Executive Summary

The year 2019–2020 is a remarkable year for hydrogen because three hydrogen demonstration projects were started in Australia, Brunei Darussalam, and Japan with the support of the Government of Japan. For the Brunei project, hydrogen is produced as a by-product of gas generated under the liquefaction process from natural gas to liquefied natural gas (LNG). After hydrogen is produced, it is transformed to methylcyclohexane (MCH) by chemical reaction with toluene and transported from Brunei Darussalam to the Kawasaki coastal area in Japan. The hydrogen is then brought to a natural gas power plant site to be mixed with natural gas to generate electricity at an experimental stage. Hydrogen production is expected to reach a maximum of 210 tonnes per year. Another hydrogen project in Australia produces hydrogen from unused brown coal applying a gasification technology and carbon capture utilisation and storage (CCUS). The hydrogen is subsequently changed to liquefied hydrogen (LH2) for transporting from Victoria State in Australia to Kobe city in Japan by an LH2 tanker, which is similar to an LNG tanker. In Kobe city, the hydrogen is used to generate power (100% hydrogen fuel) as demonstration. Last but not least, Japan's hydrogen project in the Fukushima Prefecture produces hydrogen from water electrolysis using electricity generated by the solar PV system. The capacity of the solar PV system is 22 MW and the expected hydrogen production is 206 tonnes per year, which is consumed for power generation, fuel cell electric vehicles (FCEVs), and heat use in the industry sector.

Major hydrogen demand comprises fuel for power generation, direct burning at combine cycle gas turbine (CCGT), and FCEVs. For power generation, CCGT technology to burn hydrogen mixed with natural gas is already available, but there is a concern about the hydrogen mixing ratio. If the mixing rate is high, we need a hydrogen burner to replace a natural gas burner. Technically, a 100% hydrogen burner is possible. It is already being tested and will be commercially available in the near future if the price of hydrogen becomes affordable. The FCEV's price is extremely high due to the smaller market size and expensive hydrogen price as fuel. It will surely follow a learning curve (initially the high price will decrease due to market penetration, such as solar PV panel and lithium-ion battery) but it is still long way from becoming commercial. Anyway, the hydrogen demand potential for power generation and FECV will depend on the supply cost of hydrogen. And there will be many issues and challenges to reduce the cost, which are technical innovations to improve hydrogen supply efficiency and policy support to increase the hydrogen demand market.

Hydrogen supply cost is essential to enable a shift to a hydrogen society. Hydrogen supply cost consists of two parts: (i) production costs and (ii) transport and storage costs. Transport includes short, middle, and long distance. Hydrogen is basically produced from fossil fuels (coal, oil, and gas) and water electrolysis. For fossil fuel, unused fossil fuels such as flared gas at oil and gas fields and low-ranked coals (lignite and brown coal) should be sources of hydrogen. If we apply the CCUS system to treat CO_2 coming from the hydrogen production process based on fossil fuels, the hydrogen is classified as blue hydrogen. For water electrolysis, electricity with zero CO_2 emissions, such as renewable energy and hydroelectricity, should be used to produce hydrogen. We can expect a decrease in the cost of hydrogen production due to technology development, but an increase in market scale is more important. For a long-distance transport of hydrogen, such as Brunei Darussalam to Japan and Australia to Japan, this phase 2 study focuses on MCH and LH2. For MCH, direct MCH synthesis will be available in the future, which will directly produce MCH from toluene using renewable electricity. This will surely contribute to the reduction of hydrogen supply costs. For LH2, we can expect a similar development path as LNG, where large-scale LH2 transportation by a dedicated LH2 tanker will surely contribute to reducing the hydrogen supply cost.

Under the phase 2 study, two hydrogen workshops were held in Bangkok, Thailand and Bandar Seri Begawan, Brunei Darussalam. The workshops aimed to (i) increase and provide an accurate and common understanding of hydrogen in East Asia, (ii) introduce the ERIA hydrogen potential study phase 1, and (iii) share hydrogen policies amongst East Asia Summit (EAS) countries. ERIA collaborated with the Petroleum Institute of Thailand (PTIT) to hold the workshop in Bangkok and to publish ERIA's hydrogen potential study through the *PTIT Focus,* PTIT's monthly newsletter. For the hydrogen workshop in Brunei Darussalam, ERIA joined the ASEAN hydrogen workshop hosted by Brunei's Ministry of Energy and the International Policy Studies, Universiti Brunei Darussalam. After the presentation of ERIA experts, technology and engineering experts of ASEAN participated in the workshop to discuss the possibility of hydrogen use in the ASEAN region.

Hydrogen will be an energy option in the future due to its abundant source base, multiple production paths, and environmental friendliness. In addition, no negative aspects of variable renewable energy (vRE), such as intermittency and lower capacity factor, can be absorbed when it is transformed into hydrogen. Therefore, EAS countries should start discussing hydrogen amongst themselves because of their diversity; some are rich hydrogen-producing countries and others demand hydrogen. Thus, ERIA organised the First EAS Hydrogen Working Group Meeting in December 2019 participated in by hydrogen experts from China, India, Indonesia, Malaysia, New Zealand, and Thailand. After ERIA's presentations on its hydrogen potential study phase 1 and two hydrogen demonstration projects in Japan, participants discussed future hydrogen use in terms of national policy on hydrogen, the perspectives on the hydrogen demand–supply situation as well as hydrogen supply chain in the EAS region. Unfortunately, due to COVID-19, the Second Working Group meeting was postponed to Fiscal Year 2020–2021.

Hydrogen will be an important energy source in the future and will surely contribute to the reduction of CO_2 emissions; however, its high supply cost will be a major issue. Because of the immature technology of hydrogen production, government support for both supply and demand sides, such as through technology development and policy implications such as feed-in tariff for hydrogen, will be crucial for the EAS region to enjoy the benefits of a hydrogen society based on its robust supply chain.