INDIAN NUCLEAR SOCIETY NEWS

Kakrapar Atomic Power Station (KAPS) 3 & 4 - 700 MWe indigenous Pressurised Heavy Water Reactors of the Nuclear Power Corporation of India Limited (NPCIL), Department of Atomic Energy (DAE), dedicated to the Nation by Hon'ble Prime Minister Shri Narendra Modi

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QUARTERLY BULLETIN OF

INDIAN NUCLEAR SOCIETY

OCTOBER TO DECEMBER 2023, VOL. 23, ISSUE 4

CONTENTS

FROM THE EDITOR'S DESK

Dear INS Members,

By all measures, the INSIC-2023 was a successful Conference, held at the imposing DAE-Convention Centre, located in the idyllic surroundings of Anushaktinagar, Mumbai.

The Conference organized by the Indian Nuclear Society (INS) in association with the Nuclear Power Corporation of India Ltd., (NPCIL), brought together more than 450 Delegates including some from Government Sectors and Industry.

The theme of the Conference, 'Nuclear for Clean Energy Transition' was aptly elaborated by the Chief Guests, Shri B. C. Pathak, Chairman & Managing Director, NPCIL, and Shri V. Bhasin, Director, Bhabha Atomic Research Centre. India has set an ambitious target of reducing CO2 emissions by 50% by 2030 and achieving carbon neutrality by 2070. Nuclear power will be an important element of this transition by building large NPPs to replace aging thermal power plants.

The emphasis on clean energy transition, and how nuclear energy can effectively contribute to it was the video-message from Mr. Rafael Mariano Grossi, Director-General, International Atomic Energy Agency (IAEA) to the audience at INSIC-2023.

President, INS, in his address spotlighted that the current world energy mix of 76% fossil fuels, 16.2% renewables and 7.8% nuclear, is just not compatible with goal of limiting CO2 content of atmosphere to 442 ppm and temperature rise around 1.5°C by 2050. For this an energy mix of 54% renewables, 33% nuclear and 13% fossil fuels is required. This mix will improve the poor air quality that 90% of the world population is presently living in.

Coincidentally, the 2023 UN Climate Change Conference COP28 concluded on December 13, 2023, as the INSIC-2023 was going on, and the COP 28 closed with an agreement that for the first time, signals the "beginning of the end" of the fossil fuel era by laying the ground for a swift, just and equitable transition, underpinned by deep emissions cuts and scaled-up finance. Several of the participating countries agreed to triple the nuclear energy component in their energy mix.

The various sessions that followed was a forum where experts, professionals, industrialists and administrators from all over the world converged to share their ideas, cutting-edge research, emerging trends and to highlight the importance of a collective effort towards a sustainable and energy-efficient future.

This issue of the INS News covering the INSIC-2023 will provide highlights of the Conference to those who could not attend it and be a memorabilia for those who attended. Director General, IAEA's message, President INS' address and all available abstracts of the invited talks are included in the following pages. Photographs of Invitees, Delegates, industry participants, poster sessions are also included.

Three Panel Discussions and one Conference Round-up were there in the INSIC-2023, chaired by stalwarts in the field and provided important take-home messages. Including these in this issue would have made it very lengthy and, hence, will be included in the next issue of INS News.

Last, but not the least, the INSIC-2023 was also the time when a Cooperation Agreement was signed between the INS and French Nuclear Society (SFEN), on December 14, 2023, in the sidelines of Conference, by Ms. Valerie Faudon, Director General, France, on behalf of SFEN and Dr. B.N. Jagatap, President, Indian Nuclear Society, on behalf of INS. Copies of the Cooperation Agreements signed by the INS with The American Nuclear Society (ANS), and the Atomic Energy Society of Japan (AESJ) are also included.

To sum up, the Organizing Committee of the INSIC-2023 managed the Conference and its associated logistics, remarkably well and the INSIC-2023 showcased the purpose of the Indian Nuclear Society and its relevance in the Nuclear Energy scenario in India.

(Dr. M. G. R. Rajan)

SUMMARY REPORT ON THE INTERNATIONAL CONFERENCE INSIC-2023 ORGANISED BY INDIAN NUCLEAR SOCIETY ON "NUCLEAR FOR CLEAN ENERGY TRANSITION".

Introduction:

Indian Nuclear Society (INS) in association with NPCIL had organized the Indian Nuclear Society International Conference-2023 (INSIC-2023) with the theme "Nuclear for Clean Energy Transition" from December 12-15, 2023, at DAE Convention Centre, Anushaktinagar, Mumbai 400 094.

The INSIC-2023 was organized to bring together International and Indian experts from Industry, R&D Organizations and Academia to deliberate on the directions for decarbonisation with Nuclear as an essential foundation of the energy source. INSIC-2023 was arranged to bring more clarity on Nuclear Energy which is the inevitable choice to achieve deep-decarbonisation, since it is the largest source of base load power with minimum carbon footprint.

The intention of organizing INSIC-2023 was based on the present Government of India's Policy i.e. 'Make in India', which gives vision to bring Indian Industries at par with global industries.

Shri Vivek Bhasin, Director, BARC, and Guest of Honour, cutting the ribbon to mark the start of INSIC-2023

Brief details about INSIC-2023

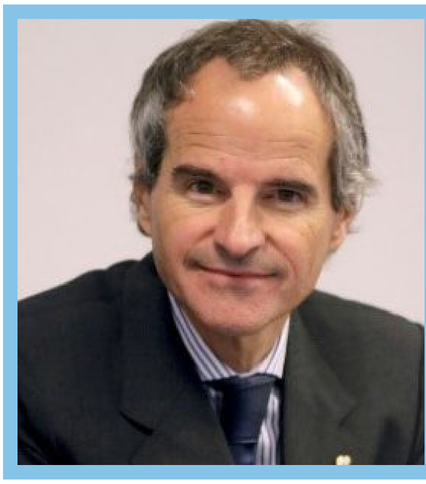
About 450 delegates from Nuclear Fraternity and Nuclear Related Industry participated in the INSIC-2023 International Conference, including 30 foreign delegates. Shri S. K. Malhotra and Shri Grover Prince compered the inaugural session. Shri. Harish Kalsi, Convenor, INSIC-2023 welcomed the Chief Guests and delegates and highlighted the relevance of the Conference in the context of mitigating global warming.

The Indian Nuclear Society's International Conference INSIC-2023 on the theme "Nuclear for Clean Energy Transition" was inaugurated by Shri B C Pathak, Chairman & Managing Director, Nuclear Power Corporation of India Ltd. Shri Pathak talked about the NPCIL's strength in the design, construction, operation and maintenance of Pressurized Heavy Water Reactors (PHWRs). He said that NPCIL's records in the operation of 220 MWe PHWRs are world-renowned. He further added that NPCIL is now focusing on optimizing and standardizing the design of 700 MWe reactors with several passive safety systems. He said that nuclear capacity in the country is going to increase by 14,500 MW in the coming decade.

Shri Vivek Bhasin, Director, Bhabha Atomic Research Centre, who was the Guest of Honour, emphasized the need for accelerating the growth of nuclear power to replace fossil fuel-based power plants at a fast pace.

Prof. B.N. Jagatap, President, Indian Nuclear Society, in his presidential address said that in order to restrict the global temperature rise to 1.5oC, the world needs to achieve an energy mix with 54% renewables, 33% nuclear and 13% fossil. This would need tripling or almost quadrupling the energy by 2050. He said that during COP-28 summit held recently at Dubai, many countries have declared to triple their nuclear capacity. He further said that nuclear renaissance will call for life extension and management of aging nuclear reactors, accelerated growth of nuclear power through Gen III and III+ nuclear reactors, and rapid progress in innovative nuclear technologies like Small Modular Reactors (SMRs), nuclear hydrogen and breeder reactors etc. He informed that during the conference, Indian Nuclear Society is going to sign cooperation agreements with the French Nuclear Society and European Nuclear Society.

Dr. S. Gangotra, Secretary INSIC-2023 delivered the vote of thanks to all those who were directly or indirectly involved in organizing and conducting INSIC-2023.



Rafael Mariano Grossi
Director General

IAEA
International Atomic Energy Agency

It is a pleasure to address the Indian Nuclear Society's International Conference hosted in Mumbai.

I understand that a considerable number of speakers from India and from abroad are participating in this conference to deliberate on nuclear energy's role in the clean energy transition.

The Indian Nuclear Society and the Nuclear Power Corporation of India are providing a timely opportunity for discussion among experts from academia, industry and policy that I am confident will create a broader understanding of the path ahead.

Given the IAEA's central role in supporting nuclear's inclusion in the global energy basket, I would be pleased to speak on your first topic: "The road to net zero emission and the energy mix for the future".

Let me begin with COP28. This year, the International Atomic Energy Agency (IAEA) gathered the countries that use or support nuclear energy, and together we made an unequivocal statement: net zero needs nuclear energy.

It was the first time; such a public statement had been made and it included the important message that nuclear power needs a fair and even playing field when it comes to financial support.

Like everything we do at the IAEA, our statement was based on fact. Analysts widely agree that nuclear power capacity will need to more than double by 2050 for current climate goals to be reached. We will need even more capacity to go beyond the electricity grid and decarbonise transport and industry.

India's decisions regarding nuclear power will make a significant impact on the path ahead.

The country's nuclear power program has evolved from a limited, self-reliant system. Today, it continues the tradition of self-reliance but is more open to international collaboration. With 8 reactors under construction and many more planned, India is the world's second largest domestic builder of nuclear power plants, with only China building greater numbers.

India's pioneering three-Stage approach comes with potentially global implications and is being closely watched.

Last month, I discussed with Prime Minister Narendra Modi India's economic, climate and nuclear energy goals. He made clear his government's determination to increase non-fossil energy capacity and to triple nuclear installed capacity within a decade. We also discussed advanced reactors, including Small Modular Reactors.

This is an area where the IAEA is very active. Our nuclear harmonisation and standardization Initiative is one example. It brings all stakeholders towards harmonising regulatory approaches and standardizing design approaches so that SMRs can be safely deployed in good time.

There are two other areas I would like to mention, Atoms4NetZero and our indispensable work in nuclear safety and security. Atoms4NetZero assists countries in mapping out their journey to net zero showing the ways nuclear energy is helping and can help their progress.

That brings me to safety, an area where I recognize and commend your commitment. The IAEA plays a central role in safety and also security. It's safety standards and security guidelines are widely relied on, and its peer reviews help countries keep improving their safety and security.

In Ukraine, the IAEA has been there from the start of the war to keep the world informed of the situation at one of the Europe's largest nuclear power programs. We are helping to reduce the risk of an accident through our ongoing presence at all Ukraine's nuclear power plants including Zaporizhzhya.

For Ukraine's people, for the future of nuclear and our planet, we cannot afford an accident.

Let me end on a positive note and tell you about a historic event coming up. The first ever nuclear energy summit will take place in Brussels in March 2024. Many heads of state that support nuclear have already confirmed their attendance. The world is at a crossroads on the path towards sustainable development and prosperity. I am determined to do everything I can to support the wider uptake of nuclear power. I commend you for the important part you are playing on this journey and wish you every success at this conference and in the indispensable work you do towards ensuring India's economic growth and the attainment of its climate goals.

INSIC-2023 INAUGURAL CEREMONY

Dignitaries on the dais (L to R) Dr. S. Gangotra, Secretary INSIC-2023, Shri Vivek Bhasin, Director, BARC, Shri B.C. Pathak, CMD, NPCIL, Dr. B.N. Jagatap, President INS, Shri Harish Kalsi, Convenor, INSIC-2023. On the right is Shri S.K. Malhotra who anchored the function.

Shri Harish Kalsi, Convenor, INSIC-2023 welcoming the delegates.

Shri Vivek Bhasin, Director, BARC, and Guest of Honour, addressing the gathering

Dr. B.N. Jagatap, President INS, giving the Presidential Address.

Shri B.C. Pathak, CMD, NPCIL, addressing the delegates to the Conference

Recorded video talk from Mr. Rafael Grossi, Director General IAEA, being played to the audience.

Dr. S. Gangotra delivering the Vote of Thanks

Director, BARC and CMD, NPCIL with INS Office Bearers and INSIC-2023 Organizing Committee Members

Audience at the Conference

The Inaugural Session ended with the National Anthem

Group Photos of the Delegates and Invitees to INSIC-2023

Admiring the beautiful rangoli of the INSIC-2023 logo.

Dr. Rama Rao, Co-Convenor INSIC-2023 explaining the Conference Programme to Director, BARC

At the selfie point

INS PRESIDENTIAL ADDRESS - INSIC-2023

Prof. B. N. Jagatap

Honourable Shri B.C. Pathak, CMD NPCIL, Shri Vivek Bhasin, Director, BARC, Shri Harish Kalsi, Convener, INSIC-2023, Dr. Suresh Gangotra, Secretary, INSIC-2023,

Distinguished invitees invited speakers and delegates from India and abroad, Members of Executive Committee of INS, Members of Organizing and Advisory Committees of the conference, Life members of Indian Nuclear Society, Industry representatives, Media persons, Students, Ladies and Gentlemen.

On behalf of Indian Nuclear Society and on my own behalf, I extend a warm welcome to you all. Special words of welcome are due to delegates from abroad, who have made it to the conference on the invitation of the organizing committee.

INS is indeed proud to host this conference on the theme, **Nuclear for Clean Energy Transition**, which is intimately connected to the most pervasive issue of mitigating the climate change.

Friends, we understand that the stability and resilience of the Earth system and human well-being are inseparably linked. Unabated use of fossil fuels has put the Earth system on a trajectory moving rapidly away from its stable state. The world has recognised the indispensable role of nuclear energy in achieving global net-zero green-house gas emission and in keeping a 1.5 degrees limit on temperature rise by the middle of this century.

Current world energy mix consists of 76% fossil fuels, 16.2% renewables and 7.8% nuclear. With business-as-usual scenario, by 2050 CO_2 content of the atmosphere will reach 520 ppm and the rise in global temperature will be 3.2^o C. An alternate scenario of energy mix is to have 54% renewables, 33% nuclear and 13% fossil fuels. This mix will limit CO2 content of atmosphere to 442 ppm and temperature rise around 1.5^{0}C. This scenario will also result in 90% reduction in the people who are presently subject to low air quality.

This calls for tripling and almost quadrupling the nuclear energy by 2050. As we know, several countries have issued a declaration to triple nuclear energy during COP28 summit, very recently at Dubai.

An action plan to realize the nuclear renaissance rests on three important pillars: life extension and management of aging nuclear reactors, accelerated growth of nuclear power by Gen III and III+ nuclear reactors, and rapid progress in innovative nuclear technologies like Small Modular Reactors, Nuclear Hydrogen, Breeder reactors etc. INSIC-2023 will have intense deliberations on all these issues. We have also included talks on accelerator-based technologies which may help to sustain carbon neutrality after 2050. It is important to note here that the nuclear renaissance is not just more nuclear power, it's also cleaner, safer, and efficient power.

Rapid growth in nuclear power needs significant efforts in capacity building and public outreach. I am happy to inform the audience that Indian Nuclear Society is working in these areas in a major way. Apart from the climate change, nuclear energy is also a driver for many of the sustainable goals through nuclear agriculture, radiation food processing, nuclear medicine, nuclear desalination so on and so forth. These issues also form topics of our public discourses. In INSIC-2023, we have invited 20 engineering students so that they understand the challenging issue of energy transition and may decide to take up career in nuclear areas.

The 17th sustainable development goals are Partnership for the Goal. INS has started developing partnerships with Indian Scientific Societies to hold joint workshops and conferences. It is also entering into cooperation agreements with international nuclear societies. During this conference, INS will sign cooperation agreements with French Nuclear Society and European Nuclear Society. Our profuse thanks to Dr. Valerie Faudon, Director General of French Nuclear Energy Society and Vice-President of European Nuclear Society for her participation in this Conference

I am confident that INSIC-2023 will provide a platform for deliberation on the nuclear-mediated clean energy transition by focussing on energy mix for net zero, accelerated growth of nuclear power, advanced nuclear reactors, emerging technologies for enhanced safety and security, policy framework, industry participation and many other key issues.

Finally, I extend my most warm and hearty welcome to all delegates once more and wish them memorable stay, and stimulating deliberations on one of the most important issues of our times.

Thank you one and all.

Group Photo of INSIC-2023 Organizers and Volunteers

THE THEME OF THE INSIC-2023 HAD THE FOLLOWING TOPICS

1. Global Nuclear Industry & Capability to Sustain a Three-to Four-Fold increase in Nuclear Power.
2. NPCIL on the Path of Nuclear Energy Growth
3. Growth of Gen III and III+ Reactors
4. Key Policy changes Required to Enhance the Role of Nuclear Power in India's Pathway to Net Zero.
5. Clean Core's Thorium and HALEU based ANEEL Fuel for PHWRs.
6. Emerging Technologies in Support of Nuclear Power Deployment Security & Safety.
7. Delivering on the Promise of Small Modular Reactor.
8. Developments in Hydrogen Production Schemes with Nuclear Energy.
9. Design, Development and Deployment of Alkaline Water Electrolyser Technology at BARC.
10. Sustainable Nuclear Fuel Cycle as an Answer to Spent Nuclear Fuel Management Challenge.
11. Nuclear, both Big and Small Powers the Energy Transition.
12. EDF's Gen-III & III+ Reactors – Growth Acceleration & Cost Reduction.
13. Nuclear Power Development-Technologies and Skills Challenges: lessons learned in France and opportunities in India.
14. Korea's Nuclear Power Development Experience and Competitiveness.
15. Second Stage of Indian Nuclear Programme Towards Green Energy Transition
16. Role of Larsen & Toubro in Furthering Nuclear Growth in India.
17. Role of Walchand Industries Ltd., in the Growth of Nuclear Power in India.
18. General Aspects of SMR use.
19. Climate Change and India's Energy Transition: The Role of Nuclear Power.
20. Accelerator Driven Sub-Critical System / Thorium for lower cost nuclear energy.
21. Advanced Sub Critical Micro Reactors for Energy Distribution.
22. Self-Reliance and Diversification in Heavy Water Technologies.
23. Development of High Intensity Proton Accelerators – Present Status and Future Programme.

Ten International Experts and twelve Indian Experts delivered talks on the above topics. Over and above these presentations, there were three panel discussions in which the International Experts participated. At the end, a panel gave an overview of the INSIC-2023.

ABSTRACTS OF INVITED TALKS

1.The Nuclear Industry's Capability to Sustain a Tripling of Global Capacity in Nuclear Energy to Support the Clean Energy Transition

Serge Gorlin
World Nuclear Association, UK

World Nuclear Association, in partnership with the Emirates Nuclear Energy Corporation (ENEC), launched Net Zero Nuclear earlier this year ahead of COP28 in Dubai. Net Zero Nuclear is an initiative that calls for unprecedented collaboration between government and industry leaders to at least triple global nuclear capacity to help achieve carbon neutrality by 2050. The initiative aims to focus the industry's collective efforts on realistic, actionable, solutions-focused dialogue to enable the rapid expansion of the global nuclear fleet and the acceleration of research and development into emerging nuclear technologies.

Besides looking at the rationale for NZN, this paper will look at the opportunities and challenges of meeting the 2050 target notably in the context of the markets for the nuclear fuel cycle and nuclear-grade structures, systems, components and services for nuclear power plants. The paper will also examine international efforts to encourage standardized deployment of nuclear reactors and a more harmonized approach to licensing that represent an important enabler for new nuclear. Reference will be made to recent research done by the Association and its members as reflected in 2023 editions of the The Nuclear Fuel Report and The World Nuclear Supply Chain. The paper will also present the findings of a report produced by the Cooperation in Reactor Design Evaluation and Licensing (CORDEL) Working Group of World Nuclear Association in cooperation with Canadian Nuclear Association (CNA) and Nuclear Energy Institute (NEI) entitled a Framework for International Regulatory Efficiency to Accelerate Nuclear Deployment.

The Nuclear Fuel Report, published since the 1970s examines key questions, such as how uranium resources, conversion and enrichment services will satisfy future reactor requirements and to what extent secondary supplies will continue to contribute to meeting demand. The World Nuclear Supply Chain covers the life-cycle of nuclear power plants through construction, operation and decommissioning. This includes new build of large gigawatt-scale and small modular (SMR) reactors including advanced and microreactors, as well as the reactor refurbishment to support long-term operation.

Drawing upon the invaluable insights and analyses presented in these reports this paper will provide a comprehensive understanding of the current and future landscapes.

World Nuclear Association is the international organization that represents the global nuclear industry. Its mission is to promote a wider understanding of nuclear energy among key international influencers by producing authoritative information, developing common industry positions, and contributing to the energy debate. The Association facilitates interaction between companies of the world-wide nuclear industry to share experience, identify best practice and agree common industry positions on the development of policy and regulation thus supporting international nuclear commerce.

Serge Gorlin *is Head of Membership and Business Development at the World Nuclear Association, the international trade association for nuclear energy based in London, England, where he is responsible for improving the Association's value proposition to members and for expanding its membership base.*

As Head of Industry Cooperation (2013 – 2023), he led the Association's engagement with the IAEA, NEA / OECD and ICRP in various policy areas and also managed the production of biennial market reports on nuclear fuel and the supply chain for nuclear plants.

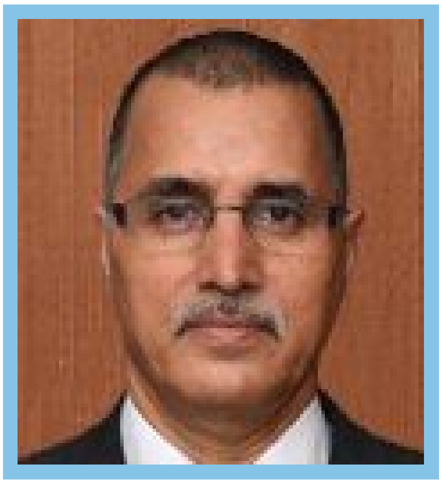
His career in nuclear began as a translator and interpreter at British Nuclear Fuels (1996 – 2000). He is the author of Nuclear English – Language Skills for a Globalizing Industry (WNU Press). He co-chairs the Transport Facilitation Working Group, a group championing the wider availability of routes to support the global transport of radioactive material.

2. NPCIL on the path of Nuclear energy growth

B.C. Pathak

Nuclear Power Corporation of India Ltd., Mumbai, India

Energy is one of the major inputs for the economic development of any country. Fossil fuel as a source of energy has played a significant role in this development but its adverse effects on global climate are beginning to surpass its benefits. Most of the developed as well as developing countries have recognized the need to address climate change concerns and agreed to reach the target of net zero carbon emission in the period between year 2050 to 2070. The world has to transit away from fossil fuels to carbon free sources of energy in the next few decades. The challenge is enormous and the options as of today are limited. In case of developing countries like India with a large aspirational population, energy assumes critical importance in view of its increasing energy demand and sustained growth in terms of industrialization & urbanization. The climate change concerns coupled with growing energy demand poses a huge challenge. One of the options that is proven and has matured is "nuclear". It can serve countries addressing climate challenges provided suitable environment for its growth is created. In India, Nuclear Power Corporation of India Limited (NPCIL) has the mandate of operating nuclear power plants and implementing the nuclear power projects for generation of electricity. In order to address the challenge, NPCIL has launched a large expansion program comprising of indigenous Pressurised Heavy Water Reactors (PHWR) and Light Water Reactors (LWR) set up with international cooperation. Indian PHWRs have undertaken a long journey from being Candu design Low-capacity reactors to being indigenous large capacity reactors with advanced features. The evolution has been based on operating experience- both national & international. The latest 700 MW Indian PHWRs display technological advancements at par with the best in the world. These PHWRs have adopted several passive safety features increasing their reliability. NPCIL strives to be globally proficient in nuclear power technology contributing towards long term energy security of the country while ensuring sustainability & Self-reliance. Nuclear power program in India has matured and is fast growing to be a copious source of electrical energy for the country.



***Shri Bhuwan Chandra Pathak** is a Mechanical Engineering graduate and began his career in 1986. He is Distinguished Scientist of the Department of Atomic Energy.*

He has a rich experience of over three decades in implementation of Nuclear Power Projects of various capacities of NPCIL starting from 220, 540, 700 to 1000 MWe of both PHWR and PWR technologies across the different sites in India. He held several key positions like Chief Construction Engineer, Project Director, Executive Director (Projects) before being appointed as Director (Projects) on NPCIL 's Board in July 2019. He has earned the reputation of a diligent and enterprising professional for his abilities to set benchmarks of outstanding achievements in his various assignments and leadership roles.

Shri Pathak took over as CMD on 23rd February 2022. He believes in a governance philosophy that fuels progress, diversification and develops a synergy through alliances taking the organization to greater heights. He works to achieve highest standards of corporate governance building a well-defined and enforced structure that best aligns the business conduct with the objectives of the organization.

He takes keen interest in establishing and nurturing sound safety culture in NPCIL fleet and is an advocate of contributing towards neighbourhood development under the Corporate Social Responsibility.

He now looks ahead with optimism in contributing to India's goal of self-reliance in energy by leading the most ambitious nuclear power expansion programme of the country.

3. Growth of Gen III and III+ Reactors

Akira Yamaguchi, Professor, School of Engineering, The University of Tokyo, Japan

Abstract not received

After graduating from the Nuclear Power Engineering Department in the Faculty of Engineering of the University of Tokyo, Yamaguchi completed his doctoral degree at his alma mater's engineering graduate school. After that, he joined the Power Reactor and Nuclear Fuel Development Corp. (PNC), now the Japan Atomic Energy Agency (JAEA). Where he engaged in research on fast reactors. He now specializes in nuclear reactor engineering, risk assessment, and so forth. After serving as a professor in the Division of Sustainable Energy and Environment Engineering in the School of Engineering at Osaka University, Yamaguchi assumed his current position in January 2015. He has served on various governmental committees, including the Electricity and Gas Industry Committee and the Nuclear Energy Subcommittee, under the Advisory Committee for Natural Resources and Energy.

4. Key Policy Changes Required to Enhance the Role of Nuclear Power in India's Pathway to Net Zero

R Srikanth,

Professor and Dean, NIAS, Bengaluru

Electricity security can be achieved only by 'having a reliable and stable supply of electricity that can meet the demand at all times at an affordable price." Coal-fired thermal power plants (TPPs) generated 74.3% of India's electricity during FY 2022-2023, and generation by TPPs continues to grow to meet demand. Most of the critical materials required for grid-scale battery storage are controlled by the top three producers, and batteries will become cost-effective only after 2030. Even as India's nuclear power capacity increases from 7.48 GW to 22.48 GW by 2031, this will be a fraction of the projected TPP capacity (260 GW).

Therefore, India's energy transition must include the rapid expansion of firm, zero-carbon nuclear energy to supplement Variable Renewable Energy (VRE) sources to reach Net Zero by 2070. However, conventional nuclear power plants (NPPs) in India can be set up only by companies controlled by the Government of India (GOI) since they require huge capital investments at each site and have large gestation periods. Besides, conventional NPPs require sites meeting stringent criteria which are very difficult to comply with in most regions of India.

Several G20 countries are developing Small Modular Reactors (SMRs) to complement conventional NPPs. Due to their smaller core damage frequency & source term, enhanced seismic isolation, and passive safety systems, such SMRs are being examined by nuclear regulators for installation and operation in sites with a 'site-boundary' emergency planning zone, and less stringent siting criteria compared to those mandated for NPPs.

The National Institute of Advanced Studies (NIAS) is conducting a 2-year research project sponsored by the Board of Research in Nuclear Sciences (BRNS) to identify suitable brownfield sites for SMRs which can be repurposed to enable a coal-to-nuclear transition in India. In this study conducted under the guidance of BRNS experts, several potential brownfield TPP sites are identified for SMRs with a total capacity of 40 GW which can be increased further by building SMR projects with enhanced seismic isolation and other features.

The Government is prioritising scarce government funds for undertaking critical poverty alleviation and infrastructure development programs. Therefore, the required growth of nuclear energy to reach Net Zero with electricity security can be achieved only by permitting the private sector to enter the atomic energy sector under certain conditions.

Further, brownfield sites suitable for repurposing into SMR projects are owned by Stet-owned Utilities, Independent Power Producers (IPPs), and Captive Power Plants (CPPs). SMRs are of specific interest to the private sector (Utilities and Captive Power Generators) since they have smaller capex and can be largely factory-built to reduce project duration and capital investments with serial manufacture under the Make-In-India program. This will also make India a global hub for manufacture of SMRs as envisaged in the G20 declaration.

GOI can therefore consider amendment of the Atomic Energy Act, the Civil Liability for Nuclear Damage Act, and related statutes to enable even private companies to set up SMRs under the overall regulation of AERB, while several administrative structures & mechanisms can be put in place to ensure strict compliance with India's track record in safety, national security, and international safeguards. This talk will focus on key policy recommendations.

Prof Srikanth *is the Dean, School of Natural Sciences & Engineering at the National Institute of Advanced Studies (NIAS) and heads the Energy, Environment, and Climate Change Program. He has a dual Ph.D. in Mining Engineering & Operations Research from the Pennsylvania State University and joined NIAS after serving industry for 20 years, primarily in Tata Steel. After working on policy-focussed research projects on coal sustainability and transition planning for the power sector, he is now conducting interdisciplinary research on nuclear power expansion, raw material security, and sustainable* *development. He works closely with BRNS, NITI Aayog, MOEFCC, and Government companies in India's power sector on matters related to India's energy transition in addition to his academic role at NIAS.*

5. Clean Core's Thorium and HALEU based ANEEL Fuel for PHWRs

Mehul Shah

Clean Core Thorium Energy, USA

Th-based fuels have the general merits of greater abundance of the element on earth crust, superior physical and nuclear properties, particularly in oxide form, better resistance to weapons proliferation and lesser production of heavier actinides in reactor irradiation. There has been worldwide effort to establish the thorium-based reactor technology for the last 50 years. Currently, Clean Core Thorium Energy is the only known company on path to commercialize Thoria-HALEU based fuel. Clean Core Thorium Energy (Clean Core) is, a Chicago-based company founded in 2017, exploring thorium driven power. Clean Core's thorium and HALEU (high-assay low-enriched uranium) fuel technology reduces life-cycle operating costs in pressurized heavy water reactor (PHWR) while increasing safety margins. Clean Core has collaborated with national and international organizations to fabricate and qualify this revolutionary fuel with the trade name of Advanced Nuclear Energy for Enriched Life (ANEEL). Clean Core's Patented ANEEL fuel is a combination of thorium and HALEU, is preparing to qualify, license and commercialize the ANEEL fuel by 2026. Formal Pre-licensing assessment activities regarding the novel ANEEL fuel design are being performed by the Canadian Nuclear Safety Commission. Heavy water reactors are used around the world and are leading some of the key economic performance matrices in some countries. Replacing existing natural uranium fuel with ANEEL fuel in PHWR will: 1. improve burnup by a factor of 6-8, 2. reduce refueling operations needed by the same factor, 3. reduce nuclear spent fuel volumes by the same factor, 4. achieves deep burn of isotopes of greatest proliferation concern, and 5. improve the level of safety and accident tolerance capability. An implementation plan and the benefits of using the ANEEL fuel design in Pressurized Heavy Water Reactors will be presented.

Mehul Shah

Mehul Shah founded Clean Core Thorium Energy in 2017 to revolutionize nuclear power generation using their patented Thorium/HALEU nuclear fuel. The ANEEL fuel, Advanced Nuclear Energy for Enriched Life, enables numerous benefits in today's worldwide fleet of CANDU/PHWR nuclear reactors.

Before founding Clean Core, Mehul served as the Founder and CEO of multiple global enterprises over three decades while acting as an angel investor into several advanced nuclear R&D efforts for over a decade. His diversified companies have spanned multiple industries and global markets. Mehul is now focusing his full time and energy on the R&D and commercialization of the ANEEL fuel as well as the deployment of nuclear energy for society's decarbonization and energy security needs.

6. Emerging technologies in support of nuclear power deployment

Valérie Faudon

French Nuclear Society (SFEN), France

The world is now experiencing a new wave of innovation in new concepts of nuclear reactors. The International atomic energy agency (IAEA) lists more than 80 different new concepts of innovative reactors from 10 to 300MW in the world.

Small/Advanced Modular Reactors (SMR/AMR) present new economic models (factory manufacturing), new safety approaches (leveraging smaller size, intrinsic safety), new methods of managing materials and waste (multi-recycling), and new applications (urban and industrial heat, hydrogen, carbon capture).

The France 2030 program, launched in 2021 and managed by the French strategic investment secretariat, supports the development of the SMR Nuward PWR reactor (2x170MWe) and includes a call for proposal for innovative reactors projects which showcase "disruptive" innovation. Around fifteen companies responded to this call for projects, with a diverse set of technologies (fast reactors with sodium, lead, molten salts, etc.) to cover multiple decarbonization needs.

__Valérie Faudon__ is the Director General for the French Nuclear Society (SFEN) and is the Vice President of the European Nuclear Society (ENS). She teaches at the PSIA (Paris School of International Affairs) at Sciences Po Paris (Institut d'Etudes Politiques de Paris). In her previous roles, she was Chief Marketing Officer at AREVA, and held several management positions at Hewlett-Packard (HP) and Alcatel-Lucent, in France and the United States. She is an alumni from Ecole Polytechnique, Ecole Nationale des Ponts et Chaussees (Civil Engineering), and Sciences Po Paris (Political Science). She holds a Master of Science in Engineering- Economic Systems from Stanford University in California.

7. Delivering on the Promise of Small Modular Reactor

Rita Baranwal & D. Alok Mishra Westinghouse, USA

The Westinghouse AP300™ **SMR is the Only SMR based on Licensed, Operating & Advanced Reactor Technology**. It is the most advanced, proven and readily deployable SMR solution. Westinghouse proudly brings 70+ years of experience developing and implementing new nuclear technologies that enable reliable, clean, safe and economical sources of energy for generations to come.

Westinghouse AP1000® reactor is already proving itself every day around the globe. Currently, four units utilizing AP1000 technology are operating in

China, setting performance records. Six more are under construction in China and one AP1000 reactor is operating at Plant Vogtle in Georgia while a second nears completion.

AP300 SMR leverages that operating experience, as well as tens of millions of hours on AP1000 reactor development. It has the benefits of the record-setting Westinghouse AP1000 PWR technology in a smaller power output to augment the backbone of your community energy system.

The AP300 SMR complements the AP1000 reactor for a cleaner energy mix, energy security, and grid flexibility and stabilization.

Rita Baranwal *is* ***Chief Technology Officer at Westinghouse Electric Company.*** *In this role, she leads the company's global research and development investments and spearheads a technology strategy to advance the company's innovative nuclear solutions. She brings nearly 25 years of experience to this role, which she has held since January 2022.*

During her career, ***Rita served as Assistant Secretary for Nuclear Energy in the U.S. Department of Energy (DOE) in a U.S. President-appointed and Senate-confirmed role.*** *She led efforts to promote R&D on existing and advanced nuclear technologies that sustain the U.S. fleet of nuclear reactors and enable the deployment of advanced nuclear energy systems. Rita also has held senior leadership roles with the Idaho National Laboratory as Director of the Gateway for Accelerated Innovation in Nuclear (GAIN) initiative and, most recently, the Electric Power Research Institute (EPRI) as Chief Nuclear Officer and Vice President of Nuclear. Earlier in her career, she led and conducted R&D in advanced nuclear fuel materials for U.S. Naval Reactors at Bechtel Bettis, Inc.*

Rita holds advanced degrees in materials science and engineering, including a Ph.D. from the University of Michigan and a Bachelor of Science (BSc) Materials Engineering from the Massachusetts Institute of Technology (MIT). She is distinguished as an American Nuclear Society Fellow.

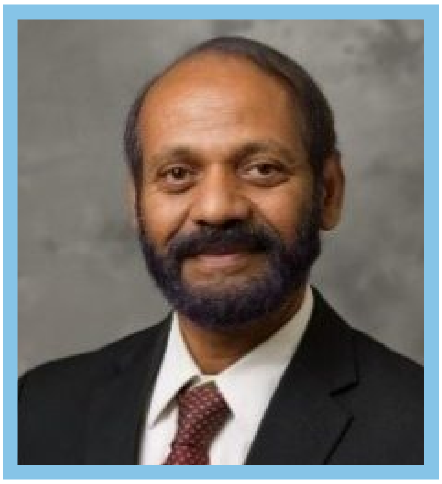
Alok Mishra *holds a PhD from IIT Bombay and an MBA with specialization in finance from University of Mumbai. He was a UNENE (University Network of Excellence in Nuclear Engineering) post-doctoral fellow at the Institute for Risk Research, University of Waterloo, Canada and was a recipient of IAEA fellowship for advanced training at Argonne National Laboratory Chicago, USA.*

Alok started his career as a trainee scientific officer with the Department of Atomic Energy in 1989. At Westinghouse he is responsible for supporting the AP1000 project in India and the development of India supply chain. Before joining Westinghouse he was working in USA as a principal consultant for consulting firms for the new build nuclear power plants safety analyses and licensing. He also worked as a consultant to the Canadian Nuclear Safety Commission for their Aging PRA studies and the OPG for its technology evaluations for the LWRs. During his early years at NPCIL, he had played a key role in resolution of safety issues in Indian NPPs. He worked for Kudankulam-1&2 licensing and was associated with Kurchatov and OKB Gidropress Institute at Moscow. Alok has keen interest in large scale multi objective optimization for risk and reliability using genetic algorithms. He has undergone advance training in joint venture management and mergers & acquisitions at IIM Bangalore. He has several publications in International referred journals/conference proceedings and has received several awards and recognitions.

8. Developments in Hydrogen Production Schemes with Nuclear Energy

Shripad T. Revankar
Professor of Nuclear Engineering at Purdue University, USA

Hydrogen has the potential to play a significant role in the world's transition to 100% clean energy. It can be used across multiple sectors to store and deliver usable energy to power the grid, drive industrial processes, or create energy dense fuels needed for long-haul trucks and airplanes. But, over 90% of the hydrogen currently produced comes from natural gas via through steam-methane reforming resulting in carbon emissions. Nuclear hydrogen is an attractive option to reduce this emission through low- and high-temperature electrolysis, and thermochemical processes to split water into pure hydrogen and oxygen. The talk will highlight current developments in nuclear hydrogen generation and potential for efficient generation of hydrogen at high temperatures. Projects on nuclear hydrogen generation schemes underway at various organization including US Department Energy labs, and GEN IV international forum are summarized.



Shripad T. Revankar *is a Professor of Nuclear Engineering at Purdue University, West Lafayette, Indiana. Currently he is Visiting Senior Professor at the IIT Jammu for fall 2023. His research interests are in advanced reactor systems, reactor safety, reactor thermal hydraulics, hybrid power systems, nuclear hydrogen generation, renewable energy, and fuel cell technology. He has published over 400 peer reviewed technical articles in archival scientific journals and conference proceedings and author/coauthor of several books including: Storage and Hybridization of Nuclear Energy: Academic Press, 2018, and Fuel Cells-Principles, Design, and Analysis, CRC Press, 2014. He is Chief Editor of Frontier in Energy- Nuclear Energy. He was elected as Fellow of ASME in 2008, Fellow of American Nuclear Society in 2015 and Fellow of American Institute of Chemical Engineers in 2017. He was recently honored with two major international awards: Technical Achievement Award by American Nuclear Society and Long Service Award jointly by Nuclear Engineering Division of ASME, Japan Society of Mechanical Engineers and Chinese Nuclear Society, for his significant contributions to reactor thermal-hydraulics through experiments, and modeling of phenomena important in the analysis of nuclear reactor safety and applications.*

9. Design, development and deployment of alkaline water electrolyzers technology at BARC

K. T. Shenoy

Bhabha Atomic Research Centre, Mumbai, India

The country has launched the National Hydrogen Mission to promote the development and deployment of green hydrogen production technologies in India. The mission is targeted to minimize carbon dioxide emissions by replacing majority of grey hydrogen which is presently used in different industries (refineries, fertilizer and steel industries) with green hydrogen. Hydrogen produced through water splitting using renewable energy sources such as solar and wind is called green hydrogen. Among the various methods for splitting water using renewable energy, water electrolysis is the only mature process for commercial deployment to the industry. Water electrolysis is the simplest single step method of hydrogen production at its highest purity at ambient temperature. Among the different electrolyzer technologies such as Alkaline Water Electrolyzer (AWE), Proton Exchange Membrane (PEM) and Anion Exchange Membrane (AEM), AWE is preferred due to its maturity, ruggedness and cell module stack life. However, currently, all the electrolyzer stacks in the country are imported. In line with Atma Nirbhar Bharath policy of Government of India, BARC is involved in the development of advanced AWE technology using indigenously developed electrodes and diaphragms. Here, nickel is considered as the candidate electrode material due to its good corrosion resistance, electrical conductivity and electrochemical activity. The present technology implements unique indigenously developed porous nickel electrodes which have better electrode kinetic performance over long endurance runs as compared to the electrodes used in commercial electrolyzers. A poly-sulfone based diaphragm is also developed as an import substitute. The cell is configured as a bipolar, zero gap filter type arrangement with anolyte and catholyte flow channels. The novel hydrodynamic design of bipolar plates and flow channels facilitate efficient removal of gas and heat from narrow spaces of the cell resulting into relatively less polarization losses and increase in efficiency at minimum pressure drop. Initially, the conceptual feasibility has been established in a lab scale electrolyzer at a hydrogen production capacity of 4 Nlph. The system has been scaled up in subsequent steps up from kW to MW scales. The different systems have operated for more than 10,000 hours cumulatively without significant deterioration in the cell module performance. The AWE technology for 50 kW capacity (10 Nm3/hr hydrogen) has been transferred to ten leading industries for commercial deployment. In order to realize the national goals on green hydrogen at a large scale, leading refineries such as BPCL and HPCL have acquired BARC's indigenously developed AWE technology for green hydrogen production. Currently, BPCL and BARC are jointly developing higher capacity (MW scale) AWE technology under Department of Atomic Energy's Technology Incubation Program. A prototype electrolyzer stack of 0.5 MW stack capacity has been successfully developed and endurance operational trials are in progress. The talk describes the travails and success of this much sought after technology.

Shri K. T. Shenoy *joined Chemical Engineering Division of Bhabha Atomic Research Centre in 1988 after completing one-year Orientation Course (31st Batch) in Nuclear Science and Engineering. His professional expertise is in the applied research related to process and equipment development for nuclear fuel cycle. His significant technological contributions are development of solvent extraction contactors, nitrate remediation through thermal denitration, alkaline leaching of Tummalapalle uranium ore, etc. Currently, he is leading the team in scaling up and technology deployment of green hydrogen production and nuclear desalination. He is serving in many safety committees of BARC and AERB. He was designated as Head, Chemical Engineering Division, BARC in Jan. 2013. He took over as Associate Director, Chemical Engineering Group in October, 2020. Currently, he is Director, Chemical Engineering Group since September, 2022*

10. Sustainable Nuclear Fuel Cycle as an answer to SNF Management Challenge

Elena Artemova

TENEX (Rosatom), Russia

On the road to net zero emission, India needs to develop huge nuclear power fleet based on large and small reactors. The vital part of the large-scale development of the nuclear power is the timely foundation of the spent nuclear fuel (SNF) management system based on its future amount and different locations of its production. Russian experience in the SNF management as well as its innovative technology may be considered as the most suitable way to deal with the SNF in India. This presentation is based on the results of the technical and economical analysis made for the particular cases of several countries and their nuclear fuel cycles.

Russia has a decade-long references in the SNF management. Currently in Russia 22.7 GWt of installed capacity of the nuclear reactors generates about 650 tHM of the SNF annually. All this SNF is transported to the centralized SNF management facilities for further reprocessing with prior temporary technological storage. The Russian reprocessing facility Mayak plant near Chelyabinsk with the capacity of 400 t per year operates since 1977 as an industrial-scale (commercial) reprocessing facility. It reprocesses not only the SNF from the Russian NPPs, but also has a history of cooperating with 17 countries in reprocessing the SNF from the overseas NPPs. Another reprocessing plant of a new generation with the capacity of 200 tons is being constructed near Krasnoyarsk.

The technology of the SNF reprocessing in the territory of Russia is further developing to improve the radioactive waste (RW) management arising from the SNF reprocessing. Such RW will undergo partitioning and will be separated into two fractions: the one is a long-lived fraction comprising the minor actinides (Am, Cm etc.) and another is a short-lived fraction comprising the isotopes of Cs and Sr. The long-lived fraction of the minor actinides in the future will be burned as a part of fuel in fast reactors, being constructed in Russia. So, only the short-lived fraction will need to be conditioned and kept for long-term storage. In this case the volume of the RW stored after the reprocessing will decrease by 5 times comparing to the volume of the RW arising from the traditional reprocessing with no partitioning. Moreover, due to the short period of half-life, the short-lived fraction of the RW will decay in 300 years to the level of activity of uranium ore and may be disposed in a near-surface disposal facility. So, the reprocessing of the SNF in Russia with the RW partitioning allows to exclude the necessity to place the SNF or the arising RW into the deep geological disposal facility.

After the SNF reprocessing in the territory of Russia, the fuel made of the recovered uranium and plutonium may be consumed in Russia or in the customer's country in accordance with the applicable non-proliferation rules and regulations. This approach to the SNF management being developed in Russia got the name of Sustainable Nuclear Fuel Cycle. This approach is a part of

Russian proposal to countries constructing the NPPs with Russian-designed reactors. Belarus has already accepted concept of SNF management based on approach outlined in his presentation and approved it as the country's National Strategy of the SNF management at a governmental level.

The SNF assembly of the LWRs consists of 96% of uranium and 1,2% of plutonium, which are valuable products and can be re-used. Russia and India both share the similar approach and develop re-using of valuable resources. International cooperation in using Russian production facilities for the reprocessing in the territory of Russia of the SNF arising from the Indian LWRs may allow India to expedite the re-use of valuable recovered uranium in its nuclear fuel cycle, thus diversifying its resource base, mitigating the costs and increasing public acceptance of the nuclear energy.

To conclude, the SNF reprocessing in Russia with the RW partitioning and further use of the recovered materials, combined under the name of Sustainable Nuclear Fuel Cycle is a sustainable, safe and economically viable answer to the SNF management issue, which is a challenge for any country having plans of the nuclear energy development.

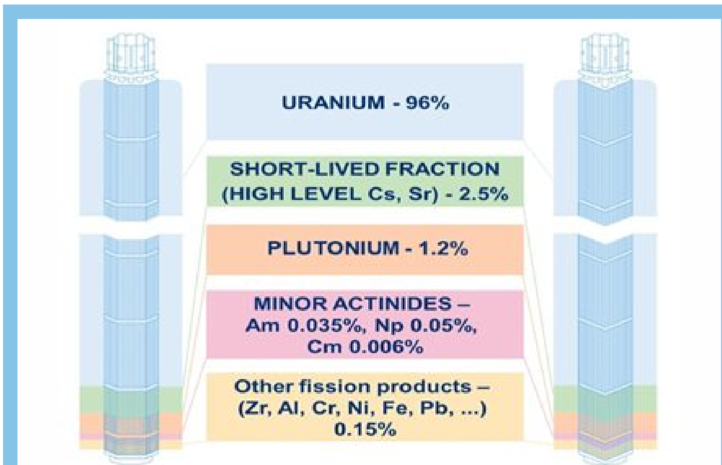


Fig.1: Fractions of the SNF reprocessing

***Ms. Elena Artemova** is the Deputy Director General, Back-end Of Nuclear Fuel Cycle, TENEX (Rosatom). Having degree in Law from St. Petersburg State University and LLM degree from Moscow Pericles Law School, Mrs. Artemova has joined Rosatom in 2002. Until 2016, Mrs. Artemova worked as Chief Legal for TENEX – Rosatom's foreign trade arm for the supplies of uranium products and services to the world market. Since 2018, Mrs. Artemova is working for international business development for the Back End products and services, coordinating projects in the SNF management, including Rosatom's assistance to Japan in the Fukushima-1 damaged fuel retrieval, projects of the SNF management at the El-Dabaa NPP (Egypt), the Akkuyu NPP (Turkey) and others.*

11. Nuclear, Both Big and Small, Powers the Energy Transition In India

G.R. Srinivasan

Ex - NPCIL, Ex - AERB and GMR Infrastructure Ltd.

There will be a global nuclear renaissance (SMRs will lead this renaissance), this one being bigger than the earlier one. Majority of the countries need nuclear to meet their NDCs (Nationally determined contribution). India never paused but needs to step up. Energy transition involves massive decarbonisation. Big reactors, mainly for power/ grid supply, and SMRs (including MSR, HTGR) in non-grid sectors including hard to decarbonize steel, chemical and other such industries. 75% of CO_2 emitters are in these sectors (Process heat, District heating, transportation, Mining, Data centres, Desalination, Hydrogen production etc.). Hydrogen, a game changer, wonderful carrier, (National hydrogen mission). 75% of new clients for Nuclear (Mainly SMRs) have never been associated with it till now.

SMRs >30 advantages, rose from the ocean, on from 1950, Safe, proven, depends on Physics rather than engineering for safety, helps Just transition and coal plant repurposing (35% cost reduction) (Energy transition emotional, reskilling, reshaping of economy), Ideal Distributed Energy Source, good for multiple uses.

The amount of energy capacity required for India and the optimum energy mix is dictated by (1) Powering the world's fastest growing economy (2) Affordable and clean power to all as per SDG7 (For Human Development Index 0.9, 5000 kwhr per capita required), and (3) Energy transition/NDC, Climate change mitigation. Nuclear (big and small) is unique as it can meet all these three, rather conflicting requirements simultaneously. (GOI is targeting 9% by 2047, could be few lakh Mwe). Glad to see Renewables are growing fast, but demand for power is growing even faster and gap needs to be filled by nuclear.

Challenges exist in the areas of industry, regulation, policy, market and infrastructure. We must do many things never done before. Must do them in mission mode. India should participate in the global efforts on standardization, harmonizing regulation, laying new regulation as current standards do not hold good, faster Licencing (Concurrent regulation adopted by AERB is the answer for global adaptation), bolder (SMRs-EPZ, Urban, even in seismic zone 3), Supply chain & HRD, PA, many other existing issues, adapting between nuclear and huge number of recipients of nuclear (Ex Tatas and JSW introducing hydrogen in blast furnace), Optimum grid mix, hybrid of nuclear and renewables, (More nuclear in grid can accommodate more renewables),multiplying in all three resource areas, men, material and money (NTPC. FDI, Privatization ex; we may need 30000 crores per year), NSRA bill to be passed, Liability Act to be amended to fall in line with global practice. I was Chairman of a FICCI committee on privatization, it covers, in its report presented to DAE, 26% to 100% road map, many models, 17 competencies, PPP model, hand holding by DAE. Space/RR model ok but to be modified for NPPs RAB model of UK enables risk sharing. Gencoms /Discoms made bankable by reforms to enable their seeking private players.

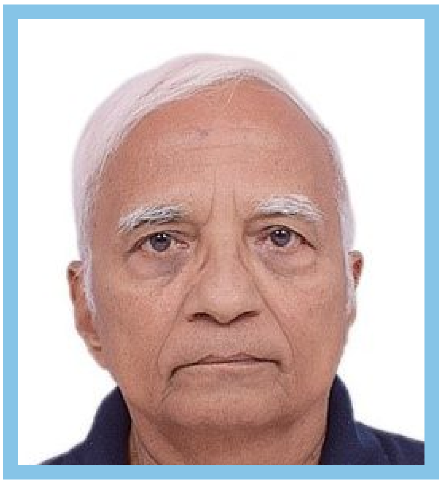
Plan for future? Four streams, ultimately all 4 on fleet mode.

(1) 700 MWe INDUs, (2) Imported LWRs, VVERs on fleet mode immediately, (3) FBRs (4) SMRs both imported and indigenous.

Different, three step model for importing SMRs, namely,

(1) Localization, (2) bidding jointly in third countries (3) absorb technology and export.

For SMR imports, do not bother about cost of initial units as they will get amortized, Use Indian advantages, Win Win situation for India and Foreign suppliers (30%, competitive bids, many countries only operating staff). Continue and streamline Long Term Operation (LTO) of existing reactors to capitalize advantages of LTO (Almost to 100 years). Develop IBSWR and CHTR; both modular soon as these are more suitable for mitigation efforts. Expedite our LWR. Establish circular economy, supply chain/EPC, regulatory readiness; 5 times 3M resources; More efficient progress and funding; taxonomy. ESG., Green bond, include nuclear in all these FDI, BOOT, PSU, PVT. GOI funding. ROI limit of 14.5% to be raised. Develop export potential, part modularize 200 Mwe Indus, <4 years. 220 Mwe INDUs can be a good substitute for SMRs. High level standing committee for energy transition.



I have a more than six decades of experience in Nuclear Industry and am still performing consultancy. Working in NPCIL, AERB and GMR infra a has given me expertise and experience in the areas of production, Regulatory and global nuclear industry. After moving to HQ of Nuclear Power Corporation (NPCIL) at Mumbai I took over successively as Directors of Health, Safety and Environment followed by QA and finally as Director (projects). I was also back up executive director for operations. Finally, I retired as Vice Chairman, AERB (Atomic Energy Regulatory Board). I enabled GMR infrastructure, a private company to sign an MOU with KEPCO, South Korea, for setting up an APR1400 in India. I had discussions with NuScale, EDF and Westinghouse for PPP model of establishing Nuclear Power Plants. My book "Nuclear Powers the Energy Transition. Global and Indian Nuclear Scenarios" (900 pages) will soon be published. The foreword for this book was written by Dr R. Chidambaram, Ex Chairman, Atomic Energy Commission. The book was launched by CMD, NPCIL. I presented a paper on "SMRs and the nuclear renaissance: Policy and regulatory issues" on February 22, 2023 at POWERGEN 2022 at Orlando, USA.

I am UpToDate with the Industry developments as well as what is required for its successful future. My experience and knowledge is not my personal property but is for sharing to enable me to give back to the industry a little bit in return.

12. Meeting Nuclear Power Development Objectives: EDF's Gen. III & III+ Reactors - Growth acceleration & Cost reduction and Industry preparedness and participation

Vakisasai Ramany

EDF, France

According to the International Energy Agency scenarios, global nuclear capacity should range between 500 GW (Stated Policy Scenario) and 812 GW (Net Zero Scenario). It represents an annual growth of installed capacity of approximately 6.5% compared to the c. 415 GW installed today. We are talking about a target of 13 GW nuclear capacity to be installed per year on an average.

At this time horizon (20-25 years), the nuclear market will be dominated by GEN III like reactors. EDF believes that there will be a requirement for several size of reactors and thus is developing its portfolio around 3 different products: EPR, EPR1200 and SMR.

Meeting the highest safety standards, EPR is the most powerful GEN III+ reactor in the world with 1650 MWe of net electric power output. The EPR technology is fully compliant with IAEA, WENRA safety standards and the European Utility Requirements (EUR). Its strong resistance is confirmed by the European post-Fukushima stress tests. In addition, EPR is already licensed by 4 recognized Safety Authorities: in France, the UK, Finland, and China. The EPR is particularly fitted for countries such as India facing both a rising energy demand and a need for replacement of coal-fired plants.

<u>Lessons learned and industry preparedness</u>

EDF has a long-lasting experience in being not only a nuclear power plant operator but also in being an Architect-Engineer of its own fleet. As EPR technology is fully derived from EDF's proven PWR technology and fleet experience, with a robust and worldwide licensing track-record, lessons learned derived from EPR design adaptations can be implemented in the frame of technology optimization.

EDF has gathered a unique experience with its EPR fleet in licensing, building, and commissioning around the world:

- in China with two successfully operating EPRs in Taishan
- in France with FLA-3 EPR, under commissioning
- in the UK with 2 EPRs under construction at Hinkley Point C and 2 more EPRs currently being finalized at Sizewell C.
- The EPR technology also operates in Finland at Olkiluoto.

This experience feeds a record state-of-the-art practice which leads to enlarge and improve project management organization and reduce project risks. As a result, a lot of time is gained. For instance, commissioning on Taishan 2 was 21 months shorter than Taishan 1 with an even higher level of localization on unit 2 because of the robust qualification processes and partnerships.

To widely share our lessons learned, EDF launched in 2015, the EPROOG, which stands for EPR Owners Operators Group. The EPROOG organization is a structured & mutual body between Owners and Operators of EPRs to support their projects and achieve the best performance of EPR units from Construction to Operation. Working groups by theme and steering committees take place several times a year with experience sharing on safety matters, good practices and lessons learned during all phases from engineering, construction, commissioning, pre-operation and operation.

Growth acceleration and Cost reduction

Our growing EPR fleet allows the series effect to play a major role. It is already observed today on the HPC project where gaining of time and quality is observed compared to Flamanville 3 project. Tomorrow the Jaitapur Nuclear Power Project (JNPP) will leverage the series effect with the launch of 6 reactors in pairs enabling construction optimization within each pair and lessons learned locally from one pair to the following.

Replication and standardization are key. Using the same reactor design, safety systems, equipments, de-risking licensing, procurement and construction and materializing cost and schedule reduction.

Early steps are taken as soon as possible in different fields. For instance, the licensing process should be launched at the earliest, as is the training process to benefit from the necessary resources ready to work as soon as the decision is taken. The strategy relies on de-risking as much as possible before the Final Investment Decision (FID) or General Framework Agreement in the context of JNPP is taken.

Allocation of risks between the Owner and the potential partner(s) and/or investor(s) must be balanced - Risk must be allocated to the stakeholder who is best able to manage it, thus requiring a lower risk premium, contributing to reduce the cost of capital and increase project competitiveness. For example, nuclear liability regimes are governed by international conventions. According to those conventions, risks and liabilities of the vendor should be limited to what the vendor delivers. Cash-flow risk is part of the owner's liability.

New EPR projects have learnt from leading construction projects across the world and been able to successfully utilize new techniques and innovations to build a legacy of skills and expertise. Techniques like largescale prefabrication and digitalization are increasing predictability and reducing the hours needed for construction. For example, the HPC project reduces project cost and time overruns with the use of virtual reality technology.

Equipment's localization can also be a key contributor to cost reduction provided the suppliers are properly accompanied to perform the requested investments in training, processes, CAPEX and quality standards to match the requirements of EDF from its supply chain.

***Vakisasai RAMANY** is currently, Senior Vice*

President – Development EDF - New Nuclear Projects & Engineering. He joined the EDF Group in 1999 as an R&D engineer, focusing on schedule optimisation and economic risk management in the context of energy market de-regulation in France. He then joined the French supply division of EDF to put in place a customer portfolio management function, heading the Aggregator department when EDF was newly facing competition. In 2008, V. Ramany joined EDF Group CFO's office to support the company's effort to grow its international business: he worked notably on major acquisitions, including that of British Energy in the UK. In 2011 V. Ramany moved to EDF Energy in the UK as M&A and Investments Director. As such he led the effort of the Group to honor its major commitments to the European Commission following the acquisition of British Energy, initiated the refinancing strategy of EDF's UK renewable business and has been one of the leading contributors to secure funding for the 3200MW Hinkley Point C Nuclear New Build project in the UK, including the development of the cooperation with China on that regard. Since September 2015 V. Ramany leads the international New Nuclear development activities for EDF Group, encompassing the development of New Nuclear projects, of international strategic cooperation in the nuclear domain and of export nuclear technologies. V. Ramany graduated from the Engineering School of Aeronautics and Space, Toulouse, France, and holds an MBA from INSEAD, Fontainebleau, France.

13. Meeting Nuclear Power Development Objectives: "Technologies and skills challenges, lessons learned in France and opportunities in India."

Antoine Guelfi EDF, France

EDF Group's Nuclear Power Fleet

Nuclear power is at the heart of France and EDF's strategy to achieve carbon neutrality and reach net zero target by 2050. Thanks to its unique fleet of 65 nuclear reactors being operated in France and in the United Kingdom (UK), EDF has gained an unrivaled **experience covering the entire lifecycle** of nuclear installations, from design to decommissioning, including construction, commissioning, operation, fuel management and waste management.

Managing a highly decarbonized electricity production mix, EDF has already proven that nuclear reactors can be safely and efficiently operated with a **very high flexibility** which allows to accommodate the increasing share of intermittent renewables on the electrical grid.

Managing several Industrial Challenges

To continue to meet its objectives in the long term, EDF with the support of the entire French nuclear industry is managing several large-scale industrial programmes:

- The **lifetime extension** of its Generation 2 PWR fleet, with the "Grand Carénage" programme, a fleet-wide investment and maintenance programme ensuring the conditions for safe operation up to 50 years and beyond.
- The **decommissioning and dismantling**

of the oldest reactors, with already eleven reactors from four different technologies being at different stages of dismantling process;

- EDF and its partners of the French nuclear industry ensure all the necessary **fuel cycle management and waste management** activities; new facilities are under development in France to meet the country needs in the long term;
- The **new build projects**, with the renewal of its own fleet in France and in the UK, and the involvement in different international new build projects, with **a unique portfolio of PWR solutions** covering large-size (EPR – 1650 Mwe), mid-size (EPR1200 – 1200 MWe) and SMR reactors (NUWARDTM - 340 MWe).

Technology challenges & solutions

These industrial challenges require **innovative and efficient technology solutions**. The EDF Group can rely on its in-house expertise, its industrial subsidiaries, and its industrial partners to develop adequate tools, processes and equipment.

For more than 60 years now, **Framatome'**s teams have developed a unique multi-disciplinary and highly technical know-how. They have been designing and supplying nuclear equipment, powering operations, maintenance and engineering services. Framatome's expertise covers design and service engineering, component manufacturing, maintenance and modernization, Instrumentation & Control, design and fuel manufacturing, commissioning, and licensing, digital solutions, cybersecurity.

The **Cyclife Group**, a 100% EDF owned company, is a European leader in nuclear **decommissioning** and **radioactive waste management.** Cyclife's teams, backed by the EDF Group's extensive experience, are addressing the challenges faced by international customers to reduce the volume of waste they generate and optimise the running costs of their equipment. Where possible, Cyclife enables its customers to recycle materials for a responsible and sustainable nuclear industry. Cyclife works with its partners from the design to the dismantling of their installations all along the lifecycle, either directly on site or at Cyclife's own facilities, through a comprehensive and integrated range of industrial and digital solutions.

Another EDF Group's asset is its **strong R&D** workforce supporting the mid- and long-term needs.

France and India: a growing nuclear industrial collaboration

In addition to the large-scale 6-unit nuclear plant project under development for the Jaitapur site, based on the flagship EPR technology, *(Please refer to the EDF presentation on new build programmes (by Mr Vakisasai Ramany)* our presentation will highlight some concrete examples of how the **French and Indian nuclear industries** have already collaborated with **successful results** for the benefits of the Indian nuclear power installations.

The presentation also identifies the potential for **further opportunities** for collaboration between the French and Indian supply chains.

Skills challenges

The industrial challenges we are facing

require a huge effort in terms of **human capacity building** for the entire nuclear supply chain.

The presentation will focus on the recent French **MATCH initiative** led by GIFEN, the federation which represents companies involved in the nuclear industry in France. The goal is to ensure that human, industrial and financial capacities match the level of resources required to deliver on the needs of these nuclear activities.

In addition to the technical fields of expertise, huge needs have been identified in the field **of large-scale nuclear project management.** The presentation will highlight some concrete examples of how the EDF Group is tackling these challenges, covering all components of nuclear project management.

Further developments are needed to reach expected level of skills and the presentation will focus on opportunities for French and Indian collaboration in that field. The role of **I2EN** (International Institute for Nuclear Energy) in developing training programmes for academic, industrial, or institutional audiences worldwide will be introduced. The experience of EDF in creating strong **partnerships** with the local supply chain will also be covered.

Antoine GUELFI *is Director of Export Services within the International New Nuclear Development Department of EDF. He is an experienced leader with more than 25 years of experience in the nuclear industry, a very strong track record in the management of high-stake and large-scale nuclear projects.*

His career has taken him to many different entities of the EDF Group: Research & Development, Corporate Audit, several Engineering divisions for existing and New Nuclear reactors as well as for Fuel and Waste Management. Among his international activities and collaborations, Antoine has acted for several years as the Secretary of the European Utility Requirements (EUR) Organisation. Recently he has led the detailed design studies for the two UK EPR nuclear islands being built at Hinkley Point (HPC Project). Antoine GUELFI graduated from the Ecole Centrale de Paris (now known as CentraleSupélec). He is also a certified Project Management Professional (PMP®) from the Project Management Institute.

14. Korea's Nuclear Power Development Experience and Competitiveness

Yoh-shik Nam

Korea Nuclear Association for International Cooperation

South Korea has made remarkable progress in the nuclear power industry since the 1960s, starting with the commercial operation of the Kori Unit 1 in 1978. From the initial turnkey base business to the partial self-reliance of Kori Units 3 and 4, Korea introduced nuclear power plants from various reactor suppliers such as Wolsong Units 1 through 4 from AECL and Hanul Units 1 and 2 from Framatome, and promoted nuclear power plant technology self-reliance in the 1980s to develop the Korean Standard Nuclear Power Plant(KSNP) from Hanbit Units 3 and 4 based on the US CE System 80 reactor model.

The KSNP was built with 10 units in a series with Hanul Units 3 and 4 as the reference model, and it also became the reference model for the KEDO nuclear power plant project that was unfortunately canceled. Following this, the APR1400 model was developed under the ambitious Korean advanced reactor development plan and successfully debuted in the global nuclear power market as the reference model for the Barakah Nuclear Power Plant in the UAE, Korea's first nuclear power plant export project, along with the commercial operation of Saeul Units 1 and 2 in 2017.

Through the process of technological self-reliance and continuous nuclear power plant construction, Korea has had a strong nuclear power business system called Team Korea and a solid supply chain centered on related SMEs.

With this excellent business system, the localization of core equipment, human resource development, and project management competitiveness led to the successful implementation of the Barakah NPP project in the UAE, and the “on-schedule, within-budget” completion of the BNPP project is considered an exemplary case in the global nuclear power market.

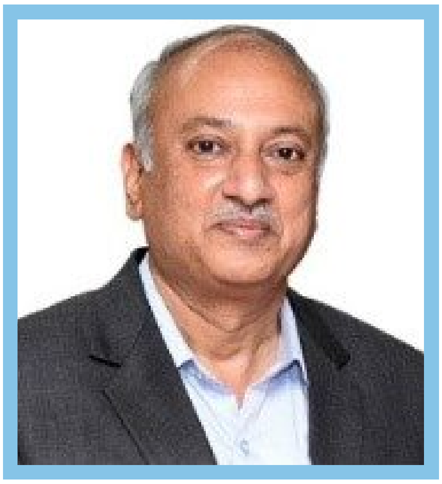
Korea is currently pursuing nuclear power projects in the Czech Republic, Poland, the United Kingdom, and Turkuye, and aims to contribute to the achievement of global carbon neutrality and energy security goals by entering the global nuclear power market.

***Yoh-shik Nam** is Vice President of the Korea Nuclear Association for International Cooperation (KNA). KNA plays a key role in promoting competitiveness of both the Korean and global nuclear industry through extensive cooperation and strong partnership in all area of nuclear power. KNA has lots of domestic and international members, including the Korea Electric Power Corporation (KEPCO) and the Korea Hydro & Nuclear Power Company (KHNP).*

Before being moved to his present position in May 2023, Mr. Nam served as Executive Vice President for Quality &Safety, Project & Overseas Nuclear Business, and Construction Project from August 2020 to February 2023, and as Site Vice President for Abu Dhabi Office in UAE from August 2018 to August 2020. He held various positions at nuclear power plants and head office in KEPCO and KHNP since he joined it in 1984.

From 1993 to 1994, Mr. Nam completed the MSc course on Radiation and Environmental Protection at Surrey University in UK, under the scheme of Korea-U.K. nuclear scholarship program. He graduated from Konkuk University in 1984, and majored in Physics.

15. Second Stage of Indian Nuclear Programme Towards Green Energy Transition



B. Venkatraman
Indira Gandhi Centre for Atomic Research,
Kalpakkam, India

Abstract not received

B. Venkatraman *is Director, Indira Gandhi Centre for Atomic*
Research, Kalpakkam, India.

16. Role of L&T in Furthering Nuclear Growth in India

Anil Parab
Larson & Toubro Ltd. Mumbai, India

Larsen and Toubro (L&T) has been an industrial partner in India's nuclear energy programme for decades. It has made substantial contribution to India's nuclear program by actively participating in the construction and development of nuclear facilities. It has contributed to all 23 nuclear power plants running in India. Various units and disciplines of L&T are involved in the nuclear development program, and their involvement typically includes: ***Engineering:*** provides engineering solutions for the design and planning of nuclear power plants, ensuring adherence to safety and regulatory standards; ***Procurement:*** handle the procurement of all critical components, materials, and in-house manufacture most critical equipment such as steam generators, end-shields, pressuriser, safety exchanger etc; ***Construction:*** entire plant end to end. ***Instrumentation and Control Systems*** and ***Electrical Systems*** which play a role in the installation and integration of electrical systems, including power distribution, generators, and other electrical components; ***Mechanical Systems:*** is involved in the installation of mechanical systems such as pumps, valves, and other machinery critical for the functioning of the nuclear power plant; ***Project Management:*** has track record to complete Tarapur-3,4 500 MWe Plant commissioning in 60 months from first pour of concrete. It has to its credit global benchmark to manufacture Steam Generators in 30 months. L&T Special Steel and Heavy Forgings have successfully indigenized 20MnMo Ni 5 5 (forgings) and low-Co SS304 plates with lowest reject rate.

As regards the future growth of nuclear power in India, L&T sees itself playing a lead role by providing industry support to fast-track India's nuclear program; by industry support to fast-track implementation of large scale Small & Modular reactors; by support to NPCIL to localise foreign technology LWR plants and by participating in the finalisation of NPCIL's strategic and policy formation.

Mr. Anil. V. Parab *is Whole-Time Director & Sr. Executive Vice President – Larsen & Toubro Limited, (Heavy Engineering & L&T Valves). He is a mechanical engineer from V.J.T.I., Mumbai and has acquired Senior Executive Management Education from the London Business School & Indian Institute of Management (Ahmedabad). During his career he created many new global benchmarks in Nuclear and Heavy Engineering. He successfully started the new business line - Modification, Revamp & Upgrades (MRU) of process plants - and implemented the latest Industry 4.0 Digital manufacturing at A.M. Naik Hazira Manufacturing Complex.*

He is Chairman of the Capital Goods & Strategic Skill Council of India (CGSC), promoted by Dept. of Heavy Industry, GOI & FICCI. He is Co-chair of FICCI, Capital Goods & Public Procurement National Committees and Member of CII Manufacturing Council. AVP is a Fellow of the Indian National Academy of Engineers (INAE) and a member of the Programme Advisory Committee of the Department of Science & Technology. AVP is also a Senate member of IIT Jammu.

17. Nuclear for Clean Energy Transition : Challenges & Indian Industry Preparedness

Vice Admiral N M Nadaph (Retd)

Walchandnagar Industries Limited, Pune, India

Government of India has declared its intention to be Net Zero Caron Emission by 2070. GOI has worked out that by 2070, there will be requirement of about 27,000 TWh power generation requirement. The nuclear power contribution will be about 215 GWe. This requirement is planned to be met by 700 MWe PHWRs primarily, supported by imported 1000 VVERs from Russia, 1650 MWe EPRs from France, 1000 MWe BWRs from US, SMRs such as 220 MWe PHWRS, 300 MWe AHWRs, up to 100 MWe indigenous / imported PWRs, imported proven PWRs, Molten Salt Reactors, High Temperature Reactors etc. Some of these will replace outgoing coal fired thermal power plants and some will be used for captive use by industry, remote locations users.

The basic criteria for choice will be use of highest standards of safety, modular construction, low construction time, affordable capital cost and unit cost.

There will be about 400 to 500 new reactors required to be set up. The total nuclear business would be about 1 Trillion USD, out of which SMR would be about 100 Billion USD or **8,000 Billion Crores Indian rupees.**

It should be noted that nuclear power plants call for highest standards technologies meeting international standards, a first time right approach and zero tolerance for defects. There will be need to assimilate different standards such as American, French, Russian etc. by Government Agencies and Industry. It calls for development of large manpower pool, their training and continuous engagement. The costs are high and development time for experience build up is large and is to be done progressively both in Government and private sectors.

Thus, this business will require large infrastructure to manufacture materials, equipment, systems, supply chain management, civil works etc. for setting each station and operating them. Thus, GOI and industry needs to get geared up to take up this challenge. This presentation indicates pre-requisites to be fulfilled by GOI and Industry and acceptance by Public at large for such large nuclear power next door. This is therefore a great challenge which needs great amount of meticulous planning, foresight, investment so that we successfully execute this dream program.

***Vice Admiral (Retd) N.M. Nadaph**, AVSM, VSM (40305A) is B.E. (Mech.) and post graduate degree holder in nuclear technology. During his illustrious career in Indian Navy (1969-2007) he participated in the Bangladesh liberation war (1971) as senior engineer. He was involved in design, engineering and development of systems and equipment for nuclear submarine; setting land-based station for testing; developing design, engineering centers at BARC, Secunderabad then PTC Kalpakkam, test stations -MTC, Vizag; construction yards for Nuclear Submarine at SBC, Vizag and construction of first Indian nuclear submarine INS Arihant as Project Manager then Project Director and then as a Programme Director. He was associated with public sector undertakings, private sector companies like L&T, WIL, BHEL etc and Government / Foreign R&D organizations such as Department of Atomic Energy, DRDO Labs, Russians for design, engineering, production of equipment, systems and construction of submarine. He served in Naval Dockyard, Mumbai as Assistant Manager Diesel Work shop, as DGM, Resource Planning and as ASD, Naval Dockyard, Vizag. He was awarded Ati Vishisth Seva Medal (AVSM), Vishisth Seva Medal (VSM), CNS Commendation.*

He is currently Advisor, Nuclear Business, Walchandnagar Industries Limited (WIL). He has been responsible for setting up Walchand Technology Centre for Walchandnagar Industries Limited in 2008 to undertake high technology design, engineering work in the domain of Nuclear, *non-conventional energy, thermal power, defense, computational Engineering; design, engineering, procurement of materials and fabrication of moderator heat exchanger for KAPP-3,4 & RAPP-7,8; design validation of 799 MWe PHWR steam generator for capability demonstration of WIL; Design, engineering, procurement of materials and fabrication of various components for replacement of Rajasthan Atomic Power station; and design, engineering activities for defense & aerospace projects*

18. On the General Aspects of SMR Use

Alexandre Volgin

Rusatom Energy Projects, Russia

Recent interest in SMR for energy generation and other purposes gained its place in numerous countries. However, this technological approach, which is not new in terms of generated power, but brought up to date, can be interesting for many other aspects, such as the development and maintenance of qualified human resources, optimized use of land or financial impact. We will try to take a more general look at these and other parameters of SMR

***Alexandre Volgin**, aged 38 years, is Nuclear Engineer and Doctor in Physics with broad international experience. He has more than 14 year of nuclear background within Engineering and R&D projects related to the PWR- and WWER-type reactors, materials, radwaste, spent nuclear casks, fuel and project management. Throughout his career he has worked at various levels of Rosatom and international companies, such as EDF and ENGIE.*

Dr. Alexandre Volgin – (AlekVladVolgin@rosatom.ru) Project Director Rusatom Energy Projects.

19. Climate Change and India's Energy Transition: The Role of Nuclear Power

D. P. Srivastava

Vivekananda International Foundation, India

The increasing frequency of climate-related events in different parts of the world has underlined the need for energy transition to clean energy sources to minimize the effect of global warming. The choices are limited to renewable and nuclear power. Most countries have accepted the goal of net zero emissions (NZE). But this concept has a deceptive simplicity. Different countries are starting from different levels of development, and per capita emissions. The developed countries and China have already completed their industrialization. India is at a low point of its development trajectory. Its electricity consumption of 1100 units per capita is 1/3rd of the global average. While the West and China have to diversify to non-fossil sources, India has to grow and diversify. The twin objectives entail very difficult choices for India.

The energy transition is taking place against the background of limited carbon space remaining. Developed countries and China have not only exhausted 80% of the carbon budget but are eating into meager space remaining at a higher pace since their per capita consumption is higher. Despite the reduction, the US and EU's per capita consumption will remain higher than that of India even in 2030. China has accepted peaking only in 2030. Its per capita consumption will keep growing till then. Its annual emissions account for 30% of global emissions currently, as against 7 % in India's case despite the two countries having comparable populations.

How much is the minimum energy needed to reach the goal of net zero emissions by 2070? What is the most cost-effective generation mix to reach this level? A VIF Task Force headed by Dr. Kakodkar asked IIT Bombay to address these two questions through mathematical modeling. The modeling was based on converting 75% of energy into electricity derived from clean energy sources. Hydrogen is to meet 10% of demand in one variant and 25% in another variant. This was a more stringent requirement than the IEA model which is based on converting only 50% of energy into electricity. No country has a sink that can absorb emissions from 50% of energy produced from fossil fuels.

The mathematical modeling brought out that a minimum of 24,000 - 30,000 TWhr of electricity is needed to reach NZE by 2070. This is considerably higher than the IEA's estimate of India's energy demand at 3,400 TWhr by 2040. Which of the two projections right? Since timelines are different, direct comparison is avoided. It is worth bearing in mind that according to NITI Aayog data, India's energy consumption in 2020 was 6,200 TWhr. Is it realistic to peg India's energy consumption two decades later at half the level of 2020 – the pandemic year, when the economic activities had slowed down? The IEA's prescription does not do justice to India's development needs. India cannot reach Swaran Kaal based on energy poverty. This goal will remain elusive unless we provide enough energy for India's industry and people.

To estimate the most cost-effective solution to reach net zero emissions, the IIT was given 5 different scenarios ranging from renewable high to nuclear high. There were also three intermediate scenarios with varying measures of coal with CCS. The mathematical modeling established that the renewable high scenario at $ 15.5 trillion was the most expensive while the nuclear high scenario at $ 11.2 trillion would be the cheapest.

The findings of the VIF-IIT modeling are in line with earlier studies done by MIT and OECD. They brought out that moving towards a low emission target without inclusion of nuclear in the energy mix would increase the cost 'disproportionately.' The MIT report mentioned that achieving the same level of generation that is produced by 100 MW of nuclear requires 600 MW of renewables. The higher capacity build-up required in the case of renewables due to their low PLF and intermittency increases the overall cost. The systems cost of renewables will go up with the increase in transmission costs. The ultra, mega solar power plants would require going to remote locations like Kutch, which increases the transmission costs.

Since the VIF report was prepared, a CEA report has acknowledged that the Renewable Electricity - Round the Clock Cost (RE-RTC) ranges from Rs 4.95 per unit to Rs 7.57 per unit. This is much higher than the cost of either thermal or nuclear, even though it is based on only 6 hours of storage.

Renewables also entail a much larger land footprint. According to the VIF study, the renewable high option for the net zero, with 10% of demand met by hydrogen will require twice the surplus land of 200,000 square km available as of now in India. The problem will become more acute in case hydrogen is to supply 25% of demand. This will require seven times the surplus land available in India. The only option is hydrogen production through thermo-chemical processes using nuclear power (High-temperature gas reactors).

There is growing pressure for India to accept peaking. G7 Summit in Hiroshima had called for all major economies to peak emissions by 2025.The US and EU's emissions have already peaked; China's emissions will peak in 2030. It will be difficult for India to remain an exception indefinitely. In case emissions are capped before the country has diversified to clean energy sources, this will seriously impact India's development trajectory.

There are no internationally agreed norms to define peaking levels, which are arbitrarily chosen. Once the 'peak' is accepted, this will decide the overall energy level available to a country to grow. We may have perhaps a decade before our emissions are capped. We need to quickly build up our generating assets to establish the claim for carbon space needed to sustain our development trajectory. This in turn means going with the available technology – a combination of 700 MW reactors and smaller 220 MW PHWRs. SMRs are prohibitively costly. The cost of NuScale SMR of 106 MW capacity has gone up from $ 6 billion to 9.3 billion dollars. The expected cost of a Rolls Royce SMR of 440 MW capacity is USD 2.5 to 3 billion. This may be more than 20 times costlier than indigenous reactors. The SMRs will also need more than a decade before they are commercially licensed. India does not have that much of time.

There is also a need to amend the Atomic Energy Act to allow private capital to come in. The Government has to provide investment resources to quickly ramp up nuclear power. Resources on this scale cannot be generated internally.

Ambassador D. P. Srivastava *retired as Indian Ambassador to Iran, where he negotiated MOU for*

Indian participation in Chabahar Port. As Joint Secretary, UNP, he dealt with the diplomatic fall-out of Pokhran II nuclear tests. Post-retirement, he served on the Board of Directors of ***GAIL****. He also served on the Board of Directors of* ***India Ports Global Ltd (IPGL).*** *He was also a* ***Senior Advisor to OVL.*** *He is currently a Distinguished Fellow at Vivekananda International Foundation (VIF).*

D. P. Srivastava coordinated the VIF Task Force on Nuclear Power: Imperative for India's Development'. He also coordinated 'India's Energy Transition in a Carbon-Constrained World'. Both the Task Forces were headed by Dr. Kakodkar, former Chairman of the Atomic Energy Commission of India. D. P. Srivastava is the author of the book 'Forgotten Kashmir: The Other Side of the Line of Control'.

20. THORIUM FOR LOWER-COST NUCLEAR ENERGY

Franklin Servan-Schreiber
Transmutex S.A, Switzerland

The world's rapid energy transition away from fossil fuel will require massive increase in carbon-free electricity production, of which nuclear will be an essential part. Relying on uranium fuel might not be possible for such a scale up, and it might create new geopolitical energy tensions. Thorium is a way forward, especially with a non-proliferant thorium – uranium233 fuel for use in water-cooled reactors. Transmutex's high-power cyclotron would enable the efficient breeding of uranium233 using subcritical production technology.

The Transmutex cyclotron design is inspired by the Paul Scherrer Institute's High Intensity Proton Accelerator, accelerating a 5 mA proton beam to 800 MeV with 20% energy efficiency and high reliability. Such a machine would enable lower-cost production of non-proliferate thorium-uranium233 fuel, using a fast neutron flux in a subcritical system, for use in water-cooled reactors.

The thorium fuel cycle promises to produce the lowest-cost base load energy, potentially cheaper than coal. The main reason is the low fuel cost due to widespread availability of thorium and production costs compensated for by the energy output of the system. Outside of financial costs, which a variable conditional on government support, fuel represents 30-40% of a plant's operating costs[a]. Thorium ore is forecasted to be significantly cheaper than uranium. Moreover, the fuel efficiency of thorium is also significantly greater than uranium, lowering overall raw material volume. Finally, the neutronics of thorium in a water-cooled reactor should extend the reactor lifetime well beyond a uranium-fueled reactor (100 years vs. 60 years baseline) [b]

Based on the following cost assumptions, we estimate the thorium fuel cycle to be 30% cheaper than uranium:

1. Thorium is four times more prevalent than uranium and more easily extractable. Moreover, 25,000 tons of thorium are readily available and waiting for a market. We estimate that the cost of thorium ore will be ten times less than uranium per ton.

2. Converting natural ore into “nuclear purity” material. We estimate similar costs for both.

References:

a. P.K. Vijayan, I.V. Dulera, P.D. Krishnani, K.K. Vaze, S. Basu, and R.K. Sinha, Overview of the Thorium Programme in India, Proceeding of the ThEC13 Conference – CERN 2013, Springer.

b. NucNet, How Much Does A Nuclear Power Plant Cost? (60-80% investment, 10-25% operations and maintenance, 7-15% Fuel, 1-6% decommissioning), 2020 March 04, www.nucnet.org

***Mr. Franklin Servan-Schreiber** is the CEO and Co-founder of Transmutex S.A, based in Switzerland*

Franklin Servan-Schreiber has a B.S. Electrical and Computer Engineering, M.S. Political Science, Carnegie Mellon University. He is a committed entrepreneur. Between 2014 and 2017, he was a volunteer with the Race for Water foundation, striving to raise awareness about plastic pollution of the Oceans. During his world tour he was struck by the severe impact pollution from human activity is having on our planet, but especially the impact that warming had on marine life. His priority became to fight climate change in whatever capacity he could. In 2018 he visited CERN and learned about research on a new way to produce carbon-free energy while "burning" nuclear waste. This was the beginning of the TRANSMUTEX adventure.

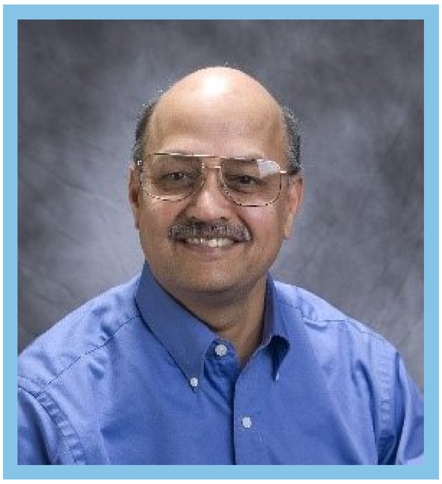
21. Advanced Subcritical Micro Reactors for Energy Distribution

Ganapati Myneni

BSCE Systems, Inc., USA

The intermittent, renewable and distributed solar and wind energy sources will not meet the zero carbon emission goals in the near future. Additionally, they won’t satisfy the growing needs of the ever-expanding world population. Though the conventional light water and natural uranium based nuclear reactors may be able to meet the projected energy needs, the long lived radio toxic spent fuel problem gives us great anxiety and convincing the world population is a daunting task. Therefore, we propose to develop and build Thorium based Advanced Subcritical Micro Reactors (ASMR) as distributed energy sources to meet the energy needs of the world in a sustainable, economic and safe manner.

These ASMR’s are Molten Salt breeder-burner in equilibrium high temperature reactors and can serve as back up to the renewable solar and wind systems and also produce green hydrogen in an economic way for ushering in the long-sought hydrogen economy. In this presentation we will introduce the basic operating principles of the ASMR's as well as their economics to not only to replace the present fossil fuel-based heat sources in industry as well as powering the futuristic fast EV chargers on the highways.



***Ganapati Myneni**, Director VT-India Nuclear Energy Partnership, Adjunct Faculty Virginia Tech, USA Board of Directors, International Symposium On Hydrogen In Matter (ISOHIM) PhD, Indian Institute of Technology Madras (1980). Recipient of Indo-German Scientific Exchange Award at the Fritz Haber Institute of the Max Planck Society, Berlin, worked on Joint European Torus (JET) and completed postdoctoral work at the University of Southampton, England. Appointed by two consecutive Governors of Virginia to Board of Directors of Virginia Nuclear Energy Consortium Authority (since 2013) and Virginia*
Energy Council (since 2014) respectively. Served as research professor/graduate faculty at the University of Virginia and North Carolina State University. Currently affiliated faculty/graduate faculty member
Virginia Tech, Virginia Commonwealth & Old Dominion University.
Present focus – developing radioisotopes based on efficient and economic ingot niobium CW SRF accelerator technology and pursuing this technology to advance nuclear energy systems internationally. Organizer of International Symposia On Hydrogen In Matter (ISOHIM). Development of Virginia Tech - India partnership to advance nuclear energy options for a
greener world.
Holder of 10 patents; edited 6 books/conference proceedings on accelerator related technologies. Authored/co-authored over 100 peer-reviewed publications on accelerator-technologies-instrumentation. Established the Virginia Accelerator-Driven Subcritical-Systems (ADS) Consortium, organizes International workshops on ADS/Thorium Utilization. ANS Life Member.

22. Multifaceted Activities of Heavy Water Board - Self Reliance through Indigenization of Technologies

S. Satyakumar
Heavy Water Board, Mumbai

India's quest for Heavy Water is the story of achieving self-reliance, indigenization of technologies for sustainable future to pursue India's three stage nuclear power programme. In due course of time, Heavy Water technology became fully matured, robust, energy efficient and environment friendly resulted in optimized cost.

Today, all production plants are operating with benchmark performance w.r.t safety, environment capacity utilization, targeted production etc. Though modest journey of Heavy Water started in India with Nangal Heavy Water Plant with a capacity of 14 MT/Annum, today India is the largest exporter of Heavy Water and is the only country that deployed multiple technologies for Heavy Water Production. With export of Heavy Water, Dr. Bhabha's vision has been realized and at present HWB is tending towards achieving monopoly status.

Applications of Deuterium in non-nuclear field are becoming broader and broader day by day as many non-nuclear applications are being taken up to commercial scale, to name a few: applications of deuterium in OLED display, semiconductors, optical fibre, medicinal chemistry, NMR solvents etc. Today, HWB takes the pride to cater the global need of Heavy Water for all these non-nuclear applications after fulfilling the demand of INPP.

After achieving sustainable production of Heavy Water for 1st stage of Indian Nuclear Power Programme (INPP), HWB ventured into multifaceted activities to meet the demand of other key input materials for INPP and subsequently, HWB's mandate has been enlarged for managing the projects of the DAE for production of Heavy Water and Specialty Materials.

India adopted closed fuel cycle which entails various solvents for processing of spent fuel and also to recover valuable radio-isotopes for societal applications. A wide array of nuclear solvents is required for fuel fabrication, spent fuel reprocessing, partitioning of isotopes etc. HWB acquired comprehensive capability for industrial scale production of nuclear solvents viz. TBP, D2EHPA, TAPO, TOPO, TiAP, DHOA, PC88A, CC6. Indigenous assured availability of these solvents is a key factor for the successful operation of closed nuclear fuel cycle & integration of 3- stage INPP. HWB has set up facilities at its site at Talcher, Vadodara and recently at Tuticorin.

Based on the core competence developed in hydrogen isotopes separation process, HWB ventured into isotope separation of other lower isotopes, viz. separation of boron isotopes (10B and 11B) so as to achieve the target of making boron carbide pellets for 2nd stage of INPP, development of both 10B and 11B enriched BF3-CaF2 complex/BF3 gas for applications in neutron detectors and semiconductors

Subsequently, HWB embarked into production of nuclear grade sodium, a key input material for fast breeder reactors. Presently, there are no manufacturers of nuclear grade sodium in India,

HWB envisioned indigenous production through development of closed electrolytic cell technology. HWB developed 2000 Amp Closed Electrolytic Cell, installed & successfully operated at HWBF, Vadodara. HWB is geared up to set up augmented facility for production of nuclear grade sodium as per the demand of various DAE units.

HWB has set up demonstration scale $H_2{}^{18}O$ plant at HWP Manuguru which is commissioned recently in May, 2023. In a significant milestone for scientific and industrial advancement, India has achieved a groundbreaking capability in the production of O-18 enriched water. It is India's pride to join in the elite group of O-18 producers.

Quality of the product has been tested by various agencies including patient scan by RMC, BARC and found par excellence. At present plant is under stabilization through optimization of various plant parameters for continuous and sustained production of $H_2{}^{18}O$. HWB is planning to set up industrial scale facility for $H_2{}^{18}O$ plant.

HWB has demonstrated its strong presence in all the stages of INPP. HWB is also working on other areas of advanced technology for nuclear, societal and environmental applications viz. recovery of rare metal from secondary sources, recovery of gallium from Bayer's liquor, recovery of Cobalt, Nickel & Molybdenum from scraps, recovery of Helium from natural and purge gas, production of Hydrogen, a clean fuel, development of efficient equipment (ARIC) for effective mass transfer in Hydro metallurgical processes. HWB is dedicated to take up any challenge in deploying technology for industrial scale production of wide category of materials to widen the horizon of department's programme.

Shri S. Satyakumar *is Outstanding Scientist and Chairman & Chief Executive of Heavy Water Board (HWB), an industrial unit of the Department of Atomic Energy. As Chief Executive, he is responsible for the smooth and efficient operation of Heavy Water Plants/HWB Facilities located at Kota, Manuguru, Thal, Hazira, Baroda, Tuticorin and Talcher.*

Shri S. Satyakumar graduated in Chemical Engineering from Andhra University in 1988. He joined HWP Manuguru in 1989 and held many responsible positions like Shift Engineer, Shift Superintendent, Dy. Technical Service Manager. His areas of interest are plant operation, chemical process trouble shooting, energy conservation, Chemical Process Quantitative Risk Assessment (CPQRA) etc.

As Director (Projects & New Activities), involved in developing new technologies in coordination with BARC like extraction of Co & Ni from scrap, recovery of Gallium from Bayer's liquor etc. He is the first author of the book on "H2S-H2O based technology for Heavy Water Production".

23. Development of high intensity proton accelerators- Present status and future program

Rajesh Kumar

Bhabha Atomic Research Centre, Mumbai, India

Proton Accelerators will find applications in ADS and waste transmutation systems, though such applications will need high energies and high intensities. A 1 GeV, 10 mA proton accelerator will be ideal for ADS. However, many useful applications like experiments related to spallation neutrons, isotope production and waste transmutation etc can be realized at lower energies and currents as well. Hence, a stage wise approach is envisaged for the development of high intensity proton accelerators. Low energy part of a high intensity proton accelerator is very crucial as space charge forces are dominant.

The Low Energy High Intensity Proton Accelerator (LEHIPA) project at BARC, Mumbai has recently been commissioned to the target energy of 20 MeV in pulsed mode. Successful development of various sub systems is an important milestone towards our future program for the development of high energy high intensity proton accelerators. The LEHIPA was commissioned in stages. The 3 MeV proton beam was utilized for irradiation experiments by Material Science Division (MSD), BARC. The 20 MeV proton beam from LEHIPA accelerator will be used for experiments related to neutron production, Radioactive Ion Beam (RIB), irradiation studies, Boron Neutron Capture Therapy (BNCT) and isotope production. A 40 MeV, 10 mA proton accelerator also proposed at BARC-Vizag site which will be the first phase of our high energy high intensity proton accelerator development program. This talk will discuss the status of LEHIPA and our future program for high intensity proton accelerators.

Rajesh Kumar *obtained his B.Tech in Electrical Engineering from NIT (earlier REC) Hamirpur and joined BARC after graduating from the 38th batch of BARC training school in 1995. He has been responsible for the design and development of various electrical components and subsystems for particle accelerators. He has participated and contributed to the successful commissioning of three different accelerators FOTIA, 400 keV RFQ based deuteron accelerator and 20 MeV LEHIPA at BARC. He is also leading the 325 and 650 MHz coupler development effort as Sub-Project coordinator for Indian Institution Fermilab collaboration (IIFC). Dr. Rajesh Kumar completed his M.Tech in Microwave Engg. from IIT Kanpur during 2003-2005 and PhD from HBNI in 2015.*

Presently, he is Head of Ion Accelerator Development Division (IADD) and leading the efforts for 20 MeV beam optimization and utilization from LEHIPA and approvals and design of upcoming 40 MeV proton accelerator MEHIPA-Phase 1.

ROUND-UP OF POSTER PRESENTATIONS AT INSIC-2023

One of the most important aspects of INSIC-2023 (12 to 15 December 2023) on Nuclear for Clean Energy Transition was, contributory abstracts and poster presentation. More than hundred authors from different DAE institutions, Indian and Foreign universities, and collaborative industries contributed two-page abstracts on spectrum of topics, relevant to achieve sustainable energy growth powered by nuclear energy to meet the challenges of carbon emission targets set by India. All the abstracts were reviewed by subject experts and around ninety-six were accepted for presentation as posters during the conference. The details of abstracts are summarised below.

The abstracts on the topic **roadmap to net zero emission and the energy mix for the future** stressed on importing LWRs through international cooperation for capacity enhancement. They also showed the scope and challenges in high temperature technology developments for nuclear and solar thermal systems for energy mix towards net zero emission. The posters featured studies on optimum generation of capacity addition by nuclear and deployment of renewable energy like roof top, PV and wind. In all there were 05 abstracts.

The abstracts on the topic **Growth of Generation III and III+ nuclear reactors**, featured the role of computational fluid dynamics in design and safety analysis of advanced pressurized water reactors and for enhancement safety features in VVERs. The abstracts also presented simulation of VVER-1000 benchmark problem with Open MC code, advancements in new passive safety systems in Pressurised Water Reactor (PWR) technology. In all there were 05 abstracts.

Abstracts on **advanced nuclear reactors** featured a wide spectrum of developmental activities which included optimising fuel design parameters for advanced reactor cores, simulation of an accelerated driven molten salt fuel system, reactivity effect of xenon in circulating fuel reactors (MSRs), modelling of coupled two-phase natural circulation based passive residual heat removal system, technology development for HTR and MSBR programs, design goals and safety aspects of advanced sodium cooled SMRs, low activation high entropy alloys for advanced nuclear reactors, design and optimisation of AHWR representative core, analysis of supercritical carbon dioxide Brayton cycle for fusion power plants and integral thermal-hydraulic test facilities for design validation of advanced nuclear reactors. In all there were 18 abstracts.

Abstracts on **life extension and management of aging nuclear reactors** presented improvements in methods for accurate fatigue life assessment, probabilistic analysis of structural integrity, anisotropy in delayed hydride cracking, refuelling strategy for material irradiation, remote tooling for coolant channel replacement, challenges in simultaneous EMCCR in 2 reactors, evaluation of radiation induced defects in SS material, performance evaluation of snubbers in operating Indian pressurized heavy water reactors, procedure for condition based qualification of cables in nuclear power plants, life management of PHT system feeder piping in Indian PHWR and assessment of core components of BWRs and PHWRs. In all there were 17 abstracts.

Abstracts on Nuclear Hydrogen production technologies featured research and developmental works comprising of CFD studies on ammonia decomposition using packed-bed membrane reactor, Ni-Fe alloy coatings on Ni-foams synthesized by electrodeposition for alkaline water electrolysis, catalytic removal of cross impurities present in O_2 and H_2 streams from alkaline water electrolyser, Cu-Ni cycle for hydrogen production, life cycle cost comparison between nuclear and solar powered electrolytic process, Fe-Ni layered double hydroxides as electrocatalyst for alkaline water splitting and green hydrogen production by high temperature steam electrolysis (HTSE). In all there were 09 abstracts.

Abstracts on **emerging technologies in support of nuclear power deployment, security and safety** featured developmental work on deployment of MED-TVC desalination plant coupled with 220 MWe PHWR, TDL based heavy water loss monitoring system, advancements in magnetic confinement strategies for fusion reactors, development of passive safety systems for advanced reactors, development of silver-impregnated zeolite for mitigation of iodine, passive decay heat removal system for nuclear power plant safety, noise analysis based fault detection and diagnostics of self-powered neutron detectors, Pt+Pd bimetallic catalysts supported over cordierite for hydrogen mitigation, intensified crystallization of ammonium uranyl carbonate by sonochemical method, use of artificial intelligence applications in NPPs, performance of indigenized 3 pitch integral coaxial Inconel SPNDs in 700mwe IPHWRs, leak assessment for concrete containment, partitioning of radioactive high level liquid waste, operational experience of Cesium pencil production at WIP-Trombay, decontamination of aluminium rods, novel approaches in the management of solid radioactive wastes, organic liquid radioactive waste management, eye cancer treatment by BARC Ruthenium Brachytherapy (RuBy) plaques, laser based tilt measurement system for fuelling machine head alignment, study of dynamic response of PHT relief piping system, seismic qualification of shut-off rod of Indian research reactors, nuclear security for small modular reactors and improvements in safety of Indian NPPs based on lessons learnt from nuclear accidents. In all there were 33 abstracts.

Abstracts on **regulatory framework and challenges for emerging nuclear technologies** presented advanced regulations for DEC management system of KKNPP-3 to 6, out-core fuel management in nuclear power plants for accounting and control of nuclear material and overview of regulatory challenges for emerging nuclear technologies. In all there were 03 abstracts.

The abstracts on **Industry preparedness and participation** featured nuclear clean energy challenges, import substitution of lubricating oil used in TG system for KKNPP units and thermal neutron irradiation testing of a cots microcontroller. In all there were 03 abstracts.

Abstracts on **policies and public acceptance of nuclear energy** showcased the current use of nuclear energy and measures to make it cost effective, balancing policy imperatives & public sentiment and public awareness; a case study on Kudankulam nuclear power project. In all there were 03 abstracts

The wide spectrum of topics covered during the conference manifested in deep seeded exchange of knowledge and ideas amongst the nuclear fraternity, industry and academia laying a foundation for future development of nuclear ecosystem in our country.

Glimpses of from the Poster Sessions - Judges interacting with Delegates' Poster Presentations

INDUSTRY PARTNERS TO INSIC-2023


LARSEN & TOUBRO


APAR INDUSTRIES LIMITED
RADIATION RESISTANT CABLES


Nuclear Power Corporation of India Limited
Nuclear Power Corporation of India Limited
एनपीसीआईएल
NPCIL
ATOMS IN THE SERVICE OF THE NATION


EXIDE INDUSTRIES LIMITED
EXIDE
POWERING NUCLEAR PLANTS
Product Range


PYROTECH ELECTRONICS PVT. LTD.
Small Enclosures
CONTROL DESK
Console
Modular, Ergonomic and Affordable


KARANDIKAR LABORATORIES PRIVATE LTD.
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HYDAC INDIA PVT LTD
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Heavy Water Board
Department of Atomic Energy
Self-reliance in Nuclear Solvents Driving the Nuclear Fuel Cycle
Heavy Water Board
Department of Atomic Energy
Heavy Water Production in India
Heavy Water Board
Department of Atomic Energy
Indigenous Production of Boron-10 & Nuclear Grade Sodium


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15

CO-OPERATION AGREEMENTS BETWEEN INS AND NUCLEAR SOCIETIES OF FRANCE, USA AND JAPAN

INS and SFEN sign Co-operation Agreement

The INS signs a Co-operation Agreement with SFEN aimed at developing exchanges and cooperation between the Societies for promoting the development of nuclear science and technology for peaceful purposes.

The Agreement was signed on December 14, 2023, in the sidelines of the INSIC-2023, by Ms. Valerie Faudon, Director General, French Nuclear Society (SFEN), France, on behalf of SFEN and Dr. B.N. Jagatap, President, Indian Nuclear Society on behalf of INS.

Ms. Valerie Faudon and Dr. B.N. Jagatap sign the Co-operation Agreement

The signatories to the Co-operation Agreement address the gathering

Indian Nuclear Society

Sfen

CO-OPERATION AGREEMENT

BETWEEN

THE INDIAN NUCLEAR SOCIETY (INS)

AND

THE FRENCH NUCLEAR ENERGY SOCIETY (SFEN)

The Indian Nuclear Society (INS) based in Mumbai and the French Nuclear Energy Society (SFEN) based in Paris, in proceeding from the common desire of both parties for promoting scientific and technological exchanges and cooperation, have reached the following agreement between the two parties:

1. This agreement is aimed at developing exchanges and cooperation between the two parties and promoting the development of nuclear science and technology for peaceful purposes.

2. Both parties undertake to do the following:

   a. Inform each other of the organization of appropriate technical and scientific conferences of international significance to be held in each country, and to charge no registration fees for maximum two officers or representatives of the other party attending general conferences operated by the parties to this agreement;

   b. Encourage the exchange of technical information, journals and periodicals which are jointly identified and agreed upon by the executive officers or official point of contact of each society;

   c. Promote as much as possible the establishment of contacts between equivalent groups in both countries;

   d. Strengthen contacts and exchange experience through communication or meetings of delegates from both parties;

   e. Publish articles in each other's journals or other periodicals required by the other party, to be subject to usual editorial and financial procedures;

   f. Encourage members of each party to participate in the training program in each country and provide lectures, papers and texts for such activities;

   g. Enhance cooperation in science popularization and public acceptance programs in nuclear energy and nuclear medicine etc.

   h. Arrange for or jointly sponsor meetings or workshops on specific topics of mutual interest.

3. The INS and the SFEN will support, as far as possible, the involvement of other learned societies and scientific/technical agencies in carrying out activities envisaged under this agreement.

4. All privileges identified or agreed to shall be reciprocal between both parties and all undertakings are subject to mutual agreement.

5. In order to facilitate the implementation of this agreement and the development of concrete plans for the future, the INS and the SFEN will each designate at least one individual who will be a point of contact (INS: President, Indian Nuclear Society: indiannuclearsociety@gmail.com, bnjagatap@gmail.com; SFEN: Valérie FAUDON, valerie.faudon@sfen.org) between the two parties, and who will be responsible for communications and be responsible for the implementation of this agreement.

6. This agreement shall come into force from the date of signature for an initial period of five years. The agreement shall be renewable for five-year period upon the expressed decision of the parties, subject to a six-month written notice of cancellation. Any amendments to this agreement should be agreed to by both parties in writing.

7. Representatives of each party shall meet at least once every two years, as appropriate, to assess the effectiveness of this cooperative agreement, to provide direction for the future, and to consider the renewal of the agreement after each five-year period.

8. Neither party shall be liable for any expenses in connection with this agreement except by prior arrangements and written agreements. Each party will provide the other party two free passes per year for its international conferences.

9. Both parties agree that any cooperation program would have to conform to the laws and regulations of the two countries.

10. Done in duplicate, written in English and signed on December 14, 2023 at Mumbai.

For INS:

Prof. B. N JAGATAP

President
Indian Nuclear Society
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India
Tel: +91 (22) 25 59 83 27

For SFEN:

Ms. Valerie Faudon

Director General
French Nuclear Energy Society
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ANS
American Nuclear Society

INDIAN NUCLEAR SOCIETY
ESTD. 1988

MEMORANDUM OF COOPERATION BETWEEN

THE AMERICAN NUCLEAR SOCIETY

AND

THE INDIAN NUCLEAR SOCIETY

The American Nuclear Society ("ANS") and Indian Nuclear Society("INS") (individually a "Party" and together the "Parties"), in proceeding from the common desire of both Parties to promote scientific and technological exchanges and cooperation, signed a Memorandum of Cooperation in 2004. It was renewed in 2010, the last one expiring September 1, 2015. Recognizing the benefit of these agreements, the ANS and the INS wish to continue with their cooperation and have reached the following Memorandum of Cooperation ("Agreement"):

1. This Agreement is aimed at developing friendly exchanges and cooperation between the two Parties and furthering the development of nuclear science and technology for peaceful purposes.
2. Both Parties undertake to:
   a. inform each other of the convocation of appropriate technical and scientific conferences of international significance to be organized by each Party, and charge no registration fees for conference speakers and two officers of the other Party, or their designees, attending two conferences per year (for the ANS, the conferences are its two national meetings);
   b. encourage the interchange of publications, including reports, monographs, proceedings, journals and periodicals, and any other material intended for unrestricted distribution published by the ANS or the INS, which are jointly identified and agreed upon by the executive officers or official points of contact of each organization, bearing in mind that the INS has shifted to a primarily free online publishing policy;
   c. promote as much as possible the establishment of contacts between equivalent groups of each Party to this Agreement;

Page 1 of 4

ANS
American Nuclear Society

8. Both Parties agree that any cooperation program shall conform to their respective Bylaws and Statutes.

The American Nuclear Society	Indian Nuclear Society
Kenneth Petersen President	B N Jagatap President
Date: August 30, 2023	Date: August 30, 2023
[signature]	[signature]
Craig H. Piercy Executive Director/CEO	G D Mittal Secretary
Date: August 30, 2023	Date: August 30, 2023
[signature]	[signature]

and budgets and to the availability of funds. They shall be carried out in accordance with their respective rules and practices.

4. In order to facilitate the implementation of this Agreement and the development of concrete plans for the future, the ANS and the INS will each designate at least one individual who will be a point of contact between the two Parties, and who will be responsible for communications and for the implementation of this Agreement.
5. This Agreement shall come into force from the date of signature for an initial period of five years. The Agreement shall be renewable for five-year periods upon the expressed decision of the Parties, subject to a six-month written notice of cancellation. Any amendments to this Agreement should be agreed to by both Parties in writing.
6. Representatives of each Party shall meet at least once every two years, as appropriate, to assess the effectiveness of this cooperative Agreement, to provide direction for the future, and to consider the renewal of the Agreement after each five-year period.
7. Neither Party shall be liable for any expenses in connection with this Agreement except by prior arrangements and written agreements.

1. The ANS and the INS shall keep each other regularly informed of their respective yearly programs of conferences, symposia, seminars and workshops.
2. Each Party shall identify with sufficient notice to the other Party those meetings they propose for co-sponsorship or cooperation by the other Party.

The rights and duties of the Party which accepts to co-sponsor or cooperate in a meeting organized by the other Party shall be defined by reference to Classes I, II, and IV of ANS co-sponsorship criteria.

MEMORANDUM OF UNDERSTANDING (MOU) FOR COOPERATION BETWEEN THE INDIAN NUCLEAR SOCIETY AND THE ATOMIC ENERGY SOCIETY OF JAPAN

The Indian Nuclear Society (INS) and the Atomic Energy Society of Japan (AESJ), in the spirit of cooperation, do hereby together accede to the following terms of the MOU.

ARTICLE I

Both Societies wish to promote the peaceful uses of nuclear science and technology and, with this objective, wish to encourage friendly cooperation between the two Societies and exchanges between their members.

ARTICLES II

All privileges identified in connection with this MOU and mutually agreed to shall be applicable reciprocally between the two Societies.

ARTICLE III

(1) Each Society will designate an official to act as the main contact with the other Society. These officials will be responsible for establishing effective communication and for initiating, coordinating, and reviewing programs of inter-society activities.

(2) Each Society will forward to the other Society, regular publications, conference Call for Papers, and other conference information.

(3) Each Society agrees to charge no basic registration fee to its main annual or semi-annual conference for up to two officially designated members of the other Society, who have pre-registered.

(4) The two Societies will identify possible fields of mutual interest as potential topics for symposia or conferences.

(5) The two Societies will establish the connections among the counterpart groups, and strengthen connections and exchange experiences through communications and meetings of delegates from the both Societies.

(6) The two Societies will encourage members of the both parties to participate in exchange programs of scientists and students and to provide lectures, papers and documents.

ARTICLE IV

This MOU shall come into the force from the date of signature. The MOU shall be renewable in a five-year period upon the expressed decisions of the Societies, subject to a six-month written notice of the termination. Any amendments of this MOU should be agreed to in a written form.

ARTICLE V

Neither Society shall be liable for any expense in connection with this MOU, except by prior arrangement and written agreement.

ON BEHALF OF THE ATOMIC ENERGY SOCIETY OF JAPAN AND INDIAN NUCLEAR SOCIETY

Prof. B.N. Jagatap President Indian Nuclear Society	Prof. Yuichi Niibori President Atomic Energy Society of Japan
25 December 2023 Date	29 November 2023 Date
Mr. G.D. Mittal Secretary Indian Nuclear Society	Mr. Yasushi Tomita Secretary Atomic Energy Society of Japan
25 December 2023 Date	7 December 2023 Date