INDIAN NUCLEAR SOCIETY

INS News Letter

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From Editor's Desk

Friends, it is unfortunate that COVID 19 is back with a vengeance. A recently published report in reputed medical Journal LANCET suggests that spread of SARS-CoV-2 is predominantly through airborne aerosols which can remain infectious up to 3 hours. These aerosols (of size varying in µm to nm range) could be trapped by air filters embedded in masks. We are reminded of the role of HEPA filters which are used to trap radioactive aerosols before releasing the air from radiological laboratories to atmosphere. Analogy with nuclear science may possibly help us understand the transmission behavior of SARS-CoV-2 aerosols.

It is encouraging to see that the challenge of carbon neutrality has been taken up seriously not only by the developed countries but also by the developing countries by recognizing the role of nuclear power in their pursuits of optimizing energy avenues. The dark clouds emanated from Fukushima 10 years back are slowly disappearing. Nuclear power capacity worldwide is poised to grow steadily, with about 50 reactors under construction today in 16 countries, notably in Asian countries viz. China, India, UAE and South Korea. During last few months, apart from 700 MWe, unit 3 of KAPP (which was connected to the grid on 10th Jan., 2021), Pakistan has connected its first Chinese assisted 1100 MWe plant in Karachi on 18th March 2021 and UAE has connected 1400 MWe Barakah unit 1 (constructed by KEPCO) in Abu Dhabi on 6th April 2021. Another momentous development was a letter coauthored by PMs / President of seven European countries addressed to the President and other dignitaries of the European Commission. It was contended " As low-emission baseload, nuclear power guarantees the continued renewable deployment to much higher penetration levels. Nuclear power seems to be also a very promising source of low-carbon hydrogen at an affordable price and can play an important role in energy sector integration". They made an urgent call to ensure a true level-playing field for nuclear power in the EU without excluding it from EU climate and energy policies and incentives, and bearing in mind that half of EU countries utilize or develop nuclear power providing close to half of EU low-emission generation, in line with the most stringent safety standards as ensured by the EURATOM framework.

There is a little doubt however that future of nuclear power in the long run rests largely on the development of safer and cost-effective technologies which may play a crucial role in building the public acceptance and help in boosting investments. In this context, lead article in present issue demonstrates that nuclear waste can be a resource of valuables rather than an environment hazard. Indian Nuclear Society like its counterparts the world over is committed to engage with all sections of the society and disseminate information which allays all the misgivings about the nuclear power and variety of societal programs in the areas of health, food and environment employing radioisotopes / radiations.

INS has made steady progress during last quarter in furthering its scientific activities. Three Webinars were organized on contemporary topics related to Nuclear Energy in India and the Carbon Constrained World (Details are given elsewhere in the NL). One can access all four NLs published since May 2020 on our website www.indiannuclearsociety.com. Solution of the crossword puzzle published in Feb., 2021 NL is included in this issue along with the names of winners. Everyone is welcome to send the solution of the puzzle of this issue to insvkmeditor@gmail.com asap. Names of winners will be published in the NL issue of Aug., 2021. INS would like to reach more professionals interested in the developments of Nuclear World and they are all invited to join the society. Membership form of INS can be downloaded from the website.

Vijay Manchanda

DAE News Brief

RRCAT develops e-Beam Facility

A multi-purpose electron-beam (e-beam) processing facility has been set up by the Raja Ramanna Centre for Advanced Technology (RRCAT) at Indore. The facility is based on the indigenously developed electron Linear Accelerator (LINAC) and is being used for the sterilization of medical devices, irradiation experiments on seeds for mutation breeding as well as grains for minimizing post-harvest losses and irradiation of gems and power electronics devices. Unlike conventional radioactive sources, accelerator-based sources can be switched on or off as and when required, and are thus considered inherently more secure. Furthermore, compared to radioactive sources, the processing time using an e-beam based facility is typically lesser by an order of magnitude.

This 10 MeV, 6 kW e-beam facility is licensed by Atomic Energy Regulatory Board AERB. It has also been accorded Food and Drug Administration (FDA) license for radiation processing of Risk Class-A medical devices and ISO 9001:2015 and ISO 13485:2016 certifications for providing electron beam processing services for sterilization of medical devices.

NFC supplies first set of steam generator tubes to BHEL

NFC and MIDHANI consortium has supplied Incoloy-800 (UNS N08800) - U Bend Steam Generator tubes to BHEL for use in the upcoming 700 MWe PHWRs for Gorakhpur Anu Vidyut Pariyojana. The consortium had bagged the prestigious order against Global tender for supply of these specialised tubes . These tubes were manufactured with complete indigenous technology starting from raw material supplied by MIDHANI to the finished tubes developed and manufactured at NFC under the Atmanirbhar Bharat mission . The first set of 2489 tubes of 26 m length U-bend in 72 different bend radii was dispatched, according to NFC.

The critical equipment required for manufacturing these tubes were indigenously developed and deployed for production. NFC has received order from NPCIL to supply one lakh tubes for the forthcoming 10 reactors to be set up by NPCIL under fleet mode.

Incineration of Low Level Radioactive Solid Waste employing Plasma Pyrolysis

Low level solid wastes (≤ 2 mGy/hr) are managed either by compaction or by incineration. Cellulosic wastes undergo incineration to offer a volume reduction factor of 30-50, whereas rubber and plastic wastes are compacted to give a volume reduction factor of about 3. Conventional incineration of such wastes releases toxic gases, viz. Dioxin and Furan. However, exhaust emissions emanating from high temperature plasma pyrolysis process are well within the standards prescribed by regulating agencies thereby making it as an effective solution for incineration of all types of potentially combustible radioactive solid waste. The 25kg/hr capacity system based on plasma pyrolysis has been designed at BARC to treat wastes in a single step at a high temperature (> 1500 K).

Affordable [^{18}F] FLT Precursors for PET Imaging

The non-invasive positron emission tomography (PET) for imaging of biological processes is a highly sensitive technique for disease diagnosis as well as for monitoring of patient response to treatment. This technique works through harnessing the variation in metabolic disorders, like overexpression of certain antigen or extensive requirement of biomolecules like amino acids, glucose etc, found in the cancerous site of the human body. Though [^{18}F] Fluoro-2-deoxyglucose ([^{18}F]FDG) is routinely used for this purpose, 3'-fluoro-L-3'-deoxythymidine ([^{18}F]FLT), is found to be a promising candidate as it is independent of glucose metabolism and because of this, there is no uptake of it in inflammatory cells and healthy brain tissues. More importantly, [^{18}F] FLT ensures greater degree of efficiency in diagnosis compared to [^{18}F] FDG. A protocol for an efficient and economically viable synthesis of three [^{18}F] FLT precursors from commercially available thymidine (as a starting material) has been developed at BARC as part of the efforts to indigenize highly expensive precursors that are presently being used.

Titanium Hydride Targets for Portable Neutron Generator Applications

Titanium Hydride targets have been specifically developed for portable neutron generators that find application in detection of special nuclear materials and explosives, detector calibration and for industrial neutron radiography. In the light of these vital applications and the restrictive monopoly of foreign suppliers, this import substitute technology assumes critical significance as these targets are consumable and need to be replaced after a few hundred hours of operation in a neutron generator. Thermal vapor deposition followed by chemi-adsorption of deuterium (D) or tritium (T) has been used to produce thin film titanium hydride (TiD_x and TiT_x) on CuX substrates. These D and T loaded targets have given neutron yield of ~10^6 and ~10^8 n/s, respectively in an indigenously developed portable neutron generator. Efforts are in progress to develop Titanium Hydride films , which can potentially result in targets for high yield neutron generator applications ($\geq 10^{10}$ n/s)

Compiled by Vijay Manchanda

Recent Developments in Recovery of Valuable Radioisotopes by HLLW Partitioning

Introduction

Management of spent fuel arising from nuclear power production has long been considered an important issue due to political, economic and societal implications associated with it. In view of the large amount of spent fuel being progressively added to the cumulative inventory globally, the significance of spent fuel management will continue to grow in future. While nuclear industry has successfully managed spent fuel quantities arising in the past, a few issues have been raised through considerations of long term strategy options for spent fuel management. It would be worthwhile to resolve or mitigate these issues for enhancing acceptance of the anticipated role of nuclear energy in the sustainable development. A central goal of nuclear sustainable development is to enhance the effectiveness of natural resource utilisation and to reduce the volume as well as radio toxicity of high level radioactive waste employing management technology based on separation science with emphasis on societal benefits of recovered radioisotopes.

India has adopted a ‘closed fuel cycle’ considering spent fuel as a material of resource. This has enabled not only optimally utilising the scarce resource of Uranium but also helped in efficient management of waste and opening the possibilities for tapping the characteristic energy of various useful radioisotopes present in waste for societal benefits which otherwise are not available in nature. Reprocessing of spent fuel enables recovery of valuable fuel elements and recycling them in future reactors for utilising as fuel. Such recovery and recycling of fuel material in reactor to generate power not only helps in ensuring the energy security of the country but also reducing the waste volume meant for geological disposal to a great extent. Spent fuel reprocessing results in recovery of more than 95% of material and hence generates a very small amount of high level liquid waste (HLLW) which is significantly lower than direct disposal of spent fuel as in case of ‘open fuel cycle’. HLLW, characterised by high concentration of radioactivity in combination with presence of long lived minor actinides, makes its safe management a great challenge. Internationally, HLLW is vitrified in suitable glass matrix with interim storage for removal of decay heat. The advantage of vitrification of HLLW into vitreous matrix is to immobilise the radioactivity in chemically durable form ascertaining containment and isolation of radioactivity from the human environment for extended period of time.

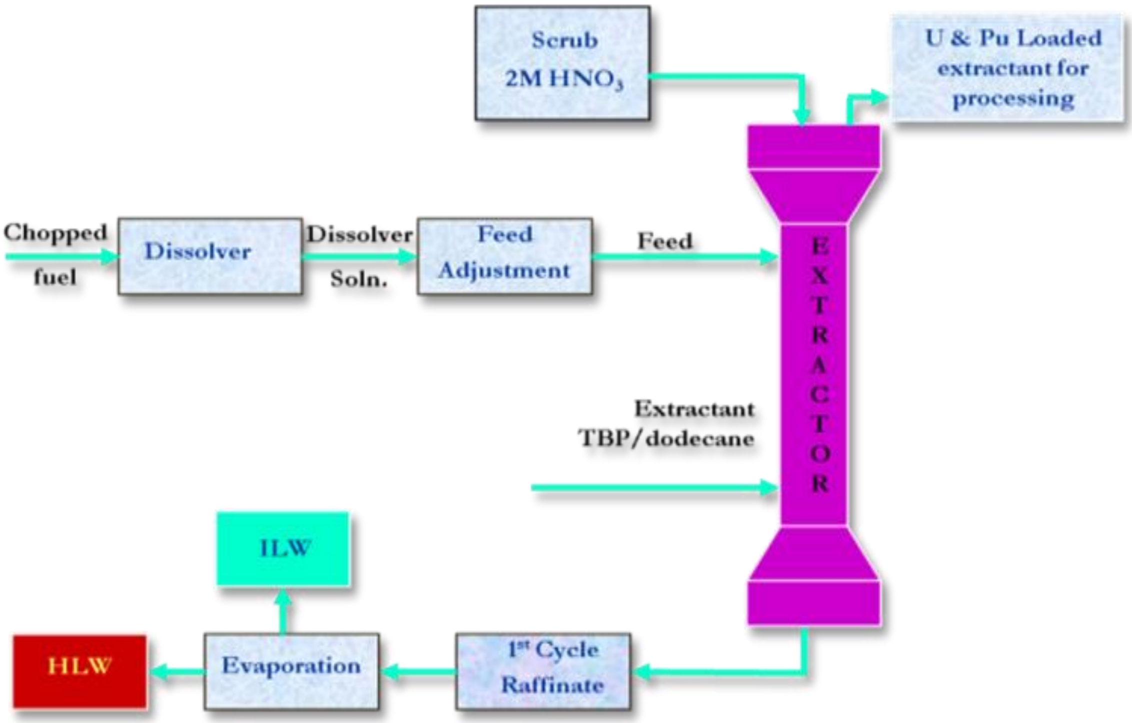

Fig. 1: Generation of HLLW from reprocessing of spent fuel

Origin of High Level Liquid Waste and its management:

Spent fuel mainly contains the valuable material like Plutonium and unutilised Uranium, fission products and minor actinides. At reprocessing plant, valuable material like Pu and U are extracted from spent fuel using solvent extraction based on PUREX process. The Pu and U are recycled back for fuel fabrication.

After extracting Pu and U, remaining materials including fission products, minor actinides etc. comes out as first cycle raffinate of solvent extraction system of PUREX process. The first cycle raffinate is concentrated further to reduce the volume, termed as High Level Liquid Waste (HLLW), contains bulk of fission products and minor actinides generated during reactor operation including about 99% of the radioactivity generated in the entire nuclear fuel cycle (**Fig.1**). HLLW, first cycle raffinate of PUREX process, mainly contains radioactive elements like fission products & minor actinides, and also contains appreciable amount of inactive components/ additives added during reprocessing such as nitric acid (1-4 M), nitrate salts of Na & corrosion products, traces of dissolved organics and their degradation products. The radioactivity of HLLW is mainly due to the presence of fission products and minor actinides which will vary depending upon the type of fuel, fuel burn-up and off-reactor cooling. The minor actinides are either themselves long lived or their decay products are long lived. Presence of actinides thus poses a challenge in the management of HLLW in respect of long-term durability of the product to ascertain the containment of radionuclides and their isolation from human environment for extended period of life. These wastes are stored in the reprocessing plants in underground high integrity stainless steel tanks with required monitoring and control instrumentation. The efficacy and adaptability of nuclear power ultimately depends a great deal on efficient management of these waste streams due to the inherent challenges associated with them. A typical composition of HLLW with respect to fission products, structural elements and process chemicals is given below in **Table 1.**

For ascertaining long term containment of radionuclides and their isolation from human environment, a three-stage programme for the management of high level waste has been adopted. The strategy has been in line with the international practice. Highly radioactive liquid wastes wherein radionuclides present in the aqueous stream are immobilised/vitrified in suitable matrices that are inert, highly durable

Table 1: Typical Composition of HLLW from PHWR fuel reprocessing [1]

Table 1A. Elemental analysis of HLLW (All concentrations are in mg/L. Dilution factor =3000L/ton of uranium.)	
Element	**Average Concentration**
Sr	54.3
Y	27.6
Mo	243
Ru	158
Rh	41
Pd	12.7
Ba	96
La	91
Ce	168
Pr	68
Nd	278
Sm	61
Cr	182
Fe	743
Mn	21.5
Na	822
Ni	100

Table 1B. Radiometric assay of HLLW	
Radionuclide	**Average Activity (Ci/L)**
Gross Alpha	99.8
Gross Beta	21009.9
Cs-137	6932.4
Cs-134	268
Ru-106	318.7
Ce-144	245.1
Sb-125	71.95
Eu-154	109.7
Eu-155	70.2
Am-241	53.1
Sr-90	4660

(resistant to chemical/aqueous attack), having good thermal and radiation stability etc. and in turn contained in high integrity storage units/canisters, which are subsequently over packed. Interim storage under surveillance and natural cooling of over packs containing conditioned wastes is practised to facilitate the dissipation of heat generated on account of decay of fission products to a level acceptable for geological disposal on the one hand and to ensure integrity of the waste form and its packaging on the other before a commitment is made for their disposal. Disposal of vitrified waste product in geological disposal facility (GDF) needs to ensure that at no stage potentially hazardous radioactive materials are recycled back into human environment in concentrations that can subject man to an unacceptable risk. As on date, waste volumes are too less and do not envisage need of geological disposal facility in near future.

Recovery of Valuable FPs from Radioactive Waste Streams

HLLW contains large number of fission products including ^{137}Cs, ^{90}Sr, ^{106}Ru, ^{144}Ce along with significant contribution of minor actinides . Radioisotopes like ^{137}Cs, ^{90}Sr, ^{106}Ru have potential for various industrial and medical applications.

Radioisotope of Cesium, ^{137}Cs, is one of the prominent fission products in HLW and is available in good quantity. ^{137}Cs decays to ^{137}Ba by emitting β and γ radiations. The energy of γ radiation of ^{137}Cs is 667 Kev and has immense potential as a sealed source for various gamma irradiation applications such as irradiation of blood and food materials. Currently, most of the irradiators are deploying ^{60}Co and only very few are based on ^{137}Cs. The ^{137}Cs has distinct advantage of longer source life, due to its larger half-life (30.2 y), over ^{60}Co (5.3 y) resulting in lesser source replenishment and lower personal exposure. In fact, applications such as blood irradiator (BI) prefers ^{137}Cs over ^{60}Co because such applications require lesser source strength and source replacement will not be required during the useful life of the unit.

Another prominent fission product in HLLW is Strontium- 90 (^{90}Sr), which has a half-life of 28.2 years and decays to Yttrium-90 (^{90}Y) by beta decay. ^{90}Y, having half-life of 64 hours, further decays to ^{90}Zr by beta decay. ^{90}Y has application as a radiopharmaceutical product for therapeutic use during treatment of cancer. Ruthenium-106 (^{106}Ru) is another useful radioisotope and has application in eye cancer treatment.

Recent developments are focused towards separation and recovery of above mentioned radioisotopes from radioactive waste and their deployment for societal applications, thus making the high level liquid waste as a material of resource, rather than merely a waste. It involves in-house development of selective extractants and special equipment for bulk recovery of ^{137}Cs & ^{90}Sr from waste. The techniques developed for the recovery of valuable nuclides from radioactive waste are briefly summarised in the following sections.

Partitioning process for recovery of useful fission products at WIP, Trombay

Several challenges are involved in the selective recovery of a radionuclide from the radioactive waste streams, which has presence of other radioactive fission products, long lived minor actinides and inactive constituents added during reprocessing. However, a multi-step solvent extraction based partitioning process with indigenously developed extractant and special equipment has been deployed at WIP, Trombay for recovery of the radio-nuclide from acidic high level liquid waste (HLLW) in mega curies at engineering scale. This involves removal of residual U and Pu in first cycle, ^{137}Cs in second cycle & actinides/lanthanides along with ^{90}Sr in third cycle. Residual U and Pu is removed using TBP based solvent. Newly developed solvent, based on Calix Crown ether is deployed in second cycle for recovery of ^{137}Cs in purified form from waste. Actinides, Lanthanides and ^{90}Sr are removed from High Level Liquid Waste using TEHDGA based solvent in third cycle. The process flow sheet has been deployed at plant scale after its extensive testing on laboratory scale with actual HLLW.

Recovery of ^{137}Cs & production of Cs glass pencils

Cesium-137 is recovered in large quantity at Solvent Extraction Facility, WIP, Trombay, using solvent extraction system and Calix Crown 6 as a solvent [2]. The purified ^{137}Cs is vitrified into a specially formulated borosilicate glass matrix to make non dispersive form of ^{137}Cs. The vitrified Cesium glass is poured in stainless steel pencils, which are further subjected to stringent quality assurance checks, as stipulated by Atomic Energy Regulatory

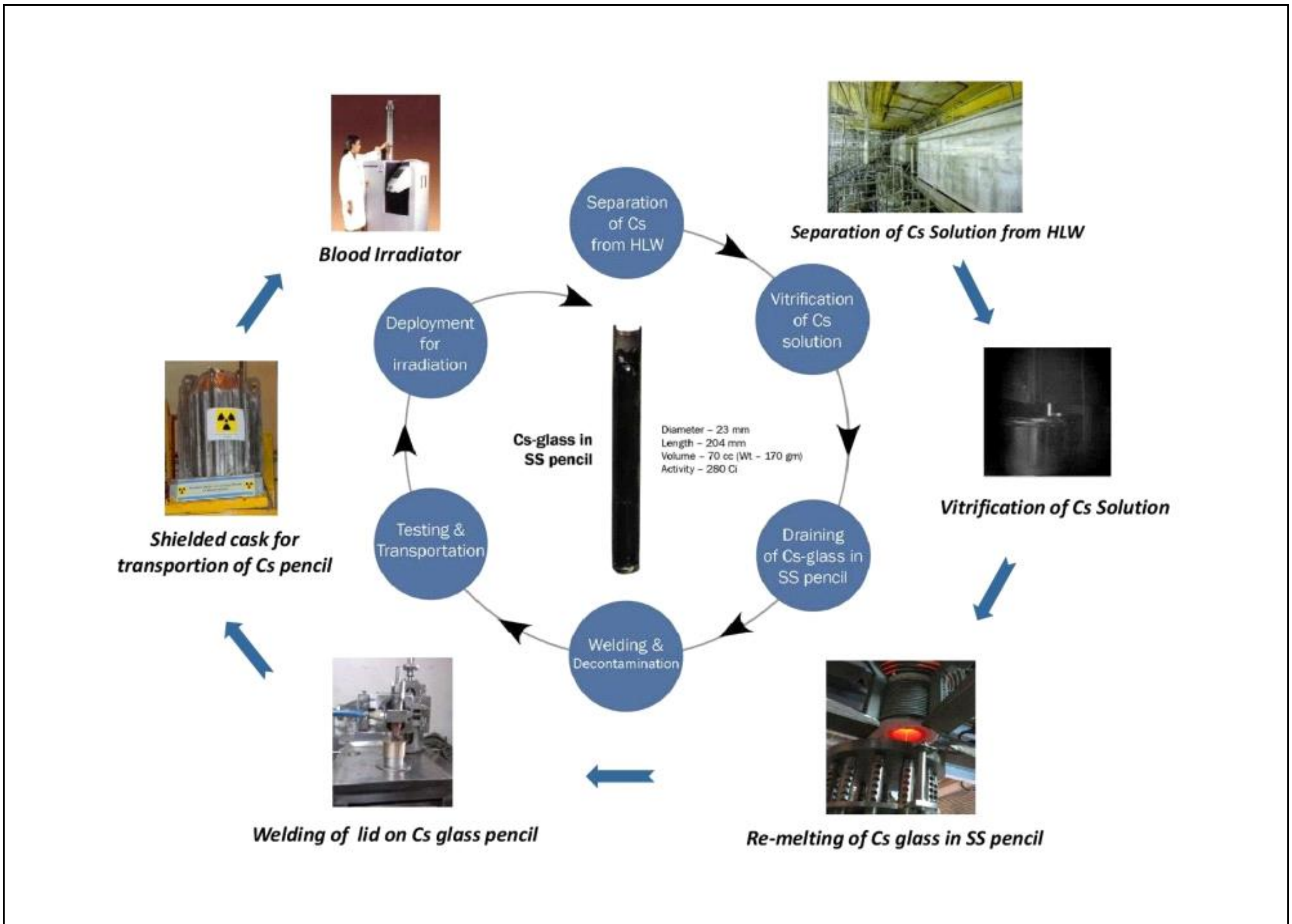

Fig. 2: Cs glass pencil production process

Board (AERB). Non-dispersive form of Cesium glass adds safety and security to irradiation source. The facility for recovery of Cs from high level liquid waste and converting it into non-dispersive glass form to produce Cs glass pencils is installed and is under operation at WIP, Trombay, since 2015. **This is the first of its kind facility in the world producing and supplying ^{137}Cs in a non-dispersive glass form for gamma irradiation applications with enhanced safety and security.** Based on requirement of irradiation, Cesium glass pencils, with specific activity 2.5 Ci/g and 5 Ci/g, have been produced. **Till date, more than 3 lakh curies of ^{137}Cs of desired quality has been recovered from HLLW and about 220 numbers of Cesium glass pencils have been produced successfully for deploying them in blood irradiator and for grain irradiation**. Various steps involved in producing Cs glass pencils are shown in **Fig. 2.**

Recovery of ^{90}Sr from HLLW for milking of ^{90}Y

Stonium-90 (^{90}Sr) is present in substantial quantities in HLLW. Daughter product of ^{90}Sr, i.e. ^{90}Y, is a useful radionuclide in nuclear medicine. Hence, ^{90}Sr is used for the generation of carrier free ^{90}Y for radiopharmaceutical applications. For obtaining radio -pharmaceutical purity of ^{90}Y, high purity of ^{90}Sr is essential. Sr is recovered in large amount along with actinides and lanthanides from third cycle of Solvent Extraction Facility of WIP, Trombay. Recently a process has been developed to recover Sr in very pure radio pharmaceutical grade. Few Ci of purified ^{90}Sr has been recovered from HLLW utilising multi step separation and purification process. The purified ^{90}Sr is used for milking of radiopharmaceutical grade ^{90}Y. The product purity of ^{90}Y has been verified and cleared by Radio-Pharmaceutical Committee for clinical trials. For large scale separation, an engineering scale facility is being designed.

Separation of Carrier-free ^{90}Y using Supported Liquid Membrane (SLM) based ^{90}Sr-^{90}Y Generator

Detailed study using supported liquid membrane (SLM) technique, in flat sheet configuration was carried out to assess the feasibility of the method for efficient separation of ^{90}Y from ^{90}Sr. The SLM system consists of a metal-specific ligand (carrier) impregnated in the pores of a flat sheet support that separates the two phases viz. source and receiver phase. Under optimized conditions, desired separations can be achieved. Two indigenously synthesized ligands viz. KSM-17 and octyl phenyl-N, N-diisobutylcarbamoyl methyl phosphine oxide (CMPO) were used as carriers. Initially, a single stage membrane-based generator system employing KSM-17 carrier, supported on a polytetrafluoroethylene (PTFE) membrane was employed but in view of its low yield, it was replaced with the two-stage system. The two stage SLM generator is principally based on the solvent extraction properties of two ligands, namely KSM-17 and CMPO under optimum conditions [3]. The system was operated in two ways viz. in simultaneous and sequential modes. A simple quality control method based on extraction paper chromatography, for accurately estimating ^{90}Sr levels in ^{90}Y, with sensitivity better than 10^{-4} %, was developed. The contamination of ^{90}Sr in the ^{90}Y product is always far below the permissible level. **Few batches of 150 mCi of ^{90}Y are being regularly supplied to Tata Memorial Hospital / RMC, Parel, Mumbai every month**. A pilot scale facility is being augmented at WIP, Trombay for enhancing the production capacity of ^{90}Y to meet the rising demand.

Recovery of ^{106}Ru and production of ^{106}Ru-based plaques for eye cancer treatment:

Partitioning of HLLW for recovery of U, Cs, Sr and separation of lanthanides & actinides from HLLW, results in the raffinate stream with good amount of ^{106}Ru. Process developed for the recovery of Ru-106 in radiochemically pure form envisaged separation of trace Cs-137, followed by conversion of Ru to RuO4, extraction of RuO_4 followed by stripping of Ru as Ru(III). The demonstration of process has resulted in recovery of ^{106}Ru of the required purity and suitable for intended applications. The recovered solution is further processed and subjected to electro-deposition on silver substrate. An electrochemical process has been developed, to deposit a layer of ruthenium on the concave surface of a silver plaque [4]. The electrodeposited substrate is sealed in between the two silver disc to form a plaque of desired size and shape. The active Ru plaque **(Fig. 3a)** has qualified all the tests as per regulatory requirements and presently under clinical trials at hospitals **(Fig. 3b). Eleven numbers of indigenously developed Ru-106 eye**

Fig. 3: (a) Ru-106 Plaque developed in BARC

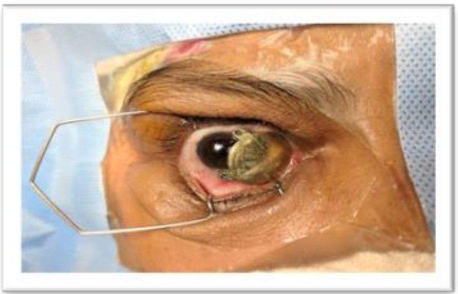

Fig. 3: (b) First use of indigenous developed Ru-106 Plaque in hospital

plaques of different geometry configurations (six numbers of round geometry plaques and five numbers of notch configuration plaques) have been supplied to various hospitals of country including AIIMS, New Delhi, Centre for Sight , Hyderabad, Shankara Eye Hospital , Bengaluru. A plaque of about 600 μCi of ^{106}Ru can treat 50 patients in a year. Performance evaluations of indigenously developed Ru-106 eye plaques are carried out by utilising them for eye cancer treatment by the hospitals and have been found at par with international standards. On the basis of feedback of the oncologists, few new configurations are being designed and developed to meet the country's demand.

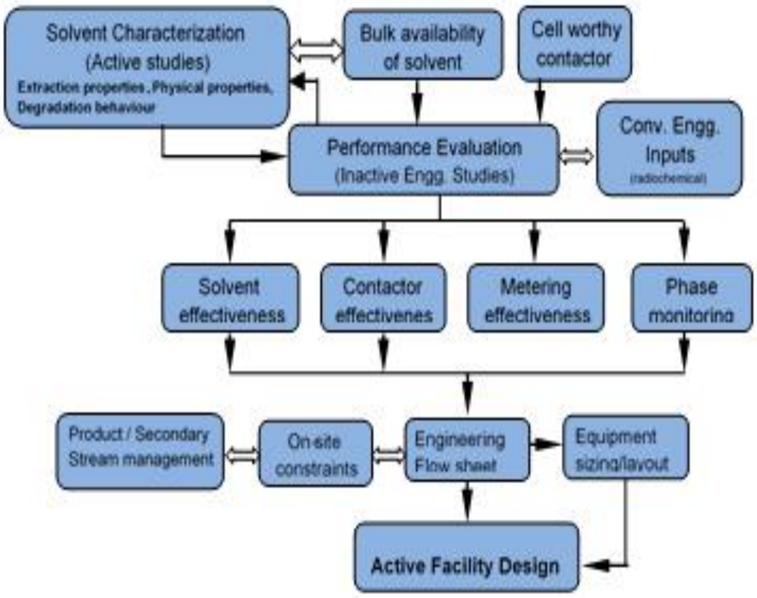

Fig. 4: Overall R&D Programme for Partitioning of HLW

Roadmap for Future R&D for Partitioning of HLW

A structured R&D framework is being pursued to develop and deploy processes and technologies for actinide partitioning of HLW. One of the most defining steps in this programme is selection of potentially successful extraction system based on the systematic study on the extraction properties and their optimization for full scale studies. Design of appropriate contacting devices and equipment for in-cell application along with its evaluation is second important set of activity. Performance evaluation of the selected contactors with the solvent system has been carried out which in turn provides the basis of the engineering flow-sheet design for such a process. Efforts have been directed towards identification of the various secondary streams that would emanate out of such a facility along with their storage and management. **Fig. 4** gives the overall R&D objectives for such a programme.

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NISARGRUNA : Technolgy for Urban and Rural Waste Management, Energy Conservation, Better Environment and Restoration of Soil Fertility

Summary: The NISARGRUNA (returning back to Nature) concept is developed mainly for decentralized processing of the biodegradable waste that would help in reducing the transportation cost and health menace associated with it. The project is expected to generate employment in the underprivileged sector of the society. It would help the ever-depleting energy sector by generating fuel for domestic cooking. The technology has evolved in last 18 years and more than 300 such NISARGRUNA plants are operative in Maharashtra, Kerala, Karnataka, Delhi, Jharkhand, Madhya Pradesh, Himachal Pradesh, Orissa, Tamil Nadu and Gujarat. The technology has been transferred to more than 150 private entrepreneurs all over the country.

Introduction: Two laws govern the Life on Mother Earth. They are - law of conservation of matter and law of conservation of energy. Matter and energy can neither be created nor destroyed. These only change forms. The various elemental cycles keep running in a steady state. The life on earth is part of this cycle. The Life cycle is thus an integration of various elemental biogeochemical cycles. It is important that all these cycles must continue in an undisturbed fashion to maintain the Nature's Cycle. We must look at every material as a potential resource.

The concept of waste therefore needs to be revamped in totality. There is no waste generated in nature. Every component that is generated is a part of some cycle. Hence each "so called waste" should be reused. We must change the name of WASTE BIN to RESOURCE BIN. This will help to change the mental attitude.

The problem of solid wet waste generated in kitchens, markets, restaurants and farms can be solved at 3 levels.

1. The kitchen waste generated in individual dwelling units can be easily composted using simple microbiological principles. BARC has developed Nisargdoot technology for this purpose. The manure generated in this process can be used for kitchen garden or community garden.

2. The second level of waste processing is at society or community level. Segregated solid waste resources generated in housing societies or wards in a municipal area can be processed by aerobic composting. Here too, manure can be used at local level.

3. The third level of waste processing is for bulk generators using Nisargruna biogas units which convert waste in organic manure and biogas.

The three-level handling of solid wet organic waste resources will stop the ever-increasing menace of dumping yards. Dumping yards are the curse in modern society and need to be stopped. This is only possible if every individual develops a concept of "Zero Waste". The zero waste concept means that individual dwelling unit processes the wet organic waste on its own and does not give it to municipal collection system. The other dry waste resources can then easily be recycled in localized central facilities. This would help in developing "Garbage free Vasundhara".

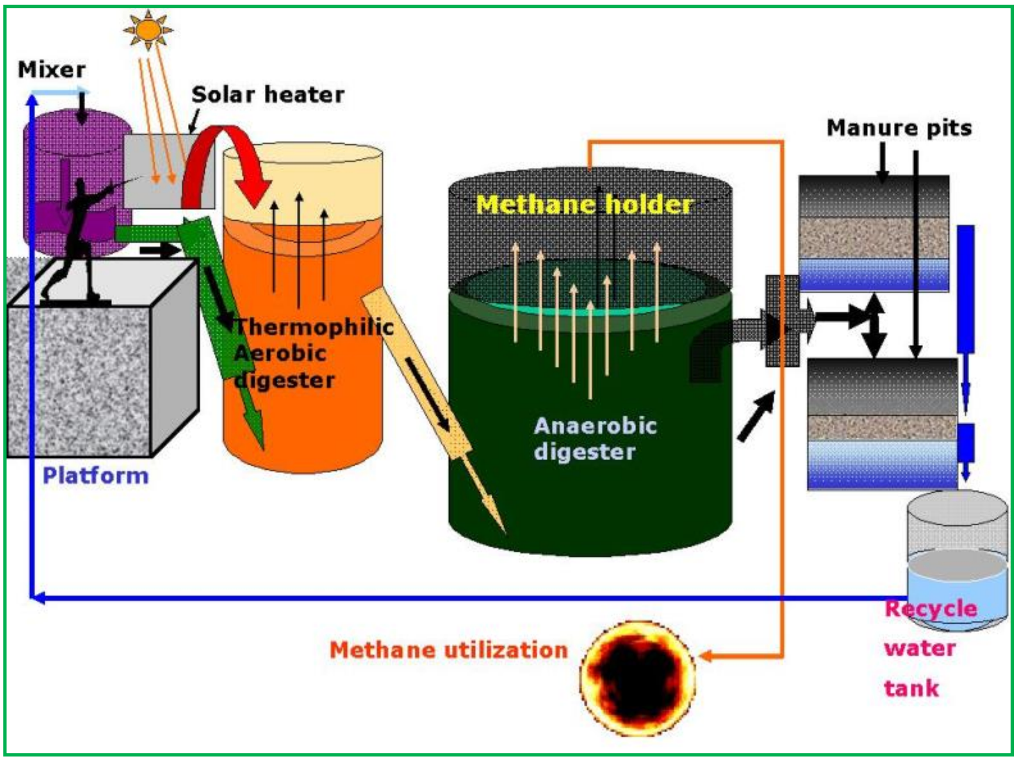
Nisargruna: The NISARGRUNA (repaying Nature's loan) concept is developed mainly for decentralized processing of the biodegradable waste that would help in reducing the transportation cost and health menace associated with it. It is expected that units of 1, 2, 5 and 10 tonne per day capacities would be ideal for urban local bodies in the country. Similar units would also be workable in rural areas for handling agro-waste. The project is expected to generate employment in the underprivileged sector of the society. It would help the ever-depleting energy sector by generating fuel for domestic cooking. The technology has evolved in last five years and fifteen such NISARGRUNA plants are operative in Mumbai, Thane, Pen, Sawantwadi, Matheran and Chandrapur (Maharashtra) .

Science of Nisargruna: The waste generated in kitchen in the form of vegetable refuge, stale cooked and uncooked food, extracted tea powder, waste milk and milk products can all be processed in this plant. Based on our understanding of thermophilic microorganisms in particular and microbial processes in general, we have introduced a 3-5 HP mixer to process the waste before putting it into predigester tank. The waste is converted in slurry by mixing with water (1:1) in this mixer. Usually this is the failure point as solid waste is difficult to get digested and can easily clog the system. If we can pulverise the waste in a paste, the digestion is assured. There will be no scum formation and no clogging. The other important thing is use of thermophilic microbes for faster degradation of the waste. The growth of thermophiles in the predigester tank is assured by mixing the waste with hot water and maintaining the temperature in the range of 45-50°C. The hot water supply is from a solar heater. Even few hours' sunlight is sufficient per day to meet the needs of hot water. Alternatively, part of biogas generated in the system can be used for getting hot water. It must be remembered that the reactions in predigester are exothermic in nature and only a proportionate quantum of hot water is needed to achieve the results. Their main role is to digest proteins and low molecular weight carbohydrates to produce volatile fatty acids. Ideally there would be two predigesters which will receive the waste on alternate days so that undisturbed digestion for about 48 hours will give desirable results.

The same result can be achieved by providing a baffle wall in single predigester. It is mandatory that the effective volume in either case will be the same. The pH of the slurry drops to 4 - 6 due to accumulation of volatile fatty acids. The total soluble solids reduce from 23-25% to 13-15% in this tank. The retention time is between 72 to 96 hours. More retention in predigester than this period would result in loss of biogas and manure in the second phase.

Predigestion is extremely important for following reasons:

- Hydrolysis of the waste
- Acidification and formation of volatile fatty acids
- Removal of scum forming components
- Removal of sulphur in the form of sulphur dioxide
- Formation of uniformly flowable slurry to ensure smooth digestion in anaerobic digester



After the predigester tank, the slurry enters the main tank where it undergoes mainly anaerobic degradation by a consortium of archaebacteria belonging to *Methanococcus* group. These bacteria are naturally present in the alimentary canal of ruminant animals (cattle). They produce mainly methane from the cellulosic materials in the slurry. As the gas is generated in the main tank, the dome is slowly lifted up. The design of the dome, which floats on a water seal, is such that there is no direct contact between the slurry and the dome. It reaches a maximum height of 4 feet holding biogas. The biogas is a mixture of methane (55-75%), carbon di oxide (40-15%) and water vapours (5-10%). It is taken through GI pipeline to the lampposts. Drains for condensed water vapour are provided on line. This gas burns with a blue flame and can be used for cooking as well. The excess gas is liberated in the atmosphere after the dome reaches maximum height. The utilization of gas should be spaced in such a manner that this release of excess gas is avoided. The main component in biogas is methane (green house gas) and it has a very high negative impact on the environment. The pressure in the dome is between 100 to 200mm of water column. The pressure is sufficient to take this gas to a distance of about 300-400m without any loss of efficiency. The pressure can be increased by putting additional weight in the form of MS discs or any other suitable and aesthetically acceptable alternative.

The undigested lignocelluloses and hemicelluloses materials then are passed on in the settling tank in the form of finely divided powder. After about a month high quality manure can be dug out from the settling tanks. There is no odour to the manure at all. The organic contents are high and this can improve the quality of humus in soil, which in turn is responsible for the fertility. The manure can be used for nurseries and fields. The manure pits are provided with filtration system that can separate out the water in an underground tank. This water can be reused in the system. The BOD of this water is less than 100-150 which is quite acceptable for reuse in the Nisargruna system. The bucket centrifuge can do the job faster.

Nisargruna technology offers an economically viable option for waste disposal. The savings on transportation of waste materials at dumping yards (considering decentralized nature of Nisargruna plants), moderate earning through gas and manure and possible carbon credits can make the technology very attractive. It would also have impacts on health sector.

Advantages of Nisargruna Technology:

1. Environmental friendly processing of biodegradable waste is achieved. This waste is completely zeroed and by products are generated.
2. The elemental cycles like nitrogen, carbon, hydrogen, oxygen etc. expect that the biodegradable waste has to go through microbial route for ensuring their availability for future life. Nisargruna achieves this objective fully.
3. The processing cost of biodegradable waste is far lesser compared to any other foreign technology.
4. Decentralized handling of the waste will reduce the transportation costs, dumping yard needs and assured processing. In long run, it means that dumping yards could be totally eliminated. If proper segregation occurs at the source, then the requirement of land-fill sites can be reduced by 60-70%.
5. Transportation of this waste through crowded areas could easily be avoided if decentralized Nisargruna plants are made available.
6. By products like biogas and manure can make the process economically attractive.
7. Processing of solid biodegradable waste in this manner would ensure that this material won't be carried to dumping yards and release methane there, in slow and unplanned composting. Since the biogas is trapped to burn, the contamination of environment with a vast quantity of methane will be completely avoided. This would earn carbon credit.
8. The use of biogas as fuel will save the classical fuel consumption including petrol, LPG and diesel. This is another reason which will ensure the carbon credit for the process.
9. In rural areas where biomass can be made available to run these plants, energy freedom can easily be achieved. The stand-alone Nisargruna plants can be rural power houses.

10. In rural areas it will reduce the use of wood as fuel thereby helping indirectly in afforestation.

11. The aesthetic looks of the country can be changed using Nisargruna technology.

12. It offers a long-life methodology to treat the biodegradable waste in a very limited space. The continuity of the process makes it possible to treat a large quantity of waste at a single site without any need of adjoining areas.

13. The technology is relatively simple and does not involve any imports. The plants can be operated by unskilled workers after training them initially for about 3-4 weeks. It is developed keeping in mind local environment and the types of wastes.

14. The manure generated in the process will help in rejuvenating the depleting organic carbon contents in our agricultural soils.

15. The processing of biodegradable waste and making it zero would tremendously improve the hygiene of the country, reduce the epidemics and make people in general healthy. The substantial reduction in health bills is a distinct possibility. It would also influence the human efficiency.

Let us all come together and spread this Nisargruna concept to achieve the dream of Zero Waste or Garbage Free Mother Earth.

Dr Sharad P. Kale
sharadkale@gmail.com

Dr Sharad P. Kale retired as Associate Director, Bioscience Group, BARC . His initiatives in solid biodegradable waste management have resulted in installation of Nisargruna biogas plants at more than 300 places in the country. He was awarded Padmashri in 2013.

An Examination of Narratives about the electricity sector

Narratives have a powerful role in any society. They could be based on facts or perceptions, or be planted by the interest groups, or might result from a serendipitous sequence of events that is difficult to trace back. Irrespective of the source of origin, narratives do influence policy formulation and decision making. After a brief introduction, I enumerate some narratives about the electricity sector in India and examine them in detail.

India is a large electricity producer, but per capita electricity consumption at about 1200 kWh (called units hereafter) in 2018-19 is significantly lower than the world average of above 3000 units. Major share (80.5%) of electricity is produced by fossil fuels, mostly coal, 8.7% by large hydro, 2.4% by nuclear and the balance 8.4% by the Renewable Energy Sources (RES). Over-dependence on coal has implications for the environment and climate change, and needs examination.

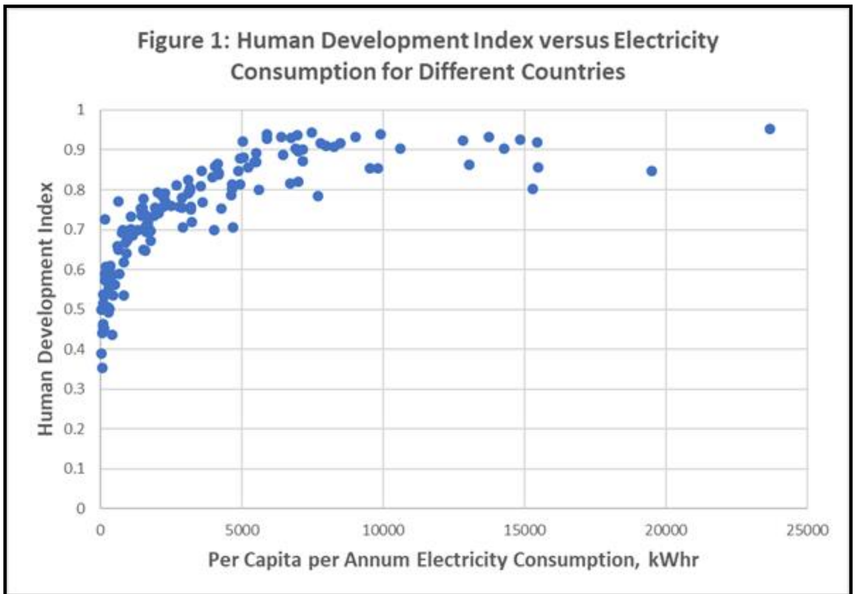
One can enumerate the following as some of the narratives about the electricity sector in India.

1. RES can meet most of the electricity demand in the country.
2. Increase in the share of RES in the electricity mix will bring down tariff for the consumers.
3. There are no biophysical constraints to the growth of electricity from various sources.
4. Coal-fired power plants are a major contributor to carbon emissions and should be phased out.
5. There are no safety issues in electricity generation technologies other than in nuclear.

The paper discusses these narratives with a view to providing an evidence-supported perspective to the public.

Narrative 1: The role of RES

To examine the role of RES, one has to look at the long-term target rather than annual growth in the generation of electricity. The first step is to set a long-term target. Analysis of data indicates that Human Development Index (HDI) of a country increases with an increase in per capita electricity consumption; the increase is first sharp and then tends to approach the value of one asymptotically. Policies and plans in India have to be engineered to achieve a high HDI, of the order of 0.9. Based on HDI and per capita electricity consumption data of various countries, and looking at comparable countries, I would argue that to achieve an HDI of about 0.9, we need to provide about 5000 units per capita per annum **(Figure 1).** Considering that (a) the share of electricity in the Total Final Consumption of energy is increasing due to structural changes in the energy sector, (b) India is urbanising and passing through an intense infrastructure building phase, (c) the population of the aspirational middle class is increasing, (d) all citizens and businesses are looking for a reliable supply of electricity 24x7, this estimate may be on the lower side.



Some important dots are: India (918, 0.640), Vietnam (1616, 0.694), Thailand (2868, 0.755), China (4279, 0.752), Malaysia (4656, 0.802), USA (12825, 0.924). Electricity data is from Key World Energy Statistics 2018, which gives data for 2016.

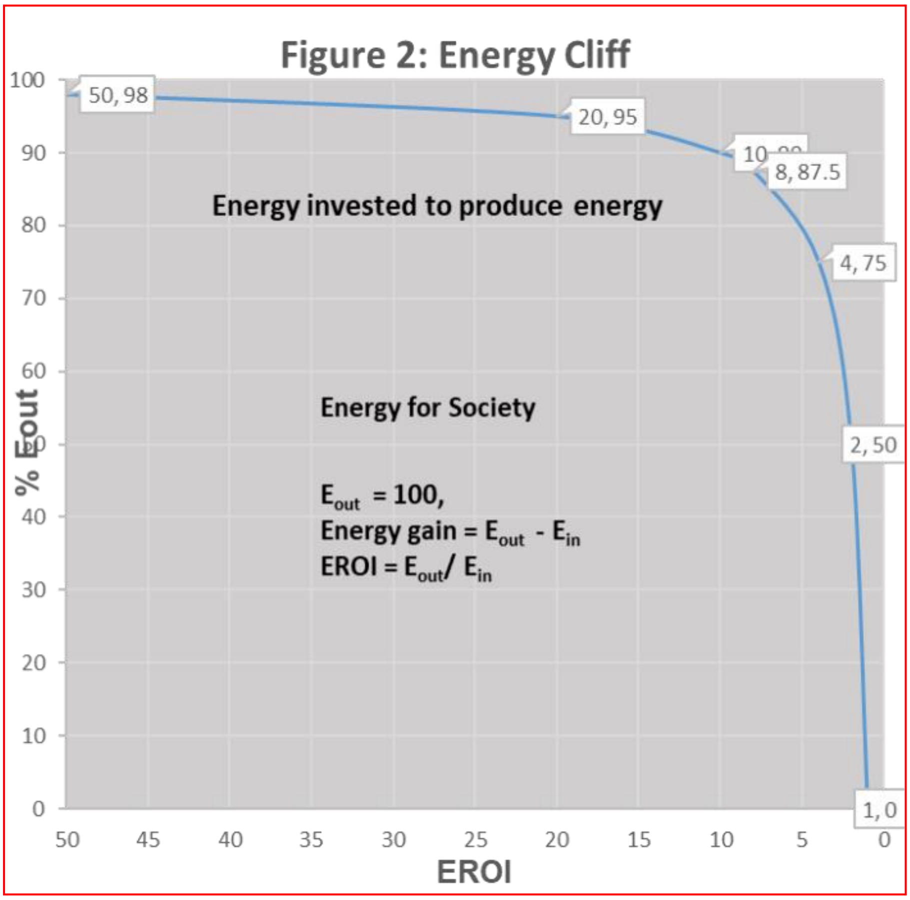
Considering that the population of India will peak at 1.6 billion by the middle of the century, and accounting for technically minimum possible transmission and distribution losses (seven per cent), this calls for a generation of 8700 billion units per annum. As per estimates, India has a wind potential of about 300 GW at a hub height of 100 metres, a solar potential of ~750 GW assuming 3% wasteland is made available, and a bio-energy potential of 25 GW. Assuming a plant load factor of 20%, all these sources can provide about 1900 billion units per annum. Large hydro generated 156 billion units during 2019-20. Assuming the full potential of solar, wind and large hydro is harnessed, their total generation cannot exceed about a quarter of the target demand of 8700 billion units. The International Panel for Climate Change (IPCC) recognizes hydro, nuclear, solar, and wind as low-carbon energy sources (See Assessment Report-5 Climate Change, Chapter 7, Energy Systems, IPCC, 2014) and one has to ensure that the electricity mix largely comprises these sources.

Therefore, India has to ramp up nuclear generation to provide the balance between the target of 8700 billion units and what can be generated by hydro, solar, and wind. Until nuclear generation is ramped up to the required level, coal has to continue as a part of India's electricity mix.

Narrative 2: The influence of integration of RES to the grid on tariff

In the general discourse on the use of RES for the generation of electricity, an impression has been created that electricity from solar and wind will be very cost-competitive. This impression is the result of two technicalities. One is the use of a wrong metric that is Levelised Cost Of Electricity (LCOE) generation for comparison, which has no parameter to account for intermittency of renewable sources and thus overestimates their benefit. The second is due to not explicitly bringing in Grid-Level Costs in the general discourse for the calculation of tariff. Grid-level costs arise from the fact that electricity is generated by a power plant, and to reach consumers it has to pass through a transmission and distribution network. Peak load in India normally occurs in the evening when solar is not available. The manager of the electricity system has to ensure that the available installed capacity is adequate to meet the peak load. Therefore, the total capital invested in the electricity system will remain the same whether solar is or is not a part of the electricity mix. The presence of solar reduces the capacity factor of plants that can operate 24x7. This results in an under-utilisation of the investment in despatchable generators. This has a positive as it means less CO_2

emissions, but it also has a negative as it results in a poor return on the capital invested in the coal-fired power plants. ***Not recognising the difference between the generator-end and the consumer-end for framing the narrative on the tariff will lead to wrong policy decisions.***



The grid level costs arising from intermittency of RES can be mitigated with the installation of storage devices such as pumped storage or batteries, or by using large hydro plants for load following. There is a cost attached to storage and has two components; (i) the capital cost of creating storage, and (ii) the operating cost including round trip efficiency which for all technology options is less than 100%. Ramping hydro plants up and down also has an increase in maintenance as the attached cost. From a policy perspective, it is desirable to recognise the need for a solution and the associated cost, and one can go in for a solution based on cost-benefit analysis. Doing a complete system analysis is the way to quantify and attribute all costs.

The use of LCOE as a metric to evaluate technology options, when intermittent sources are a part of the electricity mix, is erroneous and will lead to untenable policies. To arrive at decisions about new capacity addition, one should go in for a complete system analysis. Integration of RES to the grid will not lower electricity tariff, rather it will raise the tariff.

Narrative 3: Biophysical constraints

Easy to be extracted energy resources, particularly petroleum, have already been extracted. What remain are the resources that are difficult to extract and so require more energy for extraction. Net energy or gain (Difference between the energy output (or returned) and the energy invested) to the society from the remaining resources is declining. This aspect is expressed by energy economists in terms of the ratio, the energy returned to the energy invested, EROI in short.

When EROI equals ten, society gets 90% of the input energy; at a value of four, the society gets 75%; at a value of two, the gain to the society falls to 50%. The society gains nothing when EROI equals one. When EROI goes below about six, gain to society starts falling sharply (Figure 2). EROI is high for coal, nuclear, hydro and wind, but low for biomass, while EROI for solar (without considering storage) stands at about the point where sharp fall begins.

While looking at the solar and the wind, one has to include EROI of the storage solution adopted and all storage solutions have an EROI of less than one. A country has to aim at a mix of technologies so that the EROI of the mix as a whole is high enough to provide energy surplus to carry on with essential as well as discretionary activities.

A low EROI will result in a large energy enterprise and so will be the associated material flows and their effect on environment.

Narrative 4: Phasing out coal

In view of carbon emissions, and significant health externalities from the effect of plant emissions on exposed populations, many advocate a phase-out of coal-fired power plants. However, coal is a dominant part of the present electricity generation mix in India and contemplating its phase-out needs a careful study and in my opinion a phase-out is not desirable as it would reduce the diversity of the electricity mix. Continued use of coal is also desirable to ensure that the energy supply system of the country has a high enough EROI. For this, I would endorse the approach based on a combination of initiatives including efficiency improvements in electricity generation from coal-fired power plants, carbon capture and storage, increasing generation from nuclear, solar, wind, bio-mass, end-user efficiency improvement, and moderation in use. India should plan to taper down percentage contribution from coal-fired power plants to a certain minimum over the next three to four decades. All the new coal-fired plant should be designed to have high thermal efficiency and be equipped with pollution abatement equipment.

A complete phase-out of coal-fired power plants is not possible in view of their large contribution to the electricity mix, to maintain diversity in the mix, and to ensure that EROI of the electricity mix is reasonably high.

Narrative 5: Safety issues

Safety issues associated with nuclear power generation have come to dominate public discourse, but this is not supported by data. Data on fatalities from air pollution and accidents have been collected and are available as fatalities per TW-hour of electricity generated. Contrary to the popular belief, nuclear is by far safer than fossil fuels, and wind and solar are as safe as nuclear energy.

Regarding nuclear waste management, the pursuit of a closed fuel cycle with minor actinide separation provides a superior alternative and that is what India has been pursuing. The pursuit of a closed fuel cycle reduces high-level radioactive waste per unit of electricity produced and minor actinide separation reduces the duration for which the nuclear waste has to be stored.

Solar panels, after their life is over, constitute a humungous volume of waste: 10 million tons in the USA by 2050, 20 in China and 7.5 in India and Japan, and 4.3 in Germany. Only the EU has enacted legislation to deal with the solar waste. Battery storage is becoming popular, but has safety issues. There have been several incidents of fire in battery storage installations, and no regulations are in place for storage installations.

All energy professionals should improve engagement with the public to convince them about all aspects of energy generation including safety issues.

Concluding remarks

Examination of various narratives leads one to conclude that a country like India should have an electricity mix comprising a broad portfolio of diverse low-carbon technologies. Diversity provides security against supply disruption, resilience against severe events, and hedging against price fluctuations. All low-carbon technologies should be provided with a level playing field in terms of finance, siting, and obligations for purchase by DISCOMs.

Given a strong indigenous technology base and availability of uranium from the international market, it is time for India to ramp up nuclear installed capacity.

Acknowledgement

The paper summarises and builds on my earlier paper, "An examination of the narratives about the electricity sector" published in Current Science, 119 (12), 1910-1918, and reproduces many sentences verbatim.

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Dr. R B Grover is an Emeritus Professor in HBNI and was its first Vice Chancellor (2005-2016). He is a member of the Atomic Energy Commission. He was conferred with a Padma Shri in 2014

"Science and everyday life cannot and should not be separated."

– Rosalind Franklin

An Overview of Nuclear Energy as an indispensable option to mitigate climate change: Analysis of India's preparedness vis-a-vis. key recommendations of UNECE/JRC study

Today, the world is facing the new challenge of drastically reducing emissions of greenhouse gases. Simultaneously the policy makers are facilitating energy access to billions of people. While a variety of low carbon technologies can be employed in many combinations but the potential contribution from nuclear can play a significant role in achieving deep decarbonization targets set to be achieved by 2050 with the least cost [1]. In spite of the projected advantages on a long term run, the prospects of expansion of nuclear energy suffer due to two key factors viz. Public perception of inadequate safety and repeated failures of construction management practices in terms of their ability to deliver the products on time and without budget escalation. While some renewable technologies have become cheaper in recent decades, new nuclear plants have only become costlier. This trend needs to be reversed if nuclear energy has to play a significant role limiting the impacts of climate change, pollution and other unfolding global environmental crises.

Fundamentally this transition requires a shift from the use of polluting energy sources towards the use of sustainable alternatives. The visible impact of climate change also reminds us of the importance of resilience in the energy system and is a profound motivation for countries to 'build back better'. There are many pathways for achieving this transition and each country pursues its own route, taking into account its own endowment of natural resources as well as other local and regional factors. Some countries have chosen to pursue nuclear energy with the understanding that it can play an important role in their energy mix, while other countries have yet to make a decision or currently have chosen not to depend on nuclear energy in a big way for a variety of reasons. The UNECE report [2] meets a need expressed by global decision makers to better understand the role nuclear energy may play in the energy transition. Two other developments also urge EU countries to seriously consider nuclear as near zero emission technology needed to fight climate change as briefly brought below.

If one looks at the positions taken by major EU countries with respect to nuclear energy, it looks difficult to realise the target of a net domestic reduction of at least 55% of greenhouse gas emissions by 2030 and aiming at achieving climate neutrality by 2050 without including nuclear as low-emission technologies. This is despite its indispensable contribution in fighting climate change, as well as in realising unexploited synergies between the nuclear and renewable technologies. In view of the harsh decision, it is interesting to note that Prime Ministers of 7 EU countries have written a combine letter [3] to EU commission seeking freedom to develop nuclear power. The letter further submits that "We call on the European Commission to ensure that the EU energy and climate policy accommodates all paths to climate neutrality according to the technology neutrality principle. In this context, all available and future zero and low-emission technologies have to be treated equally within all policies, including taxonomy of sustainable investments, aiming at achieving climate neutrality by 2050."

The Joint Research Centre (JRC), European Commission's science and knowledge publication provides evidence-based scientific support to the European policymaking process [4]. In its recent assessment of nuclear energy as part of its review on energy generation activities, its Technical Expert Group [TEG] concluded that nuclear energy has near zero greenhouse gas emissions in the energy generation phase and can be a contributor to climate mitigation objectives. While consideration of nuclear energy from a climate mitigation perspective was therefore warranted, the TEG could not reach a definite conclusion on potential significant harm to other environmental objectives, in particular considering the lack of operational permanent experience of high-level waste disposal sites. Therefore, nuclear energy was not included at that stage in the EU Taxonomy. Instead, the TEG recommended that more extensive technical work be undertaken on the "do no significant harm" (DNSH) aspects of nuclear energy.

Around the world many nuclear newcomers are making steady progress in their journeys to introduce nuclear energy into their energy mix while other countries are poised to embark upon that journey. United Nations Economic Commission for Europe (UNECE, Geneva) report on "Use of Nuclear Fuel Resources for Sustainable Development - Entry Pathways" explores potential entry pathways in the context of local and regional factors, including the utilization of domestic uranium resources, which could facilitate the newcomers pursuing nuclear energy ensuing economic development. This analysis looks at India`s contribution towards reducing emissions of greenhouse gases in whatever possible measure and simultaneously making green energy available for economic growth through its 3-phase nuclear program. The key insights listed in the UNECE report and the matching steps taken/ foreseen in Indian nuclear program are listed below.

- Nuclear energy is an indispensable tool for achieving the global sustainable development agenda. It has a crucial role in decarbonizing the energy sector, as well as eliminating poverty, achieving zero hunger, providing clean water, affordable energy, economic growth, and industry innovation. Improved government policy and public perception along with ongoing innovation will enable nuclear energy to overcome traditional barriers to deployment and expand into new markets.

  Since 1950s, India has pursued nuclear program for peaceful use of energy for betterment of people. Quite early in the history of nuclear energy, India entered into collaboration with UK and Canada for setting up power plants and nuclear research reactors. It chose the pathway of developing PHWR with available uranium resources with a futuristic plan to reprocess the spent fuel and use them in fast reactors for better utilisation of limited nuclear fuel resources.

- Nuclear energy entry pathways for newcomer countries align with the 2030 Agenda for Sustainable Development. Nuclear energy programmes, based on the IAEA's Milestones Approach, support national energy needs, socio-economic, and environmental goals, and can help countries meet international climate commitments.

  Presently contribution of nuclear energy in India is just around 2 % of the generated energy. For sustainable development, India is planning a fleet of 14x700 MWe PHWRs and 4x1000 MWe VVERs through Russian collaboration. Negotiations with NSG countries are at different stages for setting up Gen III nuclear plants. All these new reactors are going to help India in meeting the international climate commitment.

- There are many sustainable options for implementing a nuclear fuel cycle and waste management strategy. Countries should adopt such strategies based on their needs (e.g. enhancing economic development and security of supply) as well as the presence of domestic mineral resources, technical capabilities, and the economic opportunities they see in the different fuel cycle options.

- **By adopting the pathway of PHWR, for sustainable growth, India is pursuing a 3-stage program to manage the limited fuel resources , the spent fuel and the waste. With the modest domestic resources, in the 1st stage, India is building indigenous PHWRs for which the technologies from mine-to mine have matured and are in place. The spent fuel coming from the 1st stage will be reprocessed, separated and fabricated as fuel for use in Fast reactors of 2nd stage. A prototype fast breeder reactor, gateway to the 2nd stage, is in advanced stage of commissioning. After several fuel cycles of reprocessed fuel in the fast reactors, thorium will be introduced in fast reactors to breed man made fissile fuel to be used latter in thorium reactors. Thorium reactors of the 3rd phase are self-sustaining. The time line for thorium reactors could however go beyond 2050.**

- Currently available nuclear reactor designs are based on mature and proven technologies that in some instances have been licensed to operate for 80 years. A range of designs are available, all of which offer high levels of safety and outstanding operating performance. They provide reliable, affordable and low-carbon electricity that will support a country in meeting its sustainable development goals.

  The operating PHWRs in India have performed with high level of safety and availability. In view of sustainable/guaranteed supply of fuel achieved through tough barriers of NPT/NSG regimes, all the operat-

ing stations are performing with high capacity factor. Many reactors have stood top in the list of best performing reactors in the world. These features demonstrate maturity in PHWR technology, overall quality control, strict regime of training, good operating practices, uncompromising safety standards and dedicated work force.

- A wide range of small modular reactor and advanced reactor designs are currently under development, with some ready for near-term deployment. These offer enhanced flexibility and will be suitable for helping to decarbonize heat and transport as well as electricity – boosting sustainability even further.

India is pursuing design and development of advanced reactor design with passive control and regulating system. Through several lab scale experiments and prototype engineering scale experiments, it has been demonstrated that 300 MWe SMR can be operated with natural circulation of the coolant. The reactor can adopt to different fuel cycles thus opening an opportunity to test future fuel types to be developed for the 2nd and the 3rd stage. India is also pursuing research and development of heterogeneous and homogeneous SMRs. Many lab scale experiments with molten salt have been setup and a large data bank has been built. The supporting thermal hydraulic and nucleonic software has been developed to validate the experimental findings.

- There are many ways in which nuclear and renewable energy technologies complement each other for the common goal of delivering clean, affordable and reliable energy.

To meet the international climate commitment, the energy mix of nuclear and renewable is very important. The recent MIT study on energy mix has shown that the potential contribution of nuclear can make a dispatchable low-carbon technology without which, the cost of achieving deep decarbonization targets increases significantly. This study considers projected energy scenario in USA and China to address highest and lowest cost of power in 2050.

UNECE report concludes by stating that sustainable pathways for nuclear development emerge as part of the full consideration of the regulatory, social, technical, environmental and economic aspects of programmes, as well as national capability and capacity.

References

[1] MIT report on Future of Nuclear Energy in a Carbon Constrained World study 2018

https://energy.mit.edu/wp-content/uploads/2018/09/The-Future-of-Nuclear-Energy-in-a-Carbon-Constrained-World.pdf

[2] United Nations Economic Commission for Europe (UNECE, Geneva) report on "Use of Nuclear Fuel Resources for Sustainable Development - Entry Pathways"2021

https://www.world-nuclear-news.org/Articles/UNECE-report-provides-pathways-for-nuclear-energy

[3] Joint letter from the Czech Republic, French Republic, Hungary, Republic of Poland, Romania, Slovak Republic and Republic of Slovenia on the role of nuclear power in the EU climate and energy policy

https://www.gov.pl/web/premier/joint-letter-by-seven-state-leaders-to-eu-commission-on-the-role-of-nuclear-power-in-eu-climate-and-energy-policy

[4] The Joint Research Centre (JRC), the European Commission's Technical assessment of nuclear energy with respect to the 'do no significant harm' criteria of Regulation (EU) 2020/852 ('Taxonomy Regulation') 2021

https://www.neimagazine.com/news/newsecs-jrc-says-nuclear-does-no-significant-harm-8635249

Contributed by Dr A. Rama Rao

The good thing about science is that it's true whether or not you believe in it.

— Neil deGrasse Tyson

INS Round Up

1.1 INS Head Quarter: Webinar Series Launched

INS is very glad to announce that it has launched its Webinar series on February 5, 2021 with Dr. A P Tiwari, Associate Director, Knowledge Management Group, BARC and a distinguished member of EC of INS as Convener. The inaugural Webinar was delivered by Dr. Anil Kakodkar. Shri S K Mehta welcomed the speaker and the audience and also delivered the Presidential Address. (For viewing the proceedings click on the link https://youtu.be/zulCZ66R4nY). The second webinar was delivered by Dr. R B Grover on February 21, 2021 (for viewing, click the link https://youtu.be/cWk_NVbqjj0). The third webinar was organised by INS jointly with Indian National Academy of Engineering (INAE) on March 31st, 2021 with Shri S.K. Sharma, C&MD, NPCIL as the distinguished speaker.

1.2 INS Branches: Hyderabad Branch Organises One-day Seminar "Radiation and Environment"

A one day seminar on "**Radiation and Environment**" was organised under the aegis of the Indian Nuclear Society (INS), Hyderabad Branch on 15th March, 2021 at AMD Complex, Hyderabad. In the introductory remarks Dr. D.K. Sinha, Director, AMD & Chairman, Indian Nuclear Society, Hyderabad Branch mentioned that the objective of organising this seminar was to create and spread societal awareness on the benefits of nuclear science and technology to mankind and remove the myths on its environmental impact. He introduced the theme of the seminar and highlighted the activities of AMD viz. exploration for Uranium, Thorium, Rare Metals and Rare Earths in an environmentally benign manner in various parts of the country including Telangana and Andhra Pradesh. Theme specific lectures by seven eminent Scientists and Academicians were delivered in the seminar. The lectures followed with a Panel Discussion in which Dr. D.K. Sinha, Director, AMD; Dr. Dinesh Srivastava, CE, NFC; Dr. R.K. Vatsa, Head, Public Awareness Division, DAE; Shri N. Rambabu, Executive Director, ECIL; and Shri M.S. Rao, GM, Tummalapalle Project, UCIL along with the invited speakers, interacted with the participants and media personnel. The seminar concluded with a vote of thanks by Dr. T.S. Sunil Kumar, Additional Director (R&D), AMD and Secretary, INS, Hyderabad Branch.

2. Programmes organised by other institutions to disseminate information related to nuclear science and technology where INS members actively participated

2.1 Dr. Anil Kakodkar chaired a panel discussion on Nuclear Energy organised by Chennai International Centre

A panel discussion on topic 'Is Nuclear Energy a Solution for Sustainable Development?' was organised on 16th April, 2021. The panel chaired by Dr. Anil Kakodkar, Former Chairman and presently Member, Atomic Energy Commission of India consisted of Seth Grae, President & CEO, Lightbridge Corporation, USA, Sean M. McDeavitt, Director, TEES Nuclear Engineering & Science Centre, TEES Nuclear Power Institute & Professor, Texas A&M University, USA and Ms. Elina Teplinsky, Partner, Pillsburry Winthrop Shaw Pittman, LLP, USA. The proceedings can be seen at link https://youtu.be/OjqWnokC-XM .

2.2 Secretary, INS speaks in the virtual discussion series of Indian Youth Nuclear Society

Indian Youth Nuclear Society (IYNS) has recently launched a virtual discussion series titled **'People Should Know'**. The inaugural episode aired on March 21, 2021 featured Shri S.K. Malhotra, Secretary, INS in discussion with Dr. Vaishnavi of IYNS. The discussion covered in detail the three stage INPP of India. The entire episode is available on link https://www.youtube.com/watch?v=RJa-7GYBU7A\

2.3 Eminent members of INS participate in a discussion platform launched by NIAS, Bengaluru

National Institute for Advanced Studies (NIAS), Bengaluru as part of its research in the domain of Science and Risk Communication and with an objective of creating a platform for engaging students, researchers and the people, started a discussion forum, **"Let us Discuss Risk Communication"**. The organiser was Prof M. Sai Baba, Visiting Professor, School of Natural Sciences and Engineering, NIAS. So far, four discussions have been held in the series with four eminent life members of INS. The speakers and corresponding links are :

Prof. V S Ramamurthy, Let Us Discuss RiskComm – Nuclear Risk Perception and

Communication @ NIAS .

Dr. D K Srivastava, Risk Perceptions of Plague Through Millenia – Nuclear Risk Perception and Communication @ NIAS (riskcommnuclear.in) .

Dr. K S Parthasarthy, Stories of Risk Communication – Nuclear Risk Perception and Communication @ NIAS (riskcommnuclear.in)

Shri S K Malhotra, https://www.youtube.com/watch?v=4mmAJBpwfE0

2.4 Eminent members of INS deliver lectures at QIP organised by IIT, Kanpur

A Short Term Course on Radiation, Health, Safety and Security was organised by IIT, Kanpur during March 2-7, 2021. Dr R.B.Grover, Emeritus Professor, HBNI delivered the inaugural address. Other speakers in the course included Dr. V K Manchanda, VP, INS and other eminent INS members . Details are available on link https://iitk.ac.in/qip/courses/20-21/radiation-health-safety-and-security/

Compiled by Sh. S.K.Malhotra

"When kids look up to great scientists the way they do musicians, actors [and sports figures], civilization will jump to the next level." – Brian Greene

Nuclear News Snippets

Nuclear power can help raise climate ambitions

https://www.world-nuclear-news.org/Articles/ Nuclear-power-can-help-raise-climate-ambitions

Canadian uranium mine and mill to resume operation

https://www.world-nuclear-news.org/Articles/ Canadian-uranium-mine-and-mill-to-resume-operation

Estonia to assess adoption of nuclear energy

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NGOs call for nuclear's inclusion in EU taxonomy

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Grid connection for Pakistani Hualong One unit

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"A man who dares to waste one hour of time has not discovered the value of life".

— Charles Darwin

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UK nuclear industry launches 'hydrogen roadmap'

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"You cannot teach a man anything; you can only help him discover it in himself".

-- Galileo

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Compiled by Sh. S.K.Malhotra

Solution to the Cross word puzzle appeared in INS NL Feb.,2021 (Vol 21 Issue 1)

Across	Down
2. Power	1.Solid
5. Expansion	3. Kinetic
7. Impulse	4.Alchemy
8. Kelvin	6.Alloy
10. Contract	7.Isotope
11. Energy	9.Beta
13. Potential	12.Terminology
14. Force	17. Joule
15. Newton	
16. Pascal	
18. Pressure	

Winners

1. Dr S.K. Saxena, BARC;
2. Dr L.M. Pant, BARC;
3. Dr S.G. Marathe, Retired BARC

Editor

"Imagination is more important than knowledge".

— Albert Einstein

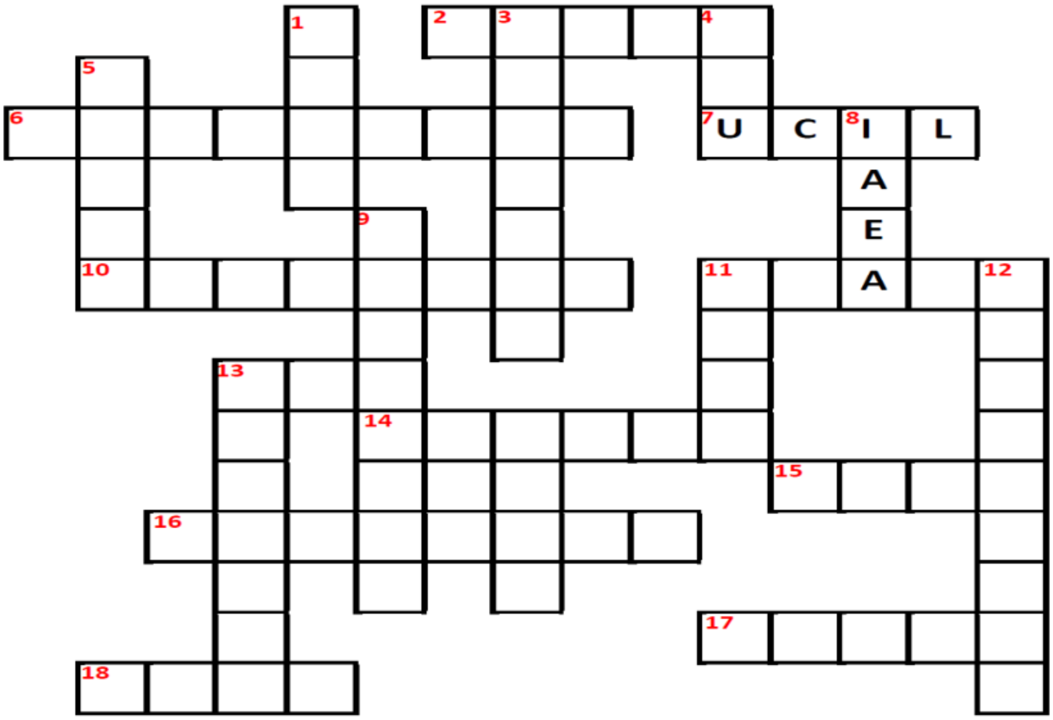
"If I have seen further it is by standing on the shoulders of Giants".

— Isaac Newton

"What you learn from a life in science is the vastness of our ignorance."

— David Eagleman

CROSSWORD PUZZLE — May 2021



Across

2 Emergency shutdown of a nuclear reactor

6 Substance used in a nuclear reactor for thermalizing the fast neutrons

7 PSU under DAE, responsible for mining of uranium in India

10 Indian -------- Observatory ; a sub-atomic particle research project being set up in a cave, 1200 m deep in a hill in Tamilnadu.

11 Acronym that means making every reasonable effort to minimize (far below the dose limit) the exposures to ionizing radiation.

13 Acronym for a popular solvent used in the PUREX process for the extraction of uranium and plutonium from spent fuel.

14 Commonly used as cover gas in PHWRs.

15 It is the total or intrinsic angular momentum of a body or particle

16 The minimum mass of a fissile material needed for a sustained nuclear chain reaction.

17 First person to win Nobel Prize twice, first in Physics and the second in Chemistry.

18 Acronym for the Soviet design of nuclear reactor also known by another acronym – LWGR.

Down

1 The unit for nuclear cross section that is used to describe the probability of a nuclear reaction.

3 The fluid that is used to remove heat from the core of a nuclear reactor.

4 Acronym for a uranium compound popularly called yellow cake which is often the final product of a uranium ore processing plant

5 Element often used for controlling the neutron flux in a nuclear reactor.

8 Acronym for an autonomous UN organization that seeks to promote the peaceful use of nuclear energy.

9 Moderator used in Chicago Pile-1, the world's first artificial nuclear reactor

11 The smallest unit of a chemical element.

12 The 15 chemical elements with atomic numbers from 89 to 103 .

13 The element providing the fissile material for the 3rd stage of Indian nuclear power programme.

Contributed by Sh. S.K.Malhotra

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

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