

Chapter 5

Economic Impact of Green Hydrogen Production

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Chapter 5

Economic Impact of Green Hydrogen Production

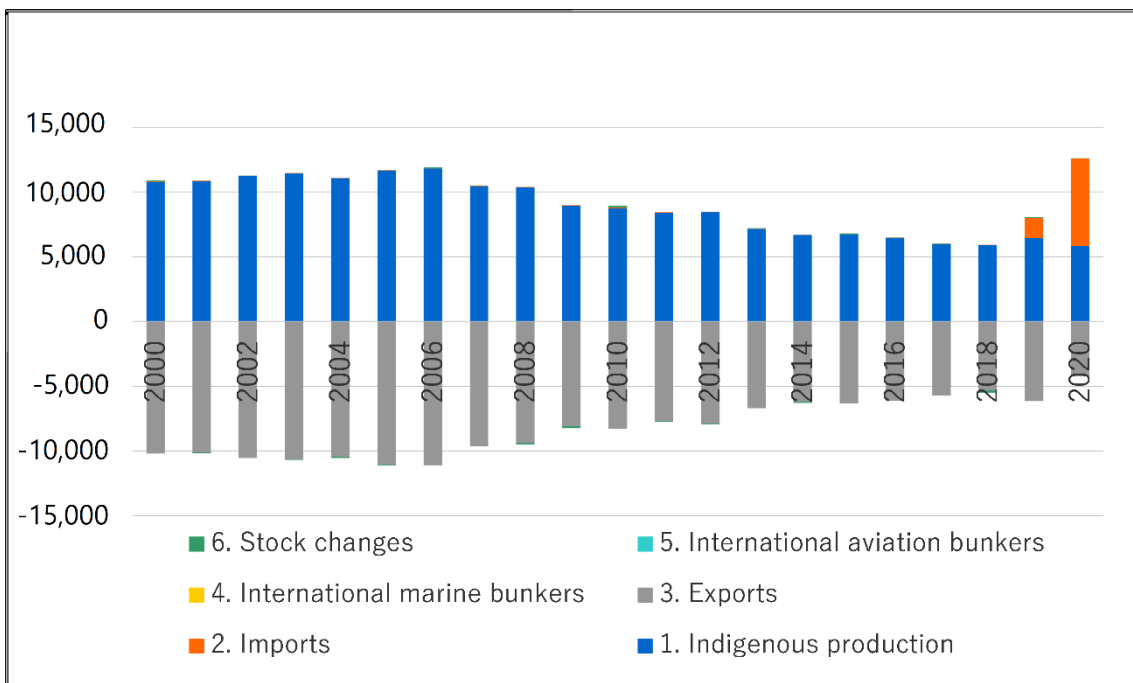
1. Historical Trend of Oil and Gas Production

Brunei Darussalam is a famous country in terms of oil and natural gas production, and exports of oil and gas are important for the country's national income. Thus, this section reviews the historical production of crude oil, petroleum products, and natural gas.

1.1. Crude Oil Production

Brunei kept its crude oil production at more than 10,000 kilotonnes of oil equivalent (ktoe) (approximately 10 petalitres) until 2006, but after that, its production declined until 2018 and was just above 5,000 ktoe in 2020. In this regard, crude oil exports have been also decreasing. However, since 2019, Brunei started to import crude oil for refinery process use, and its import amount was larger than its crude oil production in 2020 (Figure 5.1).

Figure 5.1. Supply and Demand of Crude Oil in Brunei Darussalam
(ktoe)

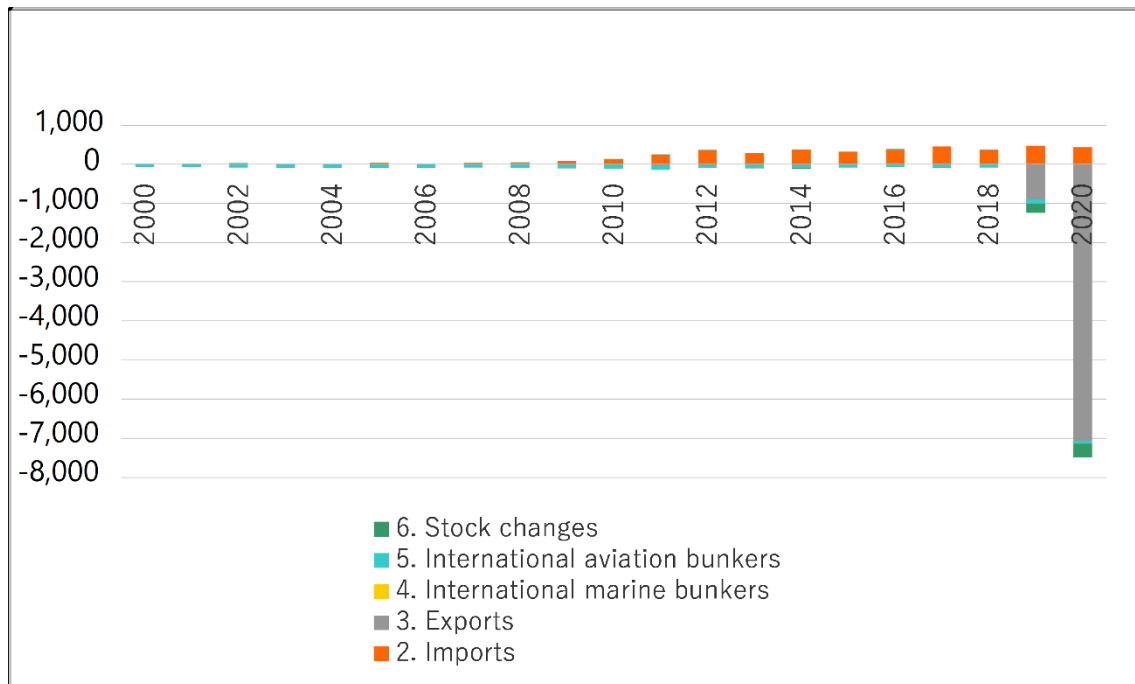


Source: APEC Energy Database operated by the Asia Pacific Energy Research Centre.

1.2. Petroleum Product Production

Brunei's petroleum production had been limited due to its small refinery capacity. Consequently, it imported petroleum products mainly from Singapore in response to increasing petroleum demand from 2009. However, it started its refinery operations in 2019, and thus also started to export petroleum products to neighbouring countries and other countries (see Figure 5.2).

Figure 5.2. Supply and Demand of Petroleum Products in Brunei Darussalam
(ktoe)

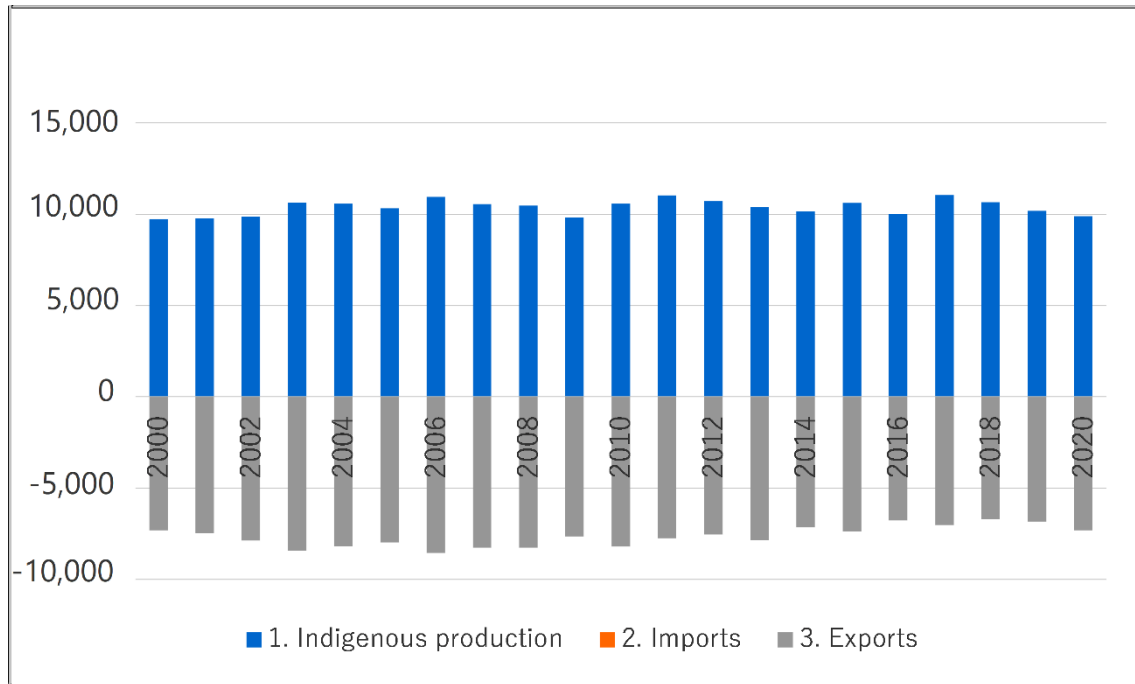


Source: APEC Energy Database operated by the Asia Pacific Energy Research Centre.

1.3. Natural Gas

Brunei has produced natural gas constantly at around 10,000 ktoe per year over the past 20 years, and its exports have also been around 7,000–8,000 ktoe per year. Natural gas has been a key player in terms of maintaining national income, however its production shows a downward trend in the last years (see Figure 5.3).

Figure 5.3. Supply and Demand of Natural Gas in Brunei Darussalam
(ktoe)

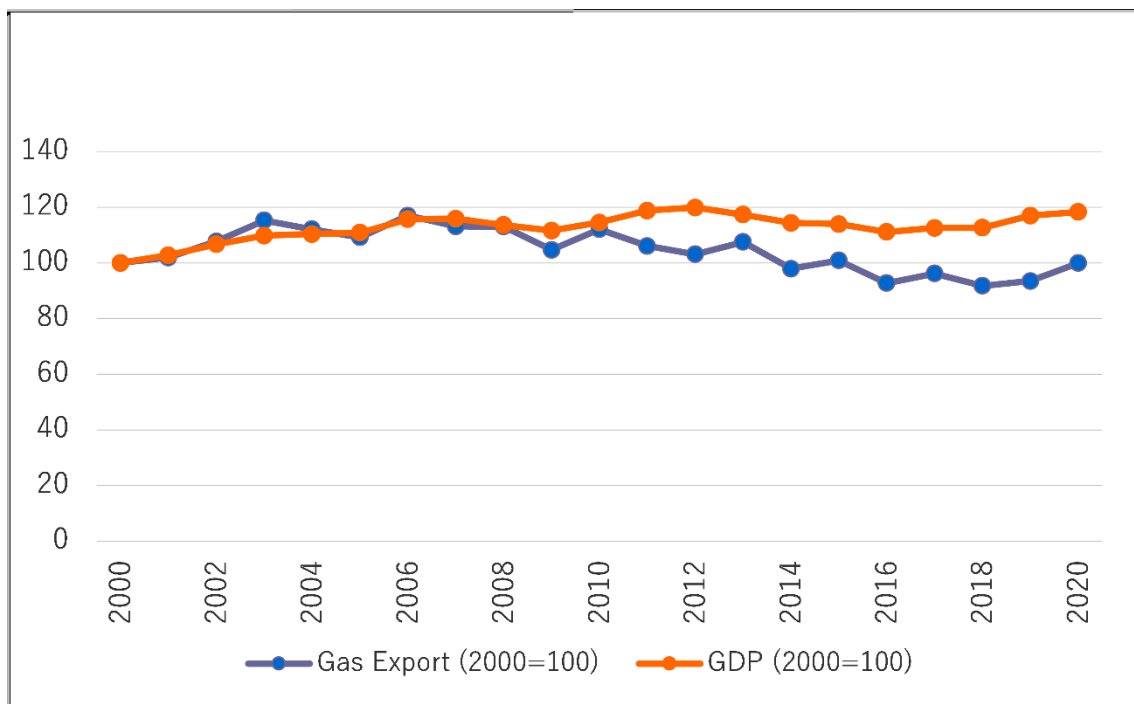


Source: APEC Energy Database operated by the Asia Pacific Energy Research Centre.

2. Relationship between Natural Gas Exports and Economic Growth

Figure 5.4 shows the relationship between natural gas exports (in ktoe) and gross domestic product (GDP) (in constant local currency units). Both natural gas exports and GDP increased from 2000, but natural gas exports showed a downward trend after 2010 and were lower than the 2000 level after 2015. On the other hand, GDP remained 20% higher than the 2000 level. One reason is that Brunei exports not only natural gas but also crude oil and methanol, and after 2019, Brunei started to export petroleum products. In addition, an increase in final demand, especially governmental expenditure and gross capital formation, such as investment in new refinery plants, also contributed to this gap (see Figure 5.4).

Figure 5.4. Relation between Natural Gas Exports and Economic Growth



Source: World Bank, World Development Indicators 2022; APEC Energy Database operated by the Asia Pacific Energy Research Centre.

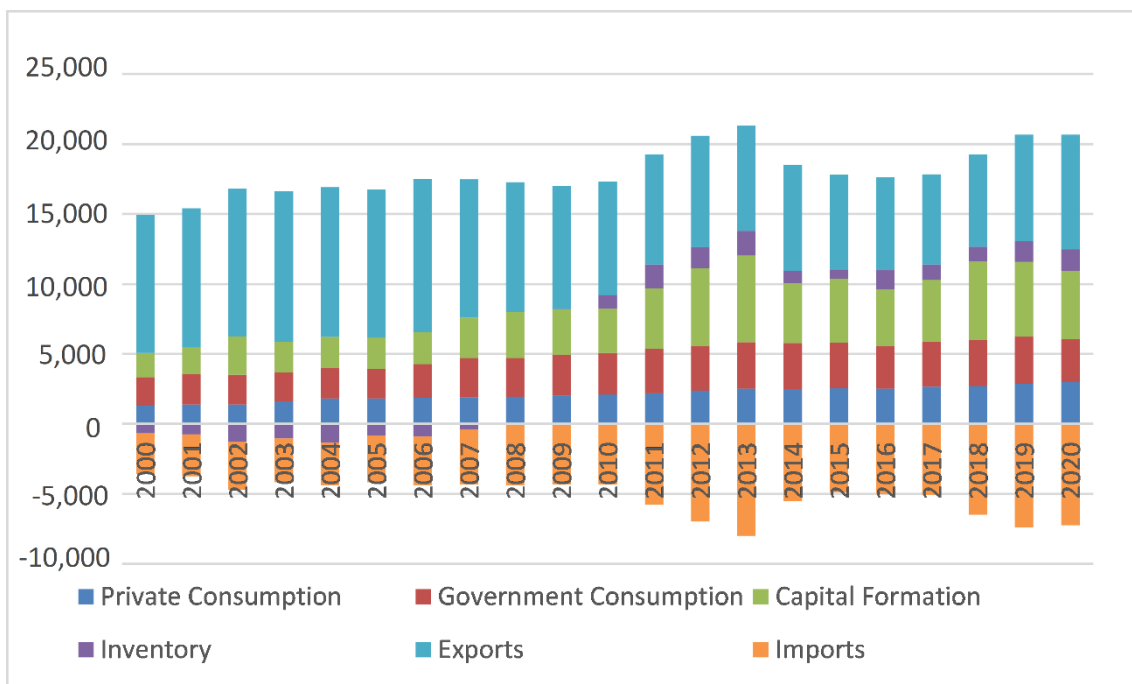
3. Change in GDP Components

GDP consists of the following economic components:

- Cp : Final private consumption (household expenditure)
- Cg : Final governmental consumption (national administration expenditure)
- I : Gross fixed capital formation (investment)
- J : Inventory (stock change)
- E : Exports (oil and gas mainly)
- M : Imports (food, consumer, and capital goods)

GDP is defined as $Cp + Cg + I + J + E - M$. Looking at Figure 5.5, exports have been a dominant component for Brunei, and oil and gas exports surely contributed directly to the country's GDP growth. However, their share has decreased recently, whilst capital formation has been increasing due to the construction of a new refinery as well as a methanol plant and a hydrogen demonstration plant, etc. The share of final consumption, which consists of private and government consumption, has been not significant compared to exports, but its share has been increasing year by year. In 2012 and 2013, imports rose along with capital formation. One reason was that the construction of the new refinery used imported machines and equipment from China.

Figure 5.5. GDP Components of Brunei Darussalam

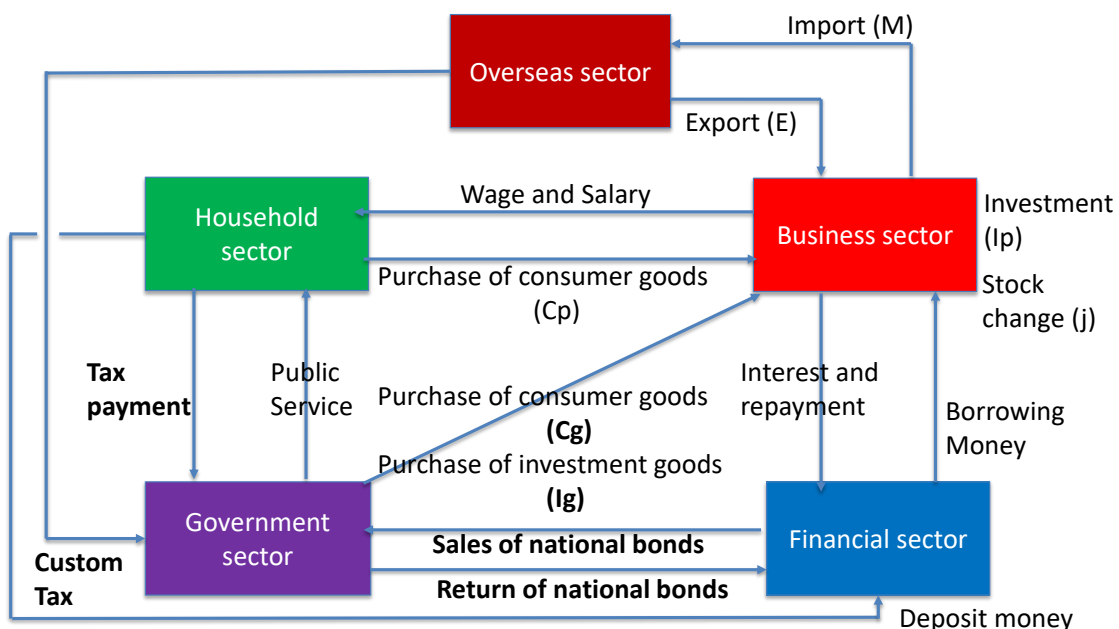


Source: World Bank, World Development Indicators 2022.

4. Economic Structure

This section provides details on the concept of the economic activities of a country. The business sector, in other words private companies, hires employees and constructs factories for producing consumer or capital goods. Meanwhile, the household sector purchases consumer goods from the domestic market using the wages and salary paid by the business sector, and this is called final private consumption. The business sector and household sector pay taxes to the government sector so that the government sector also purchases consumer goods from the domestic market. This is final government consumption. The business sector sells consumer goods to foreign countries, which are called exports. If the business sector imports consumer goods from foreign countries, these are called imports, and it sells the imported goods to the domestic market. Capital goods are treated the same as consumer goods. When the business sector purchases equipment and machinery, this is called private fixed capital formation or investment. If the household sector purchases standalone houses or condominiums, these are also classified as private fixed capital formation investment. When the government sector constructs office buildings and purchases equipment, this is called government capital formation or investment. Private + government investment is called gross fixed capital formation or investment. Inventory or stock changes mean that the business sector produces consumer goods, but if they are not sold in a period, they should be accounted for as stock change. The financial sector is a key player in supporting economic activities by the business, household, and government sectors that are not reflected directly in GDP. The financial sector engages stable money flows amongst the business, household, and government sectors (see Figure 5.6).

Figure 5.6. Simplified Economic Structure of a Country



Source: Authors.

5. Economic Contribution of Green Hydrogen Production

If Brunei will produce green hydrogen using renewable electricity, the following facilities are needed:

- a. A solar PV system, especially the floating type
- b. Water electrolysis

This section analyses the economic impacts of the installation of these two facilities.

5.1. Solar PV Systems

The estimated capacity of an installed solar PV system is 2,154 MW (see Chapter 2). If we assume the cost of a solar PV system cost is US\$800/kW, the estimated investment cost of a solar PV system is US\$1,723.2 million:

$$2,154 \text{ (MW)} \times 800 \text{ (US\$/kW)} = \text{US\$ } 1,723.21, \text{ million}$$

The gross fixed capital formation of Brunei in 2019 was B\$7 billion, so converting to US dollars:

$$7,000 \text{ (B\$ million)} / 1.36 \text{ (B\$/US\$)} = 5,147 \text{ (US\$ million)}$$

Solar PV system investment accounted for 33% of gross fixed capital formation in 2019 and was significant. But if Brunei will import all solar PV equipment from foreign countries, an economic repercussion effect cannot be expected.

In addition to an investment effect, the following economic benefits are expected:

- a. Some of the investment (such as 10% of US\$1,723.2, million) will go to local civil engineering companies.
- b. Some labour is expected to be hired at the operation stage of the solar PV system.

Based on the capital cost of the solar PV system, if we assume 20 years as its service life and 8% of capital costs as its operation cost, its generation cost is estimated using 17% of the capacity factor as follows:

$$(1,723.2, / 20 + 1,723.2*0.08) / (2,154*24*365*0.19) = \text{US\$}0.0624/ \text{ kWh}$$

5.2. Electrolysers

Usually, the unit capital cost of an electrolyser facility is defined as US\$/kWe, and it is estimated at US\$1,100–US\$1,800 per kWe in the case of a Polymer Electrolyte Membrane (PEM) electrolyser according to open sources. However, this time, if we assume a cost of US\$1,050, expecting innovative technology development in the future, the capital cost of the electrolyser facility is estimated as follows:

$$\begin{aligned} \text{Electricity coming from the solar PV system: } & 2,154 \text{ (MW)} \times 19\% \text{ (capacity factor)} = 409.26 \\ \text{Capital cost of the electrolyser: } & 409.26 \text{ (MW)} \times 1,050 \text{ (US\$/kWe)} = \text{US\$}429.7 \text{ million} \end{aligned}$$

Then, the hydrogen production cost is estimated as follows:

$$\text{Depreciation: } (1,723.2 + 429.7) / 20 = 107.64 \text{ (US\$ million)}$$

$$\text{Operation cost: } (1,723.2 + 429.7) \times 8\% = 172.2 \text{ (US\$ mill)}$$

$$\text{Hydrogen production cost: } (107.6 + 172.2) / 65.7 \text{ (kilotonnes)} = \text{US\$}4.2584 \text{ per kg-H}_2$$

The capital cost of the electrolyser is estimated at US\$429.7million, and it is just 25% of the solar PV system. But it is still significant in Brunei's annual gross fixed capital formation and should provide an effective economic repercussion effect for Brunei if the country produces the electrolyser equipment by itself. In addition, as for the solar PV system, Brunei expects profits for local civil engineering companies and an increase in employees to work at the electrolyser plant.

6. Possibility of Energy Exports

Brunei is famous for oil and gas production and exports, but will it export oil and gas continuously? In the energy transition period, from now to 2030–2035, the world will shift from coal power plants to gas power plants and use both internal combustion engine vehicles and EVs, and Brunei will be able to export oil and gas continuously. After 2040, the world will become carbon neutral by 2050 or 2060, so Brunei will not be able to export oil and gas due to a lack of demand. But Brunei will be a potential country for exporting clean energy in the form of green or blue hydrogen or ammonia. Green hydrogen will be produced by electricity from solar PV systems, and blue hydrogen will be produced from natural gas and oil with carbon capture and storage (CCS). Then, clean ammonia will be produced from green and blue hydrogen. This point is very important if Brunei will be an energy exporting country continuously until 2050 or 2060.

7. Competitiveness of Green Hydrogen Production

Not only Brunei but also other countries and regions will produce and export hydrogen to the world. Brunei's competitors are Sarawak province (Malaysia), Indonesia, Australia, India, and Middle Eastern countries. A simple comparison of the hydrogen production costs between Brunei and Middle Eastern countries is shown below:

a. Brunei's hydrogen production cost using a solar PV system:

- Capital cost of solar PV (10 MW): $800 \text{ (US\$/KW)} \times 10 \times 1000 \text{ (KW)} = \text{US\$8 million}$
- Depreciation period: 20 years
- Capacity factor: if 19%, 16,644 MWh
- Generation cost: US\$0.02403/kWh

b. Middle Eastern countries:

- Capital cost of solar PV (10 MW): $800 \text{ (US\$/KW)} \times 10 \times 1000 \text{ (KW)} = \text{US\$8 million}$
- Depreciation period: 20 years
- Capacity factor: if 25%, 21,900 MWh
- Generation cost: US\$0.01826/kWh; 24% lower than Brunei

The difference between Brunei and Middle Eastern countries is just the capacity factors, which are 19% in Brunei and 25% in the Middle East, due to different climate conditions. But in the case of the Middle East, countries need to transport hydrogen to the ASEAN region as for oil and gas. Thus, Brunei could have an advantage over green hydrogen produced in the Middle East if the hydrogen transport cost from the Middle East to Asia is expensive.

If the cost of green hydrogen produced in Brunei Darussalam is higher than in other countries, such as Middle Eastern countries and Australia, Brunei's green hydrogen will not be accepted due to economic reasons. Thus, blue hydrogen is still an option for Brunei.

8. Business Investment for the Clean Hydrogen Industry

As a result, Brunei will continue to produce clean energy in the form of blue and green hydrogen and export it to foreign countries, like oil and gas. Brunei will need to invest in blue and green hydrogen production facilities to replace oil and liquefied natural gas production facilities. Thus, Brunei will not change its business model because it will just change the type of energy from fossil fuels to clean hydrogen. In the case of blue hydrogen, CO₂ emitted from the process of producing hydrogen from natural gas should be treated by applying CCS technology because Brunei has a large potential capacity for CO₂ storage or carbon recycling (CR) technology, which produces synthetic fuels (known as e-fuel) based on the captured CO₂ and produced clean hydrogen. Brunei can consume synthetic fuels like gasoline and diesel oil internally or export them to foreign countries. Consequently, Brunei will need to invite international enterprises to start clean energy business in the country. Brunei already has experience and expertise in inviting international companies, such as Shell and Mitsubishi Corporation, so the government is focusing on setting up environmental and safety regulations for hydrogen and CCS/CR referring to the existing oil and gas regulations. In addition, the government is taking leadership in initiating the standardisation of hydrogen and CO₂ trade in the Asia-Pacific and ASEAN regions.