ELECTRICITY FOR INDIA'S FUTURE GROWTH – The Renewable Energy and Nuclear Energy Options

S P Sukhatme
Professor Emeritus
IIT Bombay

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Lecture Outline

1. Introduction
2. The Present Scenario
3. Options for the Future
   - Renewable Energy
   - Nuclear Energy
4. Concluding Remarks

INTRODUCTION

THE PRESENT SCENARIO

Energy Sources Supplying Electricity Today

- Fossil fuels : Coal & lignite , oil , natural gas

- Renewable energy sources : Hydroelectric power (large and small) , solar energy (photovoltaic), wind energy (on land) , energy from biomass & some miscellaneous sources

- Nuclear energy - Fission reactors utilizing only U235 isotope in uranium

Installed Capacity (as on 31-12-2013)

Energy source	Capacity (MW)	Percent
Fossil fuels:		
Coal & lignite	138,213	58.5
Oil	1200	0.5
Natural gas	20,381	8.6
Nuclear power	4780	2.0

(contd.)

Installed Capacity (contd.)

Renewable Energy Sources :

Hydroelectric power (large)	39,893	16.9
Solar power - PV	2647	1.1
Wind power (on land)	21,136	8.9
Hydroelectric power (small)	3804	1.6
Biomass & miscellaneous sources	4120	1.7

Total	**236,174 MW**	**100.0%**

Electrical Energy Production in India

Electricity produced in 2013-2014 = 900 to 1000 TWh

Approx. contribution of various categories :

- Fossil fuels 80%
- Renewable energy sources 17%
- Nuclear energy 3%

Per capita production in India = 800 to 900 kWh/year

Per capita production in USA = 12,000 kWh/year

Per capita production in economically developed countries

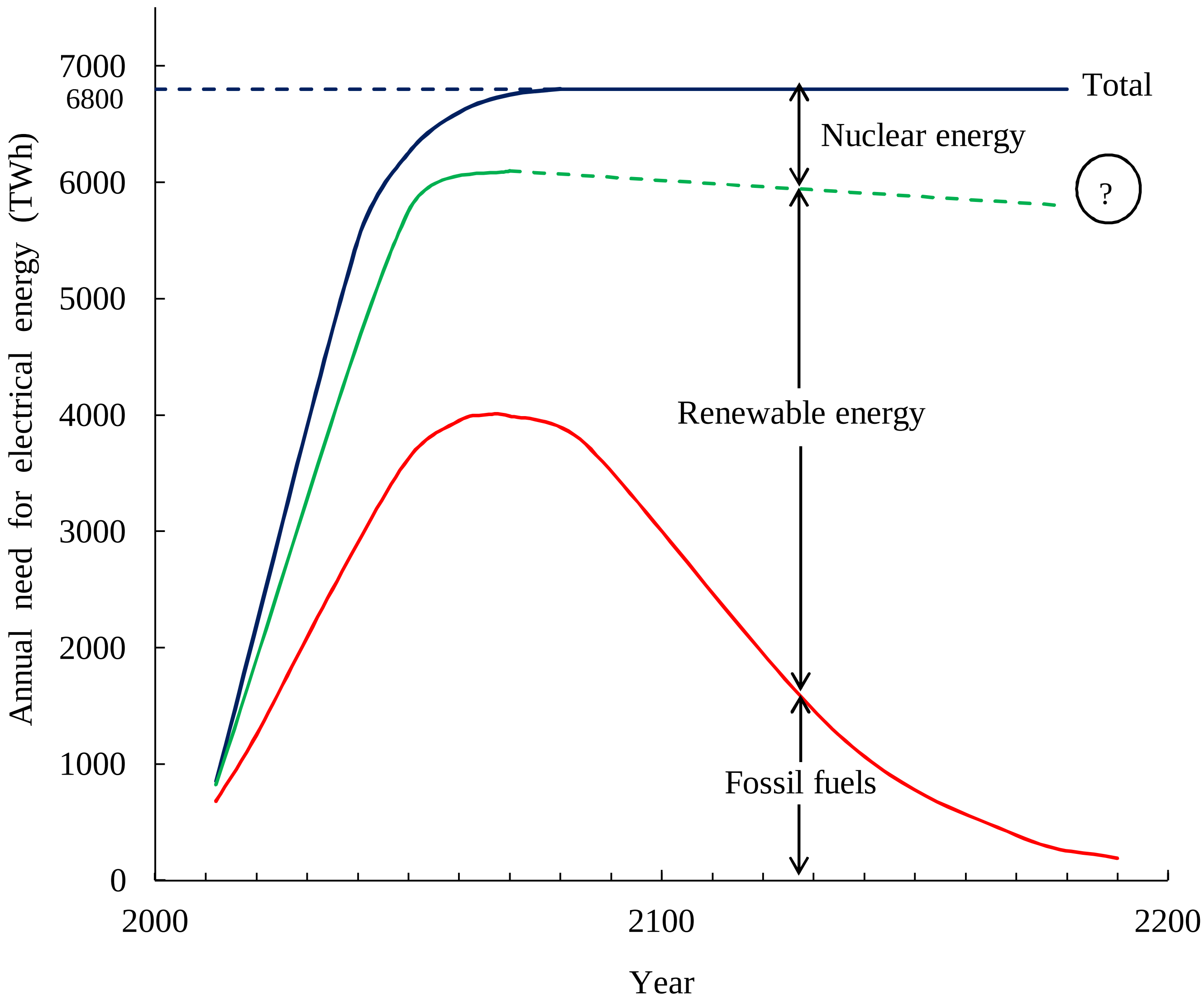
= 7000 to 8000 kWh/year

Comments

- Fossil fuels : Non-renewable. Resources likely to be exhausted in 100 to 150 years. Also, combustion emits green house gases which are causing global warning.

- Hence by the middle of the next century , the only alternatives will be renewable energy or nuclear energy.

- Renewable energy sources : Would last indefinitely. Need to be developed to the fullest possible extent to ensure sustainable development.



Variation of India's Total Need for Electricity over the Years if Individual Need is Assumed to be 4000 kWh/year. Possible Contributions of Fossil Fuels, Renewable Energy and Nuclear Energy are also Indicated.

OPTIONS FOR THE FUTURE

Renewable Energy

Listing of Renewable Energy Sources

- Solar energy – Photovoltaic conversion , Thermal energy
- Hydroelectric power (large & small)
- Wind energy (on land & off-shore)
- Power from biomass
- Ocean energy - Wave energy, Marine currents, Ocean thermal energy conversion , Tidal energy

Underlined sources are already contributing and will contribute more in the future. Some like photovoltaic, hydroelectric (large), wind (on land) will contribute substantially.

5 MW Solar PV Plant in Andhra Pradesh


India's First
1 MW Canal-top Solar Power Project

Solar Thermal Power Plants

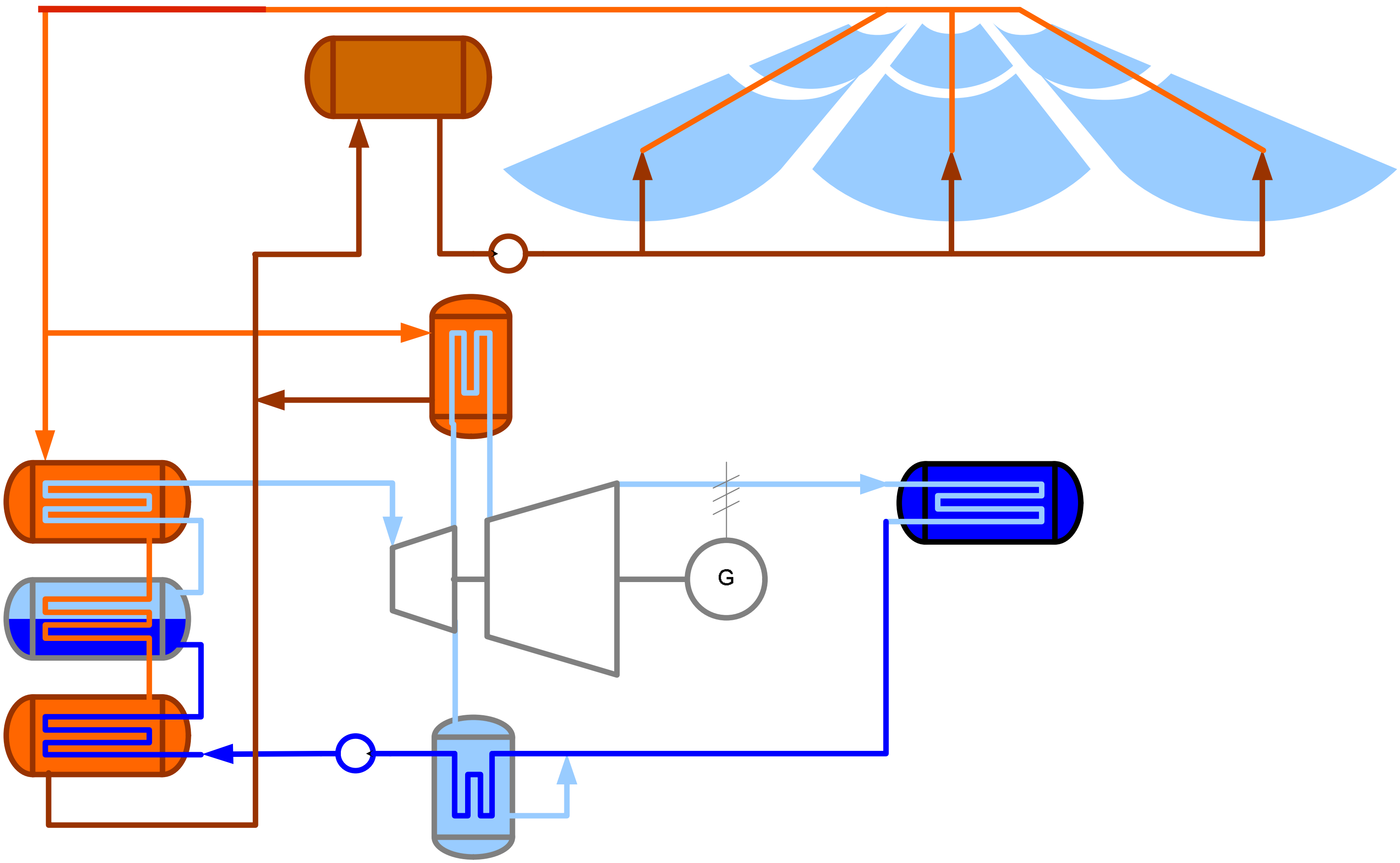
- India has made little headway with building solar thermal power plants.
- At the moment

  - 50 MW plant using parabolic trough concentrators located near Jaisalmer, Rajasthan

  - 1 MW plant using parabolic trough concentrators. Built by IIT Bombay at the Solar Energy Centre in Gurgaon.

  - 2.5 MW plant based on the central tower concept at Bikaner, Rajasthan.
- Only the first plant is operational.

1 MW Solar Thermal Power Plant – Gurgaon, Haryana



Schematic Diagram - Solar Thermal Power Plant

Solar Thermal Power Plants (contd.)

- In contrast, a number of solar thermal power plants are in operation in the world, principally in USA and Spain.

- Currently, the largest plant in the world is at Ivanpah, California, USA. It has a capacity of 392 MW and is just becoming operational. It is based on the central tower concept and is expected to generate about 1 million MWH per year.

Wind Energy (on land and off-shore)

- The growth in installed capacity of wind machines (on land) has been spectacular and the potential needs to be exploited fully.
- It is expected that the potential off-shore could also be significant because wind speeds off-shore are usually higher and steadier.
- However, no machines have been installed off the coast of India as yet.

A Typical Wind Farm

Power from Biomass

- Plant life – trees, plants, bushes, grasses, algae, etc. – and residues
- Much of India's non-commercial energy required in the form of heat is obtained from biomass.
- Thus there are limitations to the availability of biomass which can be used for electricity production.

Wave Energy

- Energy available at the ocean surface because of the interaction of the wind with the water surface.

- A number of devices have been built over the last 30 years for converting wave energy into electricity.

- The devices built have been located on the shore line, near the shore or off-shore.

Wave Energy (contd.)

- No worthwhile commercialization has taken place any where in the world.
- Difficult to give any estimate for India.
- The chances that a significant amount of wave energy will be converted to electricity in the future are poor.

Energy in Marine Currents

- Kinetic energy in marine currents off-shore is captured by installing water turbines at suitable depths.
- Devices being experimented with on a pilot scale in some locations in the world.
- No commercialization thus far, but technology development seems feasible.

Energy in Marine Currents (contd.)

- No data on suitable locations compiled for India.
- No systems installed so far in India.
- However, keeping in mind the length of our coast line, there is promise that a useful amount of electricity can be generated.

Ocean Thermal Energy Conversion

- Utilize the temp. difference (of about 20 deg C) between the upper and lower layers of water in tropical oceans.

- This temperature difference is used to run a heat engine.

- Concept first suggested in 1930. A few pilot plants built in different parts of the world. No complete system built in India.

Ocean Thermal Energy Conversion (contd.)

- Many intractable problems – Low energy conversion efficiency, high parasitic power, high cost

- No commercialization thus far.

- Capacity for generating electricity in the future appears to be insignificant.

Tidal Energy

- Energy available in water because of the rise and fall of water level during high and low tides. This energy can be tapped in coastal estuaries where the tidal range is high.

- Tidal power stations have been built in some locations in the world.

- No stations built in India so far.

Tidal Energy (contd.)

- Two potential regions identified – Gulf of Khambat and the Gulf of Kutch.
- If suitable dams are built, it is estimated that a capacity of 7900 MW can be installed. This could generate 17 TWh per year.

OPTIONS FOR THE FUTURE

Nuclear Energy

The Present Situation

- Plants under operation :

  Light water reactors - 2 Nos - 320 MW

  Pressurized heavy water reactors - 18 Nos - 4460 MW

- Plants under construction :

  Light water reactors - 2 Nos – 2000 MW

  Pressurized heavy water reactors – 4 Nos – 2800 MW

  Prototype fast breeder reactor – 1 No – 500 MW

India’s Reserves of Uranium

- Reserves are only about 60,000 t. Not extensive.
- These reserves can only provide the requirements of an installed capacity of 10,000 MW for about 30 years if India continues to use the present technology.

The Breeder Reactor

- Composition of naturally occurring uranium

U234	0.006%
U235	0.711%
U238	99.238%

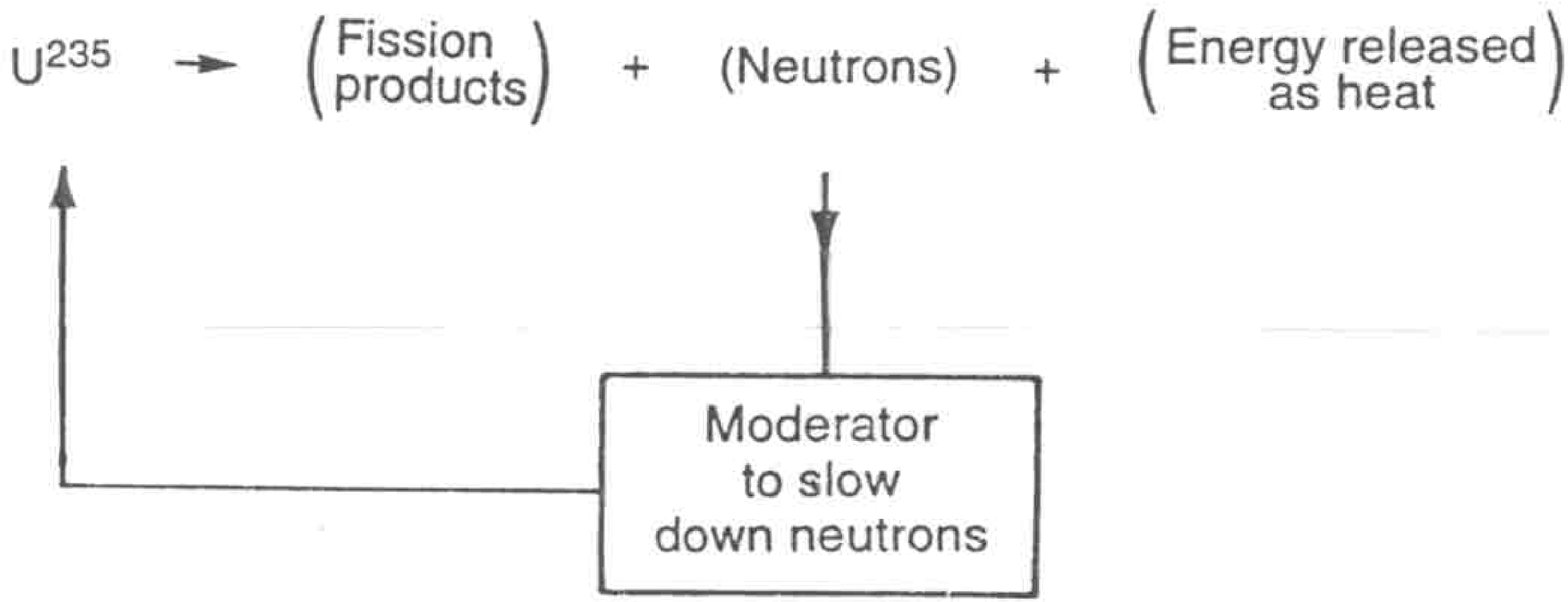
- U235 is the only naturally occurring fissile material. Since all nuclear power reactors in India today use only the U235 isotope, the abundant U238 isotope is wasted.

The Breeder Reactor (contd.)

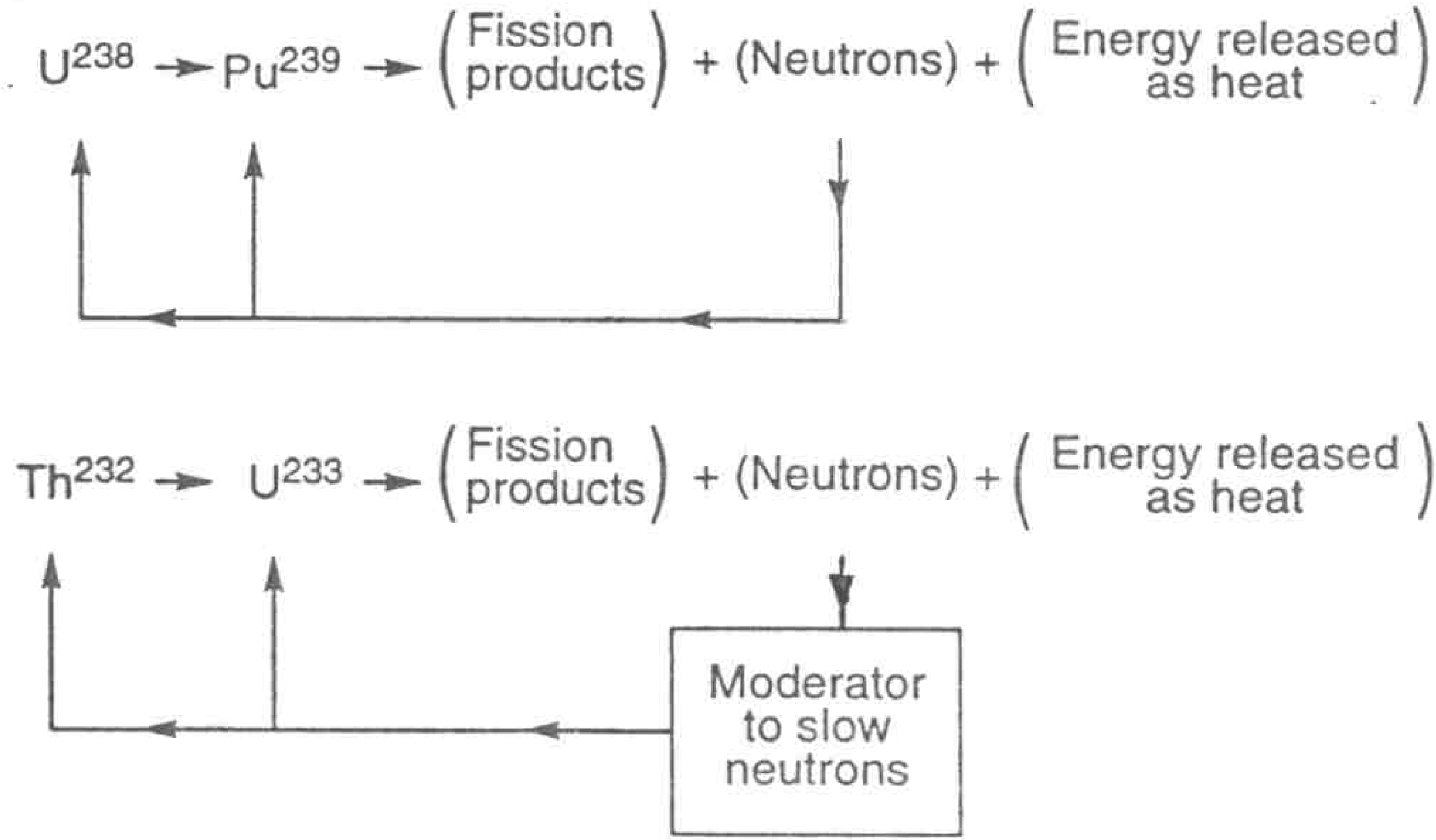
U238 is called a fertile material. It can be converted into a fissile material, plutonium 239.

Similarly, naturally occurring thorium 232 is also a fertile material. It can be converted into uranium 233 which is a fissile material.

Both these reactions can be made to occur in nuclear reactors called **breeder reactors**.



Fission reaction of U^{235}



Breeder reactions for U^{238} and Th^{232}

India’s Three Stage Fission Program

Stage I. Pressurized Heavy Water Reactors (PHWRs) and Light Water Reactors (LWRs). Energy released by the fission of U235.

Stage II. Fast Breeder Reactors (FBRs) converting U238 to Pu239. Energy released by the fission of Pu239.

Stage III. Breeder Reactors converting Th232 to U233. Energy released by the fission of U233.

Breeder Reactor Development in India

- For India, the thorium 232 to uranium 233 breeder cycle is of significance because we have large deposits of thorium.
- A Fast Breeder Test Reactor working on the plutonium 239 cycle with a capacity of 40 MW (thermal) and 13.2 MW (electrical) has been commissioned at Kalpakkam. The reactor is cooled by liquid sodium and uses plutonium-uranium carbide fuel. It has been operated upto 17.4 MW (thermal) and 2.2 MWe. The successful operation of the FBTR is being followed by the construction of a 500 MW (electrical) Prototype Fast Breeder Reactor, which is currently under construction at Kalpakkam. It is likely to go critical in 2014-15.

Nuclear Fusion

Energy is released by joining very light atoms. If research on controlled fusion is eventually successful and fusion reactors are built, they could provide the solution to the world’s energy problem.

The reactions of interest involve the fusing of the heavy isotopes of hydrogen (deuterium D and tritium T) into the next heavier element, viz. helium.

$$6D = 2\,{}^{4}He + 2p + 2n + 43.1\ MeV$$

Deuterium occurs naturally in sea water in essentially inexhaustible quantities.

- Key problems in the development of a nuclear fusion reactor are the attainment of the required high temperature by initially heating the fuel charge and the confinement of heated fuel for a long enough time for the reaction to become self-sustaining.
- Two approaches – magnetic confinement
  - laser induced fusion
- No research group has as yet come close to achieving the conditions for a self-sustaining controlled nuclear fusion reaction.

International Thermonuclear Energy Reactor (ITER)

- A number of countries have come together to launch a joint program for building and operating a fusion power reactor. The project is called ITER. Participating countries are the European Union, Russia, USA, Japan, China, India and Korea.
- Aim of ITER: To establish the scientific and technological feasibility of building a controlled fusion power reactor.
- Location – Cadarache (France)

CONCLUDING REMARKS