Role of Co-Innovation in Accelerating Towards Climate Neutrality

Dr. Nandakumar Janardhanan

Research Manager, Institute for Global Environmental Strategies (IGES), 2108-11 Kamiyamaguchi, Hayama, Kanagawa, Japan- 240-0115
Tel: +81-(0)46-855-3828, Email: janardhanan@iges.or.jp, URL: http://www.iges.or.jp

Dr. Eri Ikeda

Assistant Professor, Department of Management Studies, Indian Institute of Technology, Delhi (IIT-D), IV Floor, Vishwakarma Bhavan, Saheed Jeet Singh Marg, Hauz Khas, New Delhi, India– 110016
Tel: +91-11-26597371, Email: Eri.Ikeda@dms.iitd.ac.in, URL: https://dms.iitd.ac.in/

Ms. Sruthi Kalyani

Doctoral Scholar, Centre for East Asian Studies, Jawaharlal Nehru University, New Mehrauli Road, New Delhi - 110067, India
Tel +91-11-26704346, Email: sruthikalyani.a@gmail.com

Ms. Temuulen Murun

Policy Researcher, Institute for Global Environmental Strategies (IGES), 2108-11 Kamiyamaguchi, Hayama, Kanagawa, Japan- 240-0115
Tel: +81-(0)46-826-9597, Email: murun@iges.or.jp, URL: http://www.iges.or.jp

Dr. Kentaro Tamura

Research Director, Institute for Global Environmental Strategies (IGES), 2108-11 Kamiyamaguchi, Hayama, Kanagawa, JAPAN- 240-0115
Tel: +81-(0)46-855-3812, Email: tamura@iges.or.jp, URL: http://www.iges.or.jp

Note: The authors thank Ms. Emma Fushimi for the support in finalising the manuscript.

Abstract

Today the global demand for cleaner technologies has been growing significantly to help countries meet the Paris climate goals and carbon-neutrality targets. However, developing economies, many of which are vulnerable to adverse climate impacts, continue to face critical challenges in terms of the availability, accessibility, affordability and adaptability of low-carbon technologies. This is due primarily to the fact that the existing technology transfer mechanisms have not been able to widely promote cleaner technologies in developing countries. On the other hand, though technologically advanced countries have been keen to market cleaner technologies beyond their borders, the lack of conducive economic and policy enablers continues to remain major hurdles. This paper examines the role of "co-innovation" to strengthen collaboration among technology suppliers and recipient countries, thereby helping these stakeholders accelerate towards carbon neutrality. It discusses conducive policy and legal and financial mechanisms in the backdrop of Asia and also presents the example of Japan's role in promoting clean technologies across the region.

Introduction

Technology has been playing a pivotal role in steering the development of the economy worldwide (IPCC, 2007). Economic development and increasing production and consumption patterns have resulted in increased greenhouse gas (GHG) emissions. On the other hand, it is widely understood that the use of clean technology can significantly help reduce greenhouse gas emissions and help mitigate climate change impacts.

Today, as the world is witnessing an alarming trend in terms of growing GHG emissions, it is important to make use of advanced clean technologies to leapfrog towards carbon neutrality. The Sustainable Development Scenario (SDS) of the International Energy Agency (IEA, 2021) highlighted that radical technology transformation is required in all key sectors, especially the energy sector to enable countries to achieve their net-zero emissions targets. These changes should go well beyond nominal or incremental changes of existing technology options. In fact, these should be disruptive technologies and urgently needed integration into the key sectors. For the energy sector, the SDS focuses on four types of technology options: electrifying end-use sectors (such as advanced batteries); integrating carbon capture, utilisation and storage (CCUS); developing hydrogen and hydrogen-related fuels; and developing bioenergy (IEA, 2021). Similarly, technology changes are also critical for other industrial sectors as well as the transportation sector, which together are responsible for a significant share of energy consumption and the corresponding GHG emissions.

Technological innovation and efficient technology sharing mechanisms are important for the global community to make better use of clean technologies in meeting carbon-neutrality goals (Wang, et al., 2021). There are various technology collaboration approaches to facilitate the transfer of technology or know-how among countries. The Clean Development Mechanism (CDM), which is defined in Article 12 of the Kyoto Protocol under the United Nations Framework Convention on Climate Change (UNFCCC), has played a major role in clean technology collaboration. The CDM is viewed as the first global environmental investment and credit scheme of its kind, providing a standardised emissions offset instrument (UNFCCC, 1997). Other notable efforts such as the formation of Technology Executive Committee (TEC) and the Climate Technology Centre and Network (CTCN) under the guidance of UNFCCC have also made substantial progress in the greater use of advanced technologies across the world. However, availability, affordability, accessibility, and adaptability remain key challenges that continue to hinder technology integration.

The remainder of this paper is divided into four sections. Section 2 discusses technology cooperation in the backdrop of net-zero emissions targets, and Section 3 highlights the clean technology collaboration in the Asian region. In section 4, the paper elaborates on the concept of co-innovation and its sustainability and the scalability and replicability objectives of advanced clean technologies. It also discusses policy and legal and financial mechanisms necessary to enable co-innovation. Section 5 provides a conclusion and identifies some key policy recommendations.

Need for technology collaboration against the backdrop of net-zero targets

Low-carbon technology transfer has been one of the central agendas for developing countries to enhance their economic development and reduce their GHG emissions. The expectation for developing countries has been to receive technologies from developed countries, especially from the global North and China. Conventional technology transfer typically relies on capital imports, foreign direct investment (FDI), international aid programmes, technology licensing, and joint ventures with multinational corporations (Lema & Lema, 2012) or countries. These channels rely heavily on the transfer of "hardware" and foreign counterpart's technology and investment, focusing on more diffusion in the recipient countries (Ockwell & Mallett, 2012). This type of conventional transfer also involves major financial outlays for capital imports and licensing, often draining the recipient country of financial resources. The lack of soft skills and know-how in adopting these technologies, the failure to develop locally matched and adaptable technologies, the lack of transfer of intellectual property rights, the lack of markets, and other relevant issues have hindered these traditional technology transfer mechanisms (see also, for example, (Kirchherr & Urban, 2018; Lema, et al., 2015). For conventional transfer, FDI and joint ventures tend to showcase more successful and sustainable cases (Lee & Tan, 2007; Pigato, et al., 2020). However, most of these successful technology transfer mechanisms have gone beyond the conventional transfer approaches and have built their ecosystems. Such ecosystems involves the development of a base technology originally transferred from the source country, fine-tuning the same according to local needs, and continuously incorporating elements of local knowledge and market conditions as well as taking into account the economic, social, and environmental conditions of the recipient. The development of Maruti-Suzuki in India's passenger car manufacturing sector is an example, which has even become a household name in the Indian market.

Some key emerging technologies are considered crucial for achieving net-zero targets. Examples hydrogen, efficient batteries, and Carbon Capture and Utilisation and Storage (CCUS). Though full viability of emerging technologies remains questioned, innovation is making such technologies more and more available. The renewables such as solar energy and wind energy have already become the mainstream alternative energy sources. This is primarily because the increase in the scale of deployment and such economy of scale has led to a rapid decline in cost. It now costs less to generate these forms of renewable energy, especially solar and onshore wind energy, than it does to generate energy from fossil fuels in many countries (IEA, 2020). However, upfront costs remain high for many developing countries, which hinders wider access to low-carbon technologies in developing economies (Pigato, et al., 2020). Developing economies lack not only technology but also finance and capacity. There are also limitations to accessing technology, investing in fundamental research and development (R & D), and sustainably disseminating the technology. Some economies promote locally developed and popular approaches for reducing costs and lowering the complexity needed in production, which is often termed frugal innovation (Bhatti, et al., 2013) or "*jugaad*" innovation in the Indian context (Leliveld & Knorringa, 2017). However, this is a just short-term solution, and what is needed is an ecosystem to leapfrog in technology and innovation that could eventually help a country accelerate towards carbon neutrality.

Clean technology collaboration in Asia

Countries continue to face significant challenges due to the change in climate. In the Asian region, one of the most pressing issues is, as several studies have indicated, that many Asian coastal cities would potentially be submerged if ocean levels continue to rise (Cao, et al., 2021). This demonstrates the urgency of accelerating efforts on climate mitigation and adaptation targets and also meeting net-zero targets in the coming decades. Although many countries have been making significant efforts towards these goals, assessments have been indicating that the goals set by many economies are still insufficiently ambitious (Climate Action Tracker, 2022). The continuous and rapid growth in Asian region, however, faces a challenge in balancing the increasing demand for energy and altering existing patterns of consumption and production to make a noticeable reduction in GHG emissions. Technology innovation and clean energy development play a key role in this regard by reducing GHG emissions without compromising the growth objective. This suggests that greater policy attention needs to be paid to the integration of clean technologies also to offer the co-benefit of helping to achieve sustainable development targets.

Technology collaboration initiatives in the Asian region are mostly fragmented. The common type of collaboration is the sale of advanced technology-based equipment by donor countries to recipient countries. Among the Asian countries, China has a market advantage over other countries and has played a remarkable role in disseminating efficient equipment based on clean energy technology, under competitive cost conditions (Janardhanan, 2021). The economy of scale and cheap labour help China supply equipment and machinery at lower cost in the international market. Due to this, many countries in Asia are heavily dependent on the supply chains from China. For example, India's renewable energy sector with its ambitious target of having 500 GW of installed capacity by 2030 depends on China for equipment and machinery supplies.

There have also been several bilateral collaboration initiatives on the technology front among other countries in the region. Japan has been actively contributing to the transfer of technology for energy-, environment-, agriculture-, and health-related activities in East, Southeast, and South Asian countries since the mid-twentieth century. Probably one of Japan's most efficient technology transfer platforms is the Joint Crediting Mechanism (JCM) (see Box 1).

The JCM has the potential to evolve into a more efficient technology collaboration approach by involving newer partners from across the globe. The replicability of the projects to introduce various new technologies would also contribute to achieving a broader range of goals and targets under the SDGs.

It is important to note that several recipient countries are keen to strengthen their domestic manufacturing industry, which in turn can contribute to the employment scenario and the local economy. The prevailing technology transfer mechanisms only make the recipient countries customers of advanced technology supplier countries and do not facilitate a conducive environment for learning, scaling up, and replicating technology applications. This demands a significant change in the way technology collaboration has been done to date. The next section focuses on co-innovation and explains how it can contribute to strengthening technology collaboration between source and recipient countries.

Co-innovation: addressing barriers to technology collaboration

The existing mechanisms of traditional technology transfer broadly hinder the actualisation of the four As of technology collaboration—availability, accessibility, affordability, and adaptability—in the following ways.[1]

The primary challenge of any shift towards newer low-carbon alternatives is to make sure that these technologies are available in the first place. The availability of alternatives through technology transfer is a collective challenge incurred by all the stakeholders involved. The governments of recipient countries act as key players in guaranteeing this 'availability' via legal and policy frameworks such as patent laws and science and technology (S & T) development plans. The challenges in addressing the availability issue are manifold and include ensuring that relevant technologies are adopted and absorbed according to local situations, eliminating non-measurable barriers to the entry of technology (such as stringent local content requirements in recipient countries that may pose practical infeasibilities for the host to set up industries), and providing space for building indigenous R & D and production bases in recipient countries. By establishing technology collaborative laboratories (CoLabs) (or facilities for collaboration among active knowledge-sharing stakeholders), the collaboration stage of the co-innovation model seeks to address these availability issues.

The next significant challenge is accessibility. Once the technologies are made available, such technologies must reach end users. Equitable access, patent mechanisms, lab-to-market penetrations, and supply chain continuity, thus, become the next set of concerns. One of the major impediments to the market applicability of new technologies is the lack of a harmonised set of national standards. International standards, unless they are mandated by national regulation, act as mere voluntary guidelines. This may create market differences that may eventually impact the accessibility of alternative technologies. Hence, through expert consultation processes within the governing bodies, governments must develop synchronisation of their technical and safety regulations into a consensual international set of standards. Furthermore, market accessibility can also be augmented with green public procurement policies that may incentivise the local production of imbibed technologies. These issues can also be resolved at the collaborative stage (see Figure 1 below).

A technology that is newly accessible in the market may not be affordable to the end user. The upfront production cost of the alternatives, without any subsidies or market incentives, directly passes on to the end-user. For instance, it is observed that the production costs of the low-GWP (low global-warming potential) cooling blends are more expensive than the refrigerant components themselves, rendering the transition to sustainable cooling costly (UNEP, 2020). The additional cost of highly energy-efficient and

1 The four As are typically a generic analytical framework for analysis of the twin goals of energy security and climate mitigation.

Box 1: Joint Crediting Mechanism

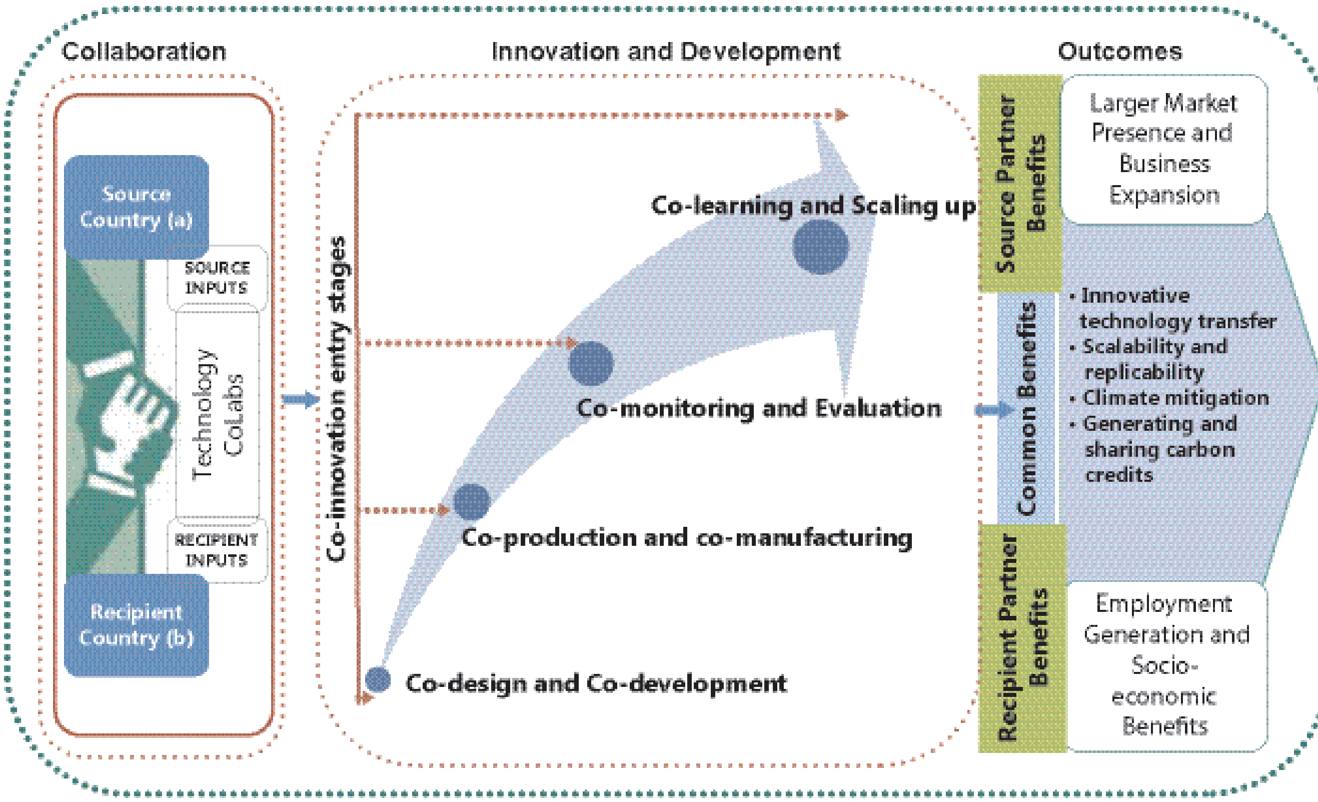
The JCM facilitates the diffusion of advanced low-carbon and zero-emission technologies, products, systems, services, and infrastructure, which contributes to sustainable development in developing countries (Government of Japan, 2013). Japan initiated this mechanism to accelerate a low-carbon society through bilateral cooperation by transferring advanced and high-efficiency technologies with financial support from the government of Japan.

To implement projects to transfer low-carbon and zero-emission technologies through the JCM, private entities from Japan and a partner country have to establish an international consortium to apply for JCM financial support. Various advanced technologies have high upfront costs, making it difficult for developing countries to implement and invest. Through the JCM, the Japanese government covers a part of the initial investment to install low-carbon and zero-emission technologies. Under the JCM, GHG emission reductions or removals from implemented projects are quantitatively evaluated by applying a measurement, reporting and verification (MRV) approach (Government of Japan, 2013).

The first bilateral agreement of the JCM was established between Japan and Mongolia in 2013 and currently, there are 17 partner countries from the Asia Pacific, Africa, and Latin American regions (Government of Japan, 2013). As of December 2021, a total of 205 projects received JCM financing support from Japan's Ministry of the Environment. The expected GHG emission reductions from all these projects are more than 19 MtCO2 by 2030 (Ministry of the Environment, Government of Japan, 2021a).

Through the JCM, capacity building and technical training are conducted to transfer advanced technologies smoothly in partner countries. With a view to implementing low-carbon and zero-emission technologies such as solar PV, the project participants from the Japanese side have regularly organised vocational training (e.g., workshops and webinars) to improve local partners' capacity building (Murun & Tsukui, 2020a). This aims to enhance the technical skills of local employees and technicians to operationalise and maintain technologies by themselves and ensure the sustainability of project implementation.

However, Japan and partner countries may need to improve and enhance the JCM for scaling up projects to reach their maximum potential. This requires active involvement from the private sector. Additionally, smoother processes may need to be developed to pursue the JCM financial support process, for which ease of documentation would be critical. As collaboration is built on mutual trust, stronger partnership between private entities from both Japan and partner countries is a necessary element in the efficient implementation and monitoring of JCM (JCM Mongolia, 2017). Since the JCM monitoring period is more than 10 years depending on the project type, it is important to develop and implement projects that are easy to monitor and maintain in the long term. One of the most important elements of the governance of the JCM is a joint committee (JC) constituting representatives from both Japan and partner countries. The JC can make all necessary decisions related to adopting rules, guidelines, and project registration under the JCM (JCM Joint Committee, 2013). Due to this equal partnership and collaboration, partner countries can transfer and introduce the technologies and projects that would contribute to their sustainable development (SD) and the achievement of sustainable development goals (SDGs).



Source: Janardhanan, et al., (2021a)

Figure 1: Co-innovation Conceptual Framework

low-carbon equipment is often passed on to the customers. Furthermore, state regulations should also ensure demand-side efficiency and place policies to reap economies of scale. The co-innovation entry-stage should conduct impact assessments of the differential tax regimes on the final product and evaluate the cost-benefits of incentivizing speedy firms for early adoption, moving fast, and greener consumer preferences.Adaptability principally focuses on end-users' ability to make full use of an imported technology or a technology's adaptability to the local requirements of end users. A common direction of technology transfer is from the Global North to the South. Often the local conditions and needs in the Global North are far different from those in the Global South. Thus, the consideration of socio-economic and environmental factors are particularly important. The adaptability to technology can be accomplished through integrated learning of local demand conditions and local knowledge in designing equipment or machinery. Mechanisms and efficiency checks, regular awareness programmes for consumers, skilling and reskilling programmes to enhance the employability of locals, training sessions for technicians, and independent assessments of climate co-benefits, etc. are important elements that can enhance the adaptability of a technology. The recipient stakeholder should have a better role in designing and improving the adaptability of new technology. Additionally, a market surveillance mechanism across sectors, products, and collaborative governments has to be set up to safeguard consumers from market shocks and non-compliant equipment.

The idea of co-innovation emerged in response to the mismatch in technology transfer practices. Co-innovation substantially improves the four As of technology collaboration. Co-innovation is defined as "*a collaborative and iterative approach to jointly innovate, manufacture, and scale up technologies*" [Janardhanan, 2019; Janardhanan, et al., 2020]. It also reflects the continuous exchange of knowledge among all stakeholders including scientists, manufacturers, and the end-users of technology to improve the product (Janardhanan, 2021). Unlike conventional technology transfer, which is a linear engagement of source and recipient players, co-innovation presents an organic engagement between the partners given greater adaptability of technology in the recipient country. Co-innovation brings profound changes to the industrial world's operating rules (Maniak & Midler, 2008) by facilitating technology fine-tuning to ensure greater adaptability to various regions.

Figure 1 demonstrates three major phases of co-innovation: (a) collaboration, (b) innovation and development, and (c) outcomes.

The first phase aims to establish a collaboration among partners involved in the co-innovation—the source and recipient partners. While the source partner is the one from which the base technology originates, the recipient partner is the host that collaborates in fine-tuning the technology application. The second phase demonstrates the entry stages of the collaboration. For a technology to be available in the market, it has to go through numerous stages from conceptualisation to design to development and marketing. The collaboration can happen at any stage between the partners, with the ultimate goal being fine-tuning and customising the technology so that it can be implemented in multiple geographic contexts. The third stage demonstrates specific advantages of co-innovation. While the source partner gets the benefit of a large market presence and business expansion opportunities, the recipient partner benefits from economic, environmental, and employment opportunities. At the same time, there are also common benefits for both, which include scalability and replicability, environmental benefits of reducing emissions, and the sharing of generated carbon credits.

The case study below (Box 2) demonstrates the opportunities for technology collaboration under co-innovation between India and Japan.

Box 2: Opportunities for Co-innovation between Japan and India

Based on work experience by the author through working on the identification of new and efficient technological options for Small and Medium-sized Enterprises (SMEs), the following three Low Carbon Technologies (LCTs) offer good opportunities for co-innovation between India and Japan:

i. Automatic looms (textile sector): Globally, India is the second-largest producer of textiles. About 95% of the 2.8 million looms installed in India are semi-automatic, conventional shuttle looms. The adoption of automatic looms in place of the conventional shuttle looms will increase productivity and improve the efficiency and quality of the fabric produced. At present, there are no manufacturers of automatic looms in India. Japan has some of the leading manufacturers of automatic looms like Tsudakoma and Toyota. However, the penetration of Japanese looms in the Indian market remains low mainly due to high costs. Considering the market potential in India, this technology is an ideal candidate for co-innovation.

ii. Efficient smelting furnaces (secondary aluminium sector): Aluminium is the second most used metal after steel. Secondary aluminium processing, which involves the conversion of ingots and scrap to cast and extruded products, is concentrated in the SME sector. The energy consumption of and consequently the GHG emissions from the secondary aluminium sector are quite high. Most units use conventional, inefficient oil-fired smelting furnaces. Some of the leading manufacturers of smelting furnaces in Japan are Nihon Kohnetsu and Sanken Sangyo. At present, only a few SME aluminium units can afford to buy smelting furnaces available in industrialised countries like Japan. The joint development of an energy-efficient smelting furnace for the aluminium industry with Japanese experts will significantly reduce energy consumption and GHG emissions.

iii. Energy-efficient agricultural pump-sets (pump-manufacturing sector): Agricultural pumps are a major consumer of electricity. More than 20 million agricultural pumps are in operation in India and about 2 million pumps are added annually. Most agricultural pumps manufactured in India have low efficiency and poor reliability. It would be a good opportunity to improve the efficiency of the locally made agricultural pumps by up to 40 per cent through co-innovation between Indian and Japanese agricultural pump manufacturers like Xylem and Tsurumi. Large-scale adoption of energy-efficient pumps would lead to huge electricity savings with consequent reduction in GHG emissions.

Source: Excerpts from the joint research conducted by the Institute for Global Environmental Strategies (IGES, Japan) and the Energy and Resources Institute (TERI, India), titled '*Co-innovation of low-carbon technologies for Small and Medium Enterprises: a framework for strengthening technology cooperation between Japan and India*' (Janardhanan, et al., 2021b)

Sustainability, scalability, and replicability of technologies through co-innovation

Unlike conventional technology transfers, co-innovation focuses on collaboration to fine-tune and customise technologies that are beneficial to climate change mitigation and carbon neutrality and that align with the key objectives of (a) sustainability, (b) scalability, and (c) replicability of low carbon technologies.

- Sustainability: The core objective of co-innovation is to promote sustainability through collaboration in the development and implementation of technologies that accelerate climate co-benefits. While the main goal of using new technology is often economic, projecting its social or environmental benefits accelerates decision-making processes to recognise its additional value. The recognition of co-benefits opens up a "window of opportunity" for additional policy goals to be achieved (Mayrhofer & Gupta, 2016). This can also help allay concerns over GHG mitigation costs (Janardhanan, et al., 2021a).
- Scalability: Enhancing the scalability of technology collaboration can broaden the reach of its outcomes to cover a wider set of beneficiaries. Collaboration on innovative technology remains critical for climate mitigation and SDGs. It is often reiterated by experts that a business-as-usual scenario may not be sufficient to address climate mitigation needs. There is a greater need to scale up clean technologies (WEF, 2015) and promote their usage across the various sectors and key industries that are responsible for GHG emissions. While a particular technology may be relevant in its initial stages for medium or small industries, it may well have the potential to be scaled up, applied, and implemented in larger industries to reduce emissions there as well. The scaling up of technology application in this way is extremely important in reaping the emission reduction benefits of clean technologies.
- Replicability: Accelerating replicability is a core element of co-innovation. The flexibility for adapting a newly developed technology to multiple geographical contexts has beneficial effects in addressing climate change (Azimoh, et al., 2017). Unlike traditional technology transfer that works in a linear direction from the source to the recipient, co-innovation is aimed at utilising the jointly developed technology or equipment in a wider geographic context. As replicability boosts economic benefits and offers wider usage of clean technologies, it also incentivizes decision-making to promote more co-innovation initiatives.

Policy, legal, and financial mechanisms to enable co-innovation

When technology is merely diffused, the transfer of tacit knowledge to a recipient country may not be guaranteed (Lema & Lema, 2016). It is now evident that the years of conventional technology transfer mechanisms (such as FDI, technology licensing, and joint ventures) have not improved the absorptive capacities of technology in recipient countries at the local level.

Firstly, for the diffusion of technologies and technological expertise to suit local production, local governments require considerable capacity. While an increasing number of countries have dedicated separate ministries for the environment and climate change, coordinated functioning of institutions and departmental task forces may improve the implementation of the co-innovation model. Most economies follow a top-down approach to climate action, particularly in the transfer of low-carbon and other climate-sound technologies. There must be synergy among local, state and national-level agencies so that technology can cater to different local conditions. Even for cases where fiscal autonomy is conferred to local governments, it has been observed that local governments prioritise economic growth over climate action, and hence refrain from investing in risk-prone newer technologies and industries to generate revenues (Zhou, 2019). The crucial role of subnational agencies in co-innovation can be understood through the following two cases. The first case can be seen in China, where, despite the establishment of an inter-ministerial National Coordinating Committee on Climate Change Policy (NCCCC), we see that excessive centralisation and the lack of coordination between administrative agencies severely affect the motivation of local governments in investing in newer, risk-prone climate technologies. This indicates that local governments cannot merely be given supervisory roles to monitor national standards; they rather should be made active players in contributing to recipient inputs at the collaboration stage. The second case involves subnational agencies in India, which have made commendable use of the quasi-federal structure of the government and moved towards institutional innovation by providing entrepreneurial support for clean energy innovation (Singh, 2021). State-level economic advisory councils have enabled support and alignment of national and sub-national net-zero targets. Thus, inter-departmental coordination within the domestic landscape can attract foreign governments and agencies to collaborate effectively.

Secondly, a major legal hurdle in the innovation and development stage of co-innovation is that the local intellectual property (IP) laws are not on a par with global standards. For instance, in the case of China, policies aspire to acquire technology "by various means" (Hannas & Tatlow, 2021) . As a member of the World Trade Organization (WTO), the Chinese state is bound for certain amendments in its national patent law. However, the enforcement mechanisms, the national review process, and the litigation systems in China are fractured, hindering effective technology transfer. While national policies aim for self-reliance through indigenous innovation, the promise of open innovation and knowledge-sharing is put under scrutiny due to various 'extra-legal' modes of technology transfers in China. Such a presence of vague IP laws and extra-legal personnel and organisations may lead to a lack of confidence and trust for host countries to collaborate with China and envision mutually benefitting co-innovation outcomes. In line with China, most developing countries have contradicting IP regulations. While unconventional transfer mechanisms such as joint R & D ventures and strategic alliances (Lema & Lema, 2016) are emerging in low-carbon technologies, there exists a simultaneous practice of traditional modes of technology use licensing, IP selling, etc. that hinder co-innovation even at the entry stages. This situation can be addressed by experimenting with alternatives to collaborative IP mechanisms such as patent pools (WIPO, 2014). Patent pools not only reap shared benefits but also reduce transaction costs. By setting up technology patent pools that incorporate a greater number of actors into the agreement, not only is access to technological know-how ensured but innovation rates are also bound to increase (Hovenkamp & Hovenkamp, 2017).

Thirdly, the co-innovation model will work only with a robust financial mechanism. Article 4.5 of the UNFCCC calls for developed (Annex I) countries not only to transfer technologies and know-how to other parties but also to "facilitate and finance" such transfers. While many corporates and regional organisations such as the European Union (EU) have established innovation funds, at present, there is no overhauling international fund specifically for technology transfer or co-innovation. Through the traditional modes of technology transfer, certain developed countries have been providing financial assistance to the least developed countries (LDCs) via one-time non-reimbursable grants (as a part of their implementation of Article 66.2 of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS)). However, the transition towards co-innovation models requires alternative financing mechanisms at all stages of development. Ideally, public funding would initiate such new high-risk projects, with governments also providing the R & D base and tax incentives to the collaborative parties. With evolving modes of financing mechanisms, governments can also support alternative private financings such as venture capital funds, incubators, and accelerators, rather than engaging only with major corporations and multinational companies.

Finally, with the CDM offering carbon offsets, there have been various concerns over the implementation of offsetting and the quality of the offsets. The benefits of shared carbon credits that the co-innovation model promises will be materialised only when the concerns of market-based balancing approaches are resolved using accurate quantification of GHG reductions with rigorous social accountability mechanisms in place.

Conclusion and policy recommendations

This paper discussed the need for clean technology against the backdrop of net-zero targets and the role of co-innovation. As climate change mitigation remains an urgent task for the world, it is imperative for the global community to enable developing countries to address this challenge collectively. Technology remains an integral part of mitigation efforts, and closing the gap in the availability, accessibility, affordability and adaptability of low-carbon solutions deserves paramount policy attention in both developing and developed countries. The paper discussed co-innovation, which is a collaborative and iterative approach to jointly innovating, manufacturing, and scaling up low-carbon technology. As radical changes are required in the way technology is developed, used, and disseminated, co-innovation will be a useful approach. The paper also highlighted that sustainability, scalability, and replicability will need to form the central elements of technology collaboration. Further, conducive policy and legal and financial enablers would play a critical role in building co-innovation.

Four specific policy recommendations can be suggested to promote co-innovation for achieving climate neutrality.

- Going beyond business-as-usual pathways: To accelerate along climate neutrality pathways, countries need to promote clean technology using approaches beyond conventional, business-as-usual pathways. In promoting the co-innovation of technology, joint conceptualization, innovation, and production, and scaling up would be some of the critical approaches that offer economic and social benefits in addition to environmental advantages.
- Prioritizing sustainability, scalability, and replicability: Technology collaboration must hold these three elements as the core objectives of co-innovation. While sustainability benefits of technologies may be the primary consideration, scalability to large-scale applications as well as replicability in other relevant sectors and regions also deserves equal attention.
- Addressing disparities in the four As of clean technology: As climate concerns deserve greater policy attention, the global community needs to address the disparities in the availability, accessibility, affordability, and adaptability of clean technology in the developing world. Greater collaboration through co-innovation needs to be built among developing and developed economies to help countries benefit from advanced technology.
- Improving enabling conditions: Among the key enablers, one of the most critical elements that shape technology collaboration is the legal framework that governs intellectual property rights. By jointly innovating, producing, and marketing machinery and equipment based on low-carbon technology, entities would share legal rights, which could potentially facilitate the technology's reach to a wider set of users.

References

✓ Azimoh, C. L., Klintenberg, P., Mbohwa, C., & Wallin, F. (2017). Replicability and scalability of mini-grid solution to rural electrification programs in sub-Saharan Africa. *Renewable Energy, 106*(June), 222-231.

- Bhatti, Y. A., Khilji, S., & Basu, R. (2013). Frugal Innovation. In C. R. Shaista Khilji, S. E. Khilji, & C. Rowley (Eds.), *Globalization, Change and Learning in South Asia* (pp. 123-145). London: Elsevier.
- Cao, A., Esteban, M., Valenzuela, V. P., Onuki, M., Takagi, H., Thao, N. D., & Tsuchiya, N. (2021). Future of Asian Deltaic Megacities under sea level rise and land subsidence: current adaptation pathways for Tokyo, Jakarta, Manila, and Ho Chi Minh City. *Current Opinion in Environmental Sustainability, 50*(June), 87-97.
- Climate Action Tracker. (2022). *Compatibility of National Action to 1.5 Degree celcius Goal*. Retrieved February 12, 2022, from https://climateactiontracker.org/countries/
- Government of Japan. (2013). *Joint Crediting Mechanism*. Retrieved from https://www.jcm.go.jp/about
- Hannas, W., & Tatlow, D. K. (2021). *China's Quest for Foreign Technology* (1 ed.). London: Routledge.
- Hovenkamp, E., & Hovenkamp, H. J. (2017). Patent Pools and Related Technology Sharing. *Faculty Scholarship at Penn Law*. Retrieved from https://scholarship.law.upenn.edu/faculty_scholarship/1766?utm_source=scholarship.law.upenn.edu%2Ffaculty_scholarship%2F1766&utm_medium=PDF&utm_campaign=PDFCoverPages
- IEA. (2020). *Projected Costs of Generating Electricity 2020*. Paris: International Energy Agency.
- IEA. (2021). *Energy Technology Perspectives 2020*. Paris: International Energy Agency.
- IPCC. (2007). *Climate Change 2007: Working Group III: Mitigation of Climate Change*. Geneva : Intergovernmental Panel on Climate Change.
- Janardhanan, N. (2019, December 01). Co-innovation of Clean Technologies: A Panacea for Climate Change? *Energy Review Newsletter*, pp. 2-6.
- Janardhanan, N. (2021). India's Energy Transition: Is China and Inhibitor or a Catalyst? In A. Mori, & A. Mori (Ed.), *China's Carbon-Energy Policy and Asia's Energy Transition* (pp. 195-209). London: Routledge.
- Janardhanan, N., Ikeda, E., Zusman, E., & Tamura, K. (2020). *Co-innovation for Low Carbon Technologies: The Case of Japan-India Collaboration*. Hayama: Institute for Global Environmental Strategies.
- Janardhanan, N., Pham, N.-B., Hibino, K., & Akagi, J. (2021a). Japan's low-carbon technology collaboration with Southeast Asia: Co-innovation and Co-benefits. In H. Farzaneh, E. Zusman, & Y. Chae (Eds.), *Aligning Climate Change and Sustainable Development Policies in Asia* (pp. 10-25). Singapore: Springer.
- Janardhanan, N., Zusman, E., Tamura, K., Ikeda, E., Sethi, G., & Pal, P. (2021b). *Co-innovation of low-carbon technologies for Small and Medium Enterprises: a framework for strengthening technology cooperation between Japan and India*. Hayama: Institute for Global Environmental Strategies.
- JCM Joint Committee. (2013). *JC Members*. Retrieved from https://www.jcm.go.jp/mn-jp/jc_members
- JCM Mongolia. (2017). *Joint Crediting Mechanism Guidelines for Developing Project Design Document Form and Monitoring Report*. Retrieved from https://www.jcm.go.jp/rules_and_guidelines/mn/file_04/JCM_MN_GL_PDD_MR_ver03.1.pdf
- Kirchherr, J., & Urban, F. (2018). Technology transfer and cooperation for low carbon energy technology: Analysing 30 years of scholarship and proposing a research agenda. *Energy Policy, 119* (August), 600-609.
- Lee, H., & Tan, H. (2007). Technology Transfer, FDI and Economic Growth in the ASEAN Region. *Journal of the Asia Pacific Economy, 11*(June), 394-410.
- Leliveld, A., & Knorringa, P. (2017). Frugal Innovation and Development Research. *The European Journal of Development Research volume, 30*(2018), 1-16.
- Lema, A., & Lema, R. (2016). Low-carbon innovation and technology transfer in latecomer countries : Insights from solar PV in the clean development mechanism. *Technological Forecasting and Social Change*. doi:https://doi.org/10.1016/j.techfore.2015.10.019
- Lema, R., & Lema, A. (2012). Technology transfer? The rise of China and India in green technology. *Innovation and Development, 2*(1), 23-44.
- Lema, R., Iizuka, M., & Walz. (2015). Introduction to low-carbon innovation and development: insights and future challenges for research. *Innovation and Development, 5*(2), 173-187.
- Maniak, R., & Midler, C. (2008). Shifting from co-development to co-innovation. *International Journal of Automotive Technology and Management, 8*(4), 449-468.
- Mayrhofer, J. P., & Gupta, J. (2016). The science and politics of co-benefits in climate policy. *Environmental Science & Policy, 57*(2016), 22-30.
- Ministry of the Environment, Government of Japan. (2021a, September 27). *List of JCM Financing Programme by Ministry of Environment, Japan (FY2013～2021)*. Retrieved from Global Environment Centre Foundation: https://gec.jp/jcm/en/wp-content/uploads/2021/09/20210927_list_en.pdf
- Murun, T., & Tsukui, A. (2020a). *Joint Crediting Mechanism (JCM) contributions to Sustainable Development Goals (SDGs)*. Hayama: IGES.
- Ockwell, D., & Mallett, A. (2012). *Low-CarbonTechnology Transfer: From Rhetoric to Reality*. London: Routledge.
- Pigato, M., Black, S. J., Dussaux, D., Mao, Z., McKenna, M., Rafaty, R., & Touboul, S. (2020). *Technology Transfer and Innovation for Low-Carbon Development. International Development in Focus*. Washington, DC.: World Bank.
- Singh, K. (2021, May). Interview: US-India Energy Cooperation. *Energy Review*,

p. 2. Retrieved from https://drive.google.com/file/d/1AZdTerfCv4Z5CQBb67NneRoqwf1234kM/view?usp=sharing

- ✓ UNEP. (2020). *Assessment report of the technology and assessment panel.* Nairobi: UNEP.
- ✓ UNFCCC. (1997). *The Clean Development Mechanism.* Retrieved February 12, 2022, from https://unfccc.int/process-and-meetings/the-kyoto-protocol/mechanisms-under-the-kyoto-protocol/the-clean-development-mechanism
- ✓ Wang, F., Harindintwali, J. D., Yuan, Z., Wang, M., Wang, F., Li, S., & Yin, Z. (2021). Technologies and perspectives for achieving carbon neutrality. *The Innovation, 2*(4), 1-22.
- ✓ WEF. (2015, October 1). *Scaling Technologies to Decarbonize Energy.* Retrieved February 12, 2022, from https://www3.weforum.org/docs/WEF_GAC_Decarbonizing_Energy_White_Paper.pdf
- ✓ WIPO. (2014, March 1). *Patent Pools And Antitrust – A Comparative Analysis.* Retrieved February 1, 2022, from https://www.wipo.int/export/sites/www/ip-competition/en/studies/patent_pools_report.pdf
- ✓ Zhou, C. (2019). *The Legal Barriers to Technology Transfer Under the UN Framework Convention on Climate Change: The Example of China* (1 ed.). (C. Zho, Ed.) Singapore: Springer Nature Singapore Pte Ltd.