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INDIAN NUCLEAR SOCIETY

INS News Letter

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Contents

Azadi ka Amrit Mahotsav

Announcement

As a part of the celebrations of Azadi ka Amrit Mahotsav, INS is likely to present November-2022 issue to its members in the printed form. Hard copy of this special issue will be sent by post to all those members who will send their correspondence address to:

indiannuclearsocietynl@gmail.com

Obituary

With profound grief, Indian Nuclear Society condoles the sudden and untimely demise of late Shri Sushil Kumar Chadda, a dynamic and an esteemed member of its Executive Committee. Shri Chadda, despite his health problems had been a very active participant in the deliberations of INS. His passing away is an irreparable loss to the INS fraternity. He graduated from BARC Training School in 1970. He also obtained M.Tech. in Design Engg. from IIT, Mumbai. He retired in 2006 from NPCIL as Associate Director, R&D, Nuclear Systems. Late Shri Chadda will always remain in our hearts and memory.

Indian Nuclear Society

From Editor's Desk

Apart from COVID, Ukraine crisis has cast long shadows on the global economy. One of the factors responsible for soaring oil and gas prices is the heavy dependence of some European nations on this energy source. Squeamishness of many European union nations on Nuclear Power post Fukushima is partially responsible for its lack of determined response to Ukraine crisis. French President Emmanuel Macron stood out as he could take a particularly assertive stance principally due to the fact that France produces 65% of its electricity from nuclear sources and its relative independence of oil and gas. The British prime minister Boris Johnson (exited now) was the other leader who was vociferous and stated , "Instead of a new one every decade, we're going to build one nuclear power reactor every year, powering homes with clean, safe and reliable energy".

In spite of the generally laggard response of west to nuclear power, 2653.1 TWh of this low-emission electricity accounting for about 10% of total global electricity and more than a quarter of the world's low-carbon electricity was generated in 2021.The Middle East and South Asia had the biggest increase, generating 20% more nuclear electricity than in 2020. For the second year in a row, China was the second largest nuclear power producer after the United States. HONGYANHE-6 (1061MWe, PWR) was connected to the grid in May 2022 in China. Newly elected South Korean President Yoon Suk-yeol wasted no time in committing his administration to resurrect the nation's nuclear energy sector, both at home and abroad which marked a dramatic policy reversal of his immediate predecessor. The government laid out a new energy policy in July, 2022 which aimed to maintain nuclear's share of the country's energy mix at a minimum of 30% by 2030. It was music to learn that even Japanese Prime Minister Kishida intends to secure about 10% of Japan's total electricity consumption through nuclear power reactors this winter. It is however necessary to invest in newer technologies to ensure safety, security and cost competitiveness of nuclear power. Fast neutron reactors operate with enough energy to cause fission of many heavy atoms, potentially eliminating both nuclear waste material and reliance on uranium as the sole fuel source. This is just one of a host of fourth-generation nuclear reactor systems that together overcome some of the shortcomings of conventional installations. China is currently operating 200 MWe High Temperature Gas Cooled Shidaowan power plant in Shandong, and Russia is successfully operating Fast Breeder Beloyarsk-3 (560 MWe) and Beloyarsk-4 (820 MWe) Reactors in Sverdlovsk Oblast.

It is heartening to learn that construction of foundation slab of Reactor Building is completed in KKNPP-6. In a milestone achievement BARC successfully deployed an indigenously evolved phytosanitary protocol involving radiation treatment (which is an improvisation over the protocol practiced earlier) to export mangoes from India to USA by sea route. Radiation grafted matrix developed at BARC has been used in demonstration plants for the treatment of waste water emanating from the dye industry at Jetpur, Gujarat and Jodhpur, Rajasthan.

Present issue has an obituary for Shri S. K. Chadda, a very dynamic member of the present EC who left us on 17th May, 2022. We will always remember his outstanding contributions to the various activities of society during the last two years.

GOI announced in 2020 the opening of the nuclear energy sector for PPP mode in medicine and agriculture sector. Faced with the huge challenge to meet the committed target of net zero carbon emission by 2070, it is time to seriously consider opening of nuclear power sector too for PPP. Dr Rajashekhar Malur, Senior Vice President, TCE Ltd analyses the role of private sector in growth of Nuclear Power in India in the present issue. Mr Ludovic Dupin (Chief Information Director, French Nuclear Society) and Mr Thomas Mieusset (Nuclear Counsellor at French Embassy, New Delhi) present a summary of the journey of nuclear power in France from inception and how the latter can support India to achieve its target of net zero carbon emission. It is my privilege to give an overview on the life of an outstanding nuclear scientist, **Glenn Theodore Seaborg,** a co-discoverer of 10 elements (including Seaborgium) ,a Nobel Laureate and Chairman USAEC (1961-1971). INS round up covers the activities of society during the past quarter. In addition to the regular features like DAE

Brief, Nuclear Snippets and Crossword puzzle, a new feature "Do you know" has been added since May 22. I once again urge members to give their feedback on various features of NL to :

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DAE NEWS Brief

A Post-harvest Technology for Development of Intermediate Moisture Shrimp

Fish and fishery products are highly perishable food commodities. Shrimp are high value, exported seafood commodity. Being highly perishable in nature shrimp has very low shelf-life and is mostly consumed fresh or in dried form. The quality of dried shrimp available in market is poor due to poor rehydration capacity. BARC has developed a process for development of Intermediate Moisture Shrimp having about 30% moisture. The developed product has a better over-all quality, rehydration capacity & can be stored at ambient temperature for 4 months. The shelf life of this product can be further extended for another 2 months by radiation processing (5 kGy) at ambient temperature. This technology promises longer shelf-life of this prime seafood commodity and may ensure better availability of shrimp in domestic as well as international market without need of cold storage or refrigerated transport.

BARC Develops Successful Protocol for Export of Mangoes to USA by Sea route

In a milestone achievement BARC successfully deployed an indigenously evolved phytosanitary protocol involving radiation treatment to export mangoes from India to USA by sea route. The process involved dipping the fruit in Sodium Hypochlorite solution at 52 degree celsius and then treating the same in a special chemical solution developed by BARC. This USDA-APHIS approved protocol helped in increasing the shelf life from 10 days to 30 days and paved the way for shipment of mangoes using cost effective sea route. Maharashtra State Agricultural Marketing Board (MSAMB) and M/S Sanap Agroanimals Private Limited were partners in this commercially viable activity.

A Process for Development of Phosphorus (P) Fertilizer Formulation from Biosludge

Phosphatic fertilizers are of great demand during recent times and the demand is increasing steadily. BARC has developed a process for development of Phosphorus fertilizer formulation from bio-sludge. Chemically synthesized phosphatic fertilizers have limitations in term of availability and they are effective at certain levels. On the contrary phosphatic fertilizer derived from biosludge slowly release phosphate and increase the crop yield at half the recommended dose. The process converts post biomethanation distillery sludge; a waste material for distilleries, into a high efficiency P fertilizer for soil application.

Air Plasma Incinerator

Breaking of organic bonds using extremely hot air in an oxygen deficient environment, and conversion of the organic material into fuel gas (called syn gas, similar to CNG used in cars but consisting of mainly CO and H_2) is called gasification. Plasma gasification technology provides an attractive and universal means to treat most types of waste including municipal, nuclear and other solid wastes in an environment friendly manner. Usual low temperature burning has the issues of producing carcinogenic substances like dioxin, furan and other pollutants like NO_X and SO_X, poor waste to gas conversion, high ash content in residue, slow process rate and devoid of fuel gas. Gasification is different from incineration as no pollutant is generated and synthesized gas (syn gas) can be used as fuel for heat/ electricity generation. The BARC developed technology of Air Plasma Incinerator adopts a judicious combination of the two in which it does high temperature gasification at the bottom of the primary chamber and allows controlled burning of the produced syn-gas at the top to supply energy required for the process. The technique drastically reduces requirement of external supply of energy and mitigates waste in an environment friendly manner extracting energy from the waste itself. The achieved waste process rate in the developed system is of the order of 1-3 ton per day depending on the type of waste.

Scan Magnet and Power Supply for Electron Beam Accelerator

In Industrial accelerators Scan magnet is required to scan beam over a wide area of 1 meter to ensure uniform dose distribution on the products to be irradiated. Magnetic field of ~1.7 kG is required to deflect 10 MeV electron beam over the scan length. An AC, dipole magnet made up of 'Si steel' is developed at BARC to serve the purpose. A triangular, bipolar, symmetrical current source is developed to energize the magnet. It is designed for an inductance of 429 mH and resistance of 4.8 Ohm. It operates at a scan frequency of 1-2 Hz.

DC Accelerator for Radiation Processing Applications

A high power DC accelerator has high throughput for radiation processing applications viz. waste water treatment, cable irradiation, modification of plastics, cross-linking & grafting, pollution control, etc. Energy for electron acceleration is provided by an efficient high voltage multiplier which is housed in a pressure vessel in N_2-SF_6 gas mixture environment at 6.0 kg/cm^2 pressure. Electron beam is generated by thermionic electron gun and accelerated in high vacuum in accelerating tubes. The accelerated beam is transported, steered, focused and scanned and is extracted in atmosphere through a titanium foil window. The extracted beam falls on product for various industrial radiation processing applications. Prototype demonstration is planned at BARC for 0.8-1.0 MeV beam energy, 0-50mA beam current and 40kWmax beam power for continuous operation.

Aluminium Visual Detection Kit (AVDK) for the Rapid Detection in Dialysis Fluids and Ground Waters

Aluminium (Al) is potentially neurotoxic due to its indiscriminate binding with various ligands (phosphate, citrate; proteins-transferrin, catecholamine). Al can cross blood brain barrier and accumulate in brain leading to memory impairment, cognitive dysfunction, neurodegenerative disorders (Parkinson's and Alzheimer's) etc. The toxic effect of Al is of concern in chronic renal failure patients on dialysis and patients receiving long term parenteral nutrition. Therefore, an accurate control of Al in commercial dialysis solutions is necessary (must be lower than 10 µg/L for dialysis fluids and 200 µg/L in drinking water) to determine its suitability. Aluminium Visual Detection Kit (AVDK) is developed by BARC for the detection of Al in peritoneal dialysis fluids and ground waters.

Huge deposits of Uranium found in Rajasthan
Rajasthan has come on the world map with huge reserves of uranium, found at Rohil (Khandela Tehsil) in Sikar district, which is over 120 km from state capital Jaipur. The Rajasthan government has forayed into the field of uranium mining by issuing a letter of intent (LoI) to Uranium Corporation of India.

Major recent Achievements of NPCIL

Twelve Reactors registered 100% Availability Factor and thirteen Reactors achieved more than 90% Plant Load Factor during May, 2022. Construction of foundation slab of Reactor Building is completed in KKNPP-6. Erection of condensate, feed water system and main steam piping is completed in RAPP-7. Calandria integrity test is completed in KAPP-4.

Compiled by Vijay Manchanda

Energy Transition – Role of private sector in growth of Nuclear Power in India

Introduction:

Sustainable Development Goals and the Paris Agreement have made it mandatory for all the signatories to ensure actions towards meeting the Nation's commitments. Energy Transition is of utmost importance since it is real and happening now with fossil fuel fired plants making way for clean and green energy. The recent report of the United Nations Inter Government Panel on Climate Change, released during COP26, stated that the Earth would warm by 1.5 degree Celsius in 20 years with catastrophic impacts [1]. The situation arising out of the Ukraine conflict and the energy crisis has led to rethinking on nuclear power generation across global economies. New Energy policy in South Korea has reversed its earlier decision on nuclear phase out [2]. Japan is speeding up its review of nuclear reactors that were shut down post-Fukushima incidents in 2011 [3]. The European Union Parliament voted allowing gas and nuclear for accessing green funding [4]. There is a revival of focus on Nuclear across the globe as clean energy for this energy transition.

As per a report by International Energy Agency [5], the pandemic did impact the energy demand globally. However, emerging markets have driven the demand back to 2019 levels. Electricity demand is heading for the fastest growth in a decade. The global economy grew by 5.5~6% in 2021, more than compensating for the 3.5% drop in 2020. Fiscal Stimulus and Vaccination have helped achieve this and India is projected to be largest growing economy in terms of GDP % growth in the current fiscal.

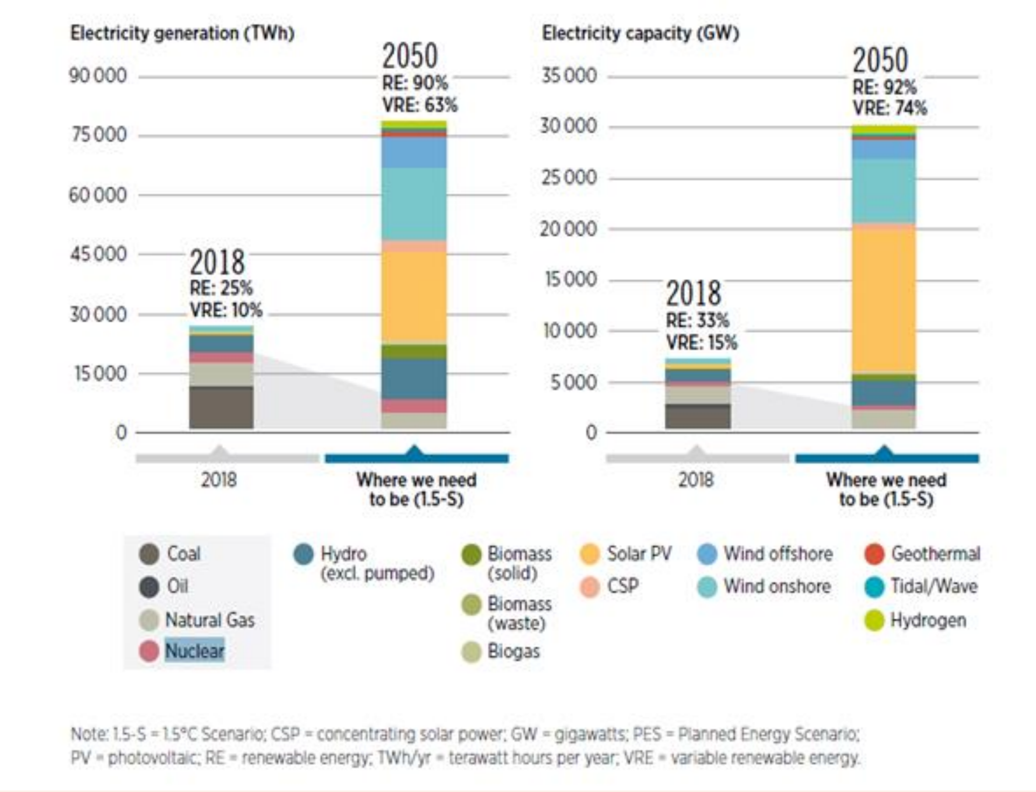

Figure 2: Electricity generation (TWh/yr) and capacity by source (GW)

Energy Transition

The share of renewables in global electricity generation jumped to 28.3% in 2021, up from 20.4% in 2011. Reaching a new high of 315 GW of capacity addition they accounted for 84% of net capacity additions in 2021resulting in a 11% growth over the previous year to yield a total installed capacity of 3,146 GW. However, that is still not enough to meet the net zero emissions by 2050 as shown in Figure 1 [6].The demand for electricity is expected to be more than double over the next three decades. In 2018, only 26% of electricity was supplied from renewable sources, and two thirds of that was hydropower. With continued declines in the cost of electricity produced by renewable sources (solar, wind, and related technologies), variable renewable energy sources (vRES) are expected to become a dominant source of electricity in 2050. As per projections by IRENA shown in Figure 2[7], 74% of the world's installed electricity capacity would be

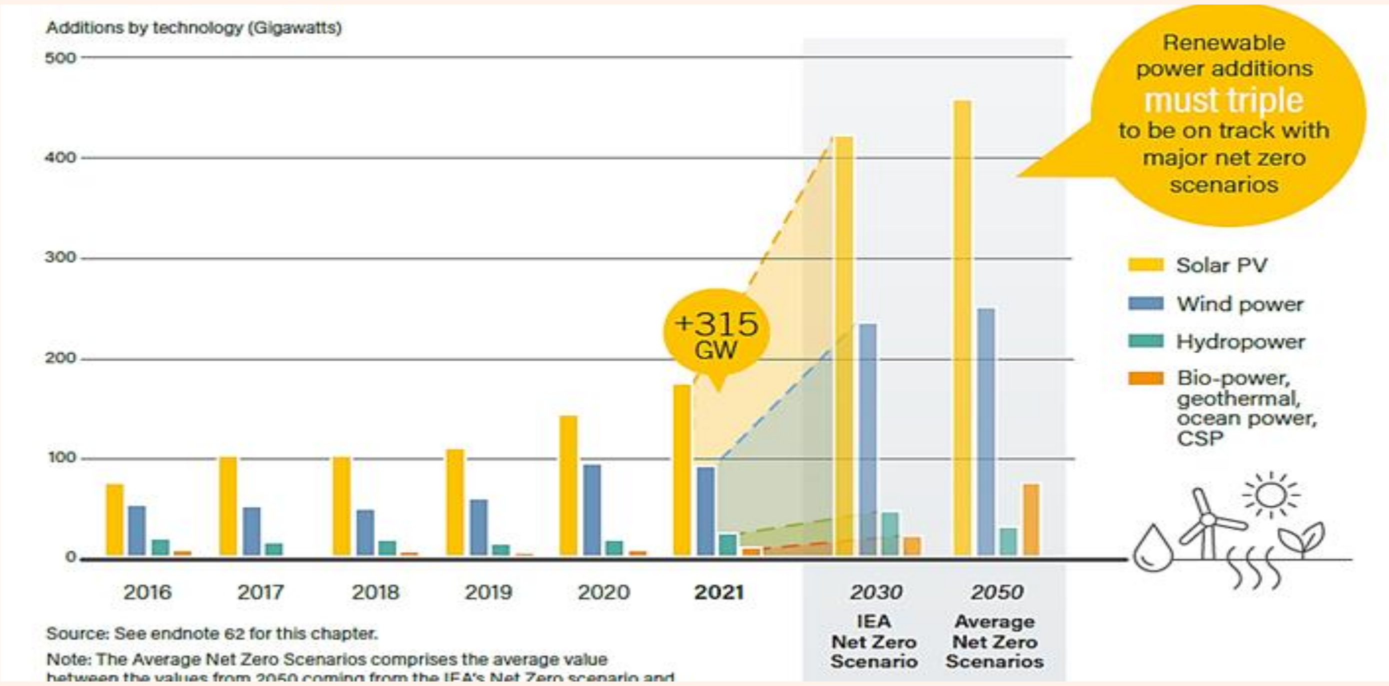

Figure 1: Growth of Renewables since 2016 and the need for achieving Net Zero scenario [6]

from variable renewable sources, and Nuclear is expected to be between 5~6% by 2050 [7].

Nuclear Power and Energy Transition

The number of operating plants has seen a marginal increase in the last three decades as shown in Figure 3a [8]. As per estimates by IEA, nuclear power generation grew by 3.5% in 2021 over 2020 globally. In 2020, as against 6 GW of capacity addition, there was 5.4GW of capacity shut down resulting in a net capacity addition of only 415MW. Considering current growth trends and policy targets, about 150GW gap is expected for Net Zero emissions scenario by 2050. To cover that gap, doubling the current rate of capacity additions as well long-term operation of existing plants is necessary. During the last 50 years, about 55 Gt of CO_2 emissions was avoided by nuclear power. That is almost equal to two years of energy related CO_2 emissions globally [5]. Figure 3b indicates CO_2e in gm/kWh for nuclear power generation vis-à-vis other power generation technologies [9].

The World Nuclear Association data [9] also demonstrates the relative benefits of nuclear vis-à-vis other sources of power generation including “green” sources. The land requirement (Figure 3c) and material usage (Figure 3d) for Nuclear is much lower than that for the renewables. The CO_2 equivalent is also much better, comparable with that of wind. Just the material required for power generation makes the nuclear far more attractive in comparison to green power sources. As already stated, various studies for 1.5° C rise in temperature have projected Nuclear share by 2050 to be around 5~6% [7]. The Inter-Government Panel on Climate Change have scenarios that say 15~20% nuclear is

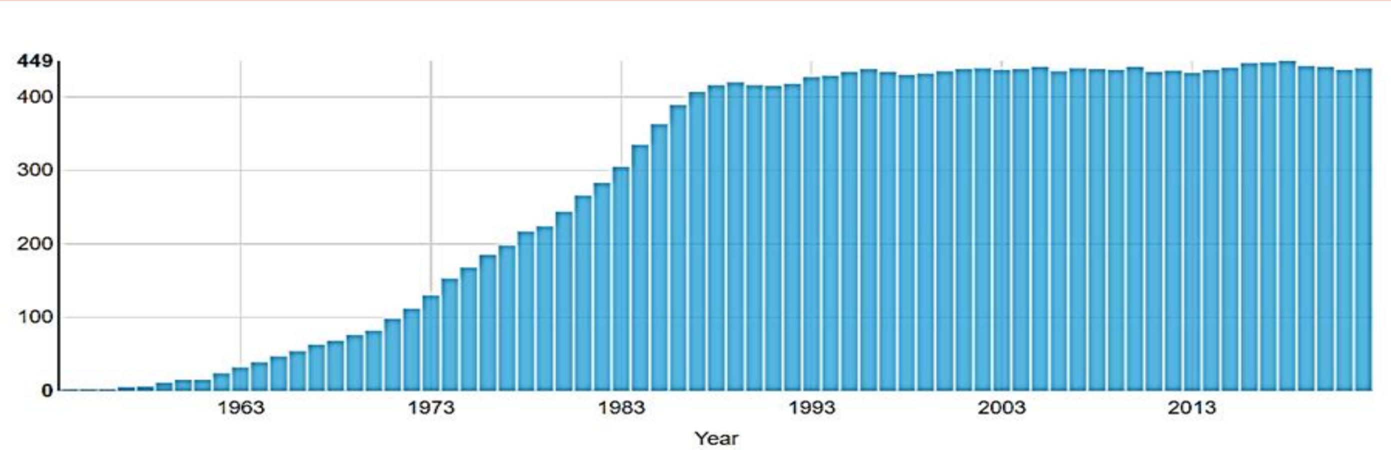

Figure 3a: Global count of number of nuclear reactors over the years [8]

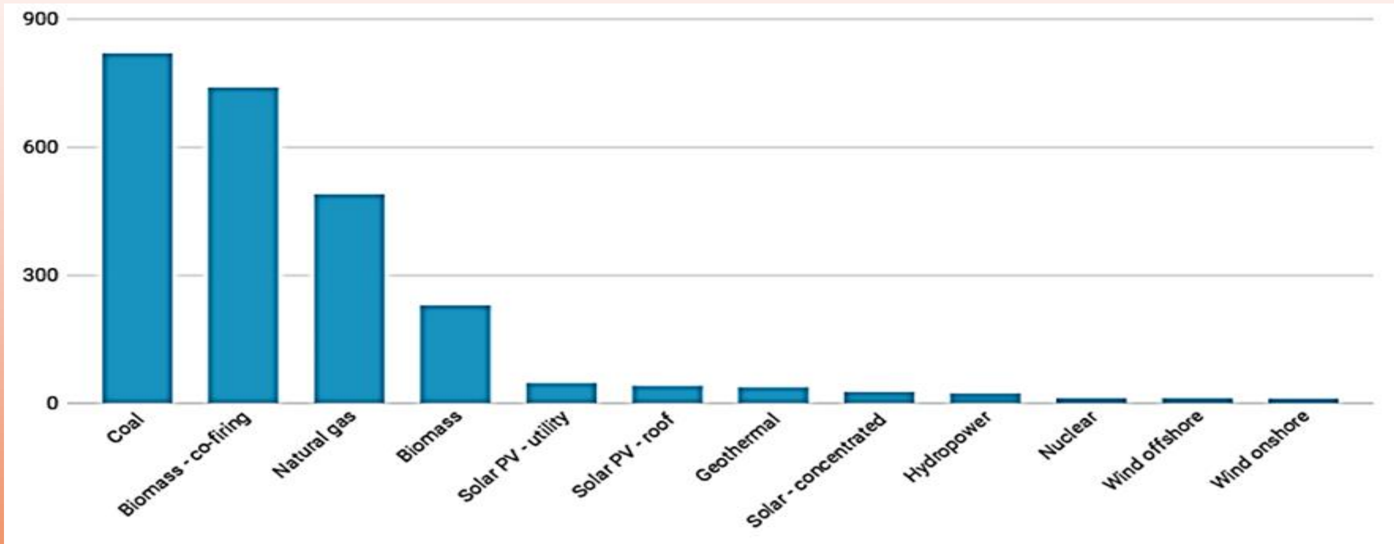

Figure 3b: CO2e in gm/kWh for nuclear vis-à-vis other power generation technologies [9]

the need if the targets have to be met for sustainable development [1]. The sector is now gaining attention and is slated for revival globally.

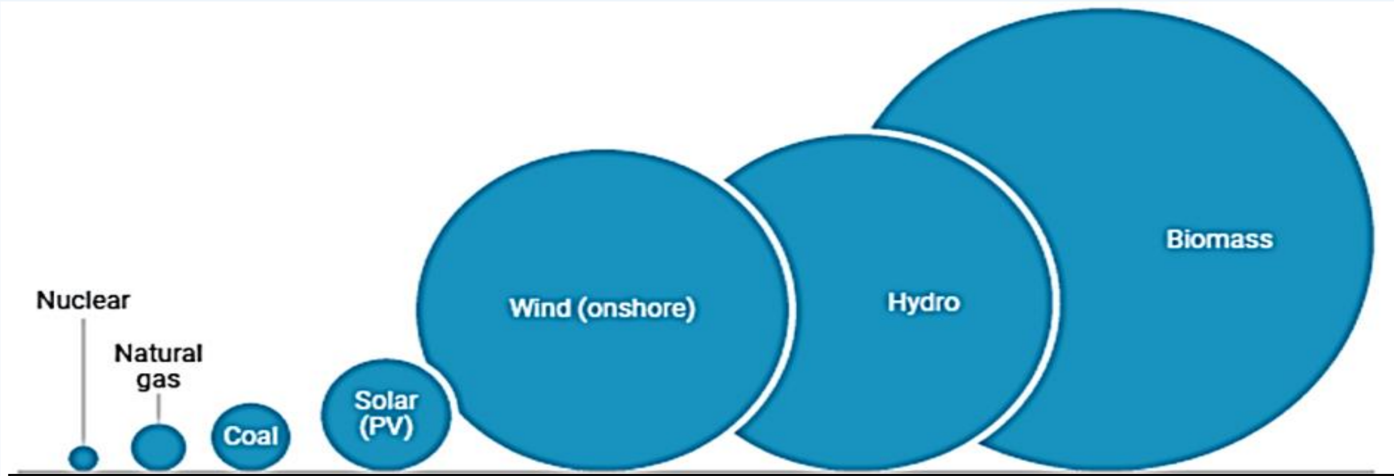

Figure 3c: Land requirement for nuclear vis-à-vis other power generation technologies [9]

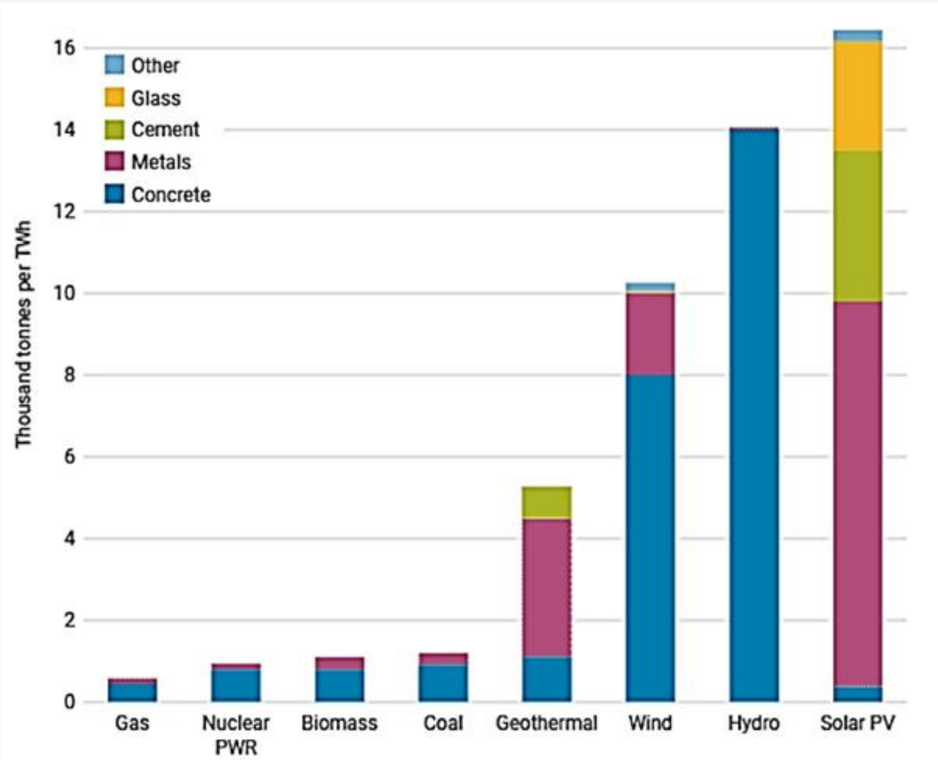

Figure 3d: Material requirement in Thousand tonnes TWh for nuclear vis-à-vis other power generation technologies [9]

India's Plans for Nuclear Power Plants

India's nuclear share continues to remain at 2~3% maximum in the overall mix. The National Infrastructure Pipeline (NIP) [10] vision is also maintaining 2% till 2025. Most of the estimates for nuclear power in 2050 maintain this 2~3% of the total electricity mix. The Union Cabinet has accorded clearance for Fleet Mode Reactors and corresponding budgetary allocations would be made as per National Infrastructure Pipeline announced in 2020. DAE's vision (set by Dr Homi Bhabha) is PHWR in Stage 1, FBR in Stage 2 and ultimately Thorium reactors in Stage 3 to achieve energy security for the country. PHWR Fleet mode developments are well known – the engineering for the Gorakhpur plant has been completed, and construction is in progress; Kaiga 5 & 6 have been awarded. PFBR is under advanced stage of commissioning.

India is also importing LWR technologies. While VVER is already in the country, EDF has submitted a techno-commercial offer for Jaitapur EPRs. Preliminary work on the same is in progress. Added to that would be work related to operating plants, safety assessments and capacity additions needed in fuel / waste management. This decade seems to be the most promising for the Nuclear power sector that the Industry has seen for a while in India.

India is also a part of the Fusion Mission and several Indian companies are providing services for the International Thermo-nuclear Experimental Reactor.

Role of TCE in India's Nuclear Journey

TCE has been a partner to DAE and NPCIL in services for Power Generation, Fuel Processing, Waste Management, and Seismic Qualifications (margin assessments with respect to current day Indian standards) for operating plants.

In power generation, except for the core reactor systems, TCE has supported NPCIL on engineering of all systems including but not limited to entire power island; balance of plant systems such as sea water intake / outfall, cooling water system, water treatment and distribution, etc.); electrical and I &C systems including power evacuation and system studies; common services (such as compressed air, chilled water, service water, DM water, fire protection and HVAC); entire plant civil, structural and piping as well as reactor auxiliary systems (cooling systems for calandria, end shield, active process water and SFSB). TCE's involvement started with the First indigenous 220 MW MAPS followed by First 500 MW at Tarapur and the First 700MW at Kakrapar. In KAPP 3 & 4, the Main plant Integrated 3D Engineering has been done by TCE along with NPCIL; while the BOTIP (Balance of Turbine Island Package) engineering, sea water intake and the heat sink systems were performed by TCE. TCE also performed the complete engineering for the nuclear island (except the core systems) and civil engineering for BOTIP for the BHAVINI FBR. In RAPP, complete engineering for BOTIP was by TCE. Figure 4 represents TCE's involvement in Nuclear Power Plants in India.

TCE has contributed to the engineering of fuel processing and waste management systems related work. That included civil and structural, electrical and I&C, layout and piping systems, common services, integrated 3D engineering and remote handling systems for spent fuel reprocessing facilities, fuel fabrication facilities, waste management plant and waste storage facilities. The work is performed for various units of DAE such as BARC, NFC, NRB, IGCAR, etc.

TCE has also contributed to services related to operating plants. Those are mostly for seismic margin assessments for various plants such as Narora, Kakrapar, Kudankulam and for a test facility at IGCAR. Capabilities include asset digitization, seismic margin assessments, probabilistic safety assessments, digitalization and Industry 4.0 applications.

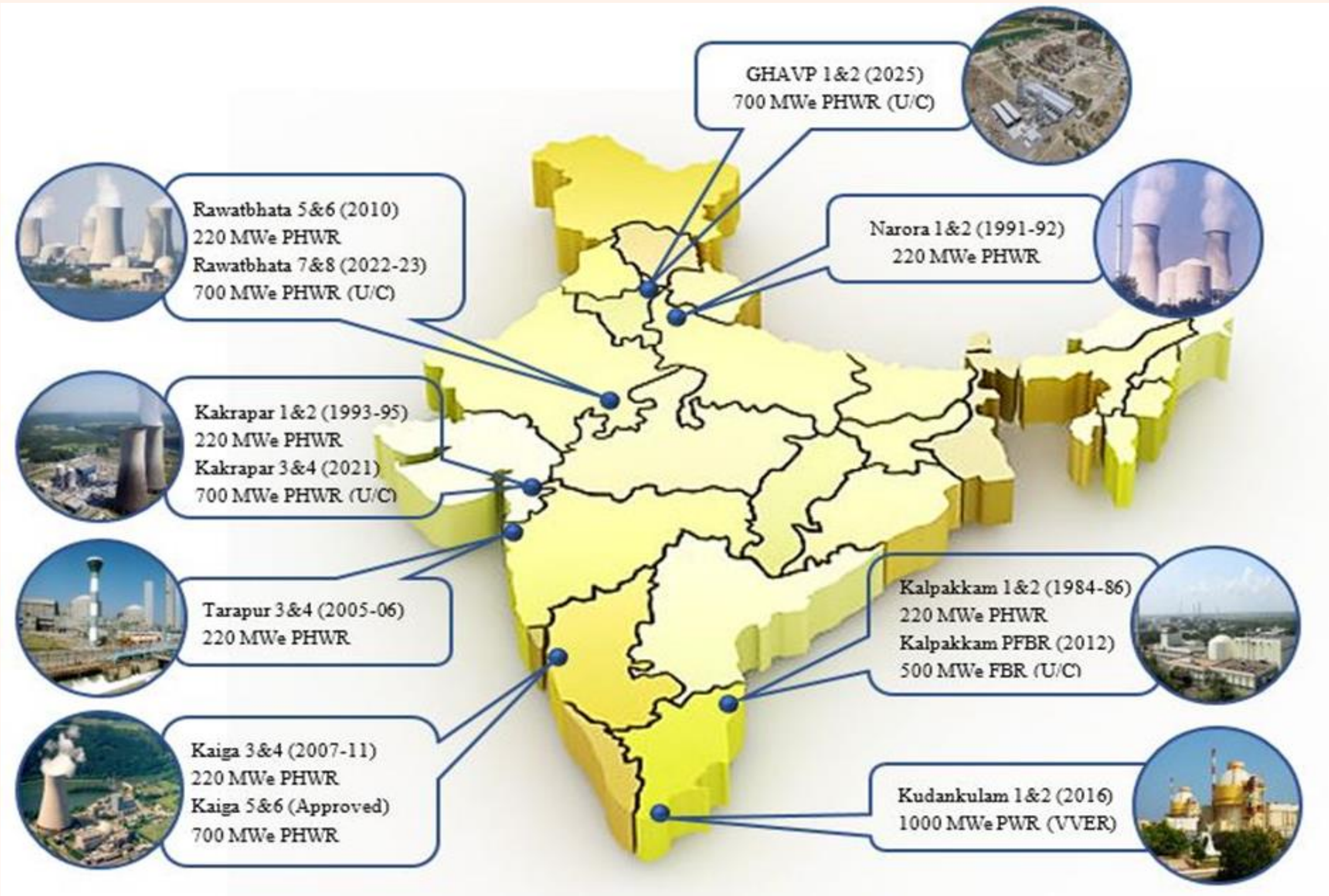

Figure 4: Nuclear Power Plants in India with engineering involvement by TCE

TCE is involved in some of the unique product development related work such as shielded platform design for removing contaminated components; Fuelling machines for PHWR, AHWR, with capability to have motion along the three axes for removing spent fuel as well as loading the fuel in the core; personnel and emergency air locks as well as automated material transfer systems for different processes inside the glove box.

Role of Private Companies in Growth of Nuclear Power Industry

For India's energy security as well as for the realization of NPCIL's plans of building 10 units of PHWRs in fleet mode (and many more in future), along with agreements in place for bringing in VVER, EPR and AP1000s, the volume of work demands greater participation of private sector in engineering and project management activities. The Department of Atomic Energy set up the Power Projects Engineering Division initially for the design activities and further incorporated NPCIL in 1987 to operate and implement nuclear power projects. Similarly, BHAVINI was set up for FBRs. This must now evolve along the organic route of more involvement of private sector.

The first nuclear reactor in France was commissioned in 1963. The oil crisis of 1973 resulted in "Messmer Plan" and subsequent installation of 56 reactors over the next 15 years. Though EDF has been the fulcrum of the industry, it has set up several companies with specific purposes, objectives, and agenda, allowing private sector participation and developed the French nuclear education system for the realization of the plan – which has resulted in French industry being at the forefront of the nuclear industry globally. India and NPCIL is possibly in a similar stage in the current times. If a country like France (of size one-sixth and population one-twentieth of India) can do it decades ago, a large country like India with its vast pool of human resources, very good education system and a strong-willed government is certainly capable of achieving its aspirations. This requires extensive work to cover the complete spectrum of professions for the development and operations of a fleet of nuclear power plants and necessary fuel cycle facilities. Expertise is required in all areas: engineers and researchers for design, operation, and innovation; technicians for operation, security and maintenance; experts in the fields of materials, radiation protection, nuclear law, project management; and professors and teachers to transfer the nuclear education, knowledge and skills. Homi Bhabha National Institute (HBNI) is performing these activities at present and can be supplemented by private sector to play a critical role for their expansion in all these spheres required for an expected enlarged nuclear programme.

NPCIL should only be involved in approval of designs and should involve private sector in the entire project lifecycle from concept to commissioning. The extent of activities performed by private sector today encompasses few areas like manufacturing of equipment, EPC contracts in project execution, operation of some auxiliary services, repair and maintenance services during operation, and engineering design activities such as 3D modelling, civil/structural designs, piping qualifications, support & EP qualifications, production of construction documentations etc. The private sector should be groomed to take up activities that are conceptual in nature and further into high end areas that NPCIL is currently doing. That should also include core reactor island related work – after ensuring necessary non-disclosure undertakings towards the intellectual property, export control, etc., from the company as well as working individuals. The available bandwidth at NPCIL should be utilized to work in parallel on several projects and ensuring overall correctness on intent and purpose while private sector resources can be used in replicating the proven designs.

The expertise on core reactor systems, fuel handling, radiation waste, thermal hydraulics etc., is not available in Indian private companies but the same is available with MNCs in India. That is because of the opportunities provided in the respective countries for those MNCs. If India's nuclear story is to fructify, then NPCIL should provide more opportunities for Indian companies to work in such niche areas. That would not only ensure 'Atmanirbhar Bharat' but also allow the Indian companies to stand on the same platform as MNCs for other global opportunities in this growing industry.

Further, when several large projects need to be carried out in parallel, NPCIL may also want to build dedicated partner teams working full time throughout the year for NPCIL on their projects in design offices as well site offices. Such teams working throughout the year for NPCIL may be placed within NPCIL's office or in an access-controlled facility within the engineering partner's office. The agreement may be for a core team that works with, understands the way of working with and develops excellent working relationships with NPCIL engineering teams, technology, and tools. Based on the varying workload, the core team may be expanded at reasonably short notices by flex and surge teams for specific engineering disciplines. The rates for different grades may be agreed beforehand through a rate card and resources could be ramped up or ramped down based on projected workload demands. Such a flexibility helps in keeping costs under control as well. This model has been in existence in software industry and is practiced in engineering industry as well. TCE has built such teams for several domestic and international customers.

When multiple construction sites must be managed simultaneously, the project management and construction supervision at specific sites may be handled by the private sector. Inspection, expediting, construction supervision, safety and quality at site, stores management, bill certification, using digital technologies and tools to manage working personnel and overall site, etc. are the activities that can be managed by partners. NPCIL should have its expertise available at site only to oversee quality assurance in construction and commissioning as per design intent, manage the PMC team and to review MIS reports and compliances as per the NPCIL's and AERB's requirements.

NPCIL should focus on overall program management – for example, a fleet program, to ensure scheduled completion of planned projects in the program using the partnership ecosystem. A command-and-control centre may be set up in their headquarters to enable digital review and governance of ongoing works at partner locations (engineering designs), vendor locations (progress on equipment orders) and construction sites. Empowering partners, holding them accountable for progress and ensuring projects progress as per schedule through proper governance using digital technologies should be the leadership role that ought to be assumed by NPCIL.

During COVID in 2020, the Finance Minister announced opening of the nuclear energy sector for medicine and agriculture needs, i.e., nuclear isotopes for therapeutic purposes, and irradiation for food security and sterilisation. Some countries like USA, UK and Japan allow private sector participation in the nuclear power industry. In India too, the sector may encourage PPP in future, to allow private sector investments that may enable achievement of growth aspirations. For energy security in the country, nuclear power generation with private sector participation and DAE / NPCIL governance may possibly bring in investments as well as provide necessary bandwidth to enable timely completion of projects. Such combined efforts would not only enable the nation to achieve its decarbonization goals but also empower the industry to stand on its feet on global platforms. Former Chairperson of Atomic Energy Commission, Dr Kakodkar opines that NPCIL can set up joint ventures with private sector partners of demonstrated capability to set up nuclear power plants to accelerate capacity building to meet the net zero target [11]. Government of India has already permitted joint ventures between NPCIL and other PSUs.

Going beyond projects into technology development arena, several academia-industry collaboration programs with necessary government funding are ongoing globally in the areas of Small Modular Reactors (SMR), High Temperature Gas Reactors, Liquid Metal Reactors, Molten Salt Reactors, Nuclear Batteries, etc. [12]. From energy security perspective, especially after the Ukraine conflict and resulting energy crisis, venture capitalists are funding the start-ups in nuclear energy with an investment of $3.4 billion in 2021 compared to $381 million in 2020[13]. SMRs, Fusion and Molten Salt are the key areas of start-up activities [14, 15]. Private sector in India can partner with DAE and academia through collaboration programs on technology development, pilots, and prototypes.

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The French Nuclear Power Model: Transposition to the Indian Energy Sector

In the 1970s, France faced sharp energy price increases following the first oil crisis. This led the country to develop a long-term energy policy aiming at ensuring its energy independence. In 1973, French Prime Minister Pierre Mesmer announced the construction of 13 light-water nuclear reactors and several fuel cycle facilities. This was, in fact, the beginning of a much larger program, as France was to build 58 nuclear reactors, spread over 19 plants, built over some 20 years. A program carried out under four successive presidential mandates without interruption or questioning.

This fleet of light water reactors is technologically homogeneous and has three power levels: three-loop 900MWe (32 reactors), four-loop 1300MWe (20 reactors), and four-loop 1450MWe (4 reactors). With 56 operating nuclear reactors, this fleet produced in 2020, 65% of France's electricity (335 out of 510 TWh). This fleet has enabled France to have the cheapest electricity in Europe and one of the least carbon-intensive electricity mixes. In its latest study published in 2022[1], the electricity company EDF calculates that one nuclear kWh produced in France emits 4 grams of CO_2, considering extraction, enrichment, production, waste management, and dismantling. The French electricity mix is emitting 35 g CO_2/KWh compared to a European average of over 300 g CO_2/KWh. To manage spent fuel and optimize uranium resources, France has decided, as India, to close its fuel cycle by recycling or reprocessing spent fuel.

The post-Fukushima reflection

In 2011, the Fukushima Daiichi accident postponed the launch of new construction projects worldwide, including in France. In order to evaluate the robustness of all nuclear reactors to possible extreme conditions (earthquake, flooding, loss of electrical power, combination of such events…), the country launched a significant stress test on its fleet following guidelines jointly defined by all European regulatory bodies.

In the early 2000s, France chose a so-called third-generation reactor, the EPR, for the future of its power plants. With its very high power

(1650MWe), its level of safety and competitiveness is significantly increased. At equivalent electricity production, it enables a more efficient use of fuel and a significant decrease of radioactive waste. In 2007, France launched the construction of an EPR which will be commissioned early 2023 at home. However, today, two units are in operation in China, one has been recently started in Finland and two reactors are under construction in United Kingdom.

The feedback from Fukushima Daiichi accident aims at eliminating the risk of a core meltdown as well as emptying the pools, and ensure that water is available at all times to cool the facilities. It has resulted in the implementation of the concept of “hardened safety core”, an ultimate safety measure to deal with extreme situations and the implementation since 2015 of the Nuclear Rapid Action Force (FARN), mobile intervention resources (compressors, pumps, electricity generators…) that can be deployed on any damaged nuclear site to provide water, electricity or compressed air. EDF is also equipping itself with new resources, such as the installation of last resort diesel or "Diesels d'ultime secours" (DUS), designed to maintain the water supply to the reactor cooling system in the event of an accident and a bunkered crisis center.

A new French program

After a decade of procrastination on the renewal of the French nuclear fleet, several reports have highlighted that the most competitive and least expensive solution to achieve carbon neutrality by 2050 is a balanced mix of nuclear and renewable energies. Thus, in early 2022, French President Emmanuel Macron announced the launch of a significant new nuclear program. The goal is to build three pairs of new EPR with an option for eight additional reactors. EDF is currently working on these new constructions (definition of the schedule, financing, sites selection…) and public enquiries will be soon set up.

The French President has also announced that significant resources will be dedicated to the development of a new SMR (NUWARD), two independent reactors of 170MWe each. Based on proven technology and integrating innovations, it will provide a complementary solution to renewable energy sources, aimed at replacing ageing coal-fired plants, supplying remote areas and energy-intensive industrial sites. It is also designed to support other potential market needs (hydrogen production, water desalinization, heat cogeneration…).

The French model is unique in the world. In two decades at the end of the 20th century, the country managed to decarbonize its electricity production in an unusual way while strengthening its energy independence and security of supply. Moreover, today, the advantage of nuclear power is major amid a climate crisis that calls for an urgent end to the exploitation of fossil fuels. France is now preparing to repeat the feat of this massive nuclear project to ensure the resilience of its energy system for the next century.

Transposition to the Indian model

As all others countries in the world, India faces a huge energy challenge as it must significantly decrease its carbon intensity while drastically increase its electricity production in coming decades. Under a scenario aligned with the Paris Agreement targets (i.e., warming below 2°C), the Indian subcontinent needs to achieve an electricity mix of 59 grams of CO_2 per kWh compared to an estimated value of 725 g CO_2 in 2019 according to the IEA.

Renewable energies, especially solar energy, will be the most important lever for this decarbonization while meeting growing consumer demand. However, nuclear energy has a significant role to play not only to produce carbon-free electricity but also to contribute to other applications as the production of green hydrogen.

IPCC and IEA calls

Experts call for the absence of global solutions in the latest IPCC report on climate change mitigation[2]. They explain that since 2015, the year of the Paris Agreement, emissions from the energy sector have increased by 4.6%. Figure 1 provides a comprehensive list, by sector, of mitigation options to reduce our net emissions by 2030 and their respective contributions. The options listed are those that are already available. Nuclear power appears as the third most crucial contributor after wind and other renewables.

In the latest report from the International Energy Agency (IEA)[3], published on 30 June 2022, Director General Fatih Birol says: "In the current context of the global energy crisis, soaring fossil fuel prices,

[1] https://www.sfen.org/rgn/les-emissions-carbone-du-nucleaire-francais-37g-de-co2-le-kwh/

energy security challenges, and ambitious climate commitments, I believe that nuclear power has a unique opportunity to make a comeback." The authors predict that global nuclear capacity will double by mid-century in a system dominated by renewables. It will increase from 405 GW installed today to more than 800 GW.

The EPR project in Jaitapur

In this context, the Indian Prime Minister, Narendra Modī, during a visit to France on 4 May, "reaffirmed his determination to ensure the success of the strategic EPR project" in India.

For the record, EDF submitted a technical and commercial offer in Spring 2021 for the engineering studies and supply of equipment for the construction of six units at the Jaitapur site in the state of Maharashtra: Jaitapur Nuclear Power Plant (JNPP).

"As a leader in low-carbon energy solutions and the world's largest nuclear operator, we are proud to support India in a major project viz. net carbon neutrality by 2070[4] and which resonates perfectly with the Group's purpose. To achieve this goal, we look forward to signing an agreement with our Indian counterpart in the coming months," said Jean-Bernard Lévy, Chairman, and CEO of EDF.

The technical configuration of the EPR for JNPP is based on the Flamanville 3 EPR reference plant in France, with design adaptations to consider the tropical climate and site conditions. It also incorporates adaptations to meet NPCIL requirements in the Indian regulatory context. JNPP is then set to become the largest nuclear power plant in the world, with a targeted installed capacity of 9.6 GWe. It will rely on the robustness of the French EPR technology - the state-of-the-art high-power generation III+ reactor and on the unique industrial capabilities of EDF and its partners: Framatome (engineering studies and equipment of the nuclear steam supply systems), GE Steam Power (engineering studies) and equipment of the 6 conventional islands, EDVANCE (engineering studies).

The JNPP will produce approximately 12 TWh of electricity per year per unit. It will avoid significant CO_2 emissions: between 50 and 80 million tons of CO_2 per year for 6 EPRs. Moreover, this nuclear project will have a minimal land footprint: 20 to 25 ha per unit, depending on the configuration of the plant.

Economic contribution

The JNPP project will bring socio-economic benefits to the Indian economy throughout the 15 years of construction and at least 60 years of operation and maintenance of the entire plant. There will be a high degree of localization for the benefit of the Indian industry. These intense localization activities have been undertaken since 2008 and accelerated since 2016 to ensure a wide range of manufacturing and sourcing opportunities.

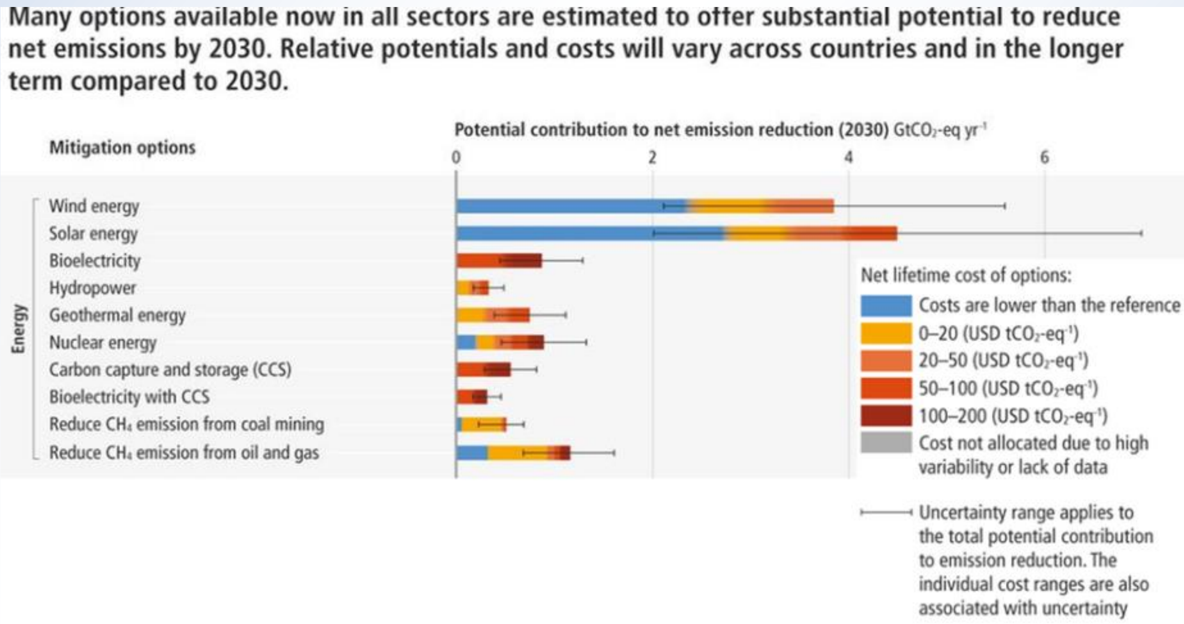
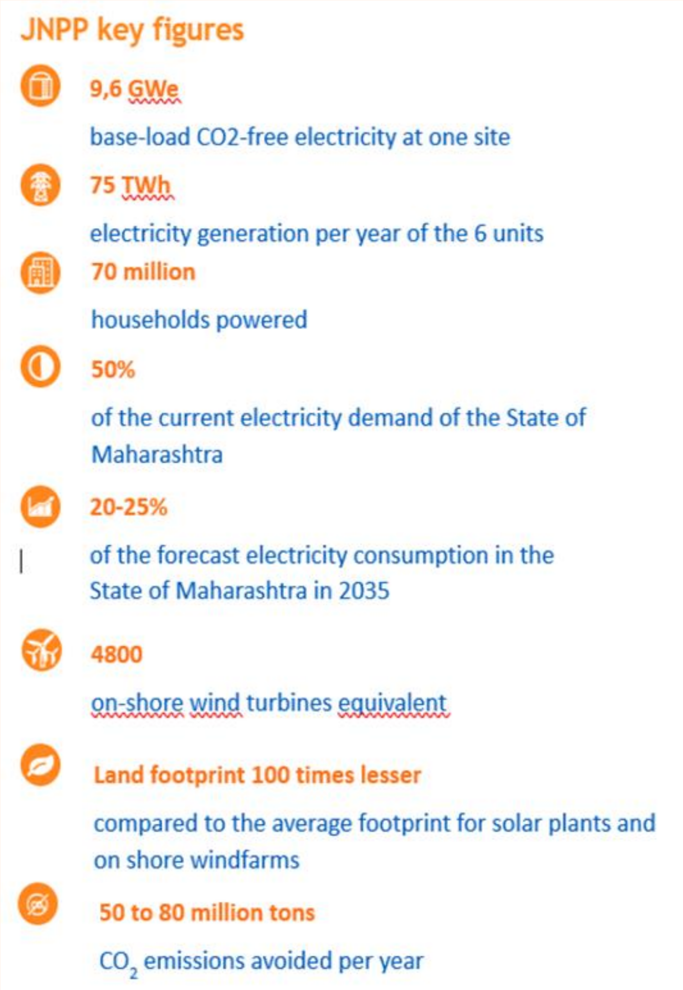


Figure 1: Overview of mitigation options and estimated range of costs and potentials in 2030

[2] https://www.ipcc.ch/report/ar6/wg2/

[3] https://www.iea.org/reports/nuclear-power-and-secure-energy-transitions?utm_content=buffer959d0&utm_medium=social&utm_source=twitter-ieabirol&utm_campaign=buffer



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[4] India's installed renewable energy capacity has increased 396% in the last 8.5 years and stands at more than 159.95 Giga Watts (including large Hydro), which is about 40% of the country's total capacity (as on 31st March 2022).

Glenn Theodore Seaborg: A Co-discoverer of 10 elements and a Nobel Laureate

Introduction

Scientific advisor to 10 U.S. presidents, co-discoverer of 10 elements and a Nobel Laureate, Glenn Theodore Seaborg, is also credited with the discovery of Plutonium, an element which has changed the course of history since second world war. His co-discoveries include about 100 isotopes, which have practical applications in research, medicine, and industry. He was awarded 50 honorary degrees for his contributions to science education and community service. From 1961 to 1971, he served chairman of the United States Atomic Energy Commission. He was Professor of chemistry at the University of California, Berkeley, Associate Director at large of the Lawrence Berkeley Laboratory, and Chairman of the Lawrence Hall of Science. He also had the rare distinction of being the only scientist in honor of whom an element was named in his lifetime. On March 13, 1994, the discoverers of element 106 recommended that this element be named Seaborgium, with the chemical symbol Sg, in his honor, which was accepted by IUPAC, in 1997.

Childhood and Education : 1912-1934

Glenn Theodore Seaborg was born in a Swedish ancestry in Ishpeming, Michigan, to Herman Theodore Seaborg and Selma Olivia Eriksson (changed to Erickson) on April 19, 1912. His only sibling, Jeanette, was born two years later. Since Glenn's parents were of Swedish origin, he learned to speak and understand Swedish before English. He started kindergarten in the High Street School in Ishpeming in September 1917 and continued there through the first three grades. Glenn was nicknamed "Lanky" because he was much taller than his classmates. Glenn never forgot his roots in Ishpeming and was always very proud of his Swedish ancestry. When Glenn was 10 years old, his family moved to Home Gardens, near Los Angeles, California. This move to California was made primarily because his mother wanted to broaden her childrens' horizons beyond the limited opportunities available in Ishpeming. Unlike in Ishpeming, where his father had guaranteed employment for life as a machinist in the iron works, in California his father never found permanent employment in his trade, and the family finances were in rather poor condition. Glenn started earning money, in his teens, by mowing lawns, and performing other odd jobs. He attended high school in the Los Angeles suburb of Watts and developed a special interest in chemistry and physics, which he attributed to his inspiring high school chemistry and physics teacher, Dwight Logan Reid. He graduated as valedictorian of his class in 1929. At first, he obtained work in a warehouse as a stevedore, but then found summer employment as a night laboratory assistant in the Firestone Tire and Rubber Co. to earn money for his freshman year at the University of California at Los Angeles (UCLA). UCLA was a tuition free public university and his earnings made it just barely possible for him to enter college in the depression year of 1929 because he could live at home and commute with friends some 20 miles to UCLA. He continued to work at a variety of odd jobs, but after getting a 99% in the Quantitative Analysis examination in the Fall of 1930, he was hired to help in the labs and stockroom for 6 hours a week at 50 cents an hour. Then he was awarded a $150 scholarship for 1931-1932, a handsome sum in those depression days. He decided to major in chemistry rather than physics because he felt it would provide him with better career opportunities if he was unable to find a position as a university teacher. During his last year, he became particularly interested in the exciting new developments in nuclear physics and chemistry. After receiving his degree in chemistry in 1933, he stayed on for the fifth year (1933-34) to take a number of courses in physics, which had just that year been started at the graduate (master's degree) level.

At University of California, Berkley (UCB): 1934-1942

Since UCLA had not instituted the graduate (Ph.D.) program in the Department of Chemistry, he moved to Berkeley to pursue graduate work in chemistry. There he met the great Prof. Gilbert Newton Lewis, dean of the college of chemistry, and the rising young nuclear physicist Ernest Orlando Lawrence, who invented the cyclotron in the early 1930s, for which he received the Nobel Prize in physics in 1939. Seaborg took formal courses in chemistry from many eminent professors at UCB and earned his Ph.D. in chemistry in the spring of 1937 with a thesis on the *"Inelastic Scattering of Fast Neutrons"*. He was asked by Prof. Lewis to stay on at Berkeley to serve as his personal research assistant. Glenn regarded Lewis as one of the scientific geniuses of his time and as a great teacher; they published several papers together. In 1939, he became an instructor at Berkeley and in 1941 he was promoted to assistant professor. During this period, he started collaborating with the physicist J. J. Livingood who had discovered several dozen new isotopes. Many of these, including Iodine-131, are widely used in nuclear medicine procedures. In 1938, he and Emilio Segré discovered ^{99m}Tc, the most widely used radioisotope for nuclear diagnostics. These experiences as a *"Radioisotope Hunter"* led eventually to the exploration of the transuranium elements, which became Glenn's life-long research interest.

Nuclear Transmutation/Fission: Neptunium Discovery

Even during his graduate years, Glenn closely followed the developments from Enrico Fermi's group in Italy, which was bombarding uranium with neutrons and producing what they thought were transuranium elements, and the research of Otto Hahn, Lise Meitner, and Fritz Strassmann in Berlin on these so-called transuranium elements. These results were widely discussed at Berkeley at the weekly nuclear seminars and physics journal club meetings. In January 1939 the exciting news of the discovery of nuclear fission by the Berlin Group came to Berkeley by word of mouth. Edwin M. McMillan and Philip H. Abelson then set out to study the fission process by bombarding uranium with neutrons (produced by the bombardment of 8-16 MeV deuterons on a beryllium target) at Berkeley's new 60-inch cyclotron. Quite unexpectedly, they produced and identified the first "*real*" transuranium element, which they chemically separated and identified as element 93, for which they proposed the name *Neptunium*.

Plutonium Discovery

Soon after the discovery of neptunium in the spring of 1940 at the University of California, Berkeley, by Edwin M. McMillan and Phillip H. Abelson, the search for the next transuranium element was underway. McMillan was working on the synthesis of next heavier transuranium element (atomic number 94), but received a call for wartime research at the Massachusetts Institute of Technology. With McMillan's concurrence, Glenn continued this search and led a team consisting of fellow instructor Joseph W. Kennedy and his first graduate student, Arthur C. Wahl, in performing the first chemical separation and positive identification of plutonium in February 1941. It was produced as the isotope ^{238}Pu in deuteron bombardments of ^{238}U. Soon after, the new isotope ^{239}Pu was produced and was found to be highly fissionable. Because of potential military applications in nuclear weapons during World War II, these results were voluntarily withheld from publication until 1946. These discoveries led to the U.S. decision to undertake a crash program to develop nuclear reactors for plutonium production to be used in the U.S. Atomic Bomb project. In April 1942, Glenn took a leave of absence from Berkeley to go to the University of Chicago Metallurgical Laboratory to direct the work on the chemical extraction and purification of plutonium produced in the reactors.

The Plutonium Project and Marriage

In March 1942, when it was clear to Glenn that he is moving to Chicago to work on the plutonium project, he proposed to Helen Lucille Griggs (then E.O. Lawrence's secretary). The understanding was that he would soon come back to Berkeley and they would be married. In June 1942, he did return from Chicago to Berkeley and took Helen to visit his parents at Home Gardens, now a part of South Gate, near Los Angeles, California. During their return journey, he then persuaded Helen to marry enroute. They disembarked from the train at Caliente, Nevada, and married at Pioche, Nevada, on June 6, 1942. Helen and Glenn's marriage was to last for more than 56 years and Seaborg often fondly referred to Helen as "his best discovery". They had six children: Peter Glenn (who died in 1997), Lynne Annette Seaborg (Mrs. William B. Cobb), David Michael, Stephen Keith, John Eric, and Dianne Karole. Helen was his constant companion and advisor and accompanied him on most of his trips, faithfully attending the scientific and other symposia in which he was involved. Personally, he was most gratified to have her support in the audience when he spoke at some of the meetings.

Separation of Plutonium and Discovery of Elements (95-102): 1942-1961

The Metallurgical Laboratory Chemistry Group, headed by Seaborg, was responsible for devising plant processes for chemical purification of plutonium for the World War II Manhattan Project to develop an atomic bomb. The plant procedures, which were developed and later used in the manufacture of kilograms quantities of plutonium at Clinton, Tennessee, and Hanford, Washington, were devised on the basis of experiments with milligram (or less quantity) of plutonium. It represented a remarkable scale-up of more than six orders of magnitude, causing much initial skepticism about the success of the project. By 1944, the process chemistry of plutonium was established on an industrial scale.

The Actinide Concept

A few attempts of Seaborg and his co-workers to produce and identify the next transuranium elements beyond Pu (Z = 94) were unsuccessful until he came up with the *Actinide Concept* based on electronic structure. A new periodic table incorporating this concept was published in *Chemical & Engineering News* in 1945. It was viewed as a "wild" hypothesis because at that time it was commonly believed that thorium, protactinium, uranium, neptunium, plutonium, and the following elements should be placed as the heaviest members of groups 4 through 10. But Seaborg postulated that the heavier actinides, like their lanthanide counterparts, would be extremely difficult to oxidize beyond the trivalent oxidation state. Therefore, he made a strong case for the positioning of separate 14 elements heavier than actinium (atomic number 89) in the periodic table of elements as a 5f transition series under the lanthanide 4f transition series. This concept was verified when chemical separations based on trivalent homologues of the lanthanides were successfully used in 1944 to identify elements 95 and 96 , subsequently named *Americium and Curium*.

Nobel Prize: Post World War II Period

Glenn Seaborg returned to Berkeley from Chicago in May 1946 as Professor of chemistry, along with his associates, like Isadore Perlman, Burris B. Cunningham, Stanley G. Thompson, and Albert Ghiorso. In the following years up to 1958, Seaborg and co-workers, (including many graduate students and postdoctoral fellows), went on to synthesize and identify the next six transuranium elements with atomic numbers 97 through 102. The first of these, Berkelium (97) and Californium (98), were produced at the Berkeley 60-inch cyclotron in 1949 -50. Shortly thereafter, in 1951, Seaborg and McMillan shared the Nobel Prize in chemistry for their research on the transuranium elements. Elements 99 and 100 were most unexpectedly produced in the debris from the first thermonuclear device, which was designed and tested by the Los Alamos Scientific Laboratory on Eniwetok Atoll in the South Pacific on November 1, 1952. Its huge yield of some 10 megatons created such an instantaneous high neutron flux that at least 17 neutrons were captured by the ^{238}U in the device. Seaborg's group at Berkeley was the first to separate and obtain evidence for these new elements, working together with scientists from Argonne National Laboratory and Los Alamos to confirm these results. The group proposed the names *Einsteinium* and *Fermium* for these elements in honor of the great scientists Albert Einstein and Enrico Fermi.

Room 307 Gilman Hall at the University of California, Berkeley.

This photograph was taken on February 21, 1966, when the room was still much the same as it was at the time of first chemical identification of plutonium

Single Atom Chemistry

Mendelevium (^{101}Md), the ninth transuranium element to be discovered, was first identified by Albert Ghiorso, Bernard G. Harvey, Gregory R. Choppin, Stanley G. Thompson, and Seaborg in early 1955 as a result of the bombardment of about 10^9 atoms of the isotope ^{253}Es (20-day half-life) with helium ions in the Berkeley 60-in. Cyclotron. The isotope produced was ^{256}Md, which decayed with a short half-life (approximately 1 h) by electron capture to ^{256}Fm, which in turn decayed predominately by spontaneous fission with a half-life of 2.6 h. This first identification was notable in that only a few atoms per experiment were produced. The definitive experiments were performed in a memorable all night session, February18, 1955, with chemical identification by the ion exchange adsorption elution technique. A total of five spontaneous fission counts were observed in the element 101 portion, and a total of eight spontaneous fission events were also observed in the element 100 position. This element was the first to be discovered on a *one-atom-at-a-time* basis, and the techniques developed served as a prototype for the discovery of subsequent elements. Seaborg and co-workers produced

The codiscoverers of element 106,seaborgium (Sg) at the Heavy Ion LinearAccelerator building of the Lawrence Berkeley Laboratory at the time of discovery in 1974. From left to right: Matti Numia, Jose R. Alonso, Albert Ghiorso, E. Kenneth Hulet, Carol T. Alonso, Ronald W.Lougheed, Glenn T. Seaborg, and J.Michael Nitschke

Nobelium (102) in 1958 using the heavy ion linear accelerator at the Berkeley Radiation Laboratory. According to the actinide hypothesis, it was expected that nobelium should have a relatively stable 2+ state by analogy with ytterbium, which can be reduced from 3+ to 2+ with strong reducing agents. However, it was found that not only is the 2+ state of nobelium achievable, it is the most stable oxidation state of nobelium in aqueous solution. In addition to the discovery of transuranium elements, Seaborg and his colleagues were responsible for the identification of more than 100 isotopes of elements spread throughout the Periodic Table. During the period 1946-58, Seaborg served as director of the Nuclear Chemistry Division and in 1954 became an Associate Director of the Berkeley Radiation Laboratory. In addition to their pioneering work on the production and chemical properties of the transuranium elements, the division furnished much of the data on alpha-particle radioactivity and nuclear energy levels needed for the evolution of modern theories of nuclear structure.

Public Services & Other Responsibilities

Seaborg served in the first General Advisory Committee to the Atomic Energy Committee from 1947 to 1950. Consistent with his immense interest in athletics, he accepted Chancellor Clark Kerr's invitation to serve as Berkeley's faculty athletic representative from 1953 to 1958 and played a leading role in organizing the Athletic Association of Western Universities. When Kerr became president of the University of California in 1958, Seaborg was asked to serve as chancellor, which he did until 1961 when President-elect John F. Kennedy asked him to come to Washington, D.C., to chair the U.S. Atomic Energy Commission.

The Washington, D.C. Years (Chairman, The U.S. Atomic Energy Commission): 1961-1971

Seaborg was granted the leave of absence from the University of California to take up the responsibilities as the Chairman of the U.S. Atomic Energy Commission (AEC). His tenure from 1961 to 1971 was longer than any other chairman's and spanned the presidencies of John F. Kennedy, Lyndon B. Johnson, and Richard M. Nixon. Seaborg negotiated for the limited nuclear test ban treaty, which prohibited the testing of nuclear devices in the atmosphere or under the sea. This treaty was approved by the U.S. Senate in 1963. Seaborg was a strong supporter of the use of nuclear energy for power generation and led delegations to several countries, including the Soviet Union, for the promotion of peaceful uses of atomic energy. Even as Chairman, USAEC, he continued his interest in transuranium element research and the National Transplutonium Production Program was established at the High Flux Isotope Reactor, which was commissioned at the Oak Ridge National Laboratory in the mid-1960s. These facilities were used for the production of rare heavy-element isotopes used in the synthesis of new heavy elements and in heat sources for space exploration. Other radioactive isotopes for applications in biology, nuclear medicine, and industry were also produced. As AEC chairman, due to his strong support, the basic research programs in the physical sciences, biology, and medicine nearly doubled. He also felt the need of the improvement of teaching in science and mathematics to attract young people to careers in science.

Return To Berkeley: 1971-99

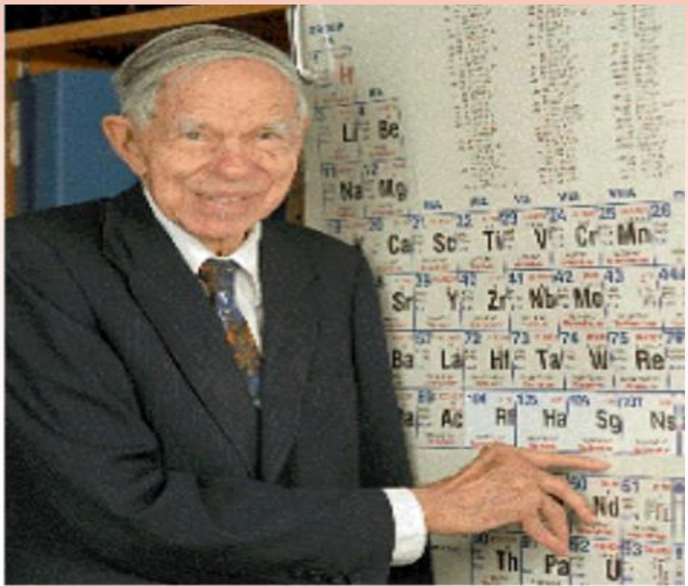
Seaborg returned to Berkeley in 1971 as University Professor of Chemistry. He continued to teach until 1979. He supervised the Ph.D. research of more than 65 students. In 1982, he became the first director of the Lawrence Hall of Science, which he founded. He served as Associate Director at large of the Lawrence Berkeley National Laboratory until his death in 1999. He was active in many international organizations for fostering the application of chemistry to world economic, social, and scientific needs. Seaborg maintained and even escalated his interest in better education in science and mathematics at all levels and served on many federal and state committees. President Reagan appointed him to be a member of the Commission on Excellence in Education (NCEE). Seaborg presented the report *"A Nation at Risk"* in April 1983. In 1989, Seaborg and the then Secretary of Energy James Watkins hosted a Mathematics/Science Action Conference at the Lawrence Hall of Science that again called for a revitalization of science education in the U. S. In 1989, Seaborg was asked to brief President George A. Bush on the *"cold fusion"* phenomenon.

Other Interests

Seaborg was a keen student of history and kept a

Journal since he was eight years old. After his return to Berkeley from Washington in 1971, he made a concerted effort to put them into a book form, which occupied him for several years. His Journals also formed the basis for monographs on his years as Chancellor at Berkeley, as Chairman of the AEC, and on several other fronts. On the rare occasions that he did not remember something that was asked, he would look it up in his Journals. He had a fabulous memory and was able to synthesize and apply to the situation at hand. One might almost say in the parlance of his time that he was a *"parallel processor"*! In 1990 he decided that a symposium must be held to commemorate the fiftieth anniversary of the first chemical separation and proof of the discovery of plutonium on February 23, 1941. In this meeting, the announcement of the initial establishment of the Glenn T. Seaborg Institute for Trans-actinium Science at Lawrence Livermore National Laboratory was made by its former director and Seaborg Ph.D. student Roger Batzel. The institute is devoted to the study of the transactinium elements with special emphasis on the education and training of future generations of scientists in heavy-element research. Seaborg's legacy as a Citizen-Scholar was also commemorated by establishing the Glenn T. Seaborg Centre and the new Seaborg Science Complex, in 1998, for teaching and learning science and mathematics at Northern Michigan University in the Upper Peninsula, not far from his birthplace in Ishpeming. Seaborg loved to hike, and he and his wife, Helen, laid out an interconnected network of 12-mile trails in the East Bay Hills above Berkeley extending to the California-Nevada border that forms a link in a cross-country trek of the American Hiking Society. He was also a strong supporter of the Berkeley athletic program. Football was his favorite spectator sport and he liked to point out that during his tenure as chancellor the Berkeley football team went to the Rose Bowl!

Element 106, which was reported in 1974 was named "Seaborgium" in honor of Nobel Laureate Glenn T. Seaborg. The name Seaborgium, with its chemical symbol of "Sg," was announced at the 207th national meeting of the American Chemical Society in San Diego. The announcement was made by Kenneth Hulet, retired chemist from Lawrence Livermore National Laboratory (LLNL) and one of the co-discoverers of seaborgium. This name was officially approved by the International Union of Pure and Applied Chemistry in 1997. It was the first time an element has been named for a living person. Seaborg, the co-discoverer of plutonium and nine other transuranium elements remarked, *"This is the greatest honor ever bestowed upon me, even better, I think, than winning the Nobel Prize. Future students of chemistry, while learning about the periodic table, may have reason to ask why the element was named after me, and thereby learn more about my work."*



Glenn Seaborg points out Seaborgium on the periodic table

Achievements & Honours

It is a daunting assignment to make an attempt to enumerate the major achievements of Seaborg, which culminated in Nobel Prize in chemistry in 1951. He held more than 40 patents, authored more than 500 scientific articles and authored some 50 books, including an autobiography published in 1998 entitled *A Chemist in the White House: From the Manhattan Project to the End of the Cold War*. Although most of his writings were in the field of nuclear chemistry, history of science, science education and public science policy, he has also collaborated on works in sports and collegiate history. The partial list of books and other major publications by Glenn T. Seaborg can be retrieved from "http://en.wikipedia.org/wiki/Bibliography of Glenn T. Seaborg". One of his last accolades was being voted one of the top 75 distinguished contributors to the chemical enterprise over the last 75 years by the readers of Chemical & Engineering News. It was this award that he accepted at a huge

In April 1992, Glenn Seaborg and his wife, Helen, celebrated his 80th birthday at Lawrence Hall of Science. The Time magazine cover behind them depicts Seaborg as chair of the Atomic Energy Commission, a position he held for a decade beginning in 1961.

ceremony and reception at the August 1998 American Chemical Society meeting in Boston the evening before he suffered a stroke. Seaborg's death came on February 25, 1999. while he was convalescing at home in Lafayette, near Berkeley. A few of the several awards bestowed on Seaborg are listed below:

Awards

1. 1947: Named as one of America's 10 outstanding young men by the U.S. Junior Chamber of Commerce;

2. 1947: Recipient of the American Chemical Society's Award in Pure Chemistry;

3. 1948: John Ericsson Gold Medal by the American Society of Swedish Engineers;

4. 1948: Nichols Medal of the New York Section of the American Chemical Society;

5. 1951: *Nobel Prize in Chemistry*

6. 1953: John Scott Award and Medal of the City of Philadelphia;

7. 1957: Perkin Medal of the American Section of the Society of Chemical Industry;

8. 1959: Atomic Energy Commission's Enrico Fermi Award ;

9. 1962: Swedish American of the Year by Vasa Order of America, Stockholm;

10. 1963: Franklin Medal of the Franklin Institute, Philadelphia;

11. 1971: Nuclear Pioneer Award of the Society of Nuclear Medicine;

12. 1973: Order of the Legion of Honor of the Republic of France, Decoration;

13. 1979: Priestley Medal;

14. 1984: Swedish Council of America's Great Swedish Heritage Award;

15. 1986: University of California's Clark Kerr Medal;

16. 1988: National Science Board's Vannevar Bush Award;

17. 1991: Presidential National Medal of Science.

Concluding Remarks

As an educator **Glenn Theodore Seaborg** inspired thousands of students to become interested in chemistry and its applications, and as a public speaker he helped develop an awareness of the impact of science on daily life and the importance of non-proliferation of nuclear weapons. It would be befitting to conclude about the accomplishments of the Science Giant Glenn Seaborg with an excerpt from the statement he delivered upon being appointed Chancellor of the University of California, Berkeley in 1958. *"There is a beauty in discovery.* ***There is mathematics in music, a kinship of science and poetry in the description of nature, and exquisite form in a molecule. Attempts to place different disciplines in different camps are revealed as artificial in the face of the unity of knowledge. All literate men are sustained by the philosopher, the historian, the political analyst, the economist, the scientist, the poet, the artisan and the musician."***

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Do you know?

Oldest water on earth dates back to 2.6 billion years

"It was absolutely mind-blowing," Sherwood Lollar, FRS and University Professor Earth Sciences ,Toronto, said. "These waters weren't hundreds of millions of years old like we might have expected. They were billions of years old."

As we all know, earth originated about 4.5 billion years ago with an explosion. In the beginning, it was a burning hot white mass of gas and dust. After millions of years, the outer surface of the earth or the earth's crust cooled and formed hard rock. Cooling of the earth also condensed water vapour into liquid water that filled the depressions to form seas. This water also flowed into fractures in rocks and became isolated deep underground for many years, serving as a time capsule of what the environment was like at the time they were sealed off. In these deep settings, water was held in cracks in the rock and, over time, they accumulated uranium, which in turn decayed over millions, or even billions of years, producing noble gases. These gases could be measured for their concentrations and ratios, from which the residence time of water in the rock has been deduced. The most ancient pocket of water known by far is ~ 2.6 billion years old, and is even older than the dawn of multicellular life.

A water sample from the mine (courtesy Canada Science and Technology Museum)

This water contained high salt content — about eight times more than that of seawater — as well as large concentration of uranium, and other radiogenic daughter products. Presence of high hydrogen and helium in these waters offers new insights about energy production and storage in Earth's crust. Considering the amounts of hydrogen and helium in these waters, scientists describe these locations as a "Pandora's box of helium-and-hydrogen-producing power." This finding raises the tantalizing possibility that ancient life might be found deep underground not only within Earth, but in similar places that may exist on Mars. Scientists believe "ancient groundwater sites may one day potentially serve as energy sources".

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Contributed by K.Tirumalesh and M.R.Iyer

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Compiled by S.K.Malhotra

INS Round up

1. INS Head Quarter

1.1 Following seven webinars were arranged by the INS under its Webinar Series-

The 20th webinar was delivered by Dr. Lalit Varshneya, RRF, Electron Beam Centre and Former Head, Radiation Technology Development Division, BARC on May 8, 2022, on ‘Radiation Technology for Sewage Sludge Hygienisation: Genesis and Development’.

The 21st webinar was delivered by Shri Neeraj Sinha, Senior Advisor, Neeti Aayog on May 21, 2022. on ‘The indigenous development of the advanced ultra supercritical technology for thermal power generation in India’.

The 22nd webinar was delivered by Dr. R N Patra, Former CMD, IREL, on June 4, 2022 on ‘Rare earth industry evolution- Indian perspective and challenges’.

The 23rd webinar was delivered by Dr. Chandan Banerjee, Deputy Director General, National Inst. of Solar Energy, on June 18, 2022 on Overview of Solar Energy Development in India’.

The 24th webinar was delivered by Dr. A S Kiran Kumar, Former Chairman, ISRO, on July 2, 2022. on ‘Harnessing Space Technology’.

The 25th webinar was delivered by Commodore Amit Rastogi, C&MD, National Reseach Development Corporation, on July 16, 2022on ‘IPR portfolio management in the context of R&D’.

The 26th webinar was delivered by Dr. Kalol Roy, Former CMD, BHAVINI, on July 30, 2022 on ‘Evolving Appropriate Engineering Strategies and Sustainable Design in Techno - commercial and Societal Framework - An Industry 5.0 Perspective’.

You tube links of these webinars can be accessed at youtube.com/Indian Nuclear Society

1.2 A joint team of a few INS EC members and BARC officers (nominated by Director, BARC) visited Nehru Science Centre, Worli to learn the status of exhibits in its Nuclear Gallery. Mandate of team was to submit a report on the Upgradation of Nuclear Gallery of NSC to Director, BARC, which was forwarded on 19th May, 2022.

2. INS Branches

2.1 INS Hyderabad Branch, under its 'Azadi ka Amrit Mahotsav Webinar Series' organised its 10th invited talk which was delivered by Padma Bhushan Dr. V. K. Saraswat, Member NITI Aayog on July 1, 2022 on 'Nuclear Power in Energy Transition to Achieve Net Zero Carbon by 2070'

2.2 INS, Rawatbhata, Rajasthan, Chapter organised an Interactive Technical Session on 15th July, 2022 for a group of 25 Industrialists and Technocrat Members of Small Scale Industries (SSI), Kota . Visiting team included President, Secretary and Managing Committee Members of SSI, Kota . Visit covered upcoming Nuclear Fuel Complex-Kota Project, Nuclear Power Corporation of India Limited, Rawatbhata and Heavy Water Plant (Kota). Multimedia presentations were arranged by all the 3 Units of Rawatbhata, DAE Center. Founder President, SSI and renowned engineer, Sh. Govind Ram Mittal also presented the activities and achievements of SSI, Kota Divison.

Chairman, Co-Chairman, Secretary, Treasurer as well as other Members of INS, Rawatbhata Rajasthan Chapter were actively involved in the program. Dr. G. Chourasiya , INS EC member coordinated the activity on behalf of Head Quarters. The visit provided an opportunity to both the parties to mutually understand their requirements and is likely to facilitate the participation of local industries in the DAE activities.

Recent Publications of INS Members of Wide Interest

1) Uranium Resources and Production: Global Availability and Indian Scenario—
A. K. Sarangi
Former Executive Director, Uranium Corporation of India Ltd. (e-mail: aksarangi@gmail.com)
Jour. Geol. Soc. India (2022) 98:877-882
https://doi.org/10.1007/s12594-022-2090-2

2) Estimating minimum energy requirement for transitioning to a net-zero, developed India in 2070
Rupsha Bhattacharyya*@, K. K. Singh@, R. B. Grover* and K. Bhanja@
* Homi Bhabha National Institute, Mumbai 400 094, India ; @ Chemical Engineering Group, Bhabha Atomic Research Centre, Mumbai 400 085, India.
(e-mail: rupsha@barc.gov.in)
Current Science, Vol. 122, No. 5, 10 March 2022

Compiled by S.K. Malhotra and Vijay Manchanda

Solution to the Cross word puzzle appeared in INS NL May,2022 (Vol 22 Issue 2)

DOWN
1. MILLI
2. MONOTHERMAL
3. TITRATE
5. CHI
6. SSSF
8. OOID
9. HARD
10. RADIOLYSIS
11. NATRIUM
15. MATERIAL
17. COUNTER
19. SOLGEL
23. CORNEA
24. GROSS

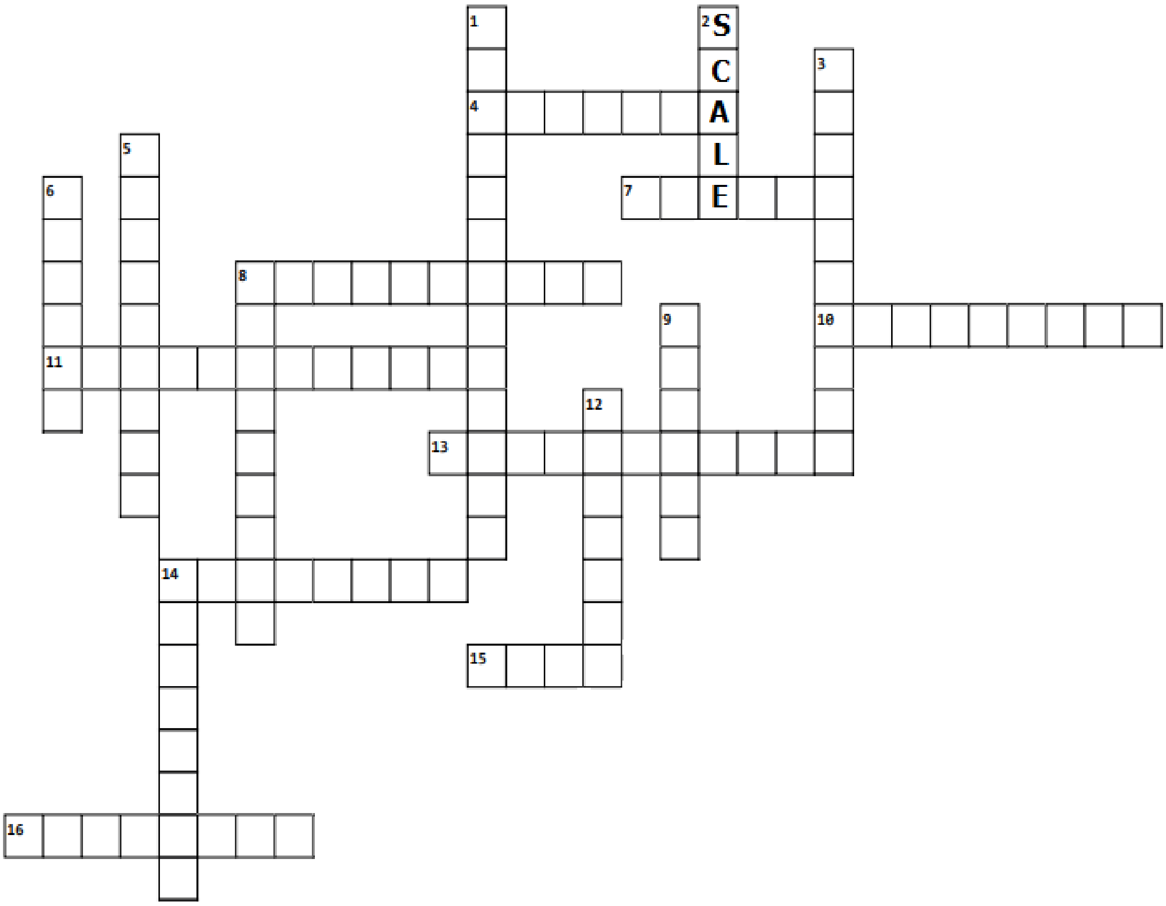
ACROSS
2. MUTANT
4. ACOUSTIC
7. INPRO
10. RAFFINATE
12. ADIT
13. RADURA
14. RAM
16. MOSCOVIUM
18. ACID
20. MOLTEN
21. PALLIATIVE
22. PITCH
25. GIRDLER
26. GLOVE

WINNERS
1. Dr Sanjay Kumar Saxena R.Ph.D., BARC
2. Dr S.G.Marathe, Ex BARC
3. Prof. A.N.Garg, Ex IITR

Editor

CROSSWORD

Contributed by A. RamaRao



Across		Down	
4	Series of coloured lines (7)	1	Action done without any perceptible time (13)
7	Apparently rather than actually (6)	2	Used to measure scientific quantities (5)
8	Objects in motion through space (10)	3	Measure to enhance clarity (10)
10	Irregular fluctuation of velocity (9)	5	Tube with a small bore (9)
11	Vibration of wave in one plane (12)	6	Term commonly used in celestial mechanics (6)
13	Constitution of a whole (11)	8	A general scientific theorem or law (9)
14	Mathematical study of continuous change (8)	9	A carrier to transfer energy (6)
15	Rotation about _ _ _ _ (4)	12	Absolute value of a real number (7)
16	Objects that emit their own light (8)	14	Laser is a _ _ _ _ _ _ _ _ light (8)

Pl send your cross word solution to insvkmeditor@gmail.com

The views and opinions expressed by the authors may not necessarily be that of INS

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Azadi ka Amrit Mahotsav

Announcement

As a part of the celebrations of Azadi ka Amrit Mahotsav, INS is likely to present November-2022 issue to its members in the printed form. Hard copy of this special issue will be sent by post to all those members who will send their correspondence address to:

indiannuclearsocietynl@gmail.com

Kailash Gharat for INS