Indian Monazite – A Potential Source For Future Thorium Energy

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D SINGH

CHAIRMAN AND MANAGING DIRECTOR

INDIAN RARE EARTHS LIMITED, MUMBAI

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Thorium – A Potential Nuclear Fuel

- Useful substance for nuclear energy generation.
- Reserves are widely distributed in nature.
- Excellent chemical and metallographic stability demonstrated by its neutron damage resistance.
- Advantage over Uranium as fuel due to low radio toxicity, increased safety features and higher flexibility for breeding.
- Major hope as an alternate to fossil fuel due to its abundance, consistent nature of production and low emission of carbon dioxide.
- Integral part of India's three stage nuclear program.

Thorium Energy-The Need Of The Hour For India

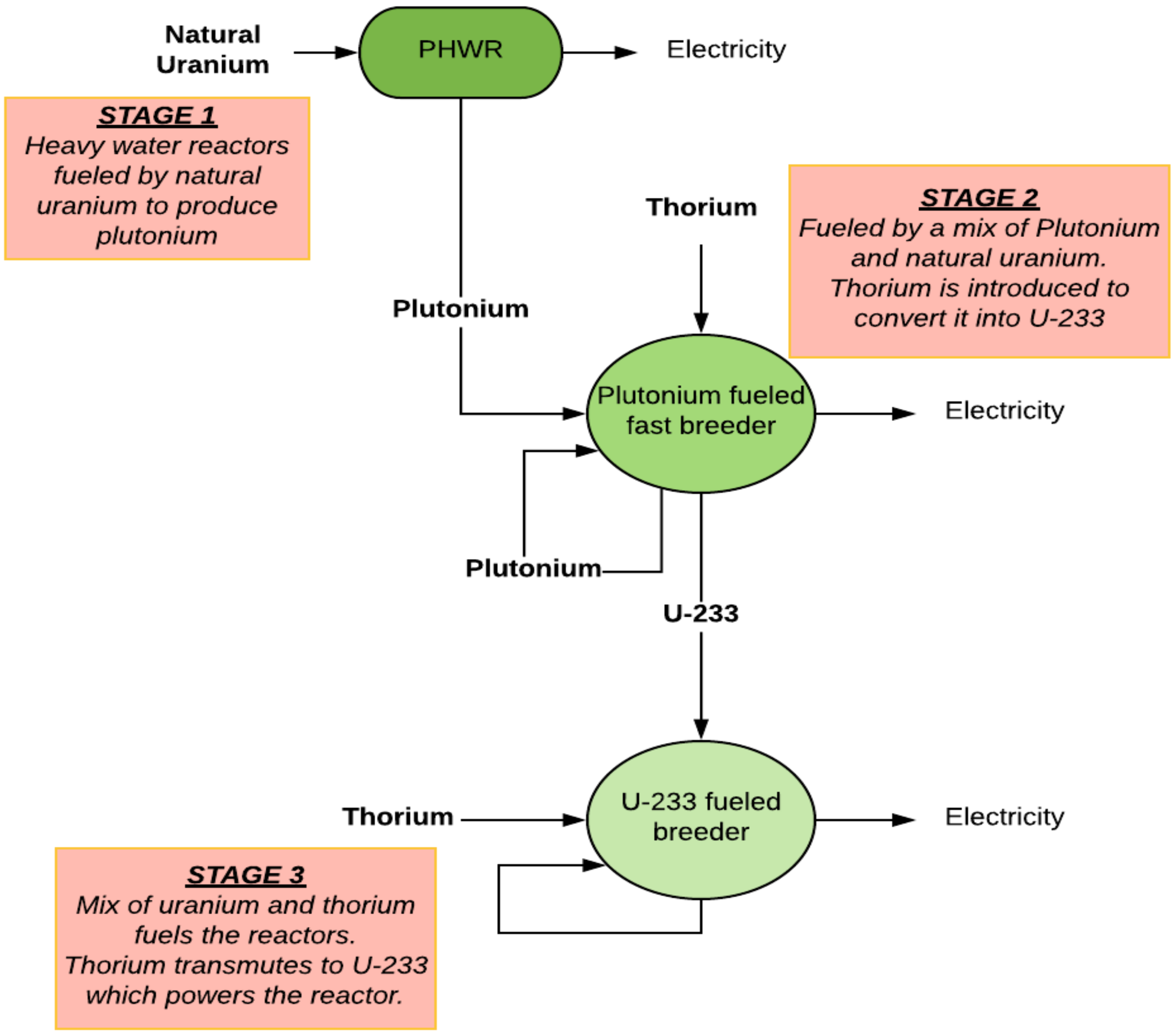
- India's energy demand expected to increase two fold by 2030.

- Thorium trending to be a key player in the energy arena.

- India is working relentlessly to generate energy - major source from nuclear & thermal energy.

- India has taken keen interest in nuclear energy technologies due to increase in population, decline of fossil fuel resources and increasing pollution.

India’s Three Stage Nuclear Program



- ✓ First stage: Natural Uranium in pressurized heavy water reactor
- ✓ Second stage: Burning of plutonium with a Uranium and Thorium blanket.
- ✓ Third stage: Thorium would be the starting material.

Thorium – Reserves

- India has one of the world's largest thorium deposits - Monazite.
- Thorium reserves make up to 25 % of global reserves.
- India has about 1.12 million tons of Thorium Oxide (ThO_2).
- Indian Thorium reserves could possibly be converted to 358,000 GW-yr of electrical energy to meet the future energy requirement.

Sources of Thorium

S. No.	Mineral	Natural Form	ThO_2 content	Crystal shape	Colour	Lustre	Streak	Hardness (Mohs Scale)	Density (#)
1	**Monazite**	(Ce, La, Th) PO_4	1-15%	As prismatic crystals or angular fragments or as rounded small glassy grains	Pink to brown	Resinous	Colourless to pale brown or yellowish	5 – 5.5	4.6 – 5.3
2	**Thorianite**	ThO_2	90%	Small cubes which become worn on edges when subjected to erosion	Black to brownish or greyish	Sub metallic to greasy	Black	5 – 7	9 or above
3	**Thorite**	$ThSiO_4$	80%	Small, square, prismatic crystals with pyramid like points similar to zircon	Black, greenish black or brown	Glassy or greasy	Brown to orange	4.5 – 5	4 - 6

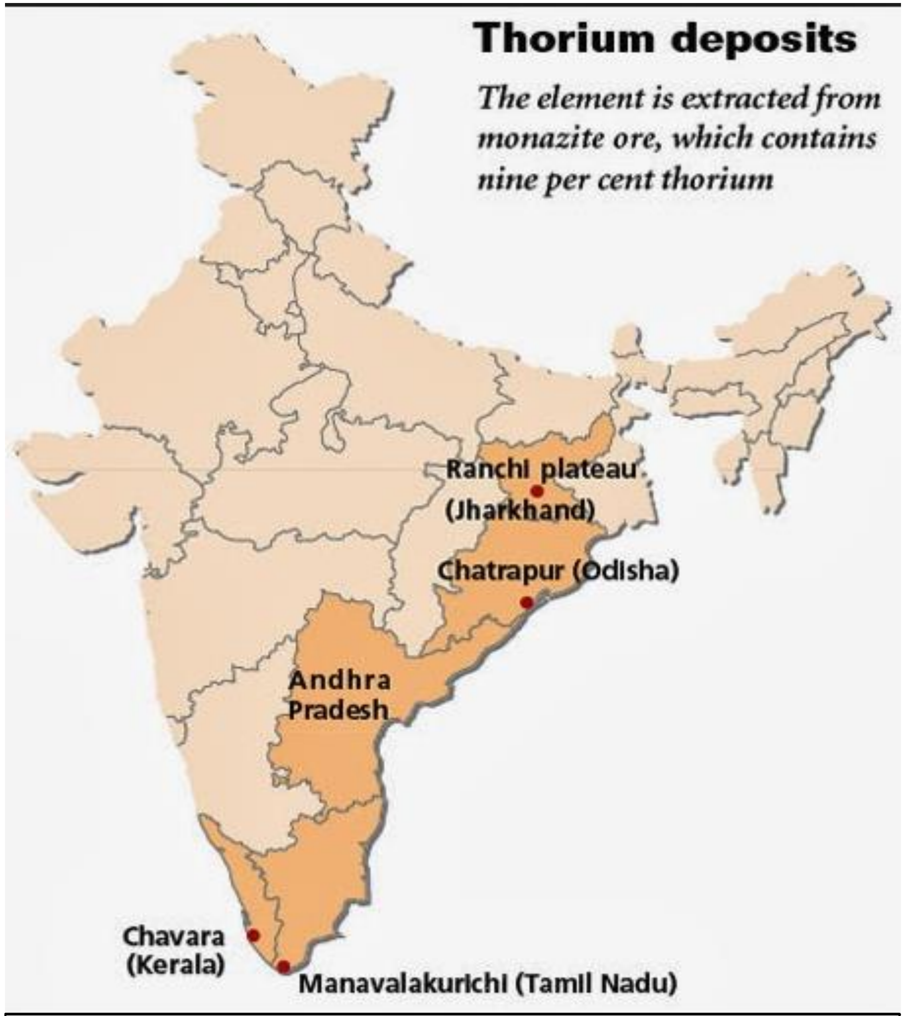
 # Higher the percentage of thorium, higher the density

Monazite – Reserves in India

- India has ~6000 Km long coastline rich in Atomic Mineral deposits.

- Placer deposits contain Atomic Minerals - Monazite, Zircon, Ilmenite, Rutile, Sillimanite and Garnet.

- Monazite content vary from Nil to 5%.



State wise resources of Monazite available in costal tracts of India

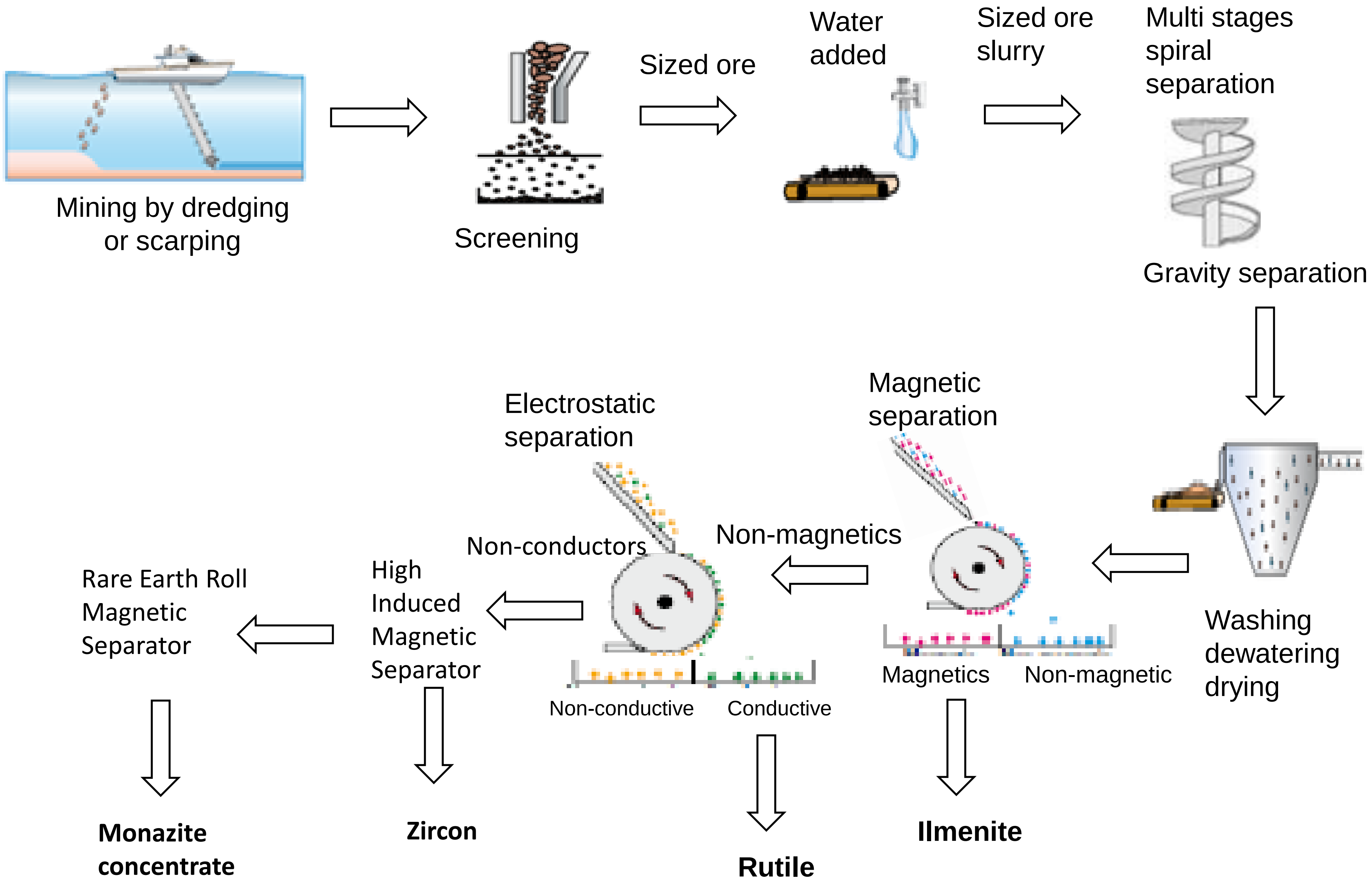
Monazite – Mineral and Chemical Composition

Typical mineral composition of monazite	
Monazite	96.0 %
Zircon	1.4 %
Ilmenite	0.6 %
Garnet	1.1%
Quartz	0.5%
Sillimanite	0.2%
Others	0.2%

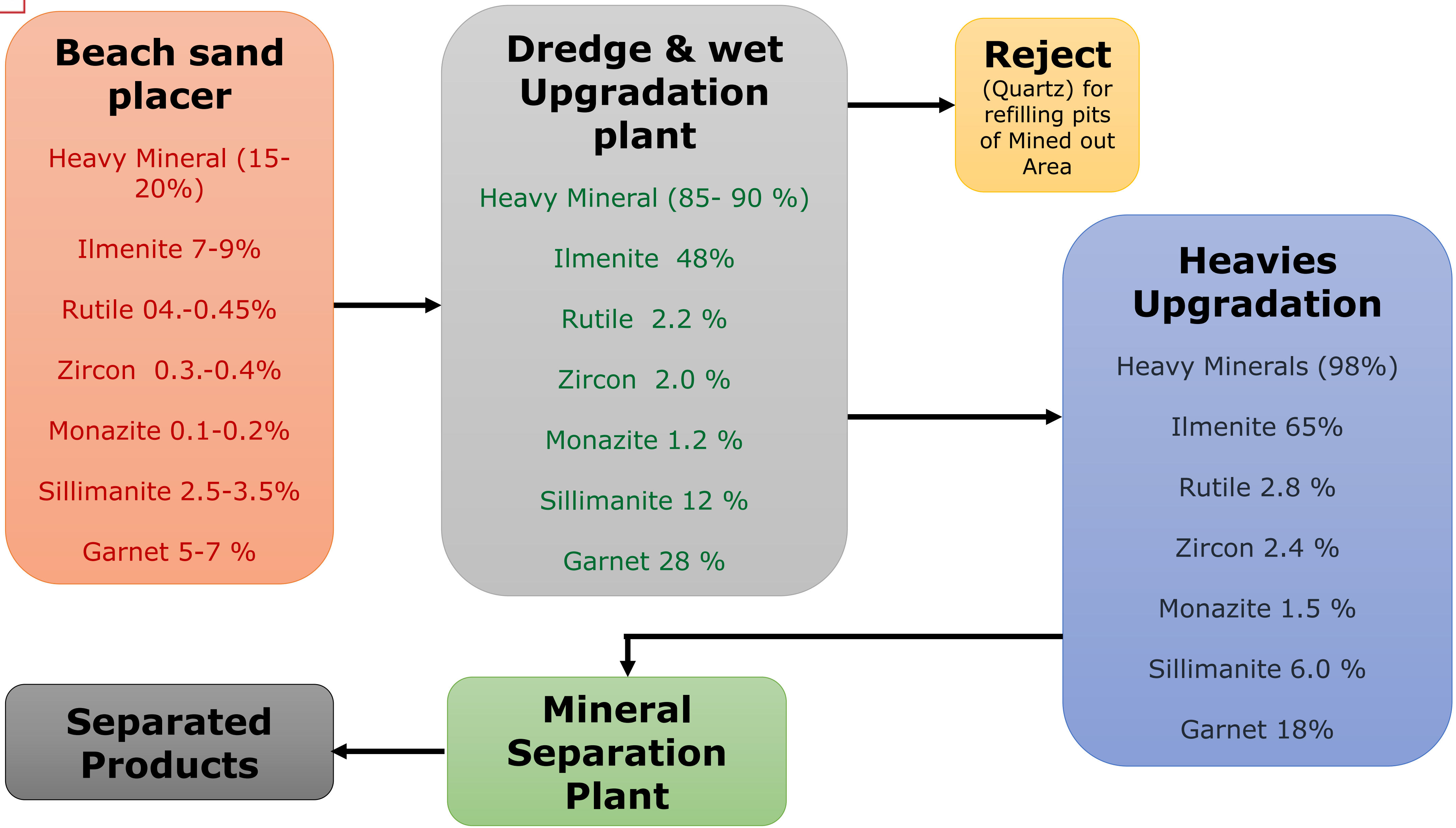
 # Monazite is weakly magnetic and non-conducting

Chemical Composition	
Constituent	**%**
Monazite content	96
TOTAL Rare earths oxide	59.2
La203	12.8
CeO_2	27.5
Pr_6O_{11}	3.1
Nd_2O_3	10.8
Sm_2O_3	2.1
Gd_2O_3	0.71
Y_2O_3	0.42
Eu_2O_3	0.06
ThO_2	8.9
PbO	0.18
Fe_2O_3	0.28
TiO_2	0.4
SiO_2	1.1
P_2O_5	27.4
CaO	1.14
MgO	0.61
Al_2O_3	0.2
ZrO_2	0.5

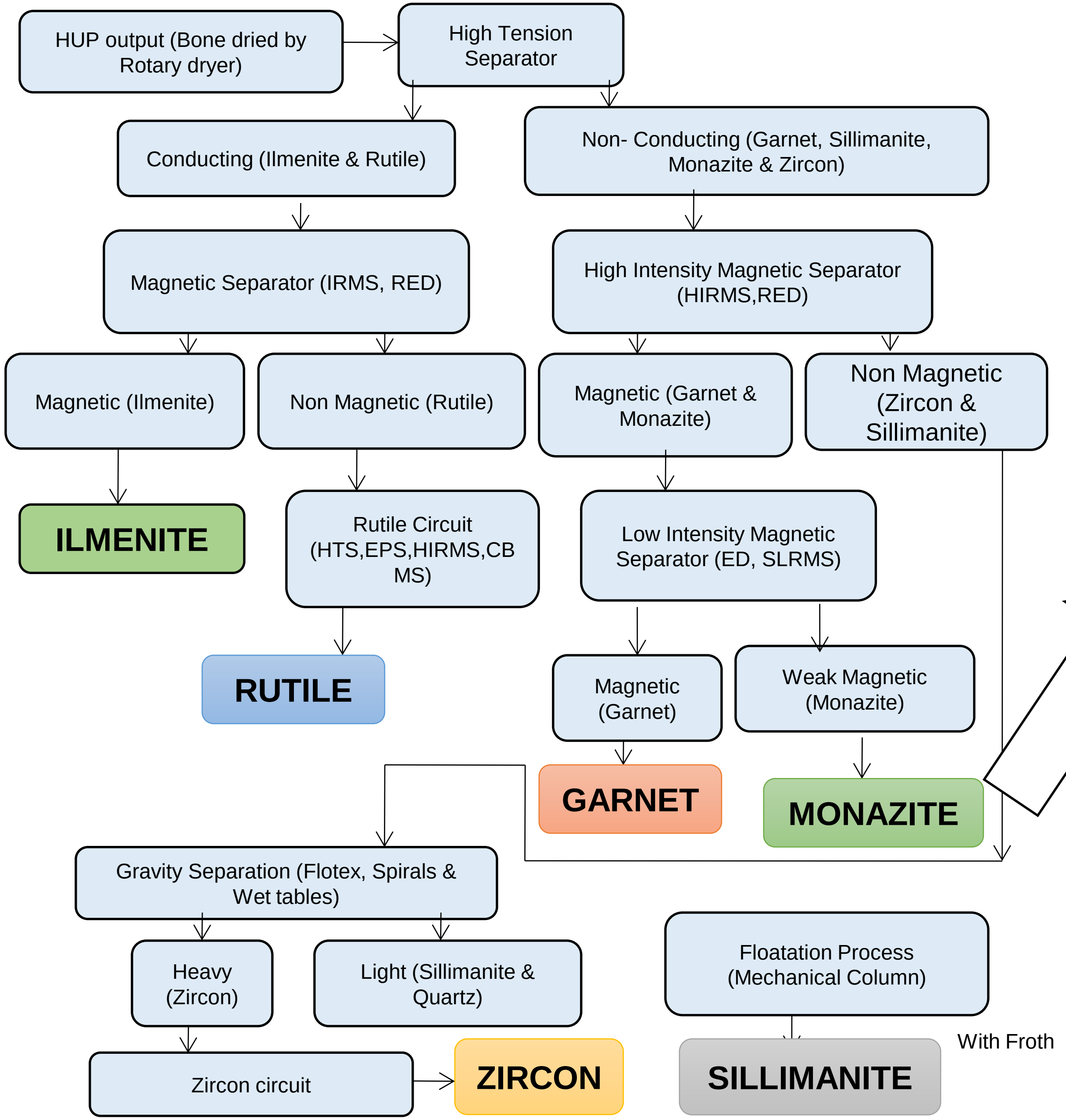
Typical Flow Sheet



Flow Sheet For Pre-concentration



Flow Sheet for Mineral Separation



Composition	%
REEs as Re2O3	59.37
P2O5	27.03
ThO2	8.88
CaO	1.24
SiO2	1.0
MgO	0.63
Fe2O3	0.32
Al2O3	0.12
PbO	0.18
TiO2	0.36
ZrO2	0.49

Composition	%
Lanthanum	22
Cerium	46
Praseodymium	5.5
Neodymium	20
Samarium	2.5
Europium	0.015
Gadolinium	1.2
Terbium	0.06
Dysprosium	0.18
Holmium	0.02
Erbium	0.01
Yttrium	0.45

Role of IREL for Thorium Energy

- India has long-term objective of becoming energy independent based on the vast thorium resources.
- Only country in the world with detailed, funded, government-approved plan to focus on thorium-based nuclear power.
- Monazite produced from beach sand by IREL at **Manavalakurichi in Tamil Nadu, Chavara in Kerala and OSCOM in Odisha** by physical/ physico–chemical processing.
- IREL has setup plant to process **10,000 tons** of monazite annually.
- Rare Earth & Thorium compounds produced from monazite.
- IREL has framed its own strategy to meet the future demand of thorium and also fulfill the country's thorium energy program.

Research & Development for utilisation of Thorium

R&D activities carried out at research organisations under DAE for utilisation of Thorium such as:

1) Thorium Oxide (Thoria) pellets contained in bundles in the initial cores of Pressurised Heavy Water Reactors (PHWRs)

2) Thoria based fuels irradiated to explore possibility of utilising their suitability in reactors.

3) The irradiated thoria pins of research reactors reprocessed to obtain Uranium-233.

4) The recovered Uranium-233 fabricated as fuel for the 30 KW thermal reactor.

5) Advanced Heavy Water Reactor (AHWR) of 300 MWe designed using thorium based fuel.

Future Challenges

- Operating experience with Thorium
- Expensive testing, analysis and licensing for using Thorium fuel with existing water cooled reactors.
- Thorium oxide has higher melting point than traditional fuel & inert. Increased cost of fuel fabrication and processing.
- Irradiated Thorium is highly radioactive and difficult to shield.
- Expensive Spent fuel handling and reprocessing.
- Thorium is not ideal compared to U-235 & Pu-239 as far as neutron economy is concerned.

Conclusion

- In coming decades, nuclear power would be the most important source of energy for India.
- Nuclear fission energy is a viable option for India’s energy demand.
- India building a modern industrialized economy with reduced carbon footprint.
- Reliance on wind & solar energy not realistic.
- Perfect solution to the energy requirement can only come from innovations.
- Only country in the world to focus on applied & fundamental research on thorium based nuclear power to meet the challenges.

Thank You

D SINGH
CHAIRMAN AND MANAGING DIRECTOR
INDIAN RARE EARTHS LIMITED, MUMBAI

Tel: 022 24225778
Email: cmd@irel.co.in