# Chapter 5

# Conclusions and Policy Implications

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# Chapter 5

# Conclusions and Policy Implications

This study investigated the energy consumption and economic costs of hydrogen as energy storage for renewables in ASEAN and East Asian countries. Downstream, two categories of applications of hydrogen energy were analysed – for the power sector and for the road transport sector. In the case of the power sector, the cost of electricity stored as hydrogen and then returned as electricity to the grid is estimated in US dollars per kilowatt-hour and compared with electricity storage using lithium batteries and pumped hydropower. In the case of transport sector, the total cost of owning and driving FCEVs is estimated in US dollars per kilometre and compared with alternative powertrains such as BEVs, PHEVs, and ICEVs.

Our results show that hydrogen transport and delivery are as important cost drivers as hydrogen production. Amongst the various hydrogen supply pathways, liquefied hydrogen pathways are the costliest. Others, including the compressed gaseous pathways and LOHC pathways, are cheaper. The cost of renewable electricity stored as hydrogen energy and subsequently converted back into electricity by fuel cell is two or three times that of the cost of storage in lithium batteries and pumped hydropower. However, by making use of mature gas turbine technology to convert hydrogen back into electricity, pathways such as compressed hydrogen and pipelines are likely to be competitive against lithium battery storage.

We note that the cost of liquefied hydrogen is extremely high because of the small scale of hydrogen production and transport demonstrated. Leading companies such as KHI believe that the cost of liquefied hydrogen will decrease as it did for liquefied natural gas, especially because liquefaction technology has already developed. KHI foresees that the cost of liquefied hydrogen will soon rapidly decrease.

Such is in line with the economies of scale in the hydrogen energy supply chain observed in our modelling. The described effects are also most evident in the case of liquefied hydrogen pathways. Therefore, as we move from 1,000 MW of RESs to a 4,000 MW source, the cost of electricity stored and transported as liquefied hydrogen will decrease by 50%–70%, depending on the country and the technologies – fuel cell or gas turbine – used to convert hydrogen back into electricity.

In the case of road transport applications, the estimated cost of hydrogen produced from renewables and dispensed to FCEVs through various pathways is typically US$6–US$7/kg, except for the liquefied hydrogen pathway, which is about US$20/kg. Such levels of fuel cost, combined with the high CAPEX of FCEVs, make FCEVs in all three fleets uncompetitive in most of the countries studied. The TCO of FCEVs is typically about two or three times that of BEVs, PHEVs, or ICEVs, except for passenger FCEVs in China. FCEVs enjoy generous government subsidies in China.

We take note that this study, however, did not consider the value of balancing services provided by hydrogen as storage or the value of reduced carbon emissions from FCEVs fuelled by hydrogen sourced from renewables.

We propose that policymakers focus on the following to make hydrogen energy, especially that produced using renewable energy, more competitive: (i) enable economies of scale in hydrogen supply chains, especially those based on renewable energy; (ii) help bring down the high CAPEX of hydrogen supply chains and FCEVs; and (iii) promote new energy market mechanisms to duly value and price the additional benefits of hydrogen energy sourced from renewables, such as balancing the grid against intermittency of renewables and carbon emission reduction.

The cost competitiveness of hydrogen energy and its downstream applications in power and road transport are similar to those of solar PV, wind power, and BEVs 10–20 years ago. Therefore, we have good reason to believe that supportive policies can help hydrogen energy and its related applications accelerate learning effects, economies of scale, and maturing of infrastructure and supply chains, thus substantially cutting the costs of producing and using hydrogen energy.

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