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Science Diplomacy Education through Serious Games – Toward Evidence-Based Simulation Design

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Introduction

Science diplomacy (SD) is increasingly recognised as a crucial field at the intersection of scientific advancement and international cooperation, addressing global challenges, such as climate change, public health, and technological governance. As the field gains prominence, so does the need for effective capacity-building educational strategies.

One promising pedagogical tool in SD education is the use of serious games—interactive, experiential learning tools designed for purposes beyond entertainment. Among these, simulation games have become popular tools in professional educational training programs, offering experiential learning to develop critical skills such as agency in role-playing, multilateral negotiation, critical thinking, time management, and strategic decision-making.

However, despite their widespread use, many simulation games prioritise immersive experiences over structured learning. They often lack mechanisms to measure learning, self-perceived skill development, or alignment with SD competencies. This paper critically examines the current use of simulation-based serious games in SD education, highlighting their constructivist, experience-focused design and identifying key limitations, including limited instructional time and insufficient theoretical scaffolding.

We propose a conceptual shift in how serious games in SD, specifically simulation games, are ideated and evaluated in SD capacity building. These should be embedded in meaningful case studies (real or fictional), supported by validated assessment tools that measure learning outcomes and reinforce core SD dimensions. Theory-informed serious game design can transform simulation games in SD from descriptive activities into powerful tools that consolidate knowledge, strengthen competencies, and advance the strategic goals of SD.

Serious Games as Pedagogical Tools in Science Diplomacy

Serious games represent a promising avenue for advancing SD education by offering immersive, interactive learning experiences that simulate real-world challenges. Defined as games designed specifically for education or training[1], serious games are increasingly used to train professionals across various sectors, including diplomacy.[2-5] These games can take several forms, including simulation games, role-playing games, strategy games, and game-based learning platforms, each providing unique learning opportunities depending on the training objectives.

Simulation games, broadly defined as structured, rule-based environments replicating real-world systems to foster experiential learning, are particularly effective for short-term educational interventions.[5] They have been a key tool for training in diplomacy and are emerging in SD capacity-building training.[6,7] These games enable participants to engage in scenario-based exercises where they can assume roles such as negotiators, diplomats, or scientists and make decisions based on the dynamics of global challenges. These interactive learning tools offer immersive environments where practitioners can develop skills such as strategic thinking, negotiation, multilateralism, and time management.[5-7] These games provide a constructivist learning experience that can complement traditional training methods.[8]

Validated simulation tools include those by Kriz (2010)[9], which explore best practices for evaluating educational games through empirical and theoretical models. Additionally, the Diplomacy Lab framework[10] provides insights into measuring the impact of simulation exercises in international relations training. These findings support the development of scalable and adaptable frameworks that meet the needs of diverse geopolitical contexts and disciplines.

Despite their potential, there is limited research on the effectiveness of simulation games in fostering measurable learning outcomes, particularly in terms of skill acquisition and alignment with SD competencies. While these simulations are powerful tools for experiential learning, their primary focus is often on providing a negotiation experience rather than explicitly reinforcing the core concepts of SD, such as multilateral cooperation, science-policy interfaces, evidence-based decision-making, science anticipation, and the role of diplomacy in global scientific collaboration. As a result, the educational impact of these games remains difficult to assess, and their ability to build SD-specific competencies is unclear.

To bridge this gap, we propose a conceptual shift that aims for SD simulations to be based on both learning science and a structured SD taxonomy. Additionally, embedding case studies (either real or fictional) into simulations, combined with validated tools to measure learning outcomes, can enhance the educational value of these games and ensure that they contribute effectively to SD capacity building. By integrating learning science principles and developing tools to assess the effectiveness of simulations, the educational value of these games can be significantly enhanced.

Alignment with global development agendas, including the SDGs, is also critical. By incorporating the SD Taxonomy, a framework that organises SD concepts into interconnected categories[11], serious games can be better designed to address the complexities of SD and ensure that the learning experience aligns with the real-world needs of science diplomats, including meta-cognition, critical thinking, and inference awareness.[12]

Rethinking Simulation Games in Science Diplomacy Education

Despite their appeal, many SD simulations struggle to translate immersive experiences into durable theoretical insights. Without prior orientation—whether via concise preparatory modules or in-game pause points—participants too often enact diplomatic scenarios without internalising the theoretical underpinnings of SD. Moreover, many current designs sacrifice pedagogical clarity for narrative richness, leaving learners adrift in complex storylines without explicit objectives and guided debriefs that translate experience into transferable SD insight. Without scaffolding, assessment, or theoretical grounding, these tools risk delivering engaging but fragmented learning experiences, constraining accountability and continuous improvement.

To enhance educational coherence, it is crucial that game mechanics are closely connected to both (1) conceptual taxonomies of SD, such as the frameworks of diplomacy for science, science for diplomacy, and science in diplomacy[13], or even regional taxonomies such as the one described by Echeverria-King (2024)[11] for Latin America or the European Commission framework (2025)[14], and (2) educational learning theories such as transformative learning theory[15], Bloom's taxonomy for serious games[16], or systems thinking.[17] When incorporated into the game's ideation, narrative, and debriefing structures, they could provide clarity regarding the specific competencies and concepts learners are expected to engage with and internalise.

Instead of advocating for a specific game design, we propose a conceptual shift in how simulation games in SD are ideated and evaluated in SD capacity building as theory-informed interventions that facilitate both cognitive and socio-emotional learning. This approach involves several key components:

- Usage of Conceptual Taxonomies of SD

  Conceptual taxonomies could provide a structured context for serious games. The organisation and classification of scientific knowledge have been a historical constant that has allowed for greater specialisation and development. This process is dynamic and includes overcoming old disciplinary boundaries to advance toward transdisciplinary methodologies that contribute to a better understanding of a problem from different levels of governance and with the inclusion of actors beyond the State.[18] Therefore, SD is embedded in a complex dynamic of knowledge creation (interdisciplinary), an encounter transmitted through experience in solving complex problems (evolutionary), and an expression that links different actors (perspectives)[19], which generates specific forms of classification according to the perspective or influence being applied. In this sense, the classification of knowledge through a conceptual taxonomy is aimed at forming and building a consensus that is accepted by the scientific community that uses it so that, at the same time, it becomes an incentive for its development and subsequent evolution.[11]

- Educationally Grounded Game Design

  Simulation games should be designed with clear educational principles, informed by learning science theories.[5] This includes understanding how learners acquire, apply, and retain knowledge, as well as how to foster deeper cognitive engagement. Games must be structured to promote critical thinking, problem-solving, and concept integration related to SD (e.g., science-policy interfaces, evidence-based decision-making, and negotiation dynamics). Games should be pedagogically intentional with clear learning goals.

- Clear and Measurable Learning Outcomes

  Clearly articulated learning outcomes are essential to guide both the game design and evaluation.[8-10] These should address not only cognitive dimensions—such as comprehension of key SD concepts and proficiency in negotiation—but also socio-emotional competencies, including empathy and emotional self-regulation. In the absence of explicit objectives, any systematic evaluation of a game's educational value is rendered methodologically unsound.

- Mixed-Methods Evaluation

  A robust evaluation framework should combine quantitative (e.g., pre/post-game surveys) and qualitative (e.g., interviews, focus groups) methods to assess knowledge retention and emotional engagement. This combination allows for assessing cognitive gains and affective responses, providing a nuanced understanding of how participants internalise concepts and shift their attitudes or behaviours. Such an approach has been shown to effectively capture learning outcomes that singular evaluation methods might overlook.[20]

- Time-Bound Evaluation

  Longitudinal studies may be impractical due to the short-term nature of most simulation games. Therefore, time-bound evaluations should focus on immediate learning outcomes and reflection. Prompt post-simulation debriefings enable participants to reflect critically, link experiences to real-world SD concepts, and consolidate knowledge. Research highlights that such timely reflection maximises educational impact by transforming experience into meaningful learning.[21,22]

- Reflexivity and Metacognitive Debriefing

  Reflexive practices and metacognitive debriefing are critical for helping learners understand the implications of their decisions during the game. These structured reflections enable participants to evaluate their actions, consider alternative strategies, and relate their experiences to broader SD frameworks. In particular, science anticipation and inference awareness are recommended in SD capacity-building exercises. Science anticipation involves adopting a long-term, sustainability-oriented strategic mindset—envisioning the future impact of decisions made during the simulation. Inference awareness requires recognising one's own cognitive biases and understanding how they can influence negotiations within SD simulation games.[12]

- Peer and Expert Feedback

  Structured peer review combined with expert evaluation can deepen learning in SD simulations by blending collaborative reflection with disciplinary insight. Peer feedback fosters diverse interpretations and mutual sense-making, encouraging participants to critically examine their reasoning and explore alternative approaches.[23] Expert feedback, in turn, situates in-game decision-making within authentic diplomatic contexts, helping learners connect their actions to real-world policy challenges and navigate complex normative frameworks.[24] When thoughtfully balanced, this interplay between participant agency and authoritative input can avoid both over- and under-structuring, supporting engagement while maintaining conceptual rigour.

Conclusion

Simulation games have great potential to transform SD education when designed with a clear pedagogical intent, grounded in conceptual frameworks, evaluated rigorously, and designed with an understanding of both SD and learning science principles. This paper advocates for a shift toward theory-informed design that draws on educational frameworks to ensure simulations contribute meaningfully to cognitive and socio-emotional development. By prioritising clear learning outcomes, mixed-methods evaluation, and time-bound assessments, simulations can offer a more rigorous, critical evaluation of their impact, allowing for deeper insights into knowledge transfer and emotional engagement. Moreover, incorporating reflexive debriefing and peer/expert feedback can transform the post-game phase into an essential learning tool that deepens the intellectual and emotional understanding of SD challenges. Ultimately, serious games in SD need to be more than engaging or entertaining experiences—they must be part of a coherent learning ecosystem that integrates theory, assessment, and reflective practice. With these considerations, simulation games can play a more integral role in developing the critical competencies required for the complex, interdisciplinary nature of SD.

References

1. Michael D, Chen S (2006) Serious games: Games that educate, train, and inform. Thomson Course Technology.

2. Bridge D, Radford S (2014) Teaching diplomacy by other means: Using an outside-of-class simulation to teach international relations theory. International Studies Perspectives, 15(4): 423–437. https://doi.org/10.1111/insp.12032
3. Cercel MO (2022) Gamification in diplomacy studies as an effective tool for knowledge transfer: Questionnaire study. JMIR Serious Games, 10(2): e32996. https://doi.org/10.2196/32996
4. Gentry SV, Gauthier A, Ehrstrom BL, Wortley D, Lilienthal A, Car LT, Dauwels-Okutsu S, Zary N, Campbell J, Car J (2019) Serious game is an effective learning method for primary health care education of medical students: A randomized controlled trial. Nurse Education Today, 79: 40–45. https://doi.org/10.1016/j.nedt.2019.05.012
5. Crookall D, Oxford R, Saunders D (1987) Towards a reconceptualization of simulation: From representation to reality. Simulation and Games, 18(2): 147–171.
6. Raji M, Alarcón-López CA, Murphy S (2023) Shaping the Future of Multilateralism through Science Diplomacy: Insights from the GESDA Science Diplomacy Immersion Program. Science Diplomacy, 6(4): 31.
7. Doole FT, Littin S, Myers SA, Somasekhar G, Steyaert JC, Lansey K (2022) Experiential learning for training future science policy and diplomacy experts. Journal of Science Policy & Governance, 21(1): 1–27
8. Mezirow J (1991) Transformative dimensions of adult learning. Jossey-Bass.
9. Kriz WC (2010) A systemic approach to simulation and gaming for learning. Simulation and Gaming, 41(5): 663–680. https://doi.org/10.1177/1046878109352839
10. Lightfoot S, Maurer H (2014) The Diplomacy Lab: Building a new model for experiential learning. International Studies Perspectives, 15(3): 362–374.
11. Echeverría-King LF, Piñeros-Ayala RE, Pantović B, Flores-Zamora AF, Figueroa P (2024) A Taxonomy of Science Diplomacy From a Latin American and Caribbean Perspective. In Developments and Approaches in Science Diplomacy: Latin America and the Caribbean, pp. 26–54. IGI Global.
12. Alarcón-López CA (2024) A critical thinking approach for sustainable and anticipatory science diplomacy. In Developments and Approaches in Science Diplomacy: Latin America and the Caribbean, pp. 1–25. IGI Global.
13. AAAS (2009) Science diplomacy: A key to improving international relations. American Association for the Advancement of Science.
14. European Commission: Directorate-General for Research and Innovation, Gjedssø-Bertelsen R, Bochereau L, Chelioti E, Dávid Á, Gailiūtė-Janušonė D, Hartl M, Liberatore A, Mauduit, J, Müller J, Van-Langenhove L (2025) A European framework for science diplomacy: Recommendations of the EU Science Diplomacy Working Groups. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/9235330
15. Dirkx JM (1998) Transformative learning theory in the practice of adult education: An overview. PAACE Journal of lifelong learning, 7: 1–14.
16. Buchanan L, Wolanczyk F, Zinghini F (2011) Blending Bloom's taxonomy and serious game design. In Proceedings of the International Conference on Security and Management (SAM). The Steering Committee of The World Congress in Computer Science, Computer Engineering and Applied Computing (World Comp), pp. 1).
17. Hofstetter E, Leifler O, Johansson B, Berggren P (2024) Facilitating systems thinking in serious game design by highlighting inter-player relationships. Proceedings of the European Conference on Cognitive Ergonomics, 2024: 1–8.

18. Klein JT (2017) Typologies of interdisciplinarity. Frodeman R, Klein JT, Pacheco RC (Eds.), The Oxford Handbook Of Interdisciplinarity, pp. 21–39.

19. Manassero-Mas MA, Vázquez-Alonso Á (2019) Conceptualización y taxonomía para estructurar los conocimientos acerca de la ciencia. Revista Eureka Sobre Enseñanza y Divulgación de la Ciencia, pp. 3104–3116.

20. Oberle M, Leunig J, Ivens S (2020) What do students learn from political simulation games? A mixed-method approach exploring the relation between conceptual and attitudinal changes. European Political Science, 19: 367–386.

21. Crookall D (2014) Engaging (in) gameplay and (in) debriefing. Simulation & Gaming, 45(4–5): 416–427.

22. Burns CL (2015) Using debriefing and feedback in simulation to improve participant performance: an educator's perspective. International Journal of Medical Education, 6: 118.

23. Reinholz DL, Dounas-Frazer DR (2016) Using peer feedback to promote reflection on open-ended problems. The Physics Teacher, 54(6): 364–368.

24. Simon A (2020). Teaching and learning about foreign policy decision-making via board-gaming and reflections. European Political Science, 19(1): 9–28.

International Cooperation in Science and Technology: A Suggestive Indian Model*

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Introduction

Global trade is becoming technology-savvy through disruptive scientific innovations, making it more technology-focused. These evolving technological demands are slowly recognising the role of small stakeholders and transforming the world into a global laboratory for developing world-class products. This transformation is also redefining advancing science and technology between nations.

In this regard, scientific cooperation is crucial in fulfilling national needs, ensuring technological freedom, industrial reliance, and boosting the economy. Such collaborations involve the sharing and exchanging of ideas, human resources, infrastructure, and regulatory aspects that impact the futuristic export and import policies. As the challenges facing humanity become more complex and transboundary, it is empirical to shift from individually-driven initiatives to team-based efforts with the rational involvement of commercial entities.

Science is facing multifaceted challenges worldwide, such as rising research costs, shortage of skilled researchers, limited infrastructure, restricted access to finance, diminishing venture capital and increasing regulatory expenditures. These challenges are further compounded by geopolitical tensions, creating uncertainty in research collaborations and disturbing the world's peace. Divergent intellectual property rights (IPR) regimes and conflicting data-sharing policies hinder trust and transparency in international partnerships.

Amidst these constraints, the mega-science projects, as well as concepts like science without boundaries, are showing increased traction and fostering a new ecosystem involving multiple global players to understand the scientific mysteries at a deeper level and developing complex science-powered precise products. Initiatives like the Large Hadron Collider, the COVID-19 vaccine development and the successful polio eradication highlight the transformative impact of deeper international engagements. The complexity of international cooperation is further escalated with the advent of advanced technologies

* Views in the article are of the authors and do not belong to the organisation they represent.

such as artificial intelligence, which possesses tremendous power and speed for converting an invention into a market-ready product. But it also raises ethical concerns. The unethical practice of AI and deepfake technologies might lead to the erosion of trust by increasing safety and security concerns and hinder equitable development through unequal access to AI benefits, creating a digital divide and potential for exploitation. The lack of global standards and regulatory frameworks might lead to political disagreements and complicate international cooperation. The unethical issues in AI can be resolved by sharing and following the best practices, adopting ethical guidelines and developing common standards such as those proposed in UNESCO's Recommendation on the Ethics of Artificial Intelligence (2022). In conclusion, the traditional model of scientific cooperation must transform and align with the dynamic scientific requirements.

Cooperation Modes

India runs its international scientific cooperation in three modes: (a) Technology synergy with developed countries, (b) Diplomacy with developing and least developed countries (LDCs), and (c) Targeted industrial research leading to techno-entrepreneurship. These cooperation modes are not mutually exclusive but complementary, collectively contributing to India's strategic positioning in the global science and innovation landscape.

A. Technology Synergy

This mode operates through bilateral or multilateral platforms, emphasising equitable resource-sharing and joint outcomes. All stakeholders contribute financially, intellectually and share the outcomes as joint publications, patents or demonstrator technologies. Since most of the activities under this approach are driven by individual research groups, they lack focus on process and product development. To maximise the impact of such partnerships, the cooperation has to be more visionary and aligned with long-term national priorities and global technological trends. An ideal model must assess the potential risks and ethical dimensions of technology development and overall outcome, nurture the innovation ecosystems, strengthen institutional facilities, build quality and future-ready human resources, achieve diplomatic goals and extend the scope of cooperation in mutual interest. Such a cooperation model would help position India as a key player in global technology governance.

B. Technology Diplomacy

Through the diplomacy route, India fosters partnerships with developing and least developing countries (LDCs), positioning itself as a trusted partner in South-South cooperation. It involves developing human resources in these countries (through specialised courses/ training program and entrepreneurship activities) and creating scientific infrastructure, like African Centres of Excellence (ACEs). A case in point is India's support for leather technology entrepreneurship in Rwanda, which has the potential to be replicated across other sectors and regions.

India contributes to sustainable technological development in other developing countries through initiatives in areas like renewable energy (International Solar Alliance), digital innovations (Aadhar, **U**nified **P**ayments **I**nterface (UPI) and DigiLocker), and agricultural advancements. Such initiatives can be role models of sustainable development for replication in other developing countries.

India also supports the development of scientific infrastructure and human resources through remote teaching, curricular co-development, faculty and student exchanges, laboratory training, practice entrepreneurship and regulatory capacity-building. These efforts help generate goodwill and provide access to Indian technology products in their markets. Programmes like India-Africa S&T Initiatives, ASEAN-India S&T cooperation, DST-TWAS Fellowships and the Scheme for Young Scientists and Technologists (SYST) underscore India's long-standing commitment to technology diplomacy. India's supply of COVID-19 vaccines to many developing countries is a vivid example of how science and diplomacy can work in tandem to strengthen global partnerships and promote equitable access.

C. Industrial Research and Development

Industrial R&D is a targeted approach centred on developing new hi-tech products, tools, applications and scalable, innovative solutions for global progress. Unlike in the developed world, where the industry sector contributes a substantial percentage of R&D expenditure of a nation's GDP, developing and LDCs continue to rely heavily on government resources, with limited industry participation in the research ecosystem. It suggests that while developed nations' major focus is on translational research driven by industrial needs, developing countries still operate within academic silos. Strengthening industrial R&D through international cooperation can help bridge this gap. Industrial R&D can be nurtured through networking, academic-industry matchmaking, connecting startups to global talent pools, improving access to incubators and facilitating engagement with international investors. Equally important are regulatory harmonisation, collaborative frameworks for intellectual property management and access to global testing & certification facilities. In addition, the specific entrepreneurship fellowships and end-to-end training programmes ranging from ideation to market entry can further empower the next generation of entrepreneurs. Such interventions are critical to ensure that the outcomes of R&D are scientifically sound, commercially viable and socially impactful.

Suggestions

The central point of international cooperation is its global multidimensionality. Such initiatives integrate elements of science diplomacy, national interests, and engagement with the scientific community for the betterment of society and economic prosperity. To ensure the financial sustainability of such programs, the outcomes of joint scientific collaborations must help industries develop new technology products and generate revenue, which could be further reinvested for new scientific collaborations.

Countries like India, with relatively lower investment in R&D (as a percentage of GDP), need to prioritise their scientific investments and increase industry participation in R&D. Aligning scientific priorities with market demands should be a key strategic objective. International scientific cooperation must also be informed by the export/import patterns of the partner countries to identify areas that have optimum relevance for the cooperation.

To perfectly align national goals among the parties and maximise mutual benefits, Indian S&T departments may consider developing flexible, country-specific strategic plan documents annually. Dedicated country- or region-specific committees may be established for their effective implementation. These should include representatives from S&T departments, trade and commerce ministries, regulatory authorities, and the Ministry of External Affairs, alongside academic and industrial experts. Such committees should periodically assess the short- and long-term goals, evaluate expected outcomes and returns on investment and consider the impact of international cooperation. They should also ensure the strategic vision remains aligned with respective global partners. The committee may be assisted by subcommittees involving scientific experts from both academic and industrial domains, startup representatives, entrepreneurs, and investment specialists. These subcommittees would be tasked with monitoring project execution closely, identifying roadblocks early, and recommending course corrections or project termination, if warranted, in consultation with partners. This strategy is not uncommon and practised in countries such as the United States (National Cislunar Science and Technology Strategy, 2022) and the United Kingdom (International Technology Strategy, 2023), where coordinated and outcome-driven frameworks guide global scientific partnerships. Consolidating India's international scientific engagements under a single-window mechanism could reduce duplication, improve efficiency, and facilitate smoother engagement for international collaborators.

Historically, India's international S&T cooperation focussed on academic R&D activities, scientific exchange, and human resource development. But now, industrial engagements are beginning to creep in through scientific agencies supporting R&D projects under Indo-German, Indo-UK, Indo-Singapore, Indo-Israel, Indo-Spain, etc, bilateral programs. Academic projects, especially those in fundamental research or early-stage innovation, should ideally be funded for two years to establish proof of concept. Based on expert evaluation, only the most promising projects should be extended further. The current model of supporting a project for three years under international cooperation is more appropriate for industrial sectors, particularly those targeting co-development, market validation, or technology deployment. Further, pressing challenges like climate change demand deeper engagement with industrial sectors in international S&T cooperation. Therefore, major funding under international cooperation may be reserved for research challenges likely to lead to technology/product development or nurturing startups.

International cooperation has immensely contributed to human capital development. Regular exchange and training opportunities help forge long-term scientific relationships. With its vast pool of youngsters, India looks forward to more opportunities and channels for transformation. The focus on human resource development should be on emerging and futuristic areas with an emphasis on training at pre-Ph.D. levels. Initiatives aimed at post-school and early university students in frontier areas of science would yield better long-term dividends, given their openness to learning, enthusiasm, and potential to drive innovation. The trained workforce may be encouraged to pursue entrepreneurial paths. Further, engagement with diverse stakeholders such as academia, industry, NGOs, philanthropists, Micro, Small and Medium Enterprises (MSMEs) and entrepreneurs can ensure that cooperation spans a broad spectrum of science and technology areas relevant to societal needs.

Aligning IP outcomes, however, is a herculean challenge as partner countries often operate under different rules and regulations. Therefore, both sides' concerned ministries must ensure in bilateral and multilateral agreements that IP clauses are harmonised with international legal norms rather than solely reflecting national legislation. One solution could involve including contractual clauses mandating equitable benefit-sharing from future commercialisation, even if IP ownership resides with a single party.

While such provisions may increase the risk of legal disputes, a structured approach can mitigate these concerns. All grant recipients should be legally required to compile and transfer a detailed technology licensing dossier to the partnering industry, including information on domestic and international funding contributions. Transparent tracking of contributions and enforceable benefit-sharing mechanisms can build trust, encourage greater openness in sharing scientific resources, and act as an informal source of venture capital. This, in turn, can stimulate startup formation and innovation diffusion across borders.

Conclusion

International scientific cooperation is a powerful instrument for excellent fundamental research, but it also has immense potential to enrich industrial and economic aspects. To capitalise on its strengths, such as a vast and affordable talent pool, a thriving startup ecosystem, and supportive government policies like Make in India, Startup India and Invest India Programmes, it must reimagine its cooperation frameworks to be more agile, outcome-oriented, and innovation-driven.

By enhancing the capabilities of the established scientists, empowering young researchers through capacity-building initiatives and encouraging them to spin off their own startups, India can not only accelerate the achievement of its national goals but also emerge as a key partner in addressing global scientific challenges. Aligning international cooperation with co-development and co-production models will indirectly infuse greater foreign investment and create a better sustainability and social welfare ecosystem.

India's Role in ITER: Advancing Science Diplomacy and Atomic Energy Leadership

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Introduction

India's participation in the International Thermonuclear Experimental Reactor (ITER) project underscores its commitment to advancing nuclear fusion technology and fostering global scientific collaboration. ITER is a landmark international effort to replicate the Sun's fusion process, aiming to produce limitless, clean energy. As a key partner, India contributes critical components, including cryostat manufacturing, diagnostics, and superconducting magnets, showcasing its engineering expertise. The involvement of the Institute for Plasma Research (IPR), Gandhinagar, and Indian industries strengthens the nation's technological capabilities and scientific diplomacy. The success of ITER could revolutionise the energy sector, providing a carbon-free alternative to fossil fuels. By investing in fusion technology, India positions itself at the forefront of future energy innovation, reinforcing its commitment to clean energy and international cooperation.

Flags of participating nations at the ITER site (Source: ITER)

ITER, located in Cadarache, France, is a scientific collaboration involving India, the European Union, the United States, Russia, China, Japan, and South Korea. This project seeks to demonstrate the feasibility of nuclear fusion as a sustainable, large-scale, and carbon-free energy source. Unlike conventional nuclear fission, which splits atoms and generates long-lived radioactive waste, fusion merges atomic nuclei, releasing immense energy with minimal radioactive byproducts, making it a cleaner alternative for future energy production.

ITER aims to generate 500 megawatts (MW) of power from an initial input of 50 MW, proving that fusion can be a net energy-positive process. Achieving this milestone would mark a significant breakthrough in energy science, bringing the world closer to harnessing fusion as a viable power source. If successful, ITER will lay the foundation for the development of commercial fusion reactors, which could revolutionise the global energy landscape by providing a nearly inexhaustible and environmentally friendly alternative to fossil fuels.

Indian Prime Minister and French President at the ITER site (Source: ITER)

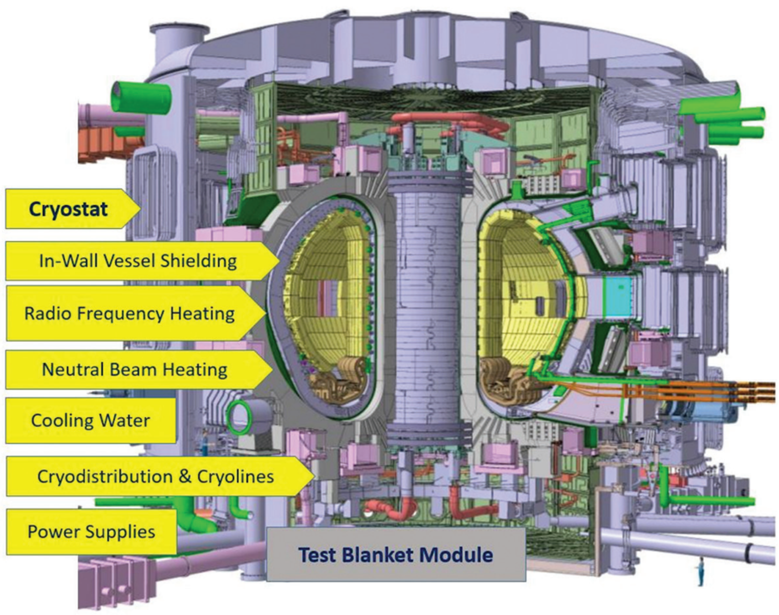
In a landmark moment for both diplomacy and science, Indian Prime Minister Narendra Modi and French President Emmanuel Macron visited the ITER facility on 12 February 2025. This historic occasion marked the first ever visit by both leaders to the world's largest and most ambitious nuclear fusion initiative, an endeavour that holds the potential to transform the global pursuit of clean and sustainable energy.

India's Technological Contributions to ITER

India officially joined ITER in 2005, committing 9.1% of the total project cost through both financial and in-kind contributions. The IPR serves as the India's nodal agency.

Among India's most significant contributions is designing and fabricating the world's largest cryostat, a massive 3,800-ton stainless steel structure. This crucial component provides structural integrity and thermal insulation to the ITER, ensuring the extreme conditions required for nuclear fusion. Additionally, India has supplied essential cooling and cryogenic systems, including cryolines and a cryodistribution system. These help maintain the superconducting magnets at ultra-low temperatures, ensuring the stability of the powerful magnetic fields needed to confine the plasma.

India also plays a key role in providing high-power electrical systems, such as radio-frequency heating sources and steady-state power supplies, essential for sustaining the fusion reaction. Further, Indian scientists have developed sophisticated diagnostic tools to monitor plasma conditions within

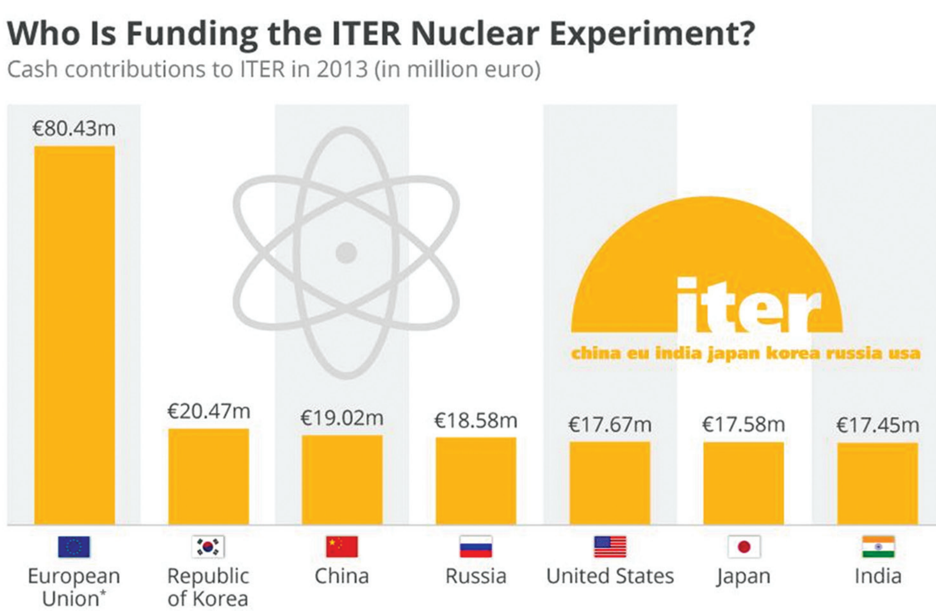


ITER – Indian Contribution (Source: ITER India)

the machine, contributing to precise measurements and control of the fusion process. Alongside this, India is actively researching advanced plasma-facing materials capable of withstanding the extreme environments within the reactor. These technological contributions reinforce India's expertise in fusion research and strengthen its position as a crucial player in international scientific collaborations aimed at achieving sustainable energy solutions.

India's Science Diplomacy through ITER

India's participation in the ITER project strengthens its scientific diplomacy by deepening global research partnerships and advancing its clean energy goals. By engaging in this prestigious mega-science initiative, India not only reinforces its research and technological capabilities but also enhances its role in global scientific policymaking. More significantly, India's active involvement in ITER exemplifies its approach



Economic footprint of the ITER project (Source: ITER) to atomic energy diplomacy, wherein the country leverages nuclear science and technology as a tool for global engagement, energy security, and geopolitical influence.

International Collaboration

One of the primary benefits of India's participation in ITER is the opportunity to collaborate with leading scientific and technological institutions worldwide. This partnership allows Indian researchers, engineers, and industries to engage with cutting-edge nuclear fusion research, positioning India at the forefront of next-generation energy technologies. The collaboration fosters the exchange of expertise between Indian scientists and their international counterparts, accelerating India's learning curve in advanced fusion technology. The knowledge gained through ITER not only enhances India's standing in global science and technology but also has far-reaching implications for its domestic nuclear energy programs. India's participation enables it to acquire crucial insights into the complexities of fusion technology, which could be instrumental in developing its indigenous fusion reactors.

Additionally, ITER serves as a valuable platform for Indian industries to integrate into the global supply chain of precision-engineered nuclear components, paving the way for international collaborations that extend beyond the realm of fusion energy. The successful involvement of Indian firms in designing, manufacturing, and assembling ITER's sophisticated systems highlights the nation's expanding capabilities in advanced nuclear engineering. These achievements enhance India's credibility as a technological collaborator in major scientific ventures. Notably, Larsen & Toubro (L&T) has played a key role in fabricating the world's largest cryostat, an essential structure that sustains the reactor's extremely low temperatures. In addition, leading Indian IT firms such as Tata Consultancy Services (TCS) and HCL Technologies have significantly contributed to developing cutting-edge control systems that help ensure ITER's operational stability and efficiency.

Atomic Energy Diplomacy

ITER provides India a strategic platform to participate in shaping global energy policies and technological frameworks. Since its nuclear program's inception, India has faced geopolitical challenges, including nuclear technology denial regimes that restricted access to advanced nuclear materials and expertise. Despite these constraints, India pursued a self-reliant nuclear energy program, achieving remarkable success in both fission and fusion research. ITER provides India with a unique opportunity to engage with the global nuclear community on equal footing, reinforcing its position as a responsible nuclear power committed to the peaceful applications of atomic energy.

Participation in ITER also enhances India's influence in global scientific policymaking. As one of the seven major partners in this multi-billion-dollar project, India has a seat at the table in shaping the future of nuclear fusion research and energy policies. This strategic positioning allows India to advocate for global energy policies that align with its long-term interests, particularly in sustainable energy development, climate change mitigation, and equitable access to advanced nuclear technologies.

India's engagement in ITER strengthens diplomatic ties with key global powers, reinforcing its broader foreign policy objectives. The project serves as a bridge for scientific cooperation between India and countries such as the United States, Russia, and the European Union, fostering trust and collaboration beyond nuclear energy. Given the growing importance of science and technology in global diplomacy, India's involvement in ITER underscores its commitment to using scientific advancements to strengthen international relations.

Domestic Front

India's contributions to ITER are shaping its domestic nuclear landscape. The cooperation also provides valuable training opportunities for Indian scientists and engineers, ensuring the country builds a skilled workforce capable of handling future fusion projects. By engaging in cutting-edge research, Indian universities and research institutions are now more equipped to contribute to the global knowledge pool on fusion energy.

Additionally, India's work on ITER complements its long-term vision of developing its own experimental fusion reactor, which aims to be a stepping stone toward an indigenous demonstration fusion power plant. The experience gained through ITER will significantly accelerate India's progress toward self-sufficiency in fusion energy research.

Secure Tomorrow

Given its rapidly growing population and increasing energy demands, energy security is a critical aspect of India's long-term development strategy. While India has made significant strides in renewable energy, including solar and wind power, these sources alone may not meet its future energy needs. Nuclear fusion presents a promising alternative, offering a nearly limitless, carbon-free energy source with minimal environmental impact.

By investing in ITER, India is preparing for a future where fusion energy could become a commercial reality. If ITER successfully demonstrates that nuclear fusion can be a net energy-positive process, it will pave the way for the development of commercial fusion power plants. Such a breakthrough would drastically reduce dependence on fossil fuels, helping India achieve its climate commitments while ensuring a stable and sustainable energy supply.

Fusion energy aligns with India's goal of reducing greenhouse gas emissions and combating climate change. Unlike conventional nuclear fission, fusion does not produce long-lived radioactive waste, making it a safer and cleaner energy alternative. By actively participating in ITER, India is positioning itself as a leader in green energy solutions, reinforcing its commitment to a sustainable and environmentally responsible future.

Conclusion

India's involvement in ITER serves as a model for how scientific collaboration can be leveraged as a tool for diplomacy, technological advancement, and energy security. Through its contributions to this groundbreaking project, India has demonstrated its ability to lead in high-end nuclear research while fostering international partnerships. At the same time, India's participation in ITER is a reflection of its broader strategy of atomic energy diplomacy, where scientific cooperation is used to enhance global influence, build strategic alliances, and drive technological progress. As the world moves closer to unlocking the potential of nuclear fusion, India's role in ITER will continue to shape the future of energy, innovation, and international cooperation. By investing in fusion technology today, India is securing its energy future and reinforcing its position as a responsible and forward-thinking global power. The lessons learned from ITER will not only benefit India's nuclear research programs but will also contribute to the collective global effort to develop a cleaner, more sustainable energy source for future generations.

Resources

1. ITER Official Website – https://www.iter.org/
2. ITER-India Website - https://www.iterindia.in/
3. Wikipedia - https://en.wikipedia.org/wiki/ITER

4. Rebut PH (1995) ITER: the first experimental fusion reactor. Fusion Engineering and Design, 30(1-2): 85–118. https://doi.org/10.1016/0920-3796(94)00403-T
5. Aberg A (2021) The ways and means of ITER: reciprocity and compromise in fusion science diplomacy. History and Technology, 37(1): 106–124. https://doi.org/10.1080/07341512.2021.1891851
6. Geng S (2022) An Overview of the ITER project. Journal of Physics: Conference Series, 2386: 012012. https://doi.org/10.1088/1742-6596/2386/1/012012
7. How India is emerging as a key stakeholder in the future energy economy. India News Network, 13.02.2025.

Towards Circular Electric Vehicle Ecosystem: Viksit Bharat's Global Vision

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Introduction

Rising global temperatures, unpredictable weather patterns, and the growing incidence of urban heat islands are among the many consequences of vehicular emissions, such as carbon dioxide, which have galvanised the international community to pursue net-zero commitments. A cornerstone of this transition is the widespread adoption of electric vehicles (EVs). The Government of India (GoI) is firmly committed to a sustainable transportation system, aiming for EVs to constitute 30% of the transport sector by 2030. To this end, the GoI has introduced a suite of supportive policies, such as the Production Linked Incentive (PLI) Scheme, Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME India Scheme) Phase I and II, Phased Manufacturing Programme (PMP), etc. The Union Budget 2025-26 further allocates financial resources to boost the domestic EV manufacturing ecosystem.

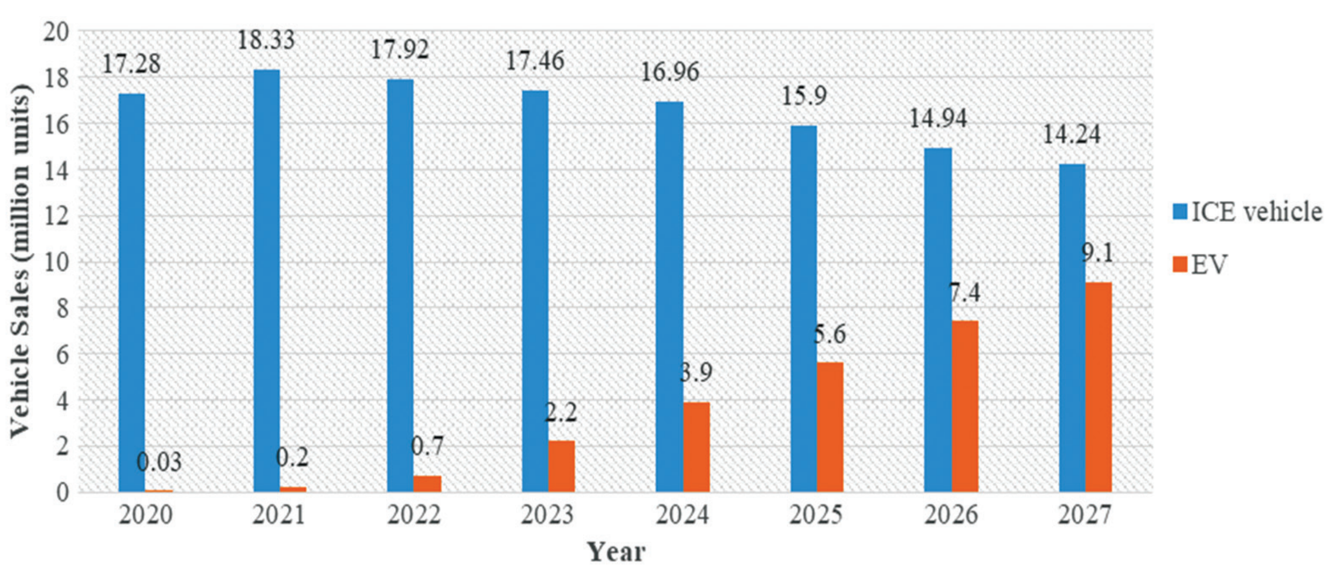

Figure 1. Sales Predictions for Internal Combustion Engine and EVs Sales in India[1]

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India's EVs sector is anticipated to experience significant growth, with sales estimated to reach 9.1 million units by 2027 (Fig. 1). Consequently, the demand for EV components, such as batteries, is projected to rise sharply and reach $140 billion by 2025. Moreover, India will require 208.3 GWh of Battery Energy Storage System (BESS) by 2029-30.[2]

Circular Economy in the EV Sector

Globally, nations are working on developing charging infrastructure to facilitate EV adoption. However, equal attention must be paid to waste battery management, a key component of the EV value chain. After multiple usage cycles, the battery reaches a stage where it is no longer appropriate for vehicular applications. Depending on their charge state and capacity, they may be repurposed for stationary energy storage applications before eventually requiring disposal.[3] Many minerals used in EV batteries, like lithium, nickel, cobalt, and manganese, are designated critical minerals by India's Ministry of Mines.[4] These resources are not just economically valuable but also pose significant hazards to human health and the environment if disposed of in landfills.[5] The Battery Waste Management Rules (2025) mandate that producers of e-waste, including batteries, ensure their disposal in a scientifically designed manner.[6]

The industrial recycling supply chain starts with collecting and transporting end-of-life batteries to recycling units. Pretreatment involves discharging, dismantling, and crushing the batteries, as well as segregation of various components. Recovery of critical minerals involves either pyrometallurgical or hydrometallurgical processes. As of 2020, the global recycling capacity was more than 100,000 tons annually, with Europe having an annual recycling capacity of 52500 tons, China (33500 tons) and the US (11000 tons). India's current capacity is just 2,000 tons but is projected to reach 30000 tons by 2030.[7]

In countries like Japan and the United States, most recyclers employ pyrometallurgy, which is highly energy-intensive. Hydrometallurgical and mechanical processes are considered more environmentally sustainable but demand significant water resources and rigorous effluent management. Emerging laboratory-scale technologies, such as green adsorbents, ionic liquids and other chemical agents, offer promise for eco-friendly metal recovery.

India's Role in Global EV Progress and Circularity

India ascends as a pivotal player in clean mobility, underscored by substantial progress in research, innovation and skilled human resources. The Global Innovation Index (2023-24) shows India is at the top in the lower-middle-income countries and 39th in the overall innovation ranking. Remarkably, four Indian innovation clusters (Delhi, Mumbai, Chennai, Bengaluru) feature in the global top 100. India ranks 8th for factors such as finance for startups & scaleups and unicorn valuation % GDP.[8]

Key policy frameworks such as the National Electric Mobility Mission Plan (NEMMP) 2020 and the recently launched National Critical Mineral Mission (NCMM) 2025 aim to develop India's clean mobility sector holistically. The country is also positioning itself to provide trained and skilled human resources to the EV industry. The nation's premier academic institutions, such as the Indian Institute of Technology (IITs) and National Institute of Technology (NITs), are collaborating with leading automotive manufacturers (e.g. Mahindra and Mahindra, Tata Motors, Maruti Suzuki, and Bajaj Auto) to establish an innovative and industry-ready workforce.

Science Diplomacy to Strengthen the Circular EV Ecosystem

With increasing demand for EVs and, subsequently, batteries, it is necessary to examine the preparedness of the mining industry to meet the continuous demand for critical minerals. In 2022, the global lithium supply was 678 kilotons, projected to rise to about 4000 kilotons by 2035, calling for robust futuristic planning to meet the growing demands for minerals (Table 1).[9]

Table 1. Projected Global Demand for Raw Materials in EV Batteries by 2035[9]		
Raw Material	**Global Supply (2022, kilotons)**	**Global Demand (2035, kilotons)**
Lithium	678	4000
Cobalt	177	489
Nickel	3160	6200
Natural Graphite	1100	7210
Synthetic Graphite	2100	5200

Presently, two countries, Australia and Chile, supply 77% of global lithium, while Indonesia contributes more than half of the global nickel requirement. The existing intricately interwoven dynamic geopolitical tapestry of the critical mineral supply chain raises concerns about the long-term availability and access to these metals (Table 2).

Table 2. Geographical Availability of Selected Critical Minerals[10]		
Mineral	**Country**	**Share in Global Supply (%)**
Lithium	Australia	37
Nickle	Indonesia	59
Cobalt	Congo	76
Manganese	South Africa	37
Antimony	China	60
Vanadium	China	70
Tantalum	Congo	42
Magnesium	China	95
Barite	India	32

Batteries differ significantly in design and composition across manufacturers, complicating recycling standardisation. To tackle this, international cooperation in science, technology, and policy is imperative. Collaborative research and development in AI-powered systems can automatically detect battery types, assess their state of health, and determine whether they should be reused, repurposed, or recycled. AI, through the application of reverse logistics, can help optimise the entire recycling value chain through a transparent connection between major stakeholders, including EV users, waste battery collection and treatment units and supply of recycled metals to the required application. It can assist in predicting material recovery yields, automate disassembly processes, and guide robotic systems to extract metals safely. AI can also aid in creating data-driven strategies for logistics, inventory, and sustainability tracking, enabling companies to meet environmental regulations and improve circular economy outcomes in the EV battery ecosystem. Joint collaborative research and development projects will further help to leapfrog recycling technologies.

Some of the positive initiatives have already been underway. For instance, the India-EU Trade & Technology Council (TTC) made a joint call for the expression of interest of startups and SMEs in establishing recycling facilities and collaborating for a smoother transition towards carbon neutrality.[11] A collaborative project between NITI Aayog and the Government of the United Kingdom aims to prepare a roadmap for battery recycling.[12] Further, initiatives such as the Mineral Security Partnership (MSP), a multilateral initiative involving 14 countries and the EU, underscore the need for diversification and strengthening the supply of global critical minerals.

Despite these initiatives, the global recycling policy landscape remains fragmented. The value chain of batteries is quite complex, involving multiple stakeholders, including battery producers, EV manufacturers, consumers, battery collectors, dismantlers, refurbishers, and recyclers. Figure 2 shows the stages and stakeholders involved in a circular EV waste battery value chain. Varied policies, geographical dispersion of stakeholders, and inconsistent standards hinder efficient cross-border collaboration. The lack of transparency, combined with geopolitical uncertainties, poses severe sustainability challenges.

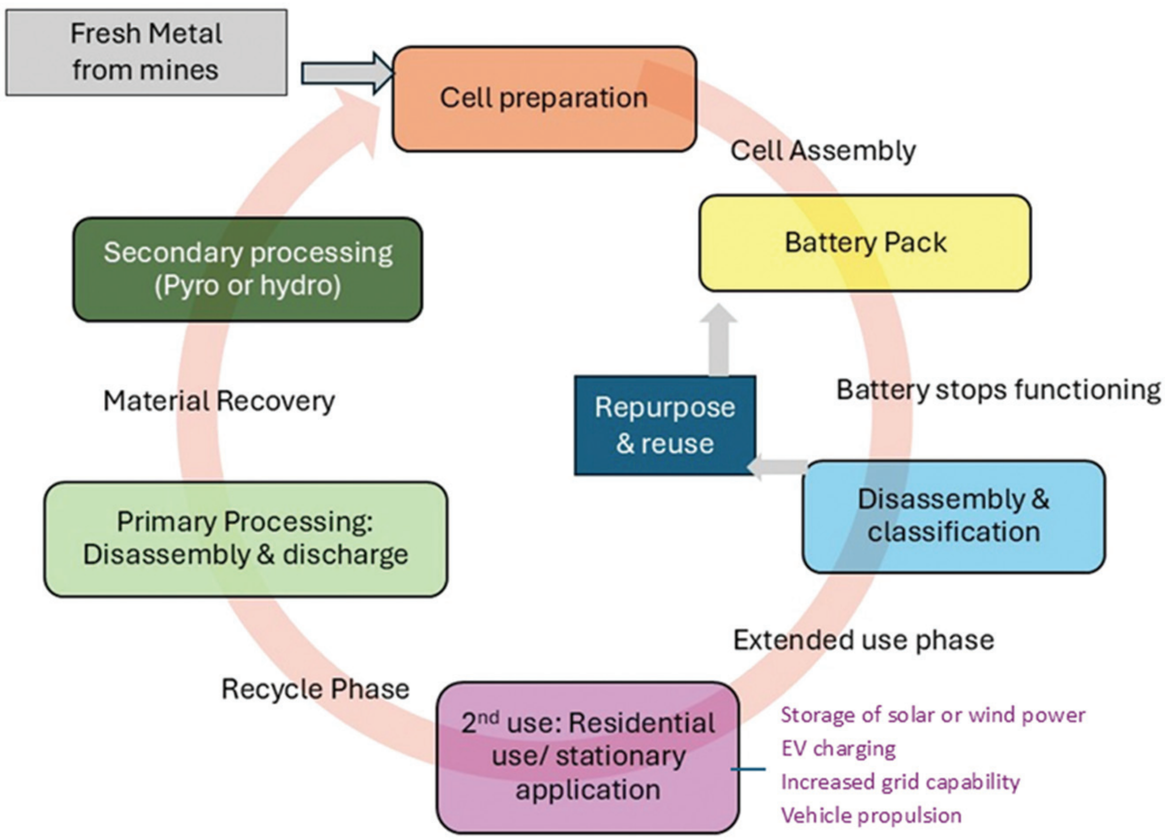

Figure 2. Circular Economy in the EV Batteries Value Chain

With the continuous global focus on expanding EVs, it is essential to establish clear and transparent global frameworks and greater international collaboration to develop a sustainable and profitable recycling system. Global funds can be established to support various clean recycling technologies that have the potential to add to the circularity of waste batteries; however, they are still at a low readiness level. For a global sustainable mobility ecosystem, it is essential to include technology transfer and global co-development for innovative battery chemistry and standardisation of recycling technologies.

Germany's Gemeinsames Rücknahmesystem Batterien (GRS Batteries) program is one of the initiatives to generate consumer awareness about the leaching of metals to soil and water from batteries disposed of in landfills. Presently, the EV battery ecosystem suffers due to the "bystander effect", as consumers are unaware of the environmental and human health hazards posed by the unscientific disposal of waste batteries.

Conclusion

To realise its EV goals while safeguarding environmental and economic interests, India must advocate for and help establish a unified global framework. Adopting and contributing to a secure, AI-enhanced "battery passport" system is crucial, with India leveraging its IT prowess. Moreover, proactive public engagement and incentivised return schemes are vital. India must actively participate in international R&D collaborations to advance recycling technologies, potentially focusing on low-carbon methods. Market-based incentives and harmonised logistics are needed to drive sustainable practices. By embracing a circular economy approach into its EV policy, India can not only meet its climate goals but also position itself as a global leader in sustainable mobility.

References

1. EY Parthenon, INDUSLAW, IVCA (2022) Electrifying Indian Mobility. https://induslaw.com/publications/pdf/alerts-2022/Electrifying-Indian-Mobility-Report-July-2022.pdf
2. Niti Aayog Report (2024) Developing Chemistry agnostic standards for energy storage technologies. https://www.niti.gov.in/sites/default/files/2024-07/Final%20report_for%20approvl_Chemistry_Agnostic_Standards.pdf
3. Kampker A, Heimes HH, Offermanns C, Frieges MH, Graaf M, Soldan Cattani N, Späth B (2023) Cost-Benefit Analysis of Downstream Applications for Retired Electric Vehicle Batteries. World Electric Vehicle Journal, 14 (4):110. https://doi.org/10.3390/wevj14040110
4. Ministry of Mines (2023) Critical Minerals for India. https://mines.gov.in/admin/download/649d4212cceb01688027666.pdf
5. Kaur PJ, Karuturi P, Malhotra R (2023) Building a Resilient Battery Value Chain. T20 India Policy Brief. https://t20ind.org/research/building-a-resilient-ev-battery-value-chain/
6. Battery Waste Management Rules (2025), The Government of India. https://cpcb.nic.in/rules-5/
7. NITI Aayog and Green Growth Equity Fund Technical Cooperation Facility, Advanced Chemistry Cell Battery Reuse and Recycling Market in India, May 2022. https://www.niti.gov.in/sites/default/files/2022-07/ACC-battery-reuse-and-recycling-market-in-India_Niti-Aayog_UK.pdf
8. GII (2024) https://www.wipo.int/web-publications/global-innovation-index-2024/en/
9. Maisel F, Neef C, Weidemann FM, Nissen N F (2023) A forecast on future raw material demand and recycling potential of lithium-ion batteries in electric vehicles. Resources, Conservation & Recycling, 192:106920. https://doi.org/10.1016/j.resconrec.2023.106920
10. U.S. Geological Survey (2025) available at https://tableau.usgs.gov/views/MCS2025_Workbook_01-28-2025_Public/MCSDashboard?%3Aembed=y&%3Aiid=1&%3AisGuestRedirectFromVizportal=y
11. PIB (2024) EU-India join forces to promote start-up collaboration on Recycling of E-Vehicles Batteries under Trade and Technology Council. https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=2017521
12. Vishvakarma S (2024) Lithium battery recycling: Opportunities, challenges, and sustainable practices. https://www.pv-magazine-india.com/2024/03/18/lithium-battery-recycling-opportunities-challenges-and-sustainable-practices/#:~:text=This%20policy%20enforces%20Extended%20Producer,battery%20reuse%20and%20recycling%20market.

Perspective

India's STI Landscape Needs Urgent Action for SDGs Success

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Introduction

Progress towards achieving the Sustainable Development Goals (SDGs) is increasingly driven by leveraging Science, Technology and Innovation (STI) at the grassroots level. Creating a sustainable world necessitates dismantling disciplinary boundaries to strengthen inter-, trans- and multidisciplinary cooperation.[1] India's approach to achieving the UN SDGs rightly emphasises advancing along a sustainable development pathway.

The vision of an *Atmanirbhar Bharat* (self-reliant India) is aligned with the broader goals of sustainable development, incorporating social scientific inclusion, economic growth, and environmental sustainability into the mandates and agendas of the Indian government. Key focus areas include self-reliance, indigenous technological developments, health security, food, energy and cyber security—all instrumental in realising STI-related SDG targets.

None of these objectives can be effectively advanced without the collaboration and active involvement of economic and social ministries, as well as state governments. The 2030 Agenda for Sustainable Development, adopted by the United Nations General Assembly, includes 17 SDGs and 169 associated targets.[1] This comprehensive action plan is centred on five key pillars: people, planet, prosperity, peace, and partnership, under the overarching commitment of "Leaving no one behind."

Countries are responsible for monitoring, reviewing, and evaluating their area-specific progress towards the SDGs and must continue these efforts until 2030. Accelerating STI for SDGs requires harnessing successful experiences to enable sustainable development transformations.[2,3] Equitable promotions of all dimensions of human development in the face of emerging global challenges is key to shaping a forward-looking development trajectory for the 21st century.

Three critical data sources inform India's path to achieving the SDGs by 2030: Sustainable Development Report 2024 (Dublin University), India's State-wise Performance on SDGs (SDG Index 2023-24, NITI Aayog), and the Report of the Technical Group on Population Projections 2011-2036 (Ministry of Health and Family Welfare).[4,5] This article explores the convergence of India's national development priorities and STI goals with the SDGs.

Overview of India's Progress in Global Sustainable Development

As we reach the halfway point in the timeline to achieve the United Nations SDGs—agreed upon by all

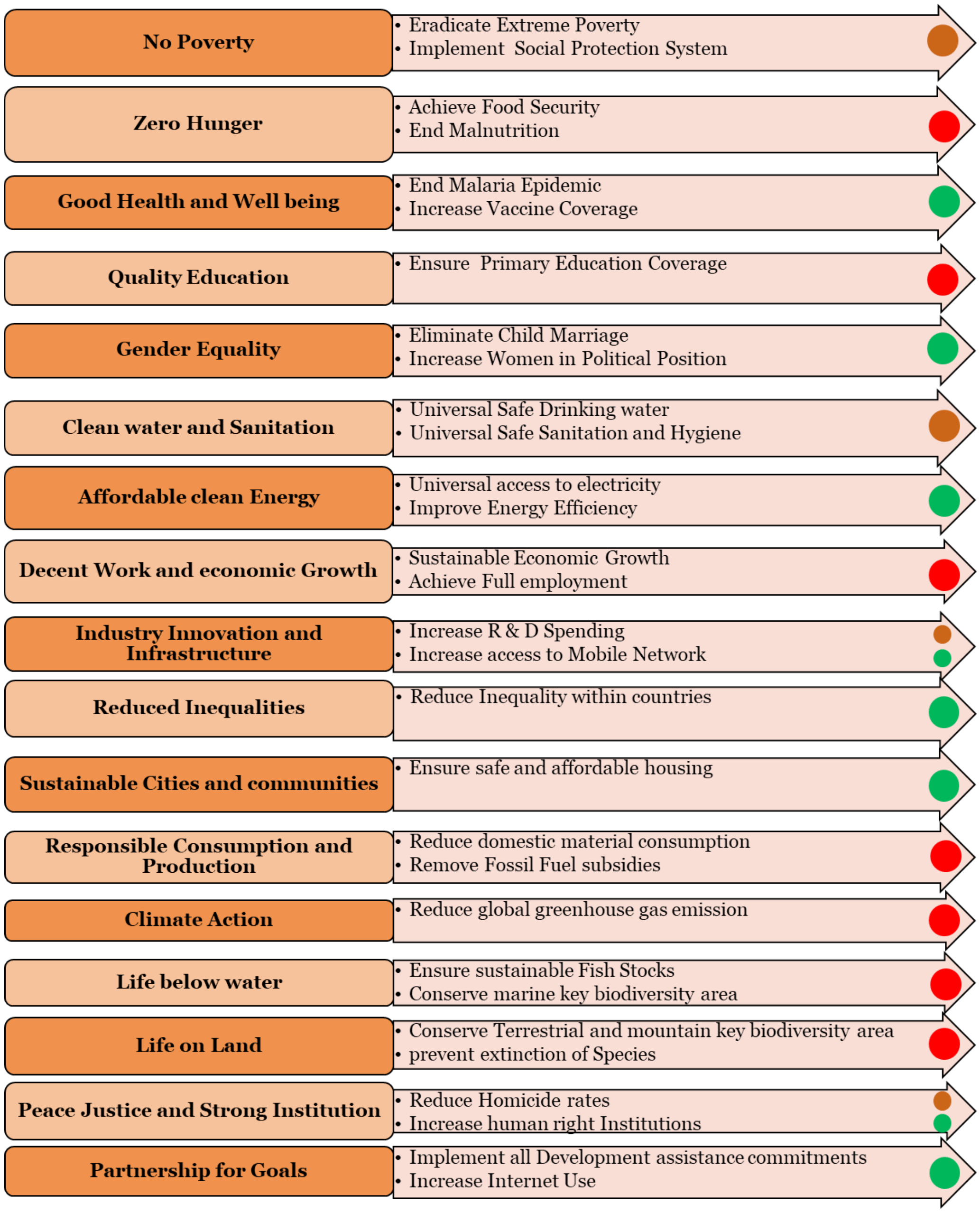

Figure 1. Snapshot of SDGs Progress (Source: Global Sustainable Development Report, 2023)
*Green: Fair progress but acceleration needed; Red: Deterioration; Brown: Limited or no Progress

countries in 2015 for completion by 2030—it is clear that significant challenges remain.[6] According to the Global Sustainable Development Report (GSDR) 2023, the World is not on track to achieve any of the 17 SDGs. The report underscores the urgency of proactive intervention, as progress will not occur automatically.

The national-level monitoring of SDG progress in India is primarily managed by NITI Aayog. The latter works closely with the Ministry of Statistics and Programme Implementation (MoSPI). Initially comprising 306 indicators, SDG framework has been revised to 295 national indicators that align with the 169 SDG targets and the Global Indicators Framework. In addition to 295 indicators, 62 priority indicators have been identified for measuring India's most essential developmental goals. However, certain key indicators, particularly those aligned with the global SDG list, are necessary for meaningful global comparisons and identifying specific gaps.[7-9] As per the STI for SDGs Roadmaps, the need for a clearer conceptual framework has been highlighted.[10,11] India's SDG framework shows gaps across several goals, including:

1. SDG 1 (No Poverty): The indicator for eradicating extreme poverty was removed in the 2023-24 government assessment.
2. SDG 6 (Clean Water and Sanitation): The measurement of the water quality indicator is missing.
3. SDG 7 (Affordable and Clean Energy): Indicators related to CO_2 emissions from fuel combustion and the share of renewable energy in total final energy consumption are not included.
4. SDG 11 (Sustainable Cities and Communities): Lacks parameters on air quality and public transport.
5. SDG 12 (Responsible Consumption and Production): No metrics for electronic waste.
6. SDG 14 (Life below Water): Of the five indicators listed, three have no targets for 2030.

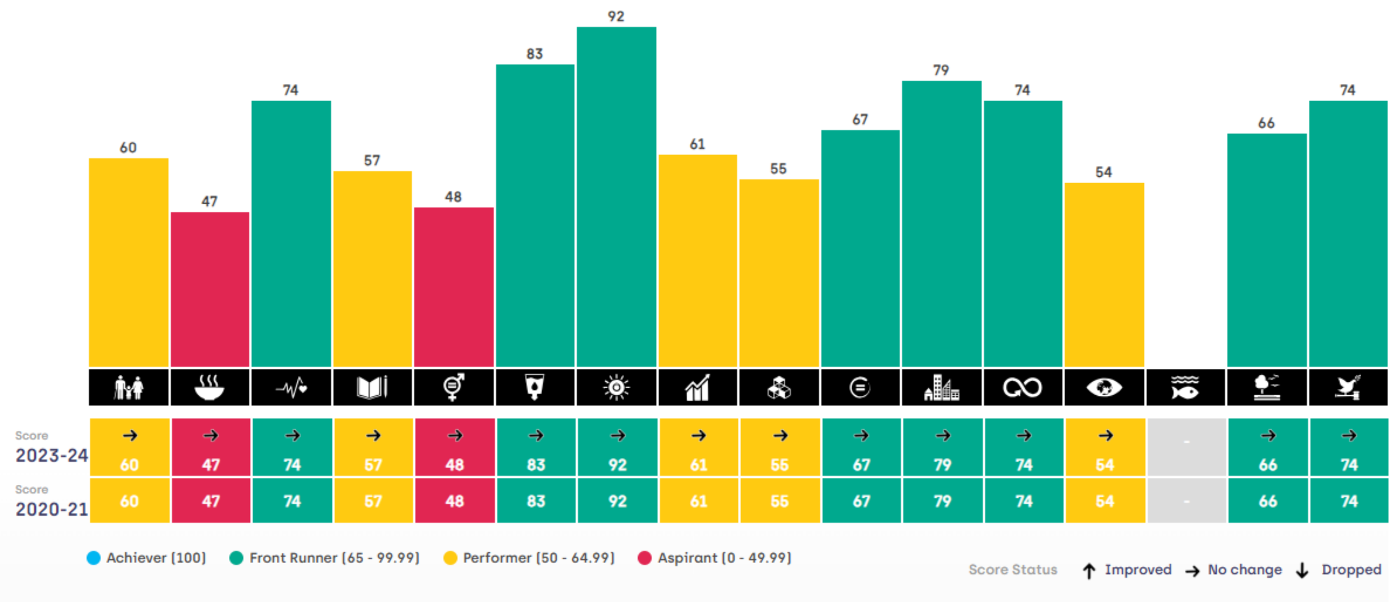

Figure 2: India's Goal-wise SDG Performance (2023-24 & 2020-21) (Adapted from the SDG India Index and Dashboard, |iTech Mission, accessed on 21 May 2025)

For effective monitoring and review, SDG indicators must be problem-oriented and tailored to national and regional dashboards. These should also integrate with Technology Readiness Levels (TRLs) to aid the progress towards Agenda 2030 and align with India's Vision @2047.

Despite some improvements, the GSDR 2023 warns that at the current pace, India is unlikely to eliminate poverty, end hunger, or provide quality education for all by 2030[11] (Figure 2; Table 1).

Table 1. Projected Impact Indicators by 2030 (GSDR 2023)

Indicator	Affecting Population/System
Poverty	575 million
Hunger	600 million
Children out of school	84 million
Global temperature rise	1.5 ^{0}C
Gender equality	300 years

Given these projections, tracking progress becomes complex and urgent. There is a pressing need to formalise mandates and fully leverage the role of STI in creating inclusive and sustainable socio-economic development. Global leaders must act decisively and accelerate progress in STI for sustainable development.[12-15]

Proposed Solution and Policy Recommendations

STI has been a significant component in operationalisation, monitoring and evaluation of the SDGs. However, one of the greatest challenges facing countries today is how to accelerate the delivery of sustainable solutions across a range of pressing issues—from poverty and education to innovation, gender equity, and climate change.[16,17] Acceleration in these areas can bridge inequalities and help close the financing gap for development. This section highlights three priority areas for policy action: Accelerating R&D trajectories, identifying transformative pathways, and improving governance mechanisms for SDG implementation.

Accelerating R&D Trajectories

Innovation competitiveness and economic growth —driven by both public and private sector investment—are essential components of a knowledge-based economy and directly influence the achievement of SDG targets. The effectiveness of R&D policy and its alignment with SDG ambitions relies on how governments set priorities, allocate resources, and evaluate progress.[18]

A goal-oriented R&D policy framework is essential to allocate resources towards identified indicators. India's commitment to becoming a developed nation by 2047 underscores the need for significant shifts in its R&D ecosystem. This transitional phase demands a strong foundation of indigenous R&D capacity and innovation-driven solutions tailored to national and global development goals.[19,20]

India has made substantial progress in the innovation metrics, moving to 39th place in the Global Innovation Index within a decade. However, further progress requires bolstering foundational aspects, including improving school education, enhancing the number and quality of professionals in R&D, and increasing employment in knowledge-intensive industries.

Encouragingly, Indian government departments are increasingly acting as buyers of indigenous, technology-based products developed by deep-tech start-ups and large enterprises alike.[21] Supportive policy initiatives in favour of technological indigenisation and advanced innovation can help build industrial capabilities, strengthen human capital, and foster innovative manufacturing ecosystems.[22] These efforts will ultimately enhance India's innovation outcomes, competitiveness, and global standing.

Identification Transformative Pathways

India's aspiration to become a global technology leader hinges on identifying and advancing transformative, self-reliant development pathways. This entails reinvigorating efforts to develop and democratise critical sector technologies through indigenous innovation and diffusion strategies. Solutions rooted in the knowledge economy must be systematically leveraged to coordinate structures that enable progress across the SDGs while addressing global challenges.[21-22] A focused diversification strategy in science education, research, and innovation is critical to bridging SDG gaps and ensuring inclusive progress.

Diversity must be central to this effort—regardless of gender, geography, social status, or economic conditions. This requires recognising and strengthening the contributions of diverse stakeholders—government schemes, private initiatives, and civil society actions—in reducing inequities and fostering inclusive development.

Improving Governance for SDGs

There is an urgent need to integrate "sustainable technologies" into mainstream governance and ensure that technology development efforts address multiple SDGs synergistically. Past experience developing and deploying context-appropriate technologies that have yielded measurable grassroots socio-economic benefits must inform current STI funding and innovation policies. A culture of collaboration, particularly between STI institutions and various government tiers, must be nurtured to solve challenges faced by small enterprises, informal sector workers, and marginalised communities.[22-23] Cross-sectoral and cross-institutional coordination is crucial to implementing timely, context-sensitive, and scalable STI solutions for sustainable development.

Conclusion

Currently, at least 45 countries have defined R&D intensity goals that are closely linked to their ability to achieve the SDGs. A nation's R&D intensity is indicative of its innovation capacity and the adaptability of its technology to local development contexts. Robust support systems are needed to foster the development, deployment, and commercialisation of sustainability-oriented technologies across the STI ecosystem. Establishing centralised and regional SDG monitoring dashboards and integrating Technology Readiness Levels (TRLs) can facilitate systematic progress tracking and evidence-based policy decisions. In the post-COVID world and amid geopolitical disruption, it is imperative to assess how STI ecosystems are contribute to the SDGs. A forward-looking policy framework must be developed to reposition STI as a core pillar of 21st-century sustainable development agendas.

References

1. Roberts EB (2001) Benchmarking global strategic management of technology. *Research Technology Management,* 44(2): 25–36.
2. Filho L W, Santos Senise R, Mirra E (2012) Innovation systems and sustainability: an approach for regional clustering and MNCs subsidiaries. *World Review of Science, Technology and Sustainable Development*, 9(1):56-73. https://doi.org/10.1504/WRSTSD.2012.044787
3. Siegel DS, Waldman D, Link A (2003) Assessing the impact of organizational practices on the productivity of university technology transfer offices: an exploratory study. *Research Policy*, 32: 27–48. https://doi.org/10.1016/S0048-7333(01)00196-2.
4. United Nations, Department of Economic and Social Affairs, Population Division (2011). World Population Prospects: The 2010 Revision, Volume I: Comprehensive Tables. ST/ESA/SER.A/313.
5. UNWCED SWS (1987) Report of the World Commission on Environment and Development: Our Common Future. https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf
6. United Nations (2013) World Economic and Social Survey 2013: Sustainable Development Challenges. UN, New York. https://doi.org/10.18356/d30cb118-en
7. Global Education Monitoring Report (2016) Education for people and planet: creating sustainable futures for all. https://www.unesco.org/gem-report/en/education-people-and-planet
8. Secretariat of the Convention on Biological Diversity (2012) Cities and Biodiversity Outlook—Executive Summary. Montreal, 16 pages. https://wedocs.unep.org/20.500.11822/32431
9. United Nations Habitat (2020) World Cities Report 2020: The Value of Sustainable Urbanization. UN Habitat. 418 pages.
10. World Economic Forum (2023) Global Health and Healthcare Strategic Outlook: Shaping the Future

of Health and Healthcare. https://www3.weforum.org/docs/WEF_Global_Health_and_Healthcare_Strategic_Outlook_2023.pdf

11. Malekpour S, Allen C, Sagar A, Scholz I, Persson Å, *et al.* (2023) What scientists need to do to accelerate progress on the SDGs. *Nature*, 621(7978): 250–254.

12. World Health Organization (WHO) (2021) Global strategy on digital health 2020–2025. Geneva: World Health Organization.

13. Smith A, Stirling A, Berkhout F (2005) The governance of sustainable socio-technical transitions. Research Policy, 34(10): 1491–1510. https://doi.org/10.1016/j.respol.2005.07.005

14. Stamm A, Dantas E, Fischer D, Ganguly S, Rennkamp B (2009) Sustainability-oriented innovation systems: towards decoupling economic growth from environmental pressures?. Discussion Paper, No. 20/2009, ISBN 978-3-88985-470-4, Deutsches Institut für Entwicklungspolitik (DIE), Bonn.

15. Stewart J, Hyysalo S (2008) Intermediaries, users and social learning in technological innovation. *International Journal of Innovation Management*, 12(3): 295–325. https://doi.org/10.1142/S1363919608002035

16. United Nations Department of Economic and Social Affairs (2019) The Sustainable Development Goals Report 2019. https://doi.org/10.18356/55eb9109-en

17. UNCTAD (2019) A Framework for Science, Technology, and Innovation Policy Reviews: Harnessing Innovation for Sustainable Development. https://unctad.org/publication/framework-science-technology-and-innovation-policy-reviews

18. Kemp R (2011) Innovation for Sustainable Development as a Topic for Environmental Assessment. *Journal of Industrial Ecology*, 15(5): 673–675.

19. Tundisi JG, Tundisi TM (2017) Science, Technology, Innovation and Water Resources: Opportunities for The Future. In: de Mattos Bicudo CE, Tundisi JG, Scheuenstuhl MCB (Rds.) Waters of Brazil: Strategic Analysis. Springer Cham, pp 149–169.

20. Udmale P, Pal I, Szabo S, Pramanik M, Large A (2020) Global food security in the context of COVID-19: A scenario-based exploratory analysis. *Progress in Disaster Science*, 7: 100120.

21. UNCTAD (2018) World Investment Report 2018. Investment and Industrial Policies. https://unctad.org/en/PublicationsLibrary/wir2018_en.pdf.

22. Tapscott D, Williams AD (2006) Wikinomics: How Mass Collaboration Changes Everything. Portfolio, New York. ISBN: 1-4362-3403-4.

23. Tagliaventi MR, Bertolotti F, Macrì DM (2010) A perspective on practice in interunit knowledge sharing. European Management Journal, 28(5): 331–345. https://doi.org/10.1016/j.emj.2010.04.001

Towards a New Paradigm of Science Diplomacy through Strategic Anticipation and Foresight

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Rethinking Science Diplomacy for a Rapidly Changing World

The accelerating pace of scientific and technological advancement is disrupting traditional models of diplomacy. In this rapidly evolving global landscape, there is an urgent need to cultivate a new generation of leaders - those equipped not merely to react but to anticipate and shape the future with strategic foresight. As nations become more interconnected across domains of research, technology supply chains, and manufacturing, the concept of scientific and technological autonomy becomes more complex. True autonomy is not about developing every technology indigenously. Rather, it involves securing resilient access to critical technologies through a blend of domestic capabilities, strategic alliances, and international cooperation. The extent of autonomy a country can realistically pursue depends on

Source: Geneva Science Diplomacy Week 2025 its ambitions within global science and technology ecosystems and its control across the value chain. Here, science diplomacy emerges not as an end goal but as a key enabler - empowering nations to drive innovation, navigate interdependence, and shape inclusive, future-ready development agendas.

Science diplomacy is increasingly recognised as a mechanism for nations to exert influence through the production, exchange, and governance of scientific knowledge. While rooted in principles of transparency, ethics, and shared responsibility, it is equally shaped by the complex realities of power dynamics, geopolitical competition, and systemic crises. In today's context, marked by pandemics, climate shocks, digital disruption, and new forms of conflict, science diplomacy must bridge the idealistic and the pragmatic. Over the past seven decades, science has become central to global politics. Institutions like the IPCC and CERN exemplify how scientific collaboration underpins diplomacy and multilateralism. Yet, the global order is shifting. Geopolitical tensions and fiscal pressures strain multilateral frameworks. In response, science diplomacy is increasingly driven by bilateral, regional, and non-state actors - from tech giants and private labs to transnational civil society. This calls for a reimagined model of diplomacy that extends beyond statecraft into a dynamic, ecosystem-wide engagement. Leaders must be prepared to navigate this terrain, not just as diplomats but as systems thinkers and coalition-builders who can harness science diplomacy to safeguard autonomy, strengthen resilience, and catalyse shared global progress.

GESDA: Geneva Science and Diplomacy Anticipator

Founded in 2019, the Geneva Science and Diplomacy Anticipator (GESDA) brings together the Federal Government of Switzerland, the Republic and Canton of Geneva, and the City of Geneva to strengthen Geneva's role as a hub for multilateralism and innovation. Its motto, "Use the future to build the present", reflects a unique mission: anticipate scientific breakthroughs and translate them into global action. GESDA's dual identity as both a think tank and a "do tank" positions it at the nexus of science, diplomacy, and societal impact. It builds on Geneva's long-standing legacy of hosting international scientific institutions and diplomatic bodies. Born from the 2015 Geneva+ initiative, GESDA was created to:

1. Anticipate and assess the implications of technological advancements on global affairs
2. Break down silos between scientific communities, policymakers, and the private sector
3. Forge innovative partnerships to address cross-cutting global challenges

In an age where science progresses exponentially, GESDA's anticipatory framework enables global actors to co-develop timely, inclusive, and actionable responses, particularly benefiting emerging economies and underrepresented stakeholders.

GESDA's Science Diplomacy Week 2025

The 2025 edition of GESDA's Science Diplomacy Week brought together 36 emerging leaders from around the world for an immersive learning and networking experience. With backing from Wellcome Trust, this initiative reflects GESDA's broader mission: to develop a new generation of anticipatory leaders in science diplomacy. A centrepiece of GESDA's approach is its Science Breakthrough Radar, an annual foresight report that maps emerging technologies over 5-, 10-, and 25-year horizons. The latest edition covers 40 breakthrough topics across five scientific domains, integrating perspectives from the Pulses of Science, Diplomacy, Impact, and Society. Martin Müller, GESDA's Executive Director of Science Anticipation, introduced how this radar informs all GESDA programming during the GESDA's Science Diplomacy Week 2025.

Insights: Anticipatory Science Diplomacy in Practice

GESDA's Science Diplomacy Week 2025 strongly emphasised on strategic anticipation - the ability to


Source: Geneva Science Diplomacy Week 2025

use foresight not just for long-term visioning but to inform present-day decision-making. The focus was on moving beyond reactive governance to proactively detect weak signals, interpret emerging trends, and co-develop adaptive strategies that support organisations and countries in navigating complexity and uncertainty.

One highlight was the Science in Diplomacy Lab (SiDLab) at the University of Geneva (UNIGE), which demonstrated how computational tools and systemic analysis can strengthen science diplomacy. By leveraging computational science, SiDLab showcased how policymakers can quantify uncertainties and better understand the science-policy interface - deepening insights into the mechanisms driving foreign policy and international cooperation. The program also incorporated experiential learning through innovative simulations like The Neurotechnology Diplomacy Game, where participants grappled with the fallout of a hypothetical ransomware attack on brain implants. These role-based simulations enabled participants, spanning scientists, diplomats, industry leaders, and citizens, to explore the ethical, political, and technical dilemmas posed by science-driven futures. Such exercises challenged assumptions and encouraged integrative thinking, offering a safe space to test policy responses and rehearse future scenarios.

At the heart of the program was strategic anticipation as an action-oriented skillset - the ability to apply foresight to real-world governance. Participants engaged in exercises that explored future scenarios of global governance, learning how to differentiate between emerging trends and weak signals. Special focus was given to technologies with exponential growth, such as AI-assisted systems, autonomous weapons, deepfakes, and synthetic biology, and the compounding security risks they present. As technological change accelerates, the potential for systemic disruption rises, underscoring the critical role of anticipatory diplomacy. Future science diplomacy leaders must be equipped not only to understand scientific breakthroughs on the 5, 10, and 25-year horizon, but also to assess their social, political, and planetary impacts. Anticipatory methods grounded in cutting-edge science and diplomacy can enhance negotiation, conflict resolution, and global governance in an era of cascading global challenges.

Leveraging Anticipatory Science Diplomacy Tools for India

India's emergence as a scientific and technological power is both promising and complex. In a world where breakthroughs in AI, synthetic biology, and neurotechnology are reshaping diplomacy, governance, and global cooperation, India must harness anticipatory science diplomacy, not merely as a tool of engagement but as a strategic capacity for shaping its future. Insights from the GESDA Science Diplomacy Week 2025 offer valuable lessons. They emphasise that anticipatory diplomacy is not about prediction alone, it's about preparing institutions, ecosystems, and leaders to detect weak signals, interpret emerging trends, and co-create inclusive, adaptive responses. It demands a systems mindset and the ability to operate across science, policy, and society. This approach is critical for India as it navigates rapid technological shifts, national ambitions, and global responsibilities. To realise this vision, India must act across three strategic dimensions:

1. Building Integrated Innovation Ecosystems - India's talent, institutions, and startups are world-class but fragmented. Siloed operations and limited cross-pollination between research, industry, and policy constrain their collective impact. An ecosystem-wide engagement model should foster mission-driven collaboration, bringing together scientists, diplomats, entrepreneurs, and civil society to align innovations with long-term national and planetary goals.
2. Institutionalising Foresight and Anticipation - Strategic anticipation must be cultivated as a core leadership skill. GESDA's simulations and the Science Breakthrough Radar illustrate how structured foresight can guide real-time governance. India should establish dedicated Centers of Excellence in Anticipatory Science Diplomacy, serving as interdisciplinary hubs for research, training, and policy experimentation. These centres can simulate future scenarios, develop response strategies, and serve as incubators for science-policy talent.
3. Thinking Globally, Acting Locally - India's innovation trajectory must be globally informed yet contextually rooted. Learning from international best practices, whether in CERN's open science model or SiDLab's use of computational tools, can enhance local capability. Indian institutions must internalise the "Think Global, Act Local" ethos to tackle uniquely Indian challenges, from agritech to healthcare, with scalable, globally relevant solutions.

By embedding anticipatory tools and mindsets across its science diplomacy architecture, India can position itself not just as a participant but as a shaper of global futures. This is not only a strategic imperative, but it is also a responsibility to ensure that the benefits of scientific progress are inclusive, ethical, and sustainable for all.

NEWS

EU and India Launch Joint Initiatives on Marine Pollution and Green Hydrogen

India and the European Union have come together to advance innovative research aimed at addressing two pressing global challenges: marine pollution and clean energy. In a joint announcement, the EU Delegation to India revealed the launch of two major research and innovation initiatives under the EU-India Trade and Technology Council (TTC), with a combined investment of €41 million (approximately ₹394 crore). These initiatives focus on finding cutting-edge solutions to combat marine pollution and on the development of waste-to-renewable hydrogen technologies. The coordinated research efforts reflect the deepening strategic partnership between the EU and India, driven by shared values and mutual commitment to sustainability, environmental protection, and clean energy transition. The funding will support collaborative projects between Indian and European research institutions, industries, and start-ups, with an emphasis on interdisciplinary research and near-market technologies. This move is seen as a significant step towards aligning research priorities and fostering science-based policymaking. The EU-India collaboration under the TTC is designed to address global challenges through joint innovation, and these new initiatives reaffirm the central role of science and technology in driving sustainable development, environmental resilience, and economic growth across both regions.

India to Build First-Ever Polar Research Vessel in Collaboration with Norway

India is set to build its first-ever Polar Research Vessel (PRV) through a strategic collaboration between Garden Reach Shipbuilders and Engineers Ltd. (GRSE), Kolkata, and Norway's Kongsberg. This milestone agreement aims to enhance India's self-reliance in advanced research vessel construction and significantly boost polar and oceanographic research capabilities. The PRV will be equipped with cutting-edge technology to support multidisciplinary scientific research in the polar and Southern Ocean regions. Designed to meet the operational requirements of the National Centre for Polar and Ocean Research, the vessel will facilitate climate studies, marine ecosystem monitoring, and deep-sea exploration, contributing to global efforts in addressing climate change and environmental sustainability. The initiative supports India's broader maritime development goals, including the promotion of indigenous shipbuilding under the Make in India programme. The collaboration also reflects a commitment to scientific advancement, sustainable development, and strengthening international cooperation in ocean science. These engagements aim to position India as a global maritime leader, fostering mutual growth and resilient, eco-friendly maritime infrastructure.

Announcements

2026-2027 Hubert H. Humphrey Fellowship Program
Submission deadline: 10 July 2025

Further information at:
https://www.usief.org.in/fulbright-fellowships/fellowships-for-indian-citizen/hubert-h-humphrey-fellowship-program/

2026-2027 Fulbright-Nehru Postdoctoral Research Fellowships
Submission deadline: 15 July 2025

Further information at:
https://www.usief.org.in/fulbright-fellowships/fellowships-for-indian-citizen/fulbright-nehru-postdoctoral-research-fellowships/

2026-2027 Fulbright-Nehru Doctoral Research Fellowships
Submission deadline: 15 July 2025

Further information at:
https://www.usief.org.in/fulbright-fellowships/fellowships-for-indian-citizen/fulbright-nehru-doctoral-research-fellowships/

TWAS-SN Bose Postgraduate Fellowship Programme
Submission deadline: 22 September 2025

Further information at:
https://twas.org/opportunity/twas-sn-bose-postgraduate-fellowship-programme

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Carl-Zeiss-Humboldt Research Award
Submission deadline: 24 December 2025

Further information at:
https://www.humboldt-foundation.de/en/apply/sponsorship-programmes/carl-zeiss-humboldt-research-award

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EMBO Scientific Exchange Grants 2025
Submission deadline: Throughout the Year 2025

Further information at:
https://www.embo.org/funding/fellowships-grants-and-career-support/scientific-exchange-grants/benefits/

MoUs Signed

India and Denmark Strengthen Energy Sector Cooperation through Renewed Partnership

India and Denmark have reaffirmed their strong energy partnership by signing a renewed Memorandum of Understanding (MoU) on 2 May 2025. The renewed MoU reflects the shared commitment of both nations to advancing clean energy transitions. It supports India's net-zero emissions target by 2070 and builds upon five years of successful cooperation under the previous MoU, originally signed on 5 June 2020. The renewed agreement aims to enhance collaboration in areas such as power system modelling, renewable energy integration, cross-border electricity trade, and electric vehicle charging infrastructure. It also promotes mutual learning through expert interactions, joint training, and study tours. The MoU paves the way for deeper engagement and long-term progress in clean and sustainable energy solutions.

CSIR-CSMCRI, India signs MoU with Pangasinan State University Philippines

In a significant move to strengthen international scientific collaboration, CSIR-Central Salt & Marine Chemicals Research Institute (CSMCRI), Bhavnagar, India, signed a MoU with Pangasinan State University (PSU), Philippines, on 9 June 2025. This partnership aims to jointly develop and promote advanced technologies in salt production. Dr. Kannan Srinivasan, Director, CSMCRI, shared that the collaboration will focus on research and development in areas such as modern salt production, membrane technology, and marine biotechnology. PSU is leading the creation of the Accelerating Salt Research and Innovation (ASIN) Center, a flagship initiative intended to modernise salt production in the Philippines. The Centre will benefit from CSMCRI's vast experience and innovations. To further strengthen this partnership, a Bilateral India–Philippines International Seminar on Advanced Salt, Water, and Marine Technologies was held on 10 June 2025, bringing together researchers, experts, and policymakers from both countries to exchange ideas and explore future opportunities.

New Publications

Açikalin SN, Erçetin SS, Olgun Z (2025) **A Science Diplomacy Scale for Higher Education: a Validity and Reliability Study in Türkiye**. *Janus.net, e-journal of international relations*, 16(1): 38-56. https://doi.org/10.26619/1647-7251.16.1.3

Adamson M, Robinson S, Barrett G, Jacobsen L (2025) **Can science diplomacy keep up with a world in crisis**? *https://blogs.lse.ac.uk/impactofsocialsciences/2025/04/29/can-science-diplomacy-keep-up-with-a-world-in-crisis/*

Camp N, Bachman M (2025) **Challenges and Opportunities for US-China Collaboration on Artificial Intelligence Governance.** *Sandia National Laboratories.* https://www.sandia.gov/app/uploads/sites/148/2025/04/Challenges-and-Opportunities-for-US-China-Collaboration-on-Artificial-Intelligence-Governance.pdf

Castaño VM, Violini G (2025) **Science diplomacy is in trouble.** *Nature Physics.* https://doi.org/10.1038/s41567-025-02911-y

D'Urso G & Giosafatto G (2025) **Space power governance, war and diplomacy: The new challenge for states.** *Media, War & Conflict*, 0(0). https://doi.org/10.1177/17506352251344041

Dinbabo MF, Mazani P (2025) **Sustainable Development Goals (SDGs) and Policy Frameworks for Development in Africa**. *New Agenda: South African Journal of Social and Economic Policy*, 96(1). https://doi.org/10.14426/na.v96i1.2518

Duma S (2025) **Science-Economic Diplomacy: Harnessing the African Continental Free Trade Area (AfCFTA) to Promote Indigenous Technological Capabilities.** Human Sciences Research Council, Policy Brief. https://hsrc.ac.za/wp-content/uploads/2025/06/Sphumelele-Duma-PB.pdf

Fiocco G, Viana TR (2025) **The Brazilian Space Diplomacy for Economic and Social Development from the Dawn of the Space Age to the Present Day.** In: Grosner, I., Froehlich, A. (eds) Space Fostering Brazilian Society. Southern Space Studies. *Springer, Cham.* https://doi.org/10.1007/978-3-031-85680-8_3

Gattuso JP, Houllier F, Adams J, Amon D, Bambridge T, *et al.* (2025) **US federal cuts threaten international ocean science and diplomacy.** *Nature Ecology & Evolution.* https://doi.org/10.1038/s41559-025-02750-3

Gordon HSJ (2025) **Demanding Epistemic Justice: Indigenous Youth as Indigenous Science Diplomats for a Sustainable Future.** *KULA: Knowledge Creation, Dissemination, and Preservation Studies*, 8(1):1-8. https://doi.org/10.18357/kula.301

Haugan P, Shannon L, Agyekum KA, Cárdenas M, Masson-Delmotte V, *et al.* (2025) **Policy Brief: Co-producing ocean actionable knowledge for transformative solutions and global cooperation**. International Science Council. https://council.science/wp-content/uploads/2025/06/ISC-Policy-Brief_co-producing-Ocean-actionable-knowledge_digital.pdf

Hyun J, Iida K (2025) **Contested Collaboration at Boundaries: Transnational Science and Medicine in Cold War East Asia.** *Historical Studies in the Natural Sciences*, 55 (2): 85–95. https://doi.org/10.1525/hsns.2025.55.2.85

Ibrahim RE, Motshegwa T, Benouar D, Khodja M, Ead H, *et al.* (2025) **Sustainable North-South Africa Collaboration for Disaster and Crisis Management: A Strategic Capacity Development Framework using Open Science, Artificial Intelligence and Geoinformatics.** *Data Science Journal*, 24:11. https://doi.org/10.5334/dsj-2025-011.

Ilcic A, Fuentes M and Lawler D (2025) **Artificial intelligence, complexity, and systemic resilience in global governance.** *Frontiers in Artificial Intelligence* 8:1562095. https://doi.org/10.3389/frai.2025.1562095

Kalbande D (2025) **ONOS as a soft power strategy: India's scholarly diplomacy through national access policies**. *Library Hi Tech News.* https://doi.org/10.1108/LHTN-04-2025-0056

Karampekios N, Sioumalas-Christodoulou K (2025) **Knowledge Dynamics in Scientific and Technological Collaboration: The Case of Greece and China.** *Journal of the Knowledge Economy*. https://doi.org/10.1007/s13132-025-02803-9

Kardava C (2025). **International Cooperation in the New Reality.** In: Baimenov, A., Liverakos, P. (eds) Public Administration in the New Reality. *Palgrave Macmillan, Singapore.* https://doi.org/10.1007/978-981-96-3845-1_8

Kim H, Mobrand E (2025) **International science as national project: lessons from South Korea for the future of international research collaboration.** *Studies in Higher Education*, 1–13. https://doi.org/10.1080/03075079.2025.2499951

Kirshenbaum S (2025) **R&D Means Something Different on Capitol Hill.** *Issues in Science and Technology*, 41(3): 86–90. https://doi.org/10.58875/QYTO9572

Mashayekh J (2025) **Techno-regionalism in the post-globalisation era: linking technological cooperation and geopolitical tensions.** *Asian Journal of Technology Innovation*, 1–30. https://doi.org/10.1080/19761597.2025.2496309

Mattes J, Philippe C (2025) **Crossing boundaries, forging unity: nuclear medicine and science diplomacy in Cold War Europe**. *The British Journal for the History of Science*, 1–25. https://doi.org/10.1017/S0007087425000317

Mihalakas AP, Macy T (2025) **Governance of the Global Commons: The role of the UN and International Law in addressing climate change**. *California Western International Law Journal*, 55(2): 257.

Mlambo VH, Masuku MM (2025) **Trouble in the Nile Basin: Ethiopia, Egypt, and Sudan and the Nile stalemate**, *Cogent Social Sciences*, 11(1): 2491851. https://doi.org/10.1080/23311886.2025.2491851

Mohsen AA (2025) **Digital Diplomacy and its Impact on International Relations: A Case Study of USA's Digital Diplomacy. Dirasat**: *Human and Social Sciences*, 52(6), 6843. https://doi.org/10.35516/hum.v52i6.6843

Namdeo SK, Chandan GN (2025) **Scientometric Analysis of Research on Deliberate Biosecurity Threats Reveals North-Transatlantic Dominance.** *Journal of Biosafety and Biosecurity.* https://doi.org/10.1016/j.jobb.2025.04.002

Olasehinde A, Tabale RP, Kwami IA, Usman MB, Mbiimbe EY (2025) **Uncovering Common Ground: Geology's Role in Promoting Global Harmony**. *Continental Journal of Applied Sciences*, 20(1), 100–127. https://doi.org/10.5281/zenodo.15524464

Oreschnikoff A (2025) **Arctic research infrastructures between normative ideals and geopolitical objectives.** *Nordic Review of International Studies*, 436–444.

Paglia E (2025) **Future of the Arctic Council: Science diplomacy, Arctic exceptionalism and innovative governance in a time of geopolitical turbulence.** *Polar Geopolitics. Sweden.* https://coilink.org/20.500.12592/5472rnr. COI: 20.500.12592/5472rnr.

Paintner U (2025) **From Student Exchange through Language Policy towards Science Diplomacy – 100 Years of DAAD**. *Gragoatá*, 30 (66): e65016. https://doi.org/10.22409/gragoata.v30i66.65016.de

Ramakrishnan L, Chadha N (2025) **Global Health Diplomacy: Navigating Politics and Security**. ORF Occasional Paper No. 477. Observer Research Foundation. https://www.orfonline.org/public/uploads/posts/pdf/20250606134208.pdf

Raymonde R (2025) **The relationship between science and policy in the fight against climate change in Haiti**. https://hal.science/hal-05041029v1

Rekvig G, Finger M (2025) **GlobalArctic. The New Dynamics of Arctic Governance.** Palgrave Macmillan Singapore. https://doi.org/10.1007/978-981-96-4868-9

Rentetzi M, Freris L (2025) **How to turn a mobile laboratory into a diplomatic bag: international relations, the IAEA and nuclear diplomacy.** *History and Technology*, 1–26. https://doi.org/10.1080/07341512.2025.2494886

Slobodan Š (2025) **Science diplomacy merging with commercial diplomacy in small and developed countries: case study of Slovenia**. *International Journal of Diplomacy and Economy*, 11(2): 138-158. https://doi.org/10.1504/IJDIPE.2025.145648

Soza F (2025) **Ideas Don't Need Passports: A New Model of Diplomacy for Developing Countries.** *Science & Diplomacy*. https://doi.org/10.1126/scidip.adz5641

Szkarłat M (2025) **Securitization of scientific cooperation**: **The case of the Arctic**. *Polish Polar Research*, 46(1): 5-15. https://doi.org/10.24425/ppr.2025.153919

Tateo A, Kana A (2025) **Recent trends and future issues in science and technology diplomacy.** SciREX core contents. https://scirex-core.grips.ac.jp/en/pdf/scirex_cc_1.5.3.pdf

Thompson KR, Bretos F, Canals P, Besancon C (2025) **Marine protected area networks as tools for Ocean Science Diplomacy: Global lessons from the Gulf of Mexico**. *Marine Policy*, 178: 106709. https://doi.org/10.1016/j.marpol.2025.106709

van Noort C (2025) **Ontological Security and Ocean Science Collaboration.** In: International Collaboration in Ocean Science and Governance. Palgrave Studies in Maritime Politics and Security. *Palgrave Macmillan, Cham.* https://doi.org/10.1007/978-3-031-85378-4_3

Vidal F, Sass L (2025) **Fragmented Arctic science: Permafrost as a salient feature in the divergence between geopolitical and chronopolitical perspectives.** *Polar Science:* 101207. https://doi.org/10.1016/j.polar.2025.101207.

Voth-Gaeddert LE (2025) **Rethinking S&T in U.S. Diplomacy: A Path to a More Adaptive State Department. ASU's Leadership,** *Diplomacy and National Security Lab.* https://osf.io/tmfsn_v1/download/?format=pdf

Wang HH, Miao ML (2025) **Global Development and Cooperation with China. New Ideas, Policies and Initiatives for a Changing World.** *Springer, Singapore.* https://doi.org/10.1007/978-981-96-2452-2_3

Wen W, Chang L, Wu Y, Han F, Zhou L (2025) **How Have China's STI Policies Shaped EU-China Cooperation?** *Journal of Studies in International Education*, 0(0). https://doi.org/10.1177/10283153251315262

Wu AY (2025) **Science diplomacy in Horizon Europea Program: Taiwan´S TSMC as an example for strengthening EU-Taiwan relations.** *UNISCI Journal*, 68: 265. http://dx.doi.org/10.31439/UNISCI-237

Yeung T, Reynolds N, Renda A (2025) **Does EU R&I policy involve low- and middle income countries**? **A look at the evidence from Horizon 2020 and Horizon Europe.** https://cdn.ceps.eu/wp-content/uploads/2025/05/A1.3.1.-Scoping-paper-Horizon-Europes-engagement-with-LMICs_Formatted.pdf

Call for Proposals

India Tunisia Joint Call for Proposal 2025

Last Date: July 31, 2025

Further information at: https://onlinedst.gov.in/Projectproposalformat.aspx?Id=2369

India-Taiwan Programme Of Cooperation In Science & Technology

Last Date: July 31, 2025

Further information at: https://www.inae.in/india-taiwan-programme/

DST DFG Joint Call on International Research Training Groups

Last Date: August 01, 2025

Further information at: https://onlinedst.gov.in/Projectproposalformat.aspx?Id=2232

EU-India (MNRE) Coordinated Call on Waste to Renewable Hydrogen

Last Date: September 02, 2025

Further information at: https://research.mnre.gov.in/home

India-Japan Cooperative Science Programme Call for Proposals-2025

Last Date: September 03, 2025

Further information at: https://dst.gov.in/callforproposals/india-japan-cooperative-science-programme-ijcsp-call-proposals-2025

EU-India Cooperation on Cumulative Impacts of Marine Pollution on Marine Organisms and Ecosystems

Last Date: September 23, 2025

Further information at: https://moes.gov.in/sites/default/files/2025-05/Guidelines_Call_for_proposal.pdf

CSIR-EU_MSCA-SE_CALL_2025

Last Date: October 17, 2025

Further information at: https://www.csir.res.in/sites/default/files/2025-04/csir-eu_msca-se_call_2025_guidelines_and_announcement_1.pdf