Chapter 2

Hydrogen Supply Potential

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Chapter 2

Hydrogen Supply Potential

This section estimates the hydrogen supply potential in the EAS region.

1. Hydrogen Production Technologies

Hydrogen hardly exists as a molecule in nature – instead, it is found in the form of oxides or carbides (e.g. H_2O and CnHm). To obtain hydrogen, energy must be used for a chemical reaction that breaks, for instance, the H–O bond or C–H bond. Heat and electricity are generally used as the energy, but other methods use light or radiation. Industrial hydrogen production processes include steam reforming of light hydrocarbons, partial oxidation, gasification of coal, and water electrolysis.

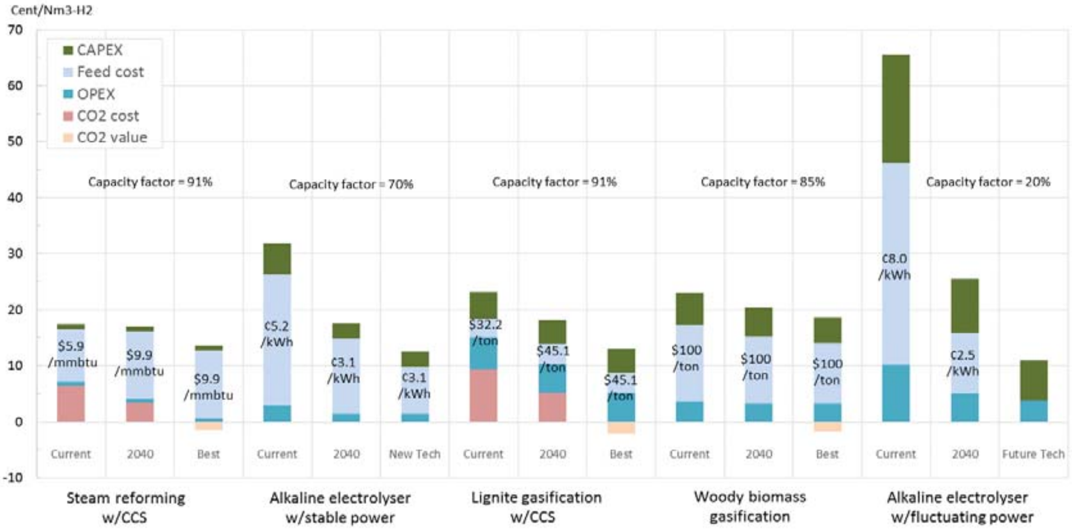
Table 2.1. Hydrogen Production Technologies

		Input Energy		
		Heat	**Electricity**	**Other**
Feedstock	**Hydrocarbon**	Steam reforming Partial oxidation Autothermal reforming Thermal cracking		
	Water	Thermochemical water splitting	Alkaline electrolysis Polymer electrolyte membrane (PEM) High-temperature steam reforming	Photolytic Biological Radiation

Source: DOE, Hydrogen Production Processes, https://www.energy.gov/eere/fuelcells/hydrogen-production-processes (accessed 18 September 2021).

Steam reforming of natural gas is the cheapest, while alkaline water electrolysis using variable renewable energy is the most expensive method (ERIA, 2019). The latter is expensive because the supply of electric power for water electrolysis is not stable, so the capacity factor of a water electrolysis device is low. Such hydrogen production costs can be halved, however, if a high operating rate can be maintained under stable power. Technological improvements may reduce the cost of alkaline water electrolysis, making it the most economical hydrogen production method.

Figure 2.1. Cost of Large-Scale Hydrogen Production



**1 : Feed Cost of Lignite gasification is based on FOT price in Intra-regional Group Countries.*
**2 : CCS cost is based on $70/t-CO2 for current and $48/t-CO2 for 2040 (CCS/Utilization Singapore Perspectives).*

CAPEX = capital expenses, CCS = carbon capture and storage, CO_2 = carbon dioxide, kWh = kilowatt-hour, mmbtu = metric million British thermal unit, OPEX = operating expenses.
Source: ERIA (2019a).

2. Hydrogen Production from Unused Energy

This phase 3 study focussed on unused energy for potential hydrogen production in 2040, specifically low-rank coal, flared gas, and untapped hydropower. Geographical coverage includes Australia, China, India, Japan, the Republic of Korea, New Zealand, as well as all of the ASEAN Members. Indonesia was divided into Kalimantan, Sumatra, Java, Sulawesi, Papua, and other regions. Only East Malaysia was targeted in Malaysia, because unused energy is concentrated in Saba and Sarawak states.

2.1. Low-Rank Coal

Coal is produced by carbonising plants over a long period of time. Low-rank coal, such as lignite or brown coal, is young coal that is not maturely carbonised. Low-rank coal has a high moisture and ash content, as well as a high oxygen content, so its calorific value is low. It is not suitable for long-distance transport or storage, because it is easily pulverised and can self-ignite. A special boiler is required for combustion, so it is not widely used. However, low-rank coal is plentiful and cheap. Therefore, if low-rank coal can be converted to hydrogen and used cleanly, it will be an effective use of resources.

Table 2.2 consolidates the amount of low-rank coal reserves in 2018. In the EAS region, about 70% of low-rank coal reserves are in Australia, followed by Indonesia, China, New Zealand, and India. These five countries constitute 97% of low-rank coal reserves in the EAS region.

Table 2.2. Low-Rank Coal Reserves in the East Asia Summit Region

(million tons)

Country	Reserves	Resources	Remaining Potential
Australia	76,508	403,382	479,890
China	8,128	324,068	332,196
India	5,073	38,971	44,044
Indonesia	11,728	27,998	39,726
Japan	10	1,026	1,036
Lao PDR	499	22	521
Malaysia	78	817	896
Myanmar	3	2	5
New Zealand	6,750	4,600	11,350
Philippines	146	842	988
Thailand	1,063	826	1,889
Viet Nam	244	199,876	200,120

Lao PDR = Lao People's Democratic Republic.

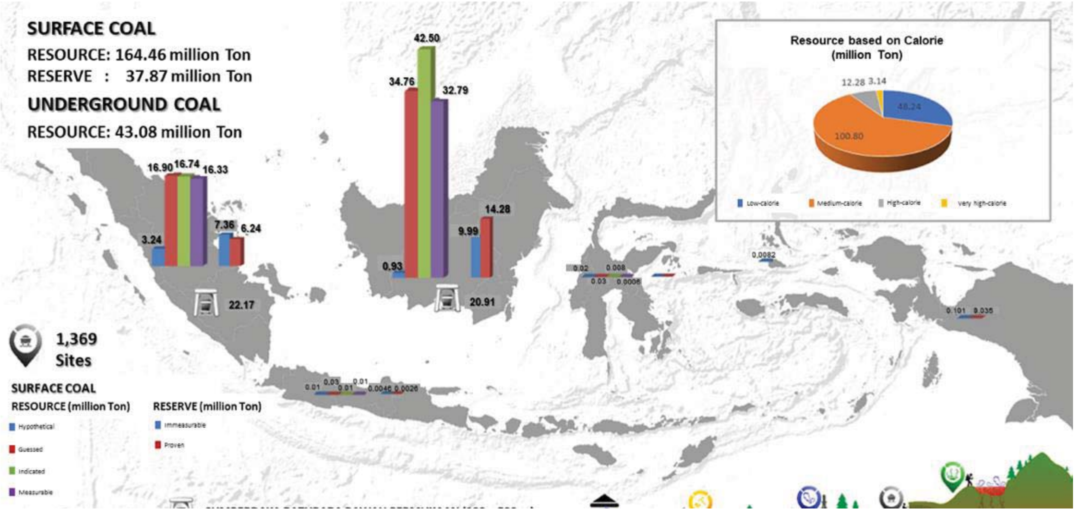
Note: Reserves are defined as the ‘proven volume of energy resources economically exploitable at today’s prices and using today’s technology’. In the meantime, resources are the ‘proven amount of energy resources [that] cannot be exploited for technical and/or economic reasons, as well as unproven but geologically possible energy resources which may be exploitable in future’.

Source: BGR (2019).

In Indonesia, most coal resources are located in Kalimantan and on Sumatra. Coal reserves total about 32.79 billion tons in Kalimantan and 16.33 billion tons on Sumatra; the ratio of coal reserves between Kalimantan and Sumatra is about 2:1. This study used this ratio to split low-rank coal reserves and production in Indonesia.

Figure 2.2. Distribution of Coal Reserves in Indonesia, October 2018

(billion tons)



Source: MEMR (2018).

The produced amount of low-rank coal is not necessarily relevant to the amount of reserves in a country. China is the third-largest endowed country in the EAS region, accounting for 7% of the total, but the production volume is the largest in the region, accounting for 45% of the total. Indonesia has the second-largest production value, followed by India and Australia at about the same volume. Although New Zealand has the same amount of resources as China and India, its production volume remains at a level that does not appear in the statistics. Indeed, New Zealand does not have a policy to increase low-rank coal production in the future.

Table 2.3. Low-Rank Coal Reserves

(million tons)

	2014	**2015**	**2016**	**2017**	**2018**
Australia	58.0	61.0	59.8	56.1	45.1
China	145.0	140.0	140.0	145.0	150.0
India	48.3	43.8	45.2	46.7	45.3
Indonesia	60.0	60.0	60.0	60.0	60.0
Lao PDR	< 0.05	4.5	13.1	13.4	15.9
Thailand	18.0	15.2	17.0	16.3	14.9

Lao PDR = Lao People's Democratic Republic.
Source: BGR (2019).

From previous data, the amount of reserves and production of low-rank coal are expected to remain the same until 2050 in the EAS region. The target period of this study is up to 2040, but the remaining amount of low-rank coal is estimated until 2050, because the investment required for hydrogen production cannot be made unless sufficient reserves remain for a certain period beyond 2040, as well as to make a safe-side estimation:

Remaining reserves in 2050 (2040) = Reserve in 2018 – (production in 2018 x 32 years) (1)

From this equation, it can be assumed that low-rank coal reserves in the Lao People’s Democratic Republic (Lao PDR), for example, will be depleted before 2050. There is also an insufficient amount of low-rank coal reserves in Japan and Myanmar.[3]

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[3] For instance, to operate 100 megawatts (MW) of a pure hydrogen-fired combined-cycle gas turbine power plant, 4.2 petajoules (PJ) of hydrogen is needed per year (i.e. 60% of thermal efficiency, 80% of capacity factor). To fuel 5,000 heavy-duty trucks, 2.5 PJ of hydrogen is needed per year (i.e. 4 kilometres [km] per litre of diesel-equivalent fuel economy and 100,000 km of driving distance). However, 10 million tons of low-rank coal for Japan can only produce 37 PJ of hydrogen, while 3 million tons for Myanmar can only produce 13 PJ. Thus, the operating life of such hydrogen production projects are less than 10 years, which may be too short to anticipate sufficient profits that can support an investment decision.

Table 2.4. Available Amount of Low-Rank Coal Reserves for Producing Hydrogen

	Reserves, 2018	Lignite Production, 2018	Lignite Consumption, 2019–2050	Remaining Reserves, 2050	Reserves Reduction, 2018–2050	Ratio, 2050
	million tons	million tons	million tons	million tons	%	
Australia	76,508	45	1,443	75,065	–2	1,664
Brunei Darussalam						
Cambodia						
China	8,128	150	4,800	3,328	–59	22
India	5,073	45	1,450	3,623	–29	80
Indonesia	11,728	60	1,920	9,808	–16	163
Kalimantan	7,819	16	509	7,310	–7	460
Sumatera	3,909	15	467	3,442	–12	236
Java					0	
Sulawesi					0	
Papua					0	
Others					0	
Japan	10			10	0	
Korea, Republic of						
Lao PDR	499	16	509		–100	
Malaysia	78			78	0	
Myanmar	3			3	0	
New Zealand	6,750			6,750	0	
Philippines	146			146		
Singapore					0	
Thailand	1,062	15	467	596	–44	41
Viet Nam	244			244	0	

Lao PDR = Lao People's Democratic Republic.
Source: Authors’ calculations.

This study then estimated the amount of hydrogen production under the following conditions. For the commercialisation rate of remaining reserves, the study assumed 75% for the high case and 25% for the low case. Regarding yield of hydrogen from the coal gasification process, the study referred to JST (2019), which estimated the amount of hydrogen produced applying coal gasification technology to two types of coal (i.e. lignite and bituminous). For lignite coal, JST (2019) found that the yield of hydrogen production is 21 tons of lignite per ton of hydrogen. If the net calorific value (NCV) of lignite is applied to JST (2019),[4] the hydrogen production efficiency from lignite is 50%. Finally, the NCV of low-rank coal was provided by IEA (2020a), which supplied the average NCV of lignite in each country. If data were not available, the study applied 10,000 kilojoules per kilogram of NCV for unit conversion. The potential of hydrogen production from low-rank coal is presented in Table 2.5.

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[4] The NCV of lignite is 11.5 megajoules per kilogram, and of hydrogen is 120 megajoules per kilogram.

Table 2.5. Hydrogen Production Potential from Low-Rank Coal

	Remaining Reserves, 2040	NCV of Lignite	Potential, High Case		Potential, Low Case	
	million tons	kJ/kg	PJ	million Nm^3	PJ	million Nm^3
Australia	75,065	9,800	274,150	21,499	91,383	7,166
Brunei Darussalam						
Cambodia						
China	3,328	10,000	12,402	973	4,143	324
India	3,623	9,546	12,890	1,011	4,297	337
Indonesia	9,808	5,100	18,641	1,462	6,214	487
Kalimantan	7,310	5,100	13,893	1,090	4,631	363
Sumatera	3,442	5,100	6,542	513	2,181	171
Java		5,100				
Sulawesi		5,100				
Papua		5,100				
Others		5,100				
Japan	10	10,000				
Korea, Republic of						
Lao PDR		9,630				
Malaysia	78	10,000	291	23	97	8
Myanmar	3	11,900				
New Zealand	6,750	17,082	42,970	3,370	14,323	1,123
Philippines	146	10,000	544	43	181	14
Singapore						
Thailand	596	10,571	2,347	184	782	61
Viet Nam	244	10,000	909	71	303	24

Lao PDR = Lao People's Democratic Republic, NCV = net caloric value, Nm^3 = normal cubic metre.
Source: Authors' calculations.

Australia has the greatest hydrogen production potential from low-rank coal, accounting for 71% of the EAS region's potential. This is because the amount of available reserves is large compared to other countries. The next greatest potential is possessed by New Zealand, which has 11% of the total region's potential due to its high NCV. However, although Indonesia has the largest amount of available reserves amongst countries ranked second or lower, the amount of hydrogen that can be produced is relatively small due to Indonesia's low NCV.

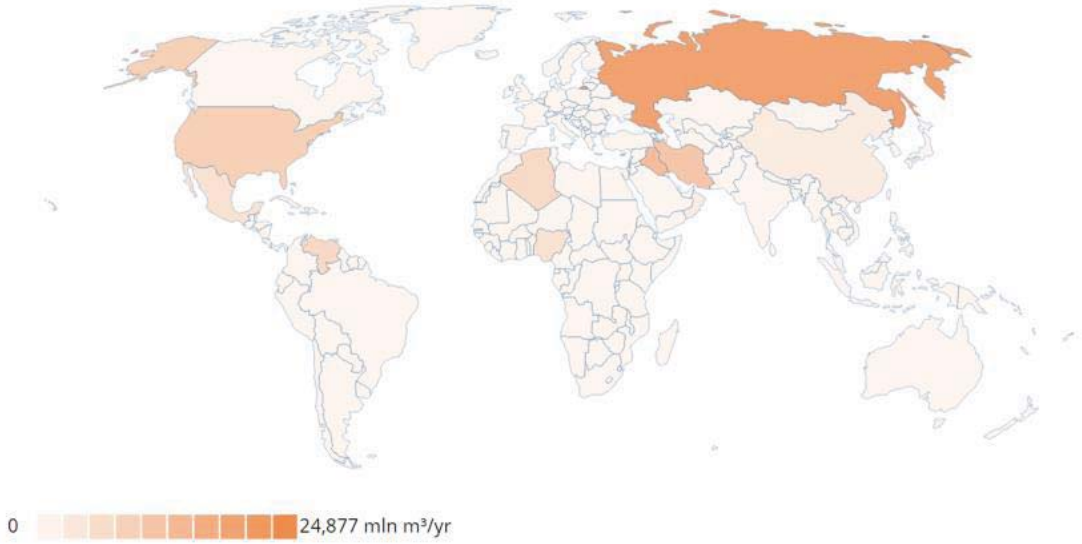
2.2. Flared Natural Gas

Flared gas is gaseous hydrocarbon that is burned for disposal; there are two types. The first is an associated gas created as a by-product of crude oil production, so the amount of flare is linked to the amount of crude oil produced. Since the associated gas contains volatile components, there is a danger of explosion, so it is incinerated on the stack as a safety measure. In addition, since oil is generally traded at a higher price than natural gas and additional costs are required for the recovery and processing of an associated gas, it is incinerated from the viewpoint of business feasibility. Flared gas, in this case, is routine as long as there is crude oil production.

The other type is light by-product gases generated from manufacturing processes such as petroleum refining, chemical industrial processes, and steel making. Since the by-product gas also has dangers, including volatility, toxicity, and odour, it is incinerated and then released into the atmosphere. In many cases, this flared gas is reused as energy, thus not routinely but temporarily generated. By considering this different nature of flared gas (i.e. routine or not), this study targeted routine generation, or that generated as a by-product of crude oil production.

In addition to the CO_2 emissions from the combustion of flared gas, methane – which has an 80 times greater greenhouse effect than CO_2 – is also released into the atmosphere when combustion is incomplete. In addition to damaging the environment, incinerating mined natural gas is a loss in terms of resource efficiency. The World Bank is thus working to eliminate routine gas flaring through its Global Gas Flaring Reduction Partnership. It has set a goal of zero routine flaring by 2030.[5] Using otherwise flared gas as a feedstock for hydrogen production is consistent with the World Bank's initiative.

Figure 2.3. Routine Gas Flares Worldwide, 2020



m^3 = cubic metre.
Source: World Bank, Individual Flare Sites, https://www.ggfrdata.org/ (accessed September 2021).

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[5] World Bank, Global Gas Flaring Reduction Partnership, https://www.worldbank.org/en/programs/gasflaringreduction#7 (accessed 18 September 2021)

According to World Bank, about 10.0 billion cubic metres (bcm) of natural gas is flared annually in the EAS region. This amount is equivalent to Viet Nam's natural gas consumption in 2019 (BP, 2020). If such flared gas can be transformed into hydrogen and used cleanly, this can reduce greenhouse gases and strengthen energy supply stability.

Table 2.6. Amount of Flared Gas, East Asian Summit Region
(bcm)

	2015	2016	2017	2018	2019
Australia	1.14	0.73	0.66	0.86	1.39
Brunei Darussalam	0.21	0.28	0.30	0.21	0.31
China	2.08	1.96	1.56	1.82	2.03
India	2.20	2.06	1.50	1.34	1.31
Indonesia	2.91	2.77	2.33	2.06	2.00
Malaysia	3.72	3.16	2.83	2.25	2.37
Myanmar	0.06	0.04	0.04	0.03	0.02
New Zealand	0.13	0.10	0.10	0.06	0.05
Philippines	0.16	0.17	0.13	0.12	0.08
Thailand	0.43	0.40	0.37	0.33	0.32
Viet Nam	1.03	0.92	0.98	0.74	0.78

Source: World Bank, Global Gas Flaring Reduction Partnership, https://www.worldbank.org/en/programs/gasflaringreduction#7 (accessed 18 September 2021)

In Indonesia, the largest oil-producing area is central Sumatra, which includes the Duri and Minas oil fields. Oil production in these two areas accounted for more than half of national production. Other major oil-producing areas are Java and Kalimantan.[6] Therefore, this study assumed 50% of oil production (i.e. gas flaring) comes from Sumatra, and 25% each from Java and Kalimantan.

As mentioned previously, the amount of flared gas changes in conjunction with the amount of crude oil produced. Thus, if crude oil production ceases in a country, the amount of flared gas will also disappear. Therefore, the study reviewed the exploitable years of oil in oil-producing countries in the EAS region (i.e. the reserve–production ratio). The situation varies from country to country, but in general, the amount of oil resources in oil-producing countries is low compared to their oil production. In many countries, the reserve–production ratio is 15–30 years, except for Viet Nam's 51 years. In addition, New Zealand and Thailand have ratios of only 4.6 and 1.7 years, respectively; it is highly likely that their oil reserves will be depleted in the near future. Indonesia also has a low ratio of 8.7 years, but the ongoing resource exploration may succeed in uncovering new reserves. Further, there is an

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[6] Indonesia Petroleum Association, Oil, https://www.ipa.or.id/en/the-industry/oil (accessed 18 September 2021).

insufficient amount of flared gas in Brunei Darussalam, Myanmar, and the Philippines.[7] This study thus assumed that crude oil production – as well as flared gas – will dissipate as of 2040 in countries with an reserve–production ratio of less than 5 years. For other countries, the amount of flared gas in 2040 was assumed to be the same as it is today.

Table 2.7. Amount of Flared Gas and Ratio of Oil in the East Asia Summit Region

	Flared Gas, 2019 (bcm)	**R/P Ratio of Oil Reserves, 2019**	**Flared Gas, 2040** (bcm)
Australia	1.390	13.4	1.390
Brunei Darussalam	0.307	24.8	0.307
Cambodia			
China	2.025	18.7	2.025
India	1.310	15.5	1.310
Indonesia	2.004	8.7	2.004
Kalimantan	0.501		0.501
Sumatera	1.002		1.002
Java	0.501		0.501
Sulawesi	0		0
Papua	0		0
Others	0		0
Japan			
Korea, Republic of			
Lao PDR			
Malaysia	2.368	11.9	2.368
Myanmar	0.023	34.6	0.023
New Zealand	0.048	4.6	0
Philippines	0.084	29.0	0.084
Singapore			
Thailand	0.315	1.7	0
Viet Nam	0.781	51.0	0.781

bcm = billion cubic metres, Lao PDR = Lao People's Democratic Republic, R/P = reserve–production.
Sources: BP (2020); World Bank, Global Gas Flaring Reduction Partnership, https://www.worldbank.org/en/programs/gasflaringreduction#7 (accessed 18 September 2021); CIA, 'Burma', The World Factbook, https://www.cia.gov/the-world-factbook/countries/burma/#energy (accessed 18 September 2021); MBIE (2020); GOP (2021).

This study estimated the amount of hydrogen production under the following conditions. It referred to Iseki (2012), which showed the efficiency of hydrogen production from the steam-reforming method and pressure swing absorption technology to purify hydrogen. It noted

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[7] As noted in the previous section for low-rank coal, for instance, to operate 100 MW of a pure hydrogen-fired combined-cycle gas turbine power plant, 4.2 PJ of hydrogen is needed per year. For instance, to fuel 5,000 heavy-duty trucks, 2.5 PJ of hydrogen is needed per year. Yet estimates show that Brunei Darussalam, Myanmar, and the Philippines can only produce 6 PJ, 1 PJ, and 4 PJ, respectively, of hydrogen from their flared gas.

that the efficiency is 60%–70% – 70% efficiency with technological improvement. Moreover, the gross calorific value (GCV) of natural gas was provided by IEA (2020a).

The potential of hydrogen production from flared gas in the region is presented in Table 2.8. Malaysia has the highest potential at 65 PJ, followed by Indonesia and China. Australia, India, and Viet Nam also have some potential.

Table 2.8. Hydrogen Production Potential from Flared Gas, East Asia Summit Region

	Flared Gas, 2040	GCV of Natural Gas	Hydrogen Production Potential	
	(bcm)	(kJ/m^3)	(PJ)	(million Nm^3)
Australia	1.390	39,914	39	3.0
Brunei Darussalam	0.307	42,000		
Cambodia				
China	2.025	38,931	55	4.3
India	1.31	39,000	36	2.8
Indonesia	2.004	40,600	57	4.5
Kalimantan	0.501	40,600	14	1.1
Sumatera	1.002	40,600	28	2.2
Java	0.501	40,600	14	1.1
Sulawesi	0	40,600		
Papua	0	40,600		
Others	0	40,600		
Japan				
Korea, Republic of				
Lao PDR				
Malaysia	2.368	39,249	65	5.1
Myanmar	0.023	39,269		
New Zealand	0	39,077		
Philippines	0.084	38,549		
Singapore				
Thailand	0.315	36,396		
Viet Nam	0.781	38,612	21	1.7

bcm = billion cubic metres, GCV = gross caloric value, kJ = kilojoule, Lao PDR = Lao People's Democratic Republic, m^3 = cubic metre, Nm^3 = normal cubic metre, PJ = petajoule.
Source: Authors' calculations.

2.3. Potential of Carbon Capture, Utilisation, and Storage

CCUS is indispensable for hydrogen production from low-rank coal or flared gas, making it free from CO_2 emissions. For this study, the carbon content value of low-rank coal was represented by lignite, and flared gas by natural gas. By applying these values from IEA (2020b), CO_2 emissions from feedstock consumption were estimated.[8]

For Australia and India, the discovered storage capacity – the sum of the capacity and sub-commercial capacity – is smaller than required. Therefore, both countries need to explore additional storage sites as well as to develop their discovered capacity. Alternatively, carbon can be recycled to conserve their limited CCUS capacities. In China, the sub-commercial capacity is sufficient to absorb possible CO_2 emissions from producing blue hydrogen.

Table 2.9. Carbon Dioxide Emissions from Feedstock Consumption and Carbon Capture and Storage Potential

	Unit	Australia	China	India
Carbon Content of Lignite	kg/GJ	27.6	27.6	27.6
Low-Rank Coal Consumption, High Case	million tons	56,299	2,496	2,718
Net Calorific Value	kJ/kg	9,800	10,000	9,546
CO_2 Emissions from Low-Rank Coal	Gton	56.0	2.5	2.6
Carbon Content of Natural Gas	kg-C/GJ	15.3	15.3	15.3
Flared Gas Consumption	bcm	1.39	2.03	1.31
Gross Calorific Value of Natural Gas	kJ/m^3	39,914	38,931	39,000
CO_2 Emissions from Flared Gas	Gton	0.0031	0.0044	0.0029
Potential of Carbon Capture, Utilisation, and Storage	Gton			
Capacity		0.12	0	0
Sub-Commercial		17	105	1
Undiscovered		414	3,067	63

bcm = billion cubic metres, CO_2 = carbon dioxide, GJ = gigajoule, Gton = gigaton, kg = kilogram, m^3 = cubic metre.
Notes: Apply the high case for low-rank coal consumption. Capacity signifies economically viable resources; sub-commercial denotes discovered but uncertain economic viability and possible inaccessibility; and undiscovered are geographically unconfirmed resources.
Source: IEA (2020a), IEA (2020b), Pale Blue Dot Energy (2020).

2.4. Untapped Hydropower Resources

The EAS region, which has a rainy climate, has great potential for hydropower generation. Hydrogen can be produced from hydropower, which is a clean energy with no carbon emissions.

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[8] In a plant, energy input for the transformation process is added to increase CO_2 emissions, which is neglected in this analysis.

Table 2.10. Hydropower Resources in the East Asia Summit Region

(gigawatt)

Country	Hydropower Resources
Australia	
Brunei Darussalam	
Cambodia	10
China	600
India	145
Indonesia	75
Japan	
Korea, Republic of	
Lao PDR	26
Malaysia	29
Myanmar	100
New Zealand	
Philippines	13
Singapore	
Thailand	15
Viet Nam	25–26

Lao PDR = Lao People's Democratic Republic.

Sources: Aroonrat and Wongwises (2015); Erdiwansyah et al. (2020); ERIA (2019b); EVN, Overview of Hydropower in Viet Nam', https://en.evn.com.vn/d6/news/Overview-of-hydropower-in-Vietnam-66-163-1514.aspx (accessed September 2021); IHA, 'China', Country Profiles, https://www.hydropower.org/country-profiles/china (accessed September 2021); IHA, 'Myanmar', Country Profiles, https://www.hydropower.org/country-profiles/myanmar (accessed September 2021); IRENA (2017); and Verma (2020).

In Indonesia, Papua and Kalimantan provinces have the greatest resources, but they are the least hydropower-developed regions – meaning they have the largest remaining resources as well. Sumatra and Sulawesi provinces also have large resources, and small resources can be found in Java. This study applied the ratios in Table 2.11 to split hydropower resources in Indonesia.

Table 2.11. Hydropower Resources in Indonesia by Region

(megawatts)

			Remaining Resources	
Province	**Resources**	**Developed**	**Capacity**	**Share to Total**
Kalimantan	21,581	32	21,549	31%
Sumatra	15,579	1,680	13,900	20%
Java	4,199	2,598	1,601	2%
Sulawesi	10,307	844	9,463	14%
Maluku	430		430	1%
Bali – Nusa Tenggara	624	6	618	1%
Papua	22,371	6	22,365	32%
Total	**75,091**	**5,166**	**69,925**	

Source: Utomo (2017).

Hydropower can harnessed in two ways. It can be directly used as electricity, or as an input energy for electrolysis to produce hydrogen. Therefore, hydropower's capacity for electricity generation is set off from the remaining resources.

The study first defined how many hydropower resources are used to generate electricity. IEA (2020c) outlined the prospect of hydropower development for electricity generation in two different scenarios: the stated policy scenario (STEPS) and sustainable development scenario (SDS). China will consume 156–211 gigawatts (GW) of hydropower resources for generating electricity from 2018 to 2040, equivalent to 26%–35% of total resources observed today. Similarly, in India, 51–68 GW of resources will be consumed for generating electricity, 35%–47% of total resources today. In ASEAN, 57–121 GW of resources will be exploited, 20%–41% of total resources today (Table 2.12).

Table 2.12. Hydropower Development Prospects for Electricity Generation, Selected Areas

Country	Scenario	Prospect	Unit	2018	2025	2030	2040	2018–2040
China	STEPS	Output	TWh	1,199	1,297	1,398	1,568	369
		Capacity	GW	352	411	446	508	156
		Capacity Factor		39%	36%	36%	35%	
	SDS	Output	TWh	1,199	1,345	1,507	1,701	502
		Capacity	GW	352	433	495	563	211
		Capacity Factor		39%	35%	35%	34%	
India	STEPS	Output	TWh	151	177	226	307	156
		Capacity	GW	49	60	76	101	51
		Capacity Factor		35%	33%	34%	35%	
	SDS	Output	TWh	151	196	258	361	210
		Capacity	GW	49	67	86	117	68
		Capacity Factor		35%	33%	34%	35%	
ASEAN	STEPS	Output	TWh	190	180	245	337	147
		Capacity	GW	46	56	77	104	57
		Capacity Factor		47%	37%	36%	37%	
	SDS	Output	TWh	190	223	327	537	
		Capacity	GW	46	72	103	167	
		Capacity Factor		47%	36%	36%	37%	

ASEAN = Association of Southeast Asian Nations, GW = gigawatt, SDS = sustainable development scenario, STEPS = stated policy scenario, TWh = terawatt-hour.
Source: IEA (2020c).

The remaining hydropower resources for producing hydrogen can be derived by extracting cumulative hydropower development for generating electricity from total resources. For ASEAN Members, the study applied the single common coefficient of 20% for STEPS and 40% for SDS to calculate the cumulative hydropower development for generating electricity.

Table 2.13. Remaining Hydropower Resources for Producing Hydrogen, East Asia Summit Region

(GW)

	Current Hydropower Resources	Hydropower for Electricity, STEPS	Maximum Remaining Hydropower Resources, 2040	Hydropower for Electricity, 2018–2040, SDS	Minimum Remaining Hydropower Resources, 2040
Australia					
Brunei Darussalam					
Cambodia	10	2	8	4	6
China	600	156	444	211	389
India	145	51	94	68	77
Indonesia	70	14	56	28	42
Kalimantan	21	4	17	8	13
Sumatera	14	3	11	6	8
Java	4	1	3	1	2
Sulawesi	11	2	8	4	6
Papua	21	4	17	8	13
Others					
Japan					
Korea, Republic of					
Lao PDR	26	5	21	10	16
Malaysia	29	6	23	12	17
Myanmar	100	20	80	40	60
New Zealand					
Philippines	13	3	10	5	8
Singapore					
Thailand	15	3	12	6	9
Viet Nam	25	5	20	10	15

Lao PDR = Lao People's Democratic Republic, SDS = sustainable development scenario, STEPS = stated policy scenario.
Source: Authors' calculations.

The study estimated the amount of hydrogen production under the following conditions. Regarding the commercialisation rate of the remaining potential, the study assumed 75% for the high case and 25% for the low case. It also estimated the capacity factor of hydropower in China, India, and ASEAN from IEA (2020c), and assumed the same for 2040. For ASEAN Members, a common capacity factor of 47% was applied to every country. It also applied, from catalogue data of existing electrolysers in the world, 5 kilowatt-hours per normal cubic metre (Nm^3) of hydrogen yield.

The estimated potential of hydrogen production from untapped hydropower resources is presented in Table 2.14. China possesses the greatest potential to produce hydrogen from hydropower, thanks to its large endowment of resources. Other significant potential can be seen in India, Indonesia, and Myanmar.

Table 2.14. Hydrogen-Producing Potential from Untapped Resources, East Asia Summit Region

	Maximum Remaining Hydropower Resources, 2040	Minimum Remaining Hydropower Resources, 2040	Capacity Factor, 2018	Potential/ Maximum Potential and High Case		Potential/ Minimum Potential and Low Case	
	(GW)	(GW)	(%)	(PJ)	(Nm^3 million)	(PJ)	(Nm^3 million)
Australia							
Brunei Darussalam							
Cambodia	8	6	47	63	5	16	1
China	444	389	39	2,901	227	848	67
India	94	77	35	549	43	150	12
Indonesia	56	42	47	441	35	110	9
Kalimantan	17	13	47	132	10	33	3
Sumatera	11	8	47	88	7	22	2
Java	3	2	47	22	2	6	0
Sulawesi	8	6	47	66	5	17	1
Papua	17	13	47	132	10	33	3
Others							
Japan							
Korea, Republic of							
Lao PDR	21	16	47	164	13	41	3
Malaysia	23	17	47	183	14	46	4
Myanmar	80	60	47	630	49	158	12
New Zealand							
Philippines	10	8	47	82	6	20	2
Singapore							
Thailand	12	49	47	95	7	24	2
Viet Nam	20	15	47	158	12	39	3

GW = gigawatt, Lao PDR = Lao People's Democratic Republic, PJ = petajoule, Nm^3 = normal cubic metre.
Source: Authors' calculations.

3. Summary and Discussion

3.1. Potential Hydrogen Production from Unused Energies

From the study, low-rank coal emerged as having the greatest hydrogen production potential. This is true for most countries in the EAS region, except Brunei Darussalam, Cambodia, the Lao PDR, and Myanmar. Cambodia, the Lao PDR, and Myanmar have greater potential in utilising untapped hydropower.

Table 2.15. Hydrogen-Producing Potential from Unused Energies, East Asia Summit Region
(million normal cubic metres)

	Low-Rank Coal		Flared Gas	Untapped Hydropower		Total Production Potential	
	Max	Min		Max	Min	Max	Min
Australia	21,499	7,166	3			21,502	7,169
Brunei Darussalam			1			1	1
Cambodia				5	1	5	1
China	973	324	4	227	67	1,204	395
India	1,011	337	3	43	12	1,057	352
Indonesia	1,462	487	4	35	9	1,501	500
Kalimantan	1,090	363	1	10	3	1,101	367
Sumatera	513	171	2	7	2	522	175
Java			1	2	0	3	2
Sulawesi				5	1	5	1
Papua				10	3	10	3
Others							
Japan							
Korea, Republic of							
Lao PDR				13	3	13	3
Malaysia	23	8	5	14	4	42	16
Myanmar			0	49	12	49	12
New Zealand	3,370	1,123				3,370	1,123
Philippines	43	14	0	6	2	49	16
Singapore							
Thailand	184	61		7	2	192	63
Viet Nam	71	24	2	12	3	85	29

Lao PDR = Lao People's Democratic Republic.
Source: Authors' calculations.

3.2. Supply and Demand Balance

This section compares the potential of hydrogen production with hydrogen demand estimated in ERIA (2020). The comparison indicates that the hydrogen production potential from unused energies is very small compared to the possible demand, with a few exceptions (Table 2.16). Australia, the Lao PDR, and New Zealand can become net exporters of hydrogen.

Table 2.16. Hydrogen-Producing Potential from Unused Energies
(million normal cubic metres)

	Production Potential		Demand Potential	Sufficiency Rate	
	Max	Min		Max	Min
Australia	21,502	7,169	13,974	154%	51%
Brunei Darussalam	1	1	1,775	0%	0%
Cambodia	5	1	352	1%	0%
China	1,204	395	163,408	1%	0%
India	1,057	352	11,990	9%	3%
Indonesia	1,501	500	44,807	3%	1%
Japan			29,252	0%	0%
Korea, Republic of			41,558	0%	0%
Lao PDR	13	3	9	137%	34%
Malaysia	42	16	24,034	0%	0%
Myanmar	49	12	1,263	4%	1%
New Zealand	3,370	1,123	1,065	317%	106%
Philippines	49	16	4,551	1%	0%
Singapore			15,098	0%	0%
Thailand	192	63	12,993	1%	0%
Viet Nam	85	29	3,668	2%	1%
	29,070	9,681	369,796	8%	3%

Lao PDR = Lao People's Democratic Republic.
Source: Authors' calculations, ERIA (2020).

3.3. Discussion

The phase 3 study had difficulty in obtaining consistent and comprehensive datasets for analysis, particularly resource data. A country may have greater – and others may have lesser – potential than this study indicated if different datasets are used. Therefore, it is appropriate to regard the results as indicative.

Further, a country must apply CCUS when producing hydrogen from fossil fuels. However, as previously discussed, estimated CO_2 storage capacity is not necessarily sufficient to decarbonise all hydrogen in the region. Evaluation of CCUS potential is immature in every country in this region. Therefore, countries should continue to explore CO_2 storage sites, develop carbon-recycling technologies, and encourage hydrogen-producing projects.

The study only examined the technical aspects of hydrogen production – not policy, regulatory frameworks, financing, or public acceptance.