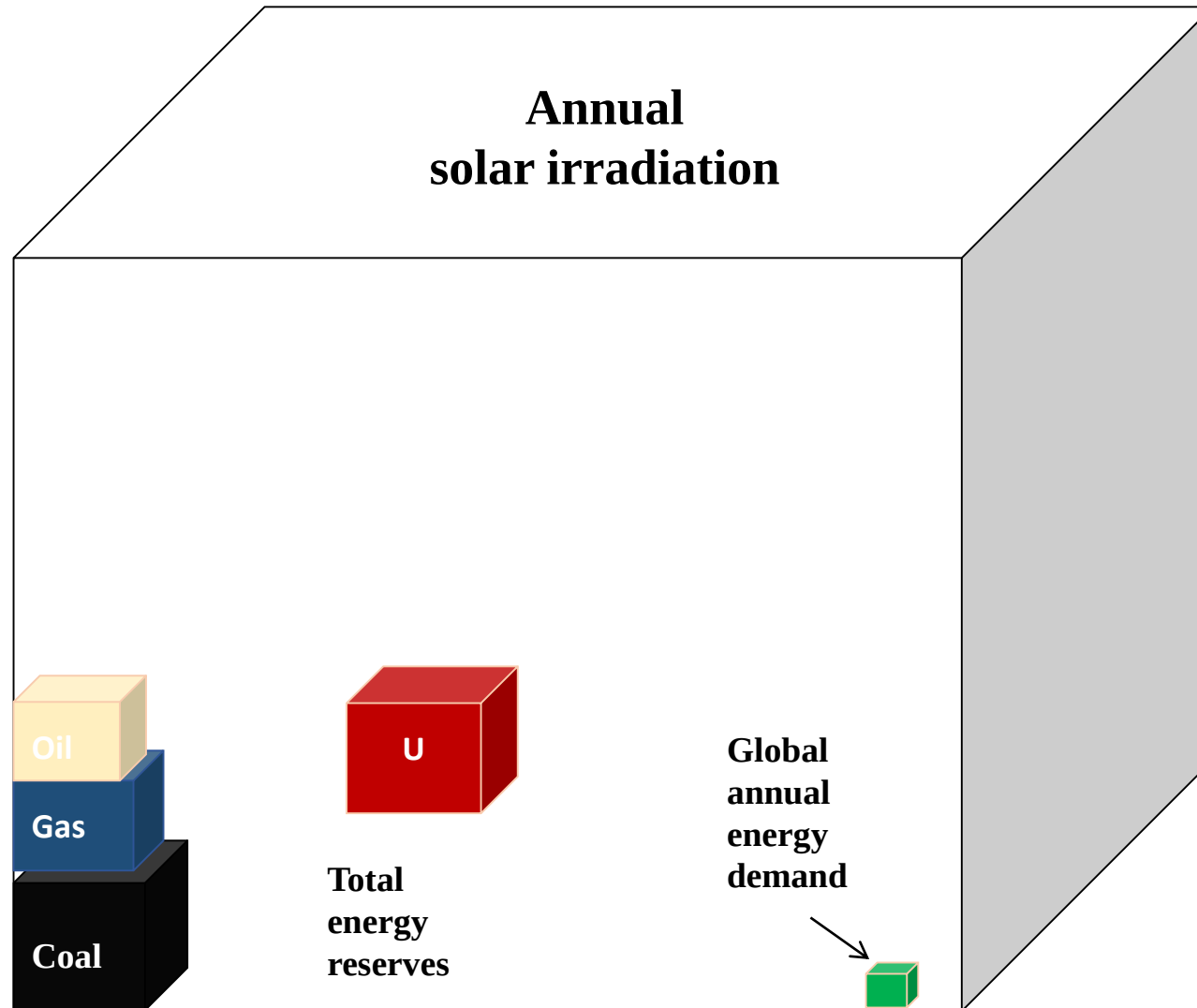
1 TW-Yr = 8.76×10^{12} KW-h ; MBDOE = 1 Million barrels per day oil equivalent

1 KW-h = 3.6×10^6 J; 1 Yr = 8.76×10^9 hrs. ; 1 Exajoule = 10^{18} J = 278 TW-h; 1 Exajoule = 31.71×10^3 MW-Yr

The difference between fossil fuel demand and total energy demand per yr. is made up from hydro-electric, nuclear and other sources. The demand for energy is increased from 10-60 TW-Yr annually in the next 100 years or so. Out of which, fossil fuels provide from 90% in 1980 to 35% in 2080 of the total demand. This clearly indicates that the fossil fuel reserves will not last long at the rate energy is consumed in the world. So alternative sources of energy must be developed for running civilized life.

1950	to	1975	-	5% per year increase
	to	1995	-	3% per year increase
		Future	-	2% per year increase

Energy Cubes: The Annual Solar Irradiation Exceeds Several Times of the Total Global Energy Demand and All Fossil Energy Reserves



NUCLEAR ENERGY FOR PEACE AND DEVELOPMENT

HARNESSING THE ATOM FOR A BETTER FUTURE

What is Nuclear Energy?

Energy released during Nuclear Fission and Nuclear Fusion.

This Energy can be used for both destructive and peaceful purpose.

NUCLEAR FISSION

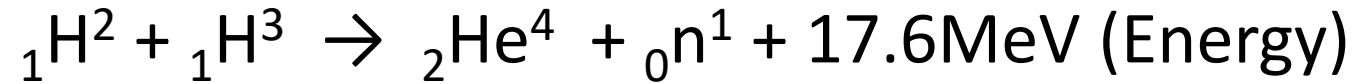
- ❑ In this process heavy nucleus splits up into smaller nuclei when bombarded with low energy neutrons.
- ❑ Fission of heavy elements is an exothermic reaction which can release large amounts of energy both as electromagnetic radiation and as kinetic energy of the fragments.
- ❑ $U^{235} + n \rightarrow \text{fission} \rightarrow X + Y + 3n + 200 \text{ MeV}$
- ❑ If each neutron releases 3 more neutrons then the number of fission increases and a chain reaction takes place.

EXAMPLE OF NUCLEAR FISSION

NUCLEAR REACTORS

NUCLEAR FUSION

- In this process two nuclei of light element combine to form heavy nucleus.

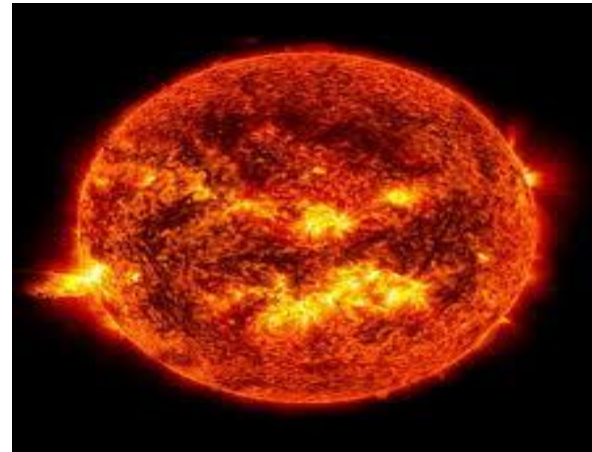


Very high temperature is required to carry out this reaction

EXAMPLE OF FUSION



HYDROGEN BOMB



SOURCE OF SUN ENERGY

FISSILE MATERIALS

Fissile material is a substance that can sustain a nuclear fission chain reaction. They are used as fuel in nuclear reactors to generate electricity. They can maintain a self-sustaining nuclear chain reaction and they are suitable for Nuclear Reactors Eg. U^{235} , Pu^{239}

U^{235} : **Only 0.7% of natural uranium is U^{235} (Isotope)**

Pu^{239} : It is artificially produced fissile material created from the fertile material U^{238}

U^{233} : Another artificially produced fissile material made from Thorium 232 (Th^{232})

1 kilogram of Uranium contains roughly the same amount of energy as **2.7 million Kilogram of Coal**. Because Uranium when used in Nuclear Fission releases a tremendous amount of energy far more than that is released by burning Coal (Combustion)

India's stockpile of fissile material is estimated to include **5.7 ± 2 Tonnes of fissile**.

India is a nuclear weapon state outside of the Nuclear Non-Proliferation Treaty

NUCLEAR POWER PRODUCTION BY COUNTRY

Nuclear power plants operate in 32 countries and generate about a tenth of the world's electricity. Most are in Europe, North America and East Asia.

As of 2022



Nuclear Electricity Supplied (GWh)

	United States	772,221		Switzerland	23,180
	China	395,354		Taiwan	22,917
	France	282,093		Pakistan	22,219
	Russia	209,517		UAE	19,300
	South Korea	167,514		Bulgaria	15,784
	Canada	81,718		Hungary	14,954
	Ukraine	81,126		Slovakia	14,830
	Spain	56,150		Brazil	13,745
	Japan	51,908		Mexico	10,539
	Sweden	50,018		Romania	10,222
	United Kingdom	43,605		South Africa	10,124
	India	41,972		Argentina	7,470
	Belgium	41,744		Iran	6,009
	Germany	31,892		Slovenia	5,311
	Czech Republic	29,310		Belarus	4,411
	Finland	24,242		Netherlands	3,931

OVERVIEW OF INDIA'S NUCLEAR CAPACITY

Current Capacity: 8,180 MW from 24 reactors.

Future Expansion: The government aims to triple the capacity to 22,480 MW by 2031-32.

Expansion Plans: This expansion includes the construction and commissioning of ten new reactors, totaling 8,000 MW, across various states.

Ongoing Projects: In addition to the ten new reactors, pre-project activities have started for another ten reactors, with completion planned by 2031-32.

Long-Term Vision: India has a long-term vision to achieve 100 GW of nuclear energy capacity by 2047.

Key Organizations: Nuclear Power Corporation of India Limited (NPCIL) is the primary organization responsible for the design, construction, commissioning, and operation of nuclear power reactors in India.

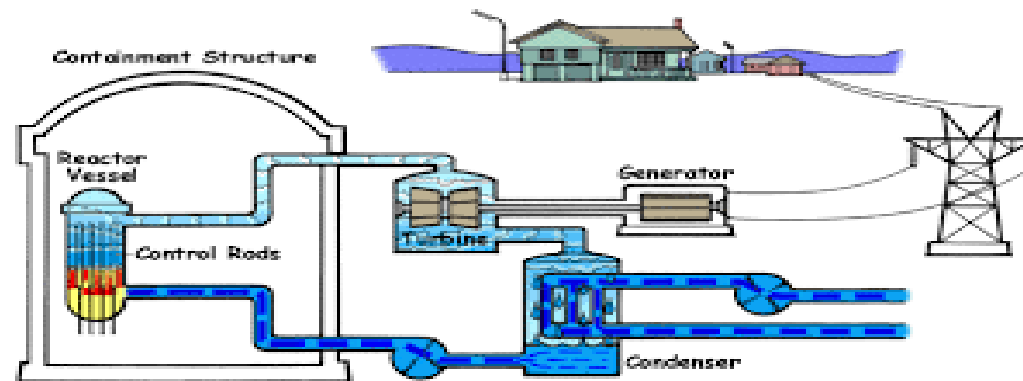
NUCLEAR REACTOR

A Nuclear Reactor is an apparatus in which Nuclear Fission is produced in the form of a controlled self-sustaining chain reaction

Types of Nuclear Reactors

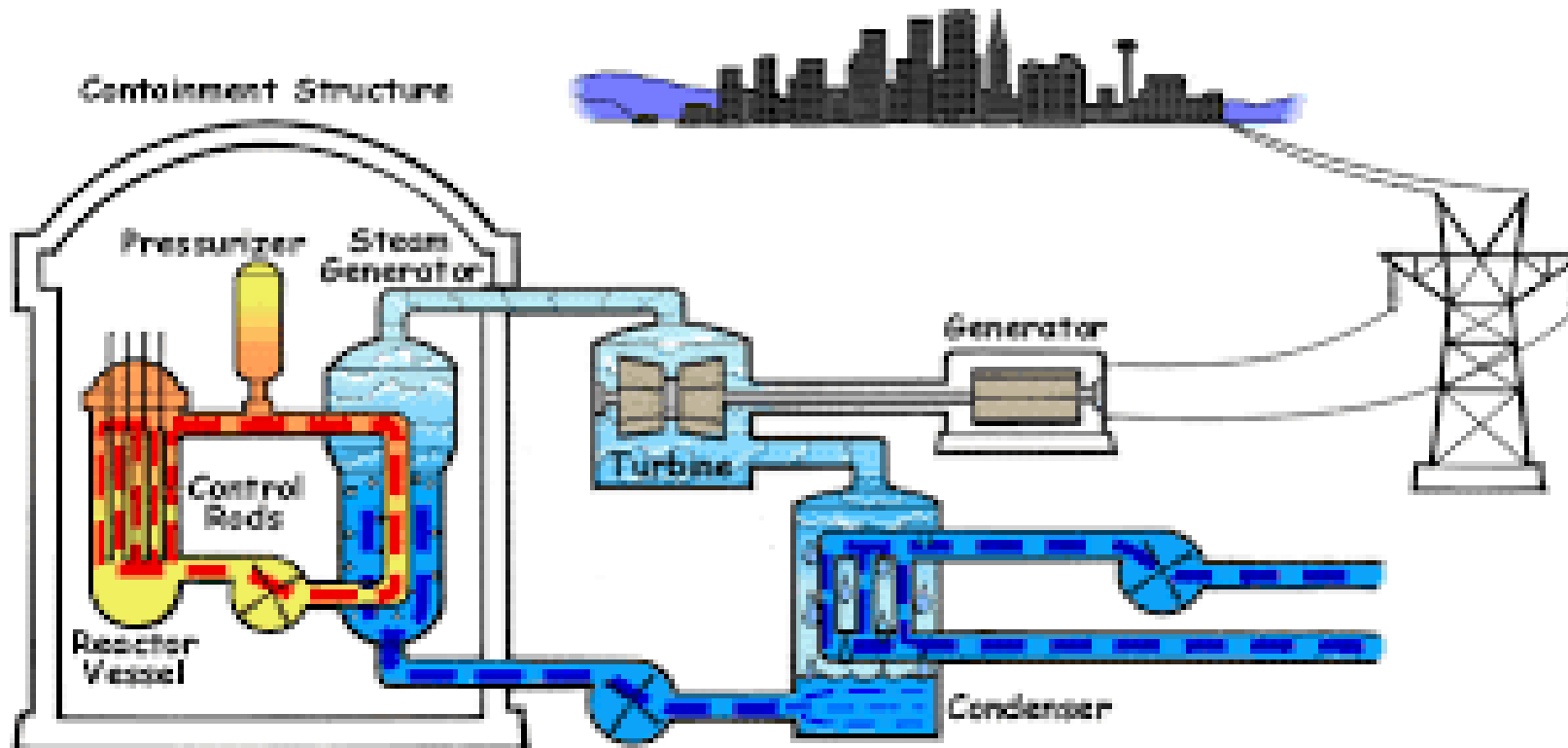
1. Boiling Water Reactor (BWR)

The Boiling Water Reactor is a type of light water reactor that is used to generate electric power. In a BWR the reactor core heats water which boils and turns to steam to directly drive a turbine. The steam then goes to a condenser and is converted back to liquid water before returning to the reactor core. BWR is the second most common type of electricity generating nuclear reactor after PWR.



2. PRESSURIZED WATER REACTOR (PWR)

In a Pressurized Water Reactor, the reactor core heats water, which does not boil. This hot water then exchanges heat with a lower pressure water system which turns to steam and drives the turbine.



ADVANTAGES & DISADVANTAGES OF BWR & PWR

- The advantage of BWR is having higher thermal efficiency due to eliminating a heat exchanger circuit and using a lower pressure vessel than PWR.
- The advantage of PWR is it operates at a lower nuclear fuel temperature. The metal temperature remains low for a given output condition.
- The advantage of PWR is it operates at a lower nuclear fuel temperature. The metal temperature remains low for a given output condition.

BENEFITS OF NUCLEAR ENERGY

- Clean and Reliable Source of Electricity.
- Reduces Green House Gas emissions and mitigates climate change.
- Enhances Energy Security and Energy Independence.
- Supports Economic Development and Growth.
- Medical applications.
- Industrial applications (Food and Agriculture).
- Space exploration.

OPERATIONAL NUCLEAR POWER PLANTS IN INDIA

1. TARAPUR- India's first nuclear power plant located in Maharashtra.
2. RAJASTHAN- Includes multiple units in Rawatbhata with RAJASTHAN-7 recently connected to the grid with 630 MW.
3. KAIGA- Situated in Karnataka.
4. KALPAKKAM- Also known as Madras Atomic Power Station located in Tamil Nadu. Its known for being completely indigenous.
5. KAKRAPAR- Located in Gujrat.
6. NARORA- Located in Uttar Pradesh.
7. KUDANKULAM- The largest nuclear power plant in India located at Tamil Nadu.

RAJASTHAN-7 is the third in series of sixteen indigenous pressurized heavy water reactor units. India has planned to built the first two units KAKRAPAR-3 & 4 in Gujrat, which began commercially operations in 2023 and 2024.

A twin unit at the sight RAJASTHAN-8 is expected to be operational in 2025 or 2026.

The nuclear fleet provided 3.1% of the country's electricity generation in 2023.

The Indian Government is aiming to connect new reactors to the grid within next 5 years

MEDICAL APPLICATIONS OF NUCLEAR ENERGY

1. Cancer detection and staging of Cancer.
2. Heart disease diagnosis for blockage and blood flow.
3. Brain imaging for detecting neurological disorders for e.g. Alzheimer, Parkinson, etc.
4. Infection detection.
5. Organ function's assessment for gall bladder, kidney etc.

In medicine radiotracer is a radioactive substance that is used to help diagnose and treat diseases. It is a molecule or compound that's being tagged with a radioactive isotope, allowing doctors to track its movement through the body using specialized imaging techniques like SPECT and PET scans. This tracking helps visualize body on the injection of nuclear medicine.

In case of Cancer treatment Chemotherapy is also a nuclear treatment.

Also, medical imaging procedures were used in diagnostic places as Xray's, CT scan which provide a one time dose.

Nuclear medicine may involve giving a small amount of radioactive material in that case patient may emit radiations for up to several days after the examination one time dosage will impact the annual radiation dose.

APPLICATIONS OF NUCLEAR ENERGY IN FOOD & AGRICULTURE INDUSTRY

Nuclear technology plays a vital role in food and agriculture through various applications including CROP IMPROVEMENT, FOOD PRESERVATION & PEST CONTROL. It also enhances food security by developing climate resistant crops, reducing food spoilage and minimizing reliance on harmful pesticides.

1. CROP IMPROVEMENT

MUTATION BREEDING- Nuclear radiation such as gamma rays, X-rays or charged particles can induce genetic mutations in plant seeds or tissues, accelerating the breeding process and creating new crop varieties with desirable traits like drought tolerance, disease resistance or higher yields.

IMPROVED WATER USE EFFICIENCY- Isotopic techniques can help analyze water movement and nutrient uptake in plants, enabling the development of more efficient irrigation strategies and promoting water conservation in agriculture which is a need of today.

2.FOOD PRESERVATION & PEST CONTROL

FOOD IRRADIATION: Irradiation with gamma rays or electron beams eliminates harmful bacteria, molds and pests in food, extending shelf life, reducing spoilage and ensuring food safety without making food radioactive or affecting its nutritional value.

DELAYED RIPING: Irradiation can also slow down the ripening process of fruits and vegetables and allowing for longer storage and distribution periods

3.SOIL HEALTH AND WATER MANAGEMENT

Nuclear techniques can be used to trace water movement and identify sources of contamination in the soil to provide better water management

Hence, Nuclear Energy is enhancing food security improving agricultural practices and ensuring the quality of food supply

SPACE EXPLORATION

Nuclear energy is also used in space exploration through the following applications

Powering Spacecraft

Enabling Nuclear propulsion

Radioisotope power system like radioisotope thermoelectric generators (RTG) provide long lasting reliable electricity for deep space missions. Nuclear thermal and electric propulsion systems offer the potential for significantly faster travel times to distant planets compared to traditional chemical rockets

BENEFITS OF NUCLEAR ENERGY IN SPACE EXPLORATION

- 1. Extended mission duration-** Nuclear power sources can operate for decades without refueling.
- 2. Increased Spacecraft speed-** Nuclear propulsion systems can significantly reduce travel time to other planets compared to chemical rockets.
- 3. Reduced reliance on solar power-** Nuclear power sources can operate independently of sunlight, making them ideal for mission to the outer solar system and surface exploration on shadowed lunar or Martian terrains.

NUCLEAR POWER SOURCES

1. RADIOISOTOPE THERMOELECTRIC GENERATORS (RTG)

These devices convert the heat from radioactive decay into electricity. They are particularly useful for missions where solar power is insufficient such as deep space probes and mission to the outer solar system.

2. FISSION SURFACE POWER SYSTEM

These systems use nuclear reactor to generate electricity for Lunar and Martian bases, particularly providing decades of reliable power without refueling.

NUCLEAR PROPULSION

1. NUCLEAR THERMAL PROPULSION (NTP)

These systems use a nuclear reactor to heat propellant generating thrust. This offers significantly higher specific impulse(a measure of fuel efficiency) than chemical rockets, allowing for faster transit times to distant destinations like **Mars**

2.NUCLEAR ELECTRIC PROPULSION (NEP)

Systems use electricity generated from a nuclear reactor to power electric thrusters, while offering lower thrust than NTP. NEP system provide high fuel efficiency and can be used for long duration missions.

POTENTIAL FUTURE MISSIONS

Nuclear energy is being considered for crewed missions to **Mars** and for establishing a sustained human presence on the **Moon and Mars**

CHALLENGES FOR NUCLEAR ENERGY

COST

Nuclear systems can be expensive to develop and launch, but the long-term benefits of extended missions and reduced travel times may offset the initial cost.

PUBLIC PERCEPTION

Nuclear Technology is often associated with safety concern and public acceptance is crucial for the continued development and use of nuclear energy in space exploration

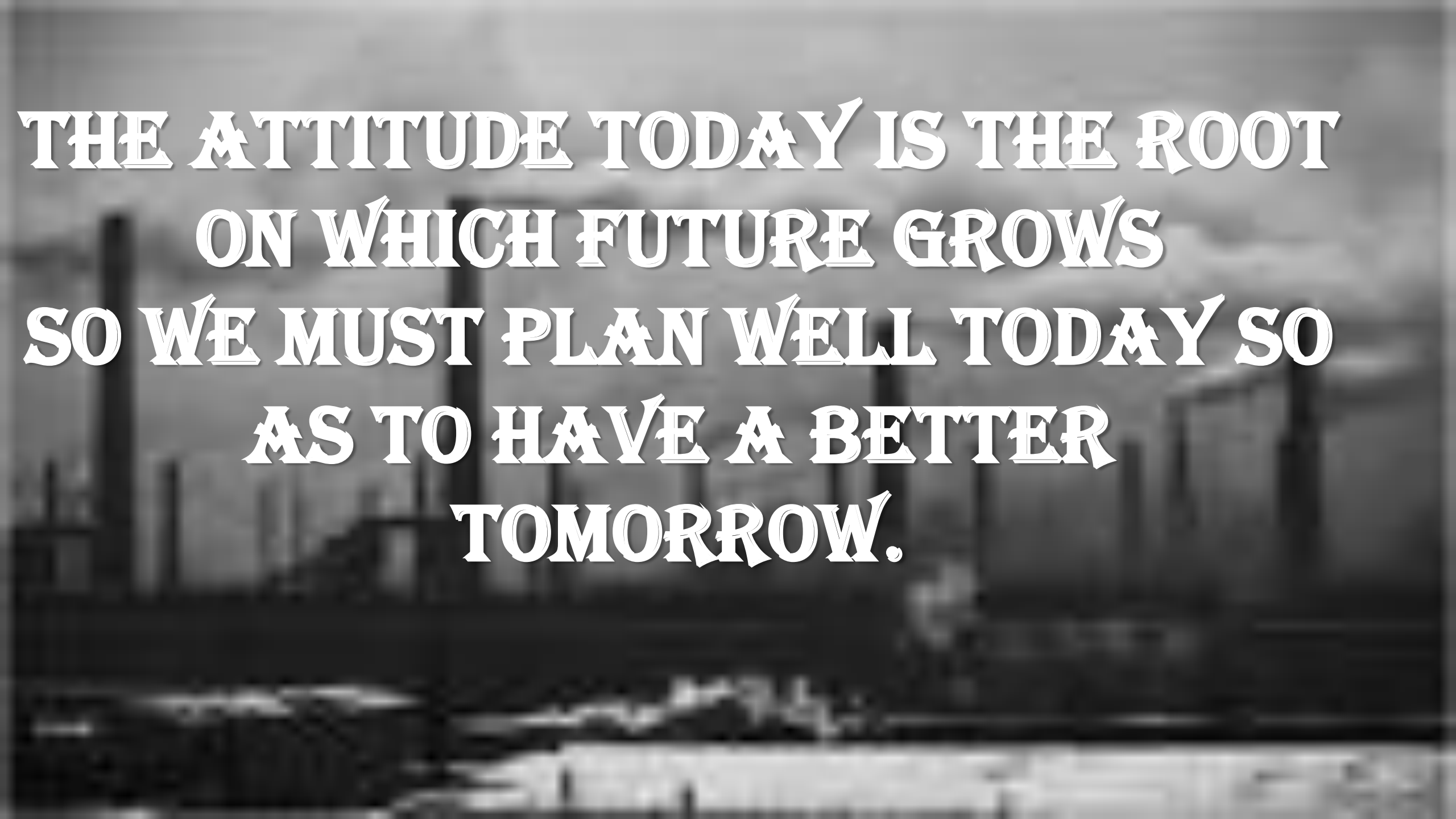
SAFETY

Safety protocols are necessary to prevent accidents and ensure the safe handling and disposal of nuclear materials in space. Even in nuclear power plants for handling the fissile material and the disposal of nuclear waste is also of concern to avoid nuclear accidents.

CONCLUSIONS

**PROBLEMS ARE OFTEN IGNORED
BECAUSE
THEY QUESTION OUR WAY OF LIFE,
AND
SOLUTIONS ARE DIFFICULT
BUT
NOT IMPOSSIBLE TO FIND**

The Nuclear Energy has vast potential in developing and developed world. It can be used for peaceful purposes and development of third world economies. Both type of nuclear reactors need to be developed indigenously for a country like India. In public perception, nuclear energy has to be handled with care to prevent accidents and disposal of waste material. The most important aspect to promote nuclear energy is the public acceptance and a nuclear power plant should be constructed away from human habitation. While disposing off the wastes it should be ensured that waste is disposed away from river or sea.



THE ATTITUDE TODAY IS THE ROOT
ON WHICH FUTURE GROWS
SO WE MUST PLAN WELL TODAY SO
AS TO HAVE A BETTER
TOMORROW.

THANK YOU

