Office of the Principal Scientific Adviser
to the Government of India

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Technology Foresight

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Office of the Principal Scientific Adviser
to the Government of India

Technology Foresight : Sectoral Perspectives

Feature Story

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In this edition of Vigyan Dhara, Scientific Secretary, Office of Principal Scientific Adviser (PSA) to the Government of India, Dr. Parvinder Maini highlights the value-addition of foresight practices in policy-making and strategic planning.

FOREWORD

The current global scenario is marked by several interconnected challenges. Environmental degradation like loss of biodiversity, soil erosion, pollution, etc. continues to escalate due to increased urbanisation, deforestation and natural calamities caused by climate change. Technological advancements, like artificial intelligence, are raising concerns about privacy and data security. Economic disruptions in global supply chains, coupled with constant changes in geopolitical scenarios, are further straining stability. Together, these issues create what is often called a "polycrisis" scenario, where multiple crises converge, making them more difficult to address individually. The United Nations (UN) Summit of the Future 2024 held on 22 - 23 September 2024, focused on addressing global challenges through a systemic approach to thinking about the future. Countries are working together to achieve global goals, including the UN Sustainable Development Goals (SDGs) and addressing climate change, emphasising the importance of a future-oriented approach.

The impact of any specific intervention gets amplified due to the complex interconnectedness of various systems—be it economic, social, environmental, or technological. For example, an intervention in climate policy can directly influence energy markets, economic growth, public health and many more, demonstrating how actions in one area ripple through others. As the interconnected nature of critical systems is becoming more evident, the need for strategic, knowledge-driven interventions becomes increasingly apparent. Policies, schemes or programs must be informed by scientific evidence to ensure they are adaptive and resilient to unforeseen changes. Evidence-driven policy processes and strategic planning, backed by data, are essential not only for addressing immediate challenges but also for driving long-term success in achieving global goals such as the SDGs.

The act of thinking about the future - futures thinking or foresight - has been a part of our global society. The Government of India has demonstrated foresight in framing the multiple country's vision and plan documents, including the multiple Five Year Plans, Ministerial vision documents, etc. These documents, acting as critical guidance, have streamlined the strategies of the government towards the envisioned future. Implementation efforts aligned with these strategies have been realised through the numerous programs, schemes and missions spearheaded by government organisations - Ministries/ Departments/ Agencies. Government organisations are at times endowed with a mandate - a responsibility given to an entity to carry out specific activities or achieve certain outcomes - as well which guides the organisations' strategic plans and efforts.

Strategic planning and decision-making are often supplemented with predictions using forecasting techniques on past and current information. Inputs on the potential future possibilities help understand the potential impacts (positive or negative) of these possibilities on the strategic efforts. Foresight as a scientific field to study the future, which emerged in the late 20th century, provides critical evidence of future possibilities. It aids in anticipating multiple possible developments in future rather than predicting a singular possibility. Understanding possible scenarios for the short-term, mid-term, and long-term future provides insights into potential conditions or circumstances that can help organisations better align their ongoing efforts, strategies, and vision. The field or discipline of foresight adds value to the evidence-driven policy processes with applications across sectors.

Internationally, there is a growing recognition of the value-addition of foresight, driven by the need to navigate complex global challenges. Multilateral organisations such as UN play a pivotal role in enhancing capabilities, among member countries, towards integration of strategic foresight into policymaking processes. UN underscores the significance of foresight through initiatives like the UN Futures Lab Network, UN 2.0 and UN Development Programme (UNDP) Foresight Manual for integrating foresight into development strategies. The European Union (EU) has institutionalised the use of foresight as a tool for science-based policymaking - a science for policy instrument, producing an annual Strategic Foresight Report. The Organization for Economic Co-operation and Development (OECD) works include developing frameworks like 'Framework for Anticipatory Governance of Emerging Technologies'. Country-level initiatives such as those from Singapore's Centre for Strategic Futures, United Arab Emirates's (UAE) Future Foresight Platform, and United Kingdom's (UK) foresight projects from the Government Office of Science exemplify how individual countries are adopting foresight practices to inform policy and strategic planning. Institutions like the Geneva Science and Diplomacy Anticipator (GESDA) focus on using foresight for emerging scientific and technological developments.

Science and Technology (S&T) drive nearly every aspect of modern life, making technology foresight the focus of this newsletter. As a primary force behind progress and development, S&T also acts as a catalyst for disruptions. Technology foresight, in particular, plays a crucial role in guiding technological advancement and in better preparing for potential risks, with a strategic emphasis on emerging technologies. It aims to identify promising technologies that can benefit the sectors or entire economy in the long term.

The Government of India has been enabling the development of the STI ecosystem including through recent initiatives such as the Atal Innovation Mission, Anusandhan National Research Foundation (ANRF), Tech Corpus of ₹1 lakh crore and India Techade. NITI Aayog (National Institution for Transforming India) serving as the apex think tank of the Government of India, provides Governments at the central and state levels with relevant strategic and technical advice across the spectrum of key elements of policy. The Office of the PSA provides pragmatic science advice towards key interventions of the Government of India, transferring scientific knowledge into usable inputs which are critical, not only in times of uncertainty but throughout the decision-making lifecycle. The Government's Mega Science Vision 2035 initiative is driven by the Office of PSA, effectively utilising foresight tools like participative consultations (nationwide) and roadmap development in six areas: High Energy Physics, Nuclear Physics, Astronomy & Astrophysics, Accelerator Science & Technology and Applications, Climate Research, and Ecology & Environmental Science.

Through instruments such as the Prime Minister's Science, Technology, and Innovation Advisory Council (PM-STIAC) and the Empowered Technology Group (ETG), the Office of PSA extends advisory on key government policies and interventions in multiple sectors, condensing evidence from scientific studies including technology foresight. ETG provides strategic direction for the development and deployment of technologies, overseeing national-level policies, guiding technology induction, and Research & Development (R&D), with indigenisation as a key priority area. The fulfilment of procurement needs from Indian resources is encouraged along with understanding of the areas with external dependencies. Utilising foresight evidences, strategic plans that align with long-term goals of indigenisation are advised, ensuring that investments in technology development are directed towards areas that are in demand and will yield maximum benefits for society and the economy.

I am pleased to share that, in this edition of the Vigyan Dhara newsletter on Technology Foresight, we showcase a few articles to explore the field and to highlight past and ongoing efforts. Dr. V K Saraswat, Hon'ble Member (S&T) of NITI Aayog shares the role of foresight in policy-making, brought out in the featured article. Vision to Action based on foresight is explored through the experiences of Dr. R Chidambaram, former PSA to the Government of India. We bring an article discussing the key use-cases and techniques of foresight. Perspectives from the sectoral foresight in Public Health, Semiconductors, Quantum Magnetometer and Nuclear Energy are shared. The article by Prof. Krishna Kumar Balaraman from Centre for Technology Foresight and Policy of Indian Institute of Technology (IIT) Jodhpur highlights the avenues available for gaining knowledge and expertise in foresight.

In this edition, we explore how technology foresight is strategically applied through key instruments of Office of PSA like ETG and PM-STIAC, to drive informed decision-making and policy recommendations. Office of PSA's collaboration for Technology Foresight being pursued with international and multilateral agencies such as the Knowledge Exchange on Technology Foresight which was held in collaboration with the European Commision, is covered as an article. I sincerely hope that this issue of Vigyan Dhara will intrigue our readers about technology foresight and provide a glimpse of the efforts on-going in developing and utilising foresight to lead our country strategically towards a brighter future achieving the vision of Viksit Bharat @2047.

Foresight Approaches and Techniques

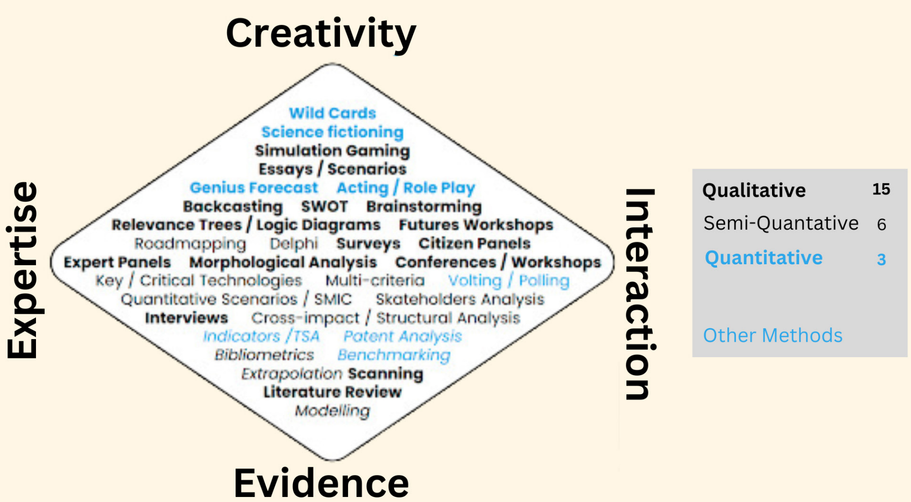
Every institution or organisation functions as a part of multiple systems, which are often interconnected leading to complexities. Given the higher frequencies of changes in recent times, disruptions in one system often impact the other interconnected systems. This combination of increased complexity and higher probability of disruptions/ changes indicates the Turbulent - Uncertain - Novel - Ambiguous (TUNA) characteristics in recent times.

Strategies to manage the evolving landscape and account for events over which there might be no control or only a little influence are essential in the TUNA world. Achieving the goal considering the evolving dynamics in the future also accounts for an effective strategy. The perspective of considering the impact of an action on the future has been advocated by the United Nations Sustainable Development Goals (UN SDGs) 2030, aimed at steering the world towards the 17 crucial goals. Science, Technology and Innovation (STI) are highly valued as catalysts of development, and as tools for addressing the critical global challenges. Looking at the wider perspective when considering technology and its disruptive changes is recognised globally, with the increasing global focus on sustainable development.

The practice of foresight involves gathering information about the future to anticipate possible developments. Foresight helps in the alignment of strategies with possible futures, by considering long-term implications and uncertainties, helping to prepare for multiple potential outcomes. Technology foresight focuses on the development and impact of emerging technologies to support the development of technology policies and innovation programs. Technology foresight aids in anticipating future technological changes and in resilient policy-making, understanding the likely risks.

Techniques

Many quantitative and qualitative techniques are used in foresight studies, with varying levels of evidence and creative thinking. Identifying prominent trends helps in better understanding the dynamics which will have immediate implications. **Trend analysis** helps analyse patterns and trends in data over time to gain insights into potential future developments and helps understand the trajectory of various critical factors.



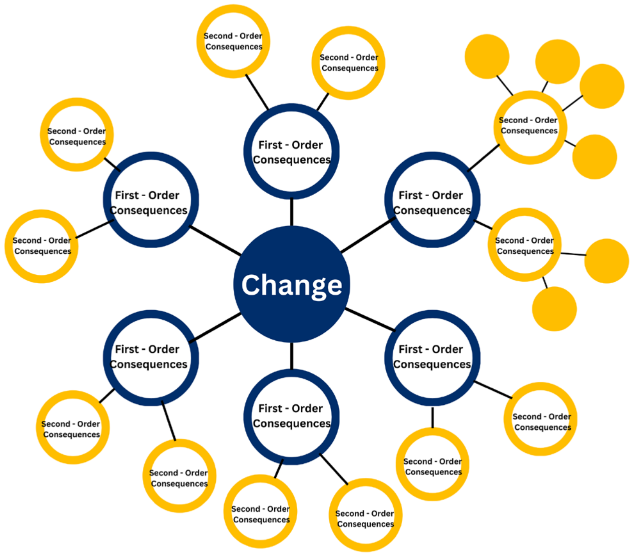
Foresight Diamond - a framework that positions technology foresight methods with its prominent type of knowledge source (creativity, expertise, interaction or evidence)
Image source: Popper, R. Foresight Methodology. Edward Elgar, 2008.

Horizon scanning is useful in detecting weak signals. Weak signals are subtle indicators of change that may not yet be widely recognised but could emerge to have significant implications for the future. It is a strategic method used to analyse external operating conditions and identify emerging trends, opportunities, and potential threats. For example, the PESTEL framework helps expand the view to the external factors - political, economic, social, technological, environmental, and legal (PESTEL) - for signals which can have an impact.

Delphi is a structured technique used to gather expert opinions and judgments about future developments. It involves multiple rounds of surveys or questionnaires administered to a panel of experts. After each round, the responses are analysed, and feedback is provided to the participants. This iterative process allows experts to refine their views based on the insights shared by others, leading to more informed and consensus-driven foresight inputs over time. The goal of the Delphi technique is to achieve a reliable convergence of opinion on specific issues or trends, making it a valuable tool for strategic foresight.

Backcasting is a strategic approach that starts with defining a desirable future vision and then working backwards to identify the steps needed to achieve that future state. Unlike forecasting, which extrapolates from the present to the future based on current trends, backcasting focuses on the end goal and determines the most effective path to get there. Integrating foresight with technology development, technology roadmapping is a strategic planning tool that outlines the steps needed to achieve technological advancements aligned with market needs and organisational goals.

Scenario Planning is a method for developing multiple plausible future scenarios based on different assumptions and drivers of change, exploring potential futures and preparing for uncertainties. Futures wheel is a visualisation tool that helps explore the consequences of a particular phenomenon by mapping out direct and indirect impacts, to understand the broader implications of specific developments.



Futures wheel visualisation technique

Gaming based approaches are participatory foresight techniques that involves designing and using strategy games to explore potential future scenarios and inform policy decisions. These appraoches create simulated environments where participants can experiment with different strategies, test assumptions, and gain insights into complex issues.

Causal Layered Analysis (CLA) stresses the importance of systems thinking to understand the underlying structures of an event, and is a technique to generate transformative spaces for the creation of alternative futures. Usually represented as an iceberg with its visible part showcasing the problem and its submerged parts indicating the deeper reasons, CLA advocates that by changing the underlying metaphor, deeper and long-lasting transformation can be achieved.

Use of foresight across future time-frames

In the short-term future, the institutional focus is often on immediate issues and strategic decisions. Foresight using horizon scanning for weak signals, trend analysis, and scenario planning helps to address current trends, risks, and opportunities that can impact their immediate environment. Foresight also helps to identify potential disruptions or changes that might affect on-going functions. Short-term foresight is crucial for adapting to market changes, regulatory shifts, and emerging technologies.

In the medium term, strategic planning and the development of objectives looking at how current trends may evolve and their implications become the focus. Delphi surveys or backcasting methods, in addition to horizon scanning and trend analysis, envision desirable futures and work backwards to identify steps needed to achieve those futures. Medium-term foresight helps organisations align their resources and capabilities with anticipated changes in the market or environment. It supports key initiatives that require a longer lead time to implement.

In the long-term (>10 years), foresight involves exploring deeper uncertainties and potential transformations that could reshape industries, societies or the global landscape over decades. This timeframe benefits from thinking about fundamental changes rather than just incremental adjustments. Methods like scenario planning (to create diverse narratives about the future), policy gaming, and extensive trend analysis aid in navigating complex systems and considering a wide range of possible futures. Long-term foresight is critical for developing strategies that address challenges such as technological disruptions, demographic changes, climate change impacts, etc. It helps build resilience against disruptive forces that may not be immediately visible but could have significant long-term effects.

Adaptability and resilience for future developments can be enhanced by employing foresight for each timeframe, that helps in making informed decisions that align with both current realities and long-term aspirations.

Foresight impact across sector types

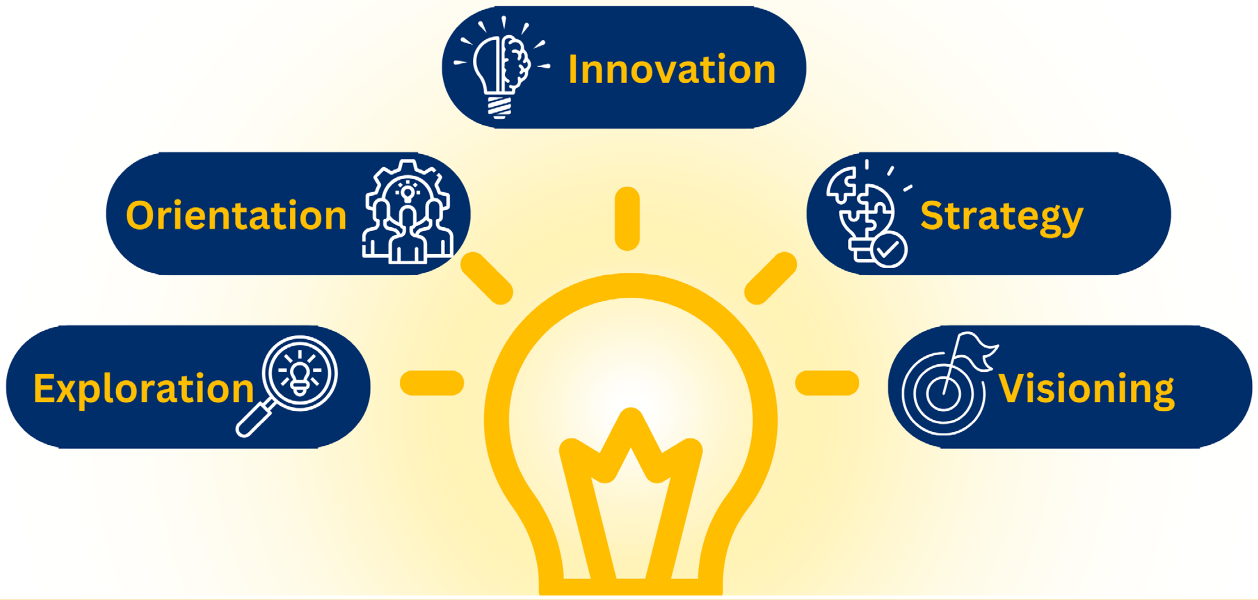
Each sector requires different approaches and techniques to navigate uncertainties effectively and capitalize on emerging opportunities. In legacy sectors, foresight helps policymakers identify gradual shifts and disruptions that could impact existing business models and regulatory frameworks. Foresight in legacy sectors can help ensure that policies remain relevant and effective in the face of evolving challenges. In the context of an emerging sector such as renewable energy, biotechnology, and space technology that are experiencing rapid growth or transformation, foresight is crucial for identifying opportunities for innovation, navigating uncertainties associated with new technologies and market dynamics. Even for sectors that are anticipated to emerge due to technological advancements or societal shifts, such as space tourism or synthetic biology, foresight should be more speculative, aiming to explore possibilities and understanding their consequences.

Use of foresight for different institutional purposes

Foresight techniques can be utilised for specific purposes like visioning, strategy making, strategic planning, etc. Foresight can enhance the visioning process by providing insights into potential future scenarios and trends that would be impactful, helping to articulate a vision that is not only aspirational but also grounded in realistic possibilities. Foresight complements strategic processes by anticipating changes in the external environment and exploring multiple possible futures, allowing for more flexible and adaptive strategies that can respond to uncertainties and new opportunities.

The value of strategic foresight in policy-making and decision-making has been widely recognized globally, as it enables institutions and organisations to anticipate future challenges, identify opportunities, and develop more robust and adaptable strategies. As the pace of change accelerates, the use of foresight in shaping the future becomes crucial and is likely to have increased importance.

(This article is written by Ms. Subarna S, Policy Fellow, OPSA-PAIU; Dr. Suryesh Namdeo, Senior Research Analyst, DST-Centre for Policy Research, IISc Bangalore contributed to the article)



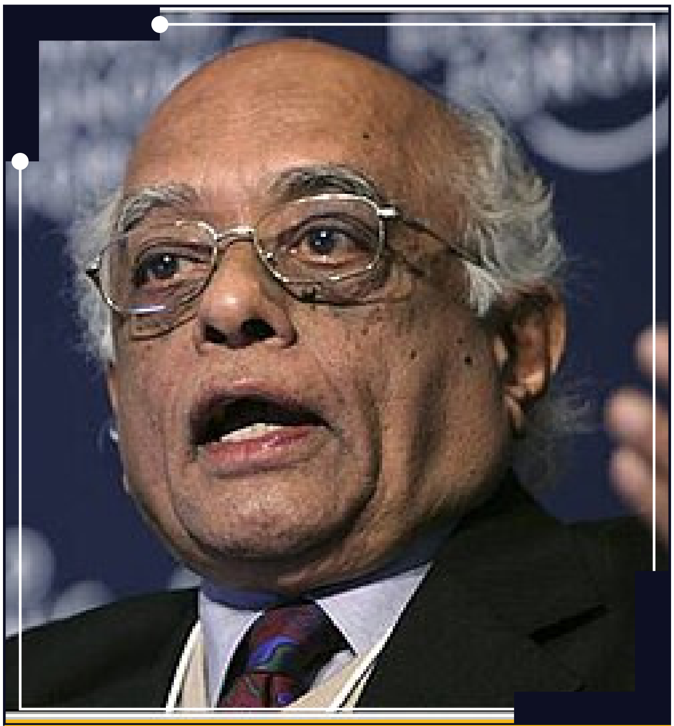
Use-cases of foresight for future preparedness
Image source: World Economic Forum

Vision to Action

Technology Foresight through the experiences of Dr. R. Chidambaram

Interviewed by Ms. Subarna S and Dr. B. Chagun Basha

Written by Ms. Nidhi



A Padma Shri and Padma Vibhushan awardee, Dr. R. Chidambaram served as the Principal Scientific Adviser to the Government of India from 2002 to 2018. A renowned physicist, Dr. Chidambaram was previously the Chairman of Atomic Energy Commission of India from 1993-2000 and is currently the DAE Homi Bhabha Chair professor at Bhabha Atomic Research Centre in Mumbai.

In an era where technology is a driving force behind national development, the ability to anticipate and prepare for future technological trends is crucial. In a candid conversation, Dr. R. Chidambaram, former Principal Scientific Adviser to the Government of India between 2002 to 2018, shares his deep insights into the role of technology foresight in shaping India's future. His perspectives highlight the importance of targeted research funding, equitable development, and building foresight capacity to ensure sustainable progress.

The Role of Foresight in Research Funding

One of the critical areas where technology foresight can make a substantial impact is in the strategic allocation of research funding. Dr. Chidambaram emphasizes the importance of prioritizing investments in emerging technologies that hold the potential to transform India's industrial and economic landscape. India's nuclear strategy is a prime example of how foresight can shape a nation's future. By closing the nuclear fuel cycle, India is maximising the energy output from its limited uranium resources. The process involves converting uranium-238 into plutonium-239 in reactors, and further utilising thorium to produce uranium-233, a highly efficient fuel. This closed fuel cycle approach, implemented in nuclear plants like Kalpakkam in Tamil Nadu, not only enhances energy security but also multiplies the power yield from the same amount of uranium.

Drawing parallels to Homi Bhabha's visionary approach to nuclear energy, which laid the foundation for India's self-reliance in the nuclear domain, Dr. Chidambaram advocates for a similar foresight-driven approach in other areas. "Energy should be at the forefront of our foresight efforts," he asserts. Underscoring the foundational role of energy technologies in supporting national development, Dr. Chidambaram advocates for considering 'per capita energy consumption' as one of the indicators towards measuring the Human Development Index for countries.

A notable success story shaped by foresight and strategic funding is India's Nanotechnology Mission under which two nanoelectronics research centers were established at IIT Bombay and IISc Bangalore. Spearheaded by the Office of the Principal Scientific Adviser under Dr. R. Chidambaram's leadership, this initiative aimed to position India at the forefront of the nanoelectronics revolution in the beginning of the 21st century. Dr. Chidambaram highlights that foresight was instrumental in identifying nanoelectronics as a critical area for investment, much like Bhabha's foresight in nuclear technology, which continues to contribute to India's strategic and energy needs.

Dr. R. Chidambaram shares his insights on the importance of developing energy technologies using technology foresight. Scan the image with Overly App to watch the full video.

"Thanks to the foresight of Dr. Homi Bhabha India was one of the very early entrants into nuclear energy. Homi Bhabha thought of building indigenous nuclear reactors at a time when we were not even building bicycles of indigenous design, that is the kind of foresight that we had, along with self confidence, not only in himself but in his countrymen as well. "

Dr. R. Chidambaram, former Principal Scientific Adviser to the Government of India

Foresight for Equitable Development

Equitable development is another key area where technology foresight can have a transformative impact. Dr. Chidambaram underscores the importance of ensuring that technological progress benefits all sections of society, particularly those in rural areas. "Rural development should be an integral part of our foresight strategy," he emphasizes. The Rural Technology Action Group (RuTAG) initiative, pioneered by Office of PSA under his leadership, is a model for how technology can be harnessed to address the unique challenges faced by rural communities. As a demand-driven mission, RuTAG aims to identify the technology needs in rural areas and engage IITs and other universities to address the challenges in adopting existing technologies, and disseminating refined solutions for these areas. By engaging academic institutions to anticipate rural development needs, RuTAG helps bridge the gap between urban and rural areas, ensuring that technological advancements are inclusive.

In addition to RuTAG, Dr. Chidambaram underscores the role of technology foresight in the creation of resource-sharing platforms like the Indian Nanoelectronics Users Programme (INUP) and the Indian Science, Technology, and Engineering facilities Map (I-STEM), both initiated by Office of PSA under his leadership. INUP provides access to nanoelectronics research facilities, while I-STEM connects researchers with available scientific instruments and facilities across India. These initiatives, along with the National Knowledge Network (NKN) - which facilitates high-speed network for research and education across the country, and is chaired by the Principal Scientific Adviser, Prof. Ajay Sood - exemplify how technology foresight can anticipate future technology needs and create mechanisms that ensure equitable access to resources, fostering a more inclusive and collaborative research environment across the nation.

Building Foresight Capacity through Coherent Synergy

Developing foresight capacity in India requires a strategic approach that brings together diverse talents and expertise.

Dr. Chidambaram emphasizes the importance of a coherent strategy in aligning the strengths of various stakeholders to address national challenges effectively. He stresses that technology foresight enables us to identify and develop technologies suited to the country's unique needs and resources, rather than simply following technological trajectories of other nations.

> *"You must select technology not because it is fashionable, but because it's important for our country. That's where technology foresight comes in."*
>
> *Dr. R. Chidambaram, former Principal Scientific Adviser to the Government of India*

Dr. Chidambaram underscores the role of international collaboration in technology foresight based on equal partnerships. Drawing from his experience, he advocates for collaborations where India is an equal partner, reflecting its advanced capabilities and development status. "We should go for international collaboration - only on an equal partnership basis. But if other countries want any help from us, we are more than happy to help," he asserts, highlighting the importance of coherent synergy in leveraging global expertise while maintaining strategic independence.

> *"India is now very well developed. There's no field in which we don't have experts, you just have to bring them together in a coherent synergy."*
>
> *Dr. R. Chidambaram, former Principal Scientific Adviser to the Government of India*

Fostering collaboration and mentorship is crucial in this context. Dr R. Chidambaram asserts that "young researchers must have self-belief, optimism and passion to grow and do great things for the country". By uniting such individuals with complementary competencies from academia, industry, and government, India can create a synergistic effect that drives innovation and ensures alignment with national priorities.

Dr. Chidambaram notes that this collaborative approach has been central to various interdisciplinary initiatives led by OPSA. While various departments in India are tasked with sector-specific expertise—such as the Department of Atomic Energy (DAE) for atomic energy, the Department of Space (DoS) for space, and the Council of Scientific and Industrial Research (CSIR) for industrial research with its extensive network of laboratories—interdisciplinary research often falls outside their traditional boundaries. Dr. Chidambaram emphasises that, in these cases, the role of the Office of the Principal Scientific Adviser becomes crucial. Through technology foresight, the PSA's office can effectively integrate diverse departmental efforts to tackle complex, cross-cutting challenges.

Citing artificial intelligence and machine learning as important technological disruptions at a global level where basic research needs to be accelerated, Dr. R. Chidambaram's insights during the interview provide a comprehensive roadmap for advancing technology foresight in India. By focusing on strategic research funding, promoting equitable development, and building foresight capacity through collaboration, mentorship, and international partnerships, India can position itself as a leader in the global technological arena. As India moves forward, technology foresight will be instrumental in shaping a future that is both innovative and equitable, benefiting all sections of society.

(Dr. B. Chagun Basha is Chief Policy Adviser, OPSA-PAIU; Ms. Subarna S is Policy Fellow, OPSA-PAIU; Ms Nidhi is Communications Consultant, OPSA)

Charting the Future of India's S&T Using Technology Foresight

Interviewed by Ms. Subarna S and Dr. B. Chagun Basha
Written by Ms. Shivangni Rani and Ms. Subarna S

Dr Vijay Kumar Saraswat is the Hon'ble Member (S&T) in NITI Aayog, the apex think tank of the Government of India, serving since 2015. He is a distinguished scientist with vast experience in defence research - in both basic and applied sciences - spanning several decades and has served as Secretary, Defence Research and Development Organisation (DRDO). He is a recipient of the country's civilian honor awards of Padma Shri (1998) and Padma Bhushan (2013).

NITI Aayog, the apex think tank of the Government of India, provides strategic and technical advice across the sectors. In conversation with Dr. V K Saraswat, Member (S&T) of NITI Aayog, on charting the future trajectory of India's S&T sector, the role of technology foresight is emphasized. Here are a few excerpts from the conversation:

Interviewer: Thank you for meeting us today to share your insights on 'Technology Foresight', its utility in decision and policy-making, its impact on future technologies, and the broader science and technology ecosystem. To begin with, please share a brief insight on technology foresight and its application.

Dr. Saraswat: Technology Foresight entails identifying, analysing, and systematically understanding future technology trends and disruptions, surpassing traditional forecasting methods. It employs various methodologies such as Trend Analysis, Scenario Planning, Delphi Method, and Horizon Scanning. These methodologies also incorporate the impact of social, economic, environmental, political, and other factors that can influence technological advancement. Understanding the long-term implications of technological advancement can align innovation with societal needs like healthcare, sustainability, and digital inclusion while driving economic growth and global competitiveness.

Interviewer: Reflecting on your leadership at DRDO, how did technological foresight influence its long-term vision and strategies? Additionally, how is this process embedded at various decision-making levels?

Dr. Saraswat: At DRDO, future planning and strategy were crucial. Under my leadership, we integrated anticipatory insights into decision-making, leveraged scenario planning, and engaged with global experts to stay updated on cutting-edge technologies. This foresight guided R&D efforts, leading to the launch of the national Ballistic Missile Defence program, enhancing the country's missile defense capability. Internally, we integrated forward thinking at all decision-making levels to foster a culture of curiosity and adaptability, encouraging the team to stay updated with evolving defense requirements. This approach shaped our technological development strategies and, in turn, our tech-driven strategy.

Interviewer: How do you see technological foresight as a tool to build a suitable anticipatory regulatory and governance system?

Dr. Saraswat: Challenges posed by technologies require an anticipatory approach to stimulate various opportunities, threats, and challenges. Building multiple scenarios using AI, and advanced analytical tools will facilitate planning for cost-effectiveness in technology adoption. Technology foresight can be utilized to develop a pre-emptive regulatory framework in collaboration with stakeholders.

"Countries that invest in foresight can proactively direct R&D towards high-impact sectors, fostering an ecosystem aligned with future development trajectories, thereby enhancing global competitiveness".

Dr. V K Saraswat, Hon'ble Member (S&T), NITI Aayog, Government of India

In policymaking, foresight enables future-resilient strategies. Amid global uncertainties like cybersecurity and digital transformation, anticipating technology shifts is crucial for crafting robust policies. This involves identifying disruptive technologies and encouraging decision-makers to make preemptive adjustments for flexible, adaptable policies.

Interviewer: As the Member (S&T) leading multiple initiatives across sectors that require long-term focus such as Energy and Climate, including the recent Carbon Capture Utilisation and Storage (CCUS) initiative, could you provide a macro perspective on how Technology Foresight shapes these policies?

Dr. Saraswat: NITI Aayog employs a multifaceted strategy that includes data-driven analysis, strategic forecasting, collaborative engagement, and global trend analysis of emerging technologies. In the CCUS sector, we explore global advancements and best practices to understand other nations' responses, identify opportunities for India to innovate, and lead while anticipating future disruptions. Mitigation strategies, driven by technology foresight, include advanced batteries, alternative fuels, and small modular reactors. We have collaborated with international organizations, and state governments to ensure a comprehensive policy framework. Analyzing future technology impacts informs current policy, positioning us advantageously and benefiting society.

Interviewer: NITI Aayog is actively collating data from multiple agencies for the Global Innovation Index (GII). Is there any internal exercise that feeds into foresight capabilities to position India on the global stage?

Dr. Saraswat: NITI Aayog coordinates data collection for GII, compiled by the World Intellectual and Property Organisation (WIPO). We collaborate with states to tailor innovation initiatives and offer technical assistance to local innovation hubs. This localized approach leverages regional strengths and fosters an inclusive innovation landscape. Additionally, NITI Aayog uses the India Innovation Index to compare states, helping them identify areas for improvement in innovation. NITI promotes knowledge-sharing platforms and Public-Private Partnerships (PPP) by collaborating with industry leaders, startups, and academic institutions. This fosters an integrated ecosystem supporting R&D and commercialization through incubators and accelerators under the Atal Innovation Mission (AIM) and other initiatives.

Scan the image with Overly App to watch the full video. Dr. V K Saraswat shares his insights on the initiatives of NITI Aayog.

Building Future Capacities and Competencies in Technology Foresight

Interviewer: Based on your institutional leadership positions from academic and research institutions, how can institutions build foresight capacities and adapt to future needs?

Dr. Saraswat: A key strategy is to focus on innovation and interdisciplinary research to address current and future challenges. Investing in cutting-edge facilities provides researchers with the latest equipment, prioritizes translational research to bridge the gap between research and practical applications, and facilitates collaboration with external stakeholders. Academic institutions and national labs should establish value creation centers to bridge the innovation gap between Technology Readiness Levels (TRL) 4 & 7. Each institution should have a Technology Forecasting team to analyze existing and emerging technologies and their socio-economic impact. Without nurturing such an ecosystem, institutions will remain stagnant.

> *"I strongly recommend that every institution should have a strong technology forecasting team to collate existing and emerging technologies and critically analyze their socio-economic impact in national and global landscapes"*
>
> *Dr. V K Saraswat, Hon'ble Member (S&T), NITI Aayog, Government of India*

Interviewer: Globally, including in the USA and EU, there's momentum to build advanced foresight capabilities in institutions and through human resource training. How do you see institutional capacities and individual competencies evolving in India in technology foresight? What advice would you give to strengthen it further?

Dr. Saraswat: India's journey toward advanced capabilities is promising but challenging. Despite significant strides in various sectors, there is still room to grow in institutional capacity and individual competencies. India's strengths include its talent pool, diverse academic institutions, and vibrant startup ecosystem. However, siloed operations limit their impact. We need an integrated ecosystem to promote design thinking aligned with national priorities

Secondly, fostering a culture of critical and strategic thinking and anticipatory skills at all levels requires a shift in the educational paradigm. India should establish dedicated Centres of Excellence to serve as hubs for training and cooperative research in interdisciplinary fields.

Thirdly, Indian institutions can gain valuable insights by learning from global institutions, and best practices. Our institutions, researchers, and scientists should 'Think Global, Act Local' to solve India-specific problems with a global outlook.

Interviewer: How can we use the idea of 'Think Global, Act Local' in better adoption and development of futuristic technologies as early movers?

Dr. Saraswat: Several transformative technologies like AI, Quantum Technologies, Blockchain, Biotechnology, Space, and Nuclear Fusion are shaping the future. To gain an early-mover advantage in AI, India must invest in high-performance computing, and build an AI-skilled workforce. 'Ethical and Responsible AI' should be prioritized to align technological development with societal values. Innovations in biotechnology, such as gene editing and personalized medicine, are advancing healthcare, R&D, and supporting startups. Therefore, collaboration between academia and industry is crucial to address India-specific needs. India needs greater investment in R&D which currently stands at 0.7% of GDP. The principle of 'man in the loop' should guide technological advancement, with a focus on addressing India-specific challenges through a collaborative approach to leverage early-mover advantages.

Interviewer: Building on your point about identifying technology areas for an early-mover advantage, how do you envision disseminating this vision? How can we synergize these ideas across stakeholders?

Dr. Saraswat: Recognizing that "Technology is the basic engine of growth" is crucial for all stakeholders. "Acting Together" should guide us and encourage collaboration for collective benefits. However, we must be mindful of technology's adverse impacts, like greenhouse gas emissions and climate change. Instead of a negative outlook, we must consider these impacts and advance technological development to create use cases that mitigate their negative impacts.

Scan the image with Overly App to watch the full video. Dr. V K Saraswat shares his insights on the use of scenarios.

Innovations in renewable energy and the circular economy demonstrate that emerging and disruptive technologies can be both transformational and sustainable. Emphasizing this message and educating stakeholders will help India transition from a knowledge economy to a product-driven nation, reinforcing the concept of science and technology for sustainable development.

(Dr. B. Chagun Basha is Chief Policy Adviser, OPSA-PAIU; Ms. Subarna S is Policy Fellow, OPSA-PAIU; Ms. Shivangni Rani is Policy Intern, OPSA-PAIU)

Technology Foresight in the Policy-advisory Instruments

Empowered Technology Group (Technology Advisory Group) and PM-STIAC

Written by Ms. Remya Haridasan

Ms. Remya Haridasan is Scientist 'D' at the Office of PSA

The Prime Minister's Science Technology and Innovation Advisory Council (PM-STIAC) and Empowered Technology Group (ETG) are two important instruments through which the Office of the Principal Scientific Adviser (PSA) provides science advice to various departments, ministries, and agencies of the Government. Both PM-STIAC and ETG are chaired by the PSA.

PM-STIAC

The PM-STIAC was constituted on 28th August 2018 as an overarching council to assess the status of specific science and technology domains, comprehend challenges, formulate interventions, develop a futuristic roadmap, and advise the Prime Minister accordingly. The PM-STIAC comprises of eminent personalities in the field of Science & Technology from Academia, Industry and Government; and Secretaries of 13 Ministries/Departments related to S&T are special invitees. The first PM-STIAC meeting was held in October 2018 wherein nine national missions were finalised. Four of the nine missions i.e. Deep Ocean Mission, Natural Language Translation Mission, AI (Artificial Intelligence) Mission, and Quantum Frontier Mission have also been approved by the Cabinet for implementation. In addition to these nine missions, three additional missions i.e. the National One Health Mission, the National Livelihood Mission and the national mission on CCUS (Carbon Capture Utilisation and Storage) were approved by PM-STIAC recently for implementation.

The PM-STIAC presents a platform for brainstorming of S&T interventions which are needed in order to address challenges in the achievement of various national priorities. The discussed interventions are then recommended to be taken up in mission mode for timely action by a Ministry/ Department which is deemed most appropriate in terms of departmental mandate, resources and experience/ expertise in the field. For example, the most recent mission approved by PM-STIAC i.e. CCUS is one of the means of addressing the challenges related to achieving the net-zero climate goals of the country and it has been recommended to be taken up by the Ministry of Power as some of the key interventions identified were related to energy conservation & efficiency, carbon trading framework, etc. fall under the purview of Ministry of Power. From a technology foresight standpoint, PM-STIAC is an apt example of how foresight is an important part of the on-going activities of Office of PSA. The process flow of PM-STIAC involves steps which are key to a foresight activity wherein weak signals of change or prominent trends are recognised through internal discussions within the Office of PSA and this is followed by (i) expert consultations to identify gaps and the interventions needed to address them and (ii) the identification of important stakeholders in the government, academia and industry who are invited to give their insightful views through presentations or interventions during the meetings. PM-STIAC provides a platform for in-depth discussions on future scenarios which implore policy interventions needed at present to achieve national goals. It is also a participatory exercise involving subject matter experts and stakeholders. During the 25 meetings of PM-STIAC held so far, 57 topics have been discussed for which 79 experts have been consulted by the Office of PSA. The meetings have successfully resulted in 11 missions, 7 policies, and 7 initiatives, with 13 Ministries and Departments identified to carry out the implementations.

ETG

The ETG was constituted through approval of the Cabinet on 28th February 2020, as an institutionalised structure to proactively lay down, coordinate and oversee national-level policies relating to procurement and induction, and R&D in technologies. The focus of ETG is on initiatives that require large outlays in both financial and human resources, and to render sound and timely advice for determining direction and trajectory of Government's R&D and Technology Development Programmes. The pragmatic and timely advice required from the ETG emphasizes on its role in technology foresight for the country. The ETG comprises of Secretaries of 6 S&T Ministries/Departments as Members i.e. Department of Atomic Energy, Department of Space, DRDO, Ministry of Electronics & Information Technology, Department of Telecommunications and Department of Science & Technology.

Major focus of ETG is on the evaluation of proposals related to R&D and technology development/procurement for approval of the Cabinet. The proposals which come to ETG are sent to subject matter experts for review before they are discussed by the ETG members. From the expert reviewers' comments, key insights are drawn about long-term implications of the proposals from the societal, technological, economic and environmental perspectives which are among key considerations in a technology foresight exercise[1]. These insights help the ETG members in decision-making. Additionally, as part of the ETG evaluation process, a proforma for self-appraisal of the technology implications of the proposal by the initiating Ministry/Department, has been introduced. The self-appraisal form has been designed to capture information such as indigenous content of the proposed mission/scheme, plan for indigenisation of imported content, global benchmarking, technology obsolescence, the impact of the proposal in terms of import substitution, national capacity building, etc. which provide critical insights for decision making by the ETG. The ETG has held 62 meetings so far in which 118 proposals from 27 ministries have been considered and 151 experts have been consulted. The decisions and recommendations of ETG, which ultimately determine the direction of the Government's focus on R&D and technology programmes, are the result of an evaluation process which is participatory and multi-dimensional, which are important features of a foresight activity.

TAG

Another of the objectives of the ETG is to identify key technologies both legacy and emerging ones that are most relevant to the country's needs and challenges. This is indeed technology foresight. For this purpose, the Technology Advisory Group (TAG) of the ETG is being leveraged. The TAG has been constituted, as per provisions of the constitution order of ETG, for providing expert advisory support to the ETG, as and when required, on matters of national importance relating to science, technology, innovation, and R&D. The TAG comprises of members from the private sector and from academia. TAG acts as another platform for brainstorming of important technology areas which need to be focussed on for achieving our national priorities. The first meeting of the extant TAG was held on 25th July 2023 in which areas of Carbon Capture Utilisation and Storage, Alternate Battery Technologies and Artificial Intelligence were discussed with a focus on technology roadmap development.

Here, a key point emerges about the linkages between the activities of TAG, PM-STIAC and ETG from a technology foresight point of view. Though there are similarities between TAG and PM-STIAC as platforms for identifying the focus areas of the Government in the area of science and technology, PM-STIAC provides wider participation with representation of Secretaries of more science Ministries/ Departments as Special Invitees. The concept presented in PM-STIAC is more mature as it is presented with the outlines of a mission. The perfect example is CCUS, wherein at the stage of TAG in July 2023, the concept was discussed with the basic elements for technology roadmap development. Later in the PM-STIAC meeting held in July 2024, the topic was discussed in more granularity with the implementing agency identified. As the mission proposal is further developed with implementation aspects, the proposal will be presented to ETG before Cabinet approval. Multiple missions that were conceptualised in PM-STIAC, and then later considered in ETG include Deep Ocean Mission, AI mission, etc. The table shows the list of such proposals with timelines.

The instruments of TAG, PM-STIAC and ETG with their inter-linkages can be considered as the triad of mechanisms for technology foresight utilised by Office of PSA.

Technology Foresight TRIAD of Office of PSA

S. No.	Topic	Date of Discussion in PM-STIAC	Date of Discussion in ETG	Date of implementation (Cabinet Approval)
1.	Quantum Mission	October 2018	February 2021	April 2023
2.	Deep Ocean Mission	October 2018	March 2021	April 2022
3.	India AI Mission	October 2018	February 2024	March 2024
4.	Biotech-PRIDE Policy	October 2018	January 2021	July 2021
5.	National Deep Tech Start-up Policy	July 2022	June 2024	Upcoming
6.	BioE3 Policy	July 2023	March 2024	August 2024
7.	India Space Policy	July 2020	July 2022	April 2023
8.	Geospatial Policy	November 2019	January 2021	December 2022
9.	NRF	November 2018	March 2021	August 2023

Proposals considered in PM-STIAC and ETG with timelines

[1] Chapter- 12: Foresight – Using Science and Evidence to Anticipate and Shape the Future, Science for Policy Handbook, 2020 (https://www.sciencedirect.com/science/article/pii/B9780128225967000127)

Technology Foresight: Sectoral Perspectives

PUBLIC HEALTH

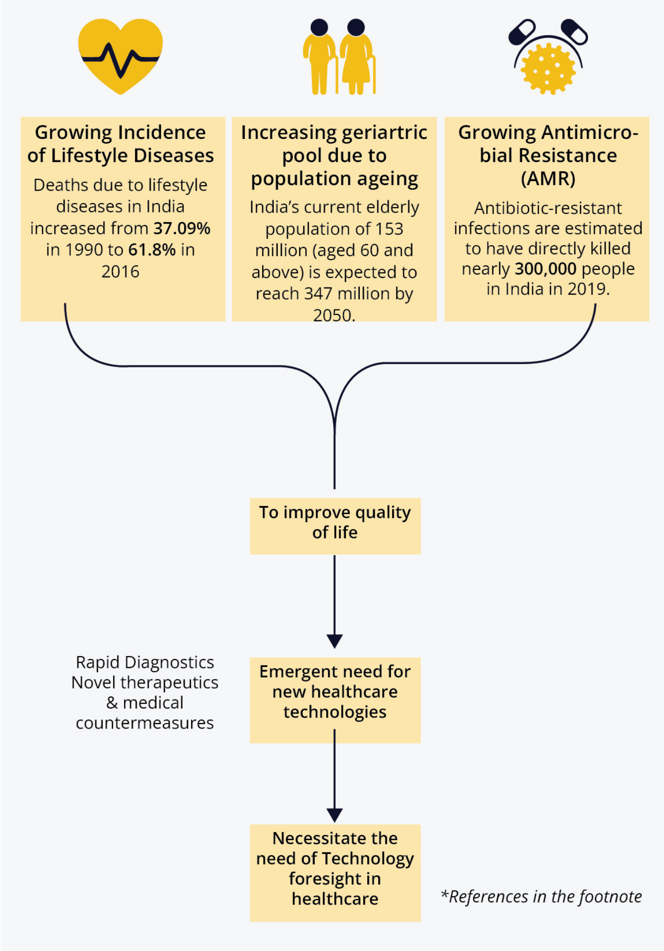
Written by Dr. Hafsa Ahmad

Dr Hafsa Ahmad is Scientist 'D' at Office of PSA

Foresight and forecasting have emerged as critical tools to enable informed science advice and decision-making for guiding effective policy formulation. The specific nuances of foresight might be different for each sector. As far as public health is concerned, foresight is not just a tool but an ambition for better preparedness for global emergencies and cross-border threats, and for engaging with challenges proactively. It is the process of systematically surveying developments that lead to the greatest health, social, and economic benefits. Novel technological advancements and technology breakthroughs may offer great health opportunities but might also pose significant challenges. Therefore, the role of foresight in the health sector becomes substantially important in identifying potential risks and arriving at mitigating measures for the same. Foresight exercises enable immediate and medium-term actions for catalysing innovations in areas of unmet needs based on a long-term vision. Identification of areas or disciplines termed as 'moonshots' emanating out of collective intelligence-based systemic and systematic foresight and forecasting efforts leads to improved economic growth. Additionally, this helps in generating possible paths for technology development and its diffusion and implementation. This reinforces further that, the technology foresight in health must align with national priorities, comparative advantages, use cases and the economic vision of the country.

Technology foresight plays a crucial role in identifying key technologies and developments in frontier areas of science that have the potential to revolutionise healthcare, enhance health equity, and propel economic growth within the sector, industry, and the country. The foresight arrived at by systematically surveying developments in disciplines like genomics, gene editing, AI, big data and digitization is having a significant impact. It contributes to the success and adoption of precision/personalised medicine and new treatment modalities for various diseases, besides leading to refinement and upswing in medical devices and technologies.

From the healthcare point of view, the rising incidence of lifestyle disorders, a growing aged population, and global public health challenges posed by emerging infectious diseases, health emergencies and antimicrobial resistance underscore an emerging need to harness new technologies to fulfil strategic requirements with comparative advantages and cost-effectiveness.



Need for Technology Foresight in the Public Health sector

Early health technology assessment (early HTA), undertaken by the Department of Health Research, National Health Authority and National Health Systems Resource Centre, has been useful in guiding the development process for medical innovations and other health-related interventions. HTA, although a pragmatic tool for evidence-based policy guidance for healthcare delivery, is largely driven by the cost-containment efforts of governments. New diagnostics, point-of-care devices, vaccines, senior care, and remote healthcare delivery are major areas where foresight is crucial from both national health priorities as well as outcomes perspectives.

To summarise, the idea of foresight is to ensure that decision-makers remain 'ahead of the curve' and become better equipped with insights for strategic planning and preparedness. The World Health Organization (WHO) established the Global Health Foresight function within its Science Division and published a normative guidance document in 2022. This function aims at proactively identifying and anticipating potential issues that have a bearing on prevention, diagnosis and treatment. This is an important step towards catalysing future thinking for a healthier world.

*Infographic references -

Source: *https://pib.gov.in/Pressreleaseshare.aspx?PRID=1540840*

Source: *https://india.unfpa.org/en/news/indias-ageing-population-why-it-matters-more-ever*

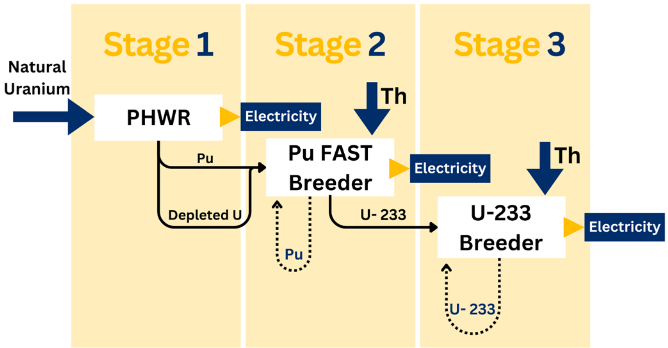
Source: *https://www.nature.com/articles/d41586-023-03912-8*

Technology Foresight: Sectoral Perspectives
NUCLEAR ENERGY SECTOR

Written by Ms. Remya Haridasan

Ms. Remya Haridasan is Scientist 'D' at the Office of PSA

The nuclear energy sector in India has been created and shaped by the futuristic vision and foresight of Dr. Homi Jehangir Bhabha who is also known as the “Father of the Indian Nuclear Program”. He established the Tata Institute of Fundamental Research (TIFR) for carrying out research in nuclear science in 1945 and the Atomic Energy Establishment, Trombay (AEET) in January 1954 for a multidisciplinary research program to intensify the efforts of harnessing nuclear energy for the benefit of the nation (AEET was renamed Bhabha Atomic Research Centre (BARC) after the sad demise of Dr. Bhabha in 1966). It is notable that these foundational steps were taken by Dr. Bhabha during a period when India was just gaining her independence. He envisioned the ambitious three-stage nuclear program for achieving long-term energy security for the country by harnessing its (limited) uranium and (vast) thorium reserves in an efficient manner.



India’s three-stage nuclear program[A]

India has nuclear ores from which ~78,000 tonnes of uranium metal and ~5,18,000 tonnes of thorium metal can be extracted[1]. In the 3-stage nuclear program, the first stage was envisaged as Pressurised Heavy Water Reactors (PHWRs) which can utilize natural uranium to generate electricity, plutonium and depleted natural uranium (which can be further utilized to generate plutonium in the next stage). The second stage was envisioned as fast breeder reactors which produce electricity, plutonium (as it is a breeder reactor) and U-233 from the thorium blankets used in the core. The U-233 thus produced was envisaged to be used in the 3rd stage. The 3rd stage will utilize U-233 breeder reactors which will produce electricity and breed U-233 using thorium. Thus, with our vast thorium reserves, long-term energy security for the country can be ensured. The three stages have been designed such that a closed fuel is achieved i.e. the spent fuel in each stage is recycled (through spent fuel reprocessing) to be used in the next stage so that optimum utilization of the uranium and thorium resources is achieved. This is unlike the open fuel cycles followed in many countries such as the US where spent fuel is considered as nuclear waste and is safely disposed of by storing it underground in stable geological formations.

India currently has 23 operating reactors, all of which are part of the 1st stage of the nuclear program. Among these, nineteen reactors are Pressurised Heavy Water Reactors (PHWRs) and four are Light Water Reactors (LWRs). The LWRs use enriched uranium fuel instead of natural uranium. As part of the second stage of the program, the Prototype Fast Breeder Reactor (PFBR) is being built in Tamil Nadu. The historic “Commencement of Core Loading” of the PFBR, India’s first indigenous Fast Breeder Reactor (500 MWe) at Kalpakkam, Tamil Nadu was witnessed by the Hon’ble PM on 4th March 2024. The technologies for the third stage of reactors for thorium utilization are currently under development.

Over the years, the Indian nuclear energy sector has made significant progress in the indigenous development of our nuclear reactors. India is the only developing nation to have indigenously developed, demonstrated & deployed nuclear reactors for electricity generation[2]. This has been possible because of tremendous efforts in research and development and at the same time building capacity of the Indian industry to meet the stringent quality requirements of the nuclear industry where safety is paramount.

Today, with the 23 operating nuclear reactors, India has an installed nuclear capacity of 7480 MWe which is about 2.8% of the total electricity generation in the country[3]. As the nation progresses towards meeting its climate goals, foresight is very important in the power sector. For India to reach Net Zero emissions by 2070, substantial nuclear power and Renewable Energy (RE) generation will be required[4]. Hence, investments in R&D and large-scale deployment of traditional and new nuclear technologies will be essential. Small Modular Reactors (SMRs) are a significant innovation in the nuclear power sector which have the potential to address some of the main challenges associated with traditional nuclear reactors in terms of modular design, lesser cost and construction time, scalability, flexibility and inherent safety. In order to meet the government’s target of 100GW of nuclear capacity by 2047, significant impetus needs to be given to R&D in SMRs and enhancing private sector participation in the nuclear sector, in addition to the current efforts of scaling up capacity with the upcoming reactors which are under construction.

[1] *https://www.barc.gov.in/randd/artnp.html*
[2] *https://www.barc.gov.in/randd/artnp.html*
[3] *https://pib.gov.in/PressReleasePage.aspx?PRID=1941010*
[4] *“Synchronizing Energy Transitions Towards Possible Net Zero for India: Affordable and Clean Energy for All”, IIM Ahmedabad, 2024.*
[A] *https://www.npcil.nic.in/WriteReadData/userfiles/file/Promotion_of_scientific_environment_in_India.pdf*

Technology Foresight: Sectoral Perspectives

Quantum Compass – Navigating the Future of Precision Measurements

Written by Mr Vivek Kumar

Mr. Vivek Kumar is Scientist 'D' at the Office of PSA

Picture a world where the unseen becomes visible, where we can navigate without satellites, diagnose diseases without invasive procedures by bringing the resolutions of magnetic resonance imaging (MRI) scans down to the nanoscale to see the magnetic fields of single cells or neurons in the brain, and uncover the Earth's hidden secrets without a single grain of soil overturned. This is the promise of quantum magnetometers - a future-shaping technology in the field of metrology and instrumentation.

Technology foresight is all about peering into the future, identifying emerging technologies, and understanding their potential impacts on society, the environment, and the global economy. Recognising the future possibilities in a cross-cutting field like instrumentation is valuable, as the potential impact will be across sectors. Quantum magnetometers are a perfect example of such an emerging technology that should be effectively enabled and prepared for.

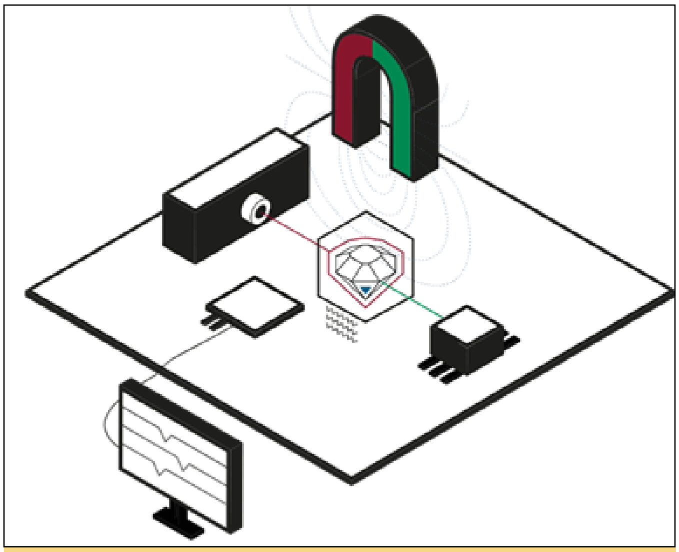
At the core of these devices is quantum physics, which uses phenomena like quantum coherence (the ability of a quantum system to maintain its quantum states and generate interference patterns), quantum superposition and entanglement to detect magnetic fields with unimaginably high sensitivity. Quantum magnetometers achieve their exceptional sensitivity by leveraging the quantum properties of atoms or defects in diamonds, known as nitrogen-vacancy (NV) centers. Here's how it works: in quantum mechanics, particles like electrons have a property called "spin," which acts like a tiny magnetic needle. When exposed to a magnetic field, the spin of these particles changes in a way that can be measured with extreme precision. A scanning probe magnetometer based on NV centers in diamond will allow the highest precision measurements of nanoelectronic circuits. On the other hand, measuring systems based on highly sensitive optically pumped magnetometers (OPMs) can be realized for applications in material probing and process analysis. A team from the Indian Space Research Organisation(ISRO) Inertial Systems Unit, Department of Space, Thiruvananthapuram is working on Atomic Magnetometers based on alkali vapour cells. These magnetometers will be capable of measuring magnetic fields at the pico-tesla level, making them suitable for interplanetary missions. They also hold the potential to serve as a subsystem for precision Nuclear Magnetic Resonance (NMR) gyroscopes.

This level of precision is far beyond the reach of classical technology. For instance, the most refined material-based sensors face limitations due to thermal noise and atomic-scale imperfections. Quantum magnetometers, however, operate on principles that can bypass these classical constraints. They rely on quantum coherence - the property that allows particles to exist in multiple states simultaneously - offering a sharpness and clarity of measurement that remains stable even at incredibly small scales. The result is an ability to detect the faintest of magnetic signals, from the whisper of a distant star's magnetic field to the delicate electrical impulses of the human heart.

Quantum magnetometers may enable MRI on single molecules. When an organism is examined at that level of detail, it will lead to the understanding of physiology at such a level that allows the understanding of the molecular process of any disease, including cancer. Quantum sensors can also monitor subtle changes in the Earth's magnetic field to predict natural disasters like earthquakes or tsunamis, or guiding explorers in the Arctic without the need for a Global Positioning System (GPS), which can fail in such remote environments. In industries, these may be used for defect analysis of nanoelectronic circuits, or for the detection of hidden material fissures.

In India, Quantum Sensing and Metrology are one of the four verticals identified under the National Quantum Mission, which emphasises the development of sensors such as gravimeters and magnetometers using quantum technologies. In the words of the Hon'ble Principal Scientific Adviser to the Government of India, Quantum Sensors are the low-hanging fruits of Quantum Technologies. Major players in Quantum Sensing in India include the IITs, Raman Research Institute and DRDO.

In connection to one of the broader visions of technology foresight to navigate towards desired futures, Quantum magnetometers can help us address some of the world's most pressing challenges: ensuring sustainable resource management, enhancing global healthcare access, improving environmental monitoring, and even securing global navigation systems against potential disruptions. This is the essence of technology foresight - a proactive, anticipatory approach to technology development that not only embraces new tools but also prepares society for their transformative impact. Quantum magnetometers, through their unparalleled sensitivity and capabilities, embody this vision, serving as both a harbinger and a tool for a future where the invisible becomes visible, and the unknown becomes known.



A measurement setup (courtesy: Q.ANT, Germany)

MPMS3 SQUID Magnetometer (Central Research Facility IIT Delhi)

Technology Foresight: Sectoral Perspectives

Charting India’s Semiconductor Future through Strategic Foresight

Written by Mr. Abhinav Dubey and Dr. B. Chagun Basha

Mr. Abhinav Dubey is Research Consultant, OPSA-PAIU and Dr. B. Chagun Basha is Chief Policy Adviser, OPSA-PAIU

Semiconductors are critical to numerous industries, including electronics, automotive, telecommunications etc. Also due to the strategic importance, technology foresight plays a vital role in shaping policies, guiding investments, and fostering innovation in the semiconductor ecosystem. The global semiconductor industry is deeply interconnected, depending on a highly intricate supply chain that spans continents and involves multiple stages, from sourcing raw materials to design, fabrication, and advanced manufacturing processes.

Within this global landscape, India's position is gaining prominence as a key player, not only through its substantial contribution to semiconductor design but also through its dedicated efforts to establish a robust domestic semiconductor manufacturing industry. Central to these efforts is the Semiconductor Technological expertise housed at the Semiconductor Lab (SCL) under the Ministry of Electronics and Information Technology (MeitY). Established as the Semiconductor Complex Limited (SCL) in 1976, this public sector undertaking was born from the Indian government's foresight on the strategic importance of semiconductors and its vision to create a self-reliant semiconductor manufacturing industry.

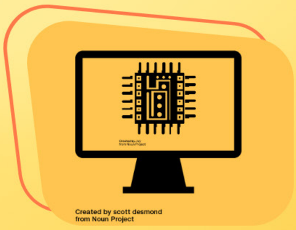
SCL capabilities include an 8" wafer fab line at 180 nm technology node which supports the fabrication of products in analogue, digital, mixed-signal, memory, optoelectronics and microelectromechanical systems (MEMS) devices. SCL customers include the Indian Space Research Organisation (ISRO) and the Indian Railways, and customers via the Chips2Startup Programme comprising institutions, MSMEs, and emerging startups in the semiconductor ecosystem. To augment SCL’s capacity, the Government of India (GoI) released the Expression of Interest for SCL Modernization in 2023. The plan includes a 100% capital infusion towards the overall project cost for establishing a new R&D line and 50% for joint ventures.

The modernisation aims to transform SCL into a Research and Development-led Center of Excellence, with capabilities extending to advanced nodes, advanced packaging, compound semiconductors, design and Electronic Design Automation tools, materials, and other key R&D areas. Additionally, there are plans to scale up SCL’s manufacturing capacity to enable volume production of semiconductor devices and chips.

Besides SCL, several initiatives in India are aimed at boosting the nation's technology and manufacturing capabilities, highlighting the importance of technology foresight for future readiness in the semiconductor sector and maximising its economic potential, driven by various external factors including geopolitics around global semiconductor technology security. One of the key initiatives is the India Semiconductor Mission (ISM), which is a specialised and independent Business Division within the Digital India Corporation. Under this mission, the Semicon India programme was established, in 2021, with a financial outlay of INR 76,000 crore for the development of a sustainable semiconductor and display ecosystem.

Under ISM, India has announced the construction of 3 semiconductor fab units in Dholera (Gujarat), Morigaon (Assam) and Sanand (Gujarat), which will cumulatively generate direct employment of 20,000 advanced technology jobs and about 60,000 indirect jobs. Developed in partnership with global semiconductor leaders such as Powerchip Semiconductor Manufacturing Corp (PSMC) of Taiwan, Renesas Electronics Corporation of Japan, and Stars Microelectronics of Thailand, these facilities will strengthen India's integration into the global semiconductor value chain, unlocking new opportunities for sustainable economic growth.

Boosting Indian Semiconductor Design



Design Linked Incentive (DLI)

- 50% product design incentive
- 6-4% product deployment incentive
- Support for 100 domestic companies
- Facilitate at least 20 companies which can achieve turnover > Rs. 1500 crore

Incentivising Domestic Semiconductor Production

Basic Custom Duty (BCD) Exemption for Semiconductor Manufacturing in India

- Aims to promote Indigenous semiconductor manufacturing
- Customs exemption on capital goods, machinery, etc.

Promoting Electronics and Semiconductor Manufacturing in India

Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS)

- 25% financial incentive on capital expenditure on electronic goods
- Focus on the downstream value chain
- Includes components, semiconductor/display fabrication units, ATMP, sub-assemblies, and capital goods

*Some of the Indian government's initiatives to bolster the semiconductor sector**

Upcoming transformations in the semiconductor sector.

The semiconductor industry is experiencing rapid advancements, driven by surging demand for memory, data storage, high performance, energy efficiency, and increasingly smaller chip designs. While silicon semiconductors have driven the growth of today's electronics industry, compound semiconductors are set to lead the next wave of technological breakthroughs across sectors such as telecommunications, photonics, smart automotive systems, and artificial intelligence (AI). Compound semiconductors are formed by combining chemical elements from two or more different groups, enabling processing speeds up to 100 times faster due to significantly higher electron mobility compared to silicon semiconductors. They also offer advantages such as heat resistance, magnetic sensitivity, microwave generation, and efficient operation at lower voltages.

The Neuromorphic chip system, which draws inspiration from the structure and operations of the human brain and cognitive processes, is another noteworthy advancement in the semiconductor industry, which can solve one of the most urgent foreseeable challenges in digital transformation: the huge energy consumption of computing centres. The neural networks found in the human brain are made up of millions of neurons and synapses that act as connecting threads, enabling the network to integrate memory and computation with parallelism and reduce power consumption and data transfer latency between the processor and the memory. The low latency and energy efficiency make the technology fascinating, particularly for AI applications, medical technologies, and portable sensor systems. Recognizing the vast potential of this emerging technology and the importance of foresight, the Office of the Principal Scientific Adviser (PSA) in 2021, in collaboration with IISc and NITI Aayog, initiated discussions to develop a roadmap and explore the establishment of a Centre of Excellence focused on Neuromorphic Computing, Nanoelectronics, Optoelectronics, and Quantum Technologies. In addition to compound semiconductors and neuromorphic chip systems, other cutting-edge research areas include the exploration of the viability of 2D materials and High Numerical Aperture Extreme Ultraviolet (High NA EUV) lithography. As India aims to position itself as a key player in semiconductor manufacturing and innovation, technology foresight is essential for identifying these emerging technologies and making informed decisions to maintain future competitiveness.

*Infographic references -

[1] *Global Invitation For Proposals For Modernization Of Semiconductor Laboratory (Scl) Facility In India* *https://www.meity.gov.in/writereaddata/files/EoI-SCL%20Modernization.pdf*

[2] *Ministry of Electronics and Information Technology. (2021, December). Design Linked Incentive Scheme. (https://chips-dli.gov.in/)*

[3] *Ministry of Electronics and Information Technology. (2022, September). Basic Custom Duty (BCD) Exemption for Semiconductor Manufacturing in India. (https://www.meity.gov.in/writereaddata/files/BCD%20Exemption%20for%20Semiconductor%20Manufacturing%2012092022.pdf)*

[4] *Ministry of Electronics and Information Technology. (2020, April). Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS). (https://www.meity.gov.in/esdm/SPECS)*

Building Technology Foresight Capacity through Global Collaboration

Insights from OPSA - EU JRC Knowledge Exchange

Global collaboration in technology foresight can be an instrumental tool for nations to anticipate and prepare for future challenges in an increasingly interconnected world. By pooling knowledge, resources, and expertise, countries can augment their domestic capabilities to identify emerging trends and shape policies that address the complexities of tomorrow. Recognizing the value of such partnerships, the Office of the Principal Scientific Adviser (PSA) to the Government of India organised a Knowledge Exchange on Technology Foresight in collaboration with the European Commission's Joint Research Centre (JRC) on June 18, 2024, to foster cross-learning and build foresight capacity within India through international engagement. Attended by 42 experts from India and the EU-JRC, this event was organised as the first in a series of international knowledge exchanges planned by Office of PSA, to bolster the in-house technology foresight capacity.

Technology Foresight: A Strategic Imperative

In her inaugural address, Dr. Parvinder Maini, Scientific Secretary at OPSA, highlighted the essential role of technology foresight in shaping resilient and future-ready policies. By identifying emerging technologies and evaluating their impacts, foresight offers evidence-based insights crucial for strategic decision-making. Technology foresight is, thus, useful for OPSA, whose mission is to pragmatically advise senior leadership on science and technology issues that cut across various sectors. Thus, during the G20 summit hosted by India in 2023, OPSA initiated the G20 Chief Science Advisers' Roundtable, providing a platform to understand contemporary science advisory mechanisms and paving the way for strengthening international collaborations. Dr. Maini highlighted India's growing emphasis on building capacity for technology foresight in the country, citing recent developments such as the establishment of the Centre for Technology Foresight & Policy at IIT-Jodhpur and the creation of a Task Force on Technology Foresight within OPSA, as necessary steps to guide India's technology policies and innovation programs.

Dr. Parvinder Maini, Scientific Secretary, Office of the Principal Scientific Adviser to the Government of India, shares the importance of technology foresight in guiding India's strategic missions. Scan the image with Overly App to watch the full video.

H.E. Mr. Herve Delphin, Ambassador of the Delegation of the European Union (EU) to India, emphasised the critical role of strategic foresight across EU institutions during his opening remarks, highlighting its value in shaping organisational planning and decision-making. He mentioned the European Strategy and Policy Analysis System (ESPAS) as a significant example of how the EU integrates foresight into its long-term strategic planning across institutions, ensuring that policies are informed by a thorough understanding of future trends and challenges. Mr. Delphin expressed optimism about foresight as a key area of cooperation between the EU and India, particularly with the upcoming 2025 EU-India Summit, where a new strategic report will be launched.

He underscored that the foresight methodologies discussed in the exchange could be pivotal in deepening EU-India collaborations.

H.E. Herve Delphin, Ambassador of the Delegation of the European Union to India, highlights how foresight can help in preparing for future technological revolutions. Scan the image with Overly App to watch the full video.

Foresight practices and their significance in the European Union

Dr. Thomas Hemmelgarn, Head of Unit of the EU Policy Lab: Foresight, Design & Behavioural Insights, highlighted the role of the Joint Research Centre (JRC) as a critical knowledge partner providing “science for policy” to support the European Union's decision-making processes. He emphasised that foresight activities at the JRC involve extensive collaboration and collective intelligence. "Foresight brings different perspectives together, which helps in avoiding groupthink," Dr. Hemmelgarn explained, underlining the importance of coordinating with different strategic foresight networks.

“We are convinced that foresight is, notably in the environment and the world we live in, a very useful tool to think in a structured manner about the future. It's not about predicting the future, but it is a tool to make us more aware of what might be coming at us.”

Dr. Thomas Hemmelgarn,
Head of Unit, EU Policy Lab: Foresight, Design & Behavioural Insights

Adding to the discussion on the approach for undertaking the foresight exercise to align with the EU’s strategic priorities, Dr. Anne-Katrin Bock, Team Leader and Senior Expert at the EU Policy Lab, discussed the thematic focus areas of foresight on technology, sustainable transitions and future risks within the JRC. Dr. Bock highlighted the use of tools like horizon scanning and weak signals, scenario planning and citizen surveys in their foresight exercise to identify the risks as well as opportunities associated with potential future developments, which served as crucial support to inform the European Commission’s annual Strategic Foresight reports.

“Foresight equips us to deal better with what might be coming. It is not a prediction, but an exploration of possible future developments and what they might bring.”

Dr. Anne-Katrin Bock,
Team Leader and Senior Expert, EU Policy Lab

Dr. Antonia Mochan, Policy Analyst at the EU Policy Lab, discussed the specific and targeted nature of technology foresight efforts at the JRC, aimed at identifying emergent and critical technologies within specific policy domains. These efforts aim to address specific challenges while also considering the enabling conditions, drivers, opportunities, and factors that might affect the public acceptability and scalability of these technologies - an aspect crucial for policymakers to consider during policy development. The EU Policy Lab leverages techniques like field monitoring, meta-literature reviews, and text mining in the databases of patents and publications to identify any emerging novelties, ensuring that strategic technologies are effectively integrated into the EU’s innovation and research agendas.

“We are not just looking at technologies themselves, but also the factors that might hamper their uptake, issues that policymakers should consider about their implementation - things like sustainability, scalability, energy use and so on.”

Dr. Antonia Mochan,
Policy Analyst,
EU Policy Lab

Foresight in the Indian Context: Sectoral Insights and Methodologies

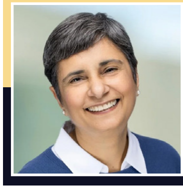
Presenting the Indian perspective on foresight, Prof. Krishna Kumar Balaraman, Head of the Centre for Technology Foresight and Policy at IIT Jodhpur discussed India's 2047 vision to be a technology-driven, knowledge-based economy. He emphasised the importance of foresight in India's policy-making and technology development, highlighting techniques like scenario analysis, technology roadmapping, and backcasting. Prof Balaraman noted that India has a robust tradition of using foresight to shape preferred futures in the fields of agriculture, space, telecommunications and fintech. He pointed out the critical role of technology foresight in navigating the dynamic and evolving landscape, particularly in areas like 5G, 6G, and digital payments, where India has made significant strides through proactive planning and the convergence of technological and social readiness.

"Foresight is also cutting through the chaff, seeing through the apparent confusion, looking at the evolving trends, weak trends, and connecting data with the future"

Prof. Krishna Kumar Balaraman,
Head, Centre for Technology Foresight and Policy,
IIT Jodhpur

Following Prof. Krishna's insightful overview of technology foresight in the country, experts delved into sectoral trends and advancements in foresight practices in India. Prof. Gagandeep Kang, Director of Global Health at the Gates Foundation, highlighted the relevance of technology foresight in anticipating the trajectories of both communicable and non-communicable diseases, which have significant implications for developing countries. Prof. Kang noted that the ongoing digital transformation, particularly the development of the National Health Stack, offers a powerful tool for health foresight by enabling sophisticated modelling and scenario planning. Furthermore, she stressed the importance of global and national initiatives, such as the World Health Organization's Global Health Foresight group and IIT Bombay's National Disease Modelling Consortium, in ensuring that India's health strategies are informed by forward-looking insights, making technology foresight a critical element in addressing future health challenges.

"What really does the future look like and what will drive that future? I think it's no surprise to anyone that it is going to be diet, education, climate, the size of the population, and the quality of health care will predict what our population is going to look like in the future"



Prof. Gagandeep Kang,
Director of Global Health, Gates Foundation

Prof. Urbasi Sinha from the Raman Research Institute, shared her perspective on the unique challenges of technology foresight in quantum science, given its inherent unpredictability and probabilistic nature. She emphasised the significance of the National Quantum Mission and international interest in harnessing quantum technologies, which have the potential to revolutionise computing and communications. She highlighted key initiatives like the Open Quantum Institute led by Geneva Science and Diplomacy Anticipator (GESDA) - which integrates technology foresight and policy-making to leverage quantum science for achieving the United Nations' Sustainable Development Goals - and OECD's global tech focus group on quantum internet, emphasising the crucial role of foresight in this R&D-intensive area. Concluding on a forward-looking note, Prof. Sinha stressed the need to balance fundamental scientific research with applied technological innovation, ensuring that quantum advancements are both transformational and practical.

"Going forward, we should ensure that foresight and insight go hand-in-hand between fundamental science and technology. If we only look into the applications that the rest of the world is already investing in, there won't be innovation for us to look forward to."

Prof. Urbasi Sinha,
Raman Research Institute, Bengaluru

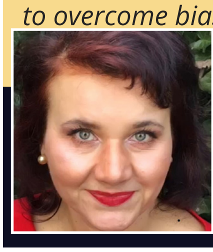
Building on the complexities of foresight in rapidly evolving fields like quantum science, Prof. Gufran Beig of the National Institute of Advanced Studies (NIAS) turned the focus to the equally challenging domain of meteorology and climatology. He highlighted the role of foresight in forecasting as a critical tool for weather prediction, meteorology and climatology. He emphasised that while advancements in forecasting models and AI/ML tools have significantly improved the accuracy of weather predictions, the increasing frequency of random and unusual phenomena driven by climate change often affects the acceptability of these forecasts. Prof. Beig also pointed to the interconnectedness of challenges across sectors, noting how the pursuit of technologies like semiconductors can have unforeseen impacts on weather and climate. He underscored the importance of leveraging technology foresight for effective risk assessment and navigating uncertainties, which are essential in addressing the broader challenges of climate change, air quality, and environmental sustainability.

"In meteorology, the important challenge is that we are looking for foresight in forecasting - since the most crucial thing is to predict weather in advance"

Prof. Gufran Beig,
National Institute of Advanced Studies

While concluding the knowledge exchange session, Dr. Liliana Pasecinic, Deputy Head of Unit, Member States Partnerships and International Relations of the Joint Research Centre at European Commission highlighted the critical role of foresight in breaking down information silos and adopting a holistic approach to contemporary challenges that span multiple policy areas. She emphasised that foresight is essential for addressing interconnected issues in fields like meteorology, emerging technologies, and health. Dr. Chagun Basha, Chief Policy Adviser, Policy Analytics and Insights Unit of the Office of PSA further echoed the importance of foresight capabilities in India, and the need to ensure further capacity building in the community. The role of international partnerships and collaborations in these efforts was stressed, with the European Union partnership being a flagship event in the series on international knowledge exchange in this domain.

"Foresight encourages to keep the focus on the long-term, embrace systemic views and perspectives to overcome biases and enhance policy design and strategy."



Dr. Liliana Pasecinic,
Deputy Head of Unit,
Member States Partnerships and International Relations, Joint Research Centre,
European Commission

The event also served as a platform to bring together the growing foresight community in India, opening up new opportunities for collaboration both within the country and with international partners, particularly the European Union. PSA is strategising to facilitate more such knowledge exchanges, fostering a deeper understanding of foresight practices and encouraging collaborative innovation for addressing future challenges.

(This article is written by Ms. Nidhi, Communications Consultant at the Office of PSA; Ms. Subarna S, Policy Fellow, OPSA-PAIU contributed to this article)

Technology Foresight – A Necessary Capability to Achieve India's Goals

Written by Prof. Krishna Kumar Balaraman

Prof. Krishna Kumar Balaraman, Head, Centre for Technology Foresight and Policy, Associate Professor, Indian Institute of Technology (IIT) Jodhpur

Foresight can be seen as both a capability and as an approach. As a capability, foresight can be seen as an "ability to visualise alternate futures, to see through the apparent confusion, to spot developments before they become trends, to see patterns before they fully emerge, and to grasp the relevant features of social, business and technological currents that are likely to shape the direction of future events". At the same time, foresight can also be seen as a capability at multiple levels - from the individual level to the group and to the macro level of countries and the world. Foresight involves participatory collaboration involving teams and individuals at different levels, and thus contrasts itself from strategic planning that involves only senior administrators/managers creating deliberate plans.

> *"Technology foresight is the most upstream element of the technology development process that provides inputs for the formulation of technology policies and strategies that guide the development of technology infrastructure"*
>
> UNIDO *United Nations Industrial Development Organization*

Technology Foresight includes a process of systematically attempting to look into the long-term future of science, technology, economy and society. To identify areas of strategic research on emerging generic technologies, it is important to know that technology foresight is a systematised effort to visualise a long-term future. To arrive at better-informed policy decisions, various stakeholders such as civil society, industry and government need to be involved. Technology Foresight can be assisted by a set of programs that help foresee, shape and direct potential future orientation of technological change. It is encouraging that more interest is being shown in the use of technology foresight. At the same time, it should also be highlighted that foresight is different from forecasting in the sense that foresight looks towards the future based on evolving trends and weak signals exhibited in the environment, whereas forecasting largely uses past data to project a future.

> *Forecasting can be a valuable tool for people who practise foresight. At the same time, foresight involves much more than just forecasting from the past and involves sensing the present and projecting evolving signals and trends in understanding evolving pathways to seek preferred futures.*

The history of India indicates that there have been many instances where the ability to foresee the future has transformed the technological landscape of the country. Notable among them include the setting up of the Indian Institutes of Technology, the space program, inroads into communication technology including 6G, and technology infusion into the finance sector from the 1980s culminating in the recent rollout of the Unified Payments Interface (UPI). Strategic foresight infused with technology awareness is giving rise to developments such as the National Health stack, and implementing various technology-based interventions in policing and urban planning. More recently, programs such as the India Semiconductor Mission and the National Quantum Mission are using the technology pivot to propel India as a technology leader for the world. It therefore becomes imperative that foresight as a capability is used more consciously and methodically by the various stakeholders for the development of the country.

Techniques that assist in developing foresight include technology roadmapping, scenario analysis, Delphi method, backcasting, decision trees, horizon scanning, and more. Employing these techniques effectively is crucial to strategise preferred future pathways. It becomes imperative for academically embedding the concept of foresight, in both theory and practice, so that the use of foresight to envisage and achieve preferred futures for the country becomes a recognized route.

Foresight studies are evolving in India through research and teaching in several institutions. The Center for Technology Foresight and Policy (CTFP) at the Indian Institute of Technology (IIT) Jodhpur is one of the leading institutions that has taken forward the futures mission to evangelise foresight both as an academic area for research and as a practice for creating futures. In its attempt, it has partnered with many institutions such as the Office of the Principal Scientific Advisor (OPSA) to the Government of India, the Central Detective Training Institute (Bureau of Police Research & Development) and the National Centre for Good Governance (NCGG). The Centre has also entered into MoUs with some of these institutions. CTFP also started programs in MS by research and PhD to take forward the research on foresight and policy.

International Workshop on Technology Needs Assessment for Green Hydrogen and CCUS - November 2023

In addition, the technology-oriented MBA-Tech program at IIT Jodhpur offers open elective courses on specific technologies such as AI, Public Policy and Strategies, IoT, AI Ethics etc. that form a strong curriculum for students interested in technology foresight. These programs can be extended for external participants such as administrators, industry executives, and researchers as well. A few more institutions are working in the area of forecasting, such as IIT Madras which offers courses on technology forecasting and on technology strategy, and the Department of Future Studies of the University of Kerala which offers an M.Phil in Future Studies. Further, researchers at institutions such as the ICAR-National Academy of Agricultural Research Management also use technology forecasting as research techniques.

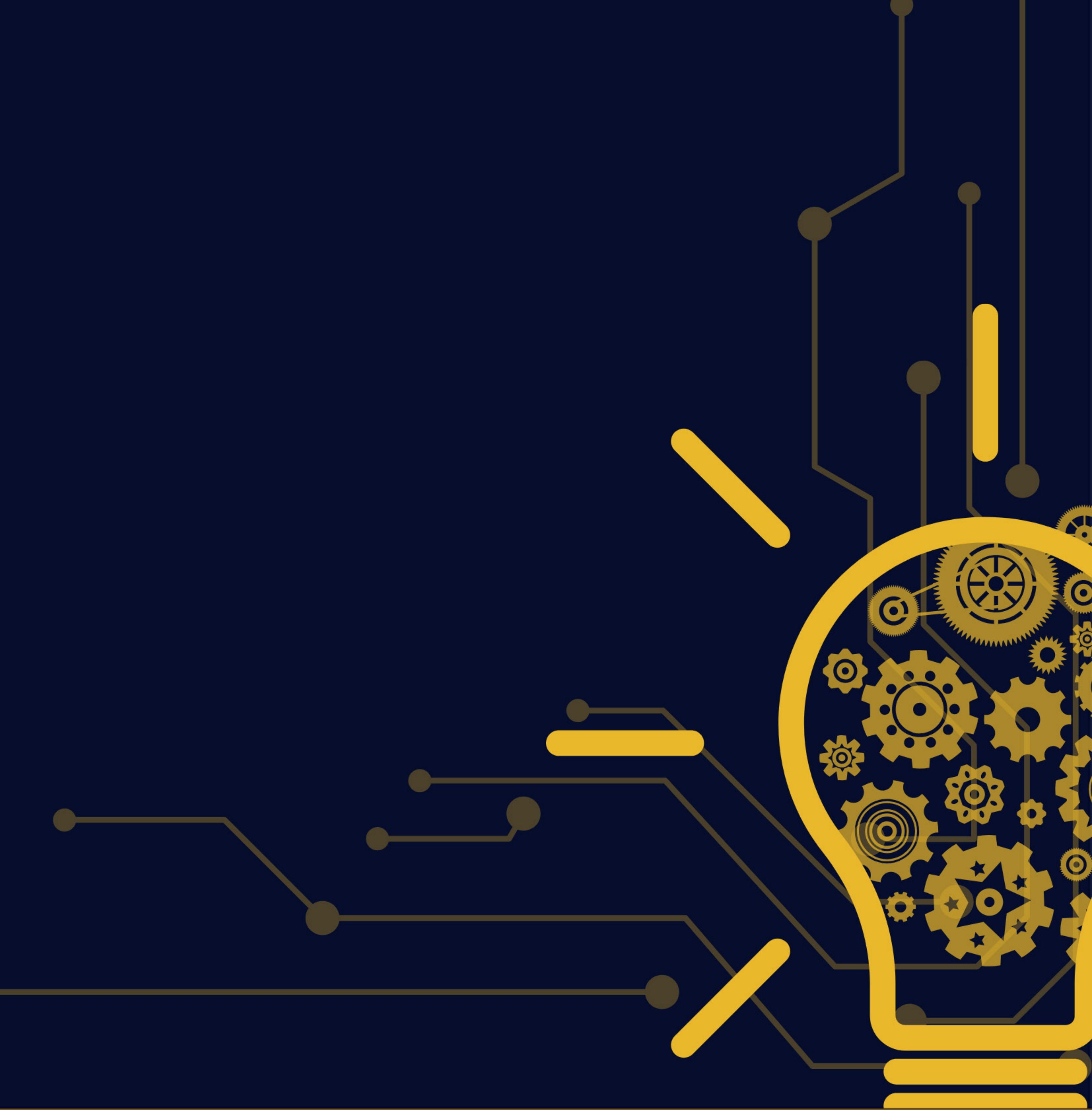
Foresight includes methodological approaches such as technology road-mapping, scenario analysis, Delphi method, backcasting, decision trees, horizon or environmental scanning, technology s-curve, etc. Other analytical approaches include statistical forecasting methods, multi-agent modelling and simulation, and digital twin projection. Foresight methods can include a systems-thinking and design-thinking perspective to visualise holistic future pathways. Evolving techniques that can be more powerfully explored in assisting foresight include patent-analysis based approach, and prompt-engineering using Large-Language Models (LLM).

A use case on a foresight-based approach includes creating the vision, mission, and goals with KPIs at the educational institution level and at department levels. IIT Jodhpur created its current vision and goals for the next few years from an institute-wide exercise involving multiple stakeholders and foresight methods such as backcasting, scenario planning, and Delphi method for technology trend evaluations. The developed vision formally includes the use of foresight – "Become India's top thought leader in technology-focused management education, research and entrepreneurship in a decade's time by spawning a new generation of managers, entrepreneurs and leaders equipped with foresight based on a blend of technology and humanity". The departments within IIT Jodhpur use this guidance for creating specific future-oriented goals and future pathways.

An instance of the use of foresight is the creation of the "Future of Cities" group anchored by CTFP at IIT Jodhpur that involved multiple subject matter experts. This initiative used foresight methods such as scenario planning and multi-agent modelling to create a future-of-city framework that will guide planning for sustainable cities. This foresight-based approach has helped IIT Jodhpur lead a multi-institution team that has been awarded a multi-crore project on the use of AI for sustainable cities. CTFP's approach to further the knowledge and use of foresight is to create focus groups on emerging areas with different subject matter experts so as to spawn possible pathways for future-oriented research and sustainable development.

With a special focus on technology, IIT Jodhpur offers several courses on technology foresight and strategy for students of IIT Jodhpur, such as 'Technology, Foresight and Strategies' and 'Foresight with Simulation Modelling and Analysis'

To foster the practical application of foresight, IIT Jodhpur also encourages its students to integrate foresight techniques into their projects. This has resulted in student projects in multiple areas using foresight such as Metaverse Foresight through Patent Analysis (2024); Metaverse Adoption in Marketing (2023); Strategic Analysis CCL technology development and Manufacturing in India (2023). It is the fervent mission of CTFP to popularise foresight as a capability and technique both in the public and the private sector. It is clear that multiple stakeholders have to cooperate and collaborate in taking forward the use of technology foresight as a learnt capability. This also requires more institutions - academic, government and private - to come together and benefit from each other's knowledge of evolving futures. Technology Foresight is a very powerful tool to achieve India's vision to become a developed country by 2047.



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