Chapter 3

Forecast for Potential Green Hydrogen Production in Brunei Darussalam

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1. Electrolysis Technologies

An electrolyser consists of a number of cells connected together with common electric terminals, i.e., bus bars. Each cell is composed of two electrodes, two porous transport layers, and the bipolar plates. Other parts of the electrolyser system include transformers, rectifiers, and process units, such as for water treatment, gas cooling, gas scrubbing, hydrogen (H_2) deoxidising, H_2 drying, and gas compression/storage.

Four types of electrolysers are under focus: alkaline electrolyser (ALK), polymer electrolyte membrane (PEM), solid oxide electrolytic cell (SOEC), and anion exchange membrane (AEM). Amongst the four types, SOEC and AEM are still in the development stages, and ALK and PEM are well-commercialised. From the view of cost and availability, ALK is much superior to PEM, but from the view of flexibility for intermittent renewable energy, PEM is better than ALK.

Table 3.1 shows a comparison of the commercialised electrolysers.

Table 3.1. Comparison between ALK and PEM

	Alkaline Electrolysis (ALK)	**Polymer Electrolyte Membrane (PEM)**
Technology maturity	Well-commercialised	Commercialised
Product H_2 purity	>99.95% module outlet (dry gas basis)	>99.7% module outlet (dry gas basis)
Responsiveness/Ramp rates	4%/sec (0%–100% load)	10%/sec (0%–100% load)
Operating load range	10%–100%	20%–100%
Electricity Efficiency		
Stack DC (kWh/Nm^3-H_2)	3.8–4.6	3.8–4.4
Plant AC (kWh/Nm^3-H_2)	4.7–5.6	4.7–5.6
Vendors/original equipment manufacturers	NEL, Thyssenkrupp, Asahi Kasei, Suzhou Jungli	Siemens, NEL, ITM Power, Cummins

Source: Authors.

2. FSPV potential and hydrogen production in Brunei

Table 3.2 shows the estimated electricity capacity and electricity generation derived by using the capacity factors for inland, offshore, and ground-mounted PV. Also, H_2 production is estimated by using an electrolyser efficiency of 4.77 kWh/Nm^3-H_2.

Table 3.2. PV Potential and H_2 Production in Brunei Darussalam

Type	Area	Site		Catchment Area	Water Storage	Average Depth	Estimated Area for PV		Estimated Electricity Capacity		Capacity Factor	Electricity Generated	Estimated H_2 Production	Remarks
				(ha)	(million m^3)	(m)	(ha)	(% of catchment)	(MW)	(MW/ha)	(%)	(MWh/y)	(kilotonnes/y)	
Floating PV	Lake, dams, and reservoir	1	Tasek Dam	427	1.1	0.26	85	20	55	0.64	19	91,032	1.70	(*2)
		2	Mengkubau Dam	1,370	16.8	1.23	197	14.4	126	0.64	19	209,858	3.93	(*1)
		3	Benutan Dam	2,900	56	1.93	639	22.0	408	0.64	19	679,540	12.71	(*1)
		4	Ulu Tutong Dam	10,800	80	0.74	517	4.8	330	0.64	19	549,628	10.28	(*1)
		5	Kargu Dam	1,430	10.7	0.75	286	20	183	0.64	19	304,860	5.70	(*2)
		6	Kago Dam	-	-	-	267	-	171	0.64	19	284,607	5.32	(*1)
		7	Imang Reservoir	1,400	10	0.71	188	-	120	0.64	19	200,398	3.75	(*1)
								Subtotal	**1,393**			**2,319,924**	**43.40**	
	Brunei Bay	1	Serasa Bay	-	-	-	47	-	30	0.64	19	50,099	0.94	(*3)
		2	Both sides of Temburong Bridge	-	-	-	1,000	-	640	0.64	19	1,065,946	19.94	(*4)
		3	Muara Besar Island	-	-	-	47	-	30	0.64	19	50,099	0.94	(*3)
								Subtotal	**700**			**1,166,144**	**21.81**	
	Land-based	1	Sg Akar	-	-	-	38	-	38	1.00	17	56,628	1.06	(*1)
		2	Pekan Belait	-	-	-	56	-	56	1.00	17	83,452	1.56	(*1)

Type	Area	Site		Catchment Area	Water Storage	Average Depth	Estimated Area for PV		Estimated Electricity Capacity		Capacity Factor	Electricity Generated	Estimated H_2 Production	Remarks
				(ha)	(million m^3)	(m)	(ha)	(% of catchment)	(MW)	(MW/ha)	(%)	(MWh/y)	(kilotonnes/y)	
Ground-mounted PV		3	Sungai Teraban	-	-	-	202	-	200	0.99	17	298,044	5.58	(*1)
								Subtotal	**294**			**438,125**	**8.20**	
Grand total									**2,387**			**3,924,193**	**73.41**	

*1 The values of the estimated area for PV and estimated electricity capacity (MW) are used from the report 'DOE Potential Sites for Solar Installation in Brunei Darussalam, November 2022'.
*2 The values of the estimated area for PV are set to 20% of the catchment area, and the values of the estimated electricity capacity are calculated using 0.64 MW/ha.
*3 The maximum value of the FSPV installed in the sea area is 5 MW in the Johor Strait, Singapore, but in the study, it was set to 30 MW which is 6 times that.
*4 PV panels shall be installed in an area of 500 m in width and 10,000 m in length on both sides of the Temburong Bridge.
Source: Authors.

3. Calculation of Green Hydrogen Cost

The green hydrogen cost is calculated from the PV potential (estimated electricity capacity), which is summarised in Table 3.2 with the following procedure.

- Electricity generated
  - (1) PV potential : 2,154 MW
  - (2) Capacity factor of PV : 17% (land-based)–19% (water surface)
  - (3) Electricity generated : 3,510,832 MWh/y
  - (4) 1,730 MW x 8,760 hrs/y x 0.19 : 2,879,412 MWh/y (water surface)
  - (5) 424 MW x 8,760 hrs/y x 0.17 : 631,420 MWh/y (land-based)
- H_2 production
  - (1) PEM electricity efficiency : 4.77 kWh/Nm^3-H_2
  - (2) H_2 production:
    - a. 3,510,832 MWh/y / 4.77 kWh/Nm3 : 736 MNm^3/y
    - b. 736 MNm^3/y / 11.2 Nm^3/kg : 65.7 kilotonnes/y
- Calculation of green hydrogen cost
  - (1) Renewable electricity cost : 0.05 0.07 US$/kWh
  - (2) Green hydrogen cost : 3.5–4.1 4.6–5.2 US$/kg-$H_2$

4. Conclusion

- Green hydrogen produced from electrolysis technologies using renewable electricity is an option for Brunei for achieving a low-carbon energy transition.
- The RE potential from FSPV systems of inland water surfaces in Brunei and Brunei Bay and from ground-mounted PV is estimated at 2,154 MWp.
- The electricity generation per year is calculated using capacity factors of 19% for water surface and 17 % for ground-mounted at 3,510,832 MWh/y.
- The above electricity generation gives 65.7 kilotonnes/y of hydrogen production using a PEM electrolyser with an efficiency of 4.77 kWh/Nm^3-H_2.
- When the RE cost in Brunei is US$0.05/kWh, the green hydrogen cost will be US$3.5–US$4.1/kg-H_2, and when the RE cost is US$0.07/kWh, the green hydrogen cost will be US$4.6–US$5.2/ kg-H_2, respectively.