Chapter 4
Potential Hydrogen Demand in Brunei Darussalam

This chapter provides a discussion on the potential hydrogen demand in Brunei in three sectors, i.e., power generation, road transport, and industrial sectors during the 2020–2050 period. The discussion is based on other studies that ERIA has conducted:

- Kimura and Han (2021): an ERIA energy outlook for the East Asian Summit countries covering the 2020–2050 period that includes Brunei;
- Kimura et al. (2021): an ERIA study on Brunei focusing on the development of Temburong District as an ecotown; and
- Purwanto et al. (2023, forthcoming): a deep analysis of hydrogen demand in the ASEAN Member States' industry sectors and the possible future situations based on four climate ambition-related scenarios.

In each of the sectors, not only the hydrogen demand potential of Brunei is presented but also the total hydrogen demand potential of all ASEAN Member States (AMS).
Closing the chapter, a discussion on the aggregated total hydrogen demand potential in Brunei and the total of all AMS will be provided.

1. Potential Demand in Power Generation

In its Business-as-Usual (BAU) scenario, Kimura and Han (2021) estimate that power generation in Brunei will increase from around 2.54 terawatt-hours (TWh) in 2020 to around 4.90 TWh in 2050. In another scenario, i.e., the Alternative Policy Scenario (APS), the power generation in Brunei will reach around 4.70 TWh in 2050.

In Kimura and Han (2021), the BAU was developed for each East Asia Summit (EAS) country, including Brunei, outlining future sector and economy-wide energy consumption, assuming no significant changes to government policies. The APS, on the other hand, was set to examine the potential impacts if additional energy-efficiency goals, action plans, or policies being considered or likely to be considered were developed. The difference between the BAU and APS in final and primary energy supply represents potential energy saving, whilst the difference in the two scenarios' CO_2 emissions represents the potential to reduce them.

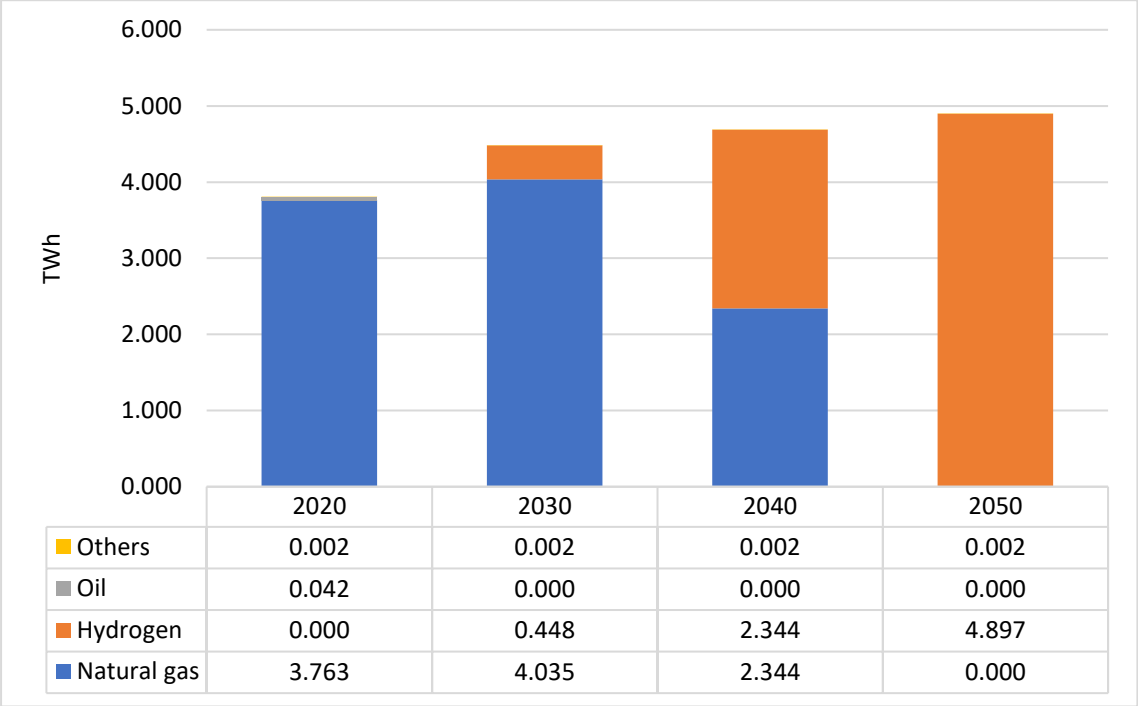
By 2020, electricity in Brunei Darussalam was 99% generated by natural gas-fired plants, with the remaining 1% by diesel-fired power plants. In the rest of the period of the BAU Scenario, i.e., 2030–2050, power in the country is entirely generated by natural gas-fired plants. In the APS, the share of natural gas during the same period is around 94% by 2030 and around 91% by 2040 and 2050, giving room for power generation by renewable energy resources, mainly solar PV.

To estimate the potential of hydrogen demand in the power sector, it is assumed that cofiring of natural gas and hydrogen will take place following an increasing share of hydrogen in natural gas-fired power plants, i.e., 0% by 2020, 10% by 2030, 50% by 2040, and 100% by 2050.

With this assumption, as shown consecutively in Figure 4.1 and Figure 4.2, by 2050, hydrogen needs in cofiring power plants in Brunei would reach around 4.9 TWh in the BAU Scenario and 4.6 TWh in the APS.

In terms of volume, if hydrogen cofiring at the gas-fired power plants has 60% efficiency, then Brunei will need around 20 kilotonnes per annum (ktpa) by 2030 in both scenarios. By 2050, the needed hydrogen will be around 230 ktpa in the BAU Scenario and around 200 ktpa per year in the APS.

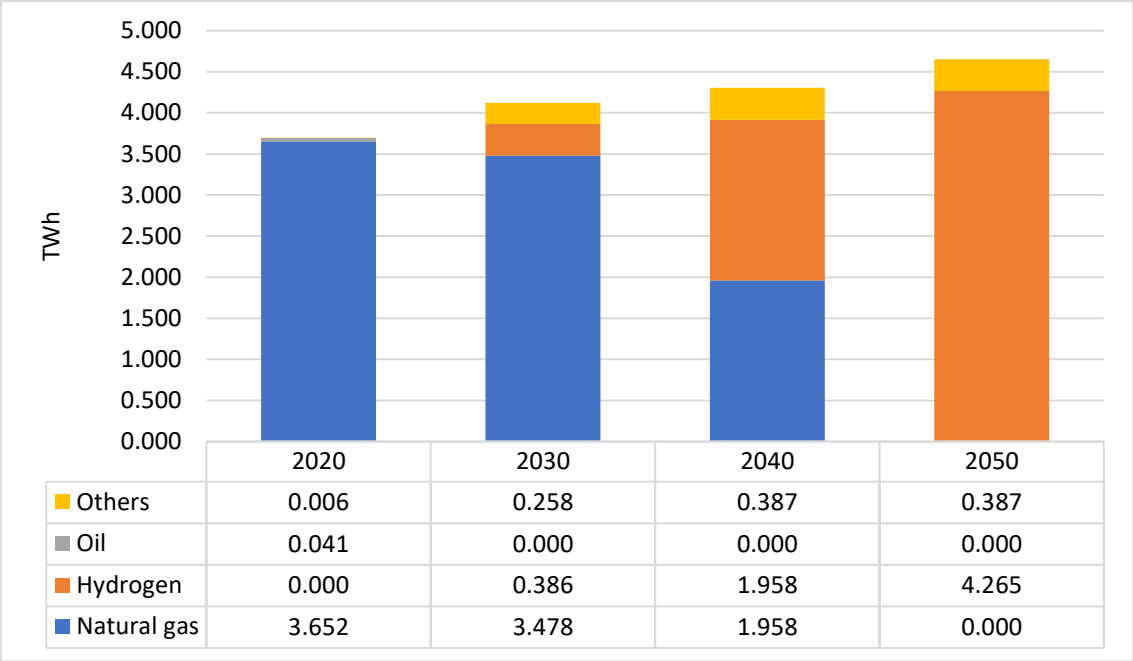
Figure 4.1. Brunei Darussalam's Estimated Power Generation Output with Hydrogen Cofiring – BAU Scenario



	2020	2030	2040	2050
Others	0.002	0.002	0.002	0.002
Oil	0.042	0.000	0.000	0.000
Hydrogen	0.000	0.448	2.344	4.897
Natural gas	3.763	4.035	2.344	0.000

BAU = Business-as-Usual Scenario of Kimura and Han (2021).
Note: Cofiring assumption of hydrogen in natural gas-fired power plants: 10% (2030), 50% (2040), and 100% (2050).
Source: Authors.

Figure 4.2. Brunei Darussalam's Estimated Power Generation Output with Hydrogen Cofiring – APS



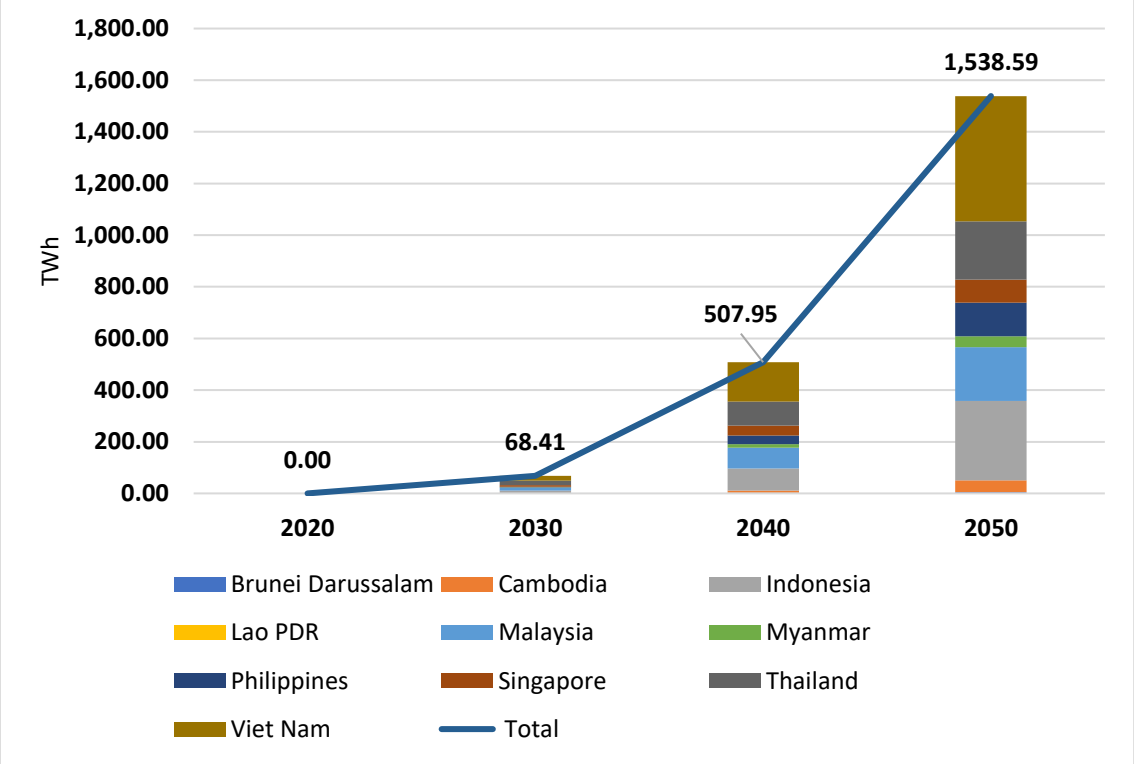
	2020	2030	2040	2050
Others	0.006	0.258	0.387	0.387
Oil	0.041	0.000	0.000	0.000
Hydrogen	0.000	0.386	1.958	4.265
Natural gas	3.652	3.478	1.958	0.000

APS = Alternative Policy Scenario of Kimura and Han (2021).
Note: Cofiring assumption of hydrogen in natural gas-fired power plants: 10% (2030), 50% (2040), and 100% (2050).
Source: Authors.

At the ASEAN level, Kimura and Han (2021) estimate that the total electricity of the 10 AMS generated in natural gas-fired power plants will grow from around 425 TWh in 2020 to 1,540 TWh in 2050 in the BAU Scenario and from around 400 TWh in 2020 to 1,270 TWh in 2050 in the APS.

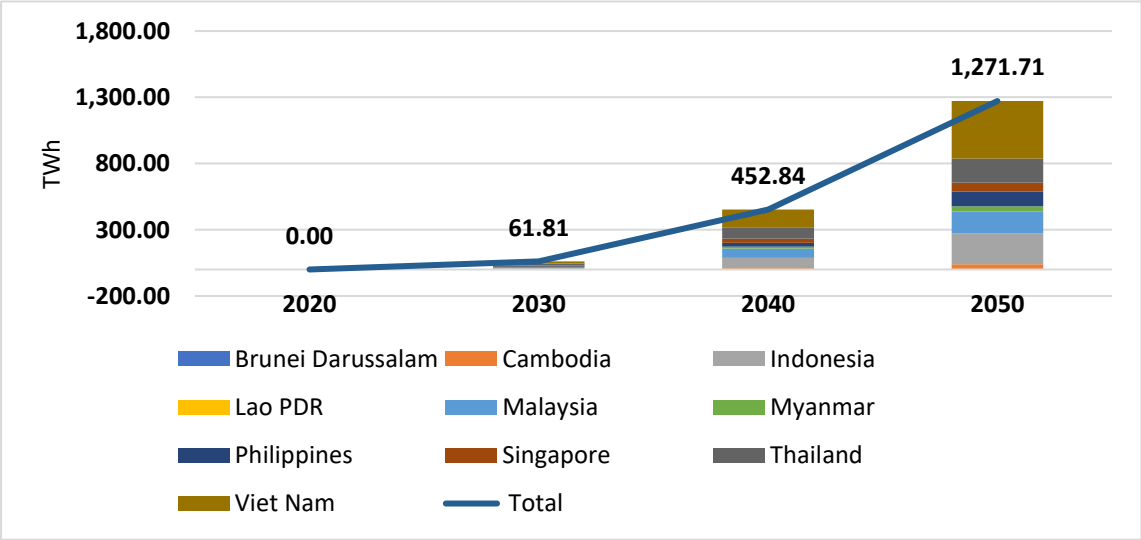
Assuming also increasing rates of hydrogen cofiring in those gas-fired power plants in all AMS of 10% in 2030, 50% in 2040, and 100% in 2050, and an efficiency rate of 60% in hydrogen burning, the total power generation by cofiring at the ASEAN level in the BAU Scenario will grow from around 68 TWh in 2030 to around 1,540 TWh in 2050 (Figure 4.3) and in the APS from around 62 TWh in 2030 to around 1,272 TWh in 2050 (Figure 4.4).

Figure 4.3. ASEAN's Estimated Power Generation Output with Hydrogen Cofiring – BAU Scenario



BAU = Business-as-Usual Scenario of Kimura and Han (2021).
Note: Cofiring assumption of hydrogen in natural gas-fired power plants: 10% (2030), 50% (2040), and 100% (2050).
Source: Authors.

Figure 4.4. ASEAN's Estimated Power Generation Output with Hydrogen Cofiring – APS Scenario



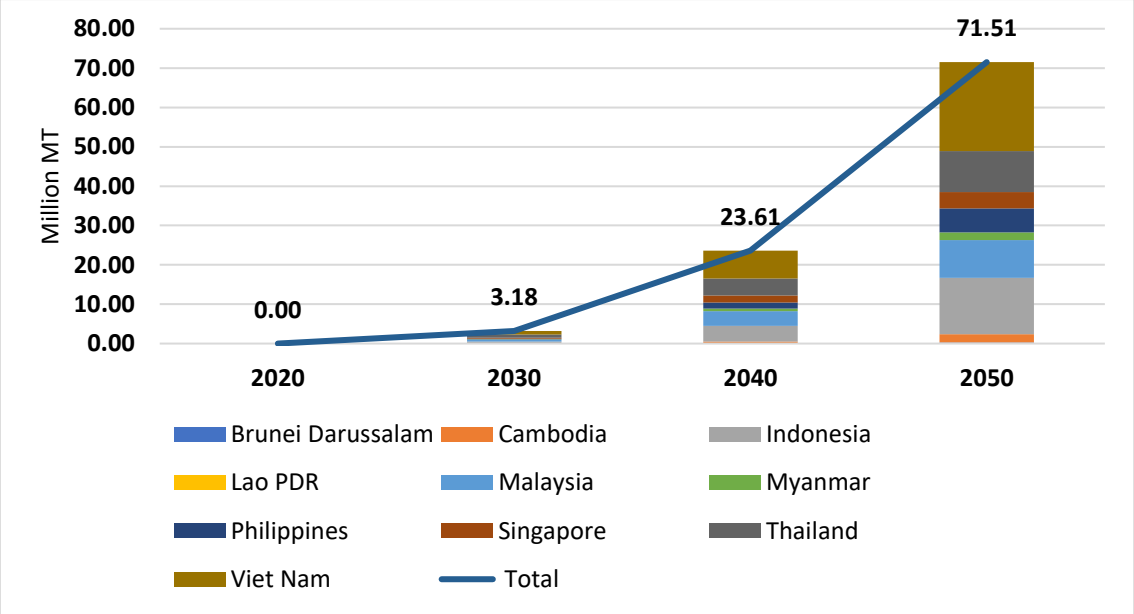
APS = Alternative Policy Scenario of Kimura and Han (2021).
Note: Cofiring assumption of hydrogen in natural gas-fired power plants: 10% (2030), 50% (2040), and 100% (2050).
Source: Authors.

In terms of volume, the demand for hydrogen in the AMS in the BAU Scenario will grow from 3.2 million tonnes per annum (mtpa) in 2030 to 71.5 mtpa in 2050 (Figure 4.5), whilst in the APS Scenario it will grow from 2.8 mtpa in 2030 to 59 mtpa in 2050 (Figure 4.6).

Brunei Darussalam's share of total potential hydrogen demand in ASEAN is very small. In the BAU Scenario, it decreases from around 0.7% in 2030 to only around 0.3% in 2050, whilst in the APS, it drops from 0.6% in 2030 to 0.3% in 2050.

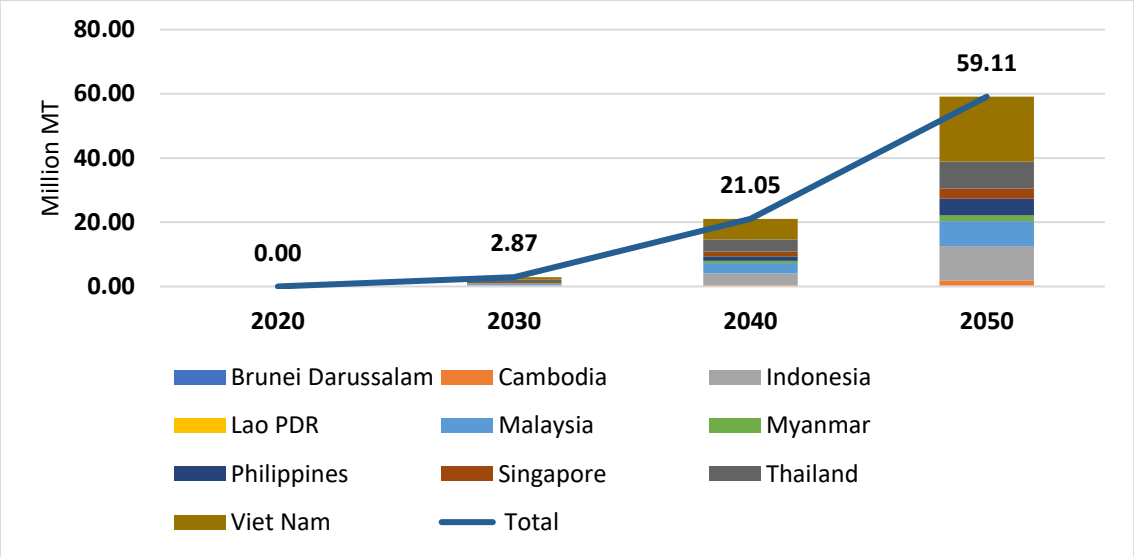
This decrease is not surprising, as Kimura and Han (2021) estimate that Brunei's generated electricity by gas-fired power plants will only grow with a compound average growth rate of slightly less than 0.5% during the 2030–2050 period, whilst that of ASEAN will be around 4% in the BAU Scenario and around 3.7% in the APS.

Figure 4.5. ASEAN's Estimated Hydrogen Demand for Cofiring in Power Generation – BAU Scenario



BAU = Business-as-Usual Scenario of Kimura and Han (2021).
Note: Cofiring assumption of hydrogen in natural gas-fired power plants: 10% (2030), 50% (2040), and 100% (2050).
Source: Authors.

Figure 4.6. ASEAN's Estimated Hydrogen Demand for Cofiring in Power Generation – APS Scenario



APS = Alternative Policy Scenario of Kimura and Han (2021).
Note: Cofiring assumption of hydrogen in natural gas-fired power plants: 10% (2030), 50% (2040), and 100% (2050).
Source: Authors.

2. Potential Demand in Road Transport

Kimura et al. (2020) study the impacts of hydrogen-powered fuel cell (FC) electric vehicles on Brunei's national energy systems and carbon dioxide emissions. For that purpose, they develop a BAU Scenario of road transport, i.e., the passenger car transport sector in Brunei to the 2050 horizon. This BAU Scenario is used as a benchmark scenario to assess the impacts of the penetration of new technologies in the passenger car fleet. In the scenario, the country's passenger car fleet develops to the horizon of 2050 without any penetration of battery electric or FC hydrogen cars. This scenario means that up to 2050, there will be only two kinds of passenger cars based on fuel type: gasoline-fuelled and diesel-fuelled passenger cars.

Three FC scenarios were elaborated to represent certain penetration levels of hydrogen-powered FC cars in the country's road passenger car fleet in 2017–2050. The level of penetration is represented by the exogenously defined percentages of shares of FCs in the total number of road passenger cars in Brunei in 2050. In all scenarios, we assumed that there is no FC in 2017, i.e., the base year.

The three main FC scenarios in Brunei are:

- FC10 – a scenario where FC hydrogen cars would comprise a 10% share of the total road passenger car fleet in 2050;
- FC20 – a scenario where FC hydrogen cars would comprise a 20% share of the total road passenger car fleet in 2050; and
- FC30 – a scenario where FC hydrogen cars would comprise a 30% share of the total road passenger car fleet in 2050.

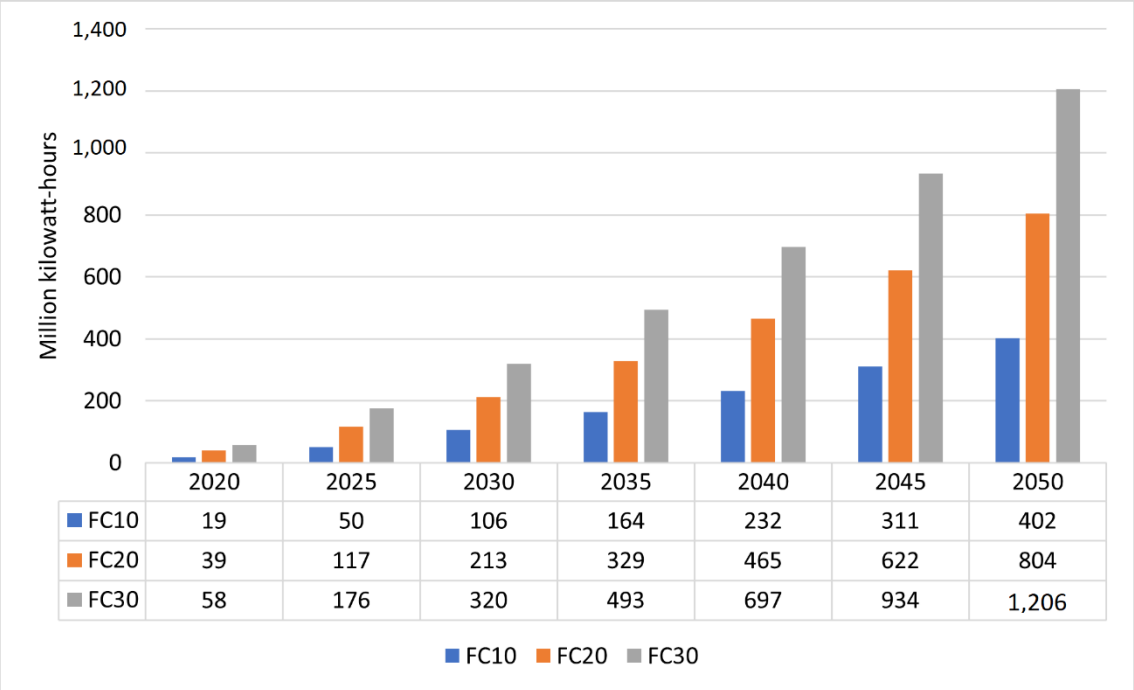
Based on historical data on passenger car ownership in Brunei Darussalam and the projected economic and socio-demographic conditions, Kimura et al. (2021) estimate the number of passenger cars in use in Brunei. The number of cars that are in use or active would grow from 270,000 units by 2017 to 370,000 by 2030, 455,000 by 2040, and 550,000 by 2050 with the ratio of gasoline-fuelled cars to diesel-fuelled cars being 70:30 during the whole period.

It is assumed that the FC efficiency of FCEVs is at 1.1 MJ/km or 3.27 km/kWh, i.e., in line with the specification of the compact hydrogen-powered fuel cell Toyota Mirai passenger car model FCA110 of the year 2015. The fuel economy of conventional passenger cars is assumed at 12.7 km/litre, whilst the average travel distance per passenger car is 24,000 km/year.

Using this assumption, in the BAU Scenario, between 2017 and 2050, energy demand from passenger car transport in Brunei would increase by around 12% per year from about 17 million gigajoules (GJ) in 2017 to approximately 36 million GJ in 2050, an increase of around 11% annually. The gasoline–diesel consumption ratio would be around 2:1, and full battery electric vehicles are assumed to enter the road passenger car fleet during the whole simulation period.

Figure 4.7 shows the hydrogen that needs to be produced in terms of energy in the country to meet the hydrogen demand in the FC scenarios. By 2050, the FC10 scenario would need about 400 GWh of hydrogen; FC20, about 800 GWh; and FC30, about 1,200 GWh of hydrogen.

Figure 4.7. Brunei Darussalam's Demand for Hydrogen in Terms of Energy in Three Hydrogen-powered Fuel Cell Vehicle Scenarios



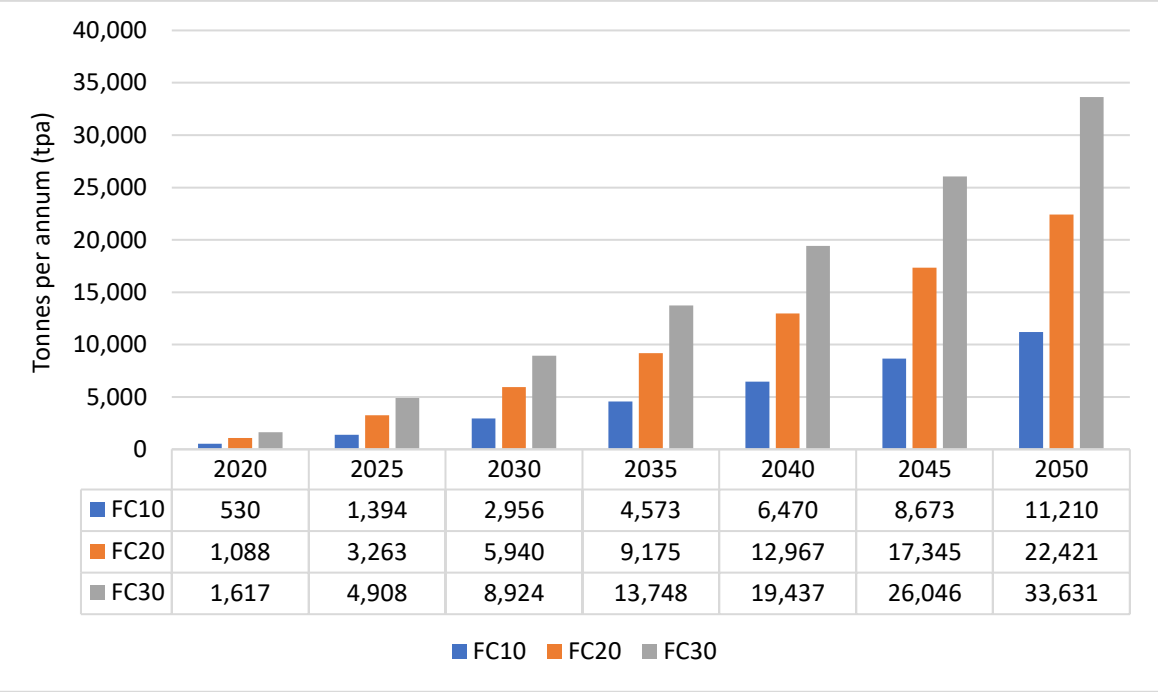
	2020	2025	2030	2035	2040	2045	2050
FC10	19	50	106	164	232	311	402
FC20	39	117	213	329	465	622	804
FC30	58	176	320	493	697	934	1,206

Note: FC10, FC20, and FC30 respectively represent scenarios of 10%, 20%, and 30% shares of fuel cell electric vehicles in the total road passenger car fleet by 2050, based on Kimura et al. (2021).
Source: Kimura et al. (2021).

The efficiencies of electrolysers to produce hydrogen are assumed at 67% between 2017 and 2020, and at 85% by 2030 and beyond, whilst between 2020 and 2030, the efficiency percentages are assumed to grow linearly from 67% to 85%.

In terms of volume, in the FC10 Scenario, Brunei's demand for hydrogen will grow from 530 tonnes per annum (tpa) in 2020 to 11,210 tpa in 2050. On the other hand, in the FC30 scenario, hydrogen demand will increase from 1,620 tpa in 2020 to 33,630 tpa in 2050. The FC20 scenario is between the other two scenarios, i.e., from 1,088 tpa in 2020 to 22,421 tpa in 2050.

Figure 4.8. Brunei Darussalam's Estimated Hydrogen Demand from the Road Transport Sector



	2020	2025	2030	2035	2040	2045	2050
FC10	530	1,394	2,956	4,573	6,470	8,673	11,210
FC20	1,088	3,263	5,940	9,175	12,967	17,345	22,421
FC30	1,617	4,908	8,924	13,748	19,437	26,046	33,631

Note: FC10, FC20, and FC30 respectively represent scenarios of 10%, 20%, and 30% shares of fuel cell electric vehicles in the total road passenger car fleet by 2050, based on Kimura et al. (2021).
Source: Kimura et al. (2021).

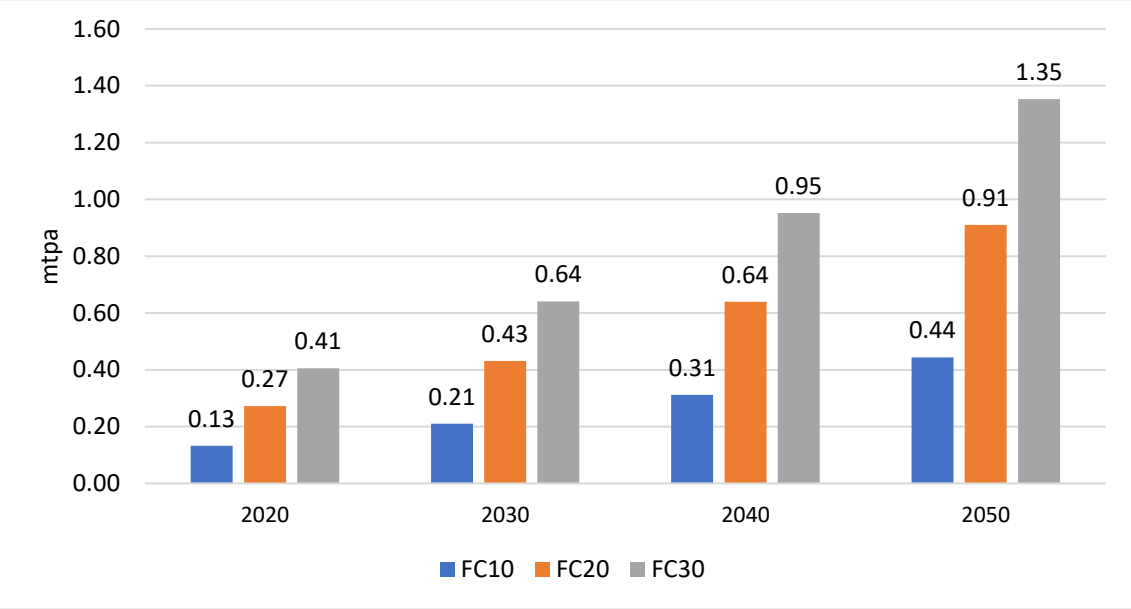
It is assumed that the effects of the F10, F20, and F30 scenarios on energy demand in the road transport sector in all ASEAN countries will be the same as in Brunei, i.e., the shares of energy in road transport that are shifted to hydrogen power FCEVs in the three scenarios in Brunei will be the same as in other ASEAN countries. Using this assumption, it is possible to estimate the needed hydrogen at the ASEAN level in each of the three hydrogen scenarios and in each of the Kimura and Han (2021) scenarios, namely the BAU and APS scenarios.

By 2030, hydrogen demand for road transport in ASEAN might reach 0.21 mtpa, 0.43 mtpa, and 0.64 mtpa in the BAU scenario in the FC10, FC20, and FC30 FCEV scenarios, respectively, and 0.18 mtpa, 0.37 mtpa, and 0.56 mtpa in the APS in the FC10, FC20, and F30 FCEV scenarios, respectively.

By 2050, hydrogen demand for road transport in ASEAN might reach 0.44 mtpa, 0.91 mtpa, and 1.35 mtpa in the BAU scenario in the FC10, FC20, and FC30 FCEV scenarios, respectively, and 0.34 mtpa, 0.70 mtpa, and 1.05 mtpa in the APS in the FC10, FC20, and F30 FCEV scenarios, respectively.

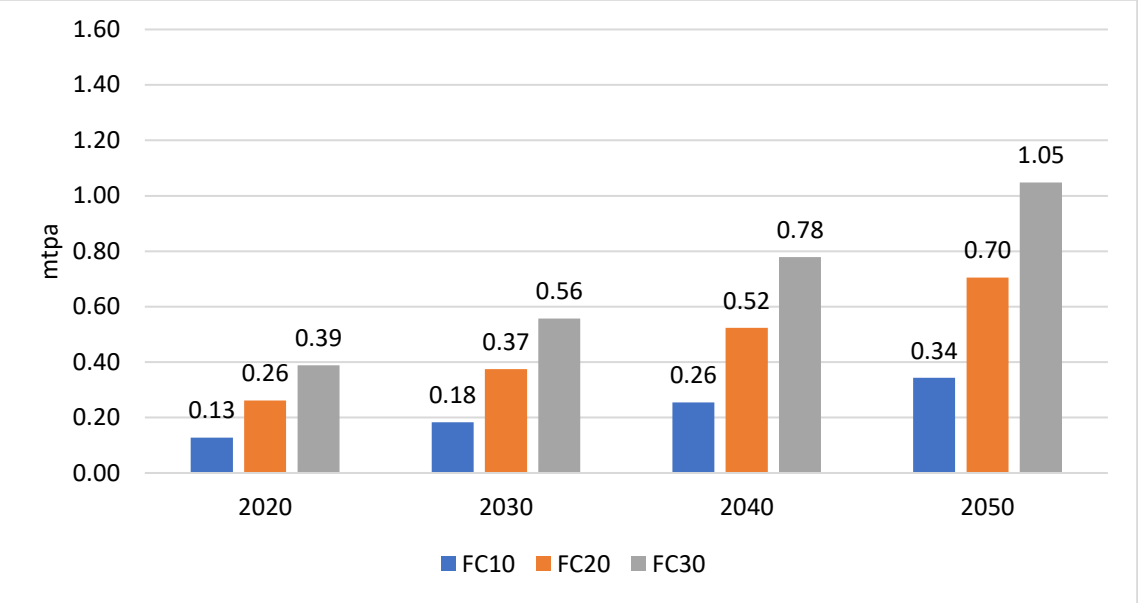
Figure 4.9 and Figure 4.10 show the estimated demand for hydrogen from road transport in both the BAU and APS scenarios differentiated by the FCEV penetration scenarios, i.e., FC10, FC20, and FC30.

Figure 4.9. ASEAN's Estimated Hydrogen Demand from the Road Transport Sector – BAU Scenario



Note: FC10, FC20, and FC30 respectively represent scenarios of 10%, 20%, and 30% shares of fuel cell electric vehicles in the total road passenger car fleet by 2050, based on Kimura et al. (2021).
Source: Kimura et al. (2021).

Figure 4.10. ASEAN's Estimated Hydrogen Demand from the Road Transport Sector – APS



Note: FC10, FC20, and FC30 respectively represent scenarios of 10%, 20%, and 30% shares of fuel cell electric vehicles in the total road passenger car fleet by 2050, based on Kimura et al. (2021).
Source: Kimura et al. (2021).

3. Potential Demand in the Industry Sector

Purwanto et al. (2023, forthcoming) aim to provide a set of policy recommendations for policymakers in AMS to accelerate the process of obtaining a hydrogen supply with lower carbon intensity in the industrial sector, as part of an optimal hydrogen market development strategy for the ASEAN region. The study departs from the fact that current hydrogen use in ASEAN countries is entirely absorbed in industry sectors, and that this hydrogen is almost entirely produced via conventional steam methane reforming with high carbon intensity.

According to Purwanto et al. (2023, forthcoming), hydrogen demand in Brunei's industry sector grew from around 39,150 tpa in 2015 to around 41,960 tpa in 2020, with slightly more than 92% of this demand coming from the oil refining sector and the rest coming from the chemical industry sector. In fact, this hydrogen use in oil refining and the chemical industry is practically the only current use of hydrogen in Brunei. In other words, apart from use in the industry sectors, hydrogen is not used elsewhere. This is not only the case in Brunei but also in other ASEAN countries and most countries in the world.

Still, according to the study, at the ASEAN level, the hydrogen demand of the region grew from around 3.270 mtpa in 2015 to around 3.680 mtpa in 2021. Hydrogen demand in Brunei's industry sector comprises only around 1% of the ASEAN total.

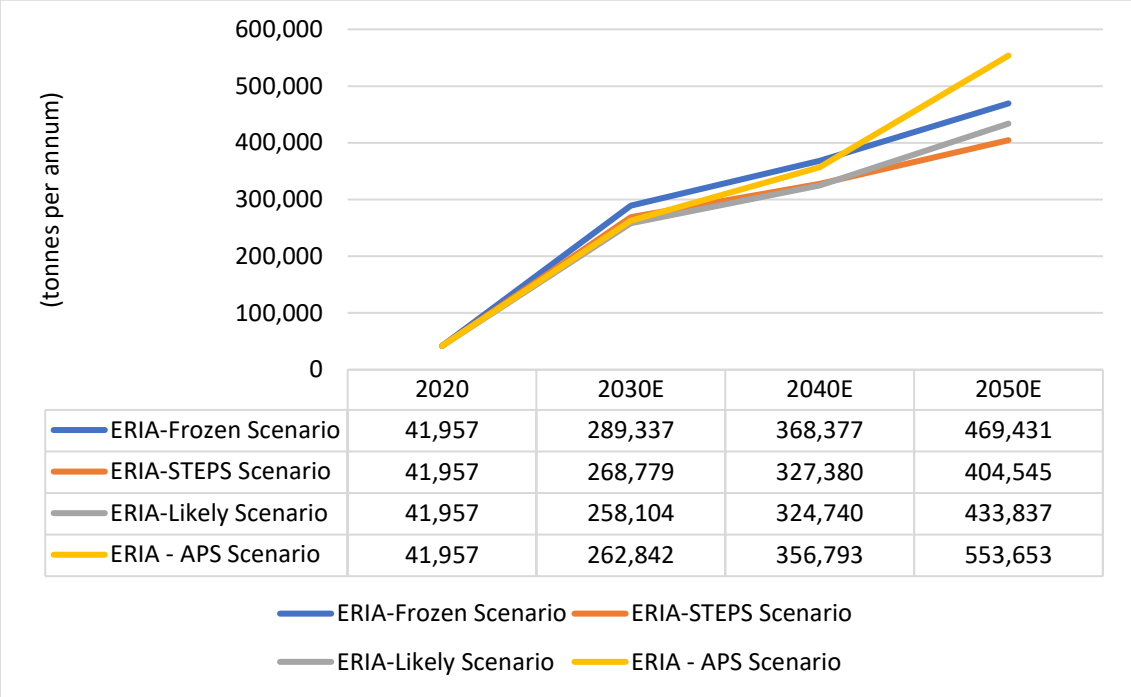
The study considers four future scenarios for the development of hydrogen demand and supply in the industry sectors.

- The ERIA-Frozen scenario relates to a future situation where the trend as shown in the demand and supply of hydrogen in the 2015–2021 period continues as it is. It assumes that ASEAN countries only maintain a business-as-usual approach without any national CO_2 or renewable energy or energy efficiency (RE/EE) targets to meet. Here, hydrogen demand and supply in the future grow at the same average rate as during the 2015–2020 period, and supply, including announced capacity expansion, will be able to meet demand using the same supply structure as during the 2015–2020 period.
- The ERIA-STEPS scenario is inspired by the Stated Policies Scenario (STEPS) described by the International Energy Agency (IEA) (2022a; 2022b). Basically, it retains the current and the latest AMS policies, including those related to the intended nationally determined contribution (INDC). The scenario has no particular outcome to achieve, meaning that there is no additional policy implementation apart from the implementation based on the INDC, e.g. shifting to a certain percentage of renewable use in power generation at a certain point in time, or increasing energy efficiency in several final sectors, etc. The scenario explores where the energy system might go without additional policy implementation and takes a granular, sector-by-sector look at existing policies and measures and those under development without any guarantee that the intended CO_2 emissions reduction will be achieved.
- The ERIA-APS scenario is based on the Announced Pledges Scenario of the IEA (2022b) that assumes that all aspirational targets announced by governments are met on time and in full, including their long-term net zero and energy access goals. Government targets in the scenario are assumed to be achieved on time and in full. The scenario includes all the climate commitments made by governments around the world, including INDCs and longer-term NDC targets, and assumes that they will be met in full and on time to fill the 'implementation gap' that needs to be closed by countries in the STEPS scenario to achieve their announced decarbonisation targets. The scenario includes net zero pledges as announced by countries, in this case, ASEAN countries' pledges.
- The ERIA-Likely Scenario represents the most likely future situation in the supply and demand of hydrogen in the four industrial sectors in ASEAN from the present time to the 2050 horizon. It is inspired by the forecast of hydrogen demand by DNV (2022). In this scenario, hydrogen produced globally to be used as feedstock would grow from around 90 mtpa in 2020 to reach 195 mtpa in 2050, whilst demand for hydrogen and its derivatives in Southeast Asia would reach 4.1% of the global total by 2050.

An ammonia plant, Brunei Fertilizer Industries (BFI, 2022), entered production in 2022 with installed maximum capacity of 3,900 tonnes per day (tpd) of ammonia and, for all cases, this fact is considered in the calculation of the future supply and demand of hydrogen of Brunei's industry sectors.

Following the four scenarios in Purwanto et al. (2023), Brunei's hydrogen industry demand by 2050 might reach from around 404,550 tpa as in the ERIA-STEPS Scenario to as high as 553,650 tpa as in the ERIA-APS Scenario (Figure 4.11).

Figure 4.11. Brunei Darussalam's Estimated Hydrogen Demand from the Industry Sectors – Four Scenarios



	2020	2030E	2040E	2050E
ERIA-Frozen Scenario	41,957	289,337	368,377	469,431
ERIA-STEPS Scenario	41,957	268,779	327,380	404,545
ERIA-Likely Scenario	41,957	258,104	324,740	433,837
ERIA - APS Scenario	41,957	262,842	356,793	553,653

Source: Purwanto et al. (2023, forthcoming).

The demand growth for hydrogen in the industry sectors in Brunei is shown in detail in Figure 4.11.

In the ERIA-Frozen Scenario, demand for hydrogen is driven by the increasing demand in oil refining due mainly to the increasing use of transport fuels, i.e. gasoline and diesel demand from cars that are assumed not to be electrified.

In the ERIA-STEPS scenario, the electrification of mobility, marked by the increasing penetration of EVs, reduces hydrogen demand in the oil refining sector, and therefore the total hydrogen demand in this scenario is lower by 2050 compared to the ERIA-Frozen Scenario.

In the ERIA-Likely scenario, EV penetration is stronger than in the ERIA-STEPS scenario, and the demand for hydrogen in oil refining in this scenario is lower than in the ERIA-STEPS scenario. On the other hand, demand for ammonia fuels used, for example, in short sea shipping or ammonia as a carrier would start to kick in in this scenario so that hydrogen needed in the ammonia industry in this scenario is higher compared to the ERIA-Frozen and ERIA-STEPS Scenarios.

Finally, the ERIA-APS Scenario sees the strongest mobility electrification and the strongest demand growth in ammonia fuels. The growth of hydrogen demand in the ammonia industry offsets the decrease in hydrogen demand in oil refining, and this scenario has the highest hydrogen demand in 2050 compared to the other three scenarios.

It is important to note that it is not only the quantity of hydrogen that changes between the scenarios but also the intensity of carbon in the production of hydrogen itself. The hydrogen

used in the industry sectors reaches the lowest carbon intensity in the ERIA-APS Scenario and the highest in the ERIA-Frozen Scenario.

Finally, by 2050, Brunei's part in the total hydrogen demand in the industry sectors in ASEAN reaches 5.7% in the ERIA-Frozen Scenario, 5.5% in the ERIA-STEPS Scenario, 5.4% in the ERIA-Likely Scenario, and 4.7% in the ERIA-APS Scenario. This decreasing percentage share with the decreasing carbon intensity of hydrogen reflects the importance of demand coming from the oil refining industry in the country, which decreases proportionally with the increasing electrification of road mode transport.

Table 4.1. Brunei Darussalam's Estimated Hydrogen Demand by Industry Sector – Four Scenarios

	2020	2030E	2040E	2050E
ERIA-Frozen Scenario				
Ammonia	0	154,243	200,939	261,772
Refinery	38,748	126,065	155,186	191,034
Methanol	0	0	0	0
Iron and steel	0	0	0	0
Chemical and others	3,209	9,028	12,252	16,626
Total	41,957	289,337	368,377	469,431
ERIA-STEPS Scenario				
Ammonia	0	133,685	181,292	245,832
Refinery	38,748	126,065	133,837	142,087
Methanol	0	0	0	0
Iron and steel	0	0	0	0
Chemical and others	3,209	9,028	12,252	16,626
Total	41,957	268,779	327,380	404,545
ERIA-Likely Scenario				
Ammonia	0	132,413	205,530	318,981
Refinery	38,748	115,803	105,793	96,648
Methanol	0	0	0	0
Iron and steel	0	0	0	0
Chemical and others	3,209	9,887	13,417	18,207
Total	41,957	258,104	324,740	433,837
ERIA-APS Scenario				
Ammonia	0	132,682	246,347	457,305
Refinery	38,748	120,720	97,635	78,965
Methanol	0	0	0	0
Iron & steel	0	0	0	0
Chemical & others	3,209	9,440	12,810	17,384
Total	41,957	262,842	356,793	553,653

Source: Purwanto et al. (2023, forthcoming).

4. Total Potential Demand

By 2050, total hydrogen demand in Brunei Darussalam could be as low as 0.68 mtpa to as high as 0.81 mtpa, whilst in the same year, in ASEAN, it could be from 67.7 mtpa to 84.5 mtpa. By 2050, Brunei's total share of hydrogen demand in ASEAN will be around 0.9%–1.2%.

The structure of the demand will change differently in Brunei compared to ASEAN. Currently, 100% of hydrogen is consumed in the industry sectors in all ASEAN countries. By 2050, in Brunei, hydrogen demand from the industry sectors will range from 60% to 72% of the total hydrogen demand of the country. Nevertheless, at the ASEAN level, by the same year, the share of the industry sectors in total hydrogen demand will be only around 9%–16%.

The use of hydrogen in power generation, i.e. in cofiring with natural gas, plays an important role in this different pathway. In Brunei, power demand growth between 2020 and 2050 will be around 0.4%–0.5% per year, whilst the average growth in ASEAN during the same period will be around 3.7%–4.2% per year.

With the development of the ammonia industry in Brunei Darussalam, the country will have the chance to participate in the development of ammonia fuels or ammonia as a carrier. If the carbon intensity of hydrogen production can be reduced significantly, then low-carbon ammonia can be a commodity that Brunei can put forward to participate in the energy transition in ASEAN, and this has been shown by the increasing demand for the ammonia industry in the ERIA-APS Scenario.