Title	International collaboration on hydrogen from observation of technology value chain : Japan and GCC
Author(s)	MITA, Kaori
Citation	年次学術大会講演要旨集, 39: 675-678
Issue Date	2024-10-26
Type	Conference Paper
Text version	publisher
URL	http://hdl.handle.net/10119/19496
Rights	本著作物は研究・イノベーション学会の許可のもとに掲載するものです。This material is posted here with permission of the Japan Society for Research Policy and Innovation Management.
Description	一般講演要旨

２Ｂ１７

International collaboration on hydrogen from observation of technology value chain: Japan and GCC

MITA Kaori （The University of Tokyo）
mita.kaori@mail.u-tokyo.ac.jp

1. **Introduction**

Blessed with abundant renewable energy, the Arab Gulf region is strategically positioned to push forward the world's hydrogen economy. To achieve a hydrogen economy, production, transportation, storage, and utilization (market) need to be established. While the Arab Gulf region is becoming the producer of hydrogen and building a supply chain for green hydrogen and blue ammonia, other countries are racing to research and develop technologies to store and transport hydrogen and create a market for its utilization. Hence, just as other renewable and clean energy technological innovation systems, the value chain of hydrogen is spreading across the globe. For instance, Japan holds the most hydrogen patents in general, specifically in fuel cells, and the third-highest number of scientific journal publications on hydrogen in general (Asna Ashari et al., 2023). Historical relations between Japan and GCC over energy and the economy could contribute to the promotion of a hydrogen economy in both countries.

Japan and GCC have a long relationship through energy imports and exports, and over the past decade or so, hydrogen-related collaboration has been seen on essentially a G-to-G basis. Although its basis is G-to-G, the exchange of knowledge and the promotion of the private sector (including government-affiliated enterprises) are the foundation of their cooperation. The earlier collaboration between Japan and UAE for hydrogen was under the large umbrella of the economic cooperation agreement in 2015. More recent collaborations have focused on supply chain development and knowledge exchanges. The Japan-UAE Hydrogen Collaboration agreement in 2021 includes policy exchanges and discussion over rules and regulations, which are especially important in building the user sectors and supply chain development. Saudi Arabia's Light House Initiative is similar in content and aims to develop a hydrogen supply chain and knowledge exchange through research and development. However, making progress seems challenging at times, mainly due to the fact hydrogen is not a primary source of energy and may not necessarily be the priority in energy security. Therefore, building knowledge infrastructure between the two countries has taken considerable time and effort from both sides. Nevertheless, the collaboration between Japan and GCC may benefit greatly to both countries. This paper explores the mechanisms of technology value chains and organizes hydrogen technology value chain (TVC), then aims to arrange discussion points for Japan-GCC collaboration on hydrogen.

2. Technological Innovation System and Technology Value Chain

In recent years, scholars have applied technological innovation system (TIS) function approach to observe new and emerging technologies that are associated with sustainability transitions (Markard et al., 2012): renewable energy development in the United Arab Emirates (Vidican et al., 2012), offshore wind development in Poland (Sawulski et al., 2019), biogas industry in Russia (Nevzorova, 2022), hydrogen direct reduction in Sweden (Kushnir et al., 2020), and more. In most cases, TIS is used to observe a single country and a single technology as the unit of analysis and may fall short of including multiple countries and sectoral changes. However, the knowledge base for current emerging technologies is spreading across the world, and it is becoming increasingly important to include geographic factors in its considerations (Binz et al., 2014; Coenen et al., 2012). In response, TIS studies have integrated sectoral and spatial aspects. The connection between emerging TIS and established sectors has been explored in overlapping structures: technology, actors, networks, and institutions (Mäkitie et al., 2018; Smink et al., 2015). Those structural overlaps influence the growth of both existing sectors and emerging TIS (Mäkitie et al., 2018). In particular, technology is connected to multiple sectors, and each sector is connected to a different knowledge base and technologies (Andersen & Markard, 2020). For example, lithium-ion batteries, which consist of multiple components and subsystems, span multiple sectors (Kamikawa & Brummer, 2024; Stephan et al., 2017). In addition, these multiple sectors are often cross-national and expand on the technology value chain (TVC). TVC is a vertical integral view of the value chain of input and output sectors, and the idea that technologies integrated into sectors add value to the process and into the large systems and contribute to the creation of knowledge (Mäkitie et al., 2022; Stephan et al., 2017). As the different but interdependent sectors connected on the technology value chain align with each other, this inter-sectoral linkage influences the growth of the TVC as a whole (Andersen et al., 2020). Furthermore, sectoral complementarity and its mechanisms are influenced by technological innovation and changes in supply and demand between input sectors and user sectors. In the case of the deployment of renewable energy, a technology to manage intermittence and energy storage is required for the renewable energy system to be integrated (Haley, 2018). Put differently, complementary technology development is necessary for renewable energy power generation to be widely adopted, thus creating demand from user sectors. Additionally, at the technology level, the competing technologies (e.g. hydro, solar, wind) may find complementarity over structural overlaps or the technology itself within the sector (Markard & Hoffmann, 2016). Finally, the mechanisms of sectoral (vertical) complementarity in TVC are known to include sectors developing together (synchronization), particular sectors expanding (amplification), and sectors that are close to each other to consolidate (integration), which could explain the TVC development (Mäkitie et al., 2022).

3. Hydrogen and Hydrogen TVC[1]

Hydrogen is a versatile energy carrier with a large potential to achieve carbon neutrality, yet it has quite complex characteristics. Hydrogen is produced and processed into an energy carrier in different ways. The type of energy carrier determines the method of storage and transportation, as well as the physical infrastructure needed for the hydrogen to be introduced in the user sectors. Each method has pros and cons in the cost of production and in maintaining energy during transportation. Therefore, this section attempts to provide a holistic view of hydrogen and its TVC, and provides a general understanding of technologies associated with hydrogen.

Hydrogen TVC expands from existing energy sectors to relatively new production segment sectors, distribution, and finally to industries and transportation sectors as users. Each process is defined as follows: sourcing concerns with the primary power generation source and source of hydrogen itself; production is the conversion of hydrogen into a carrier, and distribution includes processing hydrogen into a transportable form and the transportation itself. In general, commercially traded hydrogen is produced from fossil fuels (coal, natural gas), renewable energy, and by-products of industrial activities (steel, chemical, etc). The sourcing sector includes existing heavy and chemical industries (Harada, M. et al. 2010), energy sector (coal, natural gas), and renewable energy sector. Hydrogen produced from the existing industry is often directly consumed within the industry complex using pipelines. Coal, natural gas, and renewable energy generate power for electrolyzers to split water into hydrogen and oxygen to produce hydrogen. Additionally, hydrogen can be produced through the pyrolysis of methane which Mitsubishi Heavy Industries, Ltd. has been researching and developing and is now in the technological verification and validation stage.

Production sectors process hydrogen into energy carriers such as ammonia, e-fuel, and liquified hydrogen. Ammonia (NH3) can be produced by an electrolyzer to split water to produce hydrogen, which is then combined with nitrogen to produce ammonia to be liquified and stored, and then used as an energy source. Hydrogen itself can be liquified at low temperatures and is able to be transported directly to the user sectors, but at shorter distances, considering energy loss during transportation. Additionally, e-fuel, or Gas to Liquids (GTL), is made out of carbon dioxide captured from industrial emissions and hydrogen to create synthesis gas, then processed into liquified fuel using Fischer-Tropsch technology. Also, the boundary between the sourcing and production sectors is blurred as the technology process has overlapping functions.

Distribution sectors include technology to turn hydrogen into transportable substances and the physical transportation sector. By adding toluene, hydrogen turns into Methylcyclohexane (MCH),

---

[1] Please see technical references

which then becomes transportable over a longer distance. The benefit of this method is that both MCH and toluene are similar in handling gasoline and can utilize existing infrastructure for commercialization. By using existing infrastructure, the user sector does not require large capital investment. Traditional transportation methods including land and sea transportation, in addition to pipelines, are also part of distribution sectors, and maintaining energy loss at a low-level during transportation is one of the important points for this segment. Finally, potential users in the user sector are also from heavy industries, transportation (aviation, shipping, commercial transportation), the mobility sector, to the residential sector. According to industry personnel[2], although the mobility sector's demand for hydrogen is not large, the industry needs a hydrogen supply to popularize fuel cell vehicles (FCV) first, and thus, demand for FCV grows. The same has been said for the residential use of FC. Considering substitutability to other energy sources, hydrogen is the most useful in heavy industry sectors, shipping sectors, and large transportation sectors.

Input Sectors			User Sectors
Sourcing	**Production**	**Distribution**	**User**
Industrial byproducts **Coal, natural gas** **Renewables** **Methane** **(Nuclear, oil)**	Hydrogen (gas) Liquefied hydrogen Ammonia E-fuel, e-methane	MCH Pipeline Road transportation Shipping transportation	Industrial use (refineries, chemicals, iron and steel, aluminum) Transportations (shipping, road) Mobility (cars, aviation) Residential, commercial (fuel cell)

4. Discussion

The study explored the mechanisms of technology value chains from a literature review and organized hydrogen TVC to deepen the discussion on international collaboration between Japan and GCC, offtakers and producers of hydrogen. Hydrogen does not have multiple components like lithium-ion batteries and solar PVs but rather pertains to various sectors and technologies with diverse processes on its technology value chain. It is an energy carrier with multiple applications, yet depending on the kind of energy carrier it is converted to, the storage and transformation technologies and distribution methods need to be considered. To study further, 1) investigation of hydrogen TIS in both countries to see the current phase of development and 2) detailed hydrogen technology mapping of Japan is requisite. Japan has accumulated knowledge and invested in R&D on hydrogen as an alternative energy source since the 1970s oil shock. The Japanese government implemented the second Hydrogen Basic Strategy in 2023 to promote the use of core technologies developed in Japan to overseas markets to leverage the first mover's advantage. On the other hand, the GCC advantage of rich resources could use the opportunity to access the user market and gain knowledge through collaboration. To achieve this mutual benefit, close policy coordination between governments is crucial.

References

Andersen, A. D., & Markard, J. (2020). Multi-technology interaction in socio-technical transitions: How recent dynamics in HVDC technology can inform transition theories. *Technological Forecasting and Social Change*, *151*(October 2019), 119802. https://doi.org/10.1016/j.techfore.2019.119802

Andersen, A. D., Steen, M., Mäkitie, T., Hanson, J., Thune, T. M., & Soppe, B. (2020). The role of inter-sectoral dynamics in sustainability transitions: A comment on the transitions research agenda. *Environmental Innovation and Societal Transitions*, *34* (December 2019), 348–351. https://doi.org/10.1016/j.eist.2019.11.009

Asna Ashari, P., Blind, K., & Koch, C. (2023). Knowledge and technology transfer via publications, patents, standards: Exploring the hydrogen technological innovation system. *Technological Forecasting and Social Change*, *187*(February 2022), 122201. https://doi.org/10.1016/j.techfore.2022.122201

Haley, B. (2018). Integrating structural tensions into technological innovation systems analysis: Application to the case of transmission interconnections and renewable electricity in Nova Scotia, Canada. *Research Policy*, *47*(6), 1147–1160. https://doi.org/10.1016/j.respol.2018.04.004

Harada, M. Kawamura, Y. Lin, S., Shikata, T. (2010). Hydrogen Production Technologies from Coal.

---

[2] Author visited stakeholders from May to June 2024

Hydrogen Energy System, *35*(1), 9–16.

Kamikawa, Y., & Brummer, M. (2024). Cross-national and cross-sectoral dynamics of innovation policies: The case of lithium-ion battery technology for electric vehicles in the U.S. and China. *Technological Forecasting and Social Change*, *201*(November 2023), 123021. https://doi.org/10.1016/j.techfore.2023.123021

Kushnir, D., Hansen, T., Vogl, V., & Åhman, M. (2020). Adopting hydrogen direct reduction for the Swedish steel industry: A technological innovation system (TIS) study. *Journal of Cleaner Production*, *242*, 118185. https://doi.org/10.1016/j.jclepro.2019.118185

Mäkitie, T., Andersen, A. D., Hanson, J., Normann, H. E., & Thune, T. M. (2018). Established sectors expediting clean technology industries? The Norwegian oil and gas sector's influence on offshore wind power. *Journal of Cleaner Production*, *177*, 813–823. https://doi.org/10.1016/j.jclepro.2017.12.209

Mäkitie, T., Hanson, J., Steen, M., Hansen, T., & Andersen, A. D. (2022). Complementarity formation mechanisms in technology value chains. *Research Policy*, *51*(7). https://doi.org/10.1016/j.respol.2022.104559

Markard, J., & Hoffmann, V. H. (2016). Analysis of complementarities: Framework and examples from the energy transition. *Technological Forecasting and Social Change*, *111*, 63–75. https://doi.org/10.1016/j.techfore.2016.06.008

Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research Policy*, *41*(6), 955–967. https://doi.org/10.1016/j.respol.2012.02.013

Nevzorova, T. (2022). Functional analysis of technological innovation system with inclusion of sectoral and spatial perspectives: The case of the biogas industry in Russia. *Environmental Innovation and Societal Transitions*, *42*(December 2021), 232–250. https://doi.org/10.1016/j.eist.2022.01.005

Sawulski, J., Gałczyński, M., & Zajdler, R. (2019). Technological innovation system analysis in a follower country – The case of offshore wind in Poland. *Environmental Innovation and Societal Transitions*, *33*(July), 249–267. https://doi.org/10.1016/j.eist.2019.07.002

Smink, M. M., Hekkert, M. P., & Negro, S. O. (2015). Keeping sustainable innovation on a leash? Exploring incumbents' institutional strategies. *Business Strategy and the Environment*, *24*(2), 86–101. https://doi.org/10.1002/bse.1808

Stephan, A., Schmidt, T. S., Bening, C. R., & Hoffmann, V. H. (2017). The sectoral configuration of technological innovation systems: Patterns of knowledge development and diffusion in the lithium-ion battery technology in Japan. *Research Policy*, *46*(4), 709–723. https://doi.org/10.1016/j.respol.2017.01.009

Vidican, G., McElvaney, L., Samulewicz, D., & Al-Saleh, Y. (2012). An empirical examination of the development of a solar innovation system in the United Arab Emirates. *Energy for Sustainable Development*, *16*(2), 179–188. https://doi.org/10.1016/j.esd.2011.12.002

Technical references

In addition to 2 site visits and 11 stakeholder visits between May 2024-June 2024;

-Green Hydrogen and Carbon Neutrality. National Institute of Advanced Industrial Science and Technology, Japan. https://www.aist.go.jp/aist_j/magazine/20200303.html (Accessed April 11, 2024)

-How is hydrogen produced? Agency for Natural Resources and Energy, Japan. https://www.enecho.meti.go.jp/about/special/johoteikyo/suiso_tukurikata.html (Accessed April 10, 2024)

-Hydrogen and Fuel Cell. Iwatani. https://www.iwatani.co.jp/jpn/consumer/hydrogen/fuel-cell/ (Accessed April 10, 2024)

-Iwatani R&D Center. The Forest of Creation A place where diverse needs meet advanced technologies. https://www.iwatani.co.jp/eng/business/rd/central/ (Accessed May 23, 2024)

-Mitsubishi Heavy Industries, Ltd. Takasago Hydrogen Park. https://www.mhi.com/news/23092003.html (Accessed May 23, 2024)

-Mitsubishi Heavy Industries, Ltd. Energy Systems. Hydrogen Power Generation Handbook (Fourth Edition)

-Sho Hayashi (2024). Transition Finance towards Net-Zero in Asia and Its Challenges. Economic Research Institution for ASEAN and East Asia at CERAWeek Lyceum Session, March 18th 2024.

-SPERA Hydrogen, Chiyoda Corporation. https://www.chiyodacorp.com/jp/service/spera-hydrogen/innovations/ (Accessed April 10, 2024)

-What is e-fuel. Japan Organization for Metals and Energy Security (JOGMEC).
https://www.jogmec.go.jp/publish/plus_vol06.html (Accessed April 11, 2024)