

to breed more fuel than is consumed, and the surplus fuel could fuel additional FBRs besides converting thorium to fissile uranium.

The second stage of the indigenous nuclear program envisaged building a fleet of FBRs, which could theoretically support a 100,000 MWe program for about 500 years and extend India's uranium supply by centuries. In the third stage, thorium-fuelled reactors could likewise support a 100,000 MWe program for about 2000 years and extend the country's nuclear fuel supplies by millennia!

Is this plan technically feasible? Yes, in principle. The current fleet of commercial reactors (LWRs and PHWRs) uses less than 2% of mined uranium. Discharged fuel assemblies still contain 95% of uranium, 1% plutonium, and 4% fission products to be eventually disposed of. Besides reducing the volume of radioactive nuclear waste, spent fuel reprocessing and breeder reactors could potentially unlock a huge energy potential by converting the large unused uranium in discharged fuel into plutonium fuel and the more abundant thorium resources into useable uranium fuel. This is the Holy Grail of India's indigenous three stage nuclear program.

Will this plan be economically viable? Possibly, depending on assumptions about growth of nuclear power, future uranium prices, and most importantly, the cost competitiveness of reactor systems and associated fuel cycle infrastructure to support the second and third stages of the indigenous program.

India was not alone in pursuing such a grand nuclear energy strategy. Practically every major country that had an interest in nuclear power concluded reprocessing and recycling of spent fuel inevitable to support a large nuclear power program far into the future. Optimism about future growth of nuclear power and the perceived uranium scarcity during the 1950s and 1960s provided the momentum and justification for various closed nuclear fuel cycle initiatives worldwide.

However, the actual pace of nuclear growth, a prolonged period of low uranium prices during the 1980s and 1990s, and proliferation concerns forestalled widespread adoption of spent fuel reprocessing and recycling and breeder reactor development. Opening of new uranium mines, demilitarization of uranium mining after the end of Cold War, and conversion of dismantled nuclear warheads and excess military fissile stocks for civilian use further reduced the incentives for closed fuel cycle programs.

Currently 437 reactors with a total generating capacity of 372 GWe are in commercial operation globally, requiring about 62,000 tonnes of uranium (tU) every year. According to a recent projection by the International Atomic Energy Agency (IAEA), global nuclear capacity is expected to reach between 400 GWe (low demand case) and 680 GWe (high demand case) by 2035. Annual uranium requirements for these two scenarios are 72,000 tU and 122,000 tU respectively. Even the most optimistic future scenario

Most of these concepts are taken over from our daily experience, later defined and quantified for ~~measurement~~ and measurement and formalized formulation and physical theories. It is important to note that most of these concepts have radically changed as science advanced.

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presented by the IAEA corresponds to a global nuclear fleet of only around 600 reactors by 2035. This is quite different from the optimism of the 1950s and 1960s, when the US alone was expected to build about a thousand reactors by the year 2000.

Had nuclear power expanded as projected earlier, it could have plausibly put pressure on global uranium supplies. Anticipating such a scenario, the French, British, and the Japanese spent substantial resources building reprocessing facilities. In the US, proliferation concerns, slowing down of electricity demand after the 1973 oil shock, and no new reactor orders after the 1979 Three Mile Island accident sealed the hopes of breeder reactor development and other closed fuel cycle initiatives.

There was a brief period of optimism since the turn of the new millennium about nuclear power due to energy supply security and climate change concerns. But the 2011 Fukushima nuclear accident has dampened those prospects in many countries except in a handful of countries where there is strong official support for nuclear power.

Although short term price fluctuations have occasionally renewed questions about uranium availability for future growth, currently defined resource base is adequate to meet even high demand through 2035. The 2014 edition of the IAEA-OECD biennial publication on global uranium resources (colloquially known as "Redbook") reports total identified resources (reasonably assured and inferred) at 5.9 million tU in the lesser than \$130/kgU category, and 7.6 million tU in the lesser than \$260/kgU category. In addition, prognosticated resources and speculative resources amounted to 7.6 million tU. An aggressive uranium exploration similar to the oil and gas industry could drastically increase uranium availability, suggesting adequate uranium availability to fuel nuclear growth for a century or more or more without having to reprocess and recycle spent fuel. This doesn't rule out the possibility of dwindling of high grade uranium deposits.

Current uranium resource estimates are relatively poor because of the short and limited exploration history. For most commercially valuable metals, there has been a long progression from the mining of high-grade deposits toward lower grade ores available at greater depths and higher costs. During the Second World War some of the lowest grade uranium was mined because of wartime subsidies.

Uranium is relatively abundant compared to some of the commonly used metals such as chromium, mercury, silver, and tungsten. It is present in the earth's crust and the oceans with an average concentration of 1.8 ppmv (parts per million) and 3.3 ppbv (parts per billion) respectively and geographically widely distributed. Large amounts of uranium also exist in granites and other magmatic rocks and sea water. A few years ago, a Japanese group reported extracting uranium from sea water at a

Science, Reality and Consciousness

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It is indeed a great honor, pleasure and privilege for me to deliver the inaugural talk at this National Symposium organized by the prestigious Yoga Institute, Kairalyasathan. The theme of the Symposium is given as "Matter, Mind and Consciousness". I have chosen the theme of my talk as "Science, Reality and Consciousness" with a specific purpose - to highlight the fact that the current trend in the 21st Century among about some of the influential scientists is the Grand Unification Scheme:

Matter = Energy = Mind = Consciousness = Reality = Quantum Vacuum =
Multi-Dimensional Space-time

② This is not based on idle speculation. It is based on solid experimental facts emerging from very sophisticated experiments in the fields of physics and cosmologies over the past four hundred years, particularly in the 20th and 21st centuries. The interpretation of their results by ingenious theories that have stretched mind boggling mathematical ideas and theories. It is also important to point out the role of Science-Technology spiral that led to the feasibility of carrying out such experiments and the ~~big~~ budgetary support given by the enlightened governments, which runs into tens of billion dollars.

③ In that Grand Equivalence Equation that I have written there are many subtle concepts that are ~~hidden~~ involved, and many of them implicit:
(Animals and man-made)
Space, Time, Matter, Motion, Force, Energy, ~~radiation~~ Radiation
Mind, brain, Consciousness, Creation, Annihilation, etc. Vacuum
Quantum etc. etc. and most importantly "Reality")