ON AN OPTIMAL HYDROGEN DEVELOPMENT STRATEGY FOR ASEAN

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I. Overview

Hydrogen gas has been and continues to be extensively used in industrial processes like oil refining, chemicals, fertilizers and steel production (IEA 2019). While it also powers fuel-cell electric vehicles ("FCEV") in some countries, economic considerations and infrastructure limitations have constrained its use in transportation to date (IEA 2019). This is expected to change. On the supply-side, competitively-priced hydrogen continues to be sourced primarily from steam reforming of natural gas ("grey hydrogen").[1] While hydrogen from water electrolysis ("green hydrogen") has better potential to compete against transport fuels, especially when petroleum prices are high, it is much more expensive than grey hydrogen used for industry (Ball and Weeda 2016). However, recent research and pilot projects lead to the expectations that technologies like natural gas reforming combined with carbon capture ("blue hydrogen") and electrolysis of water using renewable-based electricity are gaining prominence and could dominate hydrogen production in the future (APERC 2018, IEA 2021).

On the demand side, industry will continue to be the largest user of hydrogen, far exceeding usage in transport.[2] While demand for battery operated electric vehicles ("BEV") including plug-in hybrids has been rising in recent years due to increased subsidies and expanding charging station networks, the transport and logistics sectors are yet to settle to any dominant technology. Indeed, recent findings indicate a future market split between BEVs dominating the light passenger vehicle markets travelling shorter distances and FCEVs used in heavier, long distance utility vehicles such as trucks and rail (Milton 2020). Furthermore, hydrogen gas' potential as future energy carrier is still being developed.

Given the complex set of factors affecting demand, supply, storage and transport of hydrogen, the search for an optimal hydrogen development strategy requires an analysis of not only technological and economic variables but also a country's geography, energy demand and supply situation and, equally importantly, their institutional set-up.[3] Only by understanding a country's geography, demographic and institutional history and the technological and economic determinants of hydrogen demand, supply, storage and transport can an optimal hydrogen development strategy be formulated.

Industries and countries, just like companies, can become victims of their own success. The literature on innovation incentives is abound with reports on industrial and institutional inertia (Belleflamme et al. 2006, 2010). In the automobile sector, for example, the German automobile multinationals have been slower than their Chinese competitors and Tesla in shifting their business models towards electric vehicles. The reason lies in their efficient infrastructure and operations being geared towards internal combustion engine technologies and supply chains and their historically strong political lobbying power (Schüsseler 2018). The latter leads them to rely on the German government to continue helping them maintain their lead in their existing markets and technologies. As a result, the technologies and market infrastructure including charging networks were not build-out as rapidly as in China or Tesla's target markets.

In this paper we develop an optimal hydrogen market development strategy for the ASEAN region. Firstly, the ASEAN region holds a population of 660 million and a combined GDP of more than 3.0 trillion USD in 2020 (ASEAN 2021). Second, the region's refinery, chemical and steel sector output and demand for passenger and logistics transportation are concentrated in Singapore, Thailand, Indonesia, Malaysia and Vietnam, five countries which makeup the region's largest industrial output and consumption market. Third, ASEAN harbors some of the world's largest natural gas reserves and resources (IEA 2021). Fourth, the existing natural gas pipeline networks in Malaysia, Indonesia, Thailand-Myanmar, Vietnam offer the potential for a future regional network of gas transport pipelines, which can be crucial for the region's hydrogen market development.[4] Fifth, while the hydrogen-consuming industries and the automobile production and supply chains in Thailand and Indonesia dominate the region, they are not overly developed yet and have the potential for significant and rapid growth into the future. The proportion of renewables-based electricity generation is small and ASEAN aims to grow renewables capacity to 23% of primary energy consumption by 2025 (IEEFA, 2020). Thus the region still holds potential for future adaptation and transformation, to be guided by the right future development strategy and policies for its energy sector including hydrogen.

II. Methods

We first analyze and model the demand for industrial, transport and energy carrier usage of hydrogen for the five major member countries and extrapolate for the region. We then study the existing hydrogen supply situation and project the theoretically optimal future hydrogen supply mix scenarios in each of the five most industrialized countries based on their industrial and energy mix, electricity generation capacities including renewables, transport sector and infrastructure characteristics. The model projections and scenario analyses are conducted by considering relevant technological and

[1] We exclude hydrogen from coal gasification from our detailed analysis given its current niche character.
[2] Its use as energy carrier and fuel or co-fuel in natural gas- or coal power generation is still in pilot stage.
[3] Rusli (2013) considers geographic, demographic, economic and socio-political determinants in developing an optimal energy policy for the oil, gas and coal industries in Southeast Asia.
[4] Trans-ASEAN natural gas pipeline network (ASEAN Centre for Energy Policy Brief 2022).

economic factors. Technological factors drive industrial and vehicle performance in terms of output, safety, convenience and driving distance and affect relative costs and competitiveness of the various hydrogen supply scenarios. Economic factors affect comparative cost competitiveness and include network externalities between hydrogen storage and transport infrastructure including refilling stations and their potential competition with electricity charging station networks. Comparing the status quo and optimal future scenarios we identify alternative hydrogen market development pathways for the five member countries. Key questions include, among others, the stages and duration of transformation from grey to blue and green hydrogen, the sequential prioritization of industrial, transport or simultaneous industrial and transport sector adaptations of supply. Next, analyzing the institutional and policy setup in each of the five major countries and the scope of current and future ASEAN-level collaborations we formulate an optimal hydrogen market development strategy for the region. We end by recommending policies that the governments of ASEAN countries can pursue, collectively and individually, to realize this strategy.

III. Results

The combined demand from hydrogenation in refineries and the chemical industry, ammonia and methanol production and steel direct reduction the ASEAN region is estimated to approximately 5.3 million tonnes of hydrogen annually by 2030. Together with usage as fuel for FCEVs the total annual consumption could amount to about 5.5 million tonnes of hydrogen annually by then. On the supply-side the combined hydrogen production, storage and transport costs into the region could range from about 2-4 US$ per kg for captive versus merchant grey hydrogen to 9-11 US$ per kg for green hydrogen, the latter cost levels depending on the cost of electricity used for electrolysis. Note that these average supply costs decrease by about 4-8 percent when hydrogen transport technologies such as organic hydrides and ammonia are used instead of liquid hydrogen (Kimura et al. 2020). Thus using green hydrogen in globally competitive refinery, chemicals and steel processing adversely impacts the competitiveness of such hydrogen consumers. First, apart from the refineries in Singapore, the region's chemical and steel processing capacities are generally not as large and efficient as those in China, Korea, Japan and the industrialized West. Second, the region's renewable power generation capacity, apart from hydropower in some member countries, is very low.

As a consequence, forcing the use of green or blue hydrogen through regulation would require significant public sector subsidies and co-financing. At the same time, the demand for hydrogen in the transport sector is still small and contingent on FCEV gaining their foothold and start dominating BEV at least in heavy duty electric vehicles such as trucks. ASEAN member states may try to accelerate the build-up of hydrogen charging station networks in the region, but such policy will require additional public sector financings for R&D and infrastructure development, which must be paid by the taxpayers. Not to mention the higher costs of FCEVs (just like BEVs) against traditional internal combustion engine vehicles, which has led governments in Europe and China to subsidize the consumers i.e. buyers of electric vehicles.

Based on these technological and economic analyses and taking into account the major ASEAN countries' institutional characteristics we recommend a three-pronged hydrogen development strategy for the region. First, governments must work with key industrial players including the refinery and chemical multinationals in Singapore, the national oil and gas and major chemical companies in Thailand, Malaysia, Indonesia and Vietnam. Focus should be on designing regulations and providing risk-sharing, incentivizing financing and partnership schemes to gradually, e.g. over a period of 10 years, shift to blue and green hydrogen. This process must go hand-in-hand with providing incentives, financing and debureaucratizing the development and growth of renewable electricity generation capacity and infrastructure in the key countries. Second, given their experience with higher value-added (natural) gas chain technologies and infrastructure and stronger institutional capacities, Singapore, Thailand and Malaysia should spear-head the build-out of hydrogen or combined hydrogen-filling and electricity-charging station networks. These countries are also in a better position to offer incentives and stimulate demand for both BEVs (lighter vehicles, shorter distances) and FCEVs (heaver utility vehicles, longer distances). On the latter, public sector collaborations with the major automobile, oil and gas marketing, logistics and supply-chain companies in Thailand, Indonesia and Singapore, Malaysia would be mutually beneficial and might offer cross-country synergies. Third, ASEAN governments should work closely with selected industrial and the region's state-controlled gas transport and trading as well as electric utilities to develop ways to utilize the planned Trans-ASEAN gas pipeline grid and electricity interconnection infrastructure synergistically with the goal of introducing hydrogen as energy storage and transport carrier and possibly also, farther in the future, as co-fuel in combined-cycle electricity generation.

IV. Conclusions

Demand for hydrogen in ASEAN is dominated by industrial use. Replacing grey with costlier green hydrogen will be detrimental to the region's industrial competitiveness. Forcing green or blue hydrogen for industrial and future transport use through regulation would require significant public sector incentives and funding. An optimal hydrogen strategy would be three-pronged: First, the cooperation between governments and key industrial players to design regulations and provide risk-sharing, incentivize financing and partnership schemes. Second, the potential roles of Singapore, Thailand, and Malaysia to spearhead the build-out of hydrogen or combined hydrogen-filling and electricity-charging station networks. Third, collaborative efforts to optimize the use of the planned Trans-ASEAN gas pipeline grid and electricity interconnection infrastructure synergistically to introduce hydrogen as energy storage and transport carrier and possibly also as co-fuel in combined-cycle electricity generation.