WHEN TRUST MATTERS

Mapping Opportunities in Establishing Hydrogen Value Chains

for Royal Norwegian Embassy in Kuala Lumpur

Executive summary

Hydrogen is likely to play an important role in the decarbonisation of hard-to-abate sectors globally, while also having the potential for application in other sectors such as transport and power generation. Because Malaysia has access to both renewable resources and an opportunity for carbon storage, interest in both green and blue hydrogen has been increasing and attracting the attention of foreign companies. However, limited development has occurred as of yet. This report aims to investigate:

1. The market potential for hydrogen in East and West Malaysia based on the availability of energy sources and expected production costs
2. Available policy & regulatory framework in Malaysia compared to international best practice
3. The ability for Norwegian companies to play a role in the development of hydrogen value chains in Malaysia and recommendations for increasing their role

Market potential

Several potential routes for producing hydrogen are available within Malaysia, with the primary energy sources that can be utilized being solar, hydropower and natural gas. Significant differences exist between the different regions, with high solar and natural gas availability everywhere but suitable hydropower primarily available in Sarawak.

The production cost expectations were modelled for the different available resources in Peninsular Malaysia, Sarawak and Sabah separately and compared to the average expected costs from the same technologies in Southeast Asia (SEA) based on data from DNV's Energy Transition Outlook.

From this analysis several conclusions were drawn regarding the market potential of hydrogen produced in Malaysia:

- Blue hydrogen production from Peninsular Malaysia is competitive until around 2030 with the cost minimum reaching around 2.66 USD/kg H_2. This primarily makes it suitable as a transitionary solution for replacing existing grey hydrogen supply. Gas from Sarawak is sold to Japan at a higher price and is thus less competitive for hydrogen production based on opportunity cost.
- The cheapest from of green hydrogen comes from hydropower in Sarawak and becomes the lowest cost option overall around 2030 at 2.61 USD/kg H_2, dropping to below 2 USD by 2050. Due to its high capacity factor the hydropower is also a potentially competitive source for hydrogen exports; it is more suitable to combine with for example ammonia production as the more constant production profile of hydropower requires less electricity- or hydrogen storage to stabilize.
- Green hydrogen from solar is not expected to be cost competitive with the SEA average, but relatively close in terms of production cost. Hence it will likely not be suitable as an export option, but may still play an important role in the domestic market as it could be competitive with imported hydrogen. Due to the higher cost it primarily makes sense as a replacement for grey hydrogen production, potentially replacing blue hydrogen after 2030 as costs decline. For other purposes such as replacing natural gas for industrial high temperature heating and in power generation cost competition will be more severe and its potential is thus dependent on the availability and cost of alternative decarbonization routes.

Executive summary

Policy & Regulation

In order to unlock the potential for hydrogen in East and West Malaysia, a suitable policy framework is required. On a Federal level, Malaysia has an extensive policy framework in place to regulate its electricity market. The current framework provides a good basis for the development of renewables through the introduction of competitive market elements, renewable development schemes such as FiT and LSS, the recent introduction of a corporate PPA scheme and overall renewable development targets. However, despite this framework being in place the planned development of renewables in especially West Malaysia is relatively limited and subject to significant constraints that limit the size of individual projects, which is not conducive to hydrogen production. As a result, hydrogen related developments have remained limited. Due to a higher penetration level of renewables in combination with local ambitions developments in Sarawak are more advanced, e.g. the Samalaju Hydrogen Plant and the H2Biscus project. However, a lack of local policy direction and clarity on the stance regarding hydrogen on a Federal level may have an impact on the realisation of these projects. Based on best practices from international markets that are more mature in the development of hydrogen, several best practices have been identified that Malaysia may benefit from to unlock all four routes with market potential. These include:

- *Targets & mandates*: Targets on hydrogen production and use provide clarity regarding the expectations of the government on the long-term role of hydrogen production, which helps de-risk investments in hydrogen production. Mandates on the use of hydrogen serve a similar purpose through guaranteed offtake.
- *PPAs & Wheeling*: Required for green hydrogen production specifically. The major planned hydrogen production projects are not co-located with renewables, and thus require access to renewables via PPAs and wheeling agreements.
- *Carbon tax & allocation*: Required for blue hydrogen specifically. The business case for blue hydrogen compared to grey hydrogen depends on monetising decarbonisation, which should offset the added cost of CCS. This requires a form of carbon taxation, as well as carbon allocation which allows the captured and stored CO_2 to be subtracted from the emissions total of blue hydrogen production projects.
- *De-risking investment*: Specifically for carbon storage, which essentially has an unlimited storage duration for CO_2 (assuming it will not later be used for other purposes such as e-fuels). This type of storage is difficult for private parties to commit to without steps taken by the government to limit liability exposure.

In addition to these policies and regulations there are some general issues with hydrogen that will need to be addressed or considered within Malaysia before successful large-scale development can occur.

- *Additionality*: A requirement being discussed in European hydrogen legislation and certification, which essentially requires renewables used for hydrogen production to specifically be developed for hydrogen production and not be diverted from the electricity grid. If adopted in other hydrogen importing countries, this would limit the potential to use existing sources such as Sarawak hydropower.
- *Standards*: For large-scale hydrogen transport, hydrogen blending at higher percentages and the repurposing of natural gas infrastructure, technical standards will need to be developed and/or adopted. These are especially relevant in terms of safety and gas quality.
- *Permitting*: There is no clear permitting process in place for hydrogen currently, which can delay the development of hydrogen production projects and introduce risks that could potentially deter investments.

Executive summary

Assessing Potential Norwegian Opportunities

In order to assess the potential role of Norwegian companies, a gap analysis was performed of Norwegian capabilities in comparison to local Malaysian capabilities. For this a combination of desktop research and interviews with Norwegian companies was employed. The analysis was based on a list of companies active in hydrogen and CCS provided by Norwep in combination with a list of the top Norwegian renewable producers, which led to an overview of 52 companies active in hydrogen and 29 in CCS. These companies were labelled based on their role in the hydrogen value chain and their presence in Malaysia or SEA, which would likely make market entry in Malaysia easier.

Norwegian companies cover a large part of the hydrogen value chain, but with a larger amount of companies active in project development and hydrogen production equipment manufacturing. In CCS the focus is primarily on capture and transport. Presence in Malaysia is limited at 17% and 21% of companies respectively, with 58% and 62% respectively having no presence in SEA at all.

Several Malaysian companies have declared their interest in hydrogen and CCS development. Notable examples are Petronas as an existing hydrogen user that has acquired a hydrogen electrolyser manufacturer, TNB as potential producer and consumer of hydrogen for power generation, SESB as owner/developer of renewables for hydrogen production in Sarawak and PETROS who own gas fields planned to be used for carbon storage.

From a mapping of capabilities of Norwegian and Malaysian companies the primary opportunities for Norwegian companies have been determined:

- Green hydrogen: Manufacturing of hydrogen production equipment & system integration
- Blue hydrogen: Carbon capture, transport & storage

While Norwegian companies have a strong track record in renewables, as EPC or end-user these are more difficult roles to take in the Malaysian market due to local competition and requirements on knowledge of the market, regulation & language.

Based on interview sessions with Norwegian companies, several potential barriers have been identified and recommendations established for unlocking participation of Norwegian companies in Malaysia. The primary recommendations include:

- *Increased strategic clarity*: Sarawak in particular has seen a high degree of interest in its renewable resources, which can be used for hydrogen production as well as direct electricity exports and domestic decarbonisation. Pre-allocation of renewables to be used for hydrogen production can provide more clarity for future developers.
- *Stimulated hydrogen development*: The most important driver for hydrogen development is access to sufficient low cost renewables. There are currently concerns about both the volume and cost of such renewables, which can be addressed through further opening up of renewable markets, ensuring availability of PPAs/wheeling and potential stimulating measures such as reducing grid connection costs.
- *Facilitation*: Ensure that some of the pre-requisites for hydrogen development are met ahead of time that reduce development risks, such as pre-emptive network upgrades (especially in Sarawak) and smoother permitting processes

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Introduction

Introduction

Hydrogen production and demand are expected to increase significantly by 2030 and beyond to meet the targets set in the Paris Climate Agreement. While hydrogen is currently primarily used as an industrial feedstock, in the future it will likely play a significant role in decarbonizing hard-to-abate sectors such as aviation, shipping and heavy industry as well as having the potential to replace a portion of natural gas demand in sectors such as power generation to support the integration of the variable renewable electricity sources that drive the energy transition.

Due to the availability of renewables for green hydrogen production as well as natural gas in combination with carbon storage sites for blue hydrogen in Peninsular (West) and East Malaysia, interest in developing hydrogen production value chain has picked up in recent years. Additionally, Malaysia is home to a wide array of domestic and international companies that form a strong industrial base with the capability to contribute to the development of hydrogen value chains. However, despite the broad interest concrete developments have been limited and progress slower than in other countries with similar interests.

In this project, DNV is tasked to conduct a review and evaluate the possibility for hydrogen value chains in Malaysia from production through transportation to end use to identify where the primary potential lies and how this can be enabled. Additionally, DNV has been asked to look into the role that Norwegian companies could play in developing hydrogen value chains in Malaysia and what is required to unlock their contribution. The project will be broken down in a series of tasks.

Task 1 will provide insights into the feasibility, potential and likely costs of hydrogen within Malaysia. It will consider regional differences, such as West and East Malaysia to draw conclusions on the potential and development pathway. The analysis will focus on the availability of the different energy sources, the cost of hydrogen production, as well as where hydrogen may play a role in both regions. This will be made possible using regional estimates from the DNV ETO analysis, information from Malaysian government websites and in-house cost modelling which will be compared with regional SEA expectations. From there, DNV will indicate where the highest potential is for hydrogen use in Malaysia, categorised in scenarios.

Task 2 aims to outline and evaluate the policy and regulatory conditions regarding energy in West and East Malaysia, with a focus on bottlenecks that currently prevent the development of renewable and hydrogen projects. There will be an investigation on the current role of renewable and hydrogen in Malaysia that includes targets, development plans (active or planned) and policies directed towards these developments. One particular interest will be the current setup of the energy market in Malaysia and the changes required to enable the use of renewable electricity for on-site or off-site hydrogen production. Through knowledge from global practises and understanding on the Malaysian market, intervention polices such as enabling and required policies will be raised along the hydrogen value chain that is uniquely attached to each of the scenarios identified in Task 1.

Task 3 paints an overall picture on the Malaysian capabilities, work system and the challenges faced by foreign companies that wish to enter the Malaysia market. A sample of Norwegian companies with both global and local presence in their respective fields were interviewed regarding their views on the Malaysian market and what would be required for foreign companies to enter. Based on insights gathered a gap analysis was performed between Norwegian and Malaysian capabilities along the blue and green hydrogen value chains that identified areas where Norwegian companies could potential play a role. Recommendations are made based on an evaluation on the potential barriers faced by Norwegian companies and the essential policies from Task 2.

Task 1 – Market potential

Introduction – general approach

1
OVERVIEW OF TECHNOLOGIES

2
RESOURCE AVAILABILITY

3
COST MODELLING (LCOH)

4
MARKET POTENTIAL

This section reflects on the hydrogen market potential in Malaysia, in comprised of four steps in Task 1's approach:

1) **Overview of technologies** –providing an overview of technologies that are available to produce hydrogen within the hydrogen value chain.
2) **Resource availability** – identification of available resources corresponding to each hydrogen production technology on a regional level in Malaysia. Potential energy resources chosen are based on current installed capacity and potential growth of the sources.
3) **Cost modelling of levelized cost of hydrogen (LCOH)** – calculating the costs of hydrogen production from identified and chosen resources in Malaysia in the previous step with DNV's internal cost modelling tool.
4) **Market potential** – based on the costs calculated, an analysis on market potential was done - reflecting on the cost competitiveness and likely development pathway on hydrogen production in Malaysia. The reflection includes a qualitative assessment of whether there is potential to use the hydrogen produced domestically or have potential exports, and scenarios/possibilities on the role of hydrogen produced.

Introduction – hydrogen value chain

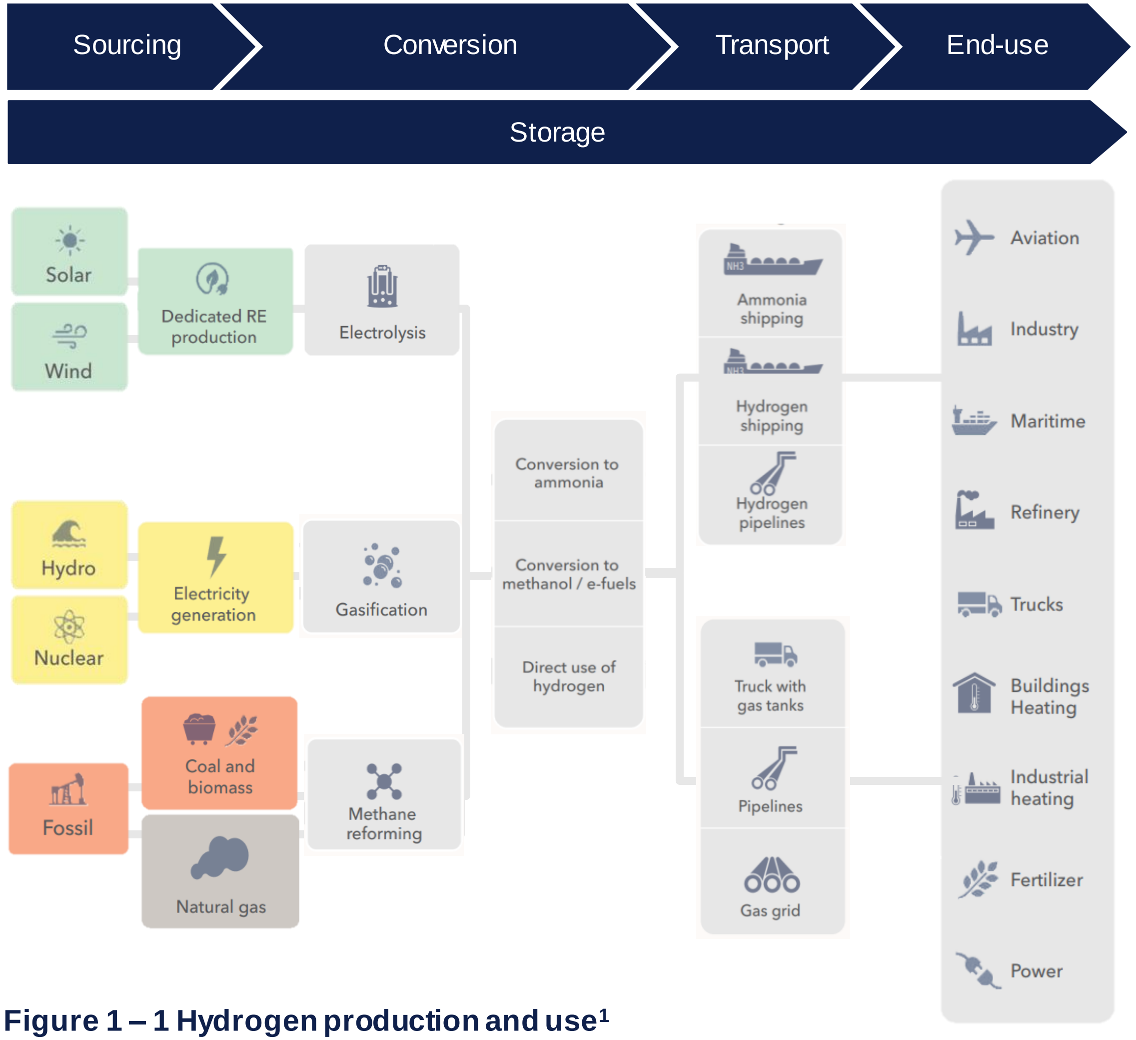


Figure 1 – 1 Hydrogen production and use[1]

To identify the market potential in Malaysia, it is important to first understand the hydrogen value chain and Malaysia's available resources to produce hydrogen. Overall, there are five steps in the hydrogen value chain:

- **Sourcing:** or also known as production, where primary energy sources (renewables/fossil fuels) are converted into gaseous hydrogen via feasible technologies (electrolysis/steam methane reforming/gasification).
- **(Re-) Conversion:** hydrogen (gaseous) produced is further converted into liquified hydrogen or hydrogen derivatives (ammonia, methanol, liquid organic hydrogen carriers (LOHC)). This is an optional step which allows a more economical transportation for longer distances.
- **Transport**: to deliver the hydrogen to end users, inter-regional or regional or local based on supply and demand. Options for transporting include shipping, trucks, and pipelines (dedicated hydrogen pipelines /repurposed gas pipelines/blending into existing gas grid).
- **End-use:** today hydrogen is used mostly in the industrial sector (ammonia production, chemicals, steel, refineries) and electricity generation. However, in the coming years its use for energy purposes such as heating and larger-scale transport will increase significantly.
- **Storage:** along the value chain, storage is typically required. For instance, prior to sending out and afterwards receiving the hydrogen (or hydrogen derivatives). Especially if it is produced from renewables which are intermittent. There are two options for storage; tanks or underground storage which provides a more central location at scale.

Demand wise, the need for hydrogen will grow significantly in the future as hydrogen will become one of the means to achieve energy independence and to increase the use of renewables. It is predicted that the demand for hydrogen feedstock would reach 195 MtH_2 /year by 2050, which is double the demand in 2020. Today's hydrogen production capacity is insufficient to meet this demand growth.

[1]*DNV. "HYDROGEN FORECAST TO 2050". 2022*

Introduction – ways of producing hydrogen

Table 1 – 1 The colours of hydrogen[1]

Category	Colour of hydrogen	Feedstock	Production technology
Produced using electricity	Green	Renewable electricity, water and/or steam by thermolysis	Electrolysis
	Yellow	Grid electricity, water	
	Pink	Nuclear electricity, water	
Produced using fossil fuels	Grey	Natural gas	Methane reforming
	Brown	Lignite	Gasification
	Black	Black coal	Gasification
	Blue	Natural gas or coal	Methane reforming or gasification with CCS
	Turquoise	Natural gas	Pyrolysis
	Green	Biogas or biomass	Reforming or gasification with or without CCS
Other	Red	Nuclear heat, water	Thermolysis
	Purple	Nuclear electricity and heat, water	Thermolysis or electrolysis
	Orange	Solar irradiance, water	Photolysis
	Green	Waste wood, plastic, municipal solid waste	Thermochemical

There are various ways to produce hydrogen, where each methodology has its own efficiency and environmental impacts. Based on the feedstock, production technology, and emission levels, the methodologies are classified into different colours (Table 1-1).

This report assumes a transition towards low-carbon hydrogen and focuses on the competitive position of production of low-carbon hydrogen from Malaysia. High carbon production technologies are therefore excluded from further study, as is nuclear due to an absence of the technology in Malaysia. As a result, the scope will focus on the following hydrogen production technologies:

Feedstock | **Production Technology**

Renewables → **Electrolysis**

i.e. Solar PV, Wind, Hydropower

Breakdown of water with electricity into hydrogen and oxygen.

Natural Gas → **Methane Reforming with CCS**

Heating of natural gas (CH_4) with steam, producing a mixture of hydrogen and carbon monoxide. Carbon capture storage (CCS) is used to capture the carbon emissions produced.

Biogas/biomass → **Reforming/Gasification**

A chemical process which converts biomass into hydrogen with heat, steam, and oxygen at high temperatures without combusting the feedstock.

[1]*DNV. "HYDROGEN FORECAST TO 2050". 2022*

Identification of potential energy sources for hydrogen

Identifying potential energy sources for hydrogen production is done per region, where potential energy sources are chosen based on two metrics; 1) Current installed capacity per region (Table 1 – 2) and; 2) Potential growth in Malaysia; whether there are any plans to further develop the energy sources based on the availability and quality. This culminates in a filtering of sources per region that will be used in the cost modelling

By 2019, Malaysia's installed renewable energy capacity is dominated by hydro (6,190 MW), Solar PV (1,056 MW) and biomass (440.6 MW) – with very little wind power due to energy resources constraint, whereas Malaysia's annual wind speed is lower than 2 m/s. Overall, primary energy supply in Malaysia is dominated by natural gas (domestic production), followed by coal[2]. There are three regions in Malaysia, where each region maps to its own subsystem;

- **Peninsular Malaysia** - operated by Tenaga Nasional Berhad (TNB) and is the main part of Malaysia's power grid, with a peak load of 18.8 GW;
- **Sarawak** - operated by Sarawak Energy Berhad (SEB) and is a smaller grid compared to Peninsular Malaysia (peak load 5.5 GW), with its generation profile mainly coming from hydro and coal. It has 3 hydropower plants – Bakun (2400 MW), Murum (944 MW) and Batang (108 MW). Another hydropower plant is currently being built and is expected to operate by 2028 (Baleh, 1,285 MW). There is currently no utility-scale PV installed in Sarawak, but there are plans to install solar PV plants.
- **Sabah** - operated by Sabah Electricity Sdn, Bhd (SESB) which is the smallest grid system (peak load 1.0 GW) with its generation dominated by gas. The hydropower generation in Sabah is less than 100 MW and is not suitable for further hydrogen production;

Overall, the resources identified are natural gas, hydropower, and solar (Table 1-2).

Available, or small size but plans to expand

Small size and limited scaling potential/plans

Table 1 – 2 Available resources* for hydrogen production

Region	Solar	Wind	Hydropower	Biomass	Natural Gas
Peninsular Malaysia	948.6 MW		2,642 MW	157.9 MW	12,237 MW
Sarawak	To be installed	Annual wind speed in Malaysia is <2 m/s	3,458 MW	221.0 MW	972.6 MW
Sabah	107.6 MW		89.6 MW	61.7 MW	1,193 MW

***Installed capacity is based on Malaysia Energy Statistics Handbook, 2020**

[2]Suruhanjaya Tenaga (Energy Commission)."*Malaysia Energy Statistics Handbook*". 2020 link: https://meih.st.gov.my/documents/10620/23817e60-6b26-4dab-9b82-2c106a661aeb

Identification of potential energy sources for hydrogen

The following potential resources were are chosen for further modelling based on current installed potential, availability, and potential for further development;

- Natural gas resources - Malaysia has access to domestic and imported natural gas resources, which sees broad utilization throughout all three areas.
- Hydropower - Malaysia has a large hydropower capacity installed in both Peninsular Malaysia and Sarawak and it is therefore a potential resource. The hydropower capacity and potential in Sabah are low, because of which it will be excluded from the cost modelling.
- Solar PV – Compared to hydropower the existing installed capacity of Solar PV is limited. Another 1,098 MW of solar capacity is required by 2025 to meet the targets in Malaysia Generation Plan, so additional development is expected in the next few years (more details on Malaysia's RE targets on Task 2). Due to the planned capacity in combination with the high potential for Solar PV inclusion in the cost analysis is warranted.

Although there is a decent amount of biomass potential (referred as bioenergy in Figure 1 – 2), is will not be included in the further cost analysis. The reason for this is that biomass availability is typically highly decentralized and therefore more suitable for smaller scale local applications instead of large scale installations required for hydrogen production. Wind energy has not been included in the analysis due to the low wind speeds across the country.

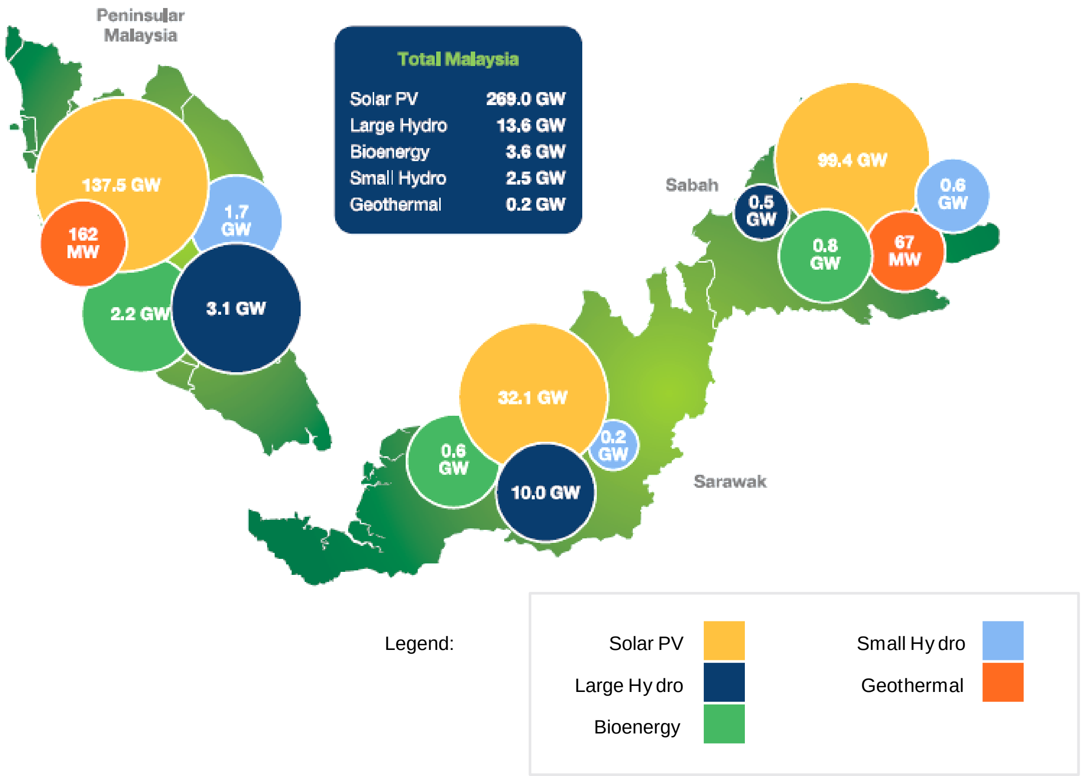


Figure 1 – 2 Summary of RE resource potential in Malaysia

[Source: Malaysia Renewable Energy Roadmap – Malaysian Photovoltaic Industry Association (mpia.org.my)]

DNV

Hydrogen production costs – Methodology

Having identified potential resources, the next step is to calculate the hydrogen production costs. To do so, an in-house production cost model has been used. This model was also used for DNV's Hydrogen Forecast to 2050, and was built based on several assumptions on technology and financial aspects such as product development and learning rates.

Input

Feedstock prices, production costs and technology, learning factors

→

In-house Hydrogen Cost Model

→

Output

Levelized Cost of Hydrogen (LCOH)

For this study, the model is further adjusted for the South East Asia (SEA) region and Malaysia's three regions (Peninsular Malaysia, Sarawak, and Sabah) for the selected technologies based on the previous identified resources – which are methane reforming, solar PV electrolysis, and hydropower electrolysis.

The results of the model provide the levelized cost of hydrogen (LCOH) including a breakdown of the costs. Based on this results, it can be identified which sources have a lower LCOH projection compared to the region (SEA)'s average - and therefore offer a potential market opportunity.

In addition, a sensitivity analysis has been conducted on gas prices, carbon prices, and operating hours/year of each technology to see which inputs influence the results the most and by how much.

Global Assumptions

- H_2 production CAPEX, OPEX & efficiency
- Methane reforming operating hours
- Asset lifetimes
- Feedstock & emission intensities

Regional (SEA)

- CCS, Electrolyser, Hydropower CAPEX & OPEX
- Solar and Hydropower Capacity Factor (SEA average)
- Financial Assumptions
- Learning rates & performance improvements for hydrogen production and renewable production

National (Malaysia)

- Price of natural gas
- Carbon tax
- Solar CAPEX & OPEX
- Solar and Hydropower Capacity Factor (per region in Malaysia)

List of assumptions and its sources can be found in the Appendix.

Hydrogen production costs – Results

- Methane reforming with CCS

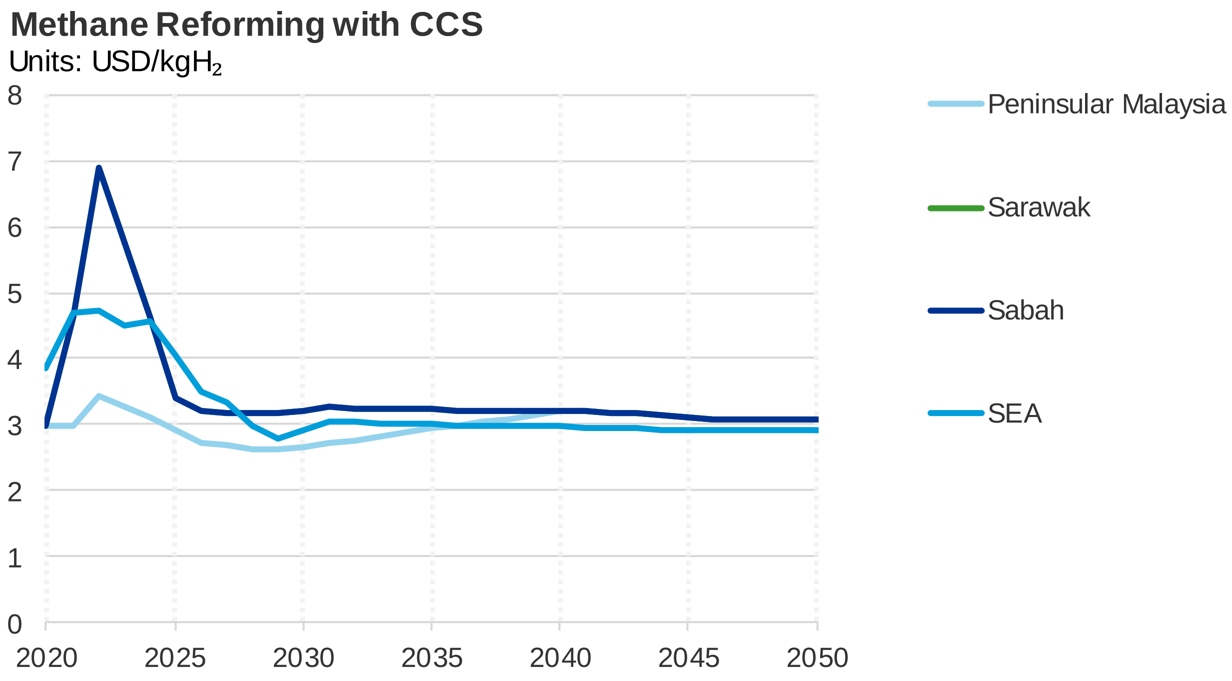


Figure 1 – 3 LCOH projection with methane reforming with CCS per region

The LCOH from methane reforming highly depends on the gas and carbon prices used as the input, and therefore future prices are a key assumption made in this modelling, listed below;

- Historical gas prices in Peninsular Malaysia are based on the historical Malaysia Reference Price (MRP);
- Sarawak and Sabah are based on PLATTS Japan – Korea marker (JKM) price since there are existing LNG exports from Sarawak to Japan;
- Future projected gas prices are based on the Henry Hub short and long term outlook trend factor, with the additional assumption that the price drop from current to future prices wouldn't be more than 25% of the gas prices in 2022. For Peninsular Malaysia, it is additionally projected that the gas prices will converge into international prices in 2030 – 2040 due to depleting domestic resources and increased reliance on LNG imports.
- In this cost modelling exercise, no carbon prices are assumed for Malaysia, but are included for the SEA region;

From the results, it can be seen that Peninsular Malaysia offers the lowest LCOH, before it converges into international prices. However, both Sarawak and Sabah are expected to remain more expensive than gas prices in Peninsular Malaysia due to high gas prices in Japan. In the longer term, the SEA region has a slightly lower LCOH compared to Malaysia since there are countries that have access to domestic gas production, resulting in a lower gas prices and hence lower LCOH.

[3]Henry Hub's Short Term Outlook. Link: https://www.eia.gov/outlooks/steo/report/natgas.php
[4]Henry Hub's Long Term Outlook Link: https://www.eia.gov/outlooks/aeo/data/browser

DNV

Hydrogen production costs – Results

- Dedicated solar PV electrolysis

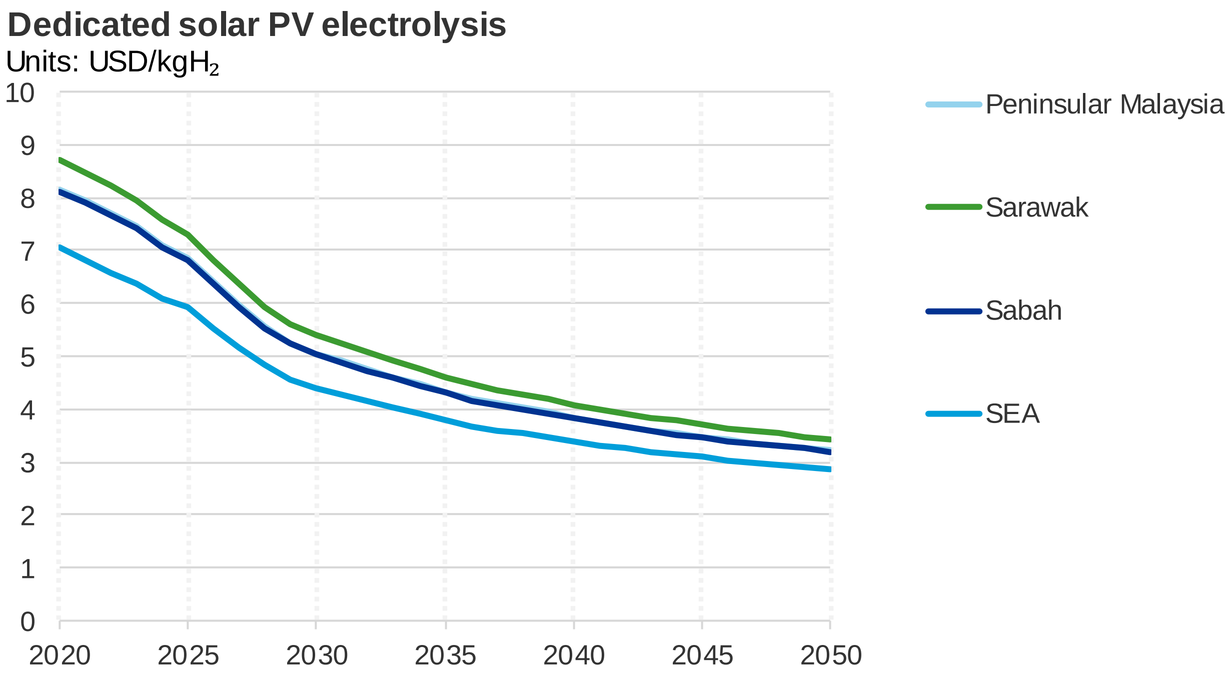


Figure 1 – 4 LCOH projection with dedicated solar PV electrolysis per region

For solar-powered electrolysis, prices are currently still high since it is a fairly new (nascent) technology. However, prices are expected to reduce significantly in a relatively short time frame due to the combination of economies of scale, projected cost reductions due to technology development, and increasing performance.

Table 1 – 3 Expected solar operating hours (capacity factor)

Expected Solar Operating Hours	Unit	2020	2030	2050
Peninsular Malaysia	hr/yr	1,762	1,871	1,966
Sarawak	hr/yr	1,612	1,711	1,798
Sabah	hr/yr	1,772	1,881	1,977

The assumed capacity factors (Table 1 – 3) per region in were based on expected solar operating hours (P50) and hydropower from internal DNV data, incorporating the expected learning trend at the region for future capacity factors.

Upon comparing each region's LCOH, the operating hour or capacity factor of the solar PV is the factor which differentiates the price outcome. For instance, Sarawak has the highest LCOH price due to lower operating hours compared to the other regions. Overall, Malaysia's solar capacity factor is at the range of 16 – 20%, whilst the SEA region capacity factor is 25%. As a result, Malaysia's LCOH is more expensive than the SEA average projected LCOH prices using dedicated solar PV electrolysis.

Hydrogen production costs – Results

- Dedicated hydropower electrolysis

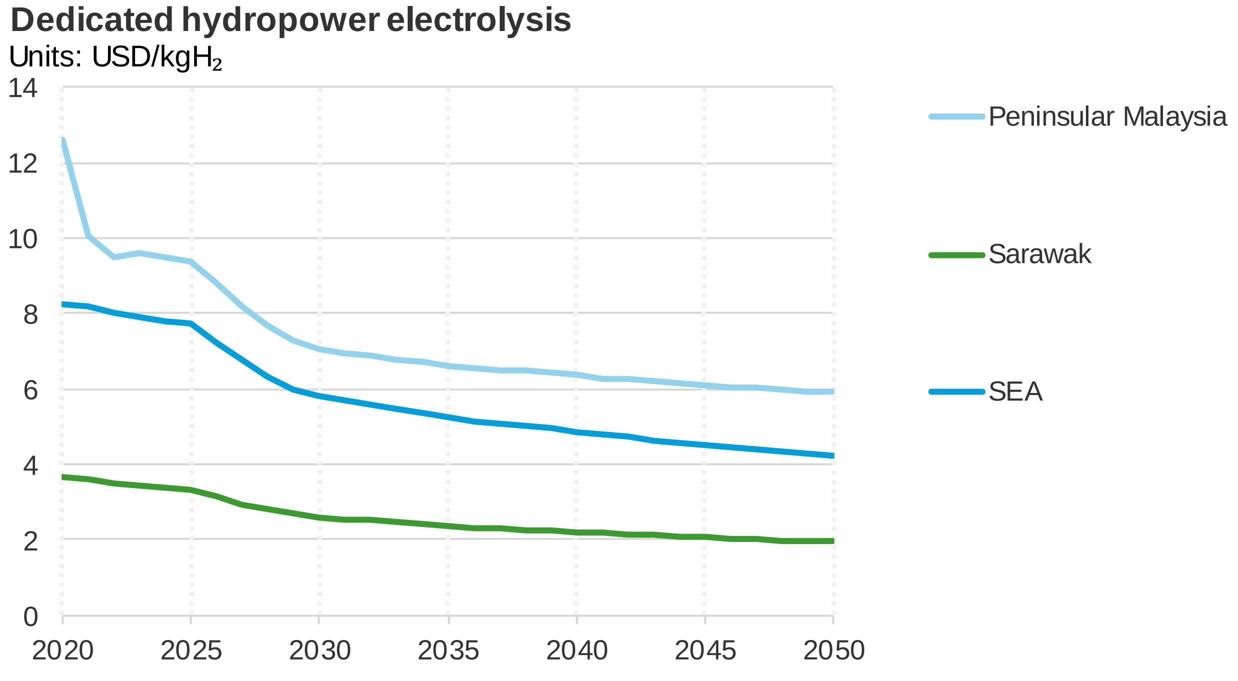


Figure 1 – 5 LCOH projection with dedicated hydropower electrolysis per region

For hydro-powered electrolysis, the LCOH projected depends highly on the CAPEX price and operating hours of the hydropower. In this model, the CAPEX price is assumed the same and constant for all regions, and so the determining factor is the operating hours of the hydropower.

To use dedicated hydropower electrolysis, developers would most likely be bounded by PPA for practicality – considering long timelines of investing and developing new hydropower plants and availability of suitable sites.

Table 1 – 4 Expected hydropower operating hours (capacity factor)

Expected Solar Operating Hours	Unit	2020	2030	2050
Peninsular Malaysia	hr/yr	1,731	1,895	1,895
Sarawak	hr/yr	6,953	6,772	6,772

The capacity factor in Peninsular Malaysia was based on Single Buyer's hourly profiles[5] while in Sarawak was an estimation based on DNV's understanding of the local hydropower assets (Table 1 – 4). Sarawak has a high capacity factor (75 – 80%) for hydro due to its topographic features and high rainfall. As a result, Sarawak hydropower has the lowest LCOH projection, the price is projected to be 3.66 USD/kgH_2 in 2020 and will decrease along with learning rates to 1.95 USD/kgH_2 by 2050.

However, Peninsular Malaysia's hydropower capacity factor is lower than Sarawak (20 – 25%) and the SEA average of 34%, and therefore projected costs are higher than for Sarawak. Roles of hydropower in both regions also differ, where in Sarawak hydropower plays an important role in power generation (80% of the total installed generation capacity) while in Peninsular Malaysia coal is more dominant and the hydropower reserves are also mainly used for flood control, irrigation, and water supply, or even as tourist area such as the Kenyir dam.

[5]Single Buyer. "*Hourly Generation Profiles*". link: https://www.singlebuyer.com.my/resources-dispatch-schedule-aggregate-monthly.php

Hydrogen production costs – breakdown analysis

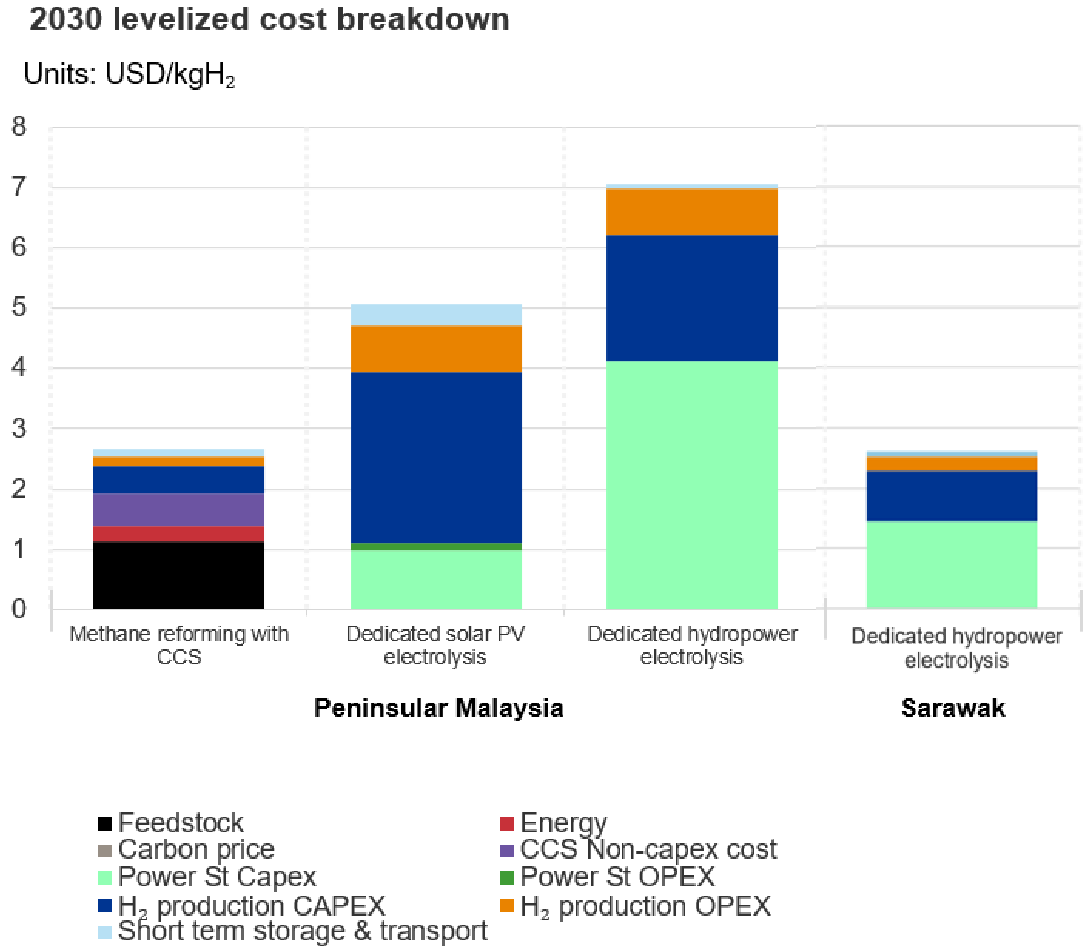


Figure 1 – 6 LCOH breakdown in 2030

Each technology has different cost elements, where the hydrogen production technology CAPEX is a contributing major factor across all technologies. Figure 1 – 6 shows Peninsular Malaysia's LCOH breakdown and per technology and Sarawak's hydropower LCOH breakdown as a reference.

- **Methane Reforming with CCS:** the feedstock price which is natural gas price contributes the most to the cost breakdown, followed by the CCS non-capex costs, gas hydrogen production CAPEX (which includes CAPEX for CCS) and OPEX for hydrogen production (methane forming).
- **Dedicated solar PV electrolysis**: the hydrogen production CAPEX (electrolyser in this case) is the highest cost element, followed by power station CAPEX (the solar PV and balance-of-system), hydrogen production OPEX, solar PV OPEX, and short term storage & transport.
- **Dedicated hydropower electrolysis:** here, the most contributing costs would be the (hydropower) power station CAPEX instead, followed by the hydrogen production CAPEX (electrolyser) and the OPEX. The same applies to Sarawak for cost components contribution, but the total LCOH is less than USD 3/kgH_2.

Cost influences in Malaysia to take into account

- **Power Cost** - Cost of electricity is a key driver for the green hydrogen LCOH, especially in case of hydropower where it amounts to >50% of overall costs. Sensitivity is reduced for solar PV electrolysis due to lower capacity factors.
- **Additional Generation Capacity** – Sarawak has an upcoming new hydropower plant (Baleh, 1,285 MW). This would potentially result in energy surplus which could be used for green hydrogen development.

Hydrogen production costs – Comparison to SEA

Table 1 – 5 compiles the LCOH costs calculated by the model per technology and region, where it can be seen for the SEA region, utilizing methane reforming would be the cheapest option, followed by solar PV electrolysis and hydropower as the most expensive option.

In comparison with SEA, there are **export opportunities in Malaysia to utilize Sarawak's high hydropower capacity factor in the long-term** and **methane reforming in Peninsular Malaysia (for short-term only)** before gas prices converge to international prices. Overall, the most cost competitive LCOH is hydropower electrolysis from Sarawak. On the other hand, the most expensive would be hydropower electrolysis in Peninsular Malaysia, followed by solar powered electrolysis in all regions. Although LCOH is expected to decrease along with learning factor and price trends, the LCOH is slightly more expensive than SEA's average. Considering the **solar powered LCOH is similar but slightly above the SEA average, it can be competitive but only for domestic use.**

Table 1 – 5 LCOH (USD/kgH_2) available resources* for hydrogen production

LCOH (USD/kgH_2)	2020	2022	2025	2030	2035	2040	2045	2050
Methane Reforming								
Peninsular Malaysia - Methane Reforming with CCS	2.98	3.44	2.91	2.66	2.94	3.21	3.11	3.07
Sarawak - Methane Reforming with CCS	2.98	6.90	3.40	3.22	3.24	3.21	3.11	3.07
Sabah - Methane Reforming with CCS	2.98	6.90	3.40	3.22	3.24	3.21	3.11	3.07
SEA - Methane Reforming with CCS	3.85	4.72	4.06	2.92	3.02	2.97	2.93	2.92
Dedicated solar PV electrolysis								
Peninsular Malaysia - Solar	8.17	7.70	6.85	5.05	4.31	3.83	3.48	3.22
Sarawak - Solar	8.72	8.22	7.31	5.39	4.60	4.08	3.70	3.42
Sabah - Solar	8.13	7.66	6.81	5.03	4.29	3.81	3.46	3.20
SEA - Solar	7.04	6.59	5.92	4.39	3.78	3.38	3.08	2.86
Dedicated hydropower electrolysis								
Peninsular Malaysia - Hydro	12.57	9.49	9.36	7.06	6.61	6.35	6.10	5.90
Sarawak - Hydro	3.66	3.49	3.35	2.61	2.37	2.21	2.06	1.94
SEA - Hydro	8.24	8.04	7.73	5.81	5.24	4.87	4.52	4.23

Legend: **Price competitive (lower than SEA region)**

Hydrogen production costs – sensitivity analysis

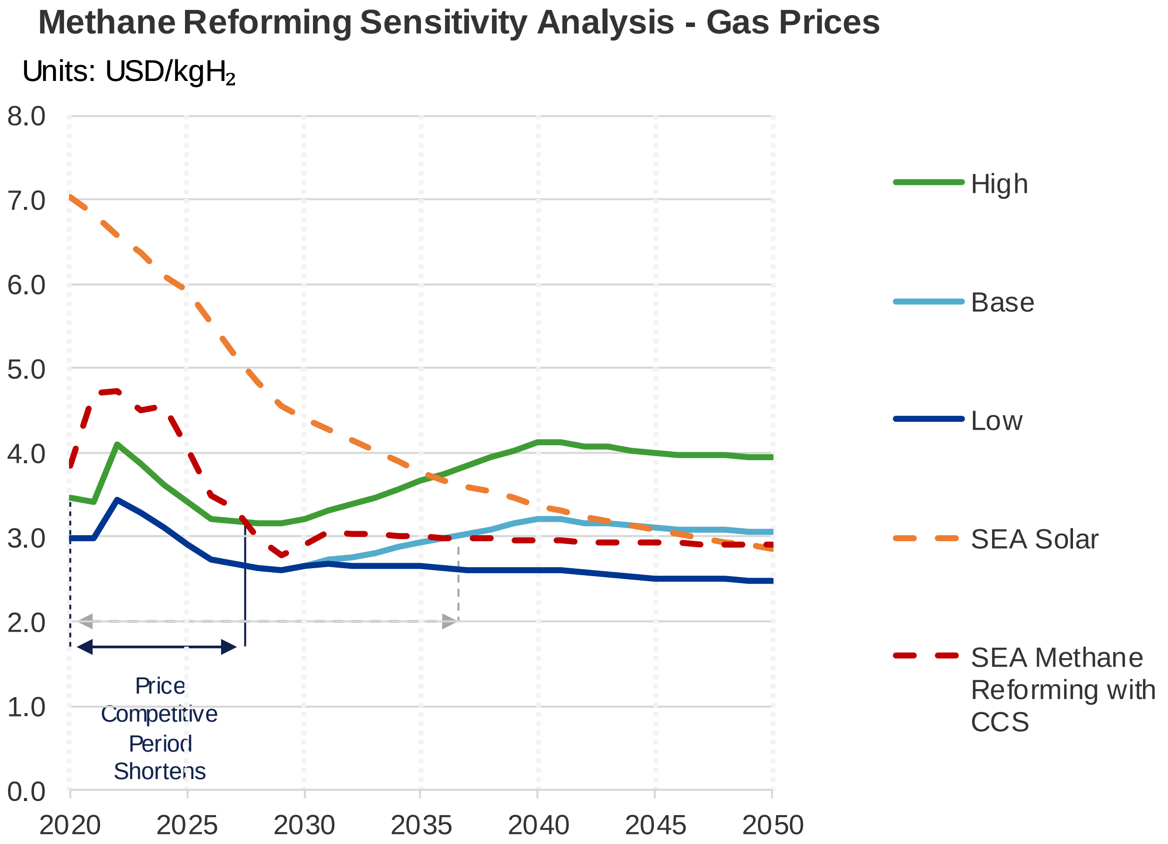


Figure 1 – 7 LCOH Gas Prices Sensitivity Analysis at Peninsular Malaysia for Methane Reforming with CCS

A sensitivity analysis has conducted on several contributing cost parameters namely; gas prices, carbon prices, CAPEX & OPEX (of electrolyser and also PV/hydro), operating hr/year. The results show that gas prices and operating hours are the two most influencing parameters (refer to Appendix for details of the analysis).

Hence, it is good to note that due to these influencing parameters, the mentioned short-term and long-term opportunities in Malaysia might not be as cost competitive as previously projected.

- **Peninsular Malaysia – Methane Reforming with CCS**

If gas prices are higher than 50% of the assumed prices (high case), the LCOH from steam methane reforming in Peninsular Malaysia will only be cost competitive (lower than SEA's average) for a shorter period. It will be cost competitive only up to 2027 instead of 2035 where prices start to converge to international prices (Figure 1 – 7).

Even when compared to SEA's average LCOH with solar power electrolysis, at the high scenario the LCOH from solar energy would be lower by 2035 already.

On the opposite, if prices in Peninsular Malaysia do not converge (low case), the prices would stay competitive for the long-term.

Hydrogen production costs – sensitivity analysis

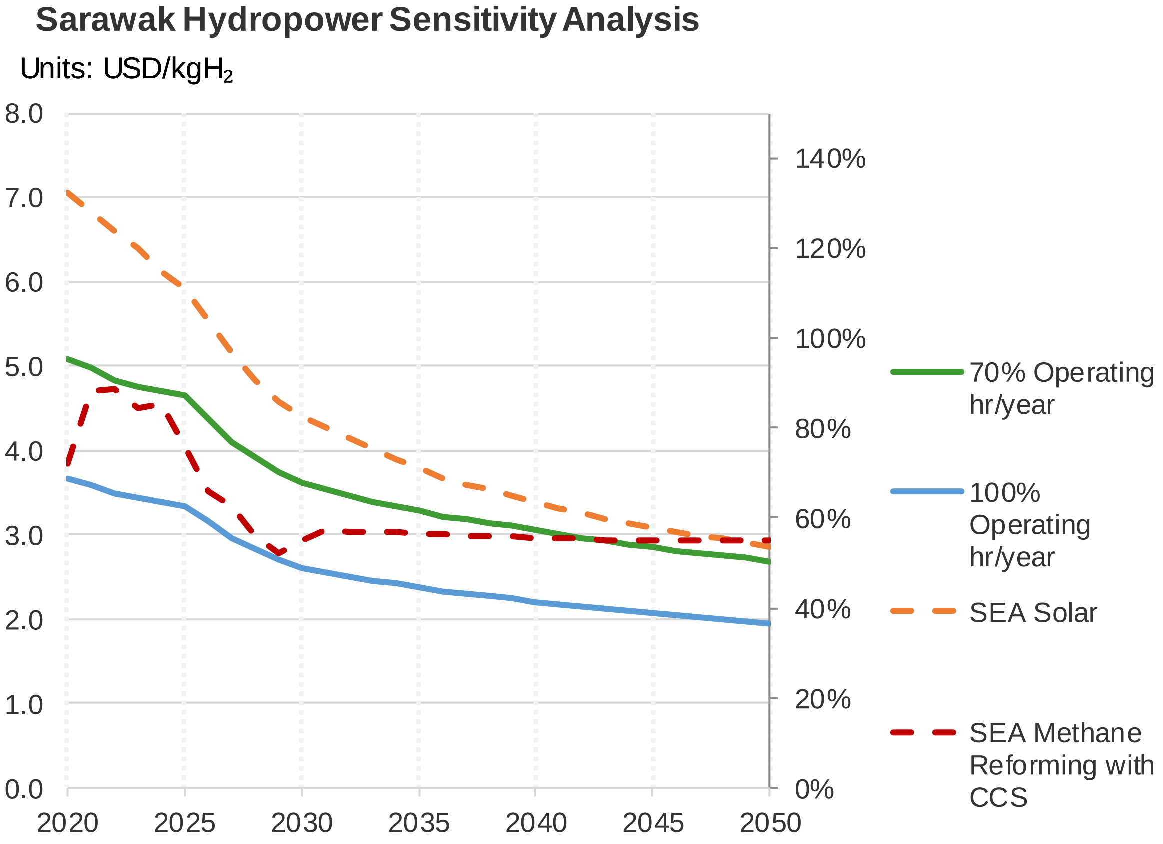


Figure 1 – 8 LCOH Hydropower Operating hr/year Sensitivity Analysis at Sarawak for Dedicated Hydropower Electrolysis

- **Sarawak - Dedicated hydropower electrolysis**

Operating hours/year is an influencing parameter for hydropower electrolysis's LCOH. With an operating hr of 70% from current data, Sarawak's dedicated hydropower electrolysis will no longer be price competitive. Instead, it will be more expensive than SEA region's blue hydrogen from steam methane reforming with CCS (Figure 1 – 8).

Therefore, both gas prices and operating hours/year (capacity factor) of hydropower is an critical parameter to be checked prior to investments in hydrogen production opportunities.

Market potential - Summary

Based on the resources availability and LCOH cost modelling, there are 4 possibilities where Malaysia could be able to produce hydrogen in a cost competitive manner:

	Hydrogen Production	Product	End-use
1	**Sarawak** Dedicated hydropower electrolysis	**Green** Hydrogen	**Towards 2030 and onwards** • Global Export Potential
2	**Peninsular Malaysia** Steam Methane Reforming with CCS	**Blue** Hydrogen	**Towards 2030** • Grey Hydrogen Replacement (domestic and export potential to nearby countries)
3	**Malaysia (All regions)** Dedicated solar PV electrolysis	**Green** Hydrogen	**Towards 2050** • Grey Hydrogen Replacement
4	**Malaysia (All regions)** Dedicated solar PV electrolysis	**Green** Hydrogen	**Towards 2050** • Fuel Replacement

A deeper dive on each likely pathway are discussed in the following slides.

Market potential - Scenarios

Based on the resource availability and LCOH cost modelling, there are 3 types of hydrogen production technology considered 1) Methane Reforming with CCS, 2) Dedicated Hydropower Electrolysis; and 3) Dedicated Solar Power Electrolysis. From there, suggested timeline, potential market, and hydrogen role scenarios where Malaysia is able to produce hydrogen in a cost competitive manner is explored (Table 1-6). LCOH price that is lower than SEA's region average is an export potential as the price can compete with other sourcing countries within the region. However, several production technologies have different characteristics (i.e. solar PV is intermittent while the others not, resulting in different potential roles in the market).

Table 1 – 6 Hydrogen market potential and role for each available technology in Malaysia

Production Technology	Projected LCOH	Potential Region in Malaysia	Timeline	Potential Market	Potential Roles of Hydrogen
Dedicated Hydropower Electrolysis	• Lower than SEA Region Average • 2030 projected price: 2.61 USD/kgH_2 • 2050 projected price: 1.94 USD/kgH_2	Sarawak	Long-term Towards 2030 and onwards	• Export (i.e. as ammonia) for feedstock and energy purposes	Sarawak's LCOH prices indicate that there could be export potential as the price can compete with other producing countries within the region in the long term. As transport of the produced hydrogen will likely take place by ship via ammonia or liquid hydrogen, the focus should primarily be on countries that have limited access to domestic renewables and no viable pipeline connection to a country that can export hydrogen at a large scale, such as South Korea or Japan. High capacity factor of hydropower plants in Sarawak results in a competitive LCOH projection at almost 2 USD/kg H_2, which is comparable with predicted competing green hydrogen costs globally (2-3 USD/kg H_2 (S&P Global Platts, 2021). The projected cost is lower than the average costs across the SEA region, indicating a long-term opportunity for low cost green hydrogen production. This price is subject to the long lifetime assumed for hydropower (with no reinvestment CAPEX) and stable capacity factor. Since hydropower electricity is not intermittent and the Sarawak source has a high capacity factor, it is more suitable for converting into green ammonia than projects utilizing solar and wind, which will be dependent on a grid connection or large scale battery storage to create a steady profile that ammonia production equipment typically needs. Ammonia production is typically a continuous process plant that doesn't allow for any shutdowns, though more flexible ammonia production technologies are in development. The converted green ammonia can be then shipped, which is a preferred transporting methodology for distances > 2,000 km. Challenges involved in using hydropower for electrolysis would be repurposing current hydropower plants for hydrogen production, and ensuring that there is still sufficient hydropower for Sarawak's strategic reserves and still serves its main function for power generation.

Market potential - Scenarios

Table 1 – 6 Hydrogen market potential and role for each available technology in Malaysia (continued)

Production Technology	Projected LCOH	Potential Region in Malaysia	Timeline	Potential Market	Potential Roles of Hydrogen
Methane Reforming with CCS	• Lower than SEA Region Average • 2030 projected price: 2.66 USD/kgH_2 • 2050 projected price: 3.07 USD/kgH_2	Peninsular Malaysia	Short-term Towards 2030	• Grey hydrogen replacement in domestic market and export potential to nearby countries	In the near future, installing CCS at existing methane reforming plants can be an initial step to take, replacing grey hydrogen with blue hydrogen within the domestic market. However, this would require the additional cost of CCS to be offset by some form of benefit and willingness from the Malaysian government to use low-cost natural gas for this purpose. With a short-term cost opportunity resulting from production costs below the SEA projected average due to low gas prices, there is a potential for exporting hydrogen to nearby countries that are willing to pay a premium for low-carbon hydrogen. The list of exporting countries is limited to those that can cost-effectively be reached by pipeline, as well as those that can accept a baseload production profile (e.g. industrial offtakers) due to limited flexibility in production from steam methane reforming (SMR) and the lack of resources for large scale hydrogen storage in Malaysia. An example of a nearby country that can function as a potential offtake market is Singapore, who has included hydrogen as its strategy for decarbonisation. Demand wise, hydrogen can be used either as energy purposes or feedstock. In the near future (up to 2030) it is projected (DNV hydrogen outlook, graph provided in Appendix as well) that the demand within SEA will be dominated by refineries and ammonia & chemicals production and not energy purposes, making this a more likely short-term route. Additionally, there are concerns about using blue hydrogen for power generation as it provides limited decarbonisation while increasing natural gas use, which comes with high (unquantified) upstream emissions from e.g. methane leakages.

Market potential - Scenarios

Table 1 – 6 Hydrogen market potential and role for each available technology in Malaysia (continued)

Production Technology	Projected LCOH	Potential Region in Malaysia	Timeline	Potential Market	Potential Roles of Hydrogen
Dedicated Solar-power Electrolysis	• Slightly above the SEA Region Average • 2050 projected price: 3.22 USD/kgH_2	Peninsular Malaysia, Sarawak, Sabah (all)	Long-term Towards 2050	• Domestic as low-carbon feedstock (Grey hydrogen replacement)	By 2050 the LCOH of dedicated solar PV electrolysis would be competitive. However, unlike hydropower, the projected LCOH in Malaysia is slightly higher than the SEA's region average due to Malaysia's solar irradiance. Exports of the green hydrogen obtained would struggle to compete with other countries within the region (e.g. Thailand) with higher solar irradiance. However, as the cost difference is limited there is still a potential case for domestic use of the produced hydrogen due to savings on import infrastructure. Since there are no concrete plans for hydrogen use for energy purposes in Malaysia, and because it is easier to reach cost competitiveness, the logical primary case is replacement of grey hydrogen for industrial use. However, as Malaysia does not have access to large scale underground hydrogen storage the viability of this case will be highly dependent on the alignment of hydrogen production from variable solar resources with demand and the cost of balancing said supply and demand which may prove to be a bottleneck in the future.

DNV

Market potential - Scenarios

Table 1 – 6 Hydrogen market potential and role for each available technology in Malaysia (continued)

Production Technology	Projected LCOH	Potential Region in Malaysia	Timeline	Potential Market	Potential Roles of Hydrogen
Dedicated Solar-power Electrolysis	• Slightly above the SEA Region Average • 2030 projected price: 5.05 USD/kgH_2 • 2050 projected price: 3.22 USD/kgH_2	Peninsular Malaysia, Sarawak, Sabah (all)	Long-term Towards 2050	• Domestic as low-carbon feedstock (fuel replacement)	To achieve decarbonisation towards 2050, hydrogen is predicted to play a role in the replacement of fuels in hard to abate sectors, especially power generation and industrial high temperature heating. In this scenario hydrogen will replace existing fuels such as natural gas, which may become feasible if natural gas prices rise. However, while industrial demand can potentially be served point-to-point the use of hydrogen for energy purposes will require a larger interconnected (inter)national network with either flexibility in production to match demand or access to large scale storage, neither of which Malaysia appears to have. It is therefore uncertain if this case will become economically viable in comparison to imports. For transportation certain use cases may exist such as long-distance trucking, though electrification is more likely. In other sectors such as Aviation (SAF) or Maritime (ammonia/methanol) it is unlikely that Malaysia can be cost competitive in production compared to e.g. Australia due to lower impacts of transport cost.

The scenarios reflected are likely pathways for role of hydrogen produced in Malaysia. Yet, the mentioned market potential scenarios have several associated circumstances and conditions, especially from the regulatory side such as requirement for incentives to replace grey hydrogen with blue hydrogen.

Therefore, the next section task 2 will take a look on Malaysia’s condition (electricity market and relevant regulations). Following that, a gap analysis was conducted to identify what barriers exist and what future enablers are required from the regulatory framework perspective to have observed potential scenarios happen in the future.

Task 2 – Conditions and Regulatory Framework

Introduction – general approach

In Task 1, potential scenarios for hydrogen in the energy system in Malaysia and East Malaysia were identified. The aim of this section is to look into the current energy framework of Malaysia and identify the potential regulatory barriers that might affect the key choices identified in the previous section and provide recommendations based on international best practice for hydrogen early market development.

Malaysia energy market overview – This provides an overview on the Malaysian energy market structure, the drivers on the market as well as the major players involved

Policies and plans – Providing an overview on relevant regulations and policies in the Malaysian energy market for Peninsular Malaysia and East Malaysia on the energy and gas market

Renewable status and targets – Providing an overview of the current renewable energy mix and state's targets in Peninsular Malaysia and East Malaysia

Hydrogen developments – Existing and upcoming updates on the actions and development on hydrogen in Peninsular Malaysia and East Malaysia

Barriers affecting potential options – Gaps in the existing regulation and policies are identified that will likely affect the hydrogen value chain pertaining to the likely scenarios identified in Task 1.

Policy intervention on barriers – Based on barriers identified, policy interventions will be categorised into policies that are already available, and the enabling and required policies that will likely be needed along the value chain to address the barriers. Recommendation to address barriers will be addressed in Task 3 upon seeking insights with selected Norwegian companies.

- Potential options for hydrogen development in Malaysia
- Malaysia energy market overview
- Regulation and Policies
- Renewable Status and Targets
- Hydrogen development
- Barriers affecting potential options
- Policy intervention to address barriers

Overview of Malaysian energy market – Electricity

Electricity (Series of development)

Tenega Nasional Berhad (TNB) held major power over the electricity supply industry in Malaysia in the past, that covered the scope of generation, transmission and distribution. Over time, the Malaysian energy market has been gradually liberalised with Suruhanjaya Tenega (ST) - awarding power plant projects to companies through a mix of direct awards and competitive bidding. The government of Malaysia maintains absolute discretion in awarding these projects.

Current energy sector framework in Malaysia is based on a single buyer model. IPPs and TNB power generation are responsible for generating electricity, which is sold to TNB (Peninsular Malaysia), Sarawak Energy (Sarawak) and Sabah Electricity (Sabah). These parties lead the distribution and retail sales of electricity in their respective jurisdictions. On the grid side, TNB operates the electricity transmission network (National Grid) in Peninsular Malaysia. The electricity grid that supplies power in Sabah is owned by SESB (partly owned by TNB and partly owned by Sabah state government) while the grid in Sarawak is operated by SEB.

In the recent years, there is push for increased use of renewable energy by the government through a series of large scale solar projects (2016 - 2020) which contributed significantly to the renewable energy capacity (RE contributed 23% to national installed power capacity - 2020). The latest fourth LSS bidding cycle saw the shortlist of bids for the development of solar farms, with projects estimated to commission in late 2022 or early 2023. However, actual project developments from the LSS 1-4 schemes are limited and progress has been slow since the first round started in 2016. As of Q4 of 2020, only 52% were operational.

The introduction of the New Enhanced Dispatch Arrangement (NEDA) in 2015 allows IPPs to supply power to the National Grid without the need to enter into a PPA. NEDA aims to reduce energy prices through a wholesale market via bidding by qualified participants. The introduction of virtual PPA under the Corporate Green Power Programme (CGPP) in 2022, with a quota of 600MW, also aims to upscale RE capacities. Those who successfully subscribe to the vPPA quota will proceed to apply as a NEDA participant, where excess electricity can be sold into the NEDA market. However, one of the eligibility criteria for a solar power plant to qualify for the vPPA is having export capacity of 5-30MW, which prevents the development of large scale projects under this scheme.

The Malaysian market also imposes limitations in ownership in power projects, with ownership or equity limitations typically set out in the terms and conditions of licenses and other approvals or in PPAs signed between IPPs and TNB. Currently, the foreign ownership equity is capped at 49%, but there was an exception in 2015 where the government allowed the acquisition of Malaysia Development Bhd power assets by a foreign entity for MYR 9.83 billion. This allowed a non-Malaysian entity to acquire 100% of the equity in an IPP. Therefore higher degrees of foreign ownership are possible, but exceptions to the current cap of 49% in foreign equity in power projects currently only appear to be granted on a case-by-case basis.

LSS progress

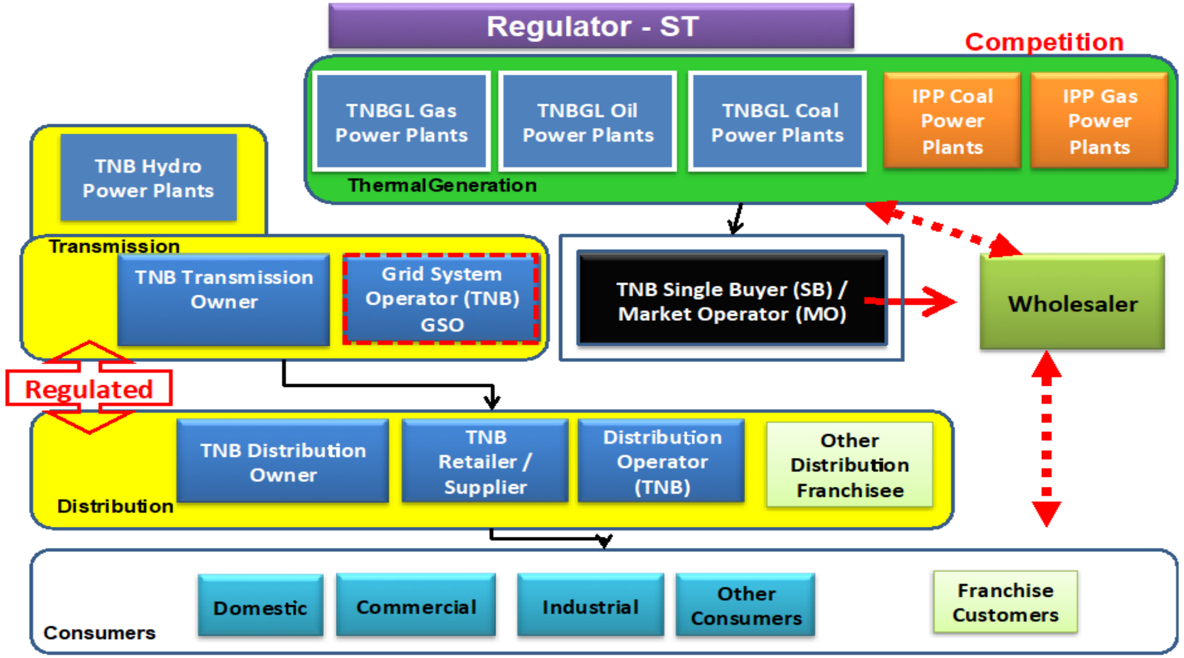


Figure 2 – 1 Diagram of Malaysia energy market

Evaluation:

There is a substantial number of energy policies available within the Malaysian framework. Malaysia could make use of these existing policies and framework as a basis to develop future policies and a market structure that aligns more with the growing hydrogen industry with the assistance from relevant authorities and agencies. Renewables development has received a lot of attention through LSS, FiT and a more recently the vPPA scheme. However, progress of the LSS scheme has been slow since the first round and there are concerns regarding low tender prices in the latest LSS 4 that might deter investments. There is also a limit on the capacity with which solar power participants can apply for a vPPA. This will limit the size of projects participating in the NEDA market, where market activities are already very limited. As such, there might be challenges for production of green hydrogen using renewables under the existing schemes. Further sections will analyse different options for Malaysia towards development on hydrogen.

Overview of Malaysian energy market – Gas

Gas (System and Players)

PETRONAS is the main gas supplier in Peninsular Malaysia who supplies natural gas to all generators through Gas Procurement Contracts. These contracts either fall under the Gas Framework Agreement between TNB on behalf of all power plants signed with PETRONAS or contracts directly with PETRONAS for other non-power sector gas generators. The generators enjoy gas at preferential rates negotiated under the Gas Framework Agreement for its generation. The distribution of gas is performed by Gas Malaysia Bhd who operates and maintains the Peninsular Gas distribution pipeline system as per its distribution licence and its subsidiaries.

The introduction of Third Party Access came into effect to allow competition with other gas suppliers who are able to take advantage of existing pipelines but consumers still procure their gas from PETRONAS as rates are comparatively lower.

In Sarawak, Shell, PETROS EP produces gas through exploration of natural reserves in the upstream. As there is little demand for gas in Sarawak, gas produced in Sarawak is sold to domestic consumers by PETRONAS while the remaining bulk is either shipped to Japan or Peninsular Malaysia through sea shipping with terms under gas contracts. The Gas distribution division under the Ministry of Utility and Telecommunication regulates the gas distribution in Sarawak.

Evaluation:
There are proper linkages connecting Peninsular Malaysia and interconnectors that connect with neighbouring countries such as Thailand, Indonesia and Singapore. In Sarawak, pipelines are limited as the low gas demand does not promote an extensive gas market. Gas networks that are already present in Peninsular Malaysia could be useful for Malaysia to take advantage of the current infrastructure and repurpose the existing pipelines to grow its hydrogen industry. As building new hydrogen pipelines are often more expensive, the existing pipeline infrastructure could give Malaysia an edge in costs if there are future plans of repurposing the existing pipelines.

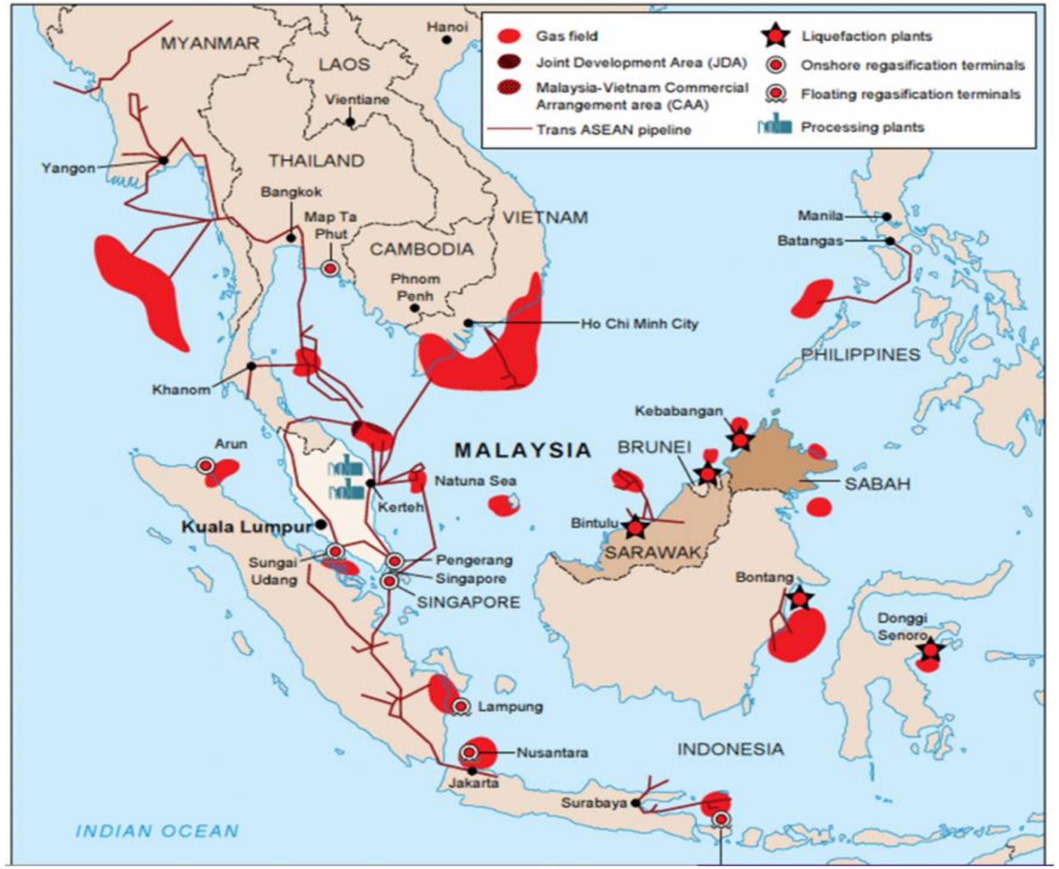


Figure 2-2 Pipeline connections and Interconnectors in Malaysia

1. Signing of the Memorandum of Understanding for the Revised Total Natural Gas Supply to the State of Sarawak for Implementation of Projects under Sarawak Gas Roadmap | Petroleum Sarawak Berhad (PETROS)

Overview of regulations/policies - Peninsular Malaysia and Sabah

The next two slides aim to look at the relevant regulations Malaysia have that ensure the stability on the electricity and gas sector. These regulations form the basis and create the foundation in Malaysia towards current and potential developments that includes renewables and hydrogen which will be tackled in subsequent slides. More information on individual regulation and policies can be found in the Appendix.

Table 2 – 1 Relevant regulations in Peninsular Malaysia and Sabah

Regulation/Policy	Role	Year	Governing Body
Electricity Supply Act 1990	• Provides framework for regulation of electricity industry • Guidelines for generation, transmission and distribution, including renewables • Ensure reliability and adequacy of electricity supply • Sets criteria for supply of electricity, including renewables	1990, latest amendment in 2019	Energy Commission
Renewable Energy Act	• Promote development and use of renewable energy sources • Provides framework for implementation of renewable energy projects and sets out the incentives and regulations governing the sector • Guidelines for licensing, registration, and promotion of renewable energy projects • Require electricity suppliers to purchase certain percentage of their electricity from RE sources	2011	Sustainable Energy Development Agency
National Renewable Energy Policy and Action Plan	• Introduced to accelerate adoption of renewable energy sources to achieve country's target • Development of new infrastructure and transmission networks to support integration of RE sources into grid	2020	Sustainable Energy Development Agency
Gas Supply Act	• Grant licenses for the construction, operation, and maintenance of gas supply facilities • Regulate supply, transportation and distribution • Ensure security, reliability and affordability of gas supply and promote efficient and sustainable use of natural gas • Introduce competition by separating companies gas supply and transportation business • Introduce Third Party Access (allow companies to access gas transmission and distribution network on a non-discriminatory basis)	1993, amendment in 2016	Energy Commission
Cross Border Electricity Sales	• Provide regulation and guidelines of cross border electricity sales through bilateral agreements between Malaysia and other countries • Includes the sources of electricity that can be sold to other countries (renewable vs non-renewables) • Selection of transmission routes, design and construction of transmission lines, and O&M of cross-border transmission facilities	2021 amendment in Electricity Supply Act	Energy Commission
Fifth Fuel Diversification Policy	• Promote renewable energy by introduction of such source into Malaysia overall energy mix • Encourage adoption of energy-efficient technologies and practices • Support research and development on efficiency and effectiveness of alternate fuels and technologies	2001	Energy Commission
Large Scale Solar (LSS)	• Introduced to promote development of large scale solar projects through private investment • Aim to diversify energy mix and increase share of RE in total electricity generation	2016	Energy Commission

1 Energy Commission - Home (st.gov.my)
2 SEDA Malaysia
3 Welcome to myTNB Portal
4 GSO

Overview of regulations/policies - Sarawak

Table 2 – 2 Relevant regulations in Sarawak

Regulation/Policy	Role	Year	Governing Body
Distribution of Gas Ordinance	• Govern the distribution of gas (all types) • Providing licensing and regulation of gas distribution activities, including construction, operation, and maintenance of gas pipelines and related facilities	2016, amendment in 2019	Sarawak State Government (Ministry of Utilities)
Gas Supply Ordinance	• Regulates the supply of gas • Provides for licensing and regulation of companies involved in the supply of gas, as well as technical, safety and environmental standards for safe and efficient supply of gas	2000, amendment in 2018	Ministry of Utilities Sarawak Energy Berhad
Sarawak Corridor of Renewable Energy	• Accelerate development of renewable energy resources and related industries • Development resources include projects such as large-scale hydroelectric power plants, solar farms and biomass power plants • Created opportunity for tax incentives, land acquisition, and infrastructure development	2008	Regional Corridor Development Authority
Natural Resources and Environment Ordinance	• Provide conservation, protection and management of state's natural resources and environment • Enforce environment standards and regulations, conducting environmental impact assessments, and promoting sustainable development practices	1993, amendment in 1998 and 2019	Natural Resources and Environment Board
Electricity Ordinance (Sarawak)	• Provide regulation of the generation, transmission, distribution and supply of electricity • SEB established as the sole licensee for generation, transmission and distribution • Established feed-in-tariff scheme for RE sources, such as solar and biomass to encourage RE projects development • Regulate electricity storage facilities	2014, amendment in 2020	Ministry of Utilities Sarawak Energy Berhad

1 SARAWAK CORRIDOR OF RENEWABLE ENERGY – RECODA
2 Official Website of the Ministry of Utility and Telecommunication (sarawak.gov.my)
3 Sarawak Energy

Malaysia renewable status and targets

Malaysia has seen growth in the renewable sector since the focus was shifted towards sustainable development. Table 2 – 3 below summarises the current status of renewables in Peninsular Malaysia and East Malaysia as well as renewable plans and targets these regions have moving forward.

Table 2 – 3 Current renewable status and future targets in Malaysia

Current Status	Future Plans and Targets
Malaysia large hydro capacity (2020) • Total: 5.7GW • Peninsular Malaysia: 2.23GW • East Malaysia: 3.47GW	**Generation Development Plan 2020** – Energy demand expect to grow at a rate of 0.6% per annum from 2021-2030 and 1.8% from 2031-2039. New capacity needed by 2030 to meet demand and replace retiring plants. • Additional capacity needed by 2030: 6.08GW
IRENA RE (2022) • Total renewables (2021): 8.8GW • Hydropower: 6.2GW, • Solar: 1.8GW • Bioenergy: 0.8GW	**Renewable Energy Transition Plan 2021-2040** – Malaysia targets to increase share of RE installed capacity. From 2030, Malaysia plans to introduce BESS (500MW) as solar having the highest RE potential. • Peninsular Malaysia: 26% - 2025, 32% - 2035 • East Malaysia: 5% by 2025, 8% by 2035
Sabah installed RE capacity (2018) • Total: 134.2MW (Solar, mini hydro, biomass and biogas) • Part of solar contribution came from FiT consisting of 39 solar developers who accounted for 21.5% of RE supply.	**Sarawak Post Covid Development Strategy (PCDS 2030)** • RE capacity mix (2030) ≥ 60% • Annual reduction of CO_2 emissions: 600k tonnes • Income from foreign markets through RE sector: ≥ 15% • Increase interconnectivity to export RE • Stimulate hydrogen economy through attracting investment for hydrogen value chain, establish hydrogen refuelling network, hydrogen transport • Establish Net Energy Metering through Renewable Energy Supply Act • Promotion of EVs
	Malaysia Renewable Energy Roadmap – Released by Minister of Energy and Natural Resources (KeTTHA). As solar has the highest potential, initiatives to promote solar development include accelerating the NEM programme as well as introducing peer to peer Energy Trading programme and enabling corporate PPA in line with TPA framework. • Solar capacity potential: 269GW • Large hydro capacity potential: 13.6GW • Small hydro capacity potential: 2.5GW

1 https://sarawak.gov.my/media/attachments/PCDS_Compressed_22_July_2021.pdf
2 Malaysia Renewable Energy Roadmap – Malaysian Photovoltaic Industry Association (mpia.org.my)
3 MyRER_webVer3.pdf (seda.gov.my)
4 REPORT ON PENINSULAR MALAYSIA GENERATION DEVELOPMENT PLAN 2020 (2021 – 2039) (ketsa.gov.my)
5 PCDS_Compressed_22_July_2021.pdf (sarawak.gov.my)

Malaysia renewable status and targets

Both Peninsular Malaysia and East Malaysia have certain renewable targets to meet in the coming years, as described in the previous slide. Based on the potential of renewables identified in the RE energy roadmap, there is still a large gap before having the untapped RE potential utilised according to the targets set out for each region (refer to Figure 2 – 1 and 2 – 2). Despite that, there was a upward revision on the initial target for 2025 from 25% to 31% which meant that Malaysia has ambitions to further enhance its renewable sector and work towards realising those untapped RE capacity. Progressive steps are taken in Peninsular Malaysia to achieve the required RE capacity mix by 2035 such as estimating the additional capacity required (Figure 2 – 3, Figure 2 – 4) and the various sources to be introduced into the system prior to the target year (Figure 2 – 5).The 600MW corporate vPPA program is part of the 1178MW new RE requirement by 2025, which limits the remaining development to meet targets to a further 578MW until 2025.

When comparing regions, Sarawak has been more proactive in attracting investment towards renewable development than Peninsula Malaysia, especially through the Sarawak Corridor of Renewable Energy. In Peninsular Malaysia, there are many governmental agencies in Peninsular such as KeTTHA and SEDA among others that are involved in various categories of the renewable energy chain which could pose a challenge in having a common target as each have their own plans and strategies. Despite so, detailed Malaysia Plans are released every 5 years which gives substantial update on progress from past plans, as well as the development and initiatives on multiple industries moving forward (including RE and hydrogen). This provides a good understanding on the current and future market development in Peninsular Malaysia. More details on the Malaysian Plan and the development roadmap can be found in the Appendix.

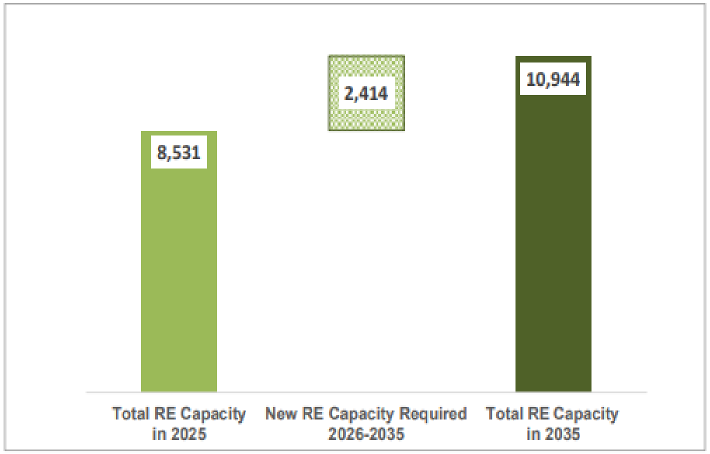


Figure 2 – 3 New RE requirement (2026 – 2035) to meet 40%RE capacity mix by 2035 (Peninsular Malaysia)

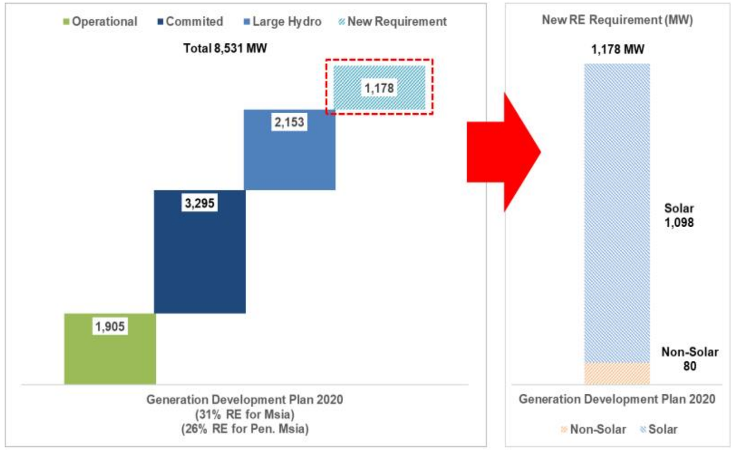
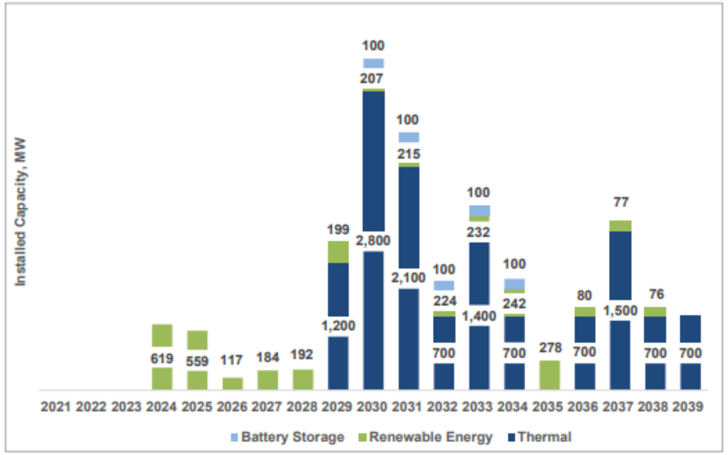


Figure 2 – 4 Breakdown of RE Requirement by 2025



(Note: Battery storage is used to stabilize the system and will not be considered in the capacity mix)

Figure 2 – 5 New capacity projection (MW) (2021-2029)

1 https://sarawak.gov.my/media/attachments/PCDS_Compressed_22_July_2021.pdf
2 Malaysia Renewable Energy Roadmap – Malaysian Photovoltaic Industry Association (mpia.org.my)
3 MyRER_webVer3.pdf (seda.gov.my)
4 REPORT ON PENINSULAR MALAYSIA GENERATION DEVELOPMENT PLAN 2020 (2021 – 2039) (ketsa.gov.my)
5 PCDS_Compressed_22_July_2021.pdf (sarawak.gov.my)

Hydrogen development in Malaysia

Hydrogen development in Malaysia is still in its early stages and limited to research, feasibility studies, and agreements to explore where hydrogen can be implemented in Malaysia. Table 2 – 4 and Table 2 – 5 list current ongoing hydrogen developments in Peninsular Malaysia and East Malaysia (Sarawak and Sabah) region respectively. The lists provided are indicative and non-exhaustive.

Table 2 – 4 Hydrogen developments in Peninsular Malaysia

Peninsular Malaysia	
Developed / In-place	**Under-development**
PETRONAS Hydrogen • Established in 2020 under the Gas and New Energy business that taps on existing blue hydrogen experience to become a competitive green hydrogen solution provider	**Collaboration with universities** • PETRONAS hydrogen research team collaborate with UKM that looked into hydrogen production from water through R&D in electrolysis technology that address cost and scalability.
Solar, Hydrogen and Fuel Cell Roadmap • Introduced in 2006 by the Ministry of Energy, Communications and Multimedia for research, development and utilisation of solar energy, hydrogen energy and fuel cells. • Limited progress due to change of focus towards RE development	**Repower Retired CCGT** • TNB teaming up with Petroliam Nasional Bhd to invest in green hydrogen and carbon capture. • Plan to repower a retired combined cycle gas fired power plant in Paka, Terengganu by using gas with hydrogen-ready technology. • Project expected to start in 2023 and scheduled to be ready by 2030 with the expectation of MYR 250 million annual EBITA and likely to avoid ~700k car CO_2 equivalent
Blueprint for Fuel Cell Industries Malaysia (2017) • Upgraded from previously abandoned SHFR. • Identification on existing hydrogen use and potential growth of various types of hydrogen based on existing regulations	**Gentari** • Aim to produce up to 1.2 million tonnes of hydrogen by 2030 through developing clean hydrogen projects in Malaysia, Canada and other competitive geographies, providing solutions for customers in key markets, partnerships and venture across hydrogen value chain through technology • MoUs that were signed
Green Technology Master Plan (2017-2030) • Green growth marked as one of the six game changers for Malaysia's growth • Strategic plans for green technology development in energy, manufacturing, transport, building for a low carbon and resource efficient economy • Limited focus on hydrogen	**Low Carbon Hydrogen Production** • Collaboration between PETRONAS and Eneos to explore low carbon hydrogen production from PETRONAS petrochemical facilities • Future plans include producing green hydrogen using renewable energy (50K tonnes hydrogen by 2027 for exports in MCH from to Japan • Signed a Joint Feasibility Study Agreement (2022) as part of its MoU (2021) to advance studies for a commercial hydrogen production and conversion project in Kerteh, Terengganu. • Eneos applied funding from Japan Green Innovation Fund. .
Gentari • Formation of a separate entity from PETRONAS that focus on new renewable resources and hydrogen • Key achievements in 2022: 13 MoUs to advance hydrogen, PM hydrogen feasibility studies with TNB, explore hydrogen supply chain opportunities with Samsung C&T and SK Group, 1st ammonia coal co-firing experiment with IHI Corporation and TNB Research	
MoU between TNB, IHI Corporation and PETRONAS • Feasibility study on low carbon hydrogen and low carbon ammonia supply chain in Malaysia • Assessment on CCS technology, blue and green ammonia co-firing in coal-fired plants. • Ammonia co-combusted test successfully conducted as part of joint initiative to decarbonise	

1 Eneos, Sumitomo partner in hydrogen gas plant in Malaysia (eog-asia.com)
2 Bintulu plant to increase Malaysian hydrogen production - Green Hydrogen News (energynews.biz)
3 MoU to develop green hydrogen, ammonia project in Sarawak (theborneopost.com)
4 Bintulu plant to increase Malaysian hydrogen production - Green Hydrogen News (energynews.biz)
5 Sarawak poised to be hydrogen producer by 2027, says premier - MIDA | Malaysian Investment Development Authority
6 Sarawak CM launches South-east Asia's first integrated hydrogen production plant | Malay Mail
7 Official Website Office of the Premier of Sarawak

Hydrogen development in Malaysia

Table 2 – 4 Hydrogen developments in East Malaysia

<table>
<tr><th colspan="2">East Malaysia</th></tr>
<tr><th>Developed / In-place</th><th>Under-development</th></tr>
<tr><td>Ministry for Energy and Environmental Sustainability
• SEDC tasked to look into the use of hydrogen as a source of renewable energy for public transport. (Current achievement of hydrogen buses and an autonomous rapid transit system that would run on hydrogen is under development).</td><td>Ministry for Energy and Environmental Sustainability
• Newly formed to accelerate the Sarawak Green Energy Agenda. Exploring sustainable aviation fuels on air travels such as biofuels, e-methanol and the potential of hydrogen fuel cells</td></tr>
<tr><td>Sarawak Green Energy Agenda (2017)
• Research in green hydrogen production
• Decarbonise and greening transport system and transition to low carbon economy</td><td>MoU between SEDC, Sumitomo Corporation and Eneos (2020)
• Plans to produce green hydrogen for exports by developing a plant in Bintulu
• Expected to be ready by 2023 with planned capacity of 1000 tonnes per year</td></tr>
<tr><td>Integrated Hydrogen Production Plant & Refuelling Station (2019)
• Announced in 2017 and operational in 2019 (First in SEA)
• Partnership between SEB and Linde
• Production of 130kg of hydrogen daily
• Provides refuelling services for 5 hydrogen buses and 10 fuel cell cars daily (serve as public transport)</td><td rowspan="2">H2biscus
• Collaboration with SEDC, Sarawak Energy, Samsung, Lotte Chemical and POSCO
• Feasibility studies (Completed-2021): Building a plant with annual capacity to produce 630K mt of green ammonia, 600K mt of blue ammonia, 460K mt of green methanol and 7K mt of green hydrogen
• Feasibility studies (Underway): Potential of supply at least 900MW of hydro-based renewable power for the H2biscus project
• Plant to be built in Bintulu, once completed (~2027), the by-product will be used for domestic purposes and exports to South Korea
• SEDC Energy to start producing green hydrogen at the PETROS multifuel station by end of 2022 (no latest news).</td></tr>
<tr><td>Education Institutes
• Hydrogen modules recently introduced at Sarawakian universities,
• Aim to equip future engineers with the necessary knowledge to thrive in the hydrogen industry going forward.
• Various research programmes and projects with companies like Airbus and various Japanese firms to test hydrogen's applications in our daily lives.</td></tr>
<tr><td>Research and Development
• The State government allocated 10 million MYR to develop hydrogen in 2019</td><td rowspan="2">Samalaju Hydrogen Plant
• MoU signed between Australian-based H2X Global, Thales New Energy and SEDC to develop a 1.3GW hydrogen plant at the Samalaju Industrial Park and Port.
• Pre-feasibility studies conducted by Thales New Energy, while the three companies accelerated the feasibility and engineering.
• Expect production of 170k tonnes of liquid hydrogen or 970k tonnes of ammonia annually for exports with first shipments in 2024/2025. Also seek to develop local electrolyser build capabilities. Export likely to be towards Europe. Two companies from Japan and Korea had expressed interest in investing on the hydrogen plant. Further details not yet released.</td></tr>
<tr><td>Land Code (Amendment) Bill (2022)
• Latest enactment placed Sarawak in a better position to promote CCUS as a potent technology for mitigating greenhouse gas emissions in the direction of a low-carbon economy</td></tr>
</table>

The development of the hydrogen industry in Malaysia is foundational to date. There are many MoUs signed (other than the ones mentioned in the tables) but most of which are still in the early stage studies and research with little or no news on moving to the next stage. Projects that are in development are very limited. Also, greater strategic direction from government is sought by private organisations who wish for more certainty when considering further research/ investigation on industry developments within the country. There should be considerable policies and market structures in place to support hydrogen to be part of the energy systems. Other jurisdictions have introduced funding (grants or loans) to match investment, and in so doing support growth of the industry.

8 Realising Malaysia's Hydrogen Ambitions - Energy Watch: Global & Regional Energy Insights, Thought leadership, & Conversations
9 SEDC to play crucial role in Sarawak's green energy agenda, says Premier Abang Jo | The Star
10 PETRONAS Partners ENEOS For First Commercial Scale Hydrogen-To-MCH Project | PETRONAS Global
11 The Hydrogen Game Changer | PETRONAS FLOW
12 TNB unit, IHI Corp, Petronas collaborate in co-firing technology for free-carbon ammonia | The Edge Markets
13 Tenaga to Invest $1.4 Billion to Repower Paka Power Plant for Clean Energy | Morningstar
14 Position Paper on Hydrogen Economy – Official Portal Academy of Sciences Malaysia (akademisains.gov.my)

Hydrogen development in Malaysia

Table 2 – 5 Hydrogen developments (planned/future)

Peninsular Malaysia						
Projects (Planned)	Project Owner	Capacity/Target Production	Timeline	Contractors/Partners	Technology Choice	Area
Repower Retired CCGT	TNB	• Repower 1.4GW power plant to equip with hydrogen ready technology	Expected to start demolition of existing plant in 2023, construction of project in 2025 and completion of complex in 2030	• PETRONAS	Methane Reforming	Perengganu, Paka
Low Carbon Hydrogen Production and Conversion	Petronas	Exports to Japan: • Production capacity of 50k tonnes in MCH form per annum	Facilities are estimated to be ready by 2027	• Eneos	Electrolysis	Kerteh, Terengganu
Ammonia Production Plant	Gentari, subsidiary of PETRONAS	• Unknown	Commercial Operation before 2030	• IHI	Electrolysis	Unknown

East Malaysia						
Projects (Planned)	Project Owner	Capacity/Target Production	Timeline	Contractors/Partners	Technology Choice	Area
Hydrogen Plant	SEDC Energy	• 1000 tonnes/year in MCH • Can be scalable and further expanded to 10,000 tonnes/year as need arises	Plant expected to be ready by 2023 (no further news)	• Sumitomo Corporation • Eneos	Electrolysis	Bintulu Petrochemical Park
H2biscus	SEDC Energy	Exports: • Green ammonia (630k tonnes) • Green hydrogen (220k tonnes) • Blue ammonia (600k tonnes) Domestic use: • Green hydrogen (7k tonnes)	Expected to achieve commercial production by end 2027	• Samsung Engineering • Lotte Chemical • POSCO holidings	Electrolysis	Tanjong Kidurong, Bintulu
Samalaju Hydrogen Plant	SEDC Energy	Exports: • Liquid hydrogen (170k tonnes) or • Ammonia (970k tonnes) Plant Capacity: 1.3GW	First shipments expected in 2024/2025	• H2X Global (Australia) • Thales New Energy	Electrolysis	Samalaju Industrial Park and Port, Bintulu

Summary – Current plans and development

Malaysia energy market overview

- **Power generation -** High dependence on coal and gas for electricity generation.
- **Renewables development** - In order to provide a more sustainable fuel in its energy mix for its increasing energy demand and rapid depletion on natural resources, there is a clear focus towards renewable development.
- **Policy and market structures development** – there is a need for adjustment of market structures and foundations for hydrogen to be a growing industry.

Current policies and plan

- **Focus on renewable capacity growth** - There is a strong focus on renewable capacity additions as well as clear renewable targets to meet. The policies are aimed towards on-grids renewable with the presence of a PPA. As for off-grid renewables, the only policy governing off-grid solar is through the NEM policy while there is currently a lack of policies for other renewables.
- **Access to gas infrastructures** - The government enacted TPA to promote competitiveness by introducing third party players to gain access to gas infrastructures and distribution pipeline that might potentially open up the possibility of transporting hydrogen via the pipelines though currently the policy only limit to LNG.
- **Investments in hydropower** - In Sarawak, SCORE was set up by RECODA to promote investments towards its hydropower resources.

Current hydrogen development

- **Funding** - There are government green funds for the development of hydrogen and fuel cell towards research universities in efforts from the 8th Malaysia Plan.
- **Initial studies and blueprint** - A more in depth strategy blueprint was released in 2017. Following which, big players such as PETRONAS and TNB collaborated with overseas players which eventually progress towards having feasibility studies and developing projects that ranges from hydrogen production to repower retired power plants and equip it with hydrogen ready technology.
- **Hydrogen refuelling stations in Sarawak** – through the government's support, there are existing hydrogen refuelling infrastructures in Kuching to for public buses.
- **Green hydrogen pilot production** – a project by SEDC Energy will start producing green hydrogen at PETROS multifuel station by end 2022 according to its timeline.
- **Hydrogen as part of curriculum** – In order to prepare future engineers in the hydrogen industry moving forward, Sarawak had already started introducing hydrogen modules in local universities to give students an edge before entering the workforce.

Despite having detailed hydrogen and fuel cell roadmap, there has been limited success in the implementation of hydrogen production. Peninsular Malaysia and Sarawak have no clear policies or a strong green hydrogen direction plan to propel the hydrogen space. The same efforts that were put towards renewable development are required to be pointed towards hydrogen as well in order to promote growth and investments towards the hydrogen value chain. Therefore, there is a need to look at the current policies that are applicable to the hydrogen value chain to look at potential gaps that could be supplemented with other policies and/or strategies.

Potential policies and barriers

From earlier information, there is a good understanding on the overview of the Malaysia's energy market, current renewable status, targets and hydrogen development. It is clear that there is a strong focus on RE with specific targets and roadmaps. Hydrogen – on the other hand, has limited focus. Although there are some turnkey projects and blueprints towards hydrogen development, there are no proper targets nor a clear strategy for organisations to work towards to. Therefore, in the following few slides, using knowledge on global experience (which has been outlined further in the Appendix) and understanding on the energy market and structure, potential policies and barriers have been identified that could be applicable for hydrogen value chains in Malaysia. These have also been aligned with the scenarios painted in Task 1. This has been split into two sections: Policies that can be utilized to overcome identified barriers based on international best practice, and general barriers for a transition towards hydrogen that have to be accounted for.

Policies intervention to overcome barrier

- List of policies relevant to Malaysia hydrogen value chain
- Potential interventions on mentioned policies recommended from international best practice that are applicable to Malaysia

Malaysia and Sarawak already have electricity and gas regulation and policies that ensure the stability of the network and its development. Since 2011, the focus has been towards renewables which prompted revisions to its existing regulation and policies to accommodate the states' direction, accompanied by relevant policies that accelerated the growth. Regulation that targets the electricity and gas sector provides a basis for hydrogen development across the value chain. There are some activities within Malaysia in progressing hydrogen development – Blueprint for Hydrogen in Peninsular and series of joint agreements and research on related technologies. Despite so, there is lack to policies to address all aspects along the chain and pave a clear path for domestic and foreign investments towards hydrogen hence these policies will be identified in the next few slides split into policies that are considered required and policies that are deemed enablers for market development.

General barriers for hydrogen development in Malaysia

- Overall requirements that Malaysia is currently lacking in for hydrogen development

Hydrogen in Malaysia is currently produced through by-products of gas-fired plants which is categorised as grey hydrogen. Hydrogen is also mainly used in industrial and petrochemicals sector. As the production of such hydrogen is not environment friendly, it is essential to switch to cleaner production methods such as blue and green hydrogen. Since Malaysia is in the early stages of hydrogen industry, especially on the greener end, there are a few barriers that could limit potential development of hydrogen in achieving greener goals. Therefore, it is essential to consider and address the barriers with the assistance of international best practices.

Policies interventions to overcome barrier in hydrogen value chain - Overview

Scenario	Timeline	Energy Production	Hydrogen Production	Transport/Storage	End Use
Sarawak Exports hydrogen from hydropower resources	Towards 2030 and onwards	Renewable energy policy Subsidies/Tax incentives	Ensure grid robustness PPA/Wheeling hydropower Low network charges	Port/Export infrastructure for hydrogen	Adopt EU standards Certification
Peninsular Malaysia Blue hydrogen for grey hydrogen replacement	Towards 2030		Carbon tax Carbon allocation Subsidies	State ownership/De-risking carbon storage	Mandate/Target Grants/loans for equipment Sustainable public procurement
Malaysia Solar hydrogen for grey hydrogen replacement **Malaysia** Solar hydrogen for fuel replacement	Towards 2050 Towards 2050	Subsidies/Tax incentives Targets/Mandate	PPA (limited availability) Subsidies Targets/Mandates	Gas Network Code Market - Point to point (Grey Hydrogen Replacement) Market - Interconnection to national market (Fuel Replacement) TPA (Gas Replacement)	Adopt EU standards Quotas/ETS (Fuel Replacement) Grants/loans for equipment Adopt EU standards

Policies available in Malaysia

Enabling policies **not** available in Malaysia

Required policies **not** available in Malaysia

Policies interventions to overcome barrier – Scenario 1

<table>
<tr><th></th><th colspan="2">Energy Production</th><th colspan="2">Hydrogen Production</th><th colspan="2">Transport/Storage</th><th colspan="2">End Use</th></tr>
<tr>
<td rowspan="3"><u>Sarawak</u>
Exports hydrogen from hydro resources</td>
<td>Renewable energy policy</td>
<td>Sarawak has renewable energy policies such as Green Energy Agenda and SCORE to attract investments and development.</td>
<td>Ensure Grid Robustness</td>
<td>The grid infrastructure/capacity need to be prepared for the upcoming Baleh hydropower plant (1,285MW) which is under construction and is expected to be commissioned by 2027.

In addition, grids need to be capable for additional loads to be able to transfer electricity from the hydropower plants to the H_2 production onsite.</td>
<td rowspan="3">Hydrogen pipeline development</td>
<td rowspan="3">Preparing export infrastructure would be essential in this scenario. This would include finding a suitable site, allocating space for ammonia production, and storage as well as jetties and pipelines needed.

If the hydrogen facilities are at the same site as the hydropower generation, proper pipelines infrastructure linkage would be required to transport the hydrogen to the export site.

Ensuring alignment of technical standards is vital. This requires international cooperation but also a review of existing standards used in Malaysia

Ensuring safety standards are important as well, For example, blends of up to 5% are acceptable both from a transport and end user perspective (with some exceptions).</td>
<td rowspan="2">Mirror EU standards</td>
<td rowspan="2">EU has already established proper framework which can be used as a starting point for creation of framework in Sarawak. Off-takers should also align with the EU standards.</td>
</tr>
<tr>
<td rowspan="2">Subsidies/Tax incentives</td>
<td rowspan="2">RECODA has initiated 100% tax exemption for 5 years for pioneer projects and up to 10 years for strategic investments. Additional benefits include preferential land prices as well as cheap electricity and water rates provided by the Sarawak State Government for renewable projects.</td>
<td>PPA/Wheeling</td>
<td>The hydrogen production facilities are often not located onsite with the hydropower plant. Hence, it is required to have PPA and wheeling between hydro power plants and hydrogen production plants to purchase of electricity for hydrogen generation.</td>
</tr>
<tr>
<td>Network charges</td>
<td>Charges to transmit energy from hydropower resources to hydrogen production facility should be kept low to encourage activity. At current context, hydrogen production facility is not available onsite with hydropower resources.</td>
<td>Certification</td>
<td>Proper hydrogen green certification with EU standards are required to prove guarantees of origin and carbon intensity</td>
</tr>
</table>

- Policies available in Malaysia
- Enabling policies **not** available in Malaysia
- Required policies **not** available in Malaysia

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Policies interventions to overcome barrier – Scenario 2

<table>
<tr><th></th><th>Energy Production</th><th colspan="2">Hydrogen Production</th><th colspan="2">Transport/Storage</th><th colspan="2">End Use</th></tr>
<tr><td rowspan="6"><u>Peninsular Malaysia</u>
Blue hydrogen for grey hydrogen replacement</td><td rowspan="6"></td><td rowspan="2">Carbon Tax</td><td rowspan="2">As the production of blue hydrogen require the use of CCS which creates additional cost, a carbon tax that is high enough should be imposed on production that releases carbon emissions, with the end goal having higher penalties on carbon emission than the additional costs required to include CCS in the system. There are progressive plans for a carbon tax to incentivise the CCS business mentioned in the latest 2023 Budget but limited information of the plans are released. As such, there are intentions for the government to introduce carbon tax to drive the ESG agenda towards carbon neutrality by 2050.</td><td rowspan="6">State ownership/ De-risking CCS</td><td rowspan="6">The Malaysian government need to be in charge of a centralised CCS and having control on receiving CO2 from emitters

To make CCS attractive for private stakeholders, government can play a role by mitigating financial risk imposed to them, either by state owning the storage of carbon or introducing a mechanism to ensure the financial sustainability of the private players.</td><td>Mandate/ Target</td><td>Target to include a certain amount of blue hydrogen in the energy mix to be used in various sectors</td></tr>
<tr><td>Grants/ Loans for equipment</td><td>New equipment may be needed to receive and consume blue hydrogen</td></tr>
<tr><td>Carbon allocation</td><td>For companies involving in blue hydrogen production with the use of CCS, there is a need to create a mechanism to quantify the carbon savings in which the savings will then be allocated to companies responsible for the carbon storage.</td><td rowspan="2">Sustainable public procurement</td><td rowspan="2">MyHIJAU Mark was approved MGTC on Oct 2012 to recognise green products and services that comply with global environmental standards which includes regional and international green certifications. However, the criteria to be qualified under MyHIJAU Mark is only applied to domestic registered business/company which limit participation.</td></tr>
<tr><td rowspan="3">Subsidies</td><td rowspan="3">Under the latest Budget 2023, companies undertaking CCS in-house activity will be eligible for investment tax allowance for 10 years, as well as full import duty and sales tax exemption on equipment for CCS technology starting 2023 till end 2027. This initiative creates the opportunity to encourage companies to transition from grey to blue hydrogen production in Malaysia but whether the policy extends to foreign companies in Malaysia is not known.

Further, to promote such activities, subsidies have to be given to promote switching from grey to blue hydrogen production due to higher associated costs.</td></tr>
<tr><td rowspan="2">Mirror EU standards</td><td rowspan="2">EU has already established proper framework which can be used as a starting point for creation of framework in Sarawak. Off-takers should also align with the EU standards.</td></tr>
<tr></tr>
</table>

Policies available in Malaysia (green)
Enabling policies **not** available in Malaysia (yellow)
Required policies **not** available in Malaysia (red)

Policies interventions to overcome barrier – Scenario 3 & 4

	Energy Production	Hydrogen Production		Transport/Storage		End Use	
Malaysia Solar hydrogen for grey hydrogen replacement and/or gas replacement		**PPA**	Current solar PPA are for domestic companies registered as solar power producer. PPA should also aimed towards overseas developers in Malaysia to enhance investment and development in domestic dedicated solar to increase capacity addition. Also, require to have PPA between solar power plants and hydrogen production plants	**Market (Point to point)**	Transportation mode of hydrogen from hydrogen production plant to consumers has to be established	**Quotas/ ETS**	Setting a cap on the total number of carbon credit units in the market or trading units with other countries to control CO2 emission in Malaysia. Currently, ETS is under planning by KASA
		Subsidies/Tax incentives	Subsidies should be aimed at hydrogen production equipment to transform solar into hydrogen. Tax incentives will also encourage business owners to adopt better technology in transforming solar into hydrogen.	**Market (Interconnection to national market)**	For fuel replacement, it is essential to have greater connectivity to other countries in order to ensure the marketplace has a diverse set of suppliers and buyers, including centralised storage or flexibility in production/demand.		
		Targets/ Mandates	Proper target of hydrogen need to be set by the relevant authorities or a common goal. The Fuel cell and hydrogen roadmap was released in 2005 under the 8th Malaysia Plan but was neglected due to shifted focus towards developing renewables. An upgraded version was released in 2017 with more focus in hydrogen. There exists technical expertise from extensive R&D programmes related to hydrogen energy funded by MOSTI and MOHE for the past 25 years under the presence of the roadmap and blueprint. Research has been ongoing but concrete development is still limited, might have to look at actual development in the ongoing 12th Malaysia Plan and subsequent plans.	**Gas Network Code**	Definition of gas need to be extended to hydrogen for supply and distribution of hydrogen. This requires engagement and agreement with all offtakers as gas quality specification is a critical operational parameter	**Mirror EU standards**	EU has already established proper framework which can be used as a starting point for creation of framework in Sarawak. Off-takers should also align with the EU standards.
				TPA	Third Party Access was implemented under the Gas Supply Act to allow competition from third party players to use own or not-owned gas supply infrastructure. However, hydrogen is not included in the gas definition at the moment. Also, participation is limited under the TPA as PETRONAS currently still dominates the market domestically since the Act was implemented in 2016. Hence, a stronger policy may be required to enhance competition (e.g limit market share or further reducing the barriers to entry) if hydrogen is included in the scope of TPA.		

- Policies available in Malaysia
- Enabling policies **not** available in Malaysia
- Required policies **not** available in Malaysia

General barriers in Malaysia

In addition to the barriers addressed previously which are specific to each cases, there are general barriers which apply to all scenarios listed previously:

Additionality requirement

- The European Union's Renewable Energy Direction (REDII) Delegated Acts define renewable hydrogen through an emissions threshold (<28.2 gCO_2e/MJ) and with other requirements, including 'additionality', which requires eligible hydrogen to have new electricity generation linked to its production. This new requirement* is proposed to avoid existing resources for power generation being diverted for hydrogen production for efficiency purposes.

- The additionality requirement would be an issue when utilizing existing plants for hydrogen production, especially for the case scenario of using hydropower plants in Sarawak. Building new hydropower plants would require time and resources and could meet with local resistance due to environmental impacts and hence is less feasible. Any eligible imports to Europe or other countries adopting this policy would need to comply. This requirement should be monitored as it may affect the produced hydrogen's positioning within the global market.

- Other jurisdictions are developing their own standards, and these may come with particular rules relating to the renewable electricity used in electrolysers.

Standards (for repurposing)

- To repurpose gas pipeline to transport hydrogen, there are standards to be taken into account; 1) quality and 2) safety. Gas quality has to be ensured in the case of hydrogen for existing and new equipment along the hydrogen value chain. Malaysia, in common with other jurisdictions, has yet to come up with proper standards to measure the quality of hydrogen and blends. A Network Code defines gas quality specifications along with commercial arrangements but Malaysia has to extend to include hydrogen to ensure operability of equipment. Fiscal metering will also be impacted by hydrogen introduction as the energy content of hydrogen containing gases is significantly lowered

- Gas transport and use is regulated through a suite of technical and safety standards, all of which would need to made fit for purpose for hydrogen. In general, blends of up to 5% are acceptable both from a transport and end user perspective (with some exceptions). Use of infrastructure above 5% needs to be validated against existing standards and as the percentage of hydrogen increases, this has implications for the operating envelope (e.g. maximum pressure and pipeline capacity).

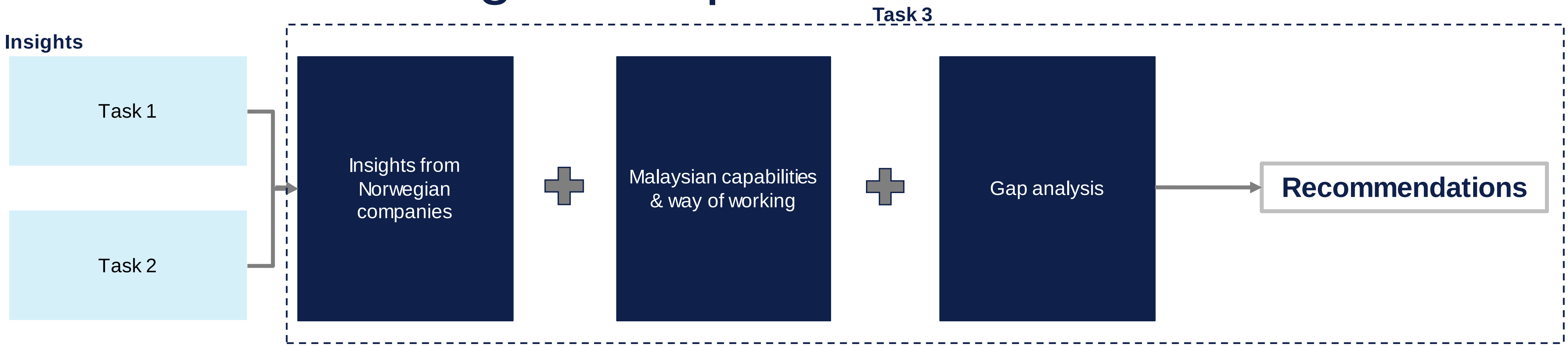
Current hydrogen development

- Planning and permitting procedures in Malaysia takes time and may hinder future development. Therefore, it is required to streamline these processes as in the future there would be a number planning and permitting processes required, namely for the renewable production sites, the hydrogen production itself, and potentially for exporting the hydrogen.

*From 1 January 2028 energy used for hydrogen production must be unsubsidised renewable production commissioned up to 3 years before the electrolyser starts operation. This relationship can be direct connection or via PPA. For hydrogen plant commissioning prior to 2028 this provision takes effect from 2038. Additionality demonstration is not required if the 'bidding zone' has a mix of more than 90% renewable (a bidding zone being delineated by regulatory coverage or the physical network boundary). The other requirements are 'temporal correlation', where prior to 1 January 2030 hydrogen must be produced within the same month as electricity generation and afterwards must be matched to within the hour, and geographic correlation where grid-connected electrolysers must be in the same bidding zone as the RE asset or in an interconnected bidding zone if the day-ahead market price in the interconnected zone is equal or higher. Note that while the EU Commission has approved the Delegated Acts as outlined here (13 February 2023), the European Parliament and Council subsequently have two months to scrutinise the proposals. A further two-month scrutiny period can be requested.

Task 3 – Assessing Potential Norwegian Opportunities

Introduction – Alignment previous tasks



Upon identifying the policy interventions across the value chain in Task 2 based on the scenarios from Task 1 and having an overview on the general barriers Malaysia could possibly face moving forward, Task 3 deep dives into the challenges faced by foreign investors entering the Malaysia market across the hydrogen value chain based on potential barriers to entry.

Insights from Norwegian companies – Norwegian companies from various involvement across the hydrogen value chain were interviewed. The purpose of these interviews was to have a glimpse on the companies capabilities and their plans to enter the Malaysia market, as well as the challenges they face attempting to have a foothold in the Malaysia market or preventing them to do so.

Malaysian capabilities & way of working – Based on information from Task 2, we identified the areas Malaysia are currently strong in and already have a strong presence in. Norwegian companies will likely to find it difficult to promote their services in such areas within Malaysia. Also, based on hydrogen projects currently in development, we also identified the type of projects and process currently preferred by Malaysian governments for projects involving foreign companies. Such information is useful for Norwegian companies as they are usually involved in a specified area along the value chain rather than having involvement across the chain.

Gap analysis - Areas across the value chain where Norwegian companies could potential play a role were identified in both green and blue hydrogen value chain. These are areas where Malaysia currently lacks in which Norwegian companies that are strong in those areas could offer their services to. However, there may be barriers based on Malaysia way of working which will be discussed in the next task.

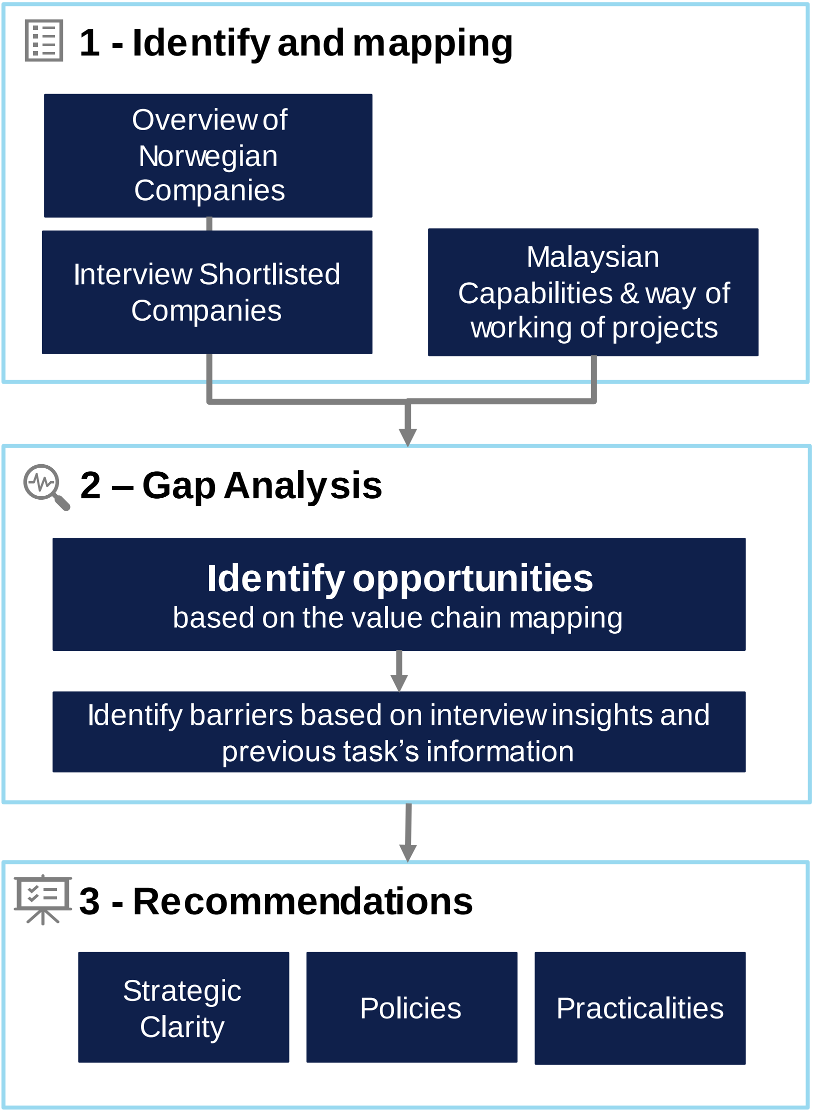
Recommendations – Tapping on the previous points, recommendations are made to address the concerns faced by the Norwegian companies entering the Malaysia market, and to form a bridge between what Norwegian companies could offer and the Malaysia way of working. In doing so, it will also address policies that are not present across the hydrogen value chain in Task 2 as well as the general barriers.

Introduction – General approach

Having identified market potential scenarios in Task 1 and an overview of the Malaysia's policy and regulatory framework in Task 2, Task 3 aims to identify opportunities for Norwegian companies in Malaysia.

The approach in identifying the opportunities is comprised in three major steps

1. **Identification and mapping of Norwegian Companies** – the first step in this task is to identify where Norwegian companies can be part of the hydrogen and carbon capture value chain in Malaysia. To do so, a mapping is made based on both the capabilities of Norwegian companies and local (Malaysian) competencies in the sector. The step is therefore comprised of several sub-steps:
   - Overview of Norwegian companies & interviews – compiling an overview of Norwegian companies in the sector to obtain a list of companies with presence in the SEA region. In which afterwards, the companies are shortlisted for further interviews to gain more insight on their thoughts on the market in Malaysia, what are their barriers to entry and where do they see themselves participating in the market.
   - Malaysian capabilities & way of working Malaysian projects – to have a value chain mapping which showcases where the domestic capabilities are, this topic is also taken a look at to complete the gap analysis in the next step.
2. **Gap Analysis** – analysing the value chain map of Norwegian and Malaysian companies in the green hydrogen and blue value chain. By doing so, gaps where Norwegian companies can complement current local competencies are identified as opportunities. In combination with the interview insights and previous information, barriers to these opportunities analysed.
3. **Recommendations** – to overcome the barriers, this study listed recommendations to improve strategic clarity, policies, and practicalities to allow Norwegian companies untap the available opportunities within the value chain.



Identify and Mapping of Norwegian Firms

Sources

- DNV Network
- Top 50 energy companies in Norway
- Norwep list of companies and segmentation

→ List of companies
- Hydrogen and;
- CCS value chain

→ Sort companies to be mutually exclusive per segment

→ Determine presence of company by having an office or not in Malaysia or SEA region

→ Shortlist Companies for interview

→ **Overview of Norwegian Companies**

In identifying and map Norwegian firms, a list of companies was first compiled from varying sources (DNV network, top 50 companies in Norway, and Norwep list of companies and segmentation). The list is then further sorted to be mutually exclusive per segment, and categorized based on each companies' presence in the SEA region into 'Active in Malaysia', 'Active in SEA', or 'Not active in the region'. A quantitative overview of the firms can be found in the next slides, with one overview for each sector (hydrogen value chain and CCS value chain).

Based on this list, several companies were approached for an interview. The basis for interviewing was to look for Norwegian firms with both a global and SEA presence and aiming for broad coverage across different segments in the hydrogen value chain.

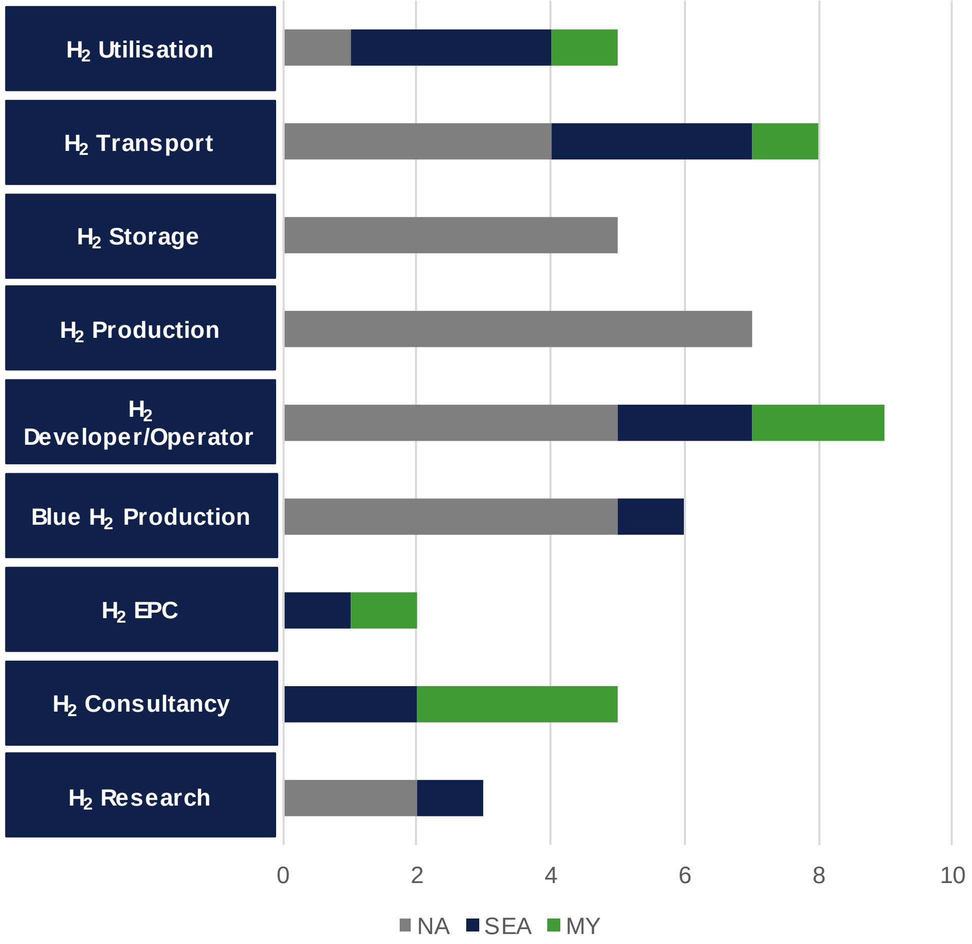
Companies interviewed for this study were Scatec, Moreld, Baker Hughes (3C), Statkraft, and NEL. Topics discussed were:

- Capability of Norwegian firms
- Companies' view on Malaysian market (attractiveness and barriers)
- Typical and preferred role within the hydrogen value chain
- What is needed for the company to enter a new market or the Malaysian market in particular

These insights were used for the capability gap analysis in identifying opportunities and gaps for the Norwegian companies to be part of the Malaysian hydrogen value chain.

Overview of Norwegian firms - Hydrogen

Norwegian Firms in the Hydrogen Value Chain



Out of 52 Norwegian companies active in the hydrogen value chain, 9 are active in Malaysia and 13 have a presence in the SEA region;

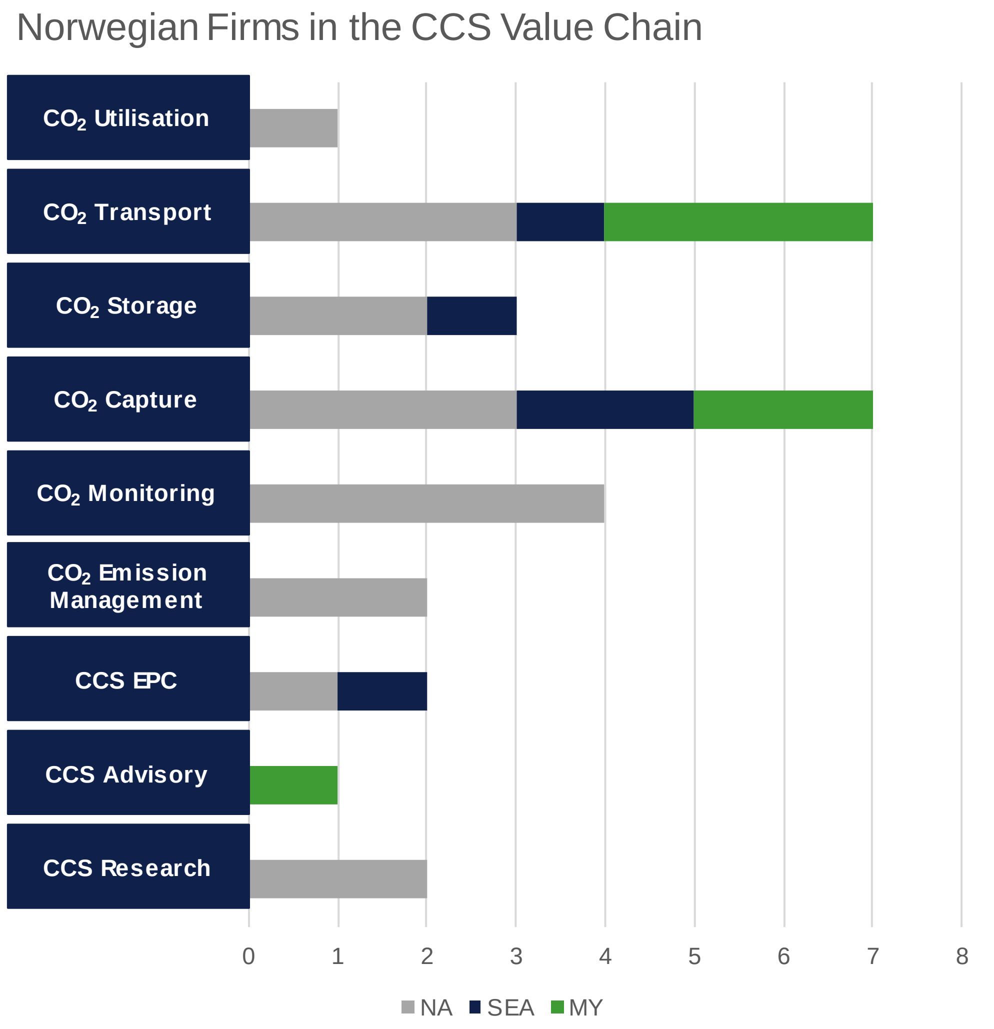
Presence	Number of Company	Percentage
Active in Malaysia	9	17.31%
Active in SEA Region	13	25.00%
Not active in SEA Region	30	57.69%

- Companies active in Malaysia are at the field of; consultancy, developer/operator, renewables development, EPC, transport, and utilisation.
- Norwegian firms on the field of H_2 production and storage value chain do not have offices in the SEA region. However, being in this field allows them to work together with a developer/operator remotely from Norway.
- Overall, sorting the number of companies from the largest to smallest, developer/operator has the most companies in the segment. Segments with the least number of company would be renewables development and EPC.

Segment	Number of Company
H_2 Developer/Operator	9
H_2 Transportation	8
H_2 Production	7
Blue H_2 Production	6
H_2 Utilisation	5
H_2 Consultancy	5
H_2 Storage	5
H_2 Research	3
Renewables Dev	2
H_2 EPC	2

- NA – Not active in SEA Region
- SEA – Active in SEA Region
- MY – Active in Malaysia

Overview of Norwegian firms



Out of 29 companies active in the CCS value chain, 6 are active in Malaysia and another 5 only in the broader SEA region;

Presence	Number of Company	Percentage
Active in Malaysia	6	20.69%
Active in SEA Region	5	17.24%
Not active in SEA Region	18	62.07%

- Companies active in Malaysia are in the field of CO_2 transport, CO_2 capture, and advisory.
- Norwegian firms in the fields of research, emission management, monitoring, and utilisation currently do not have offices in the SEA region
- Overall, sorting the number of companies from the largest to smallest, capture and transportation has the most number of companies (7 companies), and the least is utilisation and advisory (1 company).

Segment	Number of Company
CO_2 Capture	7
CO_2 Transportation	7
CO_2 Monitoring	4
CO_2 storage	3
CCS EPC	2
CCS Research	2
CO_2 Emission Mgt	2
CO_2 Utilisation	1
CCS Advisory	1

- NA – Not active in SEA Region
- SEA – Active in SEA Region
- MY – Active in Malaysia

Malaysian capabilities

Following a quantitative overview on Norwegian firms, the next step before creating doing the gap analysis is to understand where Malaysia firms' capabilities stand within the value chain, including their ways of working. Going forward, the analysis is differentiated between Peninsular Malaysia and Sarawak as different players are involved. The energy industry in Malaysia is dominated by market players that often have high involvement with the government bodies in some form or another or already having a major market share in the Malaysian market. This creates a likely scenario that these players will be highly involved in the components of the value chain after the project is developed.

Sarawak – SEB is the main company responsible for local renewable development. SEDC is also active and has signed agreements in 2022 that cover the supply and operation of Petronas PEM electrolysers for the production of green hydrogen domestically. There are EPCs in Sarawak, that have vast experience in development of RE projects but have little experience in the hydrogen arena. As for end use, there are a few turnkey projects that SEB is actively involved in that distribute green hydrogen for end users. However, as the green hydrogen market is still new to Sarawak, there are limited capabilities such as system integration, hydrogen storage and transport that might be managed by major domestic companies but require assistance from foreign expertise.

Peninsular Malaysia – Petronas is the leading gas supplier in Malaysia and has a major control on the gas market. TNB plays a critical role in Malaysia as it main roles include power generation, transmission and distribution of electricity, as well as research and development on power sector such as carbon capture. Similar to Sarawak, there are EPCs such as Petrofac and MMC Corporation Berhad with presence in the energy sector but have little experience in the hydrogen arena. Petronas And TNB is also actively involved in carbon capture and storage initiatives which will likely take over the operations at their facilities but development of equipment will likely based on foreign companies with relevant expertise. Currently, there are some projects on carbon capture by Petronas and PTTEP in Sarawak but since carbon capture, transport and storage is still relatively a new market for Malaysia, collaboration is essential with foreign expertise to build on the respective areas, as well as integrating such technologies into the system.

Table 3 – 1 Major Malaysian Companies in the Hydrogen Value Chain

State	Local Renewable Development	Equipment Manufacturing	System Integration	EPC	Hydrogen Storage	Hydrogen Transport	End Use
Sarawak	sarawak energy	PETRONAS				PETROS*	sarawak energy
Peninsular Malaysia	TENAGA NASIONAL	PETRONAS				PETRONAS*	TENAGA NASIONAL*, PETRONAS

State	Local Gas Supply	Equipment Manufacturing (SMR)	System Integration	EPC	Carbon Capture	Carbon Transport	Carbon Storage
Peninsular Malaysia	PETRONAS				PETRONAS*	PETRONAS*	PETRONAS*
Sarawak	PETRONAS				PETROS*, PETRONAS*		PETROS*, PETRONAS*

*: Companies that are marked with asterisks have plans to take up the role in the value chain, but no existing experience

Way of working projects in Malaysia

Malaysia has a relatively open and business friendly environment for foreign companies looking to invest and work on projects in the country. This is however subjected to certain constraints. Some examples from Task 2 on some of these points are highlighted in the next slide.

Regulation

Subject to projects, more information can be found in earlier slides)

Local partner/Investor

Able to help the foreign company navigate local regulations, laws and customs. The local partner can also help the foreign company establish a presence in Malaysia, such as setting up a subsidiary or joint venture

License & Permits

Required to operate in Malaysia depending on industry (Companies in the oil and gas industry may require licenses from Petronas)

Long Term relationships/ Mutual trust

Projects with foreign companies are generally collaborative and inclusive through bilateral agreements where local partners are often seen as important stakeholders. Time may be needed to navigate through challenges from on cultural differences.

Project Spectrum

Foreign companies who are able to be involved in full turnkey projects are often preferred in Malaysian projects

Malaysian capabilities & way of working Malaysian projects

CASE 1

Hydrogen Production Plant & Refuelling Station

SEB embarked on feasibility research on possibility of having a production plant and a refuelling station in Kuching in 2017. The project was launched and operational by 2019 with collaboration with Linde. Linde has expertise across a range of services (major supplier of industrial gases, engineering services and gas equipment) in over 100 countries. Linde undertook a major role in the development phase of the project while SEB took over after the project was completed.

CASE 2

H2biscus Project

SEDC signed a MoU with foreign players such as Samsung, Lotte, POSCO to build a hydrogen plant in Sarawak. The Korean companies with various expertise will together across different aspects within the development/construction phase. Samsung to build the methanol plant, Lotte to turn hydrogen into ammonia, POSCO to use the hydrogen to green its steel business. Once completed, SEB will take over the operational role.

CASE 3

Kasawari CCS

The CCS development is the second phase of the Kasawari project. Petronas took the final investment decision for the project which is scheduled to start operations by end 2025. Local contractors (MMHE and NPCC) were awarded the FEED contracts where individual contractors teamed up with foreign players such as Ranhill Worley and Technip Energies for engineering works. Feasibility studies to be headed by Xodus. Baker Hudges secured contract with MMHE to supply carbon dioxide compression equipment.

Evaluation:

From the examples above, companies that are able to deliver large scopes of work on a turn-key basis appear preferred. Malaysian companies are essential to involve in the process but play a smaller role in development, before becoming more active in the operational phase. For foreign companies it may therefore be required to partner up with local firms, even when delivering projects turn-key and with the ability to work end-to-end. This will be even more relevant for companies with expertise in more limited parts of the value chain. Foreign companies working in sub-contracting roles often do so based on bilateral agreements that are largely based on mutual trust and long-term relationships.

Capability gap analysis - Summary

Based on the overview of Norwegian companies and Malaysia companies, a value chain mapping is made to identify potential gaps where Norwegian companies can play a role;

Green hydrogen value chain mapping

	Local renewables development	Equipment manufacturing	System integration	EPC	Hydrogen storage	Hydrogen transport	End-use
Norwegian capability	**Medium**	**High**	**High**	**Medium**	**Medium**	**Medium**	**High**
Malaysian domestic capability	**High**	**Medium**	**Low**	**Medium**	**Low**	**Low**	**High**

Blue hydrogen additional capability mapping

	Local gas supply	Equipment manufacturing (SMR)	System integration	EPC	Carbon capture	Carbon transport	Carbon storage
Norwegian capability	**Low**	**Low**	**Low**	**Medium**	**High**	**High**	**High**
Malaysian domestic capability	**High**	**Low**	**Low**	**Medium**	**Low**	**Low**	**Low**

- **Green Hydrogen** – Norwegian companies can be complementary to Malaysian companies in several areas, namely equipment **manufacturing and system integration**. For equipment manufacturing, Norwegian made equipment can be utilized in Malaysian projects, though Malaysia is also developing its own expertise via Petronas PEM manufacturing. System integration is a capability Norwegian companies have, but is still limited in Malaysia and therefore is potential segment.
- **Blue Hydrogen** – Norwegian companies experience lies in **carbon capture, transport and storage,** which is a new industry in Malaysia and can make use of Norwegian's expertise in these segments.

Possible areas to play

Capability gap analysis – Green hydrogen

	Local renewables development	Equipment manufacturing	System integration	EPC	Hydrogen storage	Hydrogen transport	End-use
Norwegian capability	**Medium**	**High**	**High**	**Medium**	**Medium**	**Medium**	**High**
Malaysian domestic capability	**High**	**Medium**	**Low**	**Medium**	**Low**	**Low**	**High**

Segment	Norwegian Capability	Malaysian (Domestic) Capability
Local Renewables Development	**Medium** - Norwegian companies have a lot of experience with renewable development. However, there are limited positions for renewable developers in the Malaysian market currently and Norwegian companies do not have a strong market position locally to leverage, placing them at a disadvantage..	**High** – Tenaga Nasional Berhad and Sarawak Energy has a strong position in renewables development as being the accountable company in Malaysia for power generation.
Equipment Manufacturing	**High** – Norwegian companies (i.e. NEL) have global expertise in electrolyser manufacturing, which can be utilized in Malaysian projects.	**Medium** – Malaysia is developing its own expertise via Petronas on Polymer Electrolyte Membrane (PEM) electrolyser manufacturing, but is not yet at the scale e.g. NEL is.
System Integration	**High** - System integration is a capability Norwegian companies have within the value chain and is a potential areas to be active at due to limited capability from domestic players.	**Low** – Companies with system integration capability is still limited in Malaysia. Ongoing hydrogen pilot projects in Malaysia which require system integration expertise are currently handled by foreign companies.
EPC	**Medium –** There are several major companies that are active as an EPC in green hydrogen within Norway such as Aker Solutions and Yara, among others. However, these companies are not active in such projects within Malaysia.	**Medium** – Malaysia has several EPC companies that have capabilities in the oil and gas industry, petrochemicals and renewable energy. However, their experience with hydrogen is still limited.
Hydrogen Storage	**Medium –** Norwegian companies with hydrogen storage/distribution expertise (i.e. UMOE, Hexagon Purus) are currently not active in the region. The companies have a global presence with expertise in composite storage tank, but it is likely that there would be a strong competition with others.	**Low –** There is no well known hydrogen storage and transport players domestically as it is currently a developing sector. Pilot studies are currently focusing on other value chain segments such as hydrogen generation. There are upcoming plans by MGTC to research further on hydrogen storage but is currently at a 'Call for Proposal' stage.
Hydrogen Transport	**Medium** – Within the hydrogen transport segment, Norwegian companies are strong in the Maritime sector (i.e. Wilhelmsen who is already active in the region, yet hydrogen projects are mostly in Europe for now). However, are not much players yet in land transport.	
End Use	**High** – Both Norwegian and Malaysia have high capability in using hydrogen. For instance, YARA, who aims to decarbonize their ammonia production would be a suitable offtaker.	**High** – Both Norwegian and Malaysia has high capability in using hydrogen. Malaysia has existing industrial and petrochemical facilities which utilize hydrogen

Possible areas to play

DNV

Capability gap analysis – Blue hydrogen

	Local gas supply	Equipment manufacturing (SMR)	System integration	EPC	Carbon capture	Carbon transport	Carbon storage
Norwegian capability	**Low**	**Low**	**Low**	**Medium**	**High**	**High**	**High**
Malaysian domestic capability	**High**	**Low**	**Low**	**Medium**	**Low**	**Low**	**Low**

Segment	Norwegian Capability	Malaysian (Domestic) Capability
Local gas supply	**Low** - Norwegian companies have a lot of experience with renewable development, but limited position in the Malaysian market currently. The market also isn't very open for Norwegian companies, placing them at a disadvantage.	**High** – Similar to the green value chain, local gas supply would fall under local utility companies' accountability and domain. Therefore, local companies have a high capability whilst Foreign companies low capability.
Equipment Manufacturing (SMR)	**Low** - There are no well-known SMR manufacturers or system integrators from Norway.	**Low –** There are no well-known SMR manufacturers or system integrators from Malaysia. Existing industrial facilities SMR are usually imported from international suppliers such as Linde, Air Liquide, and Technip.
System Integration		
EPC	**Medium** - There are several major companies that are active as an EPC in blue hydrogen within Norway such as Aker and Yara, among others. However, these companies are not active in such projects within Malaysia.	**Medium** – Malaysia has several EPC companies that have capabilities in the oil and gas industry, petrochemicals and renewable energy. However, their experience with hydrogen is still limited.
Carbon Capture	**High** – Norwegian expertise lies at carbon capture, transport, and carbon storage within the blue hydrogen value chain. Some companies are active in Malaysia as well such as Aker, 3C – Baker Hughes (who is already involved in the advisory of Kasawari CCS feasibility studies).	**Low –** Both Sarawak and Peninsular Malaysia's carbon capture industry is new with limited experts in the field. Petronas and Tenaga Berhad Nasional are exploring the field through pilot projects such as the Kasawari CCS project. The project itself is appointed to two local EPC companies but foreign companies are involved as well.
Carbon Transport		
Carbon Storage		

Possible areas to play

Capability gap analysis – Barriers

Based on the previous capability gap analysis, it was identified that Norwegian companies can play a role in several segments of the value chain – namely:

- **Green hydrogen** value chain: Equipment Manufacturing and System Integration
- **Blue hydrogen** value chain: Carbon Capture, Transport, and Storage.

To unlock these opportunities, it is important to:

- Ensure the hydrogen market is developed further by ensuring availability of resources and off takers
- Structure the development of hydrogen in a way that stimulates participation of foreign / Norwegian firms

From the interview insights from Norwegian companies in the Malaysian market, it was found there are several barriers for them to participate in the Malaysian market – discussed per region on the right.

Sarawak is currently more advanced when it comes to the hydrogen market landscape. Lessons from Sarawak may apply as well to Peninsular Malaysia, such as access to low cost renewables but with different constraints.

Sarawak	Peninsular Malaysia
Project development & award process – In Malaysia, project developments are primarily on • Bilateral agreement basis • With a preference from government stakeholders for fully developed (turnkey) projects As a result, there is no clear process or procedure for project development & award. Norwegian companies have indicated a preference for pre-defined tenders with clear offtakers to de-risk investment where they can focus on smaller part of the value chain that utilizes their expertise rather than full end-to-end development. As a result of the current bilateral process companies from Korea and Japan companies have a head start due to the availability of willing offtakers domestically.	
Renewable strategy – low energy generation costs are crucial for green hydrogen development, in which a partnership with Sarawak Energy is required to access these renewables through PPAs. However, there is no clear strategy in place on how these renewables is going to be used. As of now, in addition to hydrogen production, there are multiple potential plans in line for the renewables usage – from domestic decarbonisation to potential exports to Singapore by cable. This competition is likely to drive up the prices, resulting in renewables cost that is no longer competitive. Further, grid system capability will likely be an issue for large scale renewables projects in combination with likely high grid charges. It is essential to upgrade the grid ahead of RE investment to reduce grid related issues later on, which can be aligned with potential hydrogen production.	**Limited low cost renewables –** in Peninsular Malaysia, constraints in renewable development result in limited access to low cost renewables. Solar is the only suitable renewables source in the state, but currently there is limited development. There are a number of awarded projects yet they are not being developed due to increasing material costs and low barriers to entry. Companies with limited experience were able to wind the bid by lowering their prices, planning to sell the project afterwards to a more experienced developer. However, the price is too low to be attractive or feasible and developments have slowed down. Additionally, there is limited access to PPAs.
Non-transparent Processes – The process to get hydrogen developments off the ground is non-transparent and slow, requiring different government agencies to be engaged with unclear mandates. This is slowing down key parts of the development process such as acquiring the required permits.	

Recommendations

Based on the listed barriers from last slide, this study recommends a set of improvements categorized into strategic clarity, policies to stimulate development, and additional recommendations to improve practicalities.

Strategic Clarity	• **Availability of renewables** – Clear strategy on how much renewable development will be available for hydrogen production • **Additionality** – There should be clarity on the renewable energy plants to be used for hydrogen production as the additionality requirements from RED II requires new electricity generation for hydrogen production to be considered as clean emission. • **Transparency** – Transparent process for upcoming plans for hydrogen development and project awarding
Policies to Stimulate Development	• **Low cost renewables** – crucial to allow hydrogen production being price competitive, can be done through tax reduction and/or subsidies • **Grid connection cost** – For hydrogen production facility that are not developed onsite adjacent to hydropower resources, charges to transit green energy from renewable sources to the facility should be kept low to attract investment • **PPA/wheeling** – as the renewables would be procured through PPA, it is important to have a clear mechanism and ensure the availability of PPA/wheeling of renewables power for hydrogen development projects. • **Reduce investment risks** – to minimize risks of the investors by providing financial aids, ensuring availability of hydrogen off takers, and facilitate/plan hydrogen infrastructure. • **Make blueprint more concrete** (Peninsular Malaysia) – to include specific tasks and deliverables within the blueprint as a reference and the actors to be involved for specific tasks
Practicalities	• **Improve Grid Strength** - Grid strengthening Sarawak, can be tied to clarity of process by pre-determining where to develop hydrogen production and at what capacity • **Increase renewables development** (Peninsular Malaysia) – to have more available PPAs for hydrogen development • **Permitting process** – improve the process so that permitting process no longer becomes a concern for foreign players by having clear procedures, efficient, and transparent.

Appendix

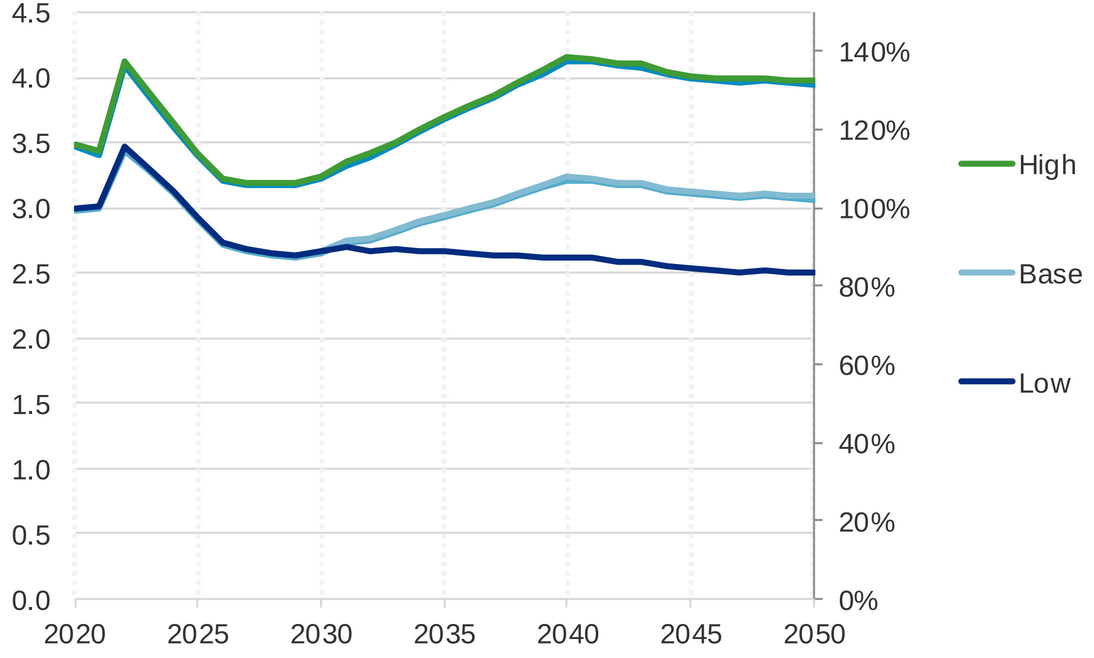
Hydrogen Production Costs – Sensitivity Analysis

- Methane reforming with CCS

Gas prices is the most influencing input factor in the LCOH projected, with (2020 base scenario price set as 100%). The high case refers to 50% gas price increment, while low case is excluding the assumption that Peninsular Malaysia's prices is converging into international prices, resulting in a lower LCOH as much as 20%.

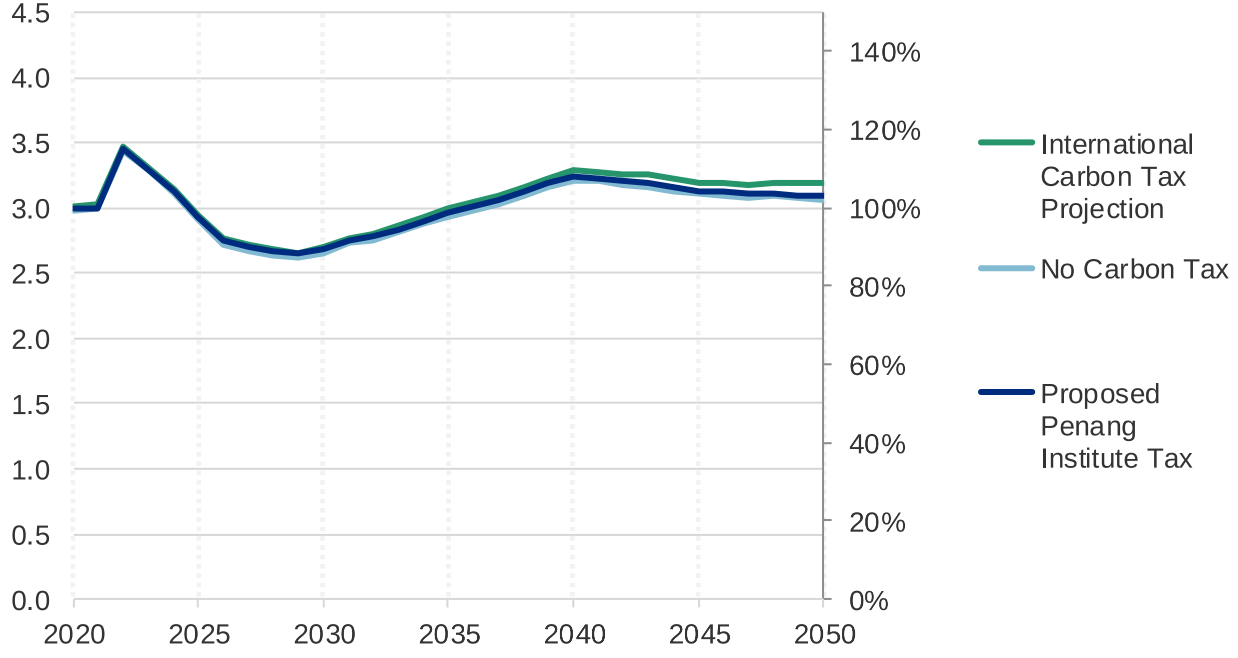
Methane Reforming Sensitivity Analysis - Gas Prices

Units: USD/kgH_2



Methane Reforming Sensitivity Analysis - Carbon Prices

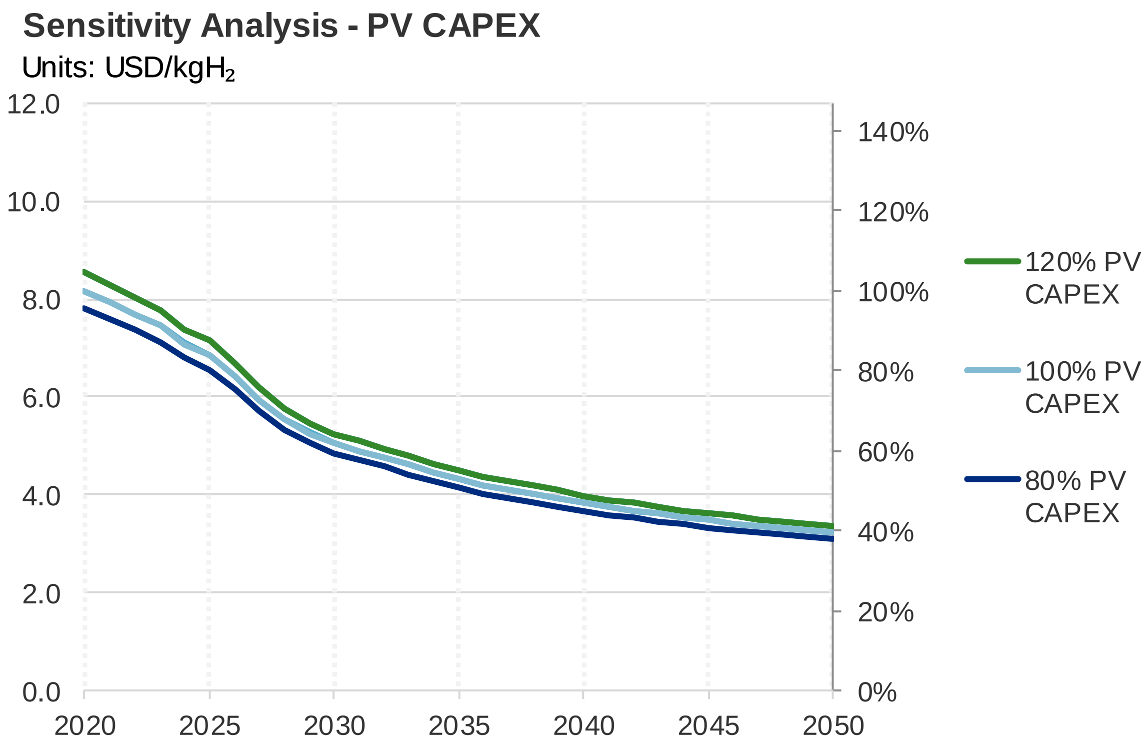
Units: USD/kgH_2

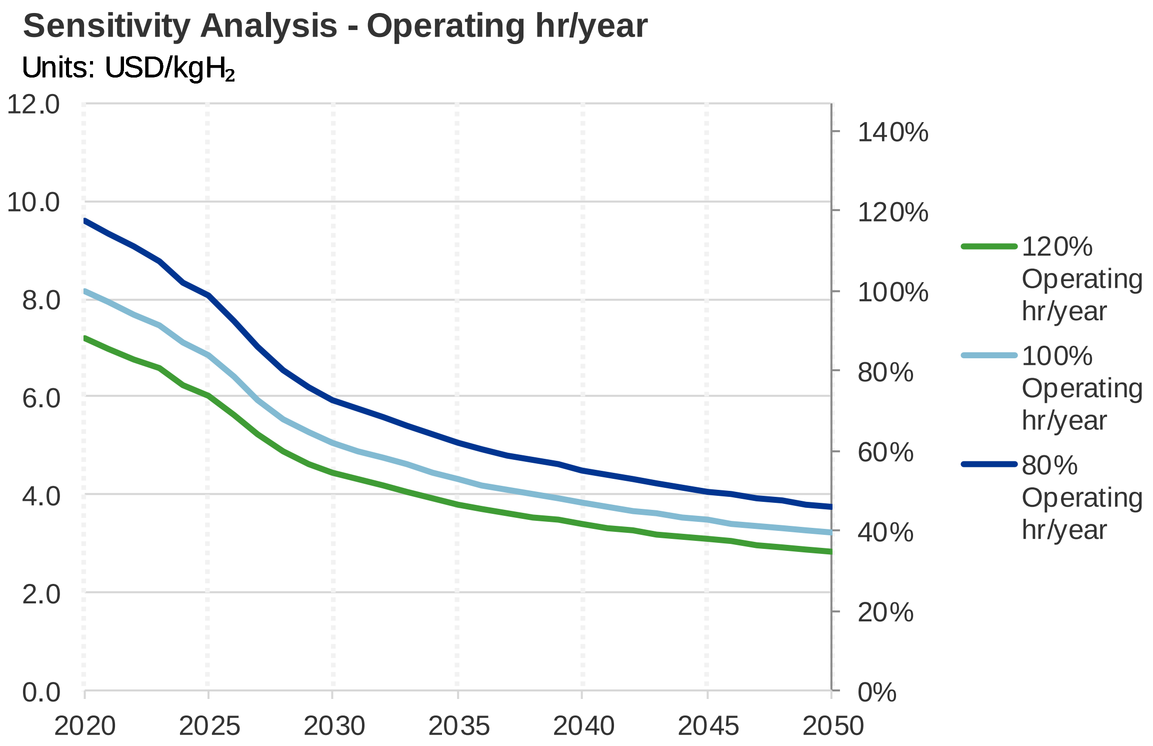


Hydrogen Production Costs – Sensitivity Analysis

- Dedicated solar PV electrolysis

Operating hr/year and is the most influencing input factor in the LCOH projected, with (2020 base scenario price set as 100%) . For CAPEX is linear trend and less influence.

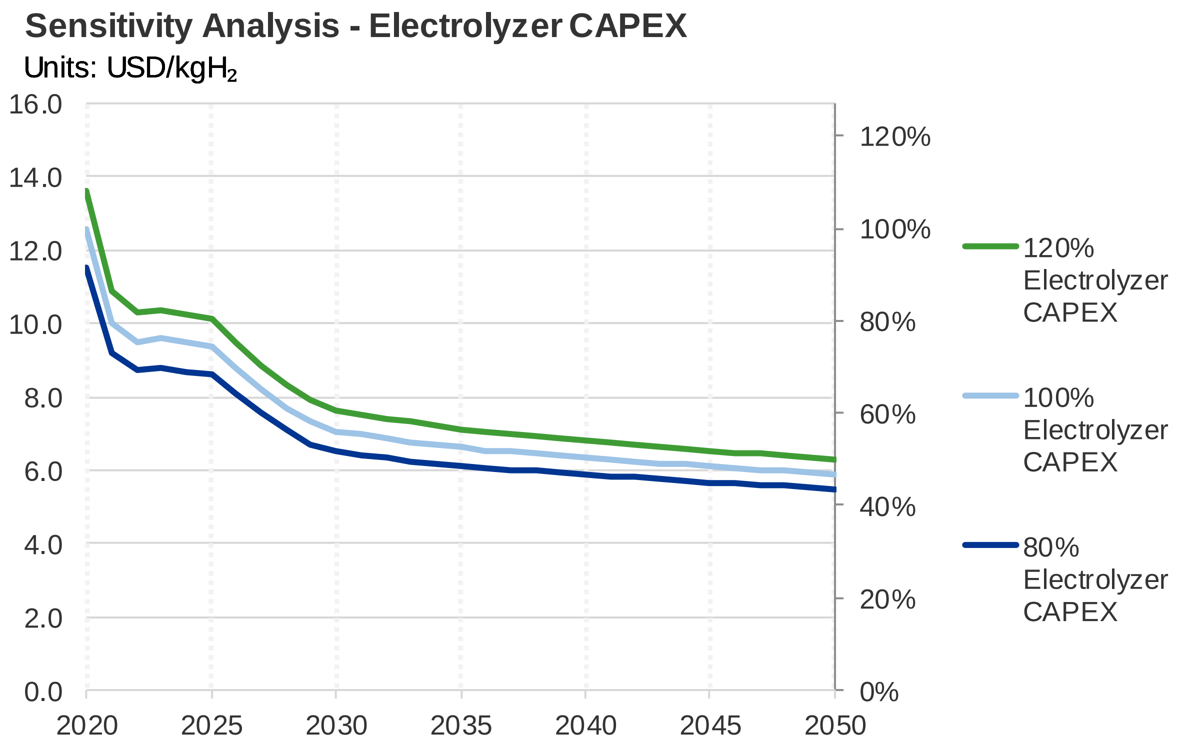


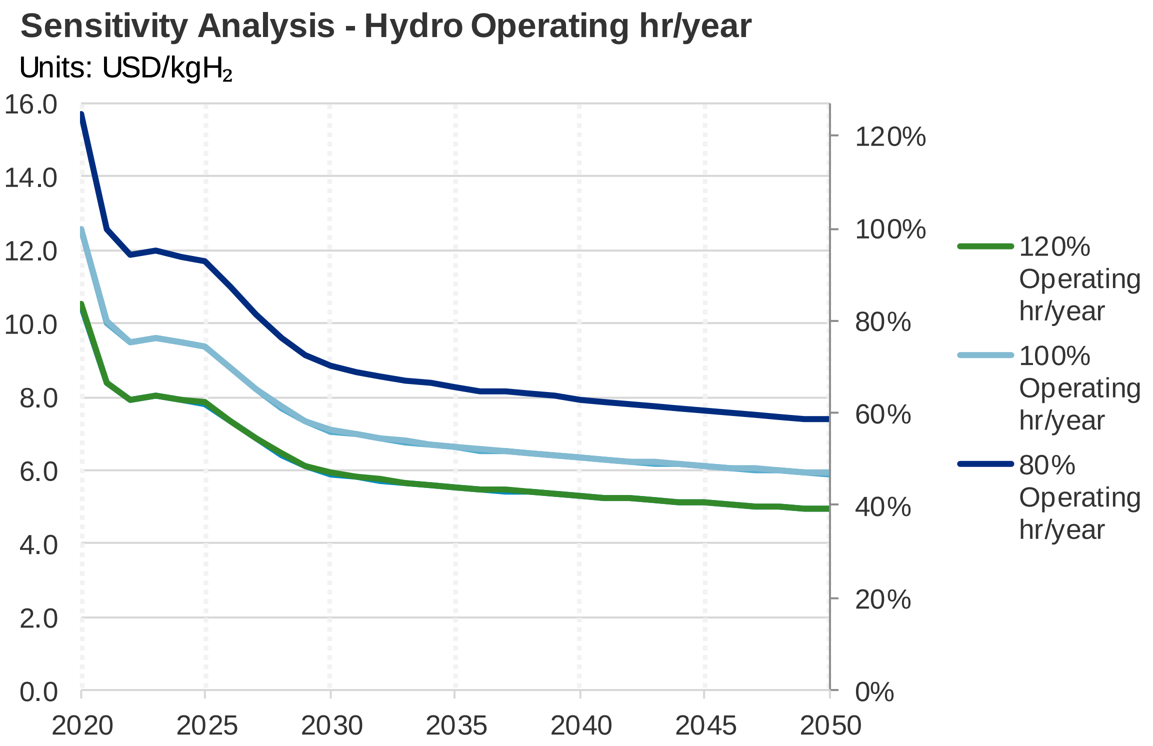


Hydrogen Production Costs – Sensitivity Analysis

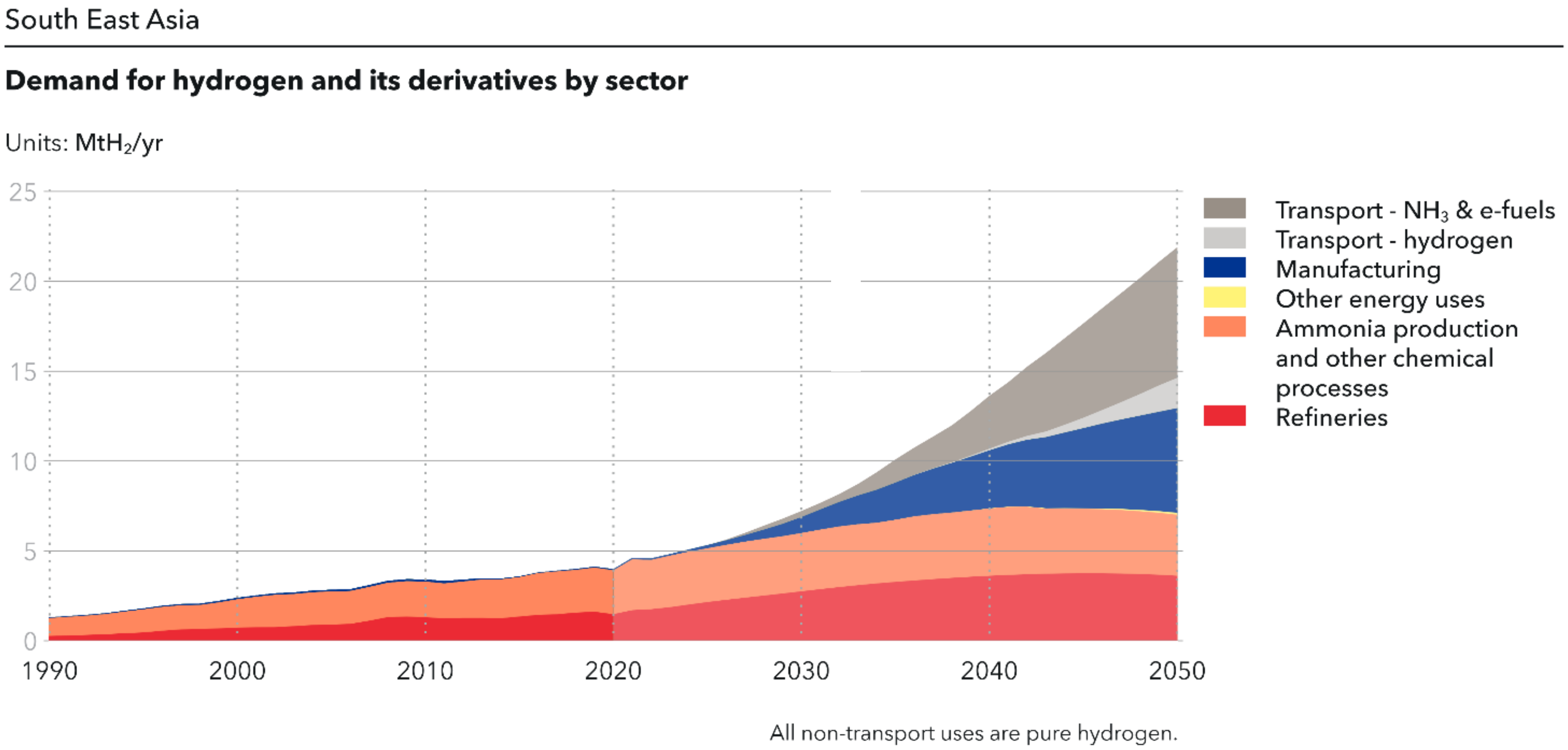
- Dedicated hydropower electrolysis

Operating hr/year and is the most influencing input factor in the LCOH projected, with (2020 base scenario price set as 100%) . For CAPEX is linear trend and less influence





Market potential – Hydrogen demand in SEA



Relevant regulations in Peninsular Malaysia

Regulation/Policy	Explanation
Electricity Supply Act 1990	Under the Electricity Supply Act, developers who wish to generate electricity through renewable sources >30MW are required to obtain license from the Energy Commission. The Energy Commission has requested for various RFPs for large scale solar PV plants (currently on its 4th RFP). Each RFP will institute a capacity size based on the government requirements and need at that point of time and bidders was welcomed to submit their capacity and tariff bids that will be subjected to selections. A draft PPA will be included and deviations of which may be negotiated before the final PPA. Net Energy Metering Scheme (NEM 3.0) was added in 2019 to boost renewable energy in Malaysia.
Renewable Energy Act 2011	Under the Renewable Energy Act, person(s) who wish to generate and supply electricity from renewable energy sources are quired to submit their application for feed in approval to become a feed in holder (1-30MW for biogas, biomass and small hydropower as well as 1kW-30MW for solar PV) to Sustainable Energy Development Authority of Malaysia (SEDA). Generated electricity will be sold under the terms of RePPA with TNB based on the feed in tariff rates that are adjusted every 1 Jan of each year. PPA will be typically 16 years for biogas and biomass, and 21 years for small hydro and solar PV.
Gas Supply Act 1993 (amendment in 2016)	TPA system came into effect in 2017 with the amendment of the Gas Supply Act in 2016 to allow third party players to source LNG and use gas facilities that they own or do not own or operate such as regasification terminals, transmission pipelines and distribution pipelines . However, this is limited to only LNG while the gas supply act have yet to include hydrogen as one of the gas sources.
Cross Border Electricity Sales Act	Under the Cross Border Electricity Sales act (Oct 2021 Revision), For Malaysia to Singapore: sales of electricity will be generated from non-renewable energy sources, transfer through Existing Interconnection not exceeding 100MW. Malaysia to Thailand, PPD is required to develop and build a Dedicated Interconnection (not connected to Grid System and no system support) for transfer between Power Producer Developer and Purchaser. Peninsular Malaysia not exporting its renewable energy to other countries but using it for domestic use.
Fifth Fuel Diversification Policy (2001)	Renewables was included as Malaysia's fifth major source of fuel.
Large Scale Solar (LSS)	The Malaysia government introduced the LSS scheme to allow electricity generation through solar PV farm with installed capacity ranging from 1MW to <30MW (for distribution connected solar PV plants), and sell to the grid. The EC administers the scheme and select potential developers through competitive bidding. 4 bidding cycles have been concluded since its introduction. In Nov 2021, the Ministry of Energy launched the Green Electricity Tariff programme (GET) that offers electricity consumers the option to purchase electricity generated from renewables sources (LSS plants, hydropower stations belonging to TNB or its subsidiaries, any other renewable energy plants approved by the Commission). Total quota of GET will be 4500GW per annum. Fully subscribed in 2022.

Relevant regulations in Sarawak

Regulation/Policy	Explanation
Distribution of Gas Ordinance 2016 (DGO)	Under the DGO, import of any gas for regasification, processing, treatment, separation, utilisation or distribution in Sarawak will require annual license fee of 0.001 MYR per MMBTU. Activities for transportation of gas will require additional annual license fee per unit. Activities for building, managing or maintaining gas pipeline or other apparatus or equipment or mechanism for distribution of gas will be charged annual based on classes of installation. License fees will also be charge for supplying of gas. Any activities involving building, managing or maintaining gas pipeline or other apparatus or equipment or mechanism for distribution of gas will require a gas license, an Approval to Install and Approval to Operate from the Ministry of Utilities of Sarawak.
Natural Resources and Environment (NREB) (amendment in 2001)	The NREB holds the responsibility of protecting and managing the environment and conservation of natural resources of the State to ensure sustainable development. To support the code, Sarawak implemented Sarawak Corridor of Renewable Energy (SCORE) in 2008, powered by large hydro resource to attract energy intensive heavy industries to the state. Regional Corridor Development Authority (RECODA) sets the strategic development of SCORE, as well as planning and executing development programmes and projects in SCORE. RECODA also design and review incentive schemes to entice investors to invest in SCORE. Since then, the generation mix has successfully transitioned from 92% fossil fuels in 2010 to 70% hydropower by 2015 in which the shift has decarbonised the grid emission intensity by 72% between 2010 and 2020.
The Electricity Rules 1999 & Electricity Ordinance (Revised 2003)	Electricity industry in Sarawak is being regulated under the Sarawak state government.
Distribution of Gas (Licensing) Regulations 2018	Person applying licence for gas related activities under the DGO has to provide a description of the area intended for carrying out of operations, site location plan to be installed with gas pipeline and other forms of specification to the Director if Gas Distribution.

Malaysia renewable status and targets

Current Status	Future Plans and Targets
Large hydro capacity in Malaysia stands at 5.7GW in 2020. Out of which, 2.23GW was from Peninsular Malaysia	Generation Development Plan 2020 – Energy demand expect to grow at a rate of 0.6% per annum from 2021-2030 and 1.8% from 2031-2039. 6.08GW of new capacity needed by 2030 to meet demand and replace retiring plants.
IRENA Renewable Energy Statistics 2022 – Total renewables in 2021 was 8.8GW. Out of which, 6.2GW was hydropower, 1.8GW was solar and the remaining was bioenergy	Renewable Energy Transition Plan 2021-2040 – Malaysia targets to increase share of RE installed capacity. • Malaysia: 31% by 2025 (up from initial target of 25%), 40% by 2035 • Peninsular Malaysia: 26% by 2025, 32% by 2035 • East Malaysia: 5% by 2025, 8% by 2035 From 2030, Malaysia plans to introduce BESS (500MW) as solar having the highest RE potential.
As of 2018, installed RE capacity in Sabah was 134.2MW, produced by solar, mini hydro, biomass and biogas sources (mostly from solar and biomass). Part of solar contribution came from FiT consisting of 39 solar developers who accounted for 21.5% of RE supply. Minister of MESTECC established the Green Financing Taskforce to mobilise affordable financing for RE developers	Sarawak Post Covid Development Strategy (PCDS 2030) – Sarawak aims to maintain at least 60% RE capacity mix by 2030, 600k tons annual reduction to CO_2 emissions and more than 15% income from foreign markets through RE sector. This will be done through promoting and increase private sector participation on renewables, stimulate the hydrogen economy through attracting investments for hydrogen production and value chain, establish hydrogen refuelling station network, hydrogen to power Automated Rapid Transit (ART). Another initiative is to export Sarawak RE by increasing interconnectivity with other regions. Also, to establish Net Energy Metering by introducing Renewable Energy Supply Act and public participation of government buildings in the Net Metering programs. Electric vehicles will also be promoted through 100MW RE generation capacity, 3 in 1 multi-fuel charging stations hydrogen, electric and conventional fuel and establishment of a EV value chain Malaysia Renewable Energy Roadmap – Released by Minister of Energy and Natural Resources (KeTTHA) which identified RE potential in Malaysia (solar being the most promising potential of 269GW capacity, followed by 13.6GW of large hydro, 3.6GW of bioenergy and 2.5GW if small hydro) in different regions of Malaysia. The initiatives to promote solar development include accelerating the NEM programme as well as introducing peer to peer Energy Trading programme and enabling corporate PPA in line with TPA framework.

Malaysia Previous Plans

The Economic Planning Unit (EPU) under the Prime Minister's Department develops the Malaysia Plans every 5 years. In order to develop the plans, extensive engagement sessions were undertaken, involving various stakeholders including ministries, state governments, private sectors and civil society organisations. As various ministries and agencies oversee different functions and manage tasks in relation to their functions, the Malaysia Plan is an important document that gives a detailed overview on Malaysia's focus towards development of all sectors, as well as having specific targets and tasks for the ministries and agencies.

RE was added as an important focus since the 8th Malaysia Plan (2001-2005) and since then there are various initiatives with varying degree of success. Through the plans as seen from the roadmap on the next slide, there were progressive steps and targets for the country to achieve though not all are effective. Despite that, we can see that as the plans progress, the country adapt to the challenges faced by various RE initiatives and improve them in subsequent plans. Also, the country seems to be more confident towards having RE as part of its sustainable development through the number of initiatives in the later plans.

Through past results, we can also see that there are huge funding and incentives available for green technology development which could promote investment towards developing hydrogen infrastructures if the country decides to expand its focus towards hydrogen development. Another example is the blending of cleaner fuel in the transportation sector which create possibilities for future cleaner hydrogen blending for similar sectors.

Malaysia Previous Plans (Roadmap)

2001 — 8th Malaysia Plan — **2005** — 9th Malaysia Plan — **2010** — 10th Malaysia Plan — **2015** — 11th Malaysia Plan — **2020**

2001–2010 (8th and 9th Malaysia Plans)

BioGen funded by UNIDO and Global Environment Facility (GEF) made two full scale demonstration models possible

Small Renewable Energy Project (SREP) implemented for <10MW grid-connected projects. Only 2 SREP for biomass and biogas built and operated. 5% RE target share in Five Fuel Policy not met

SREP target revised to 350MW with contributions were from biomass and mini hydro.

Malaysia Building Integrated Photovoltaic (MBIPV) funded by UNIDO and GEF increased BIPV utilisation up to 1.5MWp

2010–2020 (10th and 11th Malaysia Plans)

FiT mechanism implemented in 2011 under the Renewable Energy Act resulted in RE installed capacity growth from 53MW in 2009 to 243MW in 2014.

Transportation sector: Control emissions with higher use of efficient vehicles and biofuels. 35 depots constructed with in-line blending facilities (5% bio-diesel blending in automotive fuel)
2013: Government gazette EURO 4M standards
2014: Malaysia introduced B7 programme (7% bio-diesel blending)
2015: Government enforce standards from 2013 in RON97 fuel

SEDA's FiT programme only resulted 421MW of RE achieving commercial operation by 2016 out of 1349MW of approved RE. Solar PV was commercialized quickly but there were lags from rest of RE sources

Green Technology Financing Scheme (GTFS) helped 225 projects through aid of RM2.5 billion

RE installed capacity of 8885MW target not met by 2020, only 7995MW achieved. Target exceed expectation for additional power generation capacity.

Green Technology Master Plan launched in 2017 with overview to 2030. From 2016-2020, 83 RE solar and 6 RE biomass projects with total investments of RM652.8 and RM344 million enjoyed tax incentives. GTFS additionally helped 94 projects with an aid of RM1.1 billion.

Renewable Energy Transition Roadmap (RETR) developed in 2019 by SEDA to highlight progressive strategies to achieve Malaysia RE installed energy mix for electricity generation target of 20% by 2025, with electricity scenarios by 2035.

LSS: In 2016, open tender calls for up to 250MW resulted in an award of 450MW that would begin commercial operation in 2017-2018. In 2017, LSS 2 tender for capacity up to 460MW resulted in award of 562MW from received bids of 1632MW to begin commercial operation in 2019-2020. As of Apr 2018, only four LSS projects had commenced operations (34.5MW). In May 2020, the Energy Commission called for a third tender on LSS for up to 500MW to be operational in 2021.

12th Malaysia Plan: The RETR will be implemented in the current 12th Malaysia Plan (2021-2025). In accordance to the RETR, the Energy Commission depends on LSS and NEM to increase RE in the fuel mix including off-grid up to 20% in the 12th Malaysia Plan.

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Hydrogen development in Malaysia

Peninsular Malaysia	East Malaysia
PETRONAS Hydrogen established in 2020 under the Gas and New Energy business that taps on existing blue hydrogen experience to become a competitive green hydrogen solution provider	Sarawak just enacted the Land Code (Amendment) Bill, 2022, putting it in a better position to promote CCUS as a potent technology for mitigating greenhouse gas emissions in the direction of a low-carbon economy.
Solar, Hydrogen and Fuel Cell roadmap (SHFR) was introduced in 2006 by the Ministry of Energy, Communications and Multimedia for research, development and utilisation of solar energy, hydrogen energy and fuel cells. It was implemented under the 9th Malaysia Plan but was abandoned in subsequent plans because it was superseded by the RE Transformation Roadmap where more focus was towards RE through the FiT scheme. In 2017, the Blueprint for fuel cell industries in Malaysia was released which identified existing usage of hydrogen and the renewables status in Malaysia as well as the potential methods hydrogen could grow in Malaysia based on existing regulations. The 2017 blueprint was an upgraded version from the SHFR in 2006. The Green Technology Master Plan (2017-2030) was an outcome of 11th Malaysia Plan (2016-2020) which marked green growth as one of the six game changers for Malaysia growth. The plan outlines strategic plans for green technology development in areas such as energy, manufacturing, transport, building to create a low carbon and resource efficient economy. More focus was towards growing RE but lack of strategy to promote hydrogen.	Sarawak just enacted the Land Code (Amendment) Bill, 2022, putting it in a better position to promote CCUS as a potent technology for mitigating greenhouse gas emissions in the direction of a low-carbon economy. In 2020, MoU was signed by SEDC, Sumitomo Corporation and Eneos to build a hydrogen production plant in Bintulu. Based on Sarawak Chief Minister statement, hydrogen gas can be produced by using cheap electricity tariffs via hydropower to be cost efficient, where the production system would be viable in order to achieve sustainability in the long haul. (Research and development stage and expected to be ready by 2023 with a planned capacity of 1000 tonnes/year) H2biscus project: Sarawak to set up its first hydrogen plant in Bintulu in 2022 along with efforts from SEDC, Samsung, Lotte Chemical and POSCO. Expected to complete in 2-3 years. Once completed, expected to produce 630k metric tonnes of green ammonia, 600k metric tonnes of blue ammonia, 220k metric tonnes of green hydrogen, of which 7k (based on pre-feasibility study in 2021) metric tonnes will be used for domestic purposes and remainder to export to South Korea. Deputy Minister of Energy and Environmental Sustainability pointed out that Sarawak will only use 60% hydrogen, on top of other energies such as solar energy, electricity and gas
Feasibility study between PETRONAS, IHI Corporation and TNB Genko on low carbon hydrogen+ammonia supply chain in Malaysia	In 2019,10 million MYR allocated for R&D in hydrogen development.

Hydrogen development in Malaysia

<table>
<tr><th>Peninsular Malaysia</th><th>East Malaysia</th></tr>
<tr><td>Research team from PETRONAS hydrogen collaborate with UKM that looked into hydrogen production from water through R&D in electrolysis technology that address cost and scalability.</td><td>SEDC tasked to look into the use of hydrogen as a source of renewable energy for public transport. (Current achievement of 2 buses that runs on hydrogen and an autonomous rapid transit system that would run on hydrogen is under development). New Ministry for Energy and Environmental Sustainability formed in Sarawak to advance Sarawak Green Energy Agenda</td></tr>
<tr><td>TNB teaming up with oil and gas company Petroliam Nasional Bhd (both domestic) to invest in green hydrogen and carbon capture. Plan to repower a retired combined cycle gas fired power plant in Paka, Terengganu by using gas with hydrogen-ready technology. In a statement on Aug 2022, President and Chief Executive from TNB said that they will invest 6.3 billion MYR for the project while Petronas had yet to comment on the investment on its end. The project is expected to start in 2023 and scheduled to be ready by 2030 with the expectation of MYR 250 million annual EBITA and avoid approx. 700k car CO2 equivalent</td><td rowspan="2">In 2017, Sarawak embarked on research into green hydrogen production under the Green Energy Agenda with the aim of decarbonising and greening the transport system and transitioning to a low carbon economy. Sarawak Energy spearheaded the pilot project and already producing green hydrogen at their integrated hydrogen refuelling facility in Kuching (launched and operational in 2019 in partnership with Linde, less than 2 years after first announcement by SEB on undertaking research on hydrogen for energy related applications in Nov 2017) Provides refuelling services for 3 hydrogen buses which currently serve as public transport in Sarawak capital city of Kuching. Made possible using electrolysis.
SEDC Energy to start producing green hydrogen at the PETROS multifuel station by end of 2022.</td></tr>
<tr><td>Formation of Gentari (previously known as PETRONAS Gas & New Energy Sdn. Bhd. As PETRONAS subsidy towards new renewable resources and hydrogen</td></tr>
<tr><td>PETRONAS and ENEOS (Japan) collaboration explores low carbon hydrogen production from PETRONAS petrochemical facilities and in the future, green hydrogen produced using renewable energy. Both have signed a Joint Feasibility Study Agreement (JFSA) in Mar 2022 as part of its MoU signed in Aug 2021 to advance studies for a commercial hydrogen production and conversion project in Kerteh, Terengganu. For this project, Eneos has applied for funding from the Japanese government's Green Innovation Fund that sponsors decarbonisation projects and initiatives. The facilities are projected to have a total hydrogen production and conversion capacity of up to 50,000 tonnes per annum (50KTPA) by 2027 for export in MCH form to Japan, where the clean hydrogen will be distributed to Japanese industries through ENEOS' refineries.</td><td>Hydrogen modules have also been recently introduced at Sarawakian universities, which will equip our future engineers with the necessary knowledge to thrive in the hydrogen industry going forward.
This is supplemented by various research programmes and projects with companies like Airbus and various Japanese firms to test hydrogen's applications in our daily lives.
As the scale of hydrogen expands, associated costs will continue to drop, which will be yet another game changer for Sarawak's economic landscape.</td></tr>
</table>

Policy enablers to overcome identified barriers

In addition to identifying general and case-specific barriers, learnings from global examples is also taken into account.

International Examples → Intervention Phases → Interim Recommendations – Policy gaps and enablers

The following section will provide examples of policies used by international counterparts to grow their hydrogen industry. These countries include European Union, Australia, Singapore and Chile. Based on experiences gain from these international counterparts, the policies will be enacted in different phases according to the complexity of policies and the status of the country. Following which, a recommendation will be provided using a stepped programme involving the policy barriers that were identified in the previous sections. It will be categorised based on short and long term prioritisation along the hydrogen value chain.

Policy enablers to overcome identified barriers – international examples

Country	Strategy	Enablers
Australia	Australian National Hydrogen Strategy (2019)	• Supporting research, pilots, trials and demonstrations with grants • 13 regional hydrogen technology clusters • Investor stake of $500m in Hydrogen Energy Supply Chain project to demonstrate supply chain • International engagement, notably with Japan, Korea, Germany, Singapore • Coordinate consistent regulation such as with reform of the National Gas Law • Create global Guarantee of Origin certification standard • Develop a National Hydrogen Infrastructure Assessment • Develop an Australia wide transport vision • Review workforce upskilling need and potential • Increase knowledge of hydrogen

Policy enablers to overcome identified barriers – international examples

Country	Strategy	Enablers

European Union	[A hydrogen strategy for a climate-neutral Europe (2020)]
	
	[Fit for 55 (2021)]
	
	[REPowerEU (2022)]
		• Investment
		  ○ Investments in electrolysers – €24-42 billion
		  ○ Scaling up of solar and wind production/connection capacity by 80-120 GW – €220-340 billion
		  ○ Investments in retrofitting half of the existing plants with carbon capture and storage – around €11 billion
		  ○ Investments in hydrogen transport, distribution and storage, and hydrogen refuelling stations – around €65 billion
		• Funding programmes including
		  ○ The European Clean Hydrogen Alliance, identifying and building a pipeline of viable investment projects capable of accessing public and private funds
		  ○ The Strategic Forum for Important Projects of Common European Interest (IPCEI)
		  ○ Support through the Strategic European Investment Window of Invest EU (from 2021) and through the European Regional Development Fund and the Cohesion Fund
		• Carbon Border Adjustment Mechanism
		• Electrolyser Summit Joint Declaration sets out a target agreed by electrolyser manufacturers in Europe to increase their manufacturing capacity tenfold to 17.5 GW per year by 2025
		• Accelerated permitting for renewable energy projects, including renewable hydrogen
		• Rules on renewable liquid and gaseous transport fuels of non-biological origin (REDII and Delegated Acts)

Policy enablers to overcome identified barriers – international examples

Country	Strategy	Enablers
Singapore	[Singapore's National Hydrogen Strategy (2022)]	• Experiment with the use of advanced hydrogen technologies at the cusp of commercial readiness. This includes ammonia for use in power generation or as a maritime fuel • Invest in R&D to unlock technological bottlenecks, with S$129m allocated under the Low-Carbon Energy Research (LCER) Funding Initiative • Pursue international collaborations to enable supply chains, including Guarantee of Origin certification • Undertake long term land and infrastructure planning • Support workforce training and development of broader hydrogen economy

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Policy enablers to overcome identified barriers – international examples

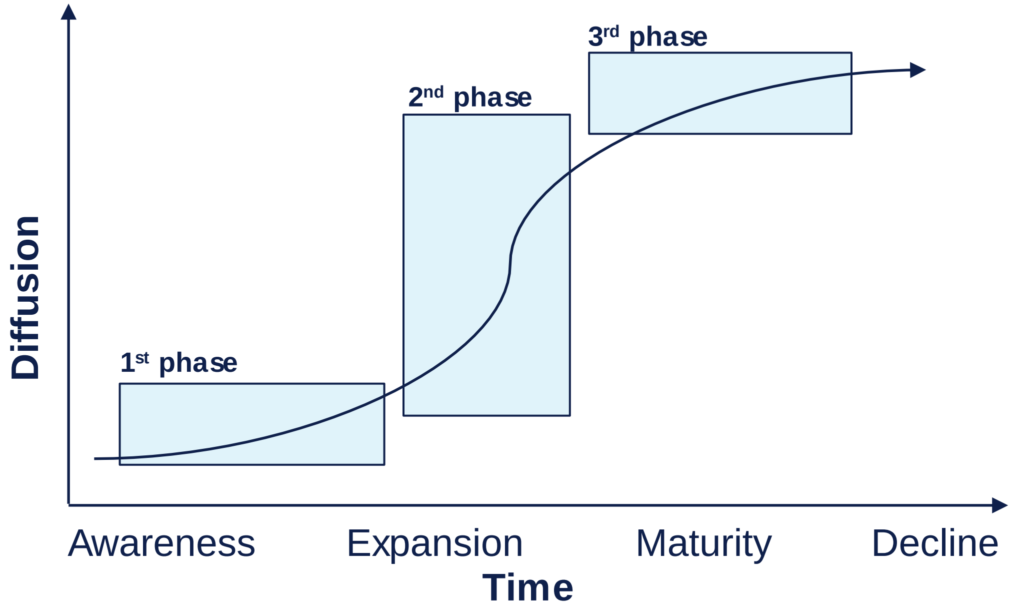
Country	Strategy	Enablers
Chile	[National Green Hydrogen Strategy (2020)]	• Promotion of domestic and export markets ○ USD$50m support for projects deploy and scale ○ Form public-private roundtable to discuss the path towards a carbon price and taxes ○ International diplomacy • Safety, standards and piloting ○ Coordinated regulatory development plan to support whole value chain ○ Taskforce formed to support developers with permitting and pilots ○ Review of natural gas regulation and infrastructure to promote the introduction of green hydrogen quotas • Social and local development ○ Participatory mechanisms between communities and projects ○ Evaluate means of replacing fossil-fuel based generation in remote communities with green hydrogen • Capacity building and innovation ○ Identify gaps and prepare national capabilities ○ R&D roadmap to solve local implementation challenges

Stepped programme of policy interventions

- Different policy options or packages of measures may be more suitable than others at different times, with some measures more relevant to early technology development and others to deployment or a mature market.

1st phase

Grants, loans, sector specific hydrogen strategies



2nd phase

E.g. Contracts for Difference auctions, obligation quotas

3rd phase

E.g. Tax incentives, consumer education measures

- Different policy measures are being considered around the world and those can be used to evaluate whether they could be introduced in Malaysia and the impacts of doing so.

Interim Recommendations – Policy gaps & enablers

	Energy production	Hydrogen electrolysis	Transport & Storage	End-use
Short-term prioritisation		PPA Carbon tax Carbon allocation Target for electrolyser production	State ownership/De-risking carbon storage	
			Ensure grid robustness (Upcoming hydropower additions in Sarawak) Reduce/Remove network charges/wheeling Port/Export infrastructure for hydrogen Subsidies	Mirror EU standards Guarantee of Origin Certification Mandate/Target
Long-term prioritisation		Target/Mandate		
			Market - Point to point (Grey Hydrogen Replacement) Market - Interconnection to national market (Fuel Replacement)	Quotas/ETS (Fuel Replacement)
General Barriers to overcome	• Monitor additionality requirement	• Develop quality and safety standards	• Streamline planning and permit processes	

Based on previous mapping, its is recommended to put in place required policies that have higher priority and enabling policies to enhance development of hydrogen. Based on the scenario analysis, prioritisations are divided into short-term (towards 2030) and long-term (towards 2050). In addition, general barriers all across the value chains should be addressed to accelerate the development. In Peninsular Malaysia, having a carbon tax and proper carbon allocation mechanism is required for the switch from grey hydrogen to blue hydrogen which there are upcoming plans in having a carbon tax. There is a link between carbon tax and having a proper mandate on hydrogen which is likely to take several years to build consensus for, design and implement but since there are ongoing plans for a carbon tax, implementing a carbon tax could a prioritisation in the short term with concurrent efforts in building a proper hydrogen development plan with targets towards the long term.

The international examples in the previous slides illustrate various policy enablers that countries adopt in building their hydrogen economy. EU is a successful example in their efforts towards hydrogen development hence Malaysia could mirror the standards that are already in place towards end users such as industry and petrochemical sectors that already have forms of hydrogen production as a short term prioritisation measure. Malaysia could also take references from countries that are still developing their hydrogen industry such as Australia and Singapore. In the short term, it is more important to create a strong foundation through required policies that are currently not available with the combination of some enabling policies that other countries already have in place. Towards the longer term, venturing into a bigger market could be identified and explored as well as enhancing the foundation created from the short term through other efforts .

Enabling policies currently **not** available in Malaysia

Required policies currently **not** available in Malaysia

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