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The editorial correspondence should be addressed to the Editor, Science Diplomacy Review, Research and Information System for Developing Countries (RIS), Core IV-B, Fourth Floor, India Habitat Centre, Lodhi Road, New Delhi-110 003, India. Phone: +91-11-24682177-80, Fax: +91-11-24682173-74. Email: science.diplomacy@ris.org.in and dgoffice@ris.org.in.

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EDITORIAL

This issue comes out at a time when the world is engaged in the battle against the Omicron variant of COVID-19. The race is on to vaccinate as many people as possible, including children across the world. Vaccine availability and affordability remains a challenge, especially in Africa, where the vaccination rates are still low. The international community has been struggling to deal with challenges such as resuming economic and social activities, mobility, and coping with the increased number of cases. Fortunately, the Omicron variant seems to be milder and less likely to cause serious illness. However, this cannot be said of any new variants that might emerge. This makes it necessary to remain vigilant and continue with basic control measures, such as masking, social distancing and hygiene while pursuing vaccination.

Meanwhile, the WHO remains at the centre of global efforts to develop, approve and facilitate the access and affordability of vaccines. An increasing number of vaccines based on diverse platforms have been authorised for emergency use. The WHO member states have agreed that there should be a new instrument to deal with future disease outbreaks. There is lack of consensus over the nature and content of this instrument - whether legally binding or not, and discussions will go on over the next few years. the member states also agreed that WHO must have a sound financial basis to operate and not rely too much on extra budgetary voluntary contributions. On this issue, also, there is lack of consensus, whether to increase the regular budget, or to have a separate financial window for WHO.

The geopolitical situation is marked by increased tensions between the US and allies on one hand, and China and Russia on the other. There is growing tension between Russia and the NATO over the security architecture in Europe. A similar tension is building up in the Indo-Pacific. This has impacted science and technology cooperation, and presents a challenge for science diplomacy. The impact could be negative on cooperation to address global challenges such as climate change, cybersecurity and governance, outer space, etc.

In this issue, we present an article on climate change and opportunities in the Indo-Pacific, which outlines and analyses the possibilities of cooperation in the battle against climate change. The second article focuses on the advantages of a water management knowledge sharing network for South Asia, including its potential for achieving the SDGs. The opportunities for science and technology cooperation between India and Taiwan in various sectors is outlined in the third article. The other two articles present a detailed account of the development of knowledge centres in Indian cities, especially Pune, which could have useful lessons for similar centres in other countries, and the challenges posed by Anti Satellite weapons and space debris in near earth orbit, as well as governance issues in this domain.

The book review section presents a review of two books. First, 'Climate Diplomacy and Emerging Economies: India as a Case Study'. The Second is 'Preventing the Next Pandemic: Vaccine Diplomacy in a Time of Anti-science'. Both the books deal with current and important global challenges. The issue also includes a review of the Belfer Centre's report on China US technology rivalry and the consequent challenges for US policy makers and others. In the commentary, we present a viewpoint on the challenges facing semiconductor industry in India, especially with respect to packaging.

Against the background of increasing attention to the potential of science diplomacy, Science Diplomacy Review seeks to present, analyse, and promote the global sciencific community's efforts to tackle a varied set of global, regional and national challenges, in collaboration with a wide variety of stakeholders and partners. We look forward to your contributions and encouragement in the future.

ARTICLE

Geopolitics, Science and Climate Diplomacy in the Indo-Pacific: An Assessment

Dhanasree Jayaram*

Dhanasree Jayaram

The Indo-Pacific, as a "geopolitical construct" (Kuo, 2018) is central to the changing dynamics of the international order. The region that this construct represents is highly vulnerable to climate change too. Hence, as the region's countries engage in climate cooperation, it has ripple effects on the geopolitical context, and vice-versa. There is a growing amount of interest in promoting energy transition, disaster risk reduction, and sustainable development in the region through cooperative mechanisms. While regional organisations such as the Pacific Islands Forum (PIF), Association of Southeast Asian Nations (ASEAN), and others have been actively institutionalising climate action in their respective regions (Vaa, 2016), other forums such as the Quadrilateral Security Dialogue (Quad), involving the US, Japan, Australia, and India, are also involved in marshalling resources for achieving climate action objectives (Roy, 2021). These initiatives are built upon the ability of science to inform policy, if not entirely guide it.

Since the conclusion of the 26th Conference of Parties (COP-26) in Glasgow in 2021, a renewed vigour is sweeping through the international community to achieve the goals set by the 2015 Paris Agreement. Although the summit failed to achieve climate ambition due to several factors (including the COVID-19 pandemic), it brought up several key aspects of climate diplomacy that could raise

* Assistant Professor, Department of Geopolitics and International Relations, and Co-Coordinator, Centre for Climate Studies, Manipal Academy of Higher Education (MAHE), India. She is a Research Fellow at the Earth System Governance.

climate ambition in the future, such as the need for scaling up climate finance (particularly for climate adaptation), enhancing the credibility of market mechanisms, accelerating innovation and use of clean technologies in emissions-heavy sectors such as power, transport, agriculture, etc. (Mountford, et al., 2021). All the countries of the Indo-Pacific recognise the need for constructive climate diplomacy that can promote climate action in the region through different forums, including by strengthening the role of reliable science in climate diplomacy. The region presents immense opportunities for climate cooperation, yet there seems to be a fragmented response to the massive global challenge. Geopolitical hurdles, apart from domestic and other related variables, continue to impede an effective collaborative approach in the region.

Against this background, this article explores the interface between science diplomacy and climate diplomacy from a conceptual perspective, as well as its geopolitical implications. However, without straightjacketing the role of science in climate diplomacy, it is important to focus on the role that geopolitics plays in shaping science diplomacy in the climate policy arena. Not only does science diplomacy advance national interests and help achieve foreign policy objectives, but it also has the potential to transform the international order by influencing state behaviour through cooperation to resolve common problems (Ruffini, 2020). Hence, this article examines the complementarities between the two; and provides explanation for the need to relook into the role of science in climate diplomacy from a geopolitical perspective rather than merely adopting a normative viewpoint pertaining to the progressive aspects of science and scientific collaboration/cooperation. Such an approach could provide a better understanding of the context in which climate action and scientific collaborations emerge and evolve, or get delayed and halted.

Science Diplomacy-Climate Diplomacy Interface and its Geopolitical Implications

The interlinkages between climate diplomacy and science diplomacy are indispensable. Whether it is 'science in diplomacy' or 'science for diplomacy' or 'diplomacy for science', climate diplomacy reflects the deep interconnections with science diplomacy. Not only is climate science integral to the concept and practice of climate diplomacy, but also solutions to the climate crisis arrived at through multilateral or other forms of cooperation involve scientific intervention. Similarly, today diplomatic arrangements in the climate policy arena are fostered by scientific initiatives, involving scientific communities.

Science diplomacy should not necessarily be conflated with cooperation and collaboration; it can equally be reflective of the competitive and adversarial geopolitics, as may be seen in the case of the Indo-Pacific. The prevailing geopolitics in the Indo-Pacific region cannot be disassociated from the frameworks of science diplomacy adopted by nation states, particularly in the case of climate change. Even if one takes the various definitions of science diplomacy, they all demonstrate close interconnections with the geopolitical scenarios. For instance, the Center for Science Diplomacy of the American Association for the Advancement of Science (AAAS) defines science diplomacy as "the use and application of science cooperation to help build bridges and enhance relationships between and amongst societies, with a particular interest in working in areas where there might not be other mechanisms for engagement at an official level" (European Commission, 2009). While this definition tends to provide a normative perspective to science diplomacy, it also unravels the contextual knowledge of conflict and cooperation that aid or impede science diplomacy.

Just as science diplomacy is often defined in terms of its normative characteristics and/or agenda, climate diplomacy is also explained often through the praxis lens. Climate diplomacy implies prioritisation of climate action on "diplomatic dialogues, public diplomacy, and external policy instruments." It entails "the use of diplomatic tools to support the ambition and functioning of the international climate change regime and to attenuate the negative impacts climate change risks pose for peace, stability and prosperity" (Climate Diplomacy, 2022). In addition, Mabey, Gallagher and Born (2013: 14) emphasise "the process through which nation states – and increasingly non-governmental and sub-state actors – determine and work to deliver their international objectives." Clearly, these understandings sum up the nature and goal of climate diplomacy – by highlighting its contribution to designing, implementing, and operationalising a climate regime; the influence of international and national interest objectives in shaping it; and the increasing role of a variety of actors beyond the traditional notions of 'diplomacy'. The Intergovernmental Panel on Climate Change (IPCC) is perhaps one of the best examples of science diplomacy as it not only is instrumental to building science-policy interface in international climate change-related decision-making, but also promotes cross-border scientific collaborations between scientists and governments for developing viable policies to tackle climate change. It has significantly aided the institutionalisation of international climate cooperation within the United Nations Framework Convention on Climate Change (UNFCCC), which is central to international climate diplomacy (Gustafsson and Lidskog, 2018).

Although climate diplomacy is largely conflated with cooperation through multilateral climate negotiations in the UNFCCC, it has assumed significance at other diplomatic platforms that are plurilateral, bilateral, and regional in nature, over the years. These platforms such as the G-20 summits, Quad, bilateral meetings, and regional organisations have incorporated climate change within their processes and discussions. For instance, following the failure of the 2009 Copenhagen Summit to reach an universally acceptable agreement, G-20 began to be viewed as a forum that "has the power to significantly reduce global greenhouse gas emissions, accelerate the deployment of clean energy technology, and help vulnerable countries adapt to a warmer world through the mobilization of public and private finance" (Houser, 2010). Climate diplomacy has also become an integral part of bilateral engagements and strategic partnerships, as seen in the case of India-EU and India-US climate diplomacy, under which several initiatives have been launched including the India-EU Clean Energy and Climate Partnership and US-India Climate and Clean Energy Agenda Partnership (Jayaram, 2021). Among regional organisations in the Indo-Pacific, the ASEAN launched the ASEAN State of Climate Change Report (ASCCR) in 2021, outlining ASEAN's plans to achieve net zero GHG emissions, integrate green recovery elements within the ASEAN Comprehensive Recovery Framework, and so on (ASEAN, 2021). These efforts build upon existing climate diplomacy frameworks developed by the ASEAN such as ASEAN Climate Change Initiative (ACCI) that promotes cooperation among the ASEAN member states to reduce deforestation, enhance reforestation, develop and deploy adaptation and mitigation measures, etc. (Dator-Bercilla, Villanueva and Chandra, 2010). They are increasingly acting as political and operational entities that nurture the conditions for climate action by building confidence/trust and generating consensus among countries. Besides, they boost climate ambition based on 'aligned' interests, implement international climate agreements through national and regional initiatives.

Climate diplomacy is influenced by "the competing political interests that underpin it" (Elliott, 2013). These competing political interests are shaped by both domestic and geopolitical factors. On the one hand, countries tend to stick to their "historical and national positions" such as Common But Differentiated Responsibilities and Respective Capabilities (CBDR-RC); and on the other, countries use climate diplomacy in order to position themselves geopolitically – for instance, as a global climate leader. For example, India has over a period of time, projected itself as a climate leader by launching diplomatic initiatives such as the International Solar Alliance (ISA) and Coalition for Disaster Resilient Infrastructure (CDRI) that promote cooperation among countries on solar energy and resilience-building or climate adaptation, respectively (Ghosh, 2021). Both ideational and material factors play into these diplomatic positions. Climate diplomacy facilitates opening up of economic opportunities, financial and technological investments, strategic partnerships, and other forms of instruments through which material progress can be ensured. At the same time, climate diplomacy is not practised in a vacuum, as it is intertwined with power hierarchies and balance of power. As seen in the period between the 2009 Copenhagen Summit and 2015 Paris Summit, the emergence of G-2 – the United States (US) and China – can be seen as a geopolitical realignment in tune with the requirements of the international climate order. In this case, US-China climate diplomacy was strengthened by the 2014 U.S.-China Joint Announcement on Climate Change and Clean Energy Cooperation (The White House, 2014). Climate diplomacy is also used as a tool for soft power projection, with countries that possess more capabilities (power) providing resources to smaller countries in order to win their goodwill and confidence for strategic purposes (Jayaram, 2021).

Geopolitical Implications of Climate Diplomacy in the Indo-Pacific

The pivot to Asia has led to geopolitical realignments in the Indo-Pacific region, with multifaceted implications for climate diplomacy in the region. The evolving US-China trade and technological conflict and the associated emergence of the geopolitical construct of the Indo-Pacific in particular has major implications for how climate policies are and will be framed in the region. The effects manifest in several forms including formation and/ or strengthening of institutions and/ or arrangements such as the Quad. One of the focus areas of the Quad is climate change – with closer attention being paid to enhancing climate ambition in the Indo-Pacific region as well as the entire world to achieve Paris targets; advancing innovation in the development and deployment of clean energy projects; and developing measures to boost climate adaptation, preparedness, and resilience (The White House, 2021).

Since the Indo-Pacific region consists of countries that are at various levels of development, it is imperative for the Quad countries to invest in sustainable development initiatives aimed at ecological protection and socio-economic development of the region's populations. Some of the specific measures that have been discussed in Quad meetings include: low-carbon transition in energy-intensive sectors such as shipping and port operations, adoption of green hydrogen, developing sustainable supply chains, and strengthening climate services (The White House, 2021). The proposed measures involve Science & Technology (S&T)-led innovation policy that could be nurtured through science diplomacy among not only the four Quad countries, but also like-minded countries that look to achieve Sustainable Development Goals (SDGs), disaster risk reduction (DRR) goals, and Paris agreement targets. The implementation of climate diplomacy measures on clean energy, climate services, and other areas can boost climate action in the region. For instance, climate services, which imply provision of climate information (that is based on science and user demand) to assist decision-making, strengthen science-policy interface, which is also central to science diplomacy between countries to promote scientific and climate cooperation that could aid early warning, preparedness, etc.

An important aspect of the Indo-Pacific strategies of major powers, including members of Quad, is the position on China. Quad itself is regarded as an informal alliance that is aimed at tackling China's rise and assertiveness in the region. It has been looking into the issue of over-dependence of the world on China in terms of the clean energy supply chain, which it proposes to weaken through cooperation in innovation and S&T. China's monopoly in the rare earths industry that is critical to global energy transition has brought the Quad countries to diversify the supply and mineral value chains through cooperation. It can be partly linked with climate diplomacy as it has implications for cooperation on clean energy between the countries. Quad's efforts are seen as a means of countering the dominance of "techno-autocrats" and establishing the rule of law through "techno-democracies"

(Wadhva, 2021). Nevertheless, the interest in diversification is not new. In 2010, China imposed an embargo (unofficially) on rare earth exports to Japan in light of the conflict between the two in the East China Sea. Since then, there have been attempts, especially by Japan, to diversify the supply chain to reduce dependence on China. Hence, geopolitical interests are deeply intertwined with future course of energy transition across the world.

Cooperation between countries in areas such as climate action and clean energy is driven by geopolitical interests too. For instance, China's Belt and Road Initiative (BRI) is a major financier of clean energy projects in many developing and least developed countries of the Indo-Pacific region. At the same time, although in 2021, in the run up to COP-26 (Glasgow Summit), China pledged to halt funding for overseas fossil fuel projects, the BRI has contributed to several such projects across the region so far. China's investments in fossil fuel projects began to increase at a time when Bretton Woods-based financial institutions such as the World Bank and International Monetary Fund had significantly cut down their investments in such projects. However, the emergence of China as a major renewable energy giant has led to it becoming a technological innovator, mass manufacturer of clean energy equipment, and provider of green technology to other countries, primarily in the Global South. On the one hand, as opined by Ivleva (2020), "China's support to energy, industrial and transportation and projects influence emissions trajectories of the partner countries, and investments often underpin the geopolitical aspirations of China and its partners." On the other hand, China's investments in clean energy innovations (such as battery storage) can also be interpreted as a bid to reduce its dependence on fossil fuel imports through the Strait of Malacca, which is a choke point that can be taken advantage of by its rivals/adversaries to threaten China, as most of China's crude oil imports traverse this strait (Yin and Lam, 2021).

As much as China is focussing on greening the BRI to maintain its legitimacy in the climate change arena, other arrangements have also sprung up that are seen to be competing with the BRI. Geopolitical competition between countries such as Japan, India, and China has brought about newer arrangements such as the Asia-Africa Growth Corridor (AAGC), which is an Indian-Japanese collaborative aimed at "partnership for sustainable and innovative development", focusses on advancing clean energy development and deployment in the Global South. The AAGC, which is aligned to the SDGs and focusses on 'green projects', is tied to both these countries' interests in "Act East" Policy and "Free and Open Indo-Pacific." With its goal of leveraging the combined strength of Asia and Africa, the AAGC has the geopolitical aspirations to thwart Chinese dominance in the region (Prakash, 2018).

Another important case is that of the International Solar Alliance (ISA) – launched by India and France – that aims to promote innovation in solar energy, innovative finance for expanding clean energy, etc. to ensure access to affordable energy in solar-rich countries that lack the financial and technological resources to harness solar energy. The ISA, together with its offshoot, One Sun One World One Grid or OSOWOG (launched at COP-26), brings together countries from both Global North and Global South to conduct R&D and mobilise investments in the solar sector. The OSOWOG is being showcased as a climate-friendly alternative to the BRI as it aims to connect 140 countries with a common grid (Jha, 2021). The ISA, being a brainchild of India, is also a tool for it to project itself as a part of the solution and as a leader on the global high table of decision-making on issues concerning global governance. Although initially the ISA was envisaged to include "sunshine countries" that lie completely or partly between the Tropic of Cancer and Tropic of Capricorn, it includes countries from across the world today, as the membership is open to all members of the UN. The ISA can be seen as a case of science diplomacy as scientists, technologists, and other members of epistemic communities help decision-makers frame policies on the future of solar energy – solar PV technology, decarbonised grid, disruptive solar technologies, etc. (Press Information Bureau, 2020).

Disaster risk reduction (DRR) is a crucial area for both science and climate diplomacy. Science is used heavily in investigating the causes for disasters as well as finding DRR solutions. Disaster science is an interdisciplinary field that is integral to efforts to "communicate the risk assessments, their socio-economic impacts, evaluations of mechanisms for risk reduction, and options for translating scientific findings to practice" (Kontar, et al., 2021). The Sendai Framework for Disaster Risk Reduction 2015-2030 draws upon principles of multilateralism that guide collaborative solutions to global challenges such as disasters that are increasing in frequency and intensity due to climate change. Yet again, knowledge exchange is the primary area of cooperation, as transboundary, co-production of knowledge (involving scientific and non-scientific communities) through science diplomacy can help reduce the risk of disasters. In this context, newly established initiatives such as the Coalition for Disaster Resilient Infrastructure (CDRI) are also aimed at reducing disaster risk, by focussing on three major pillars – "technical support and capacity-building", "research and knowledge management", and "advocacy and partnerships." The CDRI emphasises the need for promoting climate resilience through science (Srivastava, 2021). The CDRI is yet another Indian initiative that fosters collaboration and cooperation in DRR and climate change. In fact, the fact that the CDRI was launched at the 2019 UN Climate Action Summit by Indian Prime Minister Narendra Modi shows that it is an integral part of India's climate diplomacy.

The growing significance of the Indo-Pacific has prompted the European Union (EU) and its member states to also come out with their Indo-Pacific strategies. The EU's Indo-Pacific Strategy released in 2021 has seven priority areas: sustainable and inclusive prosperity; green transition; ocean governance; digital governance and partnerships; connectivity; security and defence; and human security. Most of the EU's priorities are hinged on climate diplomacy with the region's countries – building "green alliances", strengthening "cooperation on research and innovation", building "more resilient and sustainable global value chains", etc. (European Commission, 2021). The EU's (stated) approach towards the Indo-Pacific is oriented towards cooperation rather than confrontation, which makes its position on China tenuous. This is because the EU continues to engage with China on strengthening climate cooperation, while increasingly confronting it over issues related to human rights, trade, etc. (Myers, 2020). The EU's geopolitical outreach towards the Indo-Pacific is largely contingent on its ability to contribute further to DRR, climate action, biodiversity protection, development assistance, etc. in the region.

Individual countries of the EU have also released their Indo-Pacific strategies. Germany adopted its Indo-Pacific policy in 2020, under which it proposed to strengthen cooperation with actors such as the ASEAN, Australia, and Japan. In addition, climate diplomacy in particular finds a prominent place in the policy as Germany highlights its commitment to International Climate Initiative, South East Asia Energy Transition Partnership, International Solar Alliance, Coalition for Disaster Resilient Infrastructure, Roundtable on Sustainable Palm Oil, and other initiatives to boost climate mitigation and adaptation in the region. Here, the focus is on technology cooperation, capacity-building, training, green electromobility, urban resilience, climate finance, biodiversity protection, etc. (The Federal Government, 2020). France has announced its Indo-Pacific strategy, which is also guided by the presence of French territories, over 7000 permanent troops, and nearly 2 million French nationals in the region. Both France and Germany formally tie their Indo-Pacific strategies to that of the EU, especially when it comes to climate change. However, France's climate diplomacy commitments are particularly targeted at the Pacific Small Island Developing States through initiatives such as the Pacific Initiative for Adaptation and Biodiversity and Climate Risk and Early Warning Systems (CREWS) Initiative, some of which involve its partners such as the EU, New Zealand and Australia. According to the strategy, climate adaptation in the Indo-Pacific is prioritised, with a focus on "sustainable cities, water management, regional planning, the protection and promotion of natural and cultural heritage" (Ministry for Europe and Foreign Affairs, 2021).

Obstacles to Climate Diplomacy in the Indo-Pacific: A Geopolitical Perspective

The influence of geopolitical and geoeconomic factors has had impeding effects on climate diplomacy in the Indo-Pacific at various levels. For instance, geopolitical factors continue to hamper the consolidation of climate diplomacy efforts of various regional organisations. In South Asia, the South Asian Association for Regional Cooperation (SAARC) has launched action plans on climate change and built institutions to implement them, but the organisation has been largely dysfunctional due to bitter relations between India and Pakistan. The Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC), consisting of countries in the Bay of Bengal region and vulnerable to extreme weather events, has also prioritised climate change as one of the pillars of regional cooperation . However, there has been little progress in advancing climate change cooperation through information sharing using remote sensing satellites for disaster management, agriculture, etc. due to a lack of momentum within the organisation, delays in implementation, paucity of financial resources, and a reactive approach to climate change-related disasters, among other reasons (Roy, 2019). In ASEAN, the domestic scenario within countries such as Myanmar, wherein the present government has been accused of human rights violations and undermining democratic processes since it staged a coup in 2021, has impeded joint climate action. In fact, the Myanmar government-led delegation was not allowed to participate in COP-26 by the UN (Myanmar Service, 2021). Although the small island states are known to have a unified position on climate change, as they vociferously champion the cause of ambitious climate action (to keep the temperature rise below 1.5 degrees Celsius (˚C), regional organisations formed by such countries such as the PIF has been fraught with regional geopolitical challenges that affect climate cooperation too. For instance, in 2021, five Micronesian states – Micronesia, Kiribati, Nauru, Palau and the Marshall Islands – pulled out of the PIF due to the lack of their representation at the highest level of decision-making within the organisation (Secretary-General). The Pacific has re-emerged as a geopolitical space for competition among major powers such as the US, China, France, Australia, etc. (Wen, 2021).

Climate solutions are often rife with geopolitical and geoeconomic ramifications. Even while the EU establishes cooperative engagement with ASEAN countries on climate action, there continue to be challenges in the way of ASEAN-EU climate diplomacy. For instance, in the case of Southeast Asian countries such as Malaysia and Indonesia, global movements against deforestation caused by palm oil plantations and changes in regulatory frameworks in the EU to restrict biofuel imports from Southeast Asia (including environmental due diligence in supply and value chains) have led to the introduction of sustainability certification programmes. Regulatory changes in these countries are expected to foster productivity-related innovations at the level of palm oil plantations, which is critical for sustainable production of biofuels and energy transition worldwide. However, the EU's policies have only been met with criticism from these countries, as their trade and economic growth would be affected by such unilateral measures. In fact, Indonesia even threatened to pull out of the Paris Agreement when the EU proposed to phase out palm oil from biofuels by 2030 (Jong, 2019).

Geopolitical rivalries between countries such as China and India have hindered the possibility of joint climate science research in many cases. In fact, transboundary research collaborations are critical for a better understanding of the climate dynamics of regions such as the Hindu Kush-Himalaya (HKH), which is the source of Asia's 10 largest rivers (including Indus, Ganges, Brahmaputra, Salween, Mekong). Over a period of time, scientific collaborations to quantify the impacts of climate change in the region have increased, but there are still gaps in knowledge creation, as evidenced by the relative lack of knowledge about climate impacts on the cryosphere and hydrology in the region. Scientists work with each other despite border tensions/conflicts and mistrust between governments. This is essentially Track II science diplomacy, which involves cross-border collaborations between scientific communities (even that of adversarial countries) that could aid the establishment of science advice mechanisms within foreign policy as well as leverage the "apolitical" image of science as a means of winning over the external parties (Flink, 2021). However, political will matters when it comes to data sharing and other forms of scientific cooperation, as well as avoidance of conflicts over river water sharing, infrastructure projects (mainly dams), etc. Efforts have been made by organisations such as the International Centre for Integrated Mountain Development (ICIMOD) to bring all the countries of the HKH region to discuss common problems and solutions concerning climate change (Bhushal, 2020). Yet these have been far and few between. Science and climate diplomacy need to be sustained for a long time to bear fruit.

Towards a Transformative Approach to Climate Diplomacy

The indisputable interconnections between science and climate diplomacy highlight the need for a transformative approach to achieve climate action goals. A transformative approach to climate diplomacy would entail bringing about systemic and structural changes that promote inclusive growth that leaves no one behind and altering belief systems and behaviours that exacerbate climate risks and vulnerabilities, among others. The Indo-Pacific region requires recalibration of policies and resources to tackle systemic, compound, and cascading risks associated with climate change. For instance, as has been seen since the COVID-19 pandemic began, health and climate change risks often intermingle with each other and worsen the impacts on socio-economic and financial systems, as these risks cascade across political and sectoral boundaries. In 2021, the onset of cyclones – Tauktae and Yaas – in South Asia distressed healthcare provisions in the region when it was also battling the deadly COVID-19 wave by disrupting electricity systems in several affected states, thereby also affecting oxygen supply, which was critical to the survival of COVID-19 affected patients (Srivastava, et al., 2021). The interdependencies between various risks highlight the need for a more multidisciplinary, cross-institutional, cross-sectoral, and multi-risk approach to climate diplomacy.

The 15 January 2022 Tonga volcanic eruption (though not caused by climate change) has further exposed the vulnerabilities of the small islands states, archipelagic states, and other vulnerable countries of the Indo-Pacific region (UNEP, 2022). This highlights the need for investing even more in capacity-building, early warning systems, risk assessment, and preparedness in the region to tackle the various risks posed by climate change-related slow and rapid onset disasters. Similarly, the international community, particularly countries in the Indo-Pacific need to ensure that the COVID-19 pandemic does not put a dent in foreign aid and assistance from the industrialized countries to developing and least developed countries that are important for the sustainability of various science diplomacy initiatives aimed at climate cooperation. The current situation calls for an accelerated implementation of SDGs, which can be facilitated by the numerous mechanisms introduced in the region, as the COVID-19 pandemic has significantly impeded progress in the achievement of several SDGs. As is analysed in this article, the geopolitical context has played a huge role in shaping science and climate diplomacy of nation states in the Indo-Pacific. The current geopolitical realities of the Indo-Pacific call for a reinvigorated approach to climate diplomacy that does not necessarily overlook competition, power politics, and national interests. To overcome some of the above-mentioned geopolitical hurdles to climate diplomacy, an acknowledgement of the factors discussed in this article in decision-making is necessary rather than merely adopting an optimistic view of how science can provide solutions to global challenges, leading to progress in the international order. Presently, the geopolitics of the Indo-Pacific is dominated by the discourses on China's rise and its implications for the world. The Quad countries in particular have been at loggerheads with China for various reasons, as already mentioned earlier in the article. Nevertheless, despite ongoing tussles between the US and China over various issues (such as trade, technology, and human rights), on climate change, the two governments signed a bilateral agreement at COP-26 – agreeing to cooperate on "regulatory frameworks and environmental standards" to reduce greenhouse gas (GHG) emissions, maximisation of "societal benefits of the clean energy transition," "circular economy," Carbon capture, utilisation and storage (CCUS) and direct air capture, etc. (Office of the Spokesperson, 2021). This instance exemplifies the changing geopolitical dynamics in the international climate order that give rise to different diplomatic mechanisms that are targeted at regional and global climate governance.

Conclusion

The Indo-Pacific region is critical to international climate diplomacy efforts. With the emerging geopolitical faultlines and cooperative arrangements in the region, the role of science in boosting climate diplomacy is further emboldened. While science diplomacy among the Indo-Pacific countries can facilitate cooperation in the climate change arena – even mong adversarial states – there are several challenges to it. Science diplomacy pertaining to climate change manifest in the form of sharing of climate information, building capacities, joint research and development in the field of climate change, etc. Over the years, climate diplomacy between the countries of the Indo-Pacific region as well as that involves external players such as the EU has stepped up with cooperation in the above-mentioned areas. Furthermore, clean energy, adaptation, urban resilience, energy efficiency, and biodiversity protection among others have emerged as major areas of cooperation.

The Indo-Pacific region is one of the most climate-vulnerable regions; and cooperation is a necessity to arrive at and implement feasible climate solutions, particularly since the region has countries with varied climate vulnerabilities and developmental requirements. However, to analyse the contours of climate diplomacy in the region, there is a need to understand the evolving geopolitical dynamics, as they significantly influence cooperation in the Indo-Pacific. Whether it is Quad, BRI, ISA, or other initiatives, the geopolitical construct of the Indo-Pacific is inherently a factor in the evolution of climate action initiatives designed and implemented by these frameworks. Therefore, geopolitics is integral to recognition of the scope of the interface between science and climate diplomacy, the opportunities for advancing climate diplomacy, as well as the challenges to climate diplomacy, particularly in the Indo-Pacific region.

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ARTICLE

Opportunities for India Taiwan Science and Technology Cooperation

Bhaskar Balakrishnan*

Bhaskar Balakrishnan

Introduction

There is much scope for building cooperation in science and technology between India and Taiwan. Taiwan has a well-developed economy, with a strong R & D ecosystem, and competitive advantages in several high-tech areas. In semiconductor chips, Taiwan is an important global supplier of this critical input for many industries. India has a large and growing market, high quality workforce in STEM areas, and has launched ambitious plans to strengthen its STI and educational ecosystems. These are strong pull factors which can drive India Taiwan cooperation in STI.

India is a key focus country within the framework of Taiwan's New Southbound Policy, launched in 2016. The policy was created to make Taiwan less dependent on Mainland China and to improve Taiwan's cooperation with other countries. The 18 countries targeted by the New Southbound Policy are: Thailand, Indonesia, Philippines, Malaysia, Singapore, Brunei, Vietnam, Myanmar, Cambodia, Laos, India, Pakistan, Bangladesh, Nepal, Sri Lanka, Bhutan, Australia and New Zealand.

Cooperation has assumed greater importance in view of recent events, such as rising tensions between China and the USA as well as India, Australia, etc.; perceptions of China as a threat to rule based international order, especially in the Indo-Pacific region, and diversification in economic

* Science Diplomacy Fellow, RIS and Former Ambassador of India. He holds a Ph.D. in Theoretical and Mathematical Physics from State University of New York, Stony Brook.

dependence away from China. The Quad countries (US, India, Australia, and Japan) meeting at the October 2021 summit in Washington have agreed on several important initiatives on S & T cooperation. While these are some push factors, there is a strong pull basis for building long term science, technology and innovation (STI) cooperation between India and Taiwan based on its own merits and mutual advantages.

Taiwan in the Global Economy

Taiwan with a population of 23.5 million, has a per capita GDP (PPP) of USD 59,000 (13^{th} rank globally). It is well integrated into the global economy and has a foreign trade of USD 632 billion (2020), and is a member of the WTO since 2002. The total inward FDI stock in the country is USD78 billion while FDI held abroad was USD 332 billion (2017), making it a major global investor. The strongest sectors of the economy are semiconductors and ICT products. By 2020 Taiwan was the leader of the global semiconductor industry with Taiwan Semiconductor Manufacturing Company (TSMC) alone accounting for more than 50 per cent of the global market. Taiwan is the fourth largest exporter of machine tools and machine tool components in the world. Techman Robot Inc. is the world's second largest producer of cobots.

Being heavily dependent on foreign trade and markets, Taiwan has sought economic integration with various global and regional economic arrangements. In addition to the WTO, Taiwan (as Taipei, China) is a member of the Asian Development Bank, the Asia-Pacific Economic Cooperation (APEC) forum (as Chinese Taipei), an observer at the Organisation for Economic Co-operation and Development (OECD) and is a member (as Chinese Taipei) of the International Energy Agency (IEA), a member (Chinese Taipei) of International Chamber of Commerce. Taiwan signed an Economic Cooperation Framework Agreement (ECFA) with People's Republic of China on 29 June 2010, which could allow for more than 500 products made in Taiwan to enter mainland China at low or no tariffs. Taiwan has signed free trade agreements with Singapore and New Zealand.

STI Development in Taiwan

Taiwan's research intensity of GDP or Gross expenditure on research and development (GERD) has risen to 3.49 percent of total gross domestic product (2018) from 1.91 percent in 2000. (OECD, 2021), making it the third highest in the world, exceeded only by the Republic of Korea and Israel. In comparison, India has dropped to 0.7 per cent in 2019 from 0.8 per cent in 2005 (DST, 2020). The world average has risen from 1.51 per cent in 2000 to 1.72 per cent in 2017. Another important indicator is the human resources for R & D. The number of researchers per million population was 8180 in Taiwan (2017) and 255 in India (2020). These indicators show that Taiwan has emerged as a world leader in science and technology. On innovation, Taiwan has scored impressive results, being ranked as having the fifth-greatest potential for economic innovation in the world, according to a new index released by Bloomberg Economics. (5)

Taiwan's high-tech sector development has been fueled by the government's generous funding of applied scientific development. Institutions such as the Industrial Technology Research Institute (ITRI), National Applied Research Laboratories and Institute for Information Industry (III) are at the heart of this sector by conducting research, aiding the private sector with R&D and exploring new technologies. Several prominent companies have grown in this ecosystem, including Taiwan Semiconductor Manufacturing Co. and United Microelectronics Corp., which are among the world's top producers of integrated circuit chips. Eight national research centers cover four major areas of science - earth and environment, information and communication technology, biomedical technology and technology policies. III leads in digital transformation, advancing ICT development, policy making and promoting talent cultivation. The Taiwan Tech Arena is a hub for innovation and startups attracting young entrepreneurs from around the world. Taiwan's network of science parks is home to clusters of companies pursuing breakthroughs in fields such as biotechnology, personal computing and peripherals, integrated circuits, nanotechnology, optoelectronics, precision machinery and telecommunications.

STI Development in India

India ranks third among the most attractive investment destinations for technology transactions in the world. It is one of the top five nations in the field for space exploration (IBEF, 2021)(6). India has developed its capacity for R & D in all aspects of the nuclear fuel cycle and reactor technology and has a major programme for expansion of nuclear energy and applied nuclear technology. In the energy sector, India has embarked on a major programme to shift to renewable energy, especially solar energy and with France has set up the International Solar Alliance, a global collaborative platform for solar energy. Other important areas are in earth and ocean sciences including polar region science, nanomaterials, biotechnology, AI and quantum computing, cybersecurity, and aerospace. These are all areas for fruitful cooperation between India and Taiwan

The Government of India is extensively promoting research parks (RPs) and technology business incubators (TBIs), which would promote the innovative ideas till they become commercial ventures. The Council of Scientific and Industrial Research runs 37 national laboratories and 39 outreach centres. Advances are taking place in sectors such as agriculture, healthcare, space research, and nuclear power. India has a major and growing capacity in the field of production of drugs, vaccines and medical devices. It has pioneered ICT applications in diverse fields such as financial services, healthcare, education, and governance, and citizen services applied them on a massive scale. The recent Covid 19 pandemic has brought into sharp focus the need for stronger international collaboration to deal with this and future pandemics. This is a fertile field for India and Taiwan to cooperate.

India has been engaged in pursuing the SDGs through the application of STI in various sectors such as food and agriculture, water and sanitation, health, energy, environment, ICT for development, etc. The resulting technologies and frugal innovation could be of value across the developing world. In this effort, Taiwan could offer some important contributions, based on its own experience in progressing towards the SDGs. Taiwan, while not being a member to the UN, has adopted T-SDGs aligned with the SDGs adapted to Taiwan's specific conditions, with addition of an 18th goal – a nuclear-free homeland. The National Council for Sustainable Development chaired by the Prime Minister is responsible for implementation. Taiwan's first Voluntary National Review (VNR) of the implementation of the UN's SDGs was released in September 2017. Taiwan's progress towards the SDGs was presented at a workshop in New York in September 2019 (Amcham Taiwan, 2021).

India's New Education Policy 2021, and the draft Science Technology and Innovation Policy (STIP) 2020 envisage a major qualitative and quantitative jump in R & D activity. This includes increase in R&D funding, stepping up human STEM resources, STEM diaspora integration, strengthening the Indian STI ecosystem, building stronger international cooperation with partners, participation in mega and big science projects, and tackling global challenges through STI. These developments will open up more possibilities of building cooperation.

India-Taiwan STI cooperation

There is an India-Taiwan Joint Committee on Cooperation in Science and Technology headed at senior official level of Vice Minister. Under this Joint Committee there is a Indo-Taiwan S&T cooperation Programme which extends financial support through Joint Calls for proposals (the most recent in 2019) to researchers in India and Taiwan to carry out research and scientific projects. Several priority areas have been listed like renewable energy, clean energy, IoT, big data, cybersecurity, micro/nano-electronics, embedded systems & sensors, biotechnology, health care including functional genomics, drug development and biomedical devices, etc under the programme. Under India's Digital India initiative, the two sides can accelerate work on the "South Asian Silicon Valley" development project.

Taiwan's National Chung Cheng University has established a research center at IIT-Ropar under the support of Ministry of Science and Technology (MoST), Taiwan, in July 2019 to work in the field of AI and related industries. Under Taiwan's New Southbound Policy, Taipei seeks to boost STI exchanges among Indian and Taiwanese academic and research institutions. According to recent pronouncements, Taiwan is keen to further advance talent exchanges through short term fellowships and work in Taiwan's science parks.[1] The two sides also held a virtual exhibition on Taiwan-India exchanges under the New Southbound Policy in December 2020. There is huge scope for widening and deepening such exchanges.

Recent Developments

Several track 2 interactions have been held between Indian and Taiwanese sides on cooperation in science, technology and innovation. In February 2021, Research and Information Systems (India) and Prospect Foundation (Taiwan) had organised a webinar focused on Sectoral cooperation in ICT and Semiconductors, Smart Manufacturing and Industry 4.0, and Cooperation with Science Parks in Taiwan. The webinar brought together stakeholders on both sides to discuss cooperation possibilities. It was suggested that India must provide an enabling ecosystem to foster market dynamics and supply chain needs to facilitate Taiwanese companies to set up their units in India. India's strength in IC design can initiate collaborative endeavors between the two countries and also offer India immense potential to develop and strengthen its ICT industries and increase its footprint in the global supply chain. Investments and infrastructural support by the Government of India for the development of ICT industries will be critical. The present crisis in China's financial system offers opportunities to attract greater investment flows into India if some necessary reforms are carried out.

Semiconductors

In the semiconductor industry Taiwan occupies a leading role. The Taiwan Semiconductor Manufacturing Company (TSMC) is a global giant in semiconductor manufacturing and technology. TSMC has an equity base of $53 billion and over 56000 employees and has substantial in-house R & D capabilities. TSMC plans to start production of 3 nanometre chips in 2022. India has about 10 companies engaged in the industry.

The oldest institution, now called (since 2006) Semi-Conductor Laboratory (SCL), under Department of Space, Government of India; is engaged in Research & Development in the area of microelectronics to meet the strategic needs of the country. SCL has integrated facilities / supporting infrastructure all under one roof and undertakes activities focused on Design, Development, Fabrication, Assembly & Packaging, Testing and Quality Assurance of CMOS and MEMS Devices for various applications. SCL is also engaged in Fabrication of Hi-Rel Boards, Radio Sonde Systems and indigenisation of electronic sub systems. It operates a 8 inch Wafer Fabrication Facility (2021 SCL) , and uses 180 nanometer CMOS Process for Fabrication of products in Digital, Mixed Signal and Analog domains.

In the private sector, there are some interesting players. ASM Technologies Limited set up in 1992, is a publicly-listed company in India with global presence in USA, Singapore, UK, Canada, Mexico and Japan. ASM has been providing world class consulting and product development services for its global clientele. Continental Device India Pvt. Ltd., (CDIL) is a Semiconductor Manufacturer since 1964, producing various semiconductor devices for industrial applications. The other companies are engaged in engineering and R and D in semiconductors, but not in manufacturing. Clearly, the Indian semiconductor industry is in an early stage, with limited capacity for wafers and chip manufacturing.

The 180 nanometre level technology used by SCL was developed in 1999. The technology has advanced rapidly from 90 nm in 2003 to 5 nm in 2020. Semiconductor fab facilities require very large investments typically of the order of US$ 20-50 billion. Such large investments in India will require major government support, but can be of strategic value. Can both sides join together and become a reliable global supplier of semiconductor chips? This is indeed a challenge. In December 2021, the Indian government launched a USD 100 billion initiative to develop its semiconductor ecosystem (2021, PIB) This should provide many opportunities for future collaboration between Indian and Taiwan entities.

The top ten companies in Taiwan in the semiconductor sector are detailed below (9). Most of them are listed in Taiwan Stock Exchange (TSE) and NASDAQ.

Apart from semiconductor chips, the two sides can collaborate in manufacture of silicon wafers, solar cells and modules. The demand in this sector is likely to increase greatly as India steps up its solar energy programmes in the near future.

Agriculture

Taiwan and India signed a memorandum of understanding on agricultural cooperation in September 2016 covering planning, production, processing, distribution and marketing of aquaculture, farm, fishery, horticulture and livestock products. The two sides will also bolster cooperation across several fields including agricultural finance, farmers' associations, environmental sustainability, genetic resources and production materials such as fertilizers and seeds through personnel exchanges and joint academic research. Cooperation in Agricultural research

Table 1: Top Ten Companies in Taiwan in The Semiconductor Sector

Company	Products	Revenue (US$ bllion)
TSMC (Largest Semiconductor Manufacturer in the World)	Manufacture of Integrated Circuits and related services	47.85
ASE Technology	Semiconductor Assembly, Testing & Packaging	12.5
AU Optronics	Display panel, Transportation, Health, Solar energy, and smart manufacturing service.	10.5
MediaTek	Semiconductor, Processor, Semiconductor Equipment, Electronics.	8.5
LITE-ON Technology	Computer components, Consumer electronics	7.5
United Microelectronics	Semiconductor, Semiconductor Equipment, Electronics	5
Nanya Technology	Semiconductor, DRAM, Memory Chip	3
SPIL	Semiconductor, Testing & Packaging	2.8
EDOM Technology	Semiconductor, Semiconductor Equipment	2.7
Sino-American Silicon Products	Solar brick, Wafer, Solar cell, Solar module, and Solar system	2.4

Source: Retrieved from www.electronicsandyou.com/blog...[Last Reference] could be explored between the Indian Agricultural Research Institute and the Taiwan Agricultural Research Institute on basic and applied research for agronomic and horticultural crops, biotechnology, soils fertility and plant nutrition, diseases and pest managements, farm machinery, meteorology, agricultural economics, and extension. Taiwan is a leader in high quality rice production and produces a wide variety of fruits and vegetables of interest to Indian consumers.

Space

In the field of space research, the Indian Space Research Organization and the National Space Organization of Taiwan could work together in areas such as launch vehicle development, satellite payloads, remote sensing and space applications, and tracking of space objects. Taiwan has recently passed legislation in 2021, opening up the space sector to private participation, similar to what India has also done.

Atomic energy

In the field of atomic energy, Taiwan has a special status as a non party to the NPT, but is covered under a trilateral agreement with the US and the IAEA to safeguard its nuclear facilities. Taiwan generates 10 per cent of its electrical energy from nuclear sources, with two nuclear plants operating at present, with several others shut down or cancelled in view of the Fukushima nuclear accident of 2011. There is considerable public support for nuclear power, though the official policy is to phase it out by 2025.

However, a referendum held on 18 December 2021, seeking to unseal and restart work on Taiwan's Fourth Nuclear Power Plant failed to pass, with 52.3 percent voting against it. Pro-nuclear activists had argued that the country's energy shortage and the need to keep greenhouse gas emissions in check made reopening the plant a necessity. Coal-fired plants accounted for 44.95 percent of Taiwan's electricity mix.

The main agencies are the Atomic Energy Council (AEC), and the Institute of Nuclear Energy Research (INER). There is some potential for cooperation with India in areas such as nuclear safety and monitoring, applications of radioisotopes in medicine, agriculture and food preservation, etc. The National Center for Theoretical Sciences (NCTS) in Taiwan carries out frontier research in physics, including areas such as particles and fields theory; condensed matter physics; atomic molecular and optical physics, and Soft Matters, Bio-Physics and Complex Systems. Cooperation with some Indian research institutions such as the Indian Institute of Science and Tata Institute of Fundamental Research could be mutually beneficial.

Cooperation in fields of biotechnology and nanomaterials between institutions on both sides could also be explored.

Energy

In the field of energy, there are avenues for cooperation. Both sides are heavily dependent on imported fossil fuels and have ambitious targets for cutting greenhouse gas emissions, ramping up renewable energy and the associated energy storage systems. The negative result of the recent referendum on restarting a nuclear power plant makes technology for solar energy and renewables, and carbon capture use and sequestration (CCUS) technology more important in the future. This also includes going in for hydrogen based energy systems, involving massive production of hydrogen from renewable energy excess generation, storing and reconverting hydrogen into energy when needed. This is a complex effort requiring dovetailing of various sectors of the economy. India has launched a National Hydrogen Mission in August 2021, while Taiwan has also launched a Hydrogen Energy Promotion Alliance. These initiatives can lead to increased cooperation in the Hydrogen energy sector.

Biotechnology

In the field of biotechnology, some notable institutions are - Agricultural Biotechnology Research Center (ABRC) of Academia Sinica, Taiwan which does basic research in agricultural biotechnology; National Biotechnology Research Park (NBRP) which is ecosystem platform for biomedical research; Institute of Biotechnology, National Taiwan University, which specializes in bioinformatics, nano-biomedical research, tissue engineering and regenerative medicine, genomics and proteomics. These are all areas of interest to R & D institutions in India's biotechnology sector, and cooperation could be pursued.

Medical research

In medical research, the National Health Research Institutes (NHRI), a non-profit foundation established by the government conducts mission-oriented medical research in basic biomedical sciences, as well as specific diseases. These range from the common problems such as aging, cancer, infectious diseases, mental disorders, occupational diseases, to health policy. This organisation could be a useful partner for the Indian Council for Medical Research (ICMR). Collaboration in the areas of COVID-19 and control of future disease outbreaks, especially in areas such as epidemiology, diagnostics, vaccines, and therapeutics could be mutually beneficial.

Nanomaterials

In nanomaterials science, some important institutions in Taiwan are - (1) Taiwan Nanotechnology Research Center (of the University system of Taiwan) (2) Taiwan Nanotechnology Industry Development Association (TANIDA) (3) Center of Applied Nanomedicine (National Cheng Kung University), and several other research laboratories working in a wide range of areas. This offers a rich scope for collaboration with Indian institutions.

Conclusion

There is a vast scope for building cooperation between Indian and Taiwan in various fields of science and technology, for mutual benefit and for tackling global challenges. Much attention has been focused on the semiconductor sector, but other areas also offer potential benefits. Several of these have been outlined in this article. The growth of Taiwanese investment and technology collaborations around the Chennai-Bengaluru corridor could lead to benefits for both sides. Increased exchanges of researchers between higher educational institutions on both sides could also generate more cooperation. Greater stakeholder awareness on both sides needs to be stimulated. Strengthening cooperation with Taiwan is also important in the context of the geopolitical situation.

Endnote

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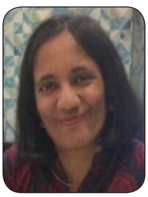
ARTICLE

Science for Diplomacy: Enabling a Knowledge Sharing and Capacity Building Framework for Water and Sanitation in South Asia

A. Peramunugamage[1], P. K. Kushwaha[2], M. Koley[3], A. B. Gunjal[4], M. Maharjan[5], F. Shahzad[6], F. Khanum[7], S. S. Kader[8]



A. B. Gunjal
(Corresponding Author)

Introduction

South Asian countries are characterized by wide gaps in basic infrastructure such as access to drinking water and sanitation or 'Clean water and sanitation' (SDG-6) which has been placed under one of the priorities that aim to ensure the 'essential basic services to all and accelerate sustainable infrastructure development' (ESCAP, 2017). The ESCAP report suggests that Sustainable Development Goals (SDGs) are an opportunity to 'carry forward the unfinished agenda of the Millennium Development Goals', and has identified seven top policy priorities for South Asian nations to fast-track SDGs. The challenges faced by the South Asian countries around SDGs are very similar and SDG-6

[1] Programmer cum System Analyst, Faculty of Engineering, University of Moratuwa, Sri Lanka.

[2] Assistant Professor, South Asia Sustainability Hub & Knowledge Network (SASH&KN), Transdisciplinary Research Cluster on Sustainability Studies (TRCSS), Jawaharlal Nehru University, New Delhi, India.

[3] Postdoctoral Fellow, DST-CPR, Indian Institute of Science (IISc), Bangalore, India.

[4] Assistant Professor, Department of Microbiology, Arts, Commerce & Science College, Pimpri, Pune, Maharashtra, India. (Corresponding Author)

[5] Associate Professor, School of Forestry and Natural Resource Management, Institute of Forestry, Tribhuvan University, Makwanpur, Nepal.

[6] Lecturer, Department of Immunology, University of Health Sciences, Lahore, Pakistan.

[7] Director, Department of Environment and Sustainability, Mrüna Limited, United Arab Emirates/ Pakistan.

[8] Senior Lecturer, Daffodil International University, Dhaka, Bangladesh

is no exception. Therefore, the authors explored the possibilities of development of a Knowledge Management Framework using the idea of an open digital platform. Such a platform could help the researchers of the whole region working on SDG-6 to come together and address issues collectively. However, due to the political complexities of the region, the authors propose to use more bottom-up approaches using science diplomacy to bring together actors from various south Asian countries. The authors have also identified some areas under SDG-6 that need immediate attention.

What is Science Diplomacy?

Science Diplomacy existed for a long time, but is formally defined by AAAS and the Royal society and used as a collective term to describe three types of 'global-politics science interface'- 'science in diplomacy' (informing foreign policy objectives with scientific advice), 'diplomacy for science' (facilitating international science cooperation), and 'science for diplomacy' (using science cooperation to improve international relations between countries) (Kaltofen & Acuto, 2018). Science diplomacy goes beyond the mere objectives of 'scientific discovery' or 'creation of a new knowledge, rather it's a strategic approach based on 'science engagement and exchange' that requires linking institutional arrangements such as governments, universities, the private sector, and civil society. It requires effective and sustainable scientific interactions, based on long-term 'integration of scientific cooperation in international relations' (Turekian, 2018).

Issues related to Rural Water Management in South Asia

According to a recent WHO/UNICEF report, two out of every ten people do not have access to safe water, five face inadequacy in sanitation facilities, and nine do not have any facility to treat their waste water.[1] In the Asia-Pacific region around 700 million people do not have access to safe drinking water and 2 billion people do not have access to adequate sanitation.[2] Clean water supply and basic

Table 1: Rural – Urban Disparity in Drinking Water Coverage in South Asia

All in percentages

	1990		1995		2000		2004	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Bangladesh	69	83	70	83	71	82	72	82
India	64	89	70	91	78	94	83	95
Nepal	67	95	75	96	83	96	89	96
Pakistan	78	95	82	95	86	95	89	96
Sri Lanka	62	91	66	93	71	96	74	98

Source: Rout,2010.

sanitation facilities are the challenges for the governments of developing countries. South Asia is one of the most populated regions in the world, where a large fraction of the population lives in the rural areas as shown in Table 1. According to a WHO/ UNICEF 2006 report, in South Asia, 20 percent of rural population are lacking adequate and safe sources of drinking water, 78 percent are lacking sanitation facilities. Current rural water management is aimed mainly at meeting the demand without a vision of long-time protection of water resources (COMSATS, 2003). Moreover, many rural communities are still unable to receive safe drinking water and have to use surface water, shallow groundwater, and rainwater as their sources of water (Prinz *et al.*, 2009).

Drinking water contamination is a serious problem and in many cases, it is contaminated with multiple elements such as excess Nitrogen (N), Phosphorus (P), Potassium (K) organic matter, bacteria, that are undesirable and more importantly with excessive fluoride, heavy metals and salt concentrations (Asif, 2013). Arsenic, iron, and manganese are also present in rural water and pose a significant danger (Azizullah *et al.*, 2011; Ali *et al.*, 2014). Owing to the lack of adequate compliance with the applicable environmental laws in rural areas, majority of the industrial waste is discharged directly into local water bodies leading to eutrophication (Karn &Harada, 2001). Pesticides and fertilizers from the agricultural field and domestic drainage cause additional damage.

Eutrophication is the excess growth of aquatic plants and algae that occurs due to uncontrolled discharge of elements like, nitrogen, phosphorus, etc. into the water body. These elementals are usually the limiting growth factors needed for photosynthesis (Schindler, 2006) along with sunlight, and carbon dioxide. Eutrophication is generally a natural phenomenon in an aged or sediment filled lakes (Carpenter, 1981), but nowadays has massively accelerated due to human activities such as discharge of industrial and agricultural waste into the aquifers.

Irrigation Water Deficit

Over-extraction of groundwater by irrigation wells has led to a decrease in groundwater levels (Ahmad *et al.*, 2014)). An analysis of data of groundwater extraction for groundwater resources assessment since 2004, 2009, 2011, 2013, and 2017 reveals that groundwater extraction has increased from 231 BCM in 2004 to 249 BCM in 2017 in India (Saha *et al,* 2021). The lack of sufficient water storage services and aging of many irrigation facilities results in losing their functions due to lack of repair and maintenance (Asif, 2013).

Sewage and Sanitation

Fecal sludge (FS) or septic tank sludge is extremely polluting when it is disposed of in public land without any consensus with the landowners (Strauss *et al.*, 2003, Valley, 2011). Most of the toilet technologies require adaptation to work under conditions of high water table and flooding. These usually cost higher and in comparison, the cheaper technologies are less reliable and do not function properly (Strauss *et al.*, 2003).

Approaches to Address Water Issues in Rural Areas

Multiple innovative technologies have emerged and it is important to adopt suitable technologies (Yu *et al.*, 2015). Capacity-building initiatives should be implemented to strengthen the understanding and skill level of local stakeholders. It would be helpful to use scientific evidence to guide policy decisions and to establish stronger cross-border relations between South Asian countries. Science diplomacy would be a way to establish technical collaboration between countries and overcome problems. Technology diplomacy will also help to lay the foundation for multi-national science ventures and reinforce relations between the South Asian countries (Susskind &Islam, 2012; TWAS, 2014).

Issues Relating to Urban Water Management

The UN World Water Development Report, 2017 highlights the fact that less than 50 percent of people in South Asia have access to improved sanitation and 35 percent of the South Asian population is urban and this is expected to cross 45 percent by 2050. Further, with the increasing production of wastewater, the overall pollution load is increasing globally, and consequently, putting the health of millions of people at risk (WWAP - United Nations World Water Assessment Programme, 2017).

Water Sensitive Urban Design and Planning

Urban water management should focus on Water Sensitive Urban Design (WSUD) based on the natural water cycle, recharging aquifers with treated water or storm water, regular water quality monitoring, low-cost sustainable treatment solutions, fecal matter management, institutional reforms, and financial incentives (Kookana*et al.*, 2020). Additionally, integrating water conservation, rainwater harvesting and wastewater recycle and reuse, urban flood mitigation, and localized water resource management are also important (Rohilla *et al*., 2017). Groundwater recharge using Rain Water Harvesting (RWH) can be implemented at different levels such as at the household level, Rooftop RWH should be developed. Success stories of Nepal discussed in Shrestha (2009) and Water Aid in Nepal (2011) Report. Channelization of Rainwater towards existing water bodies will help in their revival.

Wastewater and Sanitation

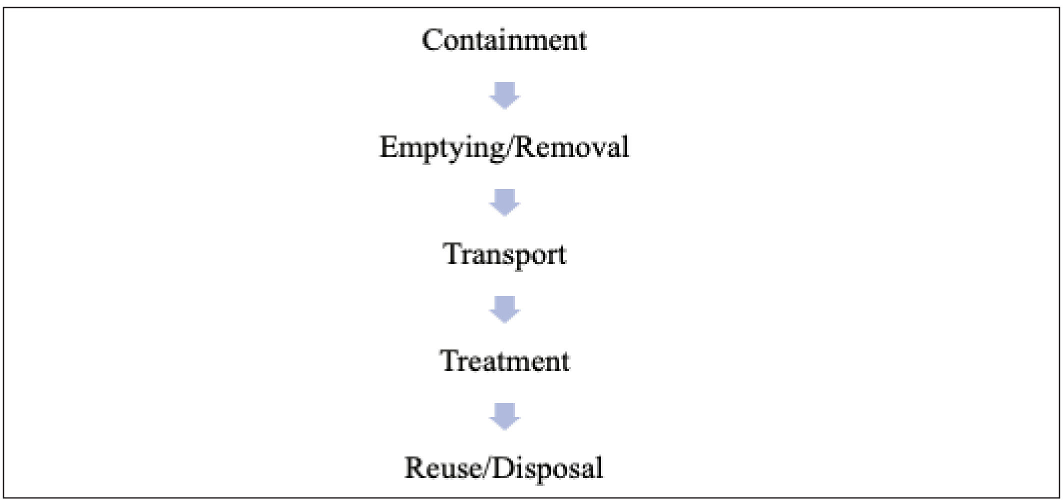
Due to population load and industrial waste, the wastewater in urban areas is highly polluted (CDP Global Water Report, 2020). Dumping of untreated septic tank/pit contents into rivers, lakes and the sea is, in many low- and middle-income countries, is a regular practice (UN-Water, 2015). There is a huge gap in adequate wastewater management infrastructure in urban areas. Existing drainage systems are in poor conditions and unevenly distributed in Asian cities that require integration of sewerage systems into watershed management plans (Kazmi & Furumai, 2005). Lack of technical know-how and sufficient funding available for building centralized systems are common issues. Contrary to this, decentralized systems (cluster or onsite) are more cost-effective for managing wastewater than centralized systems (Massoud *et al*., 2009).

Solutions lies in the Choice of Right Technology – Reliable, Affordable, and Sustainable

Energy-intensive wastewater management technologies, such as Active Sludge Process (ASP), Upflow Anaerobic Sludge Blanket (UASB), Biological Trickling Filter, Rotating Biological Contractor (RBC), Fluidized Aerobic Bioreactor (FAB), Moving Bed Bioreactor (MBBR), Submerged Aerobic Fixed Film Process (SAFF), Membrane Bioreactor (MBR) are cost-intensive and unsuitable for South Asian countries. Alternatively, Decentralized Wastewater Treatment (DWWT) technologies include Green Bridge, Bio-sanitiser, Nualgi, Bioremediation, Soil Bio-Technology, Soil Scape Filter, DEWATS, Eco-sanitization Zero discharge toilets; Fixed Film Biofilter Technology (FFBT), etc. can be considered. It is argued that mainstreaming (DWWT) systems into urban water management practices are better suited to provide sanitation services (Rohilla *et al.*, 2014).

Bioremediation or nature-based technological solutions for wastewater treatment is one of the emerging technological options under DWWT. The use of microorganisms viz., bacteria, fungi, algae, actinobacteria, and yeasts for the removal of heavy metals, organic and xenobiotic pollutants, is proving to be very effective (Shah , 2018; Boano, 2019). Bioremediation is an excellent 'green technology' (Amin et al., 2013). The effect of pre-treatment of microbial biomass with acids, alkalis, solvents will also help to enhance the bioremediation process, i.e., the removal of heavy metals from wastewater (Mani & Kumar, 2014). Even the agroindustry by-products viz., peanut shell, corn cob, sawdust, paddy husk, press mud, wheat straw, coconut shell can also be used for the removal of heavy metals from wastewater (Alayu & Yirgu, 2018; Ricciardi *et al*., 2020). This has been studied at the Savitribai Phule Pune University, Pune, Maharashtra, India (Gunjal *et al*., 2017 a, b).

Figure 1: Sanitation Service Chain

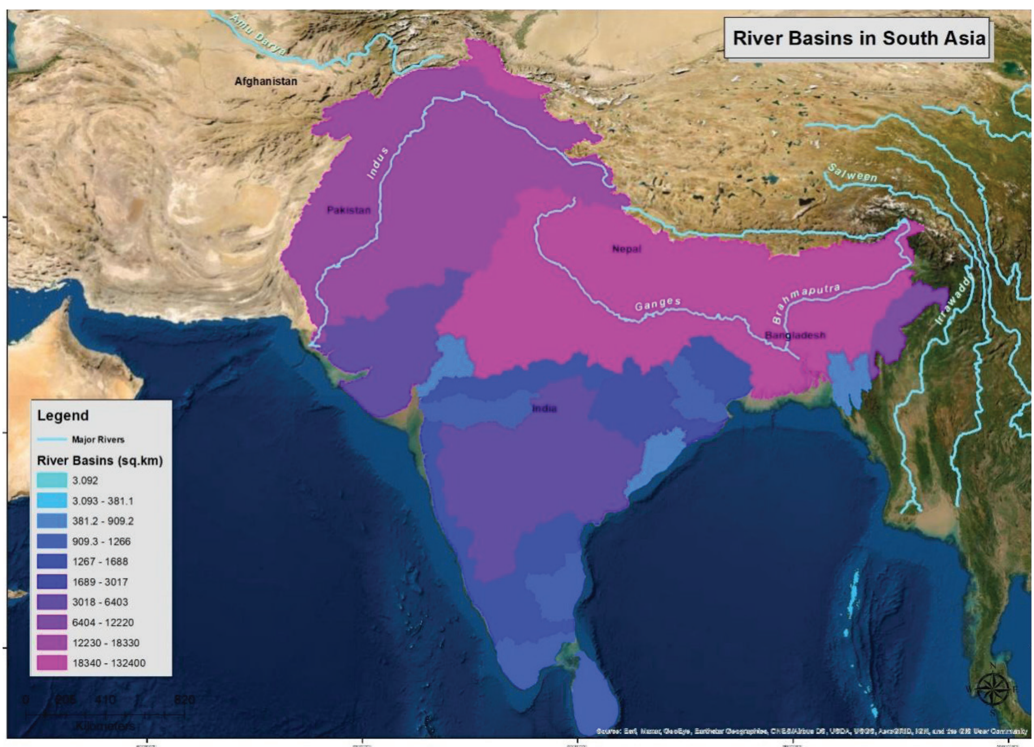


Source: UN Water, 2015.

Tran-boundary Water Cooperation

IPCC (2007) suggests that 120 million to 3.6 billion people will experience increased water stress by 2021 in South and Southeast Asia. Hindu Kush Himalayas (HKH) is known as the 'water tower of Asia' (Immerzeel *et al.,* 2010) and collectively serves 47 per cent of the world's population water supply requirement (Pomeranz *et al.*, 2013). However, HKH is undergoing rapid change due to climate change and urbanization which significantly threaten water-provisioning services across Asia (Mukherji *et al.,* 2018). On the other hand, the management of water resources is a complex mechanism due to its natural, social, and political networks and competing interests of different groups (Hossain 2013 cited in Barua, 2018). Especially when water is shared by two or more countries or even states within a country, then the situation becomes more complicated and often leads to a zero-sum problem (i.e., one party's loss is another's gain) (Barua, 2018). Regional cooperation on water resources remains a key challenge (Shresthat & Wenju, 2018). Transboundary water cooperation is a golden opportunity for achieving water security which will improve the living standard of billions of people residing in the South and East Asia region (Biswas, 2011). However, treaties alone cannot assure cooperation without the existence of relevant water agreements (Boisson de Chazournes 2003; Vinogradov *et al.*,

Figure 2: South Asia Transboundary River Basin



Source: Shrestha & Wenju, 2018.

2003). Therefore, building trust through continuous discussion and dialogues on issues related to treaties can be the best appropriate strategy for sustainable transboundary water cooperation (Biswas, 2011; Bagale, 2020). The aspect of water use efficiency and recycling needs to be taken into account in water sharing arrangements. A knowledge management framework can be an excellent tool for building such alliances among the South Asian countries around trans-boundary water cooperation.

Knowledge Sharing and Capacity Building

It is argued that 'collaborative learning environments using systems analysis with communities (social learning) and adaptive management techniques play a significant role in knowledge management (KM) practices. Incorporation of learning experiences in planning, monitoring, and reviewing processes, effectively contribute to the knowledge-building exercises (Mongila *et al.*, 2011)).

Impact of the Influential Factors on Knowledge Management Practice

The collaborative work among scientists based on science diplomacy needs to be promoted through formal educational paths and training opportunities. In the South Asian region, KM is at an emerging stage and there is no mechanism for sharing information. Therefore, scientific collaborations in South Asia require several factors including Science and technology agreements as significant scientific collaborations can only happen through bilateral, regional, and multilateral agreements, the establishment of a regional funding mechanism for collaborative research, scholarships, fellowships, science ambassadorships, and faculty exchange programs through the building of a proper KM framework. Several forms of science diplomacy can play a role here. Dogan *et al.* argue that the expectations of developing countries from science diplomacy engagement are not only limited to addressing the global challenge but also improving their national capabilities concerning the production, import, and access to technologies. There is a need for proper design and implementation of science diplomacy tools that are unique to developing countries (Ozkaragoz *et al.*, 2020)).

Developing a Knowledge Management Framework for South Asia

The proposed framework consists of three main interlinked components: Knowledge Management (KM) of the people, processes, and infrastructure & technology. It needs to achieve a balance between these three subsystems in order to achieve a successful KM effort. It includes the process of knowledge sharing, co-production of knowledge, co-designing of solutions, and institutionalization of practices of sustainable, reliable, affordable, and resilient social transformations (Abrol & Kushwaha, Forthcoming, Ely *etal.*, 2020).

This process begins with the adoption of a transdisciplinary approach (bringing together knowledge producers, practitioners, and implementing agencies) to facilitate dialogue and interactions among various actors. This can be further amplified through training and capacity building of experts and practitioners across South Asian nations, thereby, enabling a robust process of knowledge sharing and collaborations across the region. Such a KM process will further facilitate the second step of the KM framework i.e. bringing systemic changes at the level of Science & Technology based innovations. Ultimately, the third step of the proposed KM framework i.e. new socio-technical systems of change will emerge from this process as shown in figure 3.

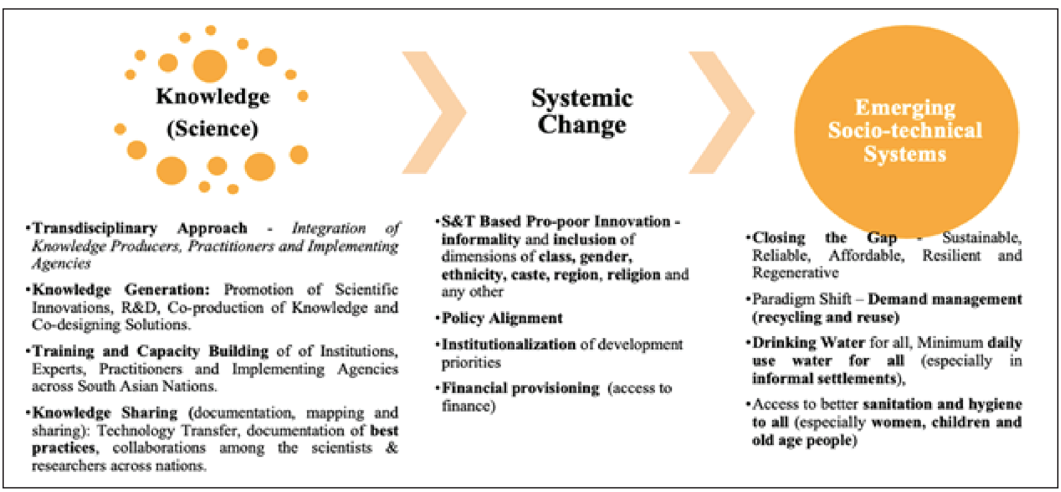
Addressing SDG 6 related Challenges through the Open Online Platform

Advances in information and communications technology (ICT) have paved the way for increased opportunities for alliances among researchers, educationists and institutions of various countries through the use of ICT and online platforms. Figure 4 depicts the proposed two-pronged approaches for building capacities and awareness through open online platforms.

Cross-country Institutional Collaborations for research and Innovations

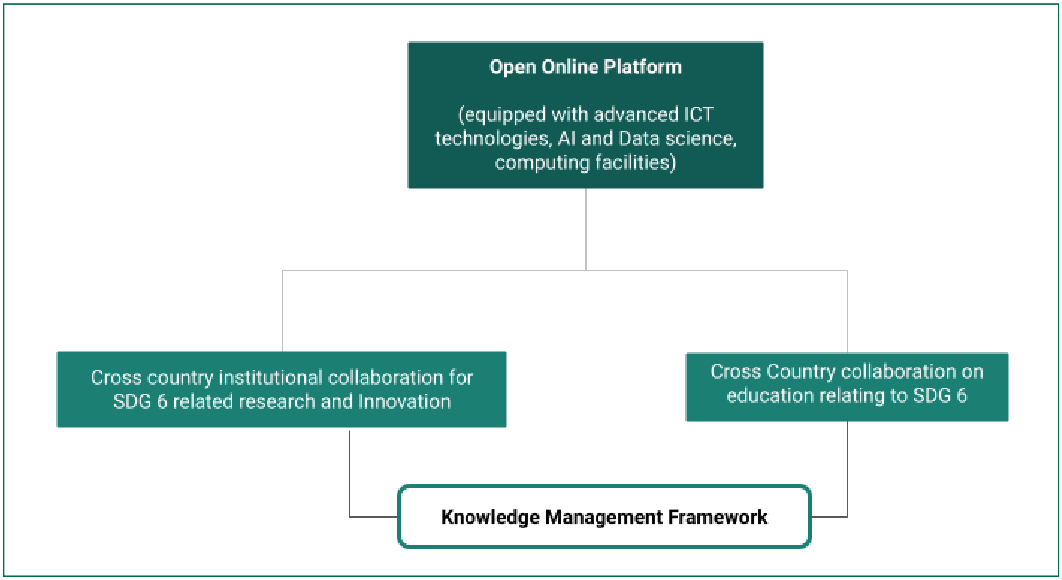
The scientists of South Asian nations must come together to deliver affordable solutions for enabling better access to clean water and sanitation. The COVID-19 pandemic has opened up the possibilities of collaborative research through digital platforms where scientists are sharing research data and collaborating to respond to the problems mankind is facing. The collaborative research efforts can motivate the design of an open platform by the Science Diplomacy group of the Global Young Academy, where problem statements around SDG-6 that need immediate attention, can be listed from the societal level by taking inputs from the affected people of different countries. The open platform is envisioned as an enabler of cross-boundary dialogue between scientists and other stakeholders.

Figure 3: Framework of Knowledge Management for Water and Sanitation in South Asia



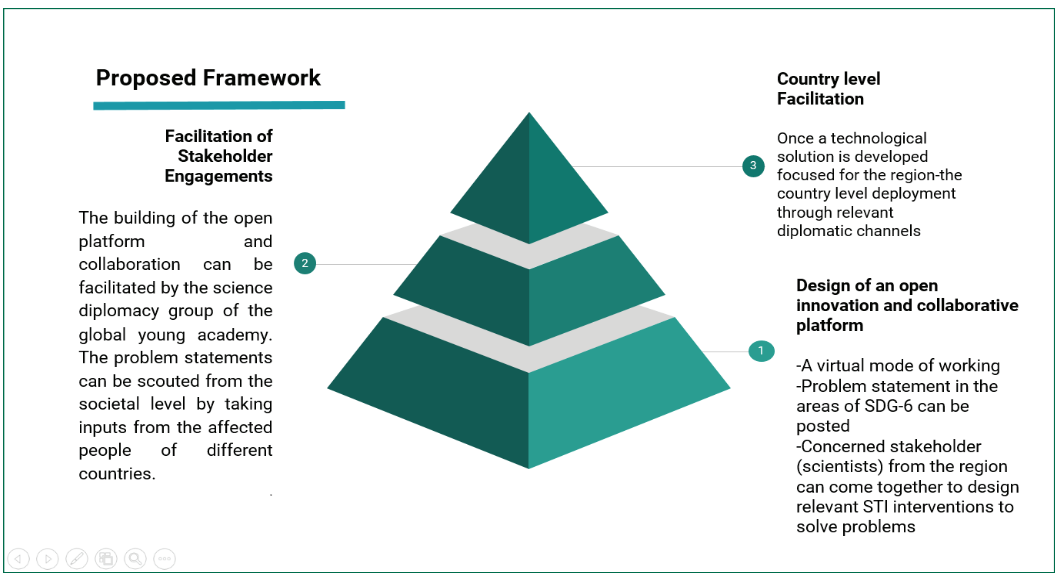
Source: Yoshino *et al.*, 2019.

Figure 4: Proposed Knowledge Management Framework for SDG6



Source: Authors' compilation.

Figure 5: Framework to Promote SDG6 through Open Innovation and Collaborative Platforms



Source: Authors' compilation.

Cross-country Collaboration for Learning and Education

The role of education in achieving the SDGs should be recognized given that education, especially open education, should be at the core of each SDG (UNESCO Survey, 2017). In recent years, many open universities in Asia adopted various forms of open education: Offering of Massive Open Online Courses (MOOCs), Open Educational (OER) Repositories, and Open Access Publications. Planning can start by developing open MOOC courses for SDG6 and gradually develop the resource platform which can be elaborated to include other SDG as well. Figure 5 describes the possible structure for both the above-mentioned frameworks.

Conclusion

Science diplomacy is the utilization of international scientific collaborations to solve common challenges and to build positive international relations. Developing ways that balance the interdependencies of transboundary waters is an issue of major international and intra-national relevance in the realm of water. In recognition of the significance of transboundary waterways, the United Nations General Assembly passed Resolution 65/154, declaring 2013 the International Year of Water Cooperation. Water diplomacy is a new EU diplomacy segment that has recently emerged in response to the EU's desire to be accepted as a normative power (EEAS) and the rising relevance of scientific diplomacy in the EU (EEAS). The key actors at the national level - the Czech Republic, the Netherlands, and the United Kingdom have different motives, aims, priorities, and agenda-setting tactics than the other EU actors, who have recently emphasized the importance of water diplomacy. The nations focused on issues such as nanotechnology in water and sanitation (Czech Republic), flood management (Netherlands), and international development work (Netherlands and United Kingdom). Examining best practices in water diplomacy reveals that water diplomacy provides opportunities for each player to develop or expand diplomatic 'niches.' In the framework of public diplomacy and country branding strategies, attention to global challenges in the field of water diplomacy revealed the goals of national and EU players who aspire to become agenda setters and "excellence sellers" in the international arena. Water diplomacy encompasses a wide range of activities including agriculture, national security, public health, and others. Because South Africa shares aquifers with Botswana, Namibia, Mozambique, Zimbabwe, Lesotho, and Swaziland (IGRAC 2014), the Water Research Commission (WRC) established Programme 4: Transboundary Water Resources (Thrust 1), and a number of reports (Breen et al. 2013; Jacobs & Nienaber 2011; Schreiner et al. 2011) addressed transboundary water issues.

Hence, working collectively is the best way for the South Asian countries to scale up their efforts to deal with SDG6 related challenges. Science diplomacy, regional and international cooperation can play an instrumental role in knowledge and capacity-building processes and can provide context-specific technological capabilities that are more reliable, affordable, and sustainable to tackle SDG 6 related challenges in this region. Deployment of an effective knowledge management framework at the South Asia level can be mutually beneficial to stakeholders of all the nations. This can collectively help in improving the regional capacity to deal with the challenges of water and wastewater management and also help tackle the future challenges arising from climate change. Adoption of this approach gives a call for the multiple actors and stakeholders to come together and take an active part in minimizing barriers wherever necessary for the management of water through science and technology interventions. The scientists need to work together for adopting economical and eco-friendly technologies for the treatment, sanitation, and management of water in South Asia. An approach combining tools of science diplomacy and knowledge management can enable open platforms for cross-country collaborations to identify and solve common problems, sharing of best practices and promote cultural awareness and mutual understanding.

Endnotes

1 See details at https://www.unwater.org/publication_categories/whounicef-joint-monitoring-programme-for-water-supply-sanitation-hygiene-jmp/.

2 Details can be accessed on http://hdl.handle.net/11540/2448.

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ARTICLE

Anti-Satellite Weapons and Satellite Mega-constellations: Pivots of Orbital Governance Reforms

Chaitanya Giri*

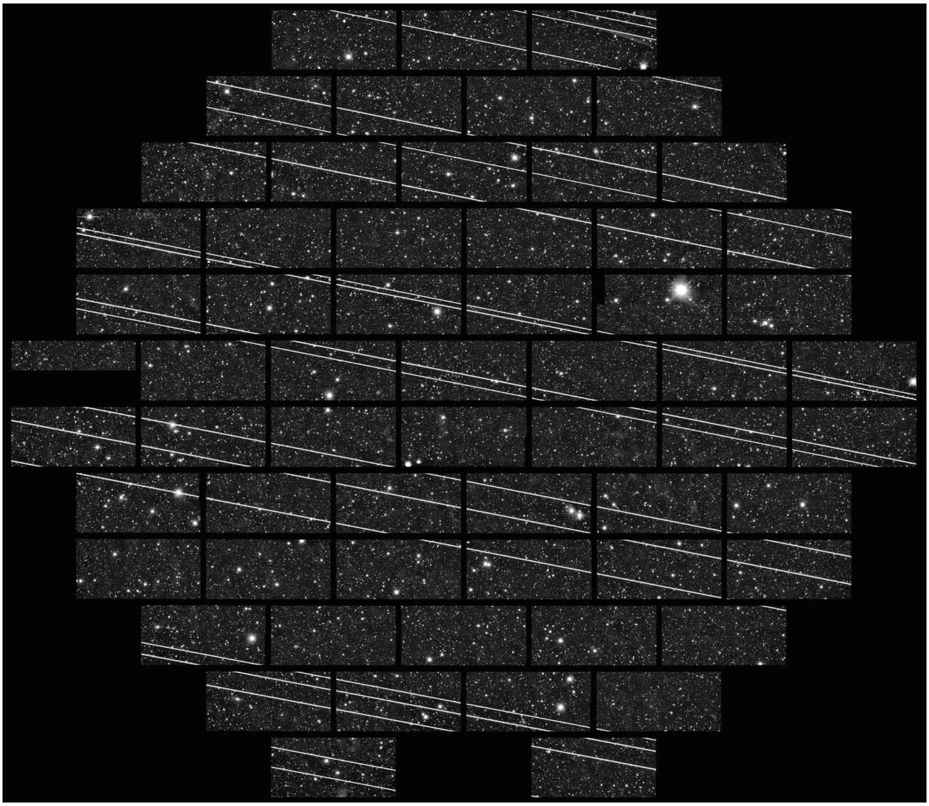
Chaitanya Giri

On 15th November 2021, the Russian Space Forces launched the *Nudol* kinetic-kill, direct-ascent, anti-satellite missile to hit a Soviet-era 39-year old *Kosmos-1408* electronics intelligence (ELINT) satellite orbiting in the Low Earth Orbit (LEO) (Miller & Watermann, 2021). Like always, the anti-satellite (ASAT) test drew criticism from a few governments from the opposite bloc (Raju, 2021). The test is no different from the six-decade-long race between leading space-capable nations to develop a credible space deterrent. All these years, there has been no international consensus on prohibiting ASAT. But, with the ever-increasing economic indispensability of the growing number of Earth-orbiting satellites and space stations and their centrality in offering various commercial socio-economic services, a prohibition on kinetic-kill ASAT weapons[1] could be on the anvil. Nevertheless, that would certainly not be the end of space governance challenges.

The U.S. Air Force carried the first successful kinetic energy kill ASAT test in 1985 by intercepting at an altitude of 252 km from mean sea level. However, this was not the first deliberate weapons-testing damage to a satellite (Martindale, 2015). The high-altitude nuclear tests conducted by the U.S. and Soviet Union between 1958 and 1963 were primarily designed to test the feasibility of nuclear blast-induced electromagnetic pulses (EMPs) in knocking out

* Consultant, RIS. He holds a Ph.D. in Astrochemistry from the Max Planck Institute for Solar System in Germany and the University of Nice in France.

Figure 1: Trails of Satellites, Part of Telecom Constellation, as Observed by Ground-Based Astronomers



Source: NSF's National Optical-Infrared Astronomy Research Laboratory/CTIO/AURA/DELVE.

power and communications infrastructure on ground. These tests did not create significant radioactive fallout and were not designed primarily with ASAT in mind. However some of these tests caused collateral damages to orbiting satellites by exposing them to severe doses of radiation and EMPs (Comprehensive Nuclear Test-Ban Treaty Organization, 2021a). In those times, the Earth's orbits were sparsely populated with satellites. Therefore, the anti-ASAT movement had not picked up pace then. The only plausible way to prohibit high-altitude explosions was to ride on the global more emphatic anti-nuclear movement and call attention to the detrimental nuclear fallout of highly irradiated ashes, dust, and energetic particles on the Earth's surface caused by nuclear explosions.[2]

Four years after the PTBT, when the 1967 Outer Space Treaty (OST) came into force, Article 4 of OST prevented the placement of nuclear weapons or use of weapons of mass destruction in Earth's orbit or on celestial bodies (United Nations Office for Outer Space Affairs, 2021a). Yet, the OST too did not directly prohibit the use of kinetic kill non-nuclear ASAT weapons, as they are not placed in the Earth's orbit and can operate as an extended-range version of a typical surface-to-air missile. The use of active satellites for ASAT purposes was also not prohibited. Consequently, since 1985 several ASAT tests have materialised with no international legal mechanism to curtail them.

Globalized Space Economy: A Deterrent for ASAT Weapons Use

ASAT weapons today can cause widespread damages than ever before, including financial losses. During the 1960s, the satellites incidentally damaged by high-altitude nuclear test explosions were operated only by governmental agencies and defence contractors closely working with these agencies. Those were the times when only a few satellites orbited the Earth's orbit and were owned by a handful number of countries. Since there were only two types of stakeholders that owned and operated the satellites, the limited financial losses due to satellite damages were absorbed fully. Even the 1972 Convention on International Liability for Damage Caused by Space Object did not create an effective accountability mechanism. The helpless writing down of damaged space-based assets due to ASAT weapons did not help curtail their use. However, with the increased military importance of satellites and consequent increase in ASAT activity, potential such losses may become difficult to overlook.

A report published by the U.S.-based not-for-profit Union of Concerned Scientists states the presence of around 4550 active satellites in the Earth's orbit in our day (Union of Concerned Scientists, 2021; United Nations Office for Outer Space Affairs, 2021b). Owing to the dense population of satellites, they have become visible even to amateur astronomers. The number of satellites in the Low Earth Orbit (LEO)[3] has seen the steepest rise, at 3790, since 2008-09. Most of these satellites are of U.S.-origin, and are those dedicated for commercial applications numbering at 2359 presently (Union of Concerned Scientists, 2021; United Nations Office for Outer Space Affairs, 2021b). As the number of commercial satellites increases, the socio-economic importance grows manifold. As a result, the equity investments in the satellite industry, both manufacturing and services, are growing.

Equity-traded funds (ETF) dedicated to the satellite industry have come up in the New York Stock Exchange (NYSE), the NASDAQ Stock Market, and European stock exchanges. The bullish trend is emerging for a reason (Bajpai, 2021). Estimates show that the global space economy may reach up to US$ 3 trillion by 2040 (Higginbotham, 2018), and the lion's share of this economic growth will come from LEO satellite services, be it fifth-generation (5G+) telecommunications, geospatial services, meteorology, environmental monitoring, and other niche applications catering to an Industry 4.0 world. The rudimentary versions of many of these satellites' applications were earlier offered entirely by civilian governmental and military agencies. But now, with the growing commercial market for these space applications, large quantum of private investments are coming forth. To add, the number of nations operating or availing commercial services from LEO satellites is higher than ever before. Most countries from across the world possess 1-9 satellites. A few possess 10-99 including India, fewer in 100-999 like China and Russia. Only the US has over 1000.

Today, many prominent satellite manufacturers and satellite services providers are listed on various stock exchanges or are dependent on venture capital. With such private capital supporting the satellite industry, the potential financial losses that kinetic-kill ASAT weapons will elicit cannot be written down. ASAT can have cascade effects on the entire global space economy, which was US$ 447 billion in 2020 (Space Foundation, 2021).

The users of anti-satellite weapons aim at the Achilles' heels of any satellite-dependent superpower. If subjected to ASAT weaponry, countries with higher space dependence are bound to suffer from wide-scale economic losses. The nations possessing most satellites are bound to be hit by ASAT-elicited direct losses first, given the international nature of satellite services and the capital financing the space industry, the secondary losses suffered by nations with a lesser number of satellites will also be far-reaching.

Satellite Megaconstellations: New Chronic Orbital Governance Threats

ASAT is a major but not the only factor leading to space debris. There are growing concerns about the unsustainable numbers of satellites pushed into Earth's orbits. Night and day-sky astronomers are anxious about the observational interferences due to the setting up of mega-constellations consisting of thousands of satellites (Boley & Byers, 2021). Such constellations can prove to be sitting ducks and targets of an ASAT kinetic kill weapon. However, even without the deliberate use of an ASAT, a densely packed satellite mega-constellations is vulnerable to non-deliberate collisions. Both ASAT (Doboš & Pražàk, 2021) and non-deliberate satellite collisions can instigate a Kessler Syndrome, a phenomenon first forecasted in 1978. The Kessler Syndrome happens when a high density of objects in LEO can advertently or inadvertently lead to a runaway self-amplifying collisional cascade rendering the orbits useless for a considerable period. In such a severe scenario, the entire space economy and other economic domains dependent on space-based assets will collapse, even leading to wars.

There are two problems at hand. First, the rapid deployment of mega-constellations can risk a chronic 'Kessler Syndrome' with a non-instigated collisional cascade between densely packed satellites orbiting around the Earth. Even in the absence of collisions, mega-constellations can cause other problems. Day- and night-time ground-based astronomers find orbiting satellite mega-constellations as physical obstructions for their seamless sky observations. Operators of space stations find such mega-constellations restricting access to Earth orbits. Atmospheric and environmental scientists find such mega-constellations as significant source of alumina, polluting the Earth's upper atmosphere. Such mega-constellations can also give rise to an acute Kessler Syndrome, if an ASAT weapon triggers a collisional cascade between satellites and ASAT-created space debris. The dual –

chronic and acute nature of the problem demands mitigation of both non-weapons and weapons threats to the Earth's orbits.

A positive step ahead is the emergence of space situational awareness (SSA) and orbital-debris removing systems. Today, many nations operate either military-run or civilian-run SSA systems to monitor and manage space traffic. Commercial SSA is also finding marketspace with the US-based SSA company LeoLabs offering its services via ground radars in Alaska, Texas, Costa Rica, Australia and New Zealand (LeoLabs, 2021). The U.S. Department of Defense' United States Strategic Command (USSTRATCOM), sensing the threat to U.S. satellite systems, has entered into SSA data- and services-sharing agreement. USSTRATCOM has such agreements with Australia, Brazil, Belgium, Canada, Denmark, Germany, Israel, Italy, Japan, South Korea, New Zealand, Norway, Poland, Spain, Thailand, United Kingdom, United Arab Emirates, the European Space Agency, the European Organization for the Exploitation of Meteorological Satellites, and more than 77 commercial satellite launchers, operators, and owners (USSTRATCOM, 2019). These agreements come in the backdrop of USSTRATCOM's crucial role in the Operation Burnt Frost ASAT test of 2008. It then coordinated between other agencies such as the National Reconnaissance Office, the Missile Defense Agency, the U.S. Pacific Command, and the National Aeronautics and Space Administration (NASA) to carry out that ASAT test (Johnson, 2021). Active debris removal or deorbiting agents are mechanisms of the mitigatory kind, where defunct satellites, debris, or launch vehicle parts are taken off from their functional orbits post their mission. In the coming years, the operators of mega-constellations will probably be vulnerable to severe liability risks (as per Article 6 and Article 8 of the OST) in case of damages to parties belonging to other states.

The growing economic stakes in LEO-based assets, cross-country venture capital investments, and the liability for damages are provoking intensely critical responses every time a kinetic kill ASAT weapon gets tested. The criticism will only exacerbate hereafter and for economic reasons.

Part of the more significant space industry, the satellite industry is progressively conjoining itself with the digital industry. Higher commercial stakes in the space industry demand greater functional fidelity of space systems. In this regard, the concept of the digital twin[4] and the internet of things may be of vital importance for ASAT prevention on the lines of the CTBT monitoring mechanisms. Internet of Things (IoT) sensors are vital for real-time sensing of space systems, essential for their functional fidelity. Digital twinning may help in predicting SSA scenarios that are inimical to any satellite, satellite small constellations, and mega-constellations. Of the many functions, IoT sensors and digital twinning could prevent unintended collisions due to densely packed constellations (Daly, 2020). Algorithmic multi-agent SSA forecasts can also warn commercial users of any debris cloud meandering on its orbital path. Such forecasts can offer them the chance to manoeuvre and avoid hazards to satellites. However, these forecasts can only help if the orbits are not densely packed with satellites. Here again, the chronic challenges created by dense population of satellites in LEO will make it difficult for satellites to make any mitigatory manoeuvre's, and cannot cope with a Kessler cascade, despite all the forecasting at hand.

The prohibition on the use of ASAT weapons cannot be pursued in isolation. Firstly, it either demands effective amendments to make the current Outer Space Treaty, or the better implementation of the 1985 Prevention of an Arms Race in Outer Space (PAROS) resolution. Unfortunately, the PAROS, which could have prevented ASAT weapons' use, also did not reach a clear consensus. The first resolution of PAROS, which "*call[s] on all States, in particular those with major space capabilities, to contribute actively to the peaceful use of outer space, prevent an arms race there, and refrain from actions contrary to that objective*" has not prevented the ASAT race (Gasparini Alves, 1991). This failure is because PAROS pre-emptively intends to prevent the placement of weapons in outer space but does not address the contemporary use of direct-ascent, surface-to-space kinetic kill ASAT weapons. However, there is increasing realization that PAROS needs to be strengthened to reduce the risks from the comprehensive militarization and weaponization of outer space. The Russia-China tabled draft Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force Against Outer Space Objects (PPWT) (United Nations Digital Library, 2021) too, in its Article 1 completely ignores the kind of ASAT weapons currently being tested.

It is likely that only commercial interests of the investors, genuine scientific activism, particularly by groups concerned about risks of densely populated Earth's orbits, and the partnerships between the global digital and space industries, can generate increased pressure for the prevention of the use of direct-ascent, surface-to-space, or air-to-space kinetic kill ASAT weapons. Therefore, it is contingent on the growing space economy to work towards a remedy for curtailing ASAT weapons.

Conclusion: Not just 'Peaceful Use' but 'Peaceful and Responsible Use'

Responsible use of Earth's orbit does not begin or end with the prohibition on ASAT weapons, especially with the development of hypersonic missiles operating in exoatmospheric realms (below 60 km height). Studies on the weaponization of LEO must give due regard to acute and chronic problems and future threats. However, there must be adequate emphasis on the chronic problems triggered by the overpopulation of LEO with satellite mega-constellations. Science and space diplomacy multilateral platforms – such as the Inter-Agency Space Debris Coordination Committee (IADC) and the International Organization for Standardization's (ISO), Orbital Debris Co-ordination Working Group (ODCWG), International Space Exploration Coordination Group (ISECG), Committee on Space Research (COSPAR), International Astronautical Federation (IAF), International Astronomical Union (IAU) in addition to the UN Office for

Outer Space Affairs and the UN Office for Disarmament Affairs – should discuss such chronic problems frequently. The basic space sciences-focusing multilaterals like IAU and COSPAR can become nodal events for discussing problems faced by astronomers, environmental scientists, meteorologists created from the space debris. Applied space sciences-focusing multilaterals like the IAF and ISECG can help focus on problems faced by space stations and other exploration missions. The IADC and ODCWG can focus on the minutiae of problems created by space debris and come up with mitigatory mechanisms. Overall the credentials of these multilaterals to create accurate policy papers, white papers, debris mitigation proposals, and problem statements, can be taken to governmental, climate and economy-related multilaterals like the Group of 20 (G20).

The Space20, a new sub-grouping within G20 multilateral architecture, can become a crucial platform for discussing the need for sustainable use of LEO and other Earth's orbits. Since the global space economy is the focus of Space20, sensitization of the space economy stakeholders who attend Space20 can prove effective. Furthermore, representation of members from some of the above-mentioned multilaterals in the Space20 meetings will better inform stakeholders. Since India will assume the presidency of the G20 Summit of 2023[5], the accompanying Space20 Convention, to be held in India, can discuss this topic. Given its recently initiated space reforms, India's ability to promote a 'responsible and sustainable global space economy' can go a long way in bringing balance to a rather harsh space race.

Endnotes

1 A kinetic-kill anti-satellite weapon is a projectile aimed for a direct-ascent attack launched from a land, sea, or aircraft-based platform to target and destroy/damage a satellite through kinetic force and without any use of explosives.

2 The yield miscalculation during the U.S.' *Castle Bravo* thermonuclear weapons test in 1954 led to an unfortunate radioactive fallout on the crew on the Japanese fishing ship *Daigo Fukuryū Maru*. The acute radiation syndrome suffered by the crew of this ship, the growing concern about atmospheric and ground contamination with radioactive isotopes (strontium-90, carbon-14, caesium-135, iodine-129, and plutonium), reinforced the growing opposition to the incessant nuclear tests of the U.S., Soviet Union, and the United Kingdom (Comprehensive Nuclear Test-Ban Treaty Organization, 2021b). As a result, the Treaty Banning Nuclear Tests in the Atmosphere, in Outer Space and Under Water of 1963, better known as the Partial Nuclear Test Ban Treaty (PTBT), came into force (United Nations Office for Disarmament Affairs, 2021). However, even the PTBT had no direct remedy for the ASAT aspect of these explosions.

3 Low Earth Orbit is the area in outer space that is confined at an altitude of 2000 kilometres from the surface of Earth.

4 Digital twin is near-precise virtual or digital model, replica, simulation of a functional system that is operating in the physical, that spans the lifecycle of the physical system, and helps in the decision-making vital for the latter system's seamless functioning.

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Pune Knowledge Cluster

Ajit Kembhavi*


Ajit Kembhavi

Science & Technology Clusters

The Office of the Principal Scientific Adviser (PSA) to the Government of India has established Science & Technology (S&T) clusters in various cities in India.[1] Their purpose is to bring together academic institutions, research and development (R&D) laboratories, industry and local administration to address challenging problems of the city and region where the cluster is located. The clusters were set up on recommendation by the Prime Minister's Science, Technology and Innovation Advisory Council (PM-STIAC), and are guided by a Cluster Apex Committee, chaired by the Vice-Chairman, NITI Aayog. The first six clusters are located in cities which already have a large number of S&T related organisations who can be partners in the cluster and work together to leverage their individual strengths and expertise.

The S&T clusters will act as a platform for a shared ecosystem of organisations in the city, sharing laboratories and equipment, allowing mobility of researchers and students, carrying out capacity building programmes and jointly executing projects of importance to the city. It is expected that the clusters will become regional providers of solutions involving high quality R&D and innovation. In the course of time the clusters should enable the city to become a national and even global leader in one or two domains which best reflect the strength of each cluster. Some details about the first batch of six S&T clusters are provided in the Table 1.

* Principal Investigator, Pune Knowledge Cluster. He is an Emeritus Professor at the Inter-University Centre for Astronomy and Astrophysics, Pune, India.

Table 1: S&T Clusters in India

Name of the Cluster	Parent Organization and Website URL
Jodhpur City Knowledge and Innovation Foundation (JCKIC) • Medical Technologies • Handicraft and Handloom • I-Governance • Thar Designs • Water and Environment • AIoT INNOVATION HUB	Indian Institute of Technology (IIT) (section-8 company) http://jckif.iitj.ac.in/
City Knowledge Innovation Cluster - Delhi Research Implementation and Innovation (CKIC- DRIIV) • Solid Waste Management • Water Security • Air Pollution • AI/ML in healthcare • Sustainable Mobility • Effective Education	Indian Institute of Technology, (IIT) (section-8 company) https://www.driiv.co.in/
Research and Innovation Circle of Hyderabad (RICH) • Life Sciences • Food & Agriculture • Sustainability • Other Initiatives	Research and Innovation Circle of Hyderabad (section-8 company) http://rich.telangana.gov.in/index.html
Bhubaneshwar City Knowledge and Innovation Cluster (BCKIC) • Quantum Engineered Advanced Materials • Waste to Value • Wetland Management • Biosciences • Polymer-based Interventions	Kalinga Institute of Industrial Technology (final stages of registering its independent cluster section-8 company) https://www.bckic.in/
Pune Knowledge Cluster (PKC) • Sustainability and Environment • Health • Big Data & AI • Sustainable Mobility • Capacity Building	Inter-University Centre for Astronomy and Astrophysics, IUCAA (under the process of section 8) https://www.pkc.org.in/
Bengaluru Science and Technology Cluster (BeST) In the process of formation	Indian Institute of Science https://sid.iisc.ac.in/bestkc/

Source: Author's compilation from official website of the office of the Principal Scientific Adviser to the Government of India.

The cluster at Bengaluru is still in the process of formation and therefore no details are included. The clusters have been provided with funds by the PSA's office, for an initial period of three years, to cover operational expenses and as seed grants for initiating projects. The clusters raise additional projects funds from various agencies, private foundations and through Corporate Social Responsibility (CSR) grants. The PSA's office proactively helps in such fund raising, systematically connecting the clusters to potential donors.[2] The example of the Pune Knowledge Cluster described in the rest of this article will provide some insights about cluster operations.

Pune Knowledge Cluster

The Pune Knowledge Cluster (PKC) was set up in August 2020. Pune was chosen for establishing a cluster because of the many academic institutions, R&D labs and knowledge based industries present in the Pune Metropolitan Region (PMR, which is larger than the region covered by the Pune Municipal Corporation, PMC) and surrounding areas, which together constitute the Pune region. Many of these organisations work at the frontiers of their domains, and have national and international standing. There is history of synergy and collaborative programmes between academic and R&D organisations, and in some cases between these organisations and industry. But there is much room for increasing these contacts, making them more systematic and productive, and for the organisations to work with civic bodies to identify important problems facing the city and to try to find solutions with the application of R&D. The PKC has been set up to facilitate such close collaborations and to address challenging problems of the region. This is done through innovative and data driven means, using scientific and technical knowledge and engaging highly skilled and motivated human resources. The PKC undertakes projects in collaboration with partner institutions in the Pune region and beyond, facilitates projects between organisations, prepares reports and position papers addressing important concerns, conducts capacity building programmes and promotes skills development and entrepreneurship amongst students and young professionals.

Administrative Structure and Staff

The PKC is currently administered by the Inter-University Centre for Astronomy and Astrophysics (IUCAA) and is on its way to becoming a Section 8 Company. It has its office on the campus of S.P. Pune University. It has a small staff including Senior Advisors and scientific and technical members working on specific projects. The PKC has an Advisory Committee consisting of eminent scientists, technologists, industrialists and heads of institutions. Funds for the operation of the PKC and seed funding for projects are provided by the PSA's office, while funds for projects are obtained from CSR programmes of companies, foundations and other funding agencies.[3] The other S&T clusters have a similar administrative structure, with some differences in detail.

Partners

The PKC has close collaboration with a number of academic institutions, R&D

labs, defense establishments and industries and has signed MoUs with many of them. The PKC has built a close relationship with Pune Municipal Corporation (PMC), Pune Smart City, Maha Metro Pune and other civic bodies in the region and the state government. The data and facilities that they provide are crucial for implementing projects for the public good. While the present partners are located mainly in the Pune region, work with organisations from other cities too is increasing. PKC is working on projects like STEM teaching with the Delhi S&T cluster, and with institutes in several cities on COVID-19 related projects. While the PKC projects have been Pune centric, they can easily be translated to the needs of other cities and regions in India and abroad. The intracity collaboration that clusters like the PKC foster can be extended to intercity collaborations. It would also be interesting for the S&T clusters in India to learn from the experience of successful clusters abroad, and to inform them of our own innovative projects. The PKC is in the process of creating joint water management related projects with Water Valley in Denmark and citizen science related projects with South Korea and USA. A good opportunity for international cluster collaborations could be provided by some of the cities in South Africa, which have the organisations and infrastructure to sustain such activity.

PKC Programme Verticals

The following verticals have been identified by the PKC for projects and activities to be undertaken:

- Health
- Environment and Sustainability
- Electric and Sustainable Mobility
- Big Data and AI
- Capacity Building

These verticals are not independent or exclusive, with the first three clearly impacting each other. All PKC projects are highly data driven, they require big data analytics and AI applications for interpretation of the data and building predictive models. The capacity building programme provides courses, workshops and internships in a variety of topics loosely covered by the verticals to young researchers and professionals; through the programme STEM teaching is provided to high school students and teachers, with topics mapped from the verticals to school syllabi.

Work Done Under the Verticals

Health

Due to the pandemic, work under this vertical has been on projects related to COVID-19. Some projects were started well before the PKC formally came into being; these provided a template of how experts from different domains could spontaneously form a group to address emergent and completely novel situations. Few of the projects under the health vertical are as follows:

Pune Serosurvey

The purpose of this survey was to gain insights into the spread of COVID-19 in the Pune Metropolitan region (PMR) and to estimate the seroprevalence of antibodies against the SARS-CoV-2 virus in five high-incidence prabhags (subwards) of the city. The survey was carried out between 20th July and 5th August 2020, and a highly specific assay was used to detect antibodies. It was found that in the five prabhags which were surveyed, the average sero prevalence rate was about 51.5 percent, there was no difference between the male and female population, the prevalence was lesser in the 66+ years population, hutments and tenements had higher prevalence, but the apartment and bungalow population too was significantly affected. The results indicate extensive spread of the infection by July-August 2020 in the prabhags studied. The main research partners were SP Pune University for data gathering, Christian Medical College (CMC) for study design, CMC and IISER-Pune for statistical analysis, Translational Health Science and Technology Institute (THSTI), Faridabad for antibody assays and virus protection assay. Among the civic partners, the PMC provided regulatory clearances for carrying out the project and helped with identifying donors for the sample collection. The Persistent Foundation, Pune was the founding partner.[4]

COVID-19 Data

The PKC, in collaboration with a number of organisations has collected large quantities of COVID-19 related data from a number of government and private hospitals in the PMR. There is daily available data on the number of cases, number of serious or critical patients, number on oxygen and fatalities etc. from April 2020 to the present day. Epidemiological data providing details about individual persons who have been detected as COVID-19 positive is available for more than 6.6 lakh (660,000) as of the first week of March 2022. Clinical data which provides details of the lab reports and case files is available for about 7000 patients. All the data is being curated, collated and analysed. Well-structured databases along with tools for data visualisation and analysis will be released shortly for all interested users and should constitute an important database for detailed studies in the future. The data has been used, from the early months of the pandemic, to provide critical inputs to the PMC and state government regarding the anticipated progression of the pandemic. The COVID-19 database will in the future evolve into a comprehensive database for all infectious diseases for the Pune region, which can be scaled to the whole state and beyond. A simple example of information generated from the data is shown in Figure 1. The PMC collected the data from a number of private and government hospitals in the PMR through iHealWell, which provides a commercial healthcare platform. The data was provided to PKC. Later PMC authorised PKC to obtain data with the help of the same company. Curating the data and development of the database was being done in collaboration with IISER-Pune and NCL, the epidemiology group at BJMC, and other partners. Data analysis and modelling have been done by SPPU. This project is supported through a grant from the Rockefeller Foundation.

Viral Surveillance Through Genome Sequencing

The aim here is to enable enhanced viral surveillance through genome sequencing of samples collected from COVID-19 positive patients, to better track SARS-CoV2 today

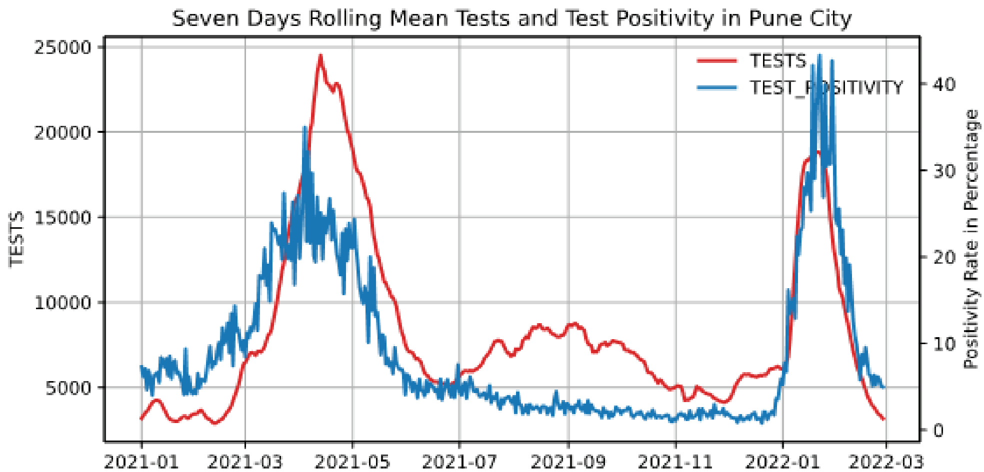


Figure 1: The seven-day average number of cases, and the positivity rate, which is the ratio of the number of people detected to be positive to the number tested in Pune, from June 2021 to 28 February 2022. A sharp increase in positivity, likely driven by the omicron variant of the virus, is seen over the last days of December. The latest numbers indicate the end of the third wave in the Pune Metropolitan Region.

and monitor future threats. More than 12,000 samples from COVID-19 positive cases in PMR have so far been sequenced at NCL and IISER-Pune, including samples from the first and second waves of the epidemic (the retrospective sample) and about 2500 from the third wave phase (prospective sample), where samples are sequenced within two weeks of collection from positive cases. The samples include those from patients with breakthrough infections, i.e., people who are infected after double vaccination and/or following an earlier episode of infection. The data will allow study of the dynamics of the disease and spread of variants in earlier phases, as well as realtime characterisation of variants associated with different clinical outcomes. Combined with the large volume of clinical and epidemiological data available for the PMR, the genome sequence database will provide a valuable resource for further studies. RNA Samples from COVID-19 positive patients for sequencing are obtained from hospitals and pathology laboratories. The partner hospitals were B. J. Medical College, Deenanath Mangeshkar Hospital, KEM Hospital, Nobel Hospital and Symbiosis Hospital, and partner Pathology Labs were AG, GenePath DX, PH, Sahyadri, Suyog and Thyrocare. IISER-Pune, NCL, NCBS, Bengaluru was research partners. It was funded by the Rockefeller Foundation, which also funded similar projects in Bengaluru (NCBS), Delhi (IGIB, Institute of Genomics and Integrative Biology). This will permit perusal of the similarities and difference which arise due to significant geographic separation.

Genome sequencing is also being used for surveillance of the spread of the virus across the PMR. In this project, led from NCL, waste water samples are collected from different parts of the city and tested for the presence of the SARS-COVID-2 virus and the positive samples are sequenced at NCL to identify possible variants. The idea here is to have an early warning system which can be used to detect the spread of the virus in the PMR before a significant number of individuals are clinically found to be positive.

Post-Vaccination Studies

In this project a large number of selected people are being followed to study their humoral (i.e. those mediated by antibody molecules that are secreted by plasma cells) and cellular responses after vaccination over a two-year period. The aim is to determine how the responses develop over the period, their longevity, and how the presence of baseline sero-immunity, which is indicative of a prior infection, influences the outcomes. The role of innate immune markers, microbiomes (all the microbes in the body), and vitamin and mineral deficiencies in influencing immune response to the vaccines will also be studied. It is planned to establish a cryo-repository of post-vaccination and convalescent plasma biological samples for future retrospective analysis and to investigate protection against possible new variants of SARS-CoV-2. The KEM Hospital, Vadu and Symbiosis University Hospital and Research Centre are Clinical and Research Partners. It is funded by the Hindustan Lever Ltd. and Unilever Industries Pvt. Ltd., who are also funding similar studies in Bengaluru (NCBS) and Vellore (CMC).

Environment and Sustainability

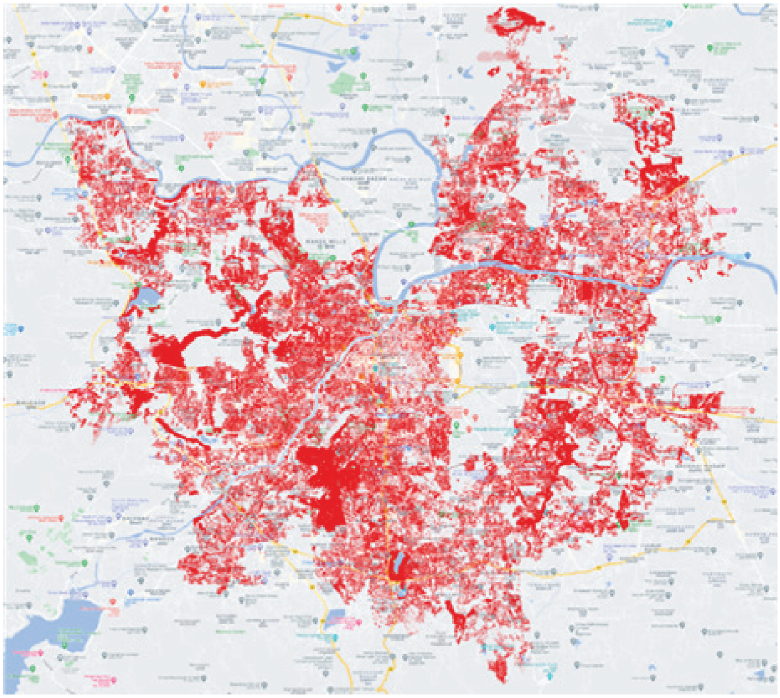
These are major areas of concern for the PKC. Projects here are of two kinds, those which can be done using existing data or data which can be easily assembled, and those which require long term perspective, planning and substantial funds. Some specific projects which have been undertaken include:

Pune Tree Cover

The aim of this project is to estimate the carbon sequestration capacity for the region in the coming 3-10 years. It would also serve as a decision tool for urban planning. There are about 5 million trees spread over an area of about 330 sq. km. under the Pune Municipal Corporation (PMC) and tree census data is available for about 4 million of those trees. The survey was carried out over a period of two years during 2016-18.

This data is being used to understand characteristics like tree density, presence of native species etc. through data mining. Tree recruitment is being estimated through a participatory sapling mapping excise, mortality through sampling techniques and tree growth measured for a stratified sample. The data will be used to build a growth model for the trees and saplings, and to predict carbon sequestration capacity over the 3-10 years. The growth model will lead to estimates of how many more trees would be needed to sequester the residual emission generated by growth in the number of vehicles and in building activity. The project will provide guidelines on suitable species for plantation on

Figure 2: The Red Dots Indicate Trees in Pune



Source: Author's compilation from the available database.

various land use categories like avenues, biodiversity parks, riparian zones and private land. Potential plantation place will be identified with the help of satellite maps. A key feature of the project is the use of high-resolution satellite maps of the Pune region provided by ISRO, together with data on the present tree cover and the growth model, to train AI based tools. The trained tools will enable future inferences regarding the tree cover to be drawn on the basis of the satellite maps alone. Once developed for the PMC, the models can be adapted to other regions in the country. Research partners of the project are Statistics and Botany departments of SPPU (project design, taxonomy, habitat improvement studies), Centre for Ecological Studies (CES) at the Indian Institute of Science, Bengaluru (project design, tree modelling), WRCS (field work) India, PMC, and Maharashtra Forest Department (providing data and use of the outcome urban planning). Schlumberger and Cummins Foundation is the funding partner.

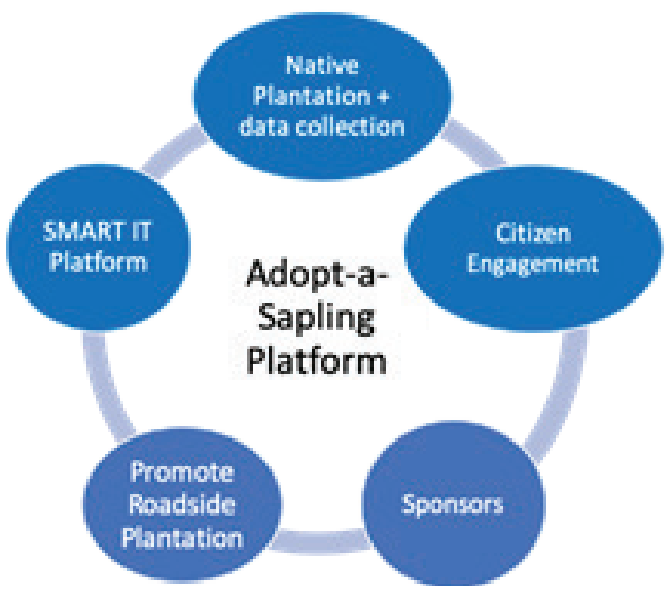
Adopt-a-Sapling

The aim of this project is to create an AI and GIS (Geographic Information System) enabled interactive platform for citizens and local government bodies to track and maintain sapling plantations. This is an example of citizen science projects being initiated by PKC. Community efforts in sapling plantations for improving tree cover in Pune city have been mainly on hills, but such efforts are needed on the roadside as well. The PMC and other organisations have sapling planting programmes along roads, but there are few mechanisms for monitoring the saplings after plantation. The Adopt-a-Sapling project will drive sapling plantation along roads with the help of Pune Smart City and other organisations, and involve citizens to monitor the health of saplings along the roads in their neighbourhood, recording their observations on the PKC platform developed for the purpose. Concerned authorities can take timely action by tracking sapling data on the platform, thus improving the survival rate of the saplings. The Project Partners include: Centre for Environment Education India (CEE) (citizen engagement) and Pune Smart City (planation strategy, citizen engagement, help with web platform design).

Mission Prakriti

This project aims at creating a self-sustaining Biodiversity Park on 1170 hectares of degraded reserve forest land in the PMR, near the village of Loni Kalbhor. It will provide a pilot model for barren land afforestation and biomass generation for biofuel production. The afforestation is to be carried out over four overlapping phases of two years each, with a total timeframe of five years. Each phase has a management plan, with a participatory approach for all stakeholders like farmers, pastoralists, ecologists and local bodies. It will lead to water, livelihood and environmental security of the area and its people, and biodiversity. There will be about 400 trees per hectare, with large increase in the biodiversity, including flora and fauna. Plantation models will be created to ensure that the Park's vegetation can sequester at least 2.8 million tonnes

Figure 3: Steps to be executed in the Adopt-a-Sapling project



Source: Author's compilation.

CO2eq. in 20 years from the time the park is built. Plantations will be made of commercially important timber and non-timber forest produce (NTFP) species including for pulp (paper), fibre (plywood) and biomass for biofuels. Additional means of income generation will be created through apiculture, pisciculture and tourism. These developments will increase the income of farmers, landless labourers and other locals, as well as the Grampanchayat and Forest Department. The project site will get notified as an International Union for the Conservation of Nature (IUCN) category VI protected area. Project Partners include Maharashtra State Government, local bodies, Wildlife Research and Conservation Society (WRCS) and GAIA the Earth Foundation. A project proposal has been submitted to various funding agencies.

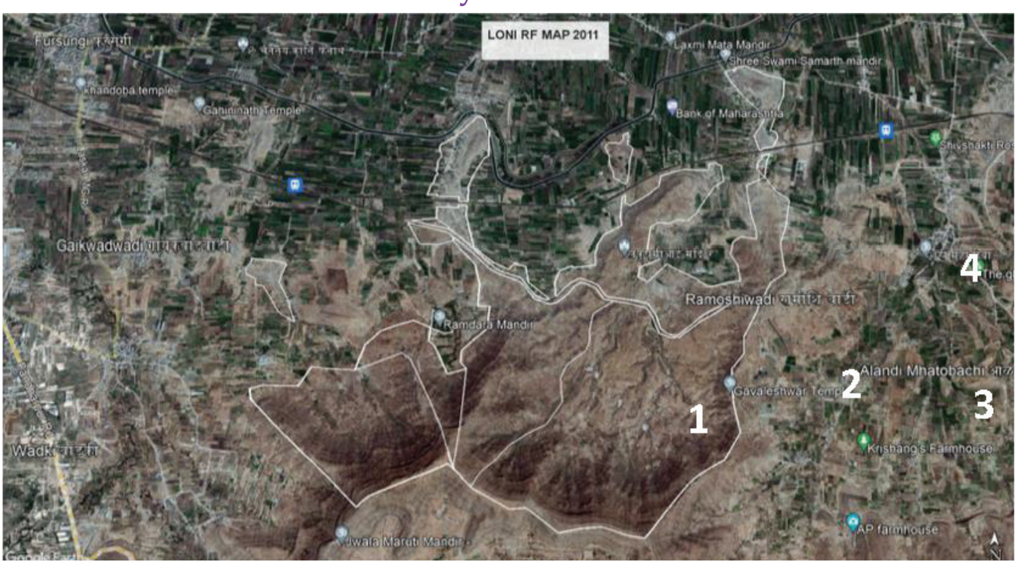
Sustainable Water Management

This project involves preparing a plan for city level water harvesting and conservation, using satellite data, water flow data from CCTVs and drones, seismic data, data on water quality and water use at different locations. The data will be used to design a city water grid to optimize storage and water harvesting in housing, office areas, asphalted roads etc. An important change here from previous efforts will be to move from Pune city centric management to a plan involving the entire PMR defined by the river basin landscape, as this provides the natural geographic boundaries. A Letter of Intent has been signed with Water Valley of Denmark for collaboration on water management projects.

Green Energy

The aim of this project is to investigate technologies that can use agricultural waste, and domestic and sewage wet waste, to produce Bio-CNG at the Zilla Parishad level. A feasibility study will be carried

Figure 4: The Deforested Area in Loni-Kalbhor which is to be Afforested. Areas to be Covered by the Four Phases are Shown



Source: Author's compilation from the available database.

out, followed by technology scouting, evaluation and pilot demonstration of Bio-CNG production in a commercially viable manner. The targeted capacity is 5 tonnes per day of bio-CNG. A waste supply chain and needed logistics will be created with the help of Zilla Parishad. The project is being discussed with industries including Praj Industries and KPIT Cummins, and PMC and Zilla Parishad.

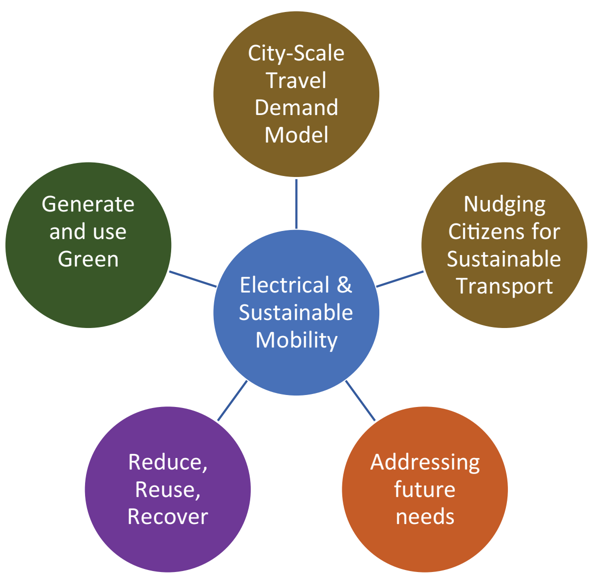
Electric and Sustainable Mobility

Pune is one of the prominent automotive hubs of India, with several national and multinational industries having a strong vehicle manufacturing base in the city and its suburbs. As a consequence, a vibrant auto component industry has emerged over the last decade. It is expected that Pune will therefore be at the forefront of the electrical and sustainable mobility manufacturing, at the vehicles as well as the components level. The PKC seeks to take advantage of this situation to undertake projects which will enable a smooth transfer to the large-scale use of the new technology vehicles and their adaption by citizens. The city has two metro lines functional, and more line should become operational soon. It will be important to use electrical vehicles to solve the last mile problem of connecting metro stations to final destinations. Some of the projects which are being undertaken keeping in mind these factors are shown in Figure 5.

Last Mile Connectivity

Pune has a well-developed system for the use of 3-wheeler autorickshaws for travel within the city. It would be natural to migrate the fleet from the conventional fuels petrol, LPG and CNG, to electrical 3-wheelers, which would provide a clean and green alternative, particularly for short distance travel within the city. These

Figure 5: Projects under Electrical and Sustainable Mobility

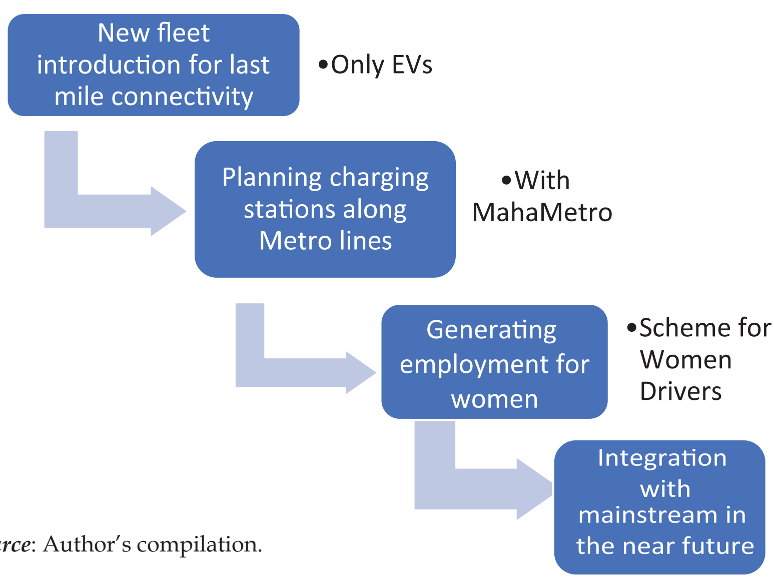


Source: Author's compilation from the available database.

will be the natural vehicles for first and last mile connectivity to metro stations, obviating the need for parking spaces. The adaption of the E-rickshaws will involve engagement with various stakeholders, including manufacturers, Maharashtra Metro, Pune Smart City, autorickshaw unions for protecting the interests of existing autorickshaw owners and drivers, users to understand their needs and expectations, and the Regional Transport Authority (RTO). It is also necessary to consider the deployment of E-minibuses in certain areas to provide connectivity for a large number of users. The overall impact on traffic patterns due to these changes can be best studied with detailed simulations of traffic flow using a digital twin of the city developed by TCS. The use of e-rickshaws will provide opportunities for women drivers, helping with their empowerment. The proliferation of E-vehicles will require the development of new skills for their operations and maintenance, presenting new opportunities for employment. The PKC has been in discussion with all the stake holders and has been collecting data to develop specific projects to help with the launch of the last mile connectivity.

A critically important element for the efficient use and deeper penetration of E-rickshaws as well as other E-vehicles, is the placement of convenient battery charging facilities along the Metro routes and Metro parking stations. Low cost, convenient and safe charging facilities will also be needed by electrical 2-wheelers, cars etc. These could be operated on a PPP model. The optimal choice of such charging stations, their placement and usage pattern can be best planned with the help of the TCS digital twin. ARAI, TCS, charging Maharashtra Metro, Pune Smart City station manufacturers, and the Delhi S&T cluster (DIIRV) are the project partners.

Figure 6: Steps for the Introduction of E-Rickshaws for Last Mile Connectivity



Source: Author's compilation.

E-Waste Management

E-waste generated from end of the life, obsolete, and surplus electronic devices consists of toxic chemicals and hazardous materials mainly cadmium, lead and mercury. It also contains precious metals including copper, iron, gold, silver and platinum. With the rapid growth of E-vehicles, there will be great increase in the E-waste generated from the Lithium-ion batteries presently used to power the vehicles. If not properly disposed, the E-waste would pose environmental and pose serious health hazards. Proper recycling of the batteries would lead to the recovery of precious metals, which is particularly important as these metals are almost exclusively imported and therefore pose a strategic risk. The PKC is engaged in a project to examine technologies developed by CMET and SPPU for recovery of the precious metals and the development of automation for a prototype plant. The prototype will be set in partnership with Mahindra Cero and other industries. Successful prototyping would result in the establishment of many small units for the recycling, minimising transportation and logistics costs. CMET-Pune, CMET-Hyderabad, Centre for Industries 4.0 Lab (C4i4, Pune) are research partners. The industry partners are Mahindra Cero along with few other industries.

Big Data and AI

These concepts and practices are a part of many PKC related activities. AI related courses have been offered under the capacity building programme, sophisticated data bases are being developed for the COVID-19 related data which has been gathered ever since the onset of the pandemic, and AI is being used in the analysis of the data, including the determination of geolocations from conventional addresses. In the trees project AI is being used to correlate space data with ground level data on trees. The citizen science project will be collecting morphological data on millions of galaxies leading to the creation of big datasets by the community, and their scientific use by students and teachers. Creation of a platform for AI applications in biology is being planned.

Capacity Building

Under this vertical the focus has been on advanced courses in science and technology, STEM programmes for high school teachers and students, and a citizen science programme in astronomy.

Advanced Courses

About ten courses have been conducted during 2021 in various areas including biology, biodiversity, epidemiology, vaccines, entrepreneurship, artificial intelligence and natural language processing. These courses typically consist of 10-12 lectures, meant for young researchers and professionals, and are given by Pune based as well as national experts in the domain. Hands-on sessions are conducted in each course, but lab sessions have so far not been possible due to pandemic related restrictions. Most courses have been recorded and are available through YouTube and will soon be made available online through the Infosys Springboard platform. A number of webinars are periodically conducted by PKC alone, or in partnership with various organisations including the PSA's office.

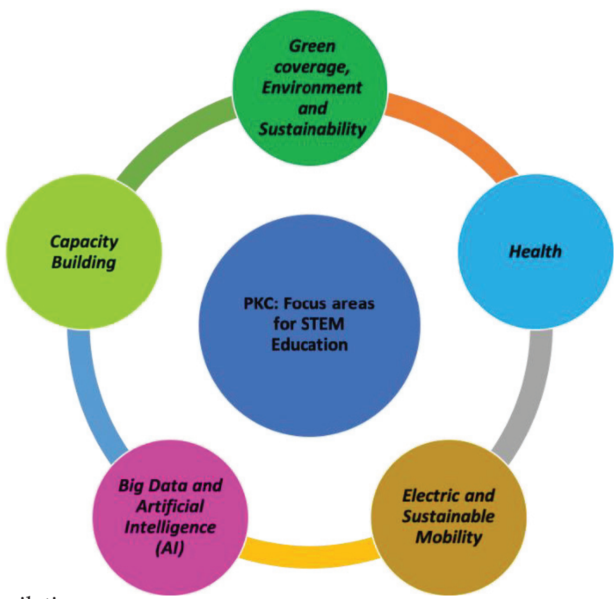
Institutional Partners of the peoject include ARI, NCL, SPPU, IIT-Bombay, CODATA Alliance, Indian National Science Academy (INSA), Indian Academy of Sciences (IASc). The Serum Institute of India, Icertis, Persistent Systems, IBM Research, CII are industrial partners. While coordinators of the courses were from partner organisations, the lecturers were from a number of organisations in India and abroad.

PKC is working with CII, Pune on skilling and training programmes on industry and entrepreneurial skills, enabling teaching with technology, industry internships for graduates and postgraduates, promoting opportunities for technology transfer and open innovation programmes. PKC is also working with CII and C4i4 on developing a Digital Lean Manufacturing Mission.

STEM for Schools

Given the difficulty that school teachers and students face in dealing with various STEM topics, particularly with the remote learning and teaching forced by the pandemic, the PKC has launched a STEM teaching programme for students and teachers from Class 6th onwards. The programmes will be aligned with recommendations of the National Education Policy (NEP 2020), and will work to foster critical thinking skills, analytical ability, logical reasoning and curiosity. The verticals of the PKC will be mapped to the existing STEM curriculum, and the subject matter will be introduced through real life scenarios and practical knowledge. Teachers will be encouraged to adopt digital technology and focus on enquiry-based learning, with hands-on activities and skill development. Comprehensive programmes for training, including

Figure 7: Areas to be Covered in the STEM Programme for School Students and Teachers



Source: Author's compilation.

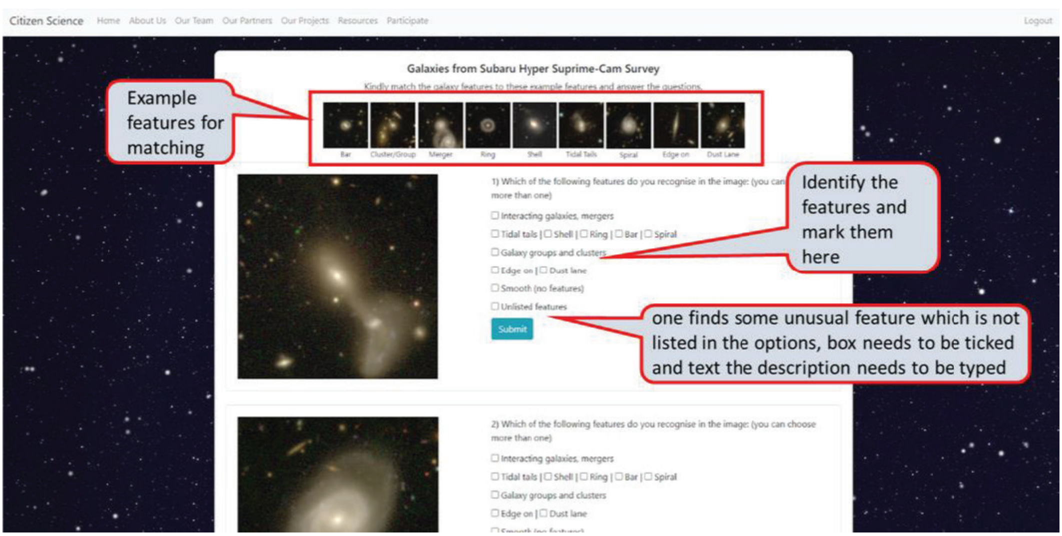
lectures as well as practical sessions, and for setting up or strengthening existing labs have been drawn and submitted for CSR and other funding. Its academic partners are IISER-Pune and the Delhi S&T Cluster (DIIRV).

A survey of school teachers to identify gaps in their knowledge has been carried out and training of about 3000 Pune Zilla Parishad Marathi medium school teachers in batches of 1000, conducted through live video, has begun on October 15. Interactive sessions are conducted before and after the lectures. Zilla Parishad, Pune, District Institute for Educational Technology (DIET), Pune are civic partners.

Citizen Science Astronomy

These programmes enable people who are not expert in astronomy to help create large astronomical databases which can be used in their research by astronomers. The first such programme to be taken up by the PKC is on the morphology of galaxies, which enables participants to find the presence of special structural features in galaxies. The participant is presented with a number of images of galaxies and has to decide whether certain kinds of feature are present in the images, using a specially designed web interface which is very intuitive to use. Experts later statistically analyse the information provided by the participants to decide which features are really present. In this fashion a large database on galaxies is produced. This can act as a training set for important AI applications to galaxy studies and cosmology. In a pilot programme, about 100 students, homemakers, senior citizens etc. have used the PKC citizen science website to analyse the images of about 20,000 galaxies to produce morphological data on them. The programme, now titled *One Million Galaxies* was inaugurated for participation by all interested citizens. It is planned to produce a database of a million

Figure 8: A Page from the Web Interface used by Participants in the Galaxy Morphology Programme



galaxies in about a year's time. New projects will be released every few months. Such programmes help to build capacity by familiarizing citizens with scientific methodology and enabling them to participate in the creation of professionally usable data. The project partners are Indian Institute of Astrophysics (IIA), IUCAA. Astronomers from California Institute of Technology (Caltech) and the Korea Institute for Advanced Study, Seoul have been contributing to the project.

Discussion

The programmes and projects undertaken by the PKC have been selected considering the needs of the city and the region, and the human expertise and resources available for the activity. Addressing the challenges faced required collaboration of experts spread across several organisations, and in some cases, substantial external funding. Since the projects concerned the city, the cooperation of civic authorities is very much needed, and has been forthcoming in good measure. This has particularly been the case with COVID-19 related work, where data has to be provided by government as well as private hospitals and was used keeping in mind the privacy of the patients. This process was facilitated by the Pune Municipal Corporation right from the beginning of the epidemic, allowing the PKC to develop databases which are fairly unique in terms of the very wide range of epidemiological and clinical information and the number of cases covered. The PKC projects in a sense are demonstrations that such cooperative endeavours for the general good are possible between organisations, none of which on its own would have been able to address the challenges. Pune has a particularly favourable ecosystem for such activity, nevertheless the binding provided by a committed organisation like the PKC is required to get people together and to get projects done.

While the PKC projects have been Pune centric, they can easily be translated to the needs of other cities and regions in India and abroad. A good example would be of some of the cities in South Africa, which have the organisations and infrastructure to sustain cluster based activity. It would be interesting for S&T clusters in India to catalyse such activity where it does not exist, and to learn from the experience of successful clusters abroad. The intracity collaboration that clusters like the PKC foster can possibly be extended to intercity collaborations.

Endnotes

1 Details are available at https://static.psa.gov.in/psa-prod/psa_custom_files/S%26T%20Cluster%20Report%202022_Website.pdf.

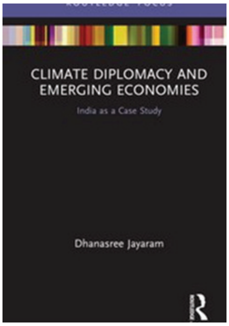
2 Further information about the clusters can be found at https://www.psa.gov.in/st-clusters.

3 Details about the PKC can be found at pkc.org.in.

4 More information available in medRxiv preprint doi: https://doi.org/10.1101/2020.11.17.20228155.

Acknowledgements

I wish to thank my colleagues from the PKC for permission to use in this article their figures, presentations and reports and for help in preparing the Tables in this article, and the PSA's office for the information about S&T clusters in other cities



Climate Diplomacy and Emerging Economies: India as a Case

Author: Dhanasree Jayaram
Publisher: (London/New York: Routledge, 2021)
Pages: 154
Price: £44.99 (hardback) ISBN: 9780367634025, £16.99 (e-copy)

Krishna Ravi Srinivas*


Krishna Ravi Srinivas

The role for Climate Diplomacy after COP-26 is obvious but how countries and groupings will use it and respond to that is a big question. Because Climate Diplomacy is inextricably linked with national climate policy as well as interests of the nations in using it to influence other countries and for other purposes, including enhancing the prestige and good will among the comity of nations. India's stand on climate change and it's response to global negotiations have been almost consistent and based on principles of equity and Common But Differentiated Responsibility (CBDR). This book takes India as a case study and has a focus on the BASIC (Brazil, South Africa, India and China) nations, their climate policies and positions globally and how as a group it has responded to global climate politics.

The introductory chapter analyses development of climate policies of countries and the factors that influence countries positions. The author discusses the realist constructivist position and its relevance, in understanding global climate politics. The first chapter

*Senior Fellow & Consultant, RIS. He is the Managing Editor of a journal titled Asian Biotechnology and Development Review (ABDR) and holds a Ph.D. from National Law School, Bangalore.

lays the basic framework for the following chapters. The author discusses in detail the emergence of BASIC and its role in global climate politics. Their working together in different Conference of Parties (COPs) and related events are described in detail. BASIC has been a vocal group in climate politics and its positions have been influential among developing countries. As countries in BASIC are emerging economies and are considered as a part of the problem as well as solution, their impact has been substantial. The coming together and common position as well as the divergences later are analysed well. India and China, used the argument of low per capita emissions vis a vis the developed countries, to resist demands for what they perceived as unfair demands on them in terms of commitments and action. BASIC group has countries that have common features as well as differences in terms of their foreign policies, their position in global environmental issues and perception of other countries on them.

The author rightly points out that while the BASIC emerged in earlier Climate Summits, they did not have much to offer in terms of new positions or proposals or as novel approaches in the later ones. Nevertheless, they were clear on resisting the pressure from developed countries and refused to accept what they perceived as unreasonable demands. The domestic climate policies and other factors do influence positions taken in Summits and climate policy has linkages with foreign policy. Thus, despite apparently common positions and demands, the factors that influence them are not the same. The author relies on constructivist approach to explain, why and how countries try to enhance their legitimacy and influence. She points out that China has emerged as a major donor for developing countries and wants to project itself as a responsible superpower. (In addition to climate change, China wants to be a major player in global biodiversity negotiations as well as evident from recent developments). Whether commitments, positions, and capabilities are commensurate with capacities is a different issue. On the other hand, a major developing country cannot afford to be asking for merely rights and concessions as that would be contrary to aspirations and claims. The book helps in understanding this.

The second and third chapters deal with domestic issues and factors in BASIC countries and their nexus with global positions and aspirations. They are written well, but the author could have discussed in greater detail, the domestic politics and issues in South Africa and their impact on international policy of South Africa. The failure of the developed countries to walk the talk in climate finance is highlighted by the author. This has resulted in developing countries becoming skeptical of the proposals of developed countries regarding reduction in global emissions. She rightly points out that using climate change as a business opportunity evokes better response and support for climate action.

India's climate policies and their development is examined in the subsequent two chapters, for the decade of 2009 to 2019. The author discusses them in two time periods, from 2009 to 2013, and, 2013 to 2019. She points out that India's position has been a response to demands on India in terms of binding commitments in emissions reductions and India's aspiration to be perceived as a major developing country, an emerging power. While the approach of fixing targets internationally was found wanting, for many countries, nationally determined contributions are preferred for obvious reasons. Since Copenhagen Summit India's approach has been informed by this. This enables countries to take positions that are commensurate with their aspirations and capabilities as well as their responsibilities to address the global challenge of climate change. The author discusses in details the domestic factors and milieu and argues that India's climate diplomacy agenda is directly correlated with foreign policy. She provides a positive assessment of policies and actions taken since 2014, pointing out the many bilateral agreements that have been signed. Similarly, she takes the position that India's climate policy is in tandem with energy policy and discusses inter alia, International Solar Alliance (ISA). But a detailed analysis of National Action Plan on Climate Change or discussion on its adequacy vis-a-vis the impact of climate change on India is missing. While the author points out the bi-lateral developments in climate change related issues, in my view, they are necessary but not sufficient. While the author discusses India's actions and commitments as a responsible power in climate change issues, it is surprising that not much is discussed about enhancing thinking and practices in climate diplomacy as well on adequacy of the current actions and positions.[1] Such a discussion would have enhanced the value of the book. The final chapter discusses areas for future research.

The book gives an excellent understanding on India's Climate Diplomacy and the role of BASIC in global climate changes. In my view given the objectives, the length of the book could have been more, providing a nuanced analysis of the some of the issues discussed and elaborating future pathways for India's climate diplomacy. It is an important and welcome addition to the literature.

Endnote

1 It is worth pointing out according to a recent study "This shared understanding of the purpose of India's climate diplomacy builds on two separate narratives – the development first narrative and the global leadership narrative. That these two mindsets provide the basis for India's broadly based climate diplomacy has implications for the wider world." (P14)

Reference

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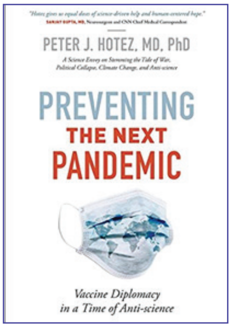

Vaccine Diplomacy through the Lens of a Practitioner

Author: Peter Hotez

Book Title: Preventing the Next Pandemic: Vaccine Diplomacy in a Time of Anti-science

Publisher: Johns Hopkins University Press

Pages: 208

Price: $27.95 (Hardback)

ISBN: 9781421440385

Kapil Patil*

Kapil Patil

The ongoing COVID-19 pandemic has seen a revival of global vaccine diplomacy with leading vaccine-producing nations not only working together to unravel the genomic structures of the SARS-COV-2 virus but also leveraged vaccines supplies as tools of solidarity and soft power projection. With the pandemic exposing critical gaps in global vaccine manufacturing and supply-chains capabilities, the role of international cooperation has once again assumed center stage as policymakers' world over are trying to grapple with the market and government failures in the production and supply of vaccines. Due to the highly technological and resource-intensive nature of this industry, the vaccine manufacturing capabilities currently exist only in the limited parts of the world thereby leaving a large number of developing countries dependent on international partners to secure access to life-saving vaccines. Effective cooperation between local and international healthcare agencies has therefore been a key to dealing with various distributional inequities created by limited supplies.

* Consultant, RIS. He holds a Ph.D. in Science Policy Studies from the Centre for Studies in Science Policy, Jawaharlal Nehru University, New Delhi, India.

Vaccine diplomacy has historically played a crucial role in addressing vaccine-related access and equity issues around the world. The contemporary vaccine diplomacy approaches richly draw upon the tireless efforts of many unsung heroes who steered the global vaccine cooperation in the past to eliminate many infectious diseases. Dr. Peter Hotez is one such unsung vaccine hero who devoted his long scientific career to understanding and eliminating the rise of various tropical and neglected diseases in large parts of middle-east and sub-Saharan Africa. Beyond his scientific expertise, what makes Dr. Hotez's work worthy of recognition is his commitment to wielding vaccines as a diplomatic tool to build the bridges of peace and stability. Dr. Hotez's latest book, "Preventing the Next Pandemic: Vaccine Diplomacy in a Time of Anti-science" offers a fascinating account of his tryst with vaccine diplomacy and to promote vaccine access to a large number of poor and marginalised people around the world.

As a leading expert on neglected tropical diseases (NTDs), Dr. Hotez began his stint in international cooperation, persuading congressional bodies to allocate funds for the distribution of essential medicines for NTDs. His push for securing congressional support and funding to combat neglected diseases in parts of Africa and developing countries became particularly relevant in the wake of the international community adopting the historic millennium development goals (MDGs) to fight poverty and hunger. With a strong interconnect between poverty and diseases, Dr. Hotez's work yielded valuable results in terms of minimising disease reduction and creating vaccine capacities in the partner countries.

A partnership that Dr. Hotez helped to forge between Texas Children's hospital and GAVI alliance supported by Bill and Melinda Gates Foundation proved to be highly beneficial for curbing the spread of diseases like Measles, Diarrhea, Rotavirus infections, and most notably Polio in many African countries. The GAVI Alliance is today recognised as a successful vaccine diplomacy model which not only expanded the remit of child vaccinations programmes but also drew interest from other international actors.

By 2014-15, the rise of infectious diseases in the pockets of poverty in many developed, as well as developing countries, warranted a renewed commitment to vaccine cooperation. Such cooperation however could not have been possible without President Obama's strong commitment to science diplomacy outlined in his speech at Cairo University and the subsequent launch of the science envoy program in 2010. Recognising the power of science as a tool to overcome ideological divides and to foster peace and public goods, the Obama administration had made science diplomacy a key feature of his political outreach to the Arab world

Being a longstanding proponent of vaccine cooperation as a diplomatic tool, Dr. Hotez would have naturally emerged as a preferred choice for President Obama's science envoy programme and to lead vaccine outreach with politically estranged middle-eastern and African countries. As part of this mission, Dr. Hotez successfully developed vaccine cooperation with countries like Saudi Arabia that was engulfed in the middle of conflict-ridden Iraq and Syria to its north and Yemen to its south. With protracted internecine wars and forced migrations becoming a major cause for the emergence of infectious diseases, Dr. Hotez mainly focused on designing new vaccine technologies to prevent specific conflict-borne diseases and illnesses.

As a career vaccine and science envoy under the Obama administration, Dr. Hotez's book offers three interesting perspectives on vaccine diplomacy. Taking a long view of the international healthcare cooperation initiatives over the past 200 years, Dr. Hotez seems rather astute in recognising the importance of vaccines as a highly valued technology, and more importantly, the enormous scientific and professional influence enjoyed by vaccines scientists and developers as guardians of health. In doing so, Dr. Hotez pays a rich tribute to his role-model Dr. Albert Sabin who successfully led the Post WWII vaccine diplomacy when he jointly developed the oral polio vaccine with Soviet scientists at the height of the Cold War in the late 1950s and 1960s.

Dr. Sabin who had developed the world's first oral polio vaccine undertook intense back-channel diplomacy with his counterparts in the erstwhile Soviet Union to test and license his oral vaccine. Took place in the backdrop of an intense arms race between the U.S. and USSR during the peak of the Cold War, the successful testing and industrial-scale production of Sabin's oral vaccine not only helped to address the Polio outbreak in Soviet member countries but also set a gold standard for promoting scientific cooperation that transcended narrow national and ideological considerations. These episodes once again serve to negate the "value neutrality" of the modern scientific enterprise and help us unpack the deeper political underpinnings attached to both competitive and cooperative dynamics between nation-states.

The second key insight from the book pertains to a grave uncertainty surrounding the future of infectious disease and what it holds for the future of vaccine securitisation efforts. Here, Dr. Hotez's focus on Anthropocene forces such as rising socio-economic inequalities, conflicts, and political instabilities, unplanned urbanization that are leading to the complex interplay between humans and wildlife is particularly relevant to understand the unexpected rise in several infectious diseases in the previous decade. Since vaccines hold the only promise for humanity to deal with future outbreaks and epidemics, Dr. Hotez thus rightly alerts the international community about the dangers posed by anti-vaccine (anti-science) forces around the world. As evidenced on a large scale during the COVID-19 pandemic, the anti-vaccine misinformation posed a serious threat to pandemic mitigation efforts and calls for appropriate public education programmes to curb the rise of anti-vaccine campaigns.

The third and most important insight from the book concerns Dr. Hotez's vision for the future of vaccine diplomacy. Reflecting upon his engagement in vaccine development during SARS, Ebola, and MERs epidemics, Dr. Hotez critically examines the approaches adopted by global initiatives like the Coalition for Epidemic

Preparedness Innovation (CEPI). While regarding CEPI as the "fellow traveler" in the vaccine cooperation, Dr. Hotez opines that CEPI's approach to disease selection is rather narrow and that there is a need to focus on various neglected diseases that disproportionately affect a large number of poor and underdeveloped countries.

Towards this end, his policy prescription involves a two-pronged science and business diplomacy approach for producing vaccines for various neglected diseases which is highly valuable. Equally important is his emphasis on crafting viable business models especially the non-profit ones to advance the development and distribution of vaccines in a large number of developing countries.

Derived from his longstanding academic and policymaking experiences, the insights and policy takeaways from Dr. Hotez's book are truly novel and offer a forward-looking roadmap on vaccine diplomacy. His emphasis on both the scientific and business aspects of vaccine development holds immense significance in the current context when policymakers' around the world are struggling to secure access to the COVID-19 vaccines. The COVID-19 pandemic has served to remind us that infectious diseases pose far greater risks to human society and that the world needs vaccine diplomacy more than ever. With ever-increasing socio-economic complexities, the success of vaccine diplomacy demands greater awareness of the underlying socio-political context and the international community would immensely benefit from Dr. Hotez's interdisciplinary vision that combines science and international relations in a synergistic manner.

The Great Tech Rivalry: China vs the U.S.

Publisher: Belfer Center for Science and International Affair
Harvard Kennedy School

Shekhar Jain*

Shekhar Jain

The Great Tech Rivalry: China vs the U.S.' authored by Graham Allison, Kevin Klyman, Karina Barbesino and Hugo Yen and published by Belfer Center for Science and International Affairs, Harvard Kennedy School is an important report in relation to U.S. and China tech war which started with a trade war during the Trump administration (SCMP Reporters, 2021). Though such tech wars are not new for the U.S., the scale (Danilin et. al. 2021)and the pace of the opponent this time sounds unprecedented, something very well reflected in the report. And after looking at the report, interrelated scenario and several recent political events (BBC, 2021; Specia, 2021), it will not be an understatement to say that like the cold war between the U.S. and U.S.S.R., the US and China tech war is going to be a path defining event of this century.

The report opens with an executive summary wherein a subtle admission is made about how several foresight analyses published at the dawn of the new millennium couldn't foresee China as the next global power. Chinese potential was subtly ignored citing their dismal economic and technological indicators. Perhaps, this is one of the reasons this report sounds a bit more cautious while assessing the technological potential of the ''The Elephant in the room', a phrase the report used for China with reference to its ignorance as a potential global power.

* Ph.D. Research Scholar, Center for Studies in Science Policy, Jawaharlal Nehru University, New Delhi.

Following the executive summary, the report has brief chapters on several new age technologies *viz:* AI, 5G, Quantum Information Science, Semiconductors, Biotechnology and Green Energy. The chapters judicially and contextually use different technological indicators to reflect on the bigger picture and to assess the technological competition between the U.S. and China. The chapters use different indicators as and when required, but largely consist of indicators such as users of a particular technology or platform e.g. China's iFlytek over Siri used in the context of AI, patent and research publication, use of Patent Cooperation Treaty (PCT), number of STEM graduates, access to raw materials, products sold, etc. In addition, chapters at several places juxtaposes the government support and policies in support of the technologies to build the argument.

The last chapter of the report i.e. 'Macro Drivers of the Tech Competition' presents a comparative analysis between the U.S. and China juxtaposing several aspects such as technological indicators, budgetary allocation and policy steps at a macro level. This chapter also describes the disadvantages that have emerged for the U.S. in comparison to China due to political regime, cultural preferences such as privacy over security and many other non-quantifiable and subjective aspects. The chapter does acknowledge the lead that the U.S. has at present, but it also warns that it is a matter of only a decade that China may overtake with respect to all the indicators. Though one important point worth highlighting is that the report nowhere does a comparison between China and the U.S. in terms of the basic research, wherein the U.S. is an undisputed leader and accounts for 60 percent of global spending on basic research. Overall, based on these data of the indicators and arguments the report provides these main conclusion(s):

- China is a full-spectrum peer competitor in AI.
- China will be a world leader in the 5G deployment and has the fast mover advantage.
- China has surpassed the U.S. in quantum communication and has rapidly narrowed America's lead in quantum computing.
- China may soon catch U.S. in semiconductor fabrication and chip design.
- Chinese researchers have narrowed America's lead in the CRISPR gene editing technique and surpassed it in CAR T-cell therapy
- China has cemented a monopoly over the green energy supply chain of the future. And hence, America's green push relies on deepening its dependence on China.
- China's approach is challenging America's traditional advantages in the macro-drivers of the technological competition, including its technology talent pipeline, R&D ecosystem, and national policies.

In a nutshell, this report succinctly presents the overview of the challenges that China is posing to the U.S. position as the global tech leader. The report is brief, to the point and relies on data on technological indicators. One of the take away from the report is that it will provoke not only the US but also the world to re-strategize and fasten their tech development efforts, particularly when several reports and articles suggest that China's growing dominance have created anxiety among the world leadership (Schuman, 2020; ORF, 2021; Williams et. al.). However, the report while giving a succinct view doesn't dwell much into the theoretical aspects or the politics around the trade war which have led the US into Tech war with China. Besides the report also doesn't discuss the aspects beyond the technological competencies wherein China doesn't fare that well which may impact the technological progress in near future. Examples of these include, China' stern relations with its neighbors which has led China into several territorial and regional disputes(Krishnan Kutty, 2020) in addition to several of its innate characteristics which poses challenges to China in gaining the dominance in world leadership (Chen, 2022). In addition, not much is reflected on the unethical practices China is routinely accused of (The Guardian, 2020). However, the report does mention a few such issues in the chapter, 'Macro Drivers of the Tech Competition' but it largely remains on the bylines and only presented in contrast with the advantages China has.

Yet the report is important as it reflects on the sheer magnitude of the growing Chinese competencies in future tech and its ambition to be a world technological leader. And howsoever the pace and scale of Chinese footprints on technological development appear unprecedented or the conflicts China is getting into or the unethical practices China is accused of, any attempts to look away will be like ignoring the Elephant in the room twice, which doesn't look like a mere exaggeration once we look at the data given and arguments made in the report.

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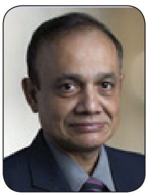
COMMENTARY

India's Semiconductor Dreams: The Packaging Reality

Ashwini Aggarwal*



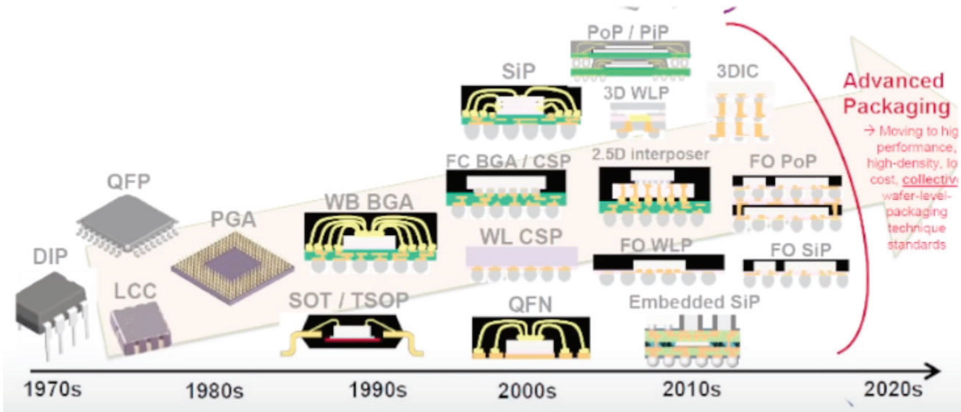
Ashwini Aggarwal

Indian aspirations in semiconductor sector have been subject to swift undercurrents – with both believers and naysayers taking extreme positions, often without a quantitative foundation to their claims. One of the latest myths have been that semiconductor packaging is an easier path for India's semiconductor aspirations to be realised. The underlying hypothesis of the some so called experts is that it is less capital intensive and the technology is easier to access and easier to execute. As per this logic, 'Outsourced Packaging' (or OSAT for Out-Sourced Assembly & Test Packaging house) is the low hanging fruit opportunity to go for. While the advent of any semiconductor packaging house in the country is significant, it is imperative to have a practitioner's perspective. Equally important is to critically assess the limitations of the above hypothesis and identify appropriate factors required to realise this part of the semiconductor value-chain.

Firstly, it is necessary to understand global trends in the packaging sector of semiconductors. Semiconductor Packaging is a series of processes at the back end of semiconductor production flow where the processed wafer with its active dies is converted into the 'packaged device'. The packaging is primarily to protect the die, given an interconnection path from the interconnect points on the dies to the connection points/contacts for

* Director – Government Affairs, Applied Materials India Pvt. Ltd. He is the Chair for industry's semiconductor task force at ELCINA and CII and a member of India Semiconductor Manufacturing Advisory Committee at SEMI, a global body for Semiconductor Manufacturing Industries.

Evolution of Semiconductor Packaging…



the external world. Packaging also adds appropriate functionalities specific to the device usage (thermal properties for heat management, requisite mechanical properties relating to the application).

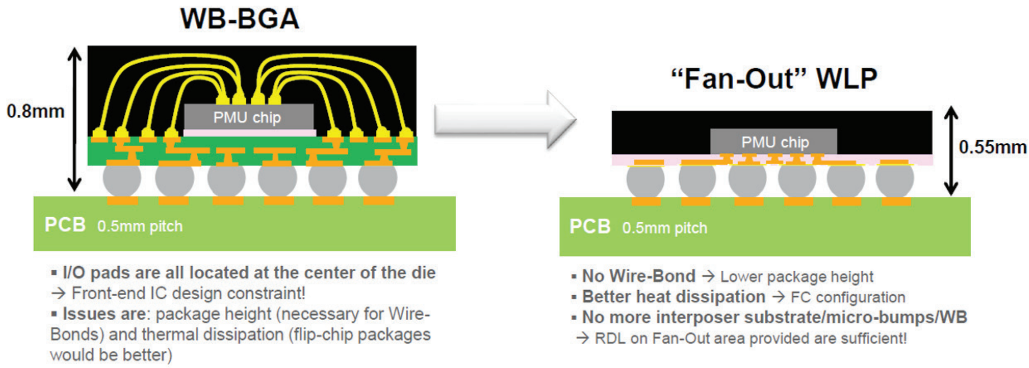
Typically, the semiconductor packaging process takes the processed wafer and dices (slices) the chip- and tests, marks and packages the die, and therefore they are also known as Assembly Testing Mark Pack (ATMP) units. Over a period, as the foundries and fabs looked at capturing the value inhouse, the role of outsourced ATMP houses (or OSAT) has increased in order to address advanced packaging requirements in the semiconductor industry.

Globally, it is relevant to note that the conventional packaging market is relatively flat in terms of growth (~2-3 per cent Compound Annual Growth Rate (CAGR) ~$32 bln by 2025), while the advanced packaging market is growing at 7-8 per cent CAGR with a projection of ~$43bln by 2025.

The advanced Semiconductor Packaging addresses challenges of the rapidly shrinking die geometries, but the relatively stable Printed Circuit Board geometries. It also serves the functional needs of packaging (for example, specific radiation hardened chips on special ceramic substrates).

The challenges for an Indian entrant to the sector include:

- Clarity of their market strategy. They should know what devices they wish to package (indeed, packaging needs for MEMS, vs Memory, vs Power electronics vs Communication vs devices are unique).
- They need to have a clear technology roadmap to survive the technological upheavals in the sector, as they will inevitably emerge in future.
- It will be risky to blindly endorse the conventional packaging. Some of the aspirants seek to import used packaging plants from abroad. If they are importing conventional packaging plant, they need to understand not just the residual life of the equipment but also the shifts in the end-markets.

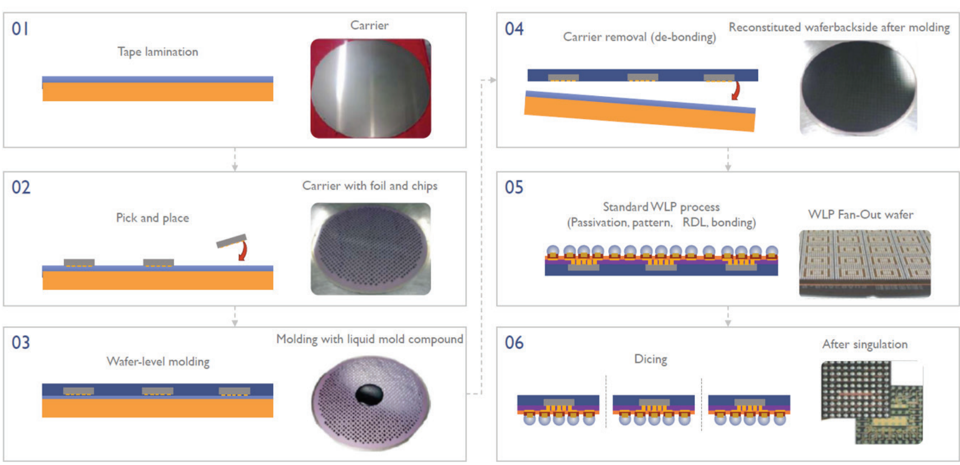


They should be sure that their targeted market will continue to use the conventional package over an acceptable period.

- Managing the logistics disability. It is impractical to expect that a fab operator will make his wafers in another country, send it to a packaging house in India and then import the finished device back to his country. The packaging house must be appropriately placed with respect to the value-chains, and an India based packaging house must produce a device which has a sufficient demand in India. Of course, eventually, it should have a mother fab in India for feeding it with processed wafers.

It is relevant to understand the economic drivers of the packaging industry. One consistent driver is the drive to bring down the cost per packaging inter-connect even as the number of inter-connects per device grow. This cost pressure has seen the semiconductor packaging industry evolve away from the wire-bond packaging of the 1980s. The gold wire-bonds, the interposers (intermediary

Fan-out packaging principle..



Source: Applied Materials

substrates), underfill materials have been taken out of the advanced packaging bill of materials. New processes have emerged where the entire wafer is reprocessed at one shot by re-constituting it on a carrier substrate (wafer, or now on a larger panel to improve process productivity), doing appropriate laminating coats of epoxy and then creating the interconnects to the die surface. And this process of interconnect creation are conceptually the processes in the mainstream fab – of growing epi coatings, patterning, etching interconnect paths and redistribution layers (RDL) of interconnects, with under-bumps and ball grid creation.

Put simply, the process is now as complicated and as sophisticated as the fab process. A Packaging house needs a huge device demand to load the OSAT lines – and to get the productivity and costs to market expectations. Packaging is evolving as a key More-than-Moore evolutionary motion. Now there is an active debate between creating a SoC (system-on-chip) vs SIP (system-in--package). The latter gives cost advantage and fast time to market with acceptable functionalities. Heterogeneous Packaging, for example, envisages optimizing the SiP by operating with dies made in different fabs at different node sizes (optimized for logic, memory, power, RF as per tech roadmaps for each function) and integrating them on emerging standard embedded bus architectures.

First step in addressing the Packaging house opportunity is to define the target market. Is it going to service power-electronics for EV/Auto industry? Then it needs to work with the target sector stakeholders and government to enable a demand aggregation strategy. Demand loading will be key to cost-effective ROI and survival.

Second step is to link the target market needs to the technology - now – and a future roadmap that keeps a competitive position for the target market. Collaboration with an appropriate technology provider will bring their proven, process recipe to enable a fast time-to-market for the Indian operator.

OSAT Landscape Evolving with M&A

- Intel , TSMC lead the ATMP companies
- And OSAT is evolving more into advance packaging with increasing capture of product value
- ASE leads the pack…but top 10 have Taiwan in lead, followed by China with 1 (USA- AMKOR) and (Singapore-UT)
- Key India challenge:
  - What will drive demand to an India OSAT?
  - It may not be practical to have a fab create a finished wafer, transport to India for ATMP – and then re-export finished product abroad..

Source: Market Research Reports

Essentially, the risks and enablers of the semiconductor packaging business are the same as that of the semiconductor fab. Rigorous market focus/understanding, appropriate technology/roadmap, financial strength and a long-term vision are the key success factors. With several Indian business houses looking at the space, there is hope that the short-cut traps will be avoided and appropriate tie-ups will result in India, designed chips getting made initially in a trusted fab abroad or in India – and packaged to our needs in India.

G20: Call for Papers

G20 is gaining importance as a global platform for articulation of economic, social and development issues, opportunities, concerns and challenges that the world is confronting now. Over the years, G20 has witnessed a significant broadening of its agenda into several facets of development. India is going to assume G20 presidency in 2022 which would be important not only for the country but also for other developing countries for meeting the Sustainable Development Goals and achieving an inclusive society. India can leverage this opportunity to help identify G20 the suitable priority areas of development and contribute to its rise as an effective global platform.

In that spirit, Research and Information System for Developing Countries (RIS), a leading policy research institution based in New Delhi, has launched a publication called G20 Digest to generate informed debate and promote research and dissemination on G20 and related issues. This bi-monthly publication covers short articles of 3000 to 4000 words covering policy perspectives, reflections on past and current commitments and proposals on various topics and sectors of interest to G20 countries and its possible ramifications on world economy along with interviews of important personalities and news commentaries.

The Digest offers promising opportunities for academics, policy makers, diplomats and young scholars for greater outreach to the readers through different international networks that RIS and peer institutions in other G20 countries have developed over the years. The interested authors may find more information about the Digest and submission guidelines on the web link: **http://www.ris.org.in/journals-n-newsletters/G20-Digest.**

Guidelines for Authors

1. Submissions should contain institutional affiliation and contact details of author(s), including email address, contact number, etc. Manuscripts should be prepared in MS-Word version, using double spacing. The text of manuscripts, particularly full length articles and essays may range between 4,000- 4,500 words. Whereas, book reviews/event report shall range between 1,000-15,00 words.

2. In-text referencing should be embedded in the anthropological style, for example '(Hirschman 1961)' or '(Lakshman 1989:125)' (Note: Page numbers in the text are necessary only if the cited portion is a direct quote). Footnotes are required, as per the discussions in the paper/article.

3. Use's' in '-ise' '-isation' words; e.g., 'civilise', 'organisation'. Use British spellings rather than American spellings. Thus, 'labour' not 'labor'. Use figures (rather than word) for quantities and exact measurements including per centages (2 per cent, 3 km, 36 years old, etc.). In general descriptions, numbers below 10 should be spelt out in words. Use fuller forms for numbers and dates— for example 1980-88, pp. 200-202 and pp. 178-84. Specific dates should be cited in the form June 2, 2004. Decades and centuries may be spelt out, for example 'the eighties', 'the twentieth century', etc.

Referencing Style: References cited in the manuscript and prepared as per the Harvard style of referencing and to be appended at the end of the manuscript. They must be typed in double space, and should be arranged in alphabetical order by the surname of the first author. In case more than one work by the same author(s) is cited, then arrange them chronologically by year of publication.

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Global Science Epistemic Justice

University of Kent

Science Diplomacy Review

Special Issue

New Dimensions of Science Diplomacy for the Twenty-First Century

Call for Papers

Guest Editors: Joy Y. Zhang (University of Kent), Trude Sundberg (University of Kent)
Editors: Bhaskar Balakrishnan (RIS), Ravi Srinivas (RIS)

Science diplomacy is not new, but its ambition, substance and actual delivery are constantly evolving. This is due to shifting paradigms of geopolitics, but also a result of the changing nature of contemporary science: how it is organised, who manages its framing and delivery. While diplomacy remains one of the most ancient forms of statecraft, the delivery of diplomacy including science diplomacy no longer hinges on state or institutional actors, but can be shaped and conducted by assemblages of private and public interests. This may be especially true in emerging information and biomedical technologies, where science diplomacy not only shapes social uptake of a particular innovation that is already available, but also may have long-term impacts on the socio-political discourses that frames the future norm of that technology. Many international partnership projects have also shown that science diplomacy can help ameliorate regional tensions, but can also whitewash neo-colonial intentions and aggravate global inequality. The rise of actors from the Global South and new conflicts of ambition underline the importance of science diplomacy and complicates its delivery.

Science Diplomacy Review (SDR) is a peer-reviewed and open access journal published by the Forum for Indian Science Diplomacy (FISD) based at Research and Information System for Developing Countries (RIS), an autonomous independent policy research think tank with India's Ministry of External Affairs.

This special issue is a collaboration between RIS and the Centre for Global Science and Epistemic Justice (GSEJ) at the University of Kent, UK. We invite contributions that unpack the idea of 'science diplomacy' through examinations on past and emerging experiences. What does it mean to different communities? Who are the emerging actors and leaders? What are the new norms and expectations of science diplomacy in global politics? What are its real-life impacts, both in relation to the wellbeing of communities and to the development of science and innovation? More importantly, how to track and assess impacts of science diplomacy? How do governance systems respond to science diplomacy? In short, what kind of science diplomacy *should* we envision for the 21st century?

We invite both full research articles (4000 to 5,000-words) and shorter articles and commentaries (1,500-3,000 words). Papers that focus on non-state actors and/or from the Global South perspectives, and papers with novel research methods are particularly welcome.

Deadline for submission of full paper: 2 August 2022

Peer-review and editorial decision: 1 October 2022

Revision and resubmission deadline: 1 December 2022

For queries and submissions, please email: science.diplomacy@ris.org.in and cc GSEJ@kent.ac.uk

About FISD

As part of its ongoing research studies on Science &Technology and Innovation (STI), RIS together with the National Institute of Advanced Studies (NIAS), Bengaluru is implementing a major project on Science Diplomacy, supported by the Department of Science and Technology. The programme was launched on 7 May 2018 at New Delhi. The Forum for Indian Science Diplomacy (FISD), under the RIS–NIAS Science Diplomacy Programme, envisages harnessing science diplomacy in areas of critical importance for national development and S&T cooperation.

The key objective of the FISD is to realise the potential of Science Diplomacy by various means, including Capacity building in science diplomacy, developing networks and Science diplomacy for strategic thinking. It aims to leverage the strengths and expertise of Indian Diaspora working in the field of S&T to help the nation meet its agenda in some select S&T sectors.

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Core IV-B, Fourth Floor, India Habitat Centre
Lodhi Road, New Delhi-110 003, India.
Ph. 91-11-24682177-80 Fax: 91-11-24682173-74-75
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