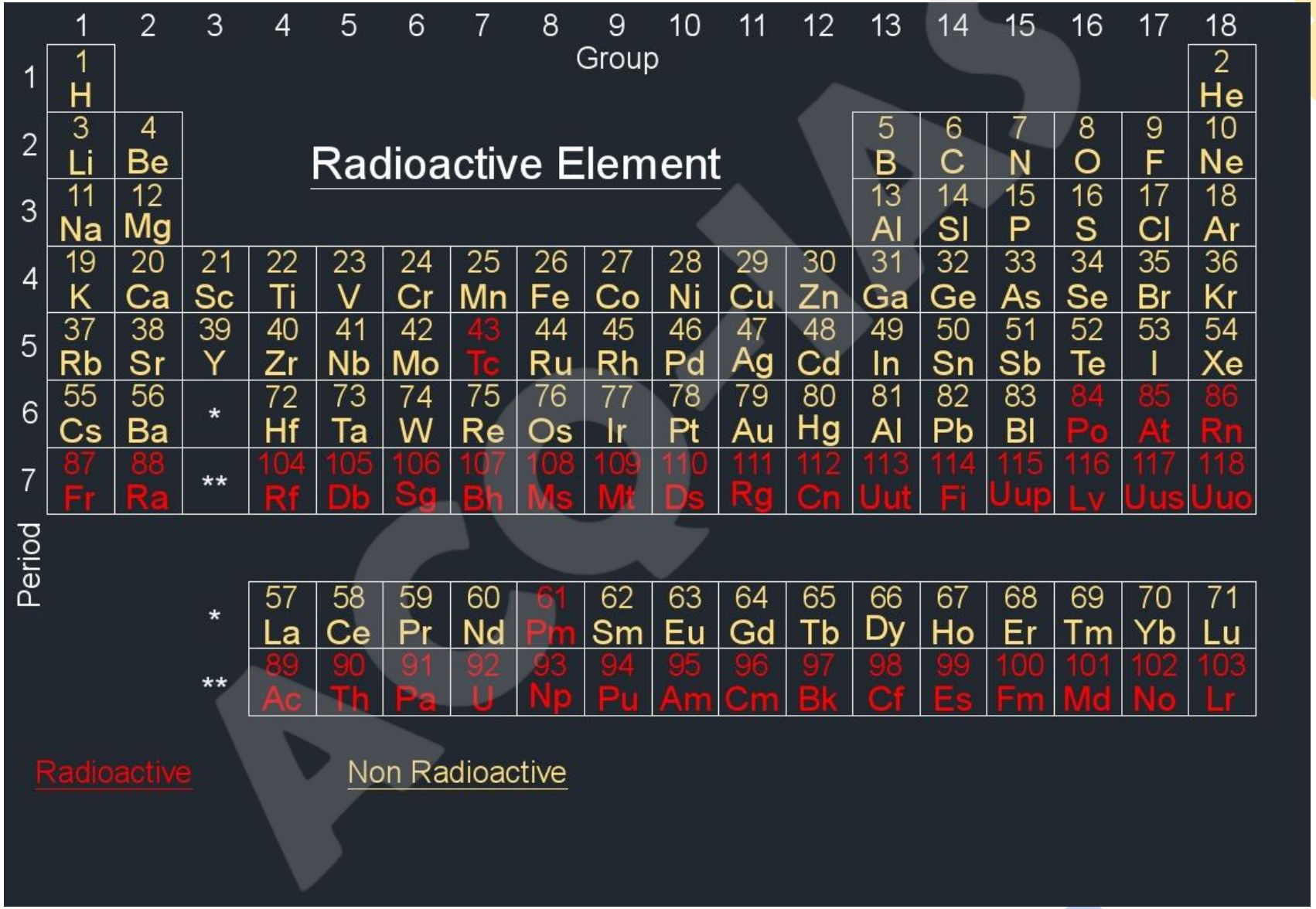
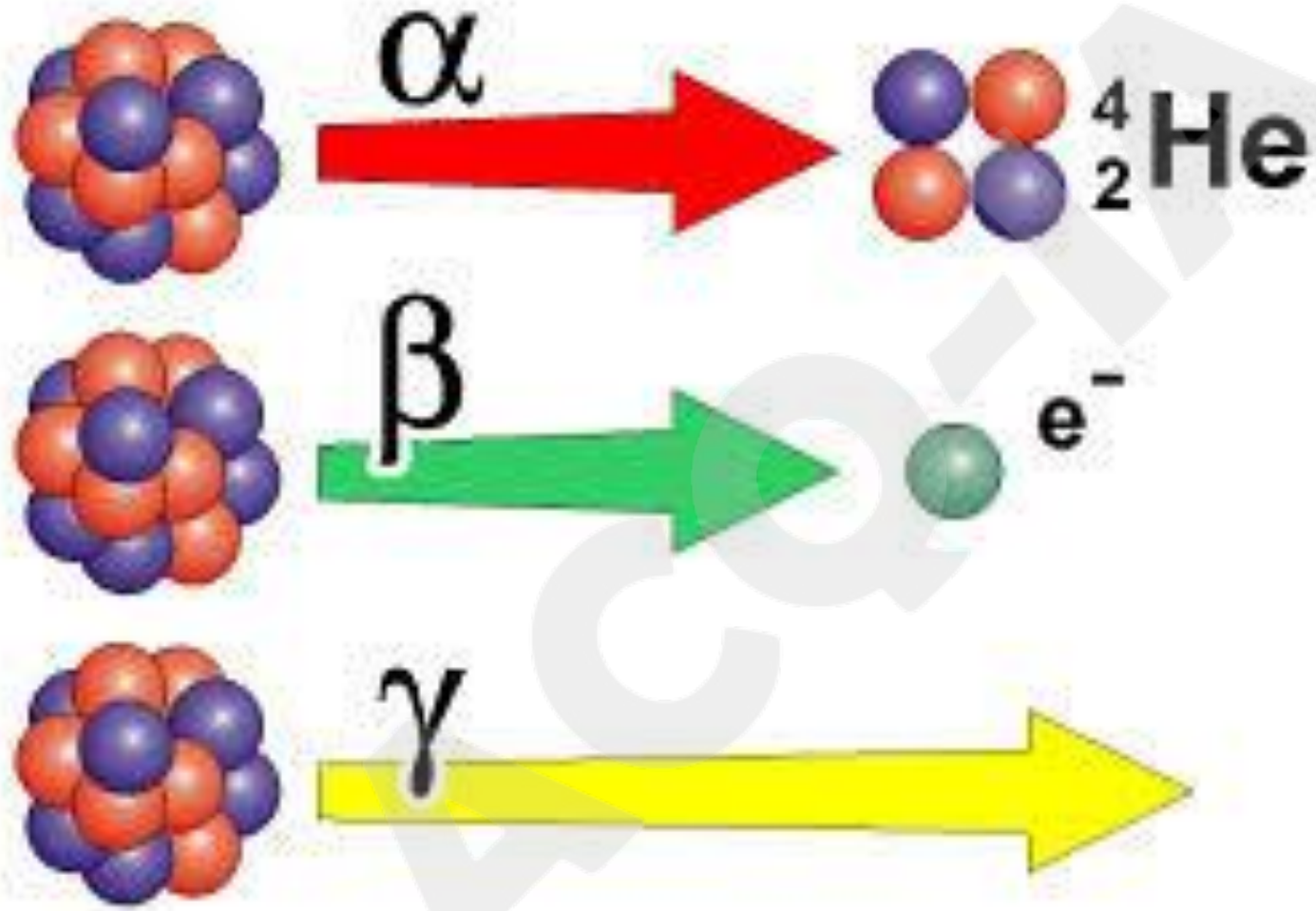
Nuclear Energy

Radioactivity

- Radioactivity is the release of energy from the decay of the nuclei of certain kinds of atoms and isotopes.
- Radioactive nuclei are nuclei that are unstable and that decay by emitting energetic particles such as photons, electrons, protons, neutrons, or alphas (two protons and two neutrons bound together).


Group
Period
Radioactive Element
1 H
2 He
3 Li
4 Be
5 B
6 C
7 N
8 O
9 F
10 Ne
11 Na
12 Mg
13 Al
14 Sl
15 P
16 S
17 Cl
18 Ar
19 K
20 Ca
21 Sc
22 Ti
23 V
24 Cr
25 Mn
26 Fe
27 Co
28 Ni
29 Cu
30 Zn
31 Ga
32 Ge
33 As
34 Se
35 Br
36 Kr
37 Rb
38 Sr
39 Y
40 Zr
41 Nb
42 Mo
43 Tc
44 Ru
45 Rh
46 Pd
47 Ag
48 Cd
49 In
50 Sn
51 Sb
52 Te
53 I
54 Xe
55 Cs
56 Ba
72 Hf
73 Ta
74 W
75 Re
76 Os
77 Ir
78 Pt
79 Au
80 Hg
81 Al
82 Pb
83 Bl
84 Po
85 At
86 Rn
87 Fr
88 Ra
104 Rf
105 Db
106 Sg
107 Bh
108 Ms
109 Mt
110 Ds
111 Rg
112 Cn
113 Uut
114 Fi
115 Uup
116 Lv
117 Uus
118 Uuo
57 La
58 Ce
59 Pr
60 Nd
61 Pm
62 Sm
63 Eu
64 Gd
65 Tb
66 Dy
67 Ho
68 Er
69 Tm
70 Yb
71 Lu
89 Ac
90 Th
91 Pa
92 U
93 Np
94 Pu
95 Am
96 Cm
97 Bk
98 Cf
99 Es
100 Fm
101 Md
102 No
103 Lr
Radioactive
Non Radioactive

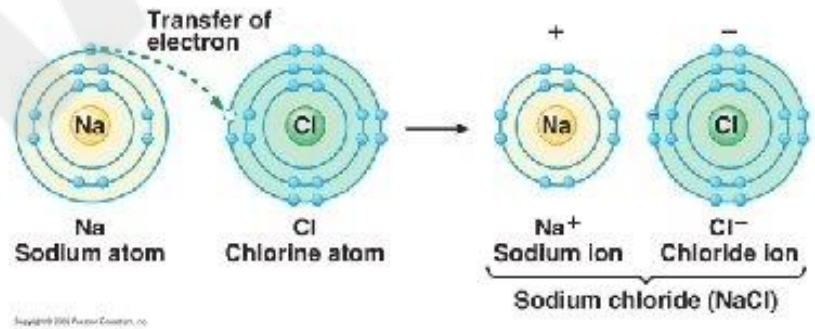

α
^4_2He
β
e^-
γ

Radioactive Isotope	Applications in Medicine
Cobalt-60	Radiation therapy to prevent cancer
Iodine-131	Locate brain tumors, monitor cardiac, liver and thyroid activity
Carbon-14	Study metabolism changes for patients with diabetes, gout and anemia
Carbon-11	Tagged onto glucose to monitor organs during a PET scan
Sodium-24	Study blood circulation
Thallium-201	Determine damage in heart tissue, detection of tumors
Technetium-99m	Locate brain tumors and damaged heart cells, radiotracer in medical diagnostics (imaging of organs and blood flow studies)

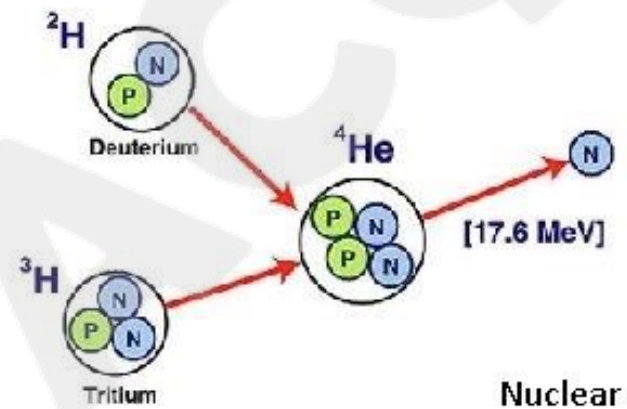
Nuclear Reactions

What is the difference between a nuclear reaction and a chemical reaction?

- Chemical reactions involve an atom's electrons
- Nuclear reactions involve the atom's nucleus.

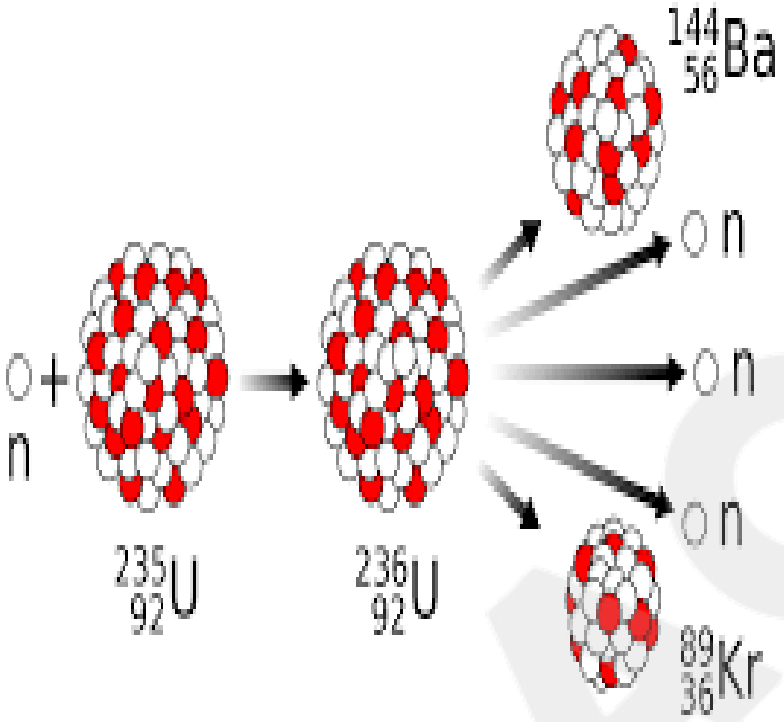


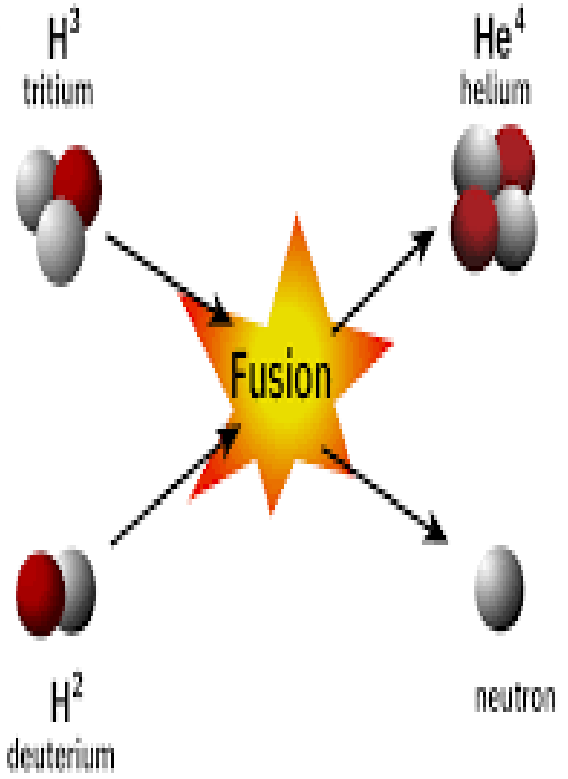
Chemical reaction

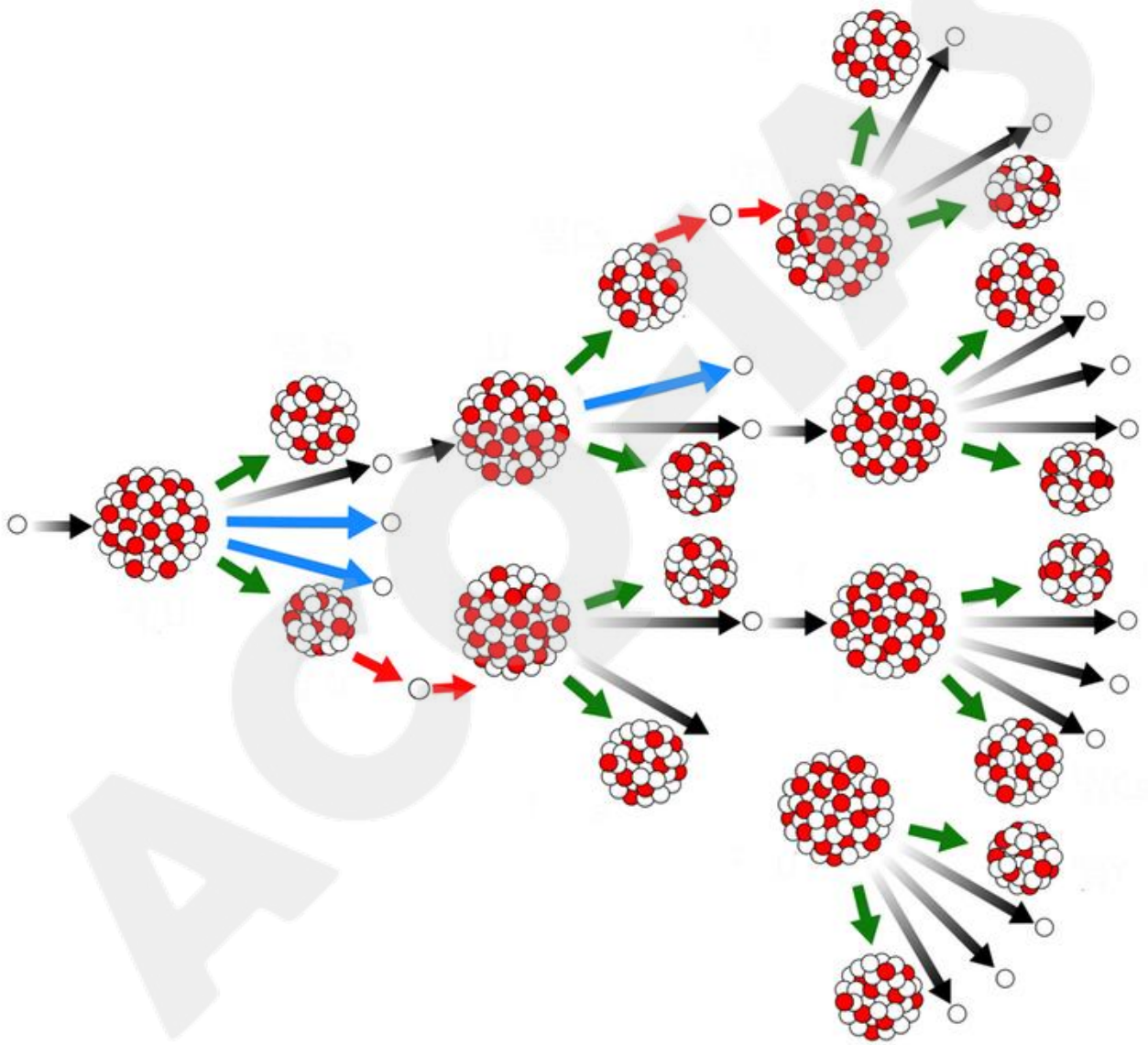


Nuclear reaction

Nuclear fission and Nuclear Fusion



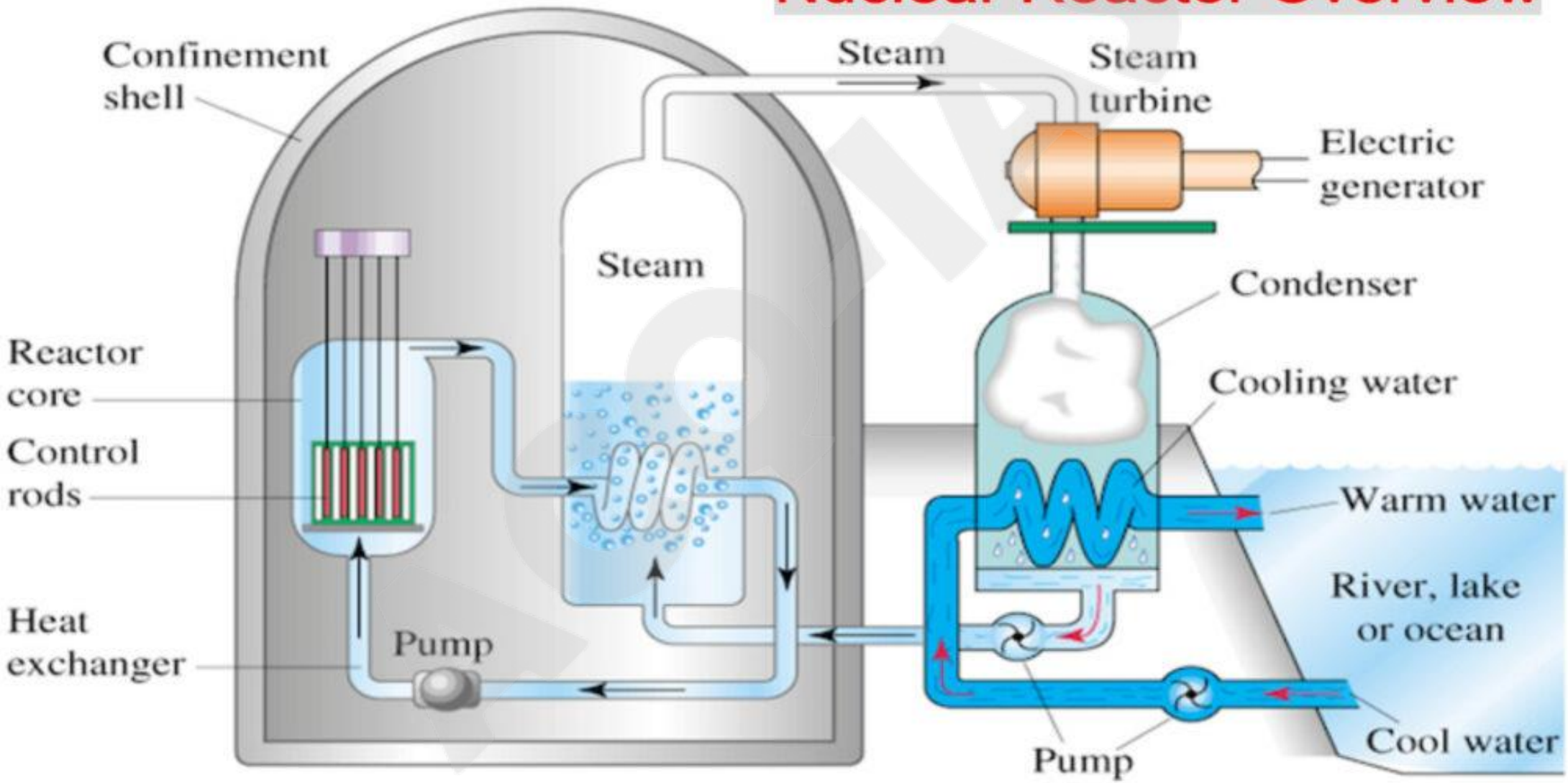




Nuclear power Reactor

Atom Bomb

Nuclear Reactor Overview

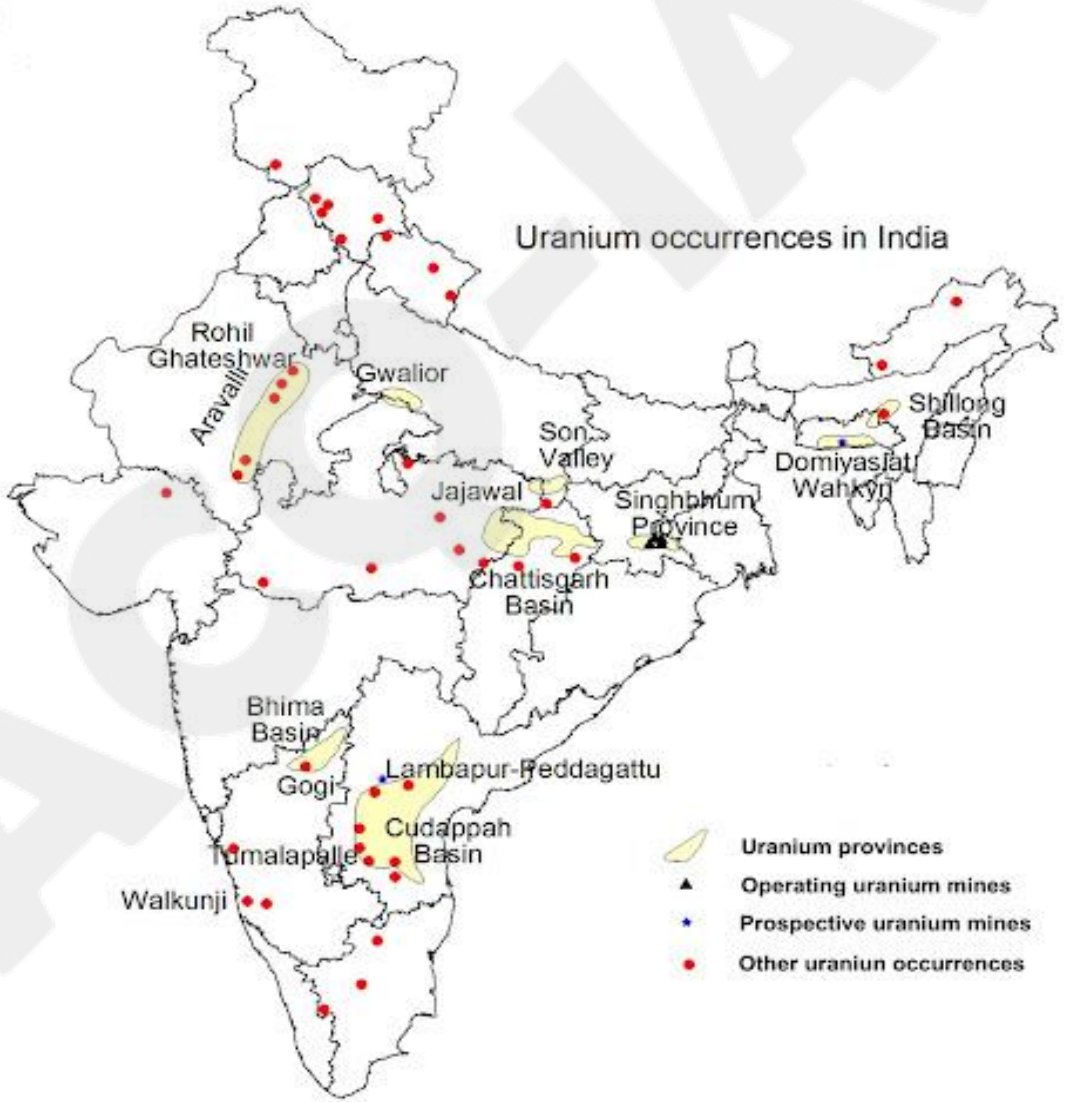


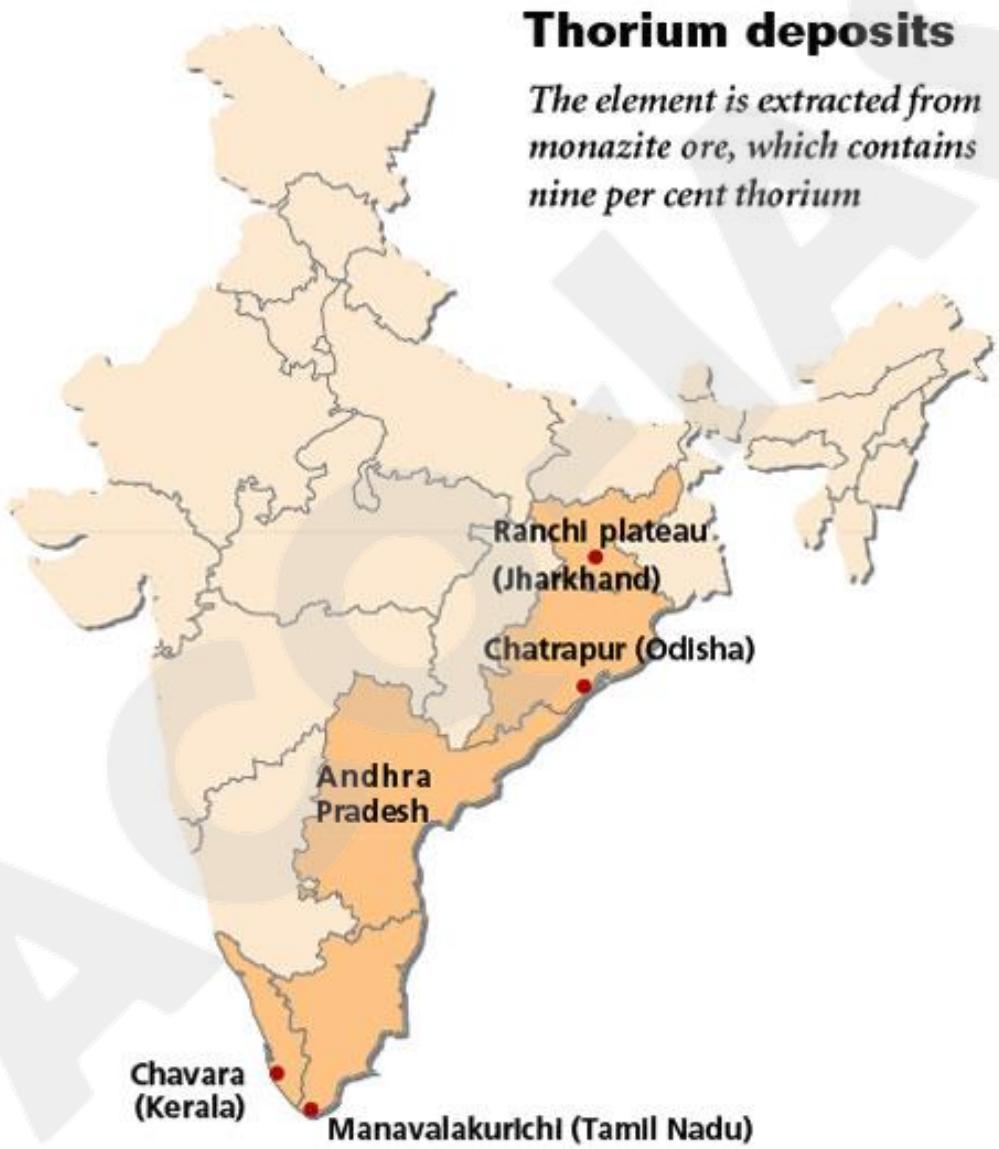
- Phenomena of slow neutron induced nuclear fission in uranium.
- The fission process produces not only very high energies (around 200 MeV per fission) but also extra neutrons that can cause fission in other uranium nuclei.
- Thus, fission process can be used to establish a chain-reacting system for continuous release of energy. A nuclear reactor is a system where a chain reaction is initiated, sustained and controlled.

Nuclear Fuels

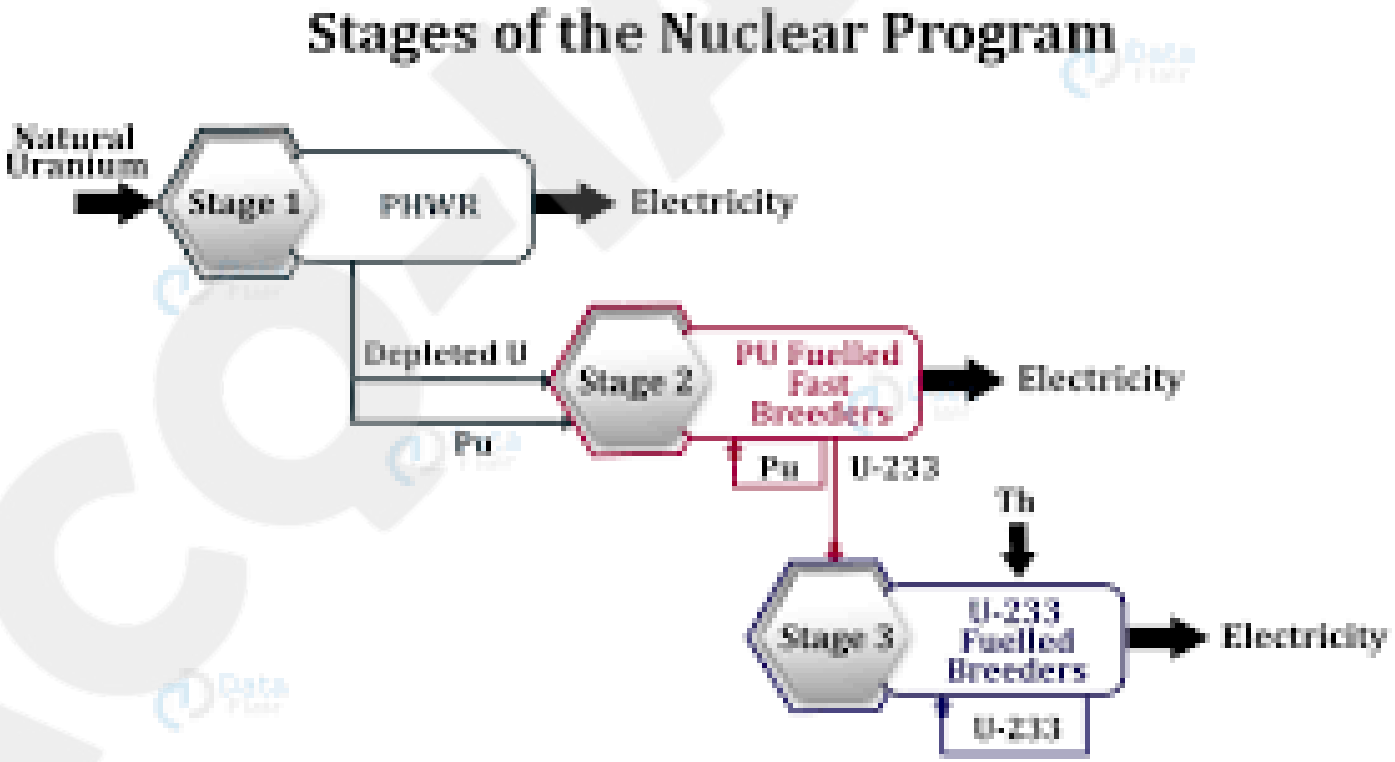
- Nuclear fuels may be classified as fissile (U-233, U-235 and Pu-239) and fertile (U-238 and Th-238). While, the fissile isotopes can be directly used as nuclear fuel, fertile isotopes need to be converted into fissile form, prior to usage.
- U-235 is the only fissile isotope occurring in nature.
- In India, the resources of exploitable uranium (natural uranium consists of mostly U-238, with 0.7 % U-235) are limited, while thorium (Th-232) is abundantly available.
- Both fissile and fertile isotopes are extremely precious commodities and their usage has to be judiciously planned for optimum utilisation.

Uranium Reserves in India




Thorium deposits
The element is extracted from monazite ore, which contains nine per cent thorium
Ranchi plateau (Jharkhand)
Chatrapur (Odisha)
Andhra Pradesh
Chavara (Kerala)
Manavalakurichi (Tamil Nadu)

Nuclear Fuel cycle- India



- The first stage nuclear power programme utilized natural uranium as fuel in Pressurized Heavy Water Reactor (PHWR) power plants
- The second stage envisages development of Fast Breeder Reactors utilizing plutonium produced in PHWRs. A modest beginning in this direction was made by constructing a sodium cooled Fast Breeder Test Reactor (FBTR)
- It is the first of its kind in the world to use plutonium-uranium mixed carbide fuel
- U-233 fuelled mini reactor called KAMINI was made operational at IGCAR

- India has huge thorium resources and hence the third phase of our nuclear power program is designed keeping this fact in mind.
- Thorium is converted to U-233 by irradiation in PHWRs and FBRs. An advanced heavy water reactor (AHWR) is being developed to expedite transition to thorium based systems
- No other country in the world possesses such vast resources of thorium

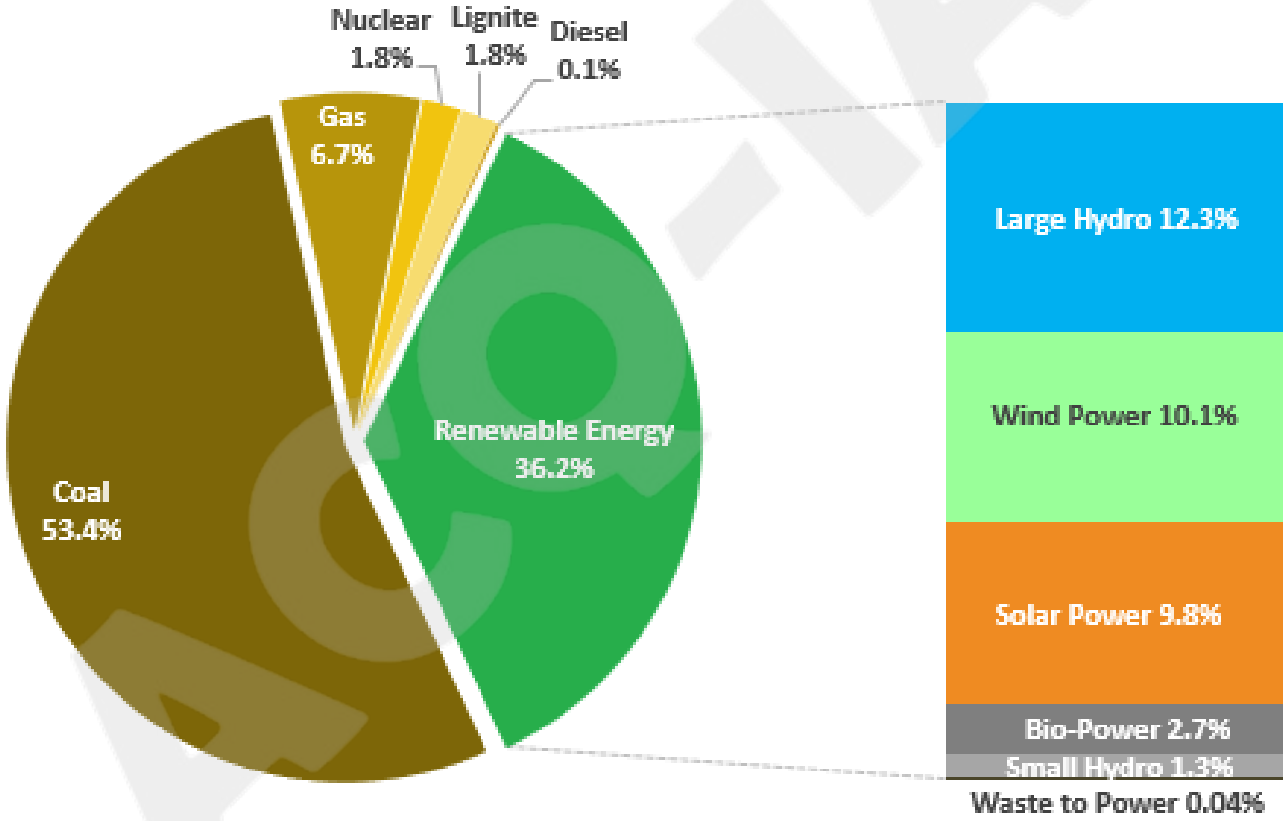
Nuclear Power In India- Architecture

- **Atomic Minerals Directorate:** for Exploration and Research is to identify and evaluate uranium resources required for the successful implementation of Atomic Energy program of the country
- **Uranium Corporation of India** is a public sector undertaking, under the Department of Atomic Energy for uranium mining and uranium processing
- **Nuclear Fuel Complex:** The fuel requirement for the power program
- **Heavy Water Board:** The organisation is primarily responsible for production of heavy water which is used as a 'moderator' and 'coolant' in nuclear power as well as research reactors

- **Nuclear Power Corporation of India Limited** (NPCIL) : operating atomic power plants and implementing atomic power projects for generation of electricity
- **Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI):** To pursue construction, commissioning, operation and maintenance of Fast Breeder Reactors for generation of electricity
- **Research Centers:** Bhabha Atomic Research Centre, Indira Gandhi Centre for Atomic Research, Raja Ramanna Centre for Advanced Technology,Variable Energy Cyclotron Centre

India - Cumulative Installed Power Capacity Mix (%)

Renewables (including Large Hydro) comprise ~36.2% of India's total installed capacity, with solar accounting for ~9.8%. Among renewables, solar accounts for ~27.2% of the installed capacity



Data from CEA, MNRE, Mercom India Solar Project Tracker (Installed Capacity as on 31 Mar 2020)

Source: Mercom India Research

Other Applications

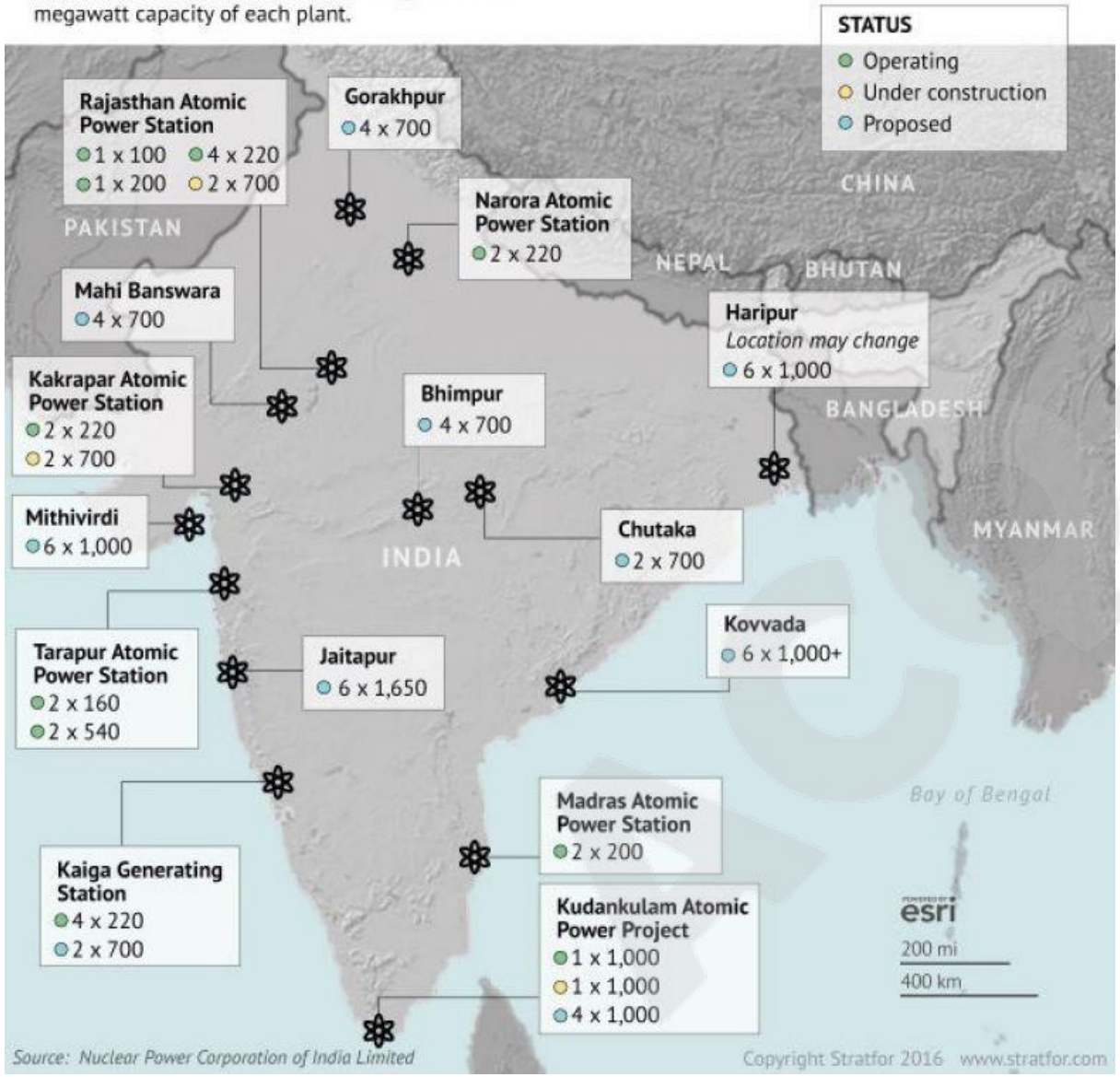
- Isotopes in Health sector, Diagnosis, Treatment
- Industrial Applications
- Radiation processing of Food for preservation.
- NISAR-GRUNA: biodegradable waste such as kitchen waste, paper, grass, gobar and dry leaves. It offers “Zero garbage and Zero effluent“ and provides high quality manure and methane gas.

Issues

- Nuclear Safety
- Civil Nuclear Liability
- Civil Nuclear Agreements, NSG issue

India's Current and Proposed Nuclear Power Plants

Map show locations, status, number of plants and megawatt capacity of each plant.



S.No.	Plant	Unit	Type	Capacity (MWe)	Date of Commercial Operation
01	Tarapur Atomic Power Station (TAPS), Maharashtra	1	BWR	160	October 28, 1969
02	Tarapur Atomic Power Station (TAPS), Maharashtra	2	BWR	160	October 28, 1969
03	Tarapur Atomic Power Station (TAPS), Maharashtra	3	PHWR	540	August 18, 2006
04	Tarapur Atomic Power Station (TAPS), Maharashtra	4	PHWR	540	September 12, 2005
05	Rajasthan Atomic Power Station (RAPS), Rajasthan	1	PHWR	100	December 16,1973
06	Rajasthan Atomic Power Station (RAPS), Rajasthan	2	PHWR	200	April 1,1981
07	Rajasthan Atomic Power Station (RAPS), Rajasthan	3	PHWR	220	June 1, 2000
08	Rajasthan Atomic Power Station (RAPS), Rajasthan	4	PHWR	220	December 23, 2000
09	Rajasthan Atomic Power Station (RAPS), Rajasthan	5	PHWR	220	February 4, 2010

10	Rajasthan Atomic Power Station (RAPS), Rajasthan	6	PHWR	220	March 31, 2010
11	Madras Atomic Power Station (MAPS), Tamilnadu	1	PHWR	220	January 27,1984
12	Madras Atomic Power Station (MAPS), Tamilnadu	2	PHWR	220	March 21,1986
13	Kaiga Generating Station (KGS), Karnataka	1	PHWR	220	November 16, 2000
14	Kaiga Generating Station (KGS), Karnataka	2	PHWR	220	March 16, 2000
15	Kaiga Generating Station (KGS), Karnataka	3	PHWR	220	May 6, 2007
16	Kaiga Generating Station (KGS), Karnataka	4	PHWR	220	January 20, 2011
17	Kudankulam Nuclear Power Station (KKNPS), Tamilnadu	1	VVER -1000 (PWR)	1000	December 31, 2014
18	Kudankulam Nuclear Power Station (KKNPS), Tamilnadu	2	VVER -1000 (PWR)	1000	March 31, 2017
19	Narora Atomic Power Station (NAPS), Uttarpradesh	1	PHWR	220	January 1,1991

20	Narora Atomic Power Station (NAPS), Uttarpradesh	2	PHWR	220	July 1,1992
21	Kakrapar Atomic Power Station (KAPS), Gujarat	1	PHWR	220	May 6, 1993
22	Kakrapar Atomic Power Station (KAPS), Gujarat	2	PHWR	220	September 1,1995

TACKLING RADIOACTIVE WASTES EFFICIENTLY

Not all nuclear wastes are particularly hazardous or difficult to manage as compared to other toxic industrial wastes.

Radioactive waste would be managed in a manner so as not to cause any undue radiation risk to the workers, the public (present as well as future generation) and the environment.

The recent technological developments in India realize the recovery of valuable radionuclide from radioactive waste for societal application besides ensuring the highest level of safety in the management of radioactive waste.

Radioactive wastes are generated during various operations of the nuclear fuel cycle

The activities like mining and processing of uranium ore, fabrication of nuclear fuel, generation of power in nuclear reactor, processing of spent nuclear fuel, management of radioactive waste, production and use of radionuclide for various industrial and medical applications, research associating with radioactive material etc. generates the different types of radioactive waste

- Radioactive waste can be in gas, liquid or solid form, and its level of radioactivity can vary

- The waste can remain radioactive for a few hours or several months or even hundreds of thousands of years

- Depending on the level and nature of radioactivity, radioactive wastes can be classified as exempt waste, Low & Intermediate level waste and High Level Waste.

- The most important and advantageous property of radioactive waste is *'Its radioactive hazard potential reduces with time depending on the half lives of radionuclide present in the waste'*.

- Such feature differentiates them significantly from conventional chemical or industrial waste

Low and Intermediate Level Waste (LILW)

- Low and Intermediate Level Waste (LILW) radioactive waste are generated in radiation facilities and nuclear fuel cycle operations ranging from uranium processing, fuel fabrication, nuclear power plants, research reactors, radiochemical facilities and fuel reprocessing.

- LILW have generally high volumes and low levels of radioactivity

HIGH LEVEL WASTE

- High level radioactive liquid waste (HLW) containing most (~99%) of the radioactivity in the entire fuel cycle is produced during reprocessing of spent fuel.

Disposal of waste is carried out in specially constructed engineering modules such as **stone lined trenches, reinforced concrete trenches and tile holes at Near Surface Disposal Facility (NSDF)**.

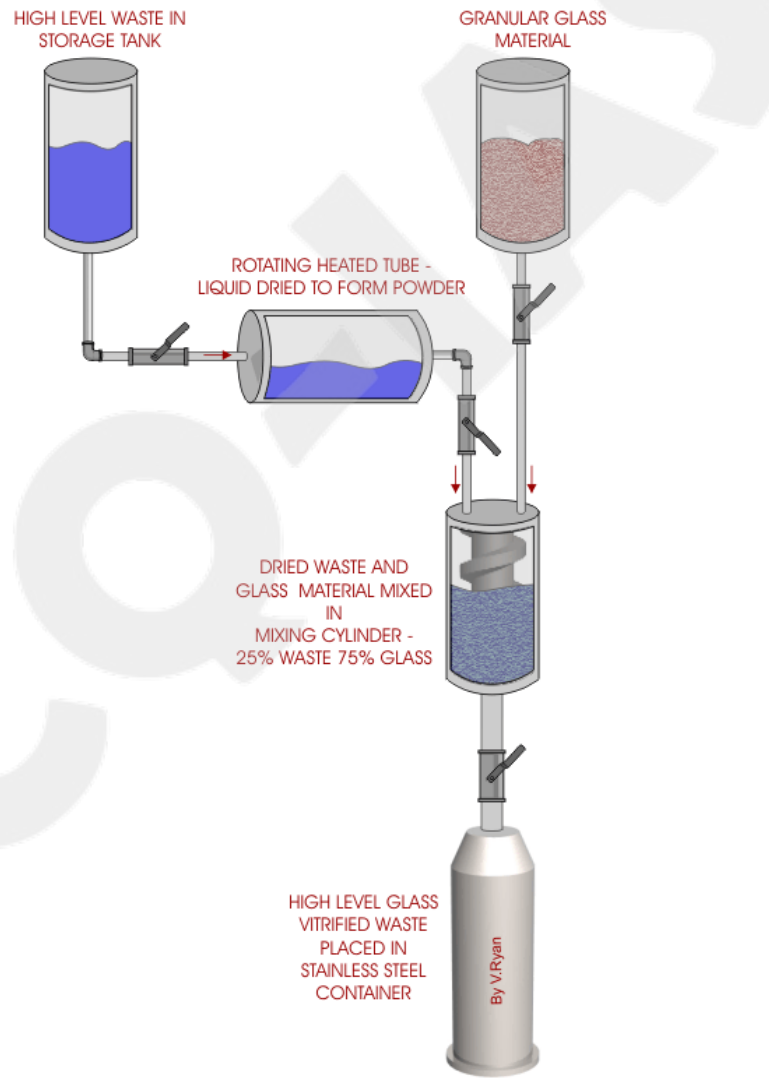
These disposal structure are located both above and under-ground

The **high level** solid wastes contain large concentration of both short and long lived radionuclide's, warranting high degree of isolation from the biosphere and usually calls for final disposal into Geological Disposal Facility (GDF)

VITRIFICATION

- India is one of the few countries to have mastered the technology of vitrification. Over the years BARC has developed the technology for vitrification of HLW

- India has a unique distinction of having operating vitrification plant at Trombay, Tarapur and Kalpakkam.


HIGH LEVEL WASTE IN STORAGE TANK
GRANULAR GLASS MATERIAL
ROTATING HEATED TUBE - LIQUID DRIED TO FORM POWDER
DRIED WASTE AND GLASS MATERIAL MIXED IN MIXING CYLINDER - 25% WASTE 75% GLASS
HIGH LEVEL GLASS VITRIFIED WASTE PLACED IN STAINLESS STEEL CONTAINER
By V.Ryan

WEALTH FROM WASTE

High level radioactive liquid waste contains various useful fission product such as 137Cs, 90Sr,106Ru etc., which have many industrial as well as medical applications.

The energy associated with these isotopes can be used for blood irradiation, food preservation, sewage treatment, therapeutic applications, brachy therapy & various other industrial applications