Chapter 3

Elaboration of Future Scenarios

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Following the analysis of the historical and current situation of hydrogen supply and demand in the previous chapter, this study aims to project the possible situations that might happen in the future. This chapter provides an overview of how future scenarios are selected, elaborated, and implemented.

In the first part, a review is performed on future scenarios of the world or Southeast Asia's energy systems as elaborated in several existing studies and their reports.

In the second part, based on the results of the first part review, several scenarios are selected and further elaborated. The scenarios are selected based on their identified policy measures that allow to make future projection of hydrogen supply and demand in the Southeast Asian region and/or countries in the four industry sectors: oil refining and chemicals, ammonia and fertiliser production, iron and steel production, and methanol production. In the final part, the methodology of each scenario's quantitative projection is given.

1. Scenarios in Different Energy Transition Outlooks and Studies

The following studies and reports provide analysis of future situations of the world and/or Southeast Asia's energy system represented in scenarios. In the subsections that follow, an overview of those scenarios in each of the studies are given:

- International Energy Agency's (IEA) 'Southeast Asia Energy Outlook 2022' Report
- IEA's 'World Energy Outlook 2022' Report
- ASEAN Centre for Energy's (ACE) '7th ASEAN Energy Outlook' Report
- Det Norske Veritas' 'Hydrogen Forecast to 2050' Report
- ERIA/IEEJ's 'Decarbonisation of ASEAN Energy Systems: Optimum Technology Selection Model Analysis up to 2060' Report

1.1. IEA's 'Southeast Asia Energy Outlook 2022' Report

The *Southeast Asia Energy Outlook 2022* (IEA, 2022a) is the fifth edition of this World Energy Outlook Special Report of the International Energy Agency (IEA) published in May 2022. The first edition was published in 2013 and the reports provide insightful prospects for the 10 ASEAN member countries. This edition includes three scenarios:

- The Stated Policies Scenario (STEPS) that reflects the countries' current policy settings based on a sector-by-sector assessment of the specific policies that are in place or have been announced.
- The Sustainable Development Scenario (SDS), which delivers on the Paris Agreement goal to limit the temperature to 'well below 2°C', alongside the goals of energy access and air pollution. This scenario is consistent with Southeast Asia's current announced climate aspirations.

- The Net-Zero Emissions (NZE) by 2050 scenario, which sets out a pathway for the energy sector to achieve net-zero CO_2 emissions in 2050 and limits the rise in global average temperatures to 1.5°C. The NZE scenario provides a global benchmark against which changes at the regional level can be assessed.

The STEPS would bring Southeast Asia's total energy supply from nearly 30 exajoules (EJ) in 2020 to more than 50 EJ by 2050, whilst CO_2 emissions would reach around 2.75 Gt of CO_2 by 2050.

In the SDS, total energy supply in Southeast Asia will reach its peak by 2045 at a bit more than 40 EJ, before decreasing to a bit below 40 EJ by 2050. The SDS is marked by the modern energy that will be available more readily and quickly than in the STEPS. Lower energy demand in the SDS reflects much greater efficiency than in STEPS, which includes the inherent efficiency gains associated with energy transitions. CO_2 emissions in the SDS would reach its peak in 2025, i.e. nearly 1.9 Gt CO_2 before decreasing significantly to a level of below 0.75 Gt CO_2 by 2050. Therefore, in the SDS, 2025 CO_2 emissions are decoupled from the growth of energy supply.

1.2. IEA's 'World Energy Outlook 2022' Report

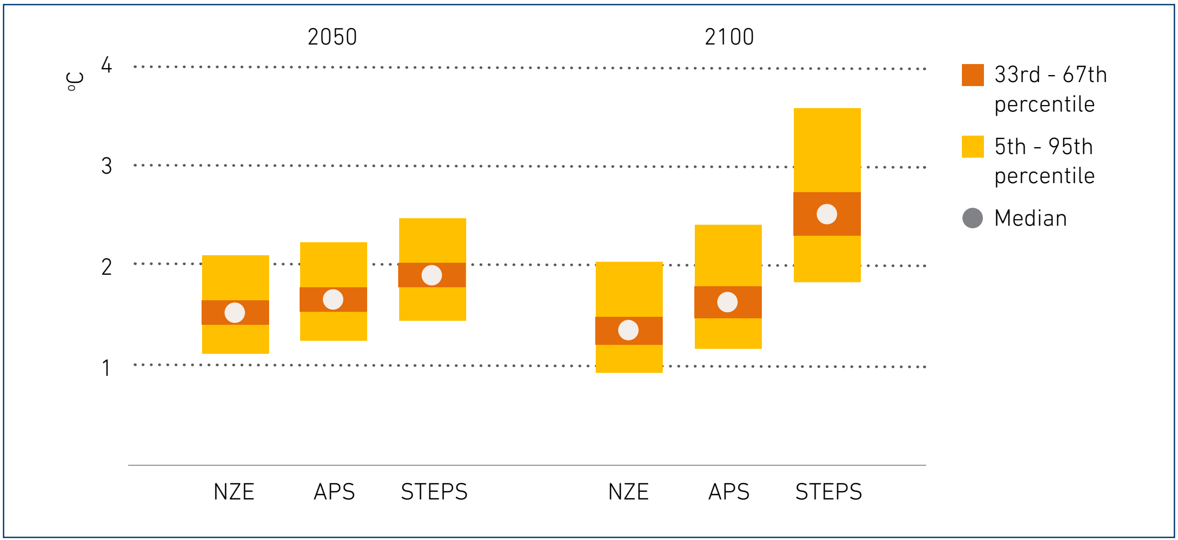
The 2022 IEA's *World Energy Outlook* (WEO) 2022 Report (IEA, 2022b) is IEA's analysis and projections, a part of the publication series that has appeared every year since 1998. It provides insights into global energy supply and demand in different scenarios and the implications for energy security, climate targets and economic development.

The *World Energy Outlook 2022* includes three scenarios:

- The STEPS shows the trajectory implied by today's policy settings. Instead of focusing on what the governments would achieve, it analyses what the governments are actually doing to achieve the targets and objectives they have set out and assesses where this leads the energy sector.
- The Announced Pledges Scenario (APS) assumes that all aspirational targets announced by governments are met on time and in full, including their long-term net-zero and energy access goals. In other words, this scenario examines where all current announced energy and climate commitments – including net-zero emissions pledges as well as commitments in areas such as energy access – would lead the energy sector to if implemented in full and on time.
- The NZE by 2050 scenario maps out a way to achieve a 1.5°C stabilisation in the rise in global average temperatures, alongside universal access to modern energy by 2030.

Figure 3.1 shows that NZE is the scenario that would most successfully curb the world's temperature rise. By 2050 temperature rise peaks at less than 1.6 °C and falls to around 1.4 °C by around 2100. In the STEPS, the world temperature rise would exceed 2 °C by 2060 and should continue to increase. The APS would keep the world temperature increase below 2 °C.

Figure 3.1. **Temperature Rise in 2050 and 2100 in the World Energy Outlook 2022 Scenarios**



NZE = Net-Zero Emissions by 2050 Scenario, APS = Announced Pledges Scenario, STEPS = Stated Policies Scenario.

Notes: Temperature rise estimates in this section are relative to 1850–1900 and match the IPCC Sixth Assessment report definition of warming of 0.85˚ C between 1995–2014.

Source: IEA (2022b).

1.3. ACE's '7th ASEAN Energy Outlook' Report

This 7th edition of *ASEAN Energy Outlook* (ACE, 2022) known as AEO7 reports the latest status of ASEAN's energy landscape. Using historical data from 2005 to 2020, the report forecasts the ASEAN energy system until 2050.

AEO7 complements the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016–2025 Phase II: 2021–2025 (ACE, 2020b), creating pathways towards achieving regional energy targets and provides analysis of four central scenarios are continued:

- The Baseline Scenario, that follows the historical trend of ASEAN Member States (AMS) energy systems. It assumes a business-as-usual level of effort put forth by each AMS, without any modelling interventions to meet existing national renewable energy or energy efficiency (RE/EE) targets.
- ASEAN Member States (AMS) Targets Scenario abbreviated as ATS, that ensures attainment of official national policies, especially for EE and RE targets. Includes power distribution panel installation targets are firmed capacity additions and provides modelling interventions to meet energy related targets under countries' Nationally Determined Contributions (NDC).

- APAEC (Regional) Targets Scenario (APS), that seeks to bridge the gap between national and regional targets outlined in APAEC 2016–2025 by escalating national energy intensity reduction and RE targets, and/or setting new targets for ASEAN Member States that could potentially adopt specific policies.
- The Least-Cost Optimisation Scenario, which is a technology-neutral optimisation applies to the power sector. It reflects all potentially viable technologies in emerging economies, such as ASEAN. This scenario considers the cost-effectiveness, affordability, and technology maturity to fulfil the growing electricity demand. It also includes the deployment of energy storage and interconnection.

Four groups of modelling parameters or assumptions have been used in ACE (2022) to obtain results of the above scenarios, i.e. energy efficiency, renewable energy, power generation capacity, and energy targets and measures in the NDC. Its results focus on identifying the gap between the AMS' targets and the regional APS targets and on the recommendations on what the ASEAN countries and regions should do to the fill the gap, therefore achieving regional targets.

1.4. DNV's 'Hydrogen Forecast to 2050' Report

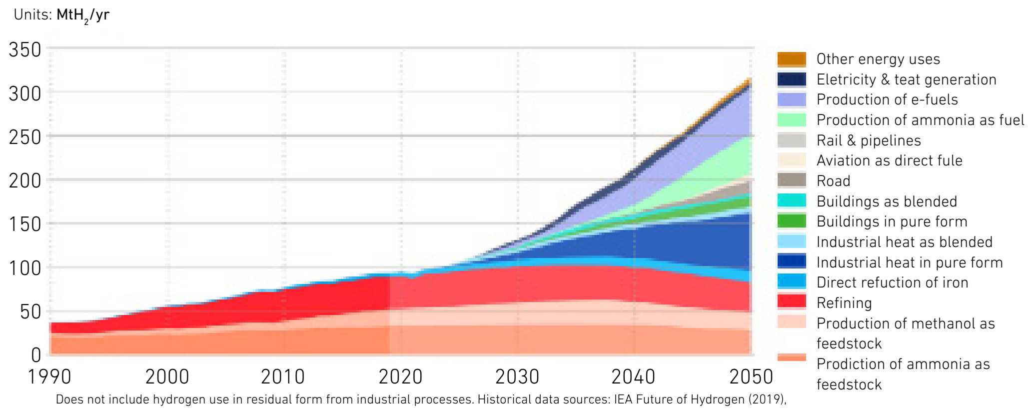
DNV, through the report *'Hydrogen Forecast to 2050'* (DNV, 2022) lays the projection of the hydrogen market in the world. The report focuses more on what is the most likely share of hydrogen uptake in the forecast, rather than what amount of share should be up taken in 2050. It clearly lays the ground on how hydrogen will be used not only as energy carrier but also as feedstock in industrial use, and this trend is projected to continue up to 2050.

The study forecasts that non-energy uses of hydrogen would grow slowly until the mid-2030s, and then would decline. Substantial growth would come from hydrogen use for energy, directly, or indirectly, i.e. hydrogen-based ammonia and e-fuels.

In 2030, 22 MT out of the 131 MT hydrogen produced globally will be used for energy purposes. That means that only around 17% of hydrogen produced in 2030 will be used for energy purpose. Production of ammonia as fuel should see it begins in the 2030–2040 decade. By 2040, hydrogen demand for energy will catch up with non-energy use of hydrogen whilst the total hydrogen produced globally would reach around 210 MT (Figure 3.2).

By 2050, only 30% of global hydrogen supply will be used for non-energy purposes. 39% will be direct use of hydrogen as energy, whilst 31% will be converted to ammonia or e-fuel for energy end users.

Figure 3.2 Global Hydrogen Demand by Sector



Does not include hydrogen use in residual form from industrial processes. Historical data sources: IEA Future of Hydrogen (2019), IEA Global Hydrogen Review (2021), USGS Mineral Commodity Summaries (1990-2022), IFA (2022)

Source: DNV (2022).

The study predicts that by 2050, Southeast Asia's hydrogen and its derivatives demand would reach 3.6% of the total global hydrogen. This means a slight increase in the region's share from around 3.4% in 2020 (IHS, 2022).

Furthermore, it is expected that hydrogen consumption for industrial use will remain as a main offtake in the future, and oil refineries will still be seen as a big demand for hydrogen. Detailed projections at global level for each of the three subsectors (oil refineries, ammonia and methanol, and iron and steel) are as follows:

Oil Refineries

The global hydrogen demand used in oil refinery processing will still see a slight increase up to 2030. The demand is projected to reach 41 MT in 2030 from the current amount of 37 MT. However, this trend will turn around and start to decline following the fall in demand for oil. The projected demand is expected to reach 34 MT in 2050.

Currently, the demand is satisfied by captive production (hydrogen captured within the refining process), and the report projected the trend is continuing, with 47% of supply is fulfilled through this process, and 8% out of this proportion is combined from CCS. Another 39% is supplied from methane reforming (both conventional and coupled with CCS). No more than 15% is supplied through electrolysis.

Ammonia and Methanol
Hydrogen demand for ammonia production will be diversified, not only as a feedstock for conventional production for industrial use (e.g. fertiliser), but also as energy carrier (ammonia as green fuel). Hence, the production for ammonia as a feedstock will run into a slight decline. 147 Mt is the projected amount of supply of hydrogen derivatives in 2050, where two-thirds are for energy carriers, and the rest, which amount to around 49 MT, will be for ammonia and methanol. Out of this, approximately 28 MT is for ammonia and 22 MT is for methanol.
The production for these derivatives will mostly from methane reforming which amounts to around 39%, whilst blue hydrogen is projected to supply 24% of the required demand.

Iron and Steel Industry
The projection sees this industry as the first uptake for hydrogen in the late 2020s. However, historically speaking, hydrogen demand for the iron and steel industry has been relatively small compared to the others. In 2020 the global demand was 5 MT, mostly used as a reducing agent in the electric arc furnace (EAF), which is not widely used compared to the conventional process. However, the trend to decarbonise the industry is already arising, and it is projected the direct reduction of iron (DRI) + EAF process will be much more favoured, hence increasing the hydrogen demand. In 2050 it is projected that 13.5 MT of hydrogen will be used for the steelmaking process. In addition to this, hydrogen in the form of direct energy use will reach 2.8 EJ/year. Hydrogen produced for the iron and steel industry will be mostly produced from methane reforming, amounting to 72% of the total supply in 2050. Hydrogen from electrolysis is not projected to grow significantly in this matter.

In brief, DNV (2022) projects that at the world level total produced hydrogen will increase from 90 MT in 2020 to reach 320 MT by 2050. The summary of the type and purpose of the hydrogen use is given in Table 3.1.

Until 2040, as feedstock hydrogen would be mainly used in non-energy purposes, i.e. in oil refining, in DRI in the steel and iron industry, and to produce methanol and ammonia in the fertiliser industry. It will only be in the 2040–2050 decade where hydrogen will be used as feedstock to produce ammonia and e-fuels such as e-methanol and e-kerosene which can be categorised as the indirect energy use of hydrogen. By 2020, the proportion of hydrogen use as feedstock in the conventional non-energy use and in indirect energy use will reach 50:50 ratio.

The direct use of hydrogen as energy will be starting from late in the 2020–2030 decade in the transport sector as well as in power generation.

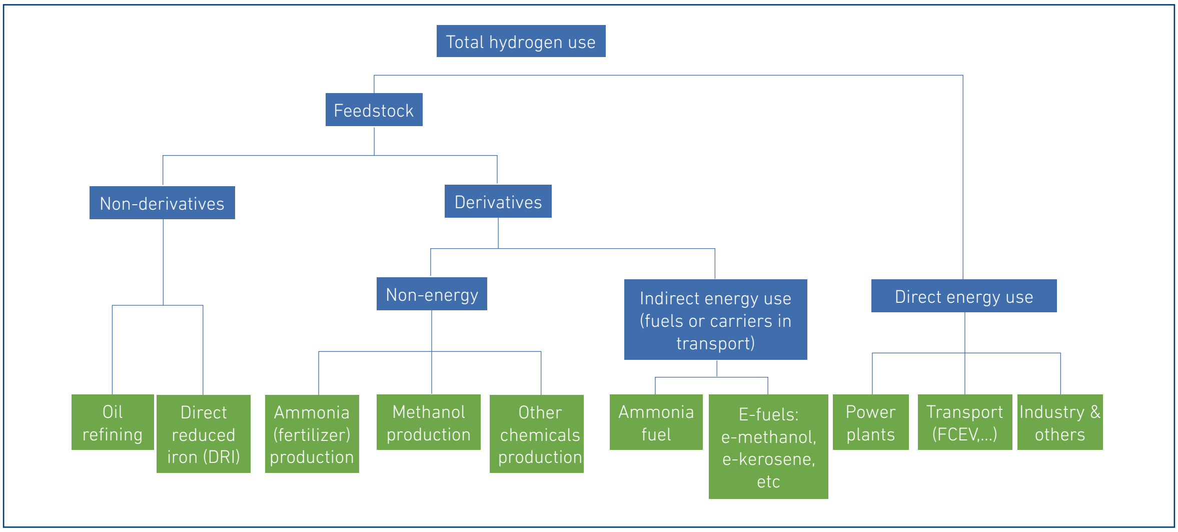
Table 3.1. Global Hydrogen Use by Types and Purpose (million tons)

Type	Purpose	2020	2030	2040	2050
Total	Total globally produced hydrogen	90	131	216	320
Feedstock	Non-energy use	90	109	108	96
	Indirect energy use (ammonia, e-fuel)	0	0	0	99
Energy	Direct energy use of hydrogen	0	22	108	125

Source: Summarised from DNV (2022).

Hydrogen produced globally to be used as feedstock would grow from around 90 MT in 2020 to reach 195 MT in 2050 as seen in Table 3.2. As given in Table 3.1, this 195 MT of hydrogen used as feedstock in 2050 can be distinguished into feedstock for non-energy use of 96 MT and indirect energy use of 99 MT.

Figure 3.3 Breakdown of Hydrogen Use



Source: Summarised from DNV (2022).

Apart from distinguishing the use of hydrogen as feedstock in non-energy use and indirect energy use, the use of hydrogen as feedstock can also be broken down into derivatives and non-derivatives. DNV (2022) estimates that by 2050, out of the 195 MT of hydrogen used as feedstock, 147 MT would be used as derivatives and the remaining 48 MT for non-derivative use (oil refining, DRI, etc.). The derivatives use (147 MT) can be split into indirect energy use (99 MT) for ammonia fuel and e-fuels (e-methanol, e-kerosene, etc) and non-energy use (48 MT), i.e. to produce ammonia (fertiliser industry), methanol, and other chemicals. By 2050, the total direct energy use of hydrogen (for power generation, transport, and industry) would reach a global total of 125 MT. Together with the 195 MT of hydrogen to be used as feedstocks, the total hydrogen produced by 2050 would thus reach 320 MT.

Figure 3.3 and Table 3.2 provide the structural and quantitative breakdown of the hydrogen use based on DNV (2022).

Table 3.2. Global Hydrogen use Break Down (million tons)*

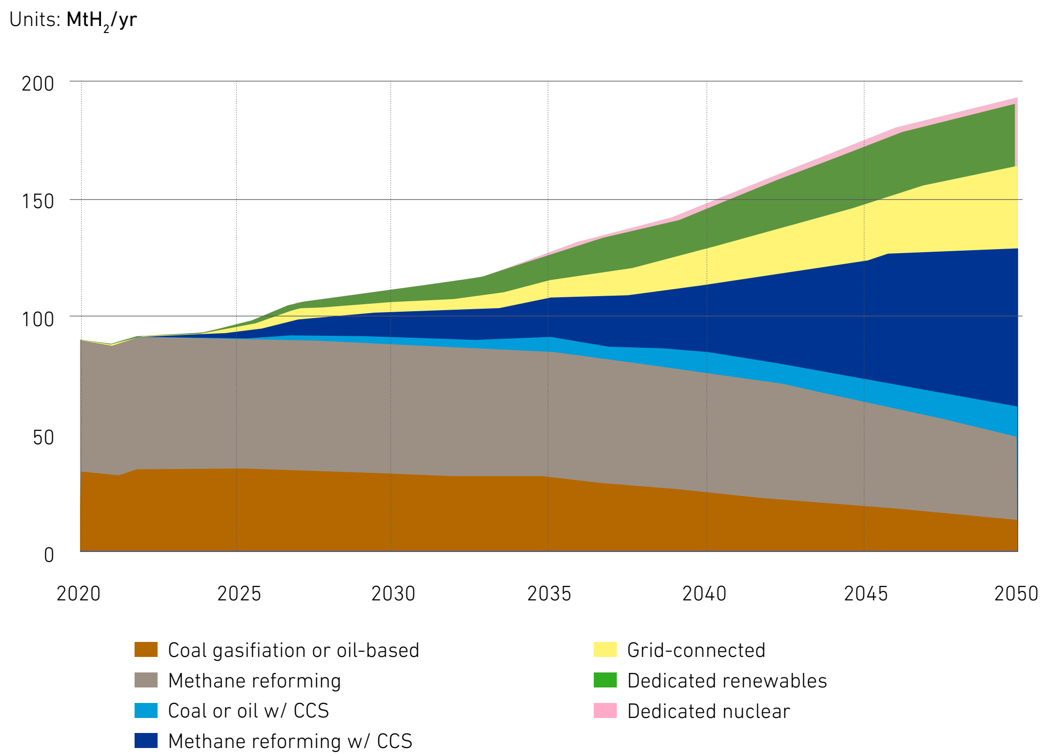
Equation	Hydrogen use	2020	2030	2040	2050
i	Feedstock – derivatives: for indirect energy carriers in transport sector (ammonia, e-fuels)	0	0	0	99
ii	Feedstock – derivatives: production of ammonia and other chemicals, such as methanol.	48			48
iii	Feedstock – non-derivatives: oil refining	37			34
iv	Feedstock – non-derivatives: direct reduced iron (DRI)	5			14
v = i	Total feedstock – derivatives as indirect energy use	0	0	0	99
vi = ii+iii+iv	Total feedstock as non-energy use	90			96
vii = i+ii	Total feedstock – derivatives	48			147
viii = iii+iv	Total feedstock non-derivatives	42			48
ix = vi+vii	Total feedstock	90			195
x	Direct energy use of hydrogen	0			125
xi = ix+x	Total produced hydrogen	90	131	216	320

*Blank cells mean that no information is given explicitly in the DNV (2022).

Source: Summarised from DNV (2022).

On the supply side, Figure 3.4 shows that as of 2020, hydrogen as feedstock is produced by only two production routes: coal gasification or oil-based and methane reforming. Other production routes would enter the market before 2025, but it is only during the 2040-2045 period that other production routes will catch up with that of coal gasification or oil-based and methane reforming. By 2050, methane reforming combined with carbon capture and sequestration (CCS) would make a bit more than one-third of the production of hydrogen as feedstock. Another one-third will be produced by dedicated renewables and grid connected whilst the rest would still be produced by coal gasification or oil-based and methane reforming.

Figure 3.4 Global Production of Hydrogen as Feedstock by Production Route



CCS = carbon capture and sequestration, MtH2/yr = million tons of hydrogen per year.

Source: DNV (2022).

1.5. ERIA's 'Decarbonisation of ASEAN Energy Systems: Optimum Technology Selection Model Analysis up to 2060' Report

ERIA's *'Decarbonisation of ASEAN Energy Systems: Optimum Technology Selection Model Analysis up to 2060'* Report (ERIA, 2022) was written in collaboration with the Institute for Energy Economics, Japan (IEEJ). The study identifies carbon-neutral pathways for ASEAN countries towards the mid 21st century by applying an optimisation approach, i.e. a linear programming model, to choose low- or zero-emissions technologies under a carbon dioxide (CO_2) emissions constraint and cost minimisation objective function.

The study includes five scenarios:

- Baseline scenario where no CO_2 emissions target is set.
- Carbon neutral (CN)2050/2060 scenario that reflects nationally declared carbon-neutral target years and considers carbon sinks in Indonesia, Malaysia, Myanmar, Thailand, and Viet Nam based on discussions with each country. This scenario has two cases as part of sensitivity analysis:
  - CN2050/2060 innovation cases scenario, where five cases describe the impacts of technological innovation.
  - CN2050/2060 stringent 2030 scenario that tightens emissions constraints in 2030 of CN2050/2060 to the same level as the IEA sustainable development scenario.
- CN2050/2060 without carbon sink assumes that energy-related CO_2 emissions become net zero by 2060 and does not consider carbon sinks.

The case assumes that the yearly net-zero emissions are achieved in ASEAN varies by country, based on the World Bank's classification by income level. Brunei and Singapore are assumed to achieve net-zero emissions by 2050 and other countries by 2060.

In the study, the use of zero-emissions energy technologies, i.e. hydrogen/ammonia, carbon capture utilisation and storage (CCUS), direct air capture (DAC), and biomass energy with CO_2 capture and storage (CCS) – will help ASEAN countries' pathways to achieving carbon neutrality by mid of the century. However, they will incur high marginal abatement costs. Hence, innovation in energy technologies will be essential to lower marginal abatement cost levels. An estimation of the amount of carbon offset by forests will be another important element in trying to achieve net-zero emissions in the ASEAN region.

The model used in the study assumes that hydrogen can be used for power generation, fuel synthesis, industry, and transport, whilst ammonia is used only for power generation. In more detail, hydrogen is assumed to be consumed in gas-hydrogen co-firing, hydrogen-firing, methane synthesis, Fischer-Tropsch synthesis, ammonia synthesis, hydrogen-based direct reduced iron-electric arc furnace, hydrogen heat (industry), fuel cell electric vehicles (FCEV) (light-duty vehicles), FCEVs (buses and trucks), hydrogen fuelled ships and aircraft. Hydrogen is assumed to be supplied through the following pathways: coal gasification, methane reforming, water electrolysis, hydrogen trade amongst ASEAN countries, hydrogen imports from outside ASEAN, and hydrogen separation from ammonia. Finally, ammonia is consumed only in coal-ammonia co-firing, and ammonia-fired power plants.

2. Scenarios in this Study

To varying degrees the five study reports, provide the necessary elements to develop future scenarios of hydrogen use in industrial sectors in the ASEAN Member States up to the horizon 2050. Four scenarios are defined to describe future scenarios, i.e. ERIA-Frozen, ERIA-STEPS, ERIA-Likely, and ERIA-APS. The following sub-sections describe these scenarios in detail.

2.1. ERIA-Frozen Scenario

The ERIA-Frozen scenario relates to a future situation where the trend is shown in the demand and supply of hydrogen by the historical trend of the 2015–2020 period as discussed in this section continue as it is. It assumes that ASEAN countries only put a business-as-usual level of effort without any national CO_2 or renewable energy or energy efficiency (RE/EE) targets to meet.

In the ERIA-Frozen scenario, it is assumed that:

- all policies implemented during the 2015–2020 period remain the same,
- hydrogen demand and supply in the future would grow at the average rate of the 2015–2020 period, and
- and that supply will always be able to meet demand using the same supply structure as it is during the 2015–2020 period.

The Frozen scenario is used as a baseline when discussing other future scenarios as it is a hypothetical situation where the only policies implemented are those in place during the 2015–2020 period. This scenario assumes that these past policies are maintained until 2050.

2.2. ERIA-STEPS

The ERIA-STEPS tries to reflect the STEPS given in the IEA (2022a) and IEA (2022b) to the Southeast Asian region.

Mainly based on the IEA's STEPS as described in IEA (2022a) and IEA (2022b), the principal characteristics of the ERIA-STEPS can be given as follows:

- ERIA-STEPS retains current and the latest ASEAN Member States' policies. The most important energy policies considered in this scenario are those related to the Intended Nationally Determined Contribution (INDC) as given in
- Table 3.3.
- For the scenario, it does not matter if governments' goals are achieved or not.
- The scenario has no particular outcome to achieve.
- The scenario explores where the energy system might go without additional policy implementation.
- At maximum, the scenario takes a granular, sector-by-sector look at existing policies and measures and those under development.

Table 3.3. **ASEAN Member States' Individual Intended Nationally Determined Contributions**

Country	Reduction Target
Brunei	Brunei has committed to reduce its total energy consumption by 63% by 2035.
Cambodia	Cambodia has conditionally committed to reduce its GHG emissions by 27% through aggregate reductions from the energy, transport, and manufacturing sectors, as well as others, and an additional contribution from the land use, land use change, and forestry sector.
Indonesia	Indonesia has unconditionally committed to reduce its GHG emissions by 26% by 2020 and 29% by 2030 compared to BAU. The target for 2030 would be increased to 41% if support is provided through international cooperation.
Lao PDR	The Lao PDR has set policies and measures to reduce GHG emissions in multiple sectors, to be implemented by 2030.
Malaysia	Malaysia intends to reduce its GHG emissions intensity of GDP by 45% by 2030, relative to the emissions intensity of GDP in 2005. This reduction consists of 35% on an unconditional basis and a further 10% upon receipt of climate finance, technology transfer, and capacity building from developed countries.
Myanmar	Myanmar has introduced policies and measures to reduce GHG emissions in multiple sectors, to be implemented by 2030.
Philippines	The Philippines has committed to reduce its GHG emissions by 70% by 2030 relative to BAU.
Singapore	Singapore intends to reduce its GHG emissions intensity by 36% from 2005 to 2030 and stabilise its emissions with the aim of peaking around 2030.
Thailand	Thailand has committed to reduce its GHG emissions by 20% by 2030 relative to BAU. This target could increase to 25%, subject to adequate and enhanced access to technology development and transfer, financial resources, and capacity building support through a balanced and ambitious global agreement under the United Nation Framework Convention on Climate Change.
Viet Nam	Viet Nam intends to reduce its GHG emissions by 8% unconditionally by 2030. This target could be increased to 25% if international support is received through bilateral and multilateral cooperation, as well as through the implementation of new mechanisms under the Global Climate Agreement, in which emission intensity per unit of GDP will be reduced by 30% from 2010 levels.

BAU = business-as-usual, GDP = gross domestic product, GHG = greenhouse gas, Lao PDR = Lao People's Democratic Republic.

Source: Summarised AMS information in the Intended Nationally Determined Contributions Portal. https://www4.unfccc.int/sites/submissions/INDC/Submission%20Pages/submissions.aspx (accessed 29 October 2020).

Nevertheless, the two IEA reports, i.e. IEA (2022a and 2022b) do not provide detailed assumed policy measures that are implemented in the industry sector, i.e. oil refining, ammonia/fertiliser, methanol, and the iron and steel industry. Several key parameters assumed are given in Table 3.4 and are taken as assumed parameters in the ERIA-STEPS. IEA (2022b) also mentioned that iron and steel industry, together with the power sector are the two driving sectors that would trigger 60% coal demand increase in Southeast Asia between 2021 and 2050, which is also assumed in the ERIA-STEPS scenario.

Table 3.4. Key Assumed Parameters Used in ERIA-STEPS for Southeast Asia taken from IEA's STEPS

Key Assumed Parameters	2021	2030	2050
Refinery capacity (Mb/d)	5.3	6.3	6.8
Refinery runs (Mb/d)	3.7	5.5	6.4
Oil production (Mb/d)	1.9	1.5	0.9
Oil demand (Mb/d)	4.9	6.7	7.4
Gas demand (bcme)	162	203	272
Natural gas production (bcm)	195	183	129
Natural gas demand (bcm)	162	203	272
Coal production (Mtce)	499	460	474
Coal demand (Mtce)	269	337	422
RE supply (EJ)	5.4	8.7	16.2
Total final consumption (EJ)	19.8	26.5	34.7
Industry consumption (EJ)	8.8	11.4	15.2
Hydrogen demand (PJ)	468	602	848
Hydrogen demand (MT)	3.3	4.24	5.98

bcm = billion cubic metres, bcme = billion cubic metres of natural gas equivalent, EJ = exajoule, Mb/d = million barrels per day, MT = million tons, Mtce = million tons of coal equivalent, PJ = petajoule, RE = renewable energy.

Source: IEA (2022b).

2.3. ERIA-APS

The ERIA-APS is based on the Announced Pledges Scenario (APS) of IEA (2022b) that assumes that all aspirational targets announced by governments are met on time and in full, including their long-term net-zero and energy access goals.

The principal characteristics of the ERIA-APS are as follows:

- Government targets in the scenario are assumed to be achieved on time and in full
- Trends reveal the extent of the world's collective ambition to tackle climate change and meet other Sustainable Development Goals (SDGs)
- The scenario includes all the climate commitments made by governments around the world including NDC as well as longer term NDC targets and assumes that they will be met in full and on time.
- The scenario fills the 'implementation gap' that needs to be closed for countries from STEPS to achieve their announced decarbonisation targets.
- The scenario includes net-zero pledges as announced by countries. In ASEAN countries:

- Malaysia and Viet Nam: carbon neutral target by 2050
- Indonesia: net-zero emissions by 2060 or before
- Thailand: net-zero greenhouse gas emissions target by 2065
- The rest of ASEAN countries: carbon neutral by 2060
- Indonesia, Malaysia, Philippines, and Viet Nam: commitment to the global methane pledge

Some principal characteristics as explained are based on the IEA's APS in IEA (2022b). Some related key assumed parameters for the Southeast Asian region of the IEA's APS Scenario are given in IEA (2022b) as summarised in Table 3.5 and are taken as assumptions in the ERIA-APS.

Table 3.5. Key Assumed Parameters Used in the ERIA-APS for Southeast Asia Taken from IEA's APS

Parameters	2021	2030	2050
Refinery capacity - SEA (Mb/d)	5.3	6.3	6.3
Refinery runs - SEA (Mb/d)	3.7	5.1	4.7
Oil production - SEA (Mb/d)	1.9	1.3	0.5
Oil demand - SEA (Mb/d)	4.9	6	3.9
Gas demand - SEA (bcme)	162	194	177
Natural gas production - SEA (bcm)	195	162	109
Natural gas demand - SEA (bcm)	162	194	177
Coal production - SEA (Mtce)	499	423	262
Coal demand - SEA (Mtce)	269	295	151
RE supply - SEA (EJ)	5.4	10.3	25.1
Total final consumption - SEA (EJ)	19.8	24.5	27.1
Industry consumption - SEA (EJ)	8.8	10.7	12.6
Hydrogen demand - SEA (PJ)	468	593	1566
Hydrogen demand - SEA (MT)	3.3	4.18	11.04

bcm = billion cubic metres, bcme = billion cubic metres of natural gas equivalent, EJ = exajoule, Mb/d = million barrels per day, MT = million tons, Mtce = million tons of coal equivalent, PJ = petajoule, RE = renewable energy, SEA = Southeast Asia.

Source: IEA (2022b).

IEA (2022b) provides detailed assumptions and policy measures at the global level in the three different industrial sectors of ammonia, methanol, iron and steel, of the NZE scenario but not of the APS.

The NZE scenario differs from APS in term of stronger and more effective intergovernmental cooperation in a mutually beneficial manner in emission mitigation that results in more reduced greenhouse gas emissions and therefore more curbed global average temperature rise in the NZE scenario.

The APS, on the other hand, is marked by the different paces of emissions decline in function of the economic levels, i.e. developed economies versus emerging market and developing economies. In the APS, the achievement of national net-zero pledges in some countries is coupled with limited efforts to prioritise emissions reductions in others, and little attention is given to technological spill overs or to the scope for working in partnership.

The ERIA-APS includes some assumed policy measures implemented in three industrial sectors of ammonia production, methanol, and iron and steel industry of the IEA's NZE scenario due to their detailed description as given in Table 3.6. Most of the policy measures and trends given in the table are given at the global level, therefore interpretation of those assumptions will be done at AMS level in chapter 4.

Table 3.6. Assumed Policy Measures and Trends in the Ammonia, Methanol, and Iron and Steel Industries of ERIA-APS Inspired by IEA's NZE Scenario

Industry Sector	Assumed Policy Measures and Trends
Ammonia	• Direct use of hydrogen, and of low-emissions synthetic fuels such as synthetic kerosene and ammonia, increases rapidly to meet demand in long-distance modes of transport, mainly aviation and shipping. • Low-emissions sources of electricity – renewables, nuclear power, fossil fuel power plants with CCUS, hydrogen, and ammonia – expand rapidly. • The use of hydrogen and ammonia blended with natural gas and coal scales up in the late 2020s. Ammonia and hydrogen co-firing, respectively in coal-fired and natural gas-fired power plants, providing 2%–3% of global electricity generation from 2030 to 2050. • By 2050, ammonia meets around 45% of demand for shipping fuel. • Hydrogen and ammonia are emerging as solutions for the seasonal storage of renewable electricity. • Global demand for low-emissions hydrogen – both produced onsite and offsite – rises to 11 million tons (MT) in 2030 for use in the production of ammonia, steel, and methanol.
Ammonia and Methanol	• Over 25% of the hydrogen produced in 2050 is converted to hydrogen-based fuels such as ammonia, methanol, and synthetic hydrocarbons. The remainder is used directly in industry, transport, and buildings.
Iron and Steel	• Global unabated coal use drops by 99% over this period; around half of the remaining 60 Mtce of unabated coal consumption in 2050 is used in the iron and steel industry. • No need for any new coal mines or mine lifetime extensions. Steam coal production falls by 50% to 2030 as coal is rapidly eliminated from the power sector in all countries. Coking coal production falls by about 30% to 2030, a smaller decline than for steam coal since the steel industry has fewer readily available alternatives.

CCUS = carbon capture utilisation and storage, Mtce = million tons of coal equivalent, NZE = Net-Zero Emissions.

Source: IEA (2022b).

The IEA report published in May 2021 (IEA, 2021d) titled *'Net Zero by 2050: A Roadmap for the Global Energy Sector'* also provides detailed information on the expected or assumed policy measures and trends in the industrial sectors in the NZE scenario. For the iron and steel industry sector especially, the report gives several key parameters of the NZE scenario. Those parameters are adopted in the ERIA-APS as presented in Table 3.7.

Table 3.7. Key Assumed Parameters in Iron and Steel Industry in the ERIA-APS based on the NZE Scenario of IEA (2021)

Parameters	2021	2030	2050
Percentage of the use of the different tech types			
Blast furnace - basic oxygen furnace (BF-BOF)			
Direct reduced iron-electric arc furnace (DRI-EAF)	24%	37%	53%
Recycling, re-use: scrap as share of input	32%	38%	46%
World H_2 demand in steel industry (MT H_2)	5	19	54
World on-site electrolyser capacity (GW)	0	36	295
Share of primary steel production:			
Hydrogen based DRI-EAF	0%	2%	29%
Iron ore electrolysis-EAF	0%	0%	13%
CCUS equipped processes	0%	6%	53%
Total final consumption - SEA (EJ)	19.8	24.5	27.1
Industry consumption - SEA (EJ)	8.8	10.7	12.6
Hydrogen demand - SEA (PJ)	468	593	1566
Hydrogen demand - SEA (MT)	3.3	4.18	11.04

BF-BOF =blast furnace-blast oxygen furnace, DRI-EAF = Direct Reduced Iron-Electric Arc Furnace, CCUS = carbon capture utilisation and storage, GW = gigawatt, MT = million tons, NZE = Net-Zero Emissions.

Source: IEA (2022b).

2.4. ERIA-Likely Scenario

The ERIA-Likely scenario represents the most likely to happen situation in the supply and demand of hydrogen in the four industry subsectors in ASEAN from the present time to the horizon 2050. In this sense, DNV (2022) study as described in Section 3.1.4 is a useful study based on which the ERIA-Likely scenario is built.

Several principal characteristics of the scenario are:

- Hydrogen produced globally to be used as feedstock would grow from around 90 MT in 2020 to reach 195 MT in 2050.
- Southeast Asian region's hydrogen and its derivatives demand would reach 3.6% of the total global hydrogen and its derivatives demand by 2050 (DNV, 2022). This means a slight increase in the region's share from around 3.4% in 2020 (IHS, 2022).
- DNV 's hydrogen forecasting: only 0.5% of global final energy mix in 2030 and 5% in 2050.
- Grid-based electrolysis costs will decrease significantly towards 2050 averaging around US$1.5/kg. Globally, green hydrogen will reach cost parity with blue within the next decade.
- Green hydrogen will increasingly be the cheapest form of production in most regions. By 2050, 72% of hydrogen and derivatives used as energy carriers will be electricity based, and 28% blue hydrogen from fossil fuels with CCS, down from 34% in 2030.
- The global hydrogen demand used in oil refinery processing will still see a slight increase up to 2030. The demand is projected to reach 41 MT in 2030 from the 2020 amount of 37 MT but shall decrease to 34 MT in 2050 due mostly to electrification in road transport.
- Hydrogen demand for ammonia production will be diversified, not only as a feedstock for conventional production for industrial use (e.g., fertiliser), but also as energy carrier (ammonia as green fuel) that will show its penetration in the late 2030 or during the 2040-2050 decade.
- No hydrogen uptake in passenger vehicles is foreseen, and only limited uptake in power generation.
- Hydrogen demand for iron/steel industries is currently relatively small compared to the others. Nevertheless, the trend to decarbonise the industry is already arising, and it is projected the direct reduction of iron (DRI) + EAF process will be much more favoured, hence increasing the hydrogen demand toward 2050.

3. Scenario Implementation

As in our analysis of the historical and current situation as in Section 3.2, in each scenario, modelling is done in a bottom-up manner. This implies that scenarios, including assumptions, data, and calculations are implemented at country and commodity level. Quantitative results obtained at the more aggregate level are merely a sum up of the results obtained at country-commodity level.

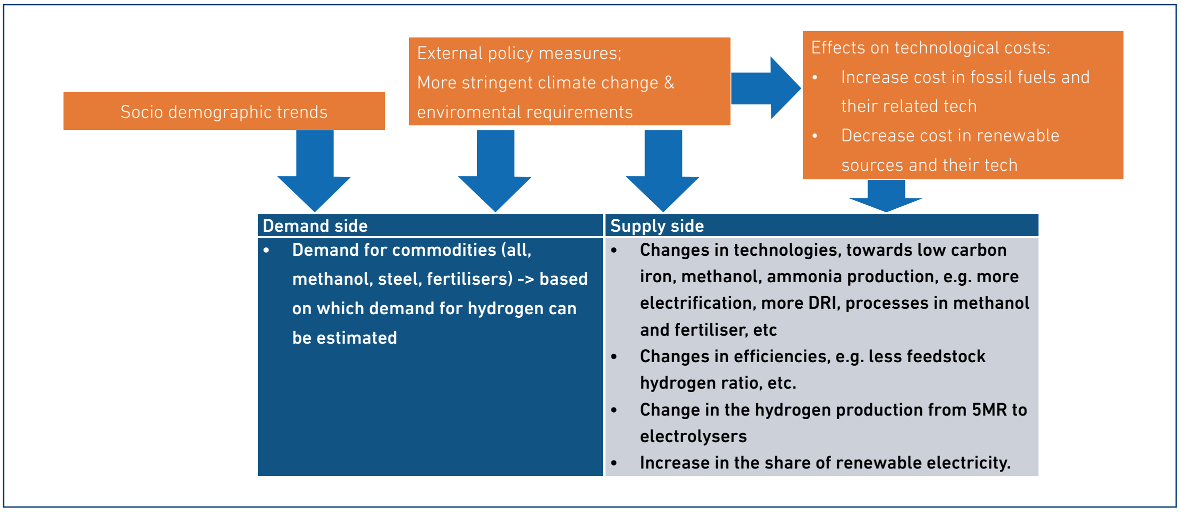
Figure 3.5 shows the principal methodology used for the scenario implementation.

The main inputs to obtain future estimates of hydrogen demand and supply in each country and industry sectors are sociodemographic trends, external policy measures that might include more stringent climate change and environmental requirements, and the effects of those policy measures on the technological costs, i.e. increasing fossil fuels and their technology related costs and decreasing renewable energy sources and their related technology costs.

Based on those inputs spread along the modelled period to the horizon 2050, the development of demand and supply for hydrogen as feedstock would be estimated. For the demand side, the need for hydrogen is to be calculated in function of the final products or commodities, i.e. refined petroleum products in the oil refining sector, fertiliser (and later ammonia fuel) in the ammonia production sector, methanol (and e-methanol) in the methanol industry, and iron and steel.

On the supply side, the inputs should affect at least four aspects the development of technologies, such as the increasing use of low-carbon iron and steel, methanol, and ammonia, low-sulphur petroleum products, the increasing use of direct reduced iron (DRI), etc. The other aspects are the change in efficiencies, such as less needed hydrogen as feedstock, the change of hydrogen production routes, and the change of renewable electricity share.

Figure 3.5 Scenario Implementation Method



DRI = direct reduced iron, SMR = steam methane reforming.

Source: Authors.

Based on those inputs spread along the modelled period to the horizon 2050, the development of demand and supply for hydrogen as feedstock would be estimated. For the demand side, the need for hydrogen is to be calculated in function of the final products or commodities, i.e. refined petroleum products in oil refining sector, fertiliser (and later ammonia fuel) in ammonia production sector, methanol (and e-methanol) in methanol industry, and iron and steel.

Using a bottom-up approach where the estimates start at the sectoral and country level, the description of the detailed assumptions such as trend, policy measures, infrastructure development, will be given in detail in the following chapter. Chapter 4 will also define the more detail calculation methods implemented in each of the industry sectors.