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Potential for Japan-India Co-Innovation for Hydrogen Development

Partnerships for National and Global Wins

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Potential for Japan-India Co-Innovation for Hydrogen Development: Partnerships for National and Global Wins

IGES Discussion Paper*

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Abstract

In this discussion paper, we demonstrate why and how co-innovation can serve as a critical enabler of a bilateral Japan-India partnership on hydrogen technologies. We argue that more than conventional approaches to technology transfer, co-innovation places a premium on the role of multi-stakeholder collaboration in triggering the transition from ideation to contextualisation, market creation and expansion, and scaling up of hydrogen technologies. We also present a partnership framework to develop and institutionalise the essential elements of co-innovation -trust, transparency, shared responsibilities, value chains, benefits-sharing, as well as skills and knowledge acquisition.

1 Introduction

The 1990s marked a potentially pivotal point in India and Japan's relationship. During this decade, India embarked upon its liberalisation economic reforms, leading to a marked expansion in trade and foreign investment. Following the negotiation of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 – and the Kyoto Protocol in 1997 – Japan too began strengthening national and international cooperation on various climate change mitigation initiatives. India and Japan have come to share extensive and deep bilateral relations across many fronts and diverse fields (MoFA, Japan, 2021). However, their collaboration on climate change has run into many bottlenecks that limit their exchanges to the traditional, unidirectional transfer of know-how using official development assistance (ODA) or foreign direct investments (FDIs) (MoFA, 2011).

There is nonetheless considerable scope to expand the collaboration between India and Japan on climate-friendly technologies. This has become increasingly evident as India's growth has created a burgeoning technological base with vast research and development (R&D)

capacities. Further, there is a growing awareness in India of the need to create and cater to the increasing demand for energy-saving and clean technologies. This awareness is also generating opportunities to engage an expanding pool of Indian stakeholders in the processes of innovation, product development, installation, and application. This is especially relevant for technologies with the potential to spur additional investments in infrastructure, create jobs, and offer opportunities to improve livelihoods in India. Generating these, and other positive spill overs can further strengthen the foundation for collaboration that, in turn, will extend and deepen as actors build mutual trust and understanding.

However, it has proven difficult for stakeholders to capture these benefits by relying on standard models of technology transfer. At the most basic level, these models tend to emphasise the transfer of technological hardware, with benefits flowing chiefly to select private-sector actors over a relatively short time. Research has nonetheless demonstrated that successful technology transfers take a more expansive view of what is being transferred, by who, to whom, over what period of time, and with what ends in mind. A growing number of studies have underlined that there is a need to move beyond focusing on one-off exchanges of hardware among a limited number of actors. Rather, there is growing emphasis on a dynamic, multi-stakeholder contextualisation process centred on the “realignments of actors, resources, and institutional arrangements” and “multiple loops of interactions that foster better local-learning opportunities” (Gregersen, 2020; Kirchherr & Urban, 2018; Peng, et al., 2019).

Co-innovation, defined as the “shared work of generating innovative and exceptional designs conducted by various actors” (Saragih & Tan, 2018), can help create a multi-stakeholder contextualisation process. Establishing such a process is in the interests of Japan, as it has been discussing ways to advance innovations to tackle climate change under the Partnership to Strengthen Transparency for co-Innovation (PaSTI) (MoEJ, 2018). Moreover, India is also likely to look favourably on such a process as it looks to develop a credible effort to back the country’s transition to future-proof alternatives to decarbonise energy-intensive industries. There is, hence, an opportunity for India and Japan to use co-innovation as a bridge to develop sustainable solutions across multiple fields.

This paper will build a narrative to respond to three key questions that are essential to constructing such a bridge—why, what, and how. Firstly, "Innovation to co-innovation: the shifting paradigm" looks at why there is a need to shift from innovation to co-innovation to find solutions collectively. Secondly, a co-innovation framework conceptualises what is required. Thirdly, to investigate how to make this possible, the section on building a construct elaborates on the inclusion of co-innovation as a critical component of bilateral partnerships between the two countries. Finally, by highlighting opportunities for co-innovation for hydrogen development, we draw inferences in support of driving national and international collaborations for innovation.

2 Innovation to Co-innovation: The Shifting Paradigm

Innovation can be defined as an unrelenting drive to break the status quo and develop a new way to go. This moves policy-makers and other stakeholders from static and closed to collaborative and open models of engagement. This collaborative, open perspective is a defining feature of the concept of co-innovation (M. Lee, et al., 2012). It is nonetheless important to distinguish between forms of innovation. Some have noted that closed innovation has some strengths, such as helping companies attain unique core competencies that can be leveraged to create the competitive advantage of a market "first mover" (Lee & Olson, 2010). Collaborative innovation, on the other hand, involves fostering partnerships between companies to design innovative value chains that combine their core competencies with those of others (K. Dawson, et al., 2014). Moreover, this open form of innovation eases restrictions and brings in a range of institutions and universities and the scientific community (Tapscott & Williams, 2006). While there are indeed merits to closed forms of innovation, the urgent need for a technological and social solution that addresses the climate emergency and delivers other sustainable benefits requires a paradigm shift toward co-innovation (Lichtenthaler, et al., 2011). Indeed, unlike the producer-centric views, co-innovation can help go beyond mere profits to embrace greater societal goods (Saragih & Tan, 2018).

Figure 1: Evolution of innovation

Source: (M. Lee, et al., 2012)

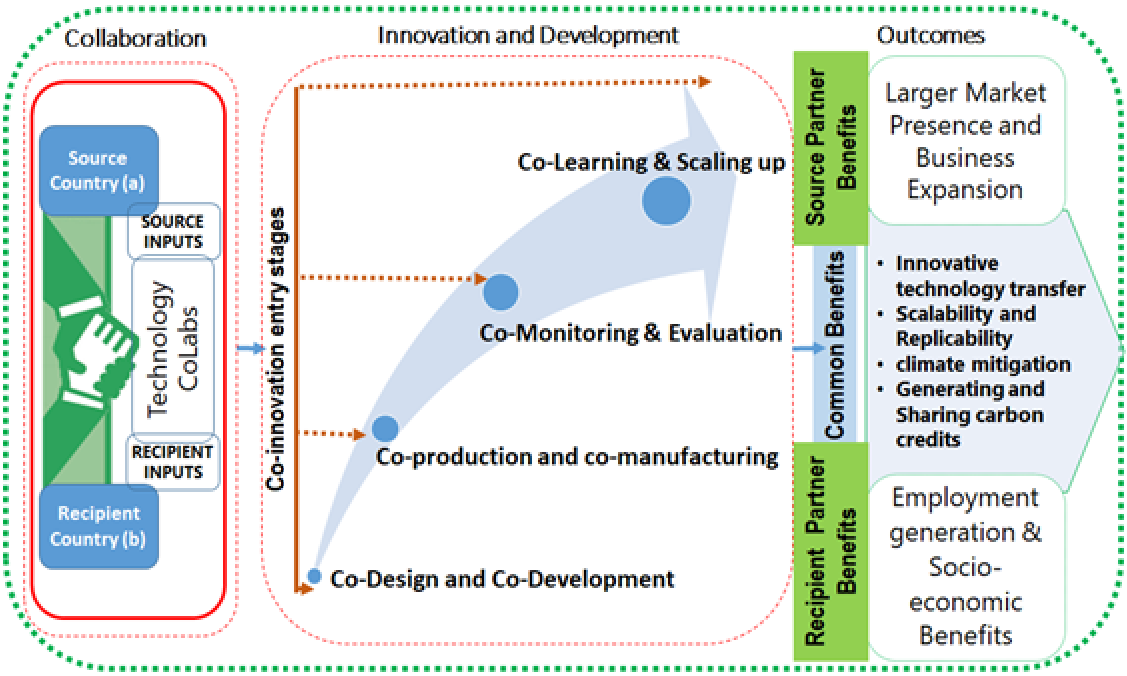
Co-innovation refers to a platform where new ideas or approaches from various internal and external sources are applied differently to create new value or experience for all stakeholders (M. Lee, et al., 2012). It offers an opportunity for internal and external actors to meaningfully participate, bridge gaps and enable a constant renewal of knowledge, to bring about an innovation-oriented culture and enable the emergence of widely-shared values (Saragih & Tan, 2018). A working paper by IGES (Janardhanan, et al., 2020) has set out a detailed description of co-innovation as a collaborative and iterative approach to jointly innovate, manufacture and scale-up technologies. The paper conceptualises the term co-innovation as not only offering access to an innovation platform but as a way to build up collective knowledge and continuously strengthen technological collaborations. This will hopefully lead to the promotion of sustainability and scalability, and the acceleration of replicability to tackle global environmental issues (Janardhanan, et al., 2020).

3 Implementing Co-innovation

The framework adapted from IGES (Figure 2) builds a theoretical construct towards implementing co-innovation across global boundaries (Janardhanan, et al., 2020). Co-innovation brings together the source and recipient countries so that they can collaboratively construct technological co-labs and share responsibilities for co-designing and co-developing solutions, and thus create value for both. Trust, transparency and willingness are the three key elements that underlie collaboration, driving actors to converge and move together toward successive stages of innovation and development.

The next step involves joint activities based on the inputs of the collaborating source and recipient. This innovation and development stage involves co-designing and co-development; co-production and co-manufacturing; and co-monitoring and evaluation (Janardhanan, 2020). Shared contributions minimise and overcome the impact of risks, bottlenecks, and investments. Co-learning and scaling up involves the concerted and deliberate use of knowledge and experience, linking a stakeholder's capacities with that of their partners to ideate and test concepts and translate those into scalable and appropriate solutions for the market. At the final stage, outcomes or co-benefits refer to shared value created, or outcomes added, that makes a reference to the value chain in relation to co-innovation. The source partner benefits from a larger market presence and the expansion of their business, whereas the recipient partner achieves socio-economic benefits via the creation of jobs and gains access to scalable, innovative, and future-proof solutions.

Figure 2: Co-innovation framework



Source: (Janardhanan, et al., 2020)

Co-innovation driven by international cooperation among developing and/or developed nations may be a key step for developing high-end solutions incorporating ideas that benefit both people and the planet. India and Japan, with their historic economic partnerships and synergy in industry relationships, have an opportunity to accelerate joint innovations across multiple sectors.

4 Co-innovation across Sectors - India and Japan

India and Japan carry out bilateral collaboration under various memoranda of cooperation (MoC) and understanding (MoU) in areas such as digital partnership, information and communication technology, specifically skilled workers, and environment and climate change (Press Information Bureau, 2021). These MoCs and MoUs have enabled both countries to form strategic partnerships and move forward with next-generation technologies. A prominent strategy to facilitate co-innovation is to open national borders to a flow of skills, knowledge, and technologies. The Japan-India Start-up Hub (Government of India, 2021), established in Bengaluru, is one such programme to drive Japanese investments in innovative Indian start-ups (Embassy of India, Tokyo, Japan, 2018). A digital partnership commits to technology matchmaking efforts, leveraging respective strengths and promoting B2B cooperation. As such, it can foster a cocreation culture within the ecosystem of electronics system design to drive innovations in hardware and software technologies.

Ultimately, however, joint innovation should not merely result in new products or services but create new markets with a focus on adaptability to local conditions (Zutshi, 2009). Collaborating Firms should focus on moving beyond selling more products to existing customers and aim to develop a new generation of products for a new customer base (Wilhelmsson, 2007). India and Japan are collaborating to introduce 5G services in India and on 5G applications in the fields of agriculture, transportation, disaster risk management, artificial intelligence and cyber security, enabling Japanese players to extend, refine, and redesign solutions to be more appropriate for Indian consumers (METI, 2018).

Interactive learning via innovation networks and communication is vital for multi-actor partnerships in agriculture, forestry, and allied sectors to unlock their potential (Reypens, et al., 2016). The synergy between India and Japan can expand priority areas such as spaces for endowed courses, job fairs, exchange of talent, and sharing of expertise and experiences. A MoC between the governments of India and Japan (Ministry of External Affairs, 2021) set out a basic framework for the joint operation of a system related to specified skilled workers (SSW), covering 14 specific industry fields. This can serve as a global programme to enable a breakthrough in co-innovation. Institutional collaborations, such as the *Japan International Cooperation Agency* (JICA) and *Japan India Technology Matchmaking Program* (JITMAP), have built up networks of social relations for the multilateral flow of knowledge across agriculture, forestry, and allied sectors.

The development of hydrogen has significant potential for collaboration between India and Japan, where both can incorporate the concept of co-innovation to generate value-added outcomes. The industry has the potential to help both India and Japan achieve their decarbonisation goals, as we present in the following case study.

5 Case: India-Japan Collaboration on Hydrogen Technologies

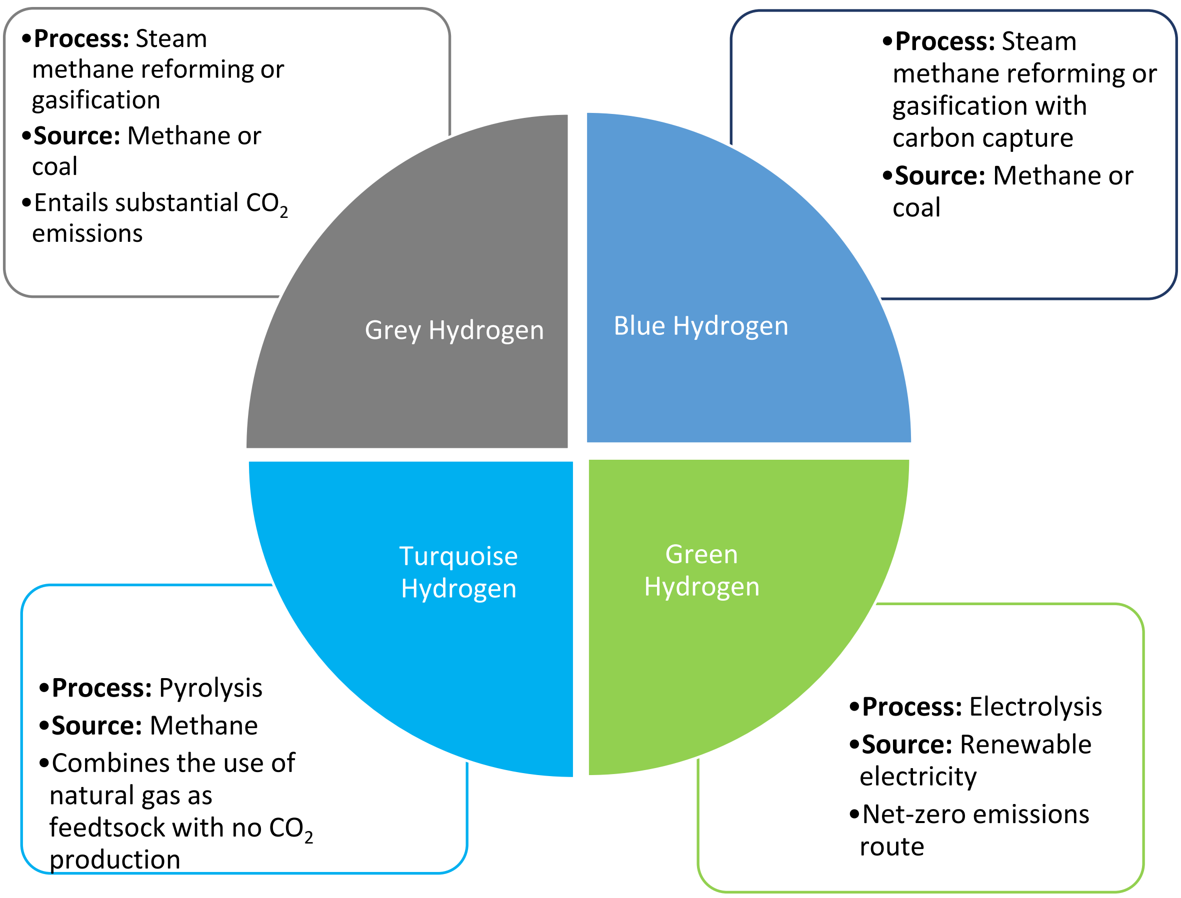
Hydrogen's industrial applications is not new. According to IEA, global consumption of pure hydrogen was around 70 million tonnes per year in 2018 (IEA, 2019). Years of industrial application of hydrogen have already provided quite important experience in terms of handling, transporting and using hydrogen. In recent years, hydrogen's potential as a low-carbon energy solution has gained much discussion (Lambert, 2020).

Hydrogen has the potential to play a key role on the path to low-carbon energy. A recent analysis of net-zero energy systems in 2050 by the International Energy Agency (IEA, 2021) highlights that hydrogen can form up to 10 percent of the global energy mix. Across end-use sectors, hydrogen holds significant promise for decarbonising hard-to-abate sectors, including the shipping industry, chemicals (primarily ammonia), aviation, and steel. The potential share of hydrogen in these sectors' energy mixes by 2050 is estimated to be 63 percent, 43 percent, 32 percent, and 20 percent respectively (IEA, 2021). In this case study, we aim to conceptualise green hydrogen and lay out the case for co-innovation by setting out the current status of India and Japan related to hydrogen technologies.

5.1 Conceptualising Green Hydrogen

Hydrogen is an energy carrier that can be produced from a variety of sources. It is often labelled differently based on its production process and use of energy sources. Figure 3 distinguishes between grey, blue, turquoise, and green hydrogen. Hydrogen that is produced from 100 percent renewable energy resources is referred to as green hydrogen (Hydrogen Council, 2021; Ghosh & Chhabra, 2021). Electrolysis is a commercially accepted process, whereby water is split into hydrogen and oxygen by applying electricity generated from a renewable energy source (Ghosh & Chhabra, 2021). Currently, hydrogen is mainly produced from conventional sources; less than four percent is produced using the low-carbon production route of electrolysis (Energy Sector Management Assistance Program, 2020).

Figure 3: Shades of hydrogen



Source: (Ghosh & Chhabra, 2021)

Green hydrogen has a vast and growing spectrum of applications, ranging from in feedstock to fuel cells, and as a chemical in oil refining, ammonia, and energy-intensive industries (IRENEA, 2019). However, the high cost of green hydrogen is a major barrier to developing a hydrogen-based economy. Electrolysers account for the highest share in the total production cost, followed by renewables to generate the electricity, and then the distribution costs. About 3,600 TWh/year of renewable supply is needed to meet the current hydrogen demand through water electrolysis, which is higher than the annual electricity production of the entire European Union (Renssen, 2020). An analysis of Jamnagar refinery in Western India conducted by CEEW found that electrolysers accounted for nearly 45 percent of the levelised cost, which is estimated to be USD 3.6/kg (INR 265.38 per kg) (Biswas, et al., 2020).

Furthermore, locations with favourable renewable profiles are situated far away from potential demand centres. This raises the cost of transporting hydrogen from Jamnagar to a steel plant in Odisha as high as USD 1.84/kg (INR 135.65 per kg) – which is more than 50 percent of the production cost. Efforts to develop new electrolyser capacity, improve energy efficiency (including durability and longevity), and develop more advanced infrastructure are key to the dissemination of clean hydrogen technologies.

Box 1. Cost of electrolysers

Electrolysers are electrochemical devices that take electrical power and water and use an electrolyte and membrane to separate hydrogen molecules (generated in the cathode) from oxygen molecules (generated in the anode).

The basic principle of electrolysers and electrolysis remains same, but the technology has evolved in terms of its physicochemical and electrochemical aspects. Electrolysers are typically categorised into four main technologies – alkaline, polymer electrolyte membrane (PEM), anion exchange membrane (AEM), and solid oxide, based on the electrolyte and temperature of operation, which further guide the selection of different materials and components (Ghosh & Chhabra, 2021).

On average, the production of green hydrogen costs two to three times more than that of the other kinds; the higher expenditures are due to the cost of input renewable power and electrolysers (IRENA, 2020). Although the increasing demand for green hydrogen globally is leading to a decline in the cost of electrolyser equipment, it is still more expensive than fossil fuel-based infrastructure. The cost of electrolysers has been attributed to the cost of components including cells, stacks, and systems etc, but in fact, this varies greatly depending on design, manufacturing strategy, and specifications. For example, the International Renewable Energy Agency 2020 report on green hydrogen costs states that PEM electrolyser systems cost between USD 700–USD 1400 per kW – which is higher than the cost of alkaline systems that cost around USD 500–USD 1000 per kW as of 2020 (IRENA, 2020).

Moreover, electrolyser capacity has scaled at a significant rate in the last couple of years. With new feasibility studies and innovations to cut costs, green hydrogen could fall below the USD 2 per kg mark by 2026 (IRENA, 2020). Also, the decreasing cost of renewable electricity can further lower the production costs of green hydrogen.

5.2 India and Japan – Status with Regard to Hydrogen Technologies

The Ministry of New and Renewable Energy (MNRE) directed the National Hydrogen Energy Board (NHEB) to prepare India's first *National Hydrogen Energy Road Map* (NHERM) in 2006. The programme aims to bridge various technological gaps in different areas of hydrogen energy, including production, storage, transportation and delivery, applications, safety standards, and capacity-building for the period up to 2020 (MNRE, 2007). In February 2021, the union ministry also announced a comprehensive *Hydrogen Energy Mission*, to be launched in 2021–2022, to upscale green hydrogen production (Economic Times, Environment, India, 2021). Over the last decade, following the allocation of around INR 1 billion (USD 13.5 million) (Department of Science and Technology, 2020), projects under the MNRE have developed fuel-cell stacks, hydrogen-fuelled vehicles, and hydrogen refuelling stations (MNRE, 2021). By August 2021, several companies in India had announced hydrogen projects across the transport, chemicals, iron, steel, and power sectors. Reliance Industries announced that hydrogen will be a part of the private refiner's move to replace transportation fuels with clean energy and become a net carbon-zero firm by 2035 (Business Standard, 2021). The National Thermal Power Corporation (NTPC), India's largest electricity generator, also announced plans to set up India's first green hydrogen fuelling station in Leh, Ladakh. Indian Oil Corporation (IOC), Adani Group, and ACME Group are also who have expressed interest in green hydrogen production plants and infrastructure development (Business Standard, 2021).

Japan was the first country to adopt a *Basic Hydrogen Strategy* as early as 2017 (Chaube, et al., 2020), which outlined Japan's vision of becoming a low-carbon energy society and the role of hydrogen in achieving this goal. Japan began investing in hydrogen R&D long before this strategy. As a part of an overall USD 18 billion (INR 1236 billion) commitment, Japan announced that it would provide Japanese firms more than USD 3 billion (INR 221 billion) for an R&D project to build a large-scale hydrogen supply chain and demonstrate the viability of hydrogen power generation, storage and carrier technologies (The Maritime Executive, 2021). It began green hydrogen production using solar energy at a facility in Fukushima in March 2020. However, the potential for producing green hydrogen varies by geography. Countries in the tropics, particularly in Asia (viz. China and India) and Northern Africa, have optimal renewable resources and other low-carbon resources for the production of hydrogen (Ghosh & Chhabra, 2021). Given the constraints in the availability of natural resources and the projected demand for hydrogen in Japan, its import capacity may significantly increase. Japan's hydrogen strategy, therefore, revolves around developing robust hydrogen supply chains through bilateral programmes with several countries and by promoting R&D in green hydrogen production, carrier technologies, storage, and application across sectors (Nagashima, 2020). Kawasaki Heavy Industries aims to deploy two ships by 2030 to bring 225,000 tonnes of hydrogen to Japan – enough to power around three million fuel-celled vehicles for 10,000 kilometres every year (Nature resource custome media, 2021).

India is building up its research expertise and intellectual capital in the field of hydrogen and fuel-cell technologies. However, market occupancy remains low due to a lack of developed infrastructure. In addition, hydrogen technology in India is at the primitive stage of proof of concepts and pilot projects and is yet to scale. Even in Japan, the hydrogen market is still not economically viable, with almost all hydrogen and fuel-cell technologies highly dependent on public funding. The ultimate objective is to usher in commercialisation by bringing down the costs of green hydrogen production, storage, and utilisation while enhancing the efficiency, safety, and reliability of the system. Table 1 presents a snapshot of potential value creation within the hydrogen industry via co-innovation between India and Japan.

Table 1: Co-innovation value for hydrogen industry

Collaboration	Aspect of collaboration	Expected project outcome	Achieved outcomes		
			Source partner	Recipient partner	Co-benefits
India- Source Japan- Recipient	Co-invest & Co-develop green hydrogen production	Development of a clean, low-carbon source of energy	Emerges as a green hydrogen production hub	Caters the large growing market	Co-learning green production methods
Japan- Source India- Recipient	Co-develop and co-deploy storage and carrier technologies	Development of global supply chain network for hydrogen	Emerges as a lead supplier by deploying the latest carrier technologies across the global supply chain	Transforms the domestic market infrastructure and promote the transition for energy-intensive industries and sectors towards clean energy sources	Co-developing potential manufacturing hubs Cost reduction via building storage and optimising supply chain infrastructure

Source: Authors' analysis

5.3 Opportunities and Priority Areas for Co-innovation

Co-innovation can have a positive global impact and contribute to the creation of new synergies in the form of cooperative initiatives in international energy trading and business. Green hydrogen has a differentially higher cost throughout its production, storage, and consumption, and thus there is an urgent need for increased R&D investments. Co-innovation can help produce new solutions that can drive the uptake of renewables for hydrogen technologies, business models, market design, and system operation.

India and Japan recently held talks on the promotion of hydrogen-based technologies as well as related trends, concerns, and solutions. This is a step forward in building international collaboration. A webinar, "Decarbonisation – Exploring Hydrogen Prospects and Innovative Technologies" (Press Information Bureau, Delhi, 2021), jointly organised by the Embassy of India in Japan, the Department of Science and Technology (DST), the IGES, and The Energy and Resources Institute (TERI), initiated a sense of convergence to help build trust and relationships over green hydrogen technologies. While Japan is already involved in international hydrogen projects in Brunei, Norway, and Saudi Arabia (Ghosh & Chhabra, 2021), India should make use of this opportunity to deliberate on the next steps for collaboration with Japan to scale up its green hydrogen industry. The governments of India and Japan have a key role to play in building such partnerships. The respective governmental institutions and scientific organisations can jointly initiate strategic partnerships that focus on hydrogen technologies. A bilateral partnership between the two countries – along with the engagement of institutions, industries, and public and private stakeholders – can assess the technology status, recognise R&D priorities, and uncover potential ways to scale up the access, affordability, and deployment of hydrogen technologies.

A specific task force on hydrogen and fuel cells comprising scientists and experts from both countries, could act as an arm of a steering committee. This task force can be organised at the government level with working groups or sub-committees working on priority areas with a focus on strengthening hydrogen cooperation between industries and institutions from both countries. We propose that India and Japan collaborate and co-create, using an overarching strategy focused on applied research in the short, medium, and long term (Figure 4). Collaborative efforts, coupled with the engagement of reputable institutions and academic entities, will also enable a platform for co-learning via shared knowledge and experiences.

Figure 4: India-Japan co-innovation- potential research priorities

<u>Short term</u>

Develop and deploy advanced storage and transportation technologies for hydrogen like, liquid organic hydrogen carriers or metal hydrides.

Identify and deploy hydrogen blending programmes in existing natural gas infrastructure and projects related to filling systems with all long-term performance assurance as well as safety parameters.

<u>Medium term</u>

Commercialise the promising production technologies, such as pyrolysis of biomass and natural gas

Promote green hydrogen production from biomass and low-cost indigenous electrolyser technology

<u>Long Term</u>

Develop novel hydrogen production techniques such as photocatalysis of water

Enable demonstration of application of hydrogen and its derivatives (like synthetic natural gas) as large-scale solution for heating/combustion applications.

Source: Authors' analysis

Green hydrogen is a new industry and India-Japan collaboration can enable both countries to leverage their vibrant clean energy industries and shape their green hydrogen markets. Co-innovative efforts towards localisation of electrolyser production and development of green hydrogen infrastructure can create an entirely new technology market within Asia. The current capacity for domestic hydrogen production is limited in Japan and the majority of hydrogen and other derivative fuels are imported from overseas (Nagashima, 2020). Japan has a large offtake market for green hydrogen and its derivatives, whereas India is emerging as a promising green hydrogen producer. The Global Hydrogen Council, in a recent study, classified India as a potential net exporter of green hydrogen from 2030 onwards (Kant, 2021). While India has the opportunity to completely reimagine and establish its green energy economy, Japan in collaboration with India can leverage the results of decades of innovation to attain consonance with the rising demand for clean and sustainable products.

6 Inferences and Way forward

Co-innovation shifts the traditional idea of value creation from developing market competency towards creating valued outcomes for all relevant stakeholders. India and Japan collaboration and co-innovation can facilitate the development of efficient solutions coupled with the concept of scalability and feasibility for relevant market conditions. Sharing of risks and investment, exchange of talents and enhancement of future trade relations between both countries would be added advantages of co-innovation.

This paper pointed out the co-innovation pillars and how far it is relevant to various sectors, to ensure joint innovation for efficient solutions. Green hydrogen is a clean energy source that has set the stage for taking initiatives beyond national boundaries, policies and programmes. Hydrogen and fuel cell technologies have seen significant progress in terms of efficiency, cost reduction and reliability, and thus present an opportunity for both India and Japan to develop synergies and strengthen steps towards co-investing, leading to commercialisation of these technologies.

Partnering with Japan can strengthen India's capability to establish manufacturing and production facilities. However, the critical question is, how can India encourage co-innovation with Japan at the policy level. With initiatives like *Make in India* and *Start-up India*, India is positioning itself as a potential production and distribution hub but success is still subject to changes in institutions and laws. Institutional efforts on collaboration to commercialise hydrogen technology pathways, adopt best practice standards and carry out training and upskilling should be channelled towards a further reduction in the carbon footprint for energy-intensive industries. Co-innovation between these two countries can boost manufacturing capacity, along with innovating and scaling disruptive technological solutions for future markets.

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