NEDO成果報告書

A Fundamental Study on the Potential of Ammonia as an Energy Source in Singapore

Nomura Research Institute Singapore Pte. Ltd.
NRI Consulting & Solutions (Thailand) Co.

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NRI

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Empower the change

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Guided by the Ammonia related policies in Singapore, there are already multiple activities in both the private and public sector to develop the supply and demand of Ammonia

Policies and Government Support

❑ **The potential use of Ammonia is supported through four key policies:**

❶ **Singapore Green Plan 2030**

- Overall plan of Singapore to reduce carbon footprint and promoting cleaner energy to achieve net-zero in 2050
- Indicates Ammonia as a potential clean fuel for power generation, shipping and Hydrogen carrier

❷ **National Hydrogen Strategy**

- A roadmap to adopt Hydrogen as a key low-carbon energy source where Ammonia is identified as a critical Hydrogen carrier.

❸ **Maritime Singapore Decarbonization Blueprint (2050)**

- A plan to reduce emissions in the maritime sector by promoting cleaner fuels, energy efficiency, and Green port initiatives which supports the development of infrastructure and usage of Ammonia

❹ **Sustainable Jurong Island**

- A plan to decarbonize Singapore's energy and chemicals hub Jurong Island which promotes Ammonia as a carrier for Hydrogen import in Singapore

❑ **Besides the Key policies, use of Ammonia is supported through:**

- **Financial programmes** such as CREATE Thematic Programme, Low Carbon Energy Research Funding Initiative and Future Energy Fund to develop low carbon technology
- **Research institutes** such as A*STAR, Nanyang Technological University, National University of Singapore, Singapore Maritime Institute which works on collaboration research and development

Supply and Demand Activity

❑ **Key activity for Ammonia is led by EMA and MPA for end-to-end Ammonia supply and usage**

- Tender to explore end-to-end Ammonia bunkering and power generation was launched and the selection process is ongoing with two consortiums conducting the feasibility study
- Many activities seen in the industry follows the tender activity

❑ **Supply of Clean Ammonia is expected through imports**

- Most of the activities focus on establishing the supply chain through import of clean Ammonia which positions Singapore as a hub
- Limited activities related to domestic production of clean Ammonia

❑ **Demand of Clean Ammonia is expected to grow in Power and Maritime applications**

- Ammonia is positioned as one of the options in the clean energy transition
- Activities seen in the use of Ammonia are:
  - Development of Vessels using Ammonia fuel and Ammonia bunkering facilities
  - Development of 100% Ammonia direct combustion power plant
  - Hydrogen supply chain using Ammonia Carrier

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Amongst the supporting policies of Singapore Green Plan, there are 3 main ones which touched upon the development of Ammonia in Singapore

Singapore's Green Plan is the national sustainability framework outlining the decarbonization pathway for the nation as a whole. It is **supported by sector-specific roadmaps to achieve net-zero by 2050**

- National Hydrogen Strategy
- Maritime Decarbonization Blueprint
- Sustainable Jurong Island
- Singapore EV Roadmap
- Enterprise Sustainability Programme
- ...

These 3 supporting policies have mentioned and outlined the strategy directions and development activities for Ammonia in Singapore

- **National Hydrogen Strategy:** Positions Ammonia as a Hydrogen carrier, driving investments in Ammonia cracking, storage, bunkering and direct power generation for Singapore's future energy mix
- **Maritime Decarbonization Blueprint:** Supports the development of Ammonia as a marine fuel, with trials and infrastructure for Ammonia bunkering in Singapore's port
- **Sustainable Jurong Island:** Facilitates industrial adoption of Ammonia for Hydrogen production, direct power generation and supports R&D in carbon capture and Ammonia cracking technologies

No specific mentions or initiatives that are targeting the development of Ammonia industry in Singapore

Source: Summarized by NRI based on public articles and reports

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It can be observed that decarbonization efforts of key policies can be broadly categorized into 3 phases with rapid commercial deployment expected to start 2030+

Summary of key milestone/timeline of Singapore decarbonization

Policy	Key milestone/timeline*			
	2020s	2030s		2050
SG Green Plan	Announce initial directions	1.5GWp of solar energy deployment Deploy 200 MWh of Energy Storage Systems New registrations of diesel cars and taxis to cease from 2025	2GWp of solar energy deployment Reduce domestic GHG emission by 3Mt per year by 2030 All new harbor craft to be fully electric or biofuel compatible	All vehicles to run on cleaner energy by 2040 Reduce GHG emissions from international shipping by 50%	Net-Zero by 2050
Hydrogen Strategy			Jurong Island to be a sustainable energy and chemicals park 100% Hydrogen compatible CCGTs	Hydrogen to supply 50% of electricity demand	
Maritime Decarb. Blueprint		Develop and commission world's first Ammonia-fueled tanker	Reduce port emission by 60% from 2005 All new harbor craft to be fully electric or biofuel compatible	Reduce GHG emissions from international shipping by 50%	
Sustainable Jurong Island		Grow the base of Sustainable products and production	Jurong Island to be a sustainable energy and chemicals park Increase the output of sustainable products by 1.5x from 2019 levels Realize 2Mt of carbon capture Refineries and crackers to be top 25% globally (energy efficiency)	Increase the output of sustainable products by 4x from 2019 levels Realize 6Mt of carbon capture per annum	
		Conducting initial R&D/ trials/ partnership to build foundations	**Start small-scale projects for commercial deployment**	**Rapid scaling up of commercial deployment**	

Note: *Only key activities related to energy/emission is showed above for high level illustration purpose
Source: Summarized by NRI based on public articles and reports; and NRI analysis

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The Singapore Green Plans outline whole of nation approach to Hydrogen/ Ammonia while the supporting policies provides sector specific targets and initiatives

Summary of Ammonia related focus in key policies

Policy	Target industry	Hydrogen/ Ammonia supply chain					
		Production	Import	Storage/Dist.	Marine Bunkering	Power	Others
SG Green Plan	• Whole of nation	The SG Green Plan mainly **positioned Hydrogen and Ammonia as possible low-carbon alternatives which can help decarbonize Singapore in general** The **use case or development plan for application of Hydrogen and Ammonia is not mentioned here**, but instead elaborate in supporting policies below					
Hydrogen Strategy	• Industrials • Power • Transport		✓	✓		✓	
Maritime Decarb. Blueprint	• Maritime • Shipping • Port			✓	✓		
Sustainable Jurong Island	• Oil & Gas • Chemicals • Power		✓	✓		✓	

Note: *Only activities with concrete plan and initiatives are taken into consideration in the illustration above based on NRI's internal understanding
Source: Summarized by NRI based on public articles and reports

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Despite not having Ammonia specifics policies, there are four main policies in Singapore that are guiding Ammonia-related developments in Singapore (1/2)

Key policies supporting Ammonia				
Policy type	**Policy Name**	**Organization**	**Announcement Date**	**Description**
Strategic policy	**❶ Singapore Green Plan 2030**	• Ministry of Education • Ministry of National Development • Ministry of Sustainability and the Environment • Ministry of Trade and Industry • Ministry of Transport	2021	**Brief of Policy** • A national sustainability roadmap with targets for energy, transport, waste, and industry to achieve net-zero emissions by 2050 **Relevance on Ammonia** • Encourages low-carbon energy solutions, including Ammonia as a clean fuel for power generation, shipping, and Hydrogen transport
Strategic policy	**❷ National Hydrogen Strategy**	• Ministry of Trade and Industry Singapore • Energy Market Authority	2022	**Brief of Policy** • A roadmap to develop Hydrogen as a key energy source, focusing on imports, infrastructure, and technological advancements **Relevance on Ammonia** • Positions Ammonia as a Hydrogen carrier, driving investments in Ammonia cracking, storage, and bunkering for Singapore's future energy mix

Source: Summarized by NRI based on public articles and reports

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Despite not having Ammonia specifics policies, there are four main policies in Singapore that are guiding Ammonia-related developments in Singapore (2/2)

Key policies supporting Ammonia				
Policy type	**Policy Name**	**Organization**	**Announcement Date**	**Description**
Strategic policy	**❸ Maritime Decarbonization Blueprint (2050)**	• Maritime and Port Authority of Singapore (MPA)	2021	**Brief of Policy** • A strategy to reduce shipping emissions through alternative fuels, electrification, and Green port initiatives **Relevance on Ammonia** • Supports the development of Ammonia as a marine fuel, with trials and infrastructure for Ammonia bunkering in Singapore's port
Strategic policy	**❹ Sustainable Jurong Island**	• Economic Development Board • JTC Corporation	2021	**Brief of Policy** • A plan to decarbonize Singapore's energy and chemicals hub, focusing on cleaner feedstocks and low-carbon energy **Relevance on Ammonia** • Facilitates industrial adoption of Ammonia for Hydrogen production, direct power generation and supports R&D in carbon capture and Ammonia cracking technologies

Source: Summarized by NRI based on public articles and reports

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Apart from the carbon tax, Singapore government has announced grants to support the R&D and development of Ammonia in Singapore

Summary of Hydrogen/ Ammonia related focus (non-key policies)

	Policies	Hydrogen/Ammonia supply chain					
		Production	Import	Storage/Dist.	Marine Bunkering	Power	Others
Financial policies	Carbon Pricing Act						
	Future Energy Fund						
	Low-Carbon Energy Research Funding Initiative						
	CREATE Thematic Programme						
International collaborations	Singapore-Japan Ammonia Fueled Bulk Carriers Joint Study						
	Singapore-Vietnam partnership on Energy and Carbon Credits						
	Singapore-New Zealand Low-Carbon Hydrogen Agreement						
	Singapore-Australia Green Economy Agreement (GAE)						

Legends:  = R&D stage , = Trials/ Demonstration Stage,  = Project development Stage

Note: Understanding of focus along the supply chain is not absolute, it is only for illustration based on high level understanding of each policies

Source: NRI internal understanding

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Apart from the 3 main policies, Singapore has announced several other financial incentives/disincentives that supports the development of Ammonia industry

Other related policies and government activities						
Policy type	Policy Name	Stage of development	Supply chain involvement	Organization	Announced date	Description
Financial (grants/ fundings)	❶ Future Energy Fund	Trials/ Demos Project development	• Import • Storage/ Distribution • Power gen.	• Energy Market Authority (EMA) • Ministry of Trade and Industry (MTI)	2023	**Brief of Policy** • A SGD 10 billion fund to improve the commercial viability of infrastructure investments for energy transition **Relevance on Ammonia** • Highlighted scope includes encouraging trials and development for Hydrogen and Ammonia related deployment
Financial (grants/ fundings)	❷ Low-Carbon Energy Research Funding Initiative (LCER FI)	R&D Trials/ Demos	• Import • Storage/ Distribution	• Agency for Science, Technology and Research (A*STAR)	2021	**Brief of Policy** • Research funding for R&D and demonstration projects on low-carbon energy technology solutions Over SGD 180 million has been allocated to this fund in the first 2 phases **Relevance on Ammonia** • Projects supported includes Hydrogen and Ammonia related infrastructure and technologies to decarbonize Singapore
Financial (grants/ fundings)	❸ CREATE Thematic Programme	R&D	• Import • Storage/ Distribution • Bunkering • Power gen.	• National Research Foundation (NRF)	2024	**Brief of Policy** • A SGD 90 million programme launched in 2024 that supports targeted initiatives that focus on sustainable solutions and technological advancements **Relevance on Ammonia** • Includes R&D projects on Ammonia as a Hydrogen carrier and its potential role in Singapore's clean energy ecosystem

Source: Summarized by NRI based on each organizations press release and announcements

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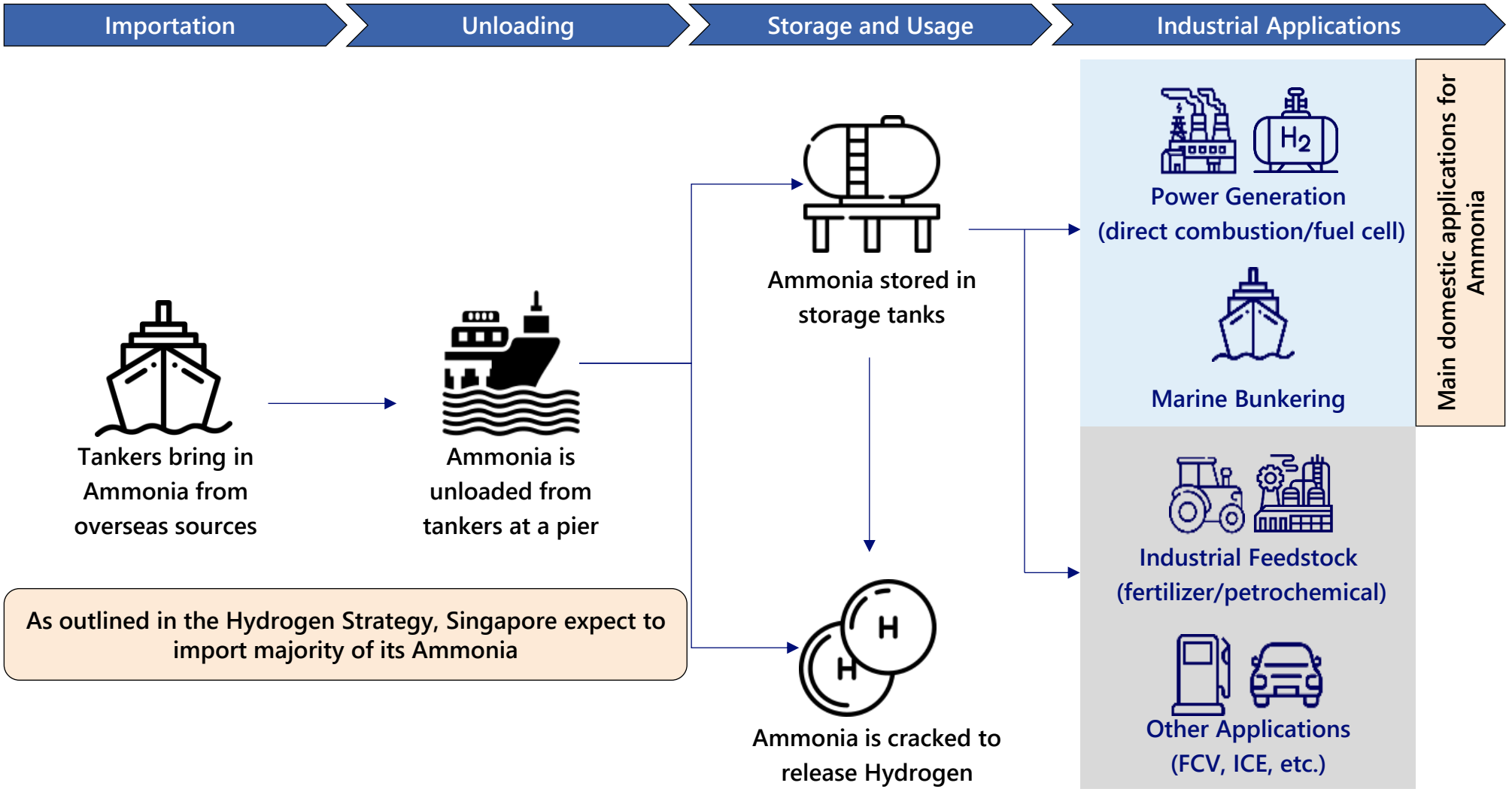
Singapore expect to import majority of its clean Ammonia where future application/development is targeted for Marine Bunkering and Power Generation



Source: Summarized by NRI based on National Hydrogen Strategy

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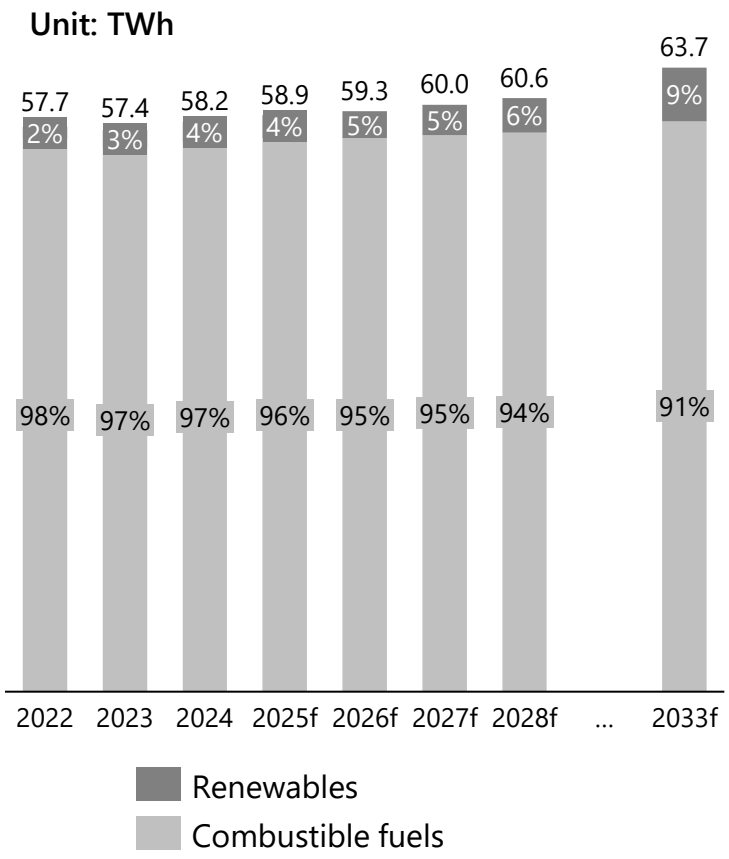
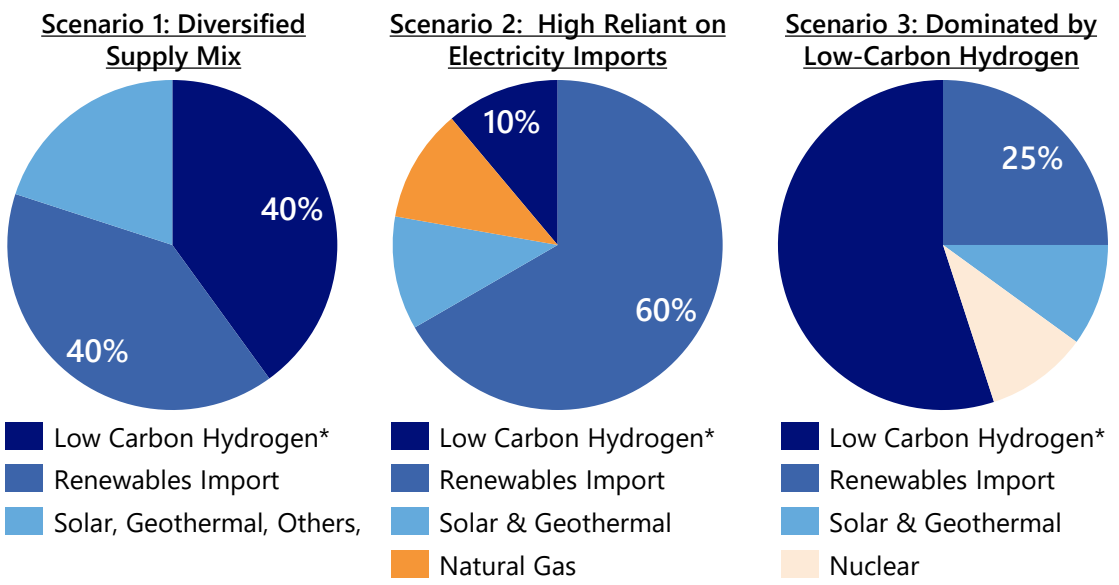
Majority of the Singapore's electricity generation will still be from conventional thermal in the short term but expected to replace to cleaner sources towards 2050

Singapore Electricity Mix Forecast 2033



<data from by Economist Intelligence Unit (EIU)>

Singapore Electricity Mix Forecast 2050**



Ideally by 2050, **Singapore has a diversified electricity supply mix with 100% clean energy**

- Relying **on Renewable electricity imports and low-carbon Hydrogen as the two major contributors**
- Through a diversified range of import sources and local backup capacity, electricity imports are a secure and affordable supply option for Singapore
- Geothermal and solar are two key domestic renewable generation sources that add up to about a fifth of the supply mix

* Low-carbon hydrogen includes its derivatives such as ammonia
** Exact estimates are not available. Percentage value in the figure is approximate value mentioned in the report.

Source: Summarized by NRI based on EIU Energy Report and EMA Report

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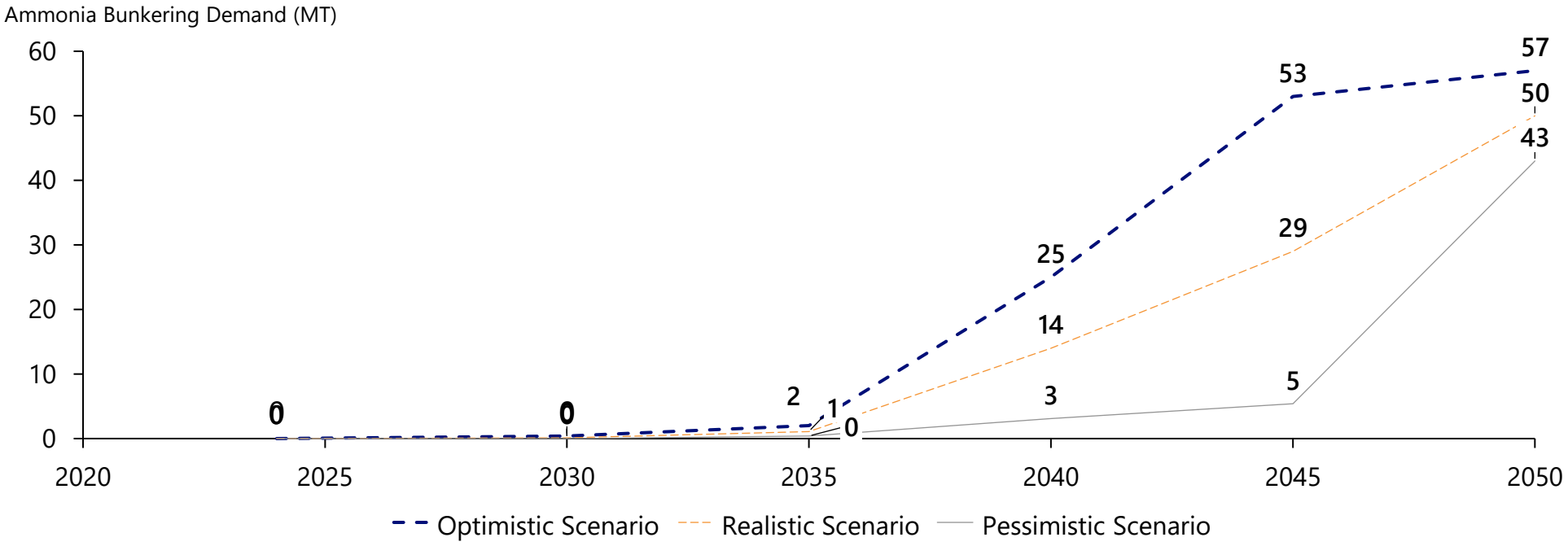
Ammonia Bunkering Demand is expected to pick up in 2035 with rapid growth to follow later in ~2040s onwards

Ammonia Bunkering Demand in Singapore



- **Currently in Singapore, Ammonia bunkering and application are still in its early development stage** with majority of the activities still focusing on the feasibility and trialing stage
- **Demand for Ammonia as a bunkering fuel is expect to only pick increase exponentially from 2040-2050**, with an estimated demand between 43-57 MT in 2050.
- **Ammonia is estimated to account for 30-40% of total marine fuel bunkering demand by 2050.**

Note: Demand potential for Ammonia will also be studied for other industrial activities, such as energy storage, fuel cells, Internal Combustion Engines (ICE) Engines (ICE)
Source: Online Publications, Expert Interviews, NRI Research & Analysis

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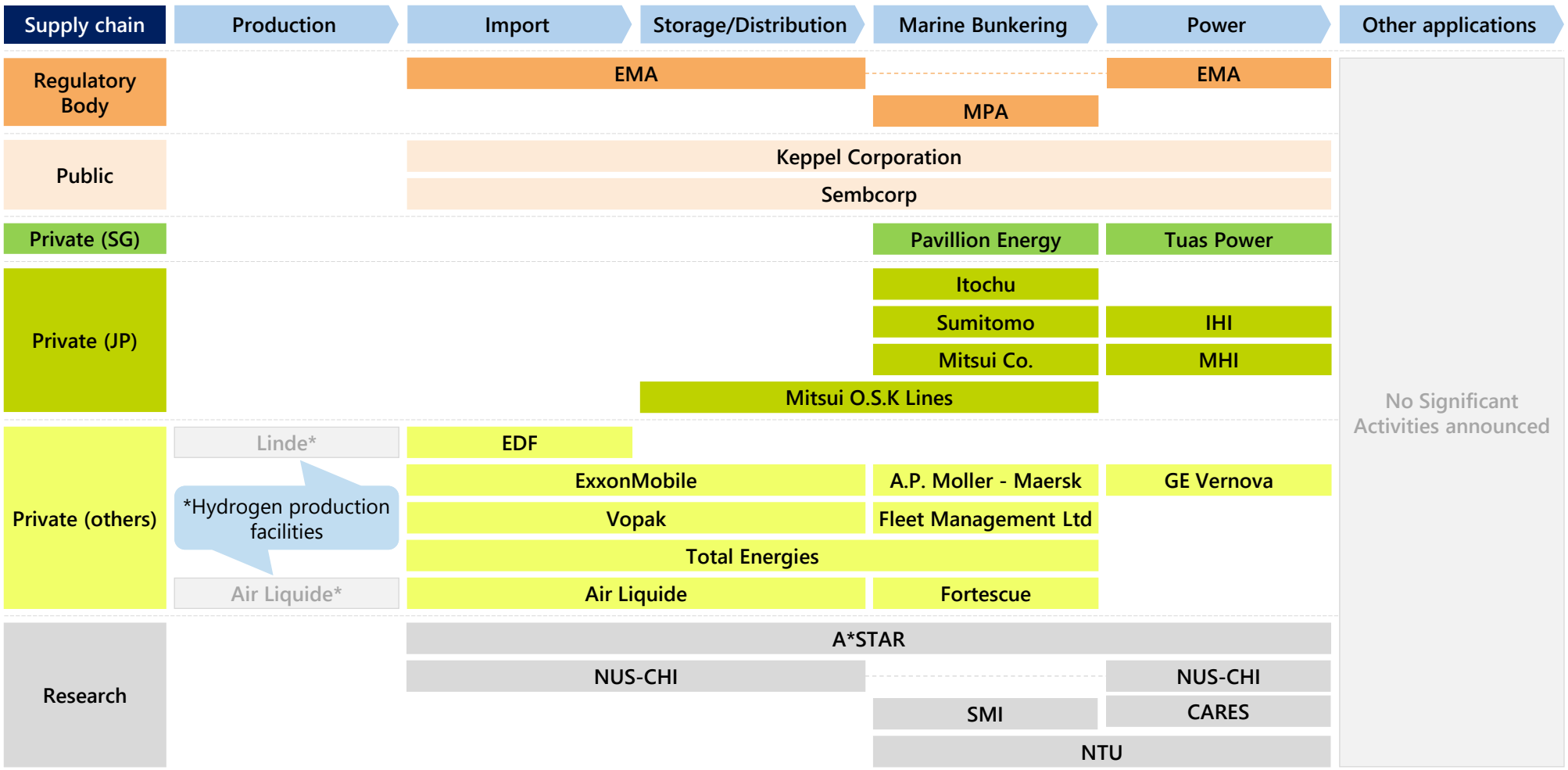
The Ammonia industry may still be in its infant stages, but there are already announced activities/interest from the local government, local players and international players

Ammonia player mapping in Singapore



Note: The above mapping is non-exhaustive and for illustration only (many of the cases are still in MoU stages and not fully developed/operating yet)
Source: Summarized by NRI based on case studied identified in this report

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There is no Ammonia focused/specialised research organization in Singapore. However, related projects are still conducted by various research organizations

Summary of Hydrogen/ Ammonia related focus (Research Organization)

Organizations		Hydrogen/Ammonia supply chain					
		Production	Import	Storage/ Dist.	Bunkering	Power	Others
Research related organization	National Research Foundation (NRF)	National Research Foundation is the lead government agency that overseas the national research agendas. It may provide research fundings and grants but primarily does not conduct research					
	Agency for Science, Technology and Research (A*STAR)		R&D, Trials	R&D, Trials	R&D, Trials	R&D, Trials	
	National University of Singapore (NUS) – Centre for Hydrogen Innovations (CHI)		R&D	R&D		R&D	
	Cambridge Centre for Advanced Research and Education in Singapore (CARES)					R&D, Trials	
	Nanyang Technological University (NTU)				R&D	R&D	
	Singapore Maritime Institute (SMI)				R&D		

Legends: = R&D stage , = Trials/ Demonstration Stage, = Project development Stage
Note: Understanding of focus along the supply chain is not absolute, it is only for illustration based on readily available information
Source: NRI internal understanding

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MPA and EMA launched an EOI for end-to-end Ammonia power generation and bunkering in Singapore. Currently, 2 consortia has been shortlisted for final selection

Progress of EMA & MPA's tender for end-to-end clean Ammonia power generation and bunkering

Tender phases	❶ Expression of Interest (EOI)	❷ Closed Request for Proposal (RFP)	❸ Feasibility study for final selection		❹ Start project
Time period	December 2022	October 2023	July 2024		Mid 2025
Objective & Overview	EMA and MPA launched the **EOI to assess the feasibility of developing an end-to-end solution for Ammonia** • procurement, import, storage, distribution, and end-use for both **power generation and bunkering**	**The Closed RFP was to further evaluate the consortiums** • Each proposal was further developed and evaluated for shortlisting	The **shortlisted consortiums will proceed to conduct final feasibility/FEED study for final shortlisting** • Selected bidder will be lead developer of the project		To be announced
Project requirement	• **Ammonia/Hydrogen power generation of minimally 50MW**, with a minimum load factor of 75% • Storage and jetty designed for at least **0.1 MT/year capacity of Ammonia bunkering**	• **Direct combustion of Ammonia for power generation of 55-65MW** • **Ammonia bunkering at a capacity of at least 0.1 MT/year**, starting with shore-to-ship bunkering followed by ship-to-ship bunkering	**Direct combustion of Ammonia for power generation of 55-65MW**	**Ammonia bunkering at a capacity of at least 0.1 MT/year**, starting with shore-to-ship bunkering followed by ship-to-ship bunkering	
Participants	Total of **26 proposals were received** at the end of the EOI (identity not disclosed)	**6 consortiums was shortlisted** for RFP grom all the proposals received in EOI • Sembcorp Industries • Keppel Corporation • Jurong Port • Engie • Tuas Power • YTL PowerSeraya	**Consortium lead:** • Keppel Infrastructure Division • Sembcorp-SLNG	**Bunkering players** • Itochu Corporation • NYK Line • Sumitomo Corporation • Mitsui & Co. • Fortescue-Equatorial Marine Fuels	

Note: This status is updated as of February 2025
Source: Summarized by NRI based on EMA, MPA and related companies' announcement

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The Singapore Maritime Decarbonization Blueprint 2050 outlines a strategy to transition Singapore's maritime industry toward net-zero emissions built on 7 focus areas

Overview:

- The Singapore government launched the Maritime Singapore Decarbonization Blueprint in support of Singapore Green Plan
- The blueprint outlines the government's strategy to enhance the port for greater environmental sustainability while maintaining its leadership in the maritime industry

Key Implications

- Development of Ammonia for maritime applications and bunkering
- To maintain international leadership and competitiveness in maritime

Key focus areas

#1 – Port Decarbonization
- Reduce carbon emissions from port operations by improving energy efficiency and using cleaner energy sources

#2 – Greening Domestic Harbor Crafts
- Reduce carbon emission from domestic harbor craft fleet by using cleaner energy sources and incentivizing adoption

#3 – Develop Future Marine Fuels and Infrastructure
- Position Singapore as a key hub by establishing standards and guidelines, conducting pilot studies and supporting industry activities

#4 – Greening of Singapore's Ships
- Tackle GHG emissions from international voyages made by Singapore-registered ships by working with ship owners and operators

#5 – Active Participation at International Platforms
- Play key roles internationally on the decarbonization agenda

#6 – R&D and Talent Development
- Be a global hub for maritime decarbonization R&D solutions, enabled by a vibrant ecosystem, with the talent

#7 – Promoting Green Finance/ Accounting
- Strengthen Singapore's capabilities in carbon accounting, reporting and green finance

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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The Maritime Decarbonization Blueprint sets out multiple target between 2020s-2050 as a progressive step towards achieving Net-Zero by 2050

Summary of key milestone/timeline of Singapore Maritime Decarbonization Blueprint

Focus area	Key milestone/timeline*		
	2020s	2030s	2050
Port Decarbonization	Announce initial directions	Reduce absolute emissions by at least 60% from 2005 levels,	Net-Zero by 2050
Greening Domestic Harbor Crafts		Reduce absolute emissions from domestic harbor craft fleet by 15% from 2021 base levels; Halve 2030-level emissions	
Future Marine Fuels, Bunkering Standards and Infrastructure		Support provision of low and zero-carbon marine fuels and enable green technologies; Halve 2030-level emissions	
Greening of Singapore's Ships		Target 150 ships to be awarded SRS Green Notation; Increase SRS adoption of low/zero-carbon fuels; Target 50% of SRS fleet to be GSP ships	
Active Participation at International Platforms		Introduce a new flagship program on maritime sustainability and decarbonization	
R&D and Talent Development		Spearhead 20 technology projects; Train over 100 researchers, scientists and engineers; Target to create and upskill about 1,200 sustainability related jobs	
Promoting Green Finance/ Accounting		Develop a maritime sector-specific carbon accounting guide; Develop a standard taxonomy for sustainable assets and activities in the maritime sector	
	Conducting initial R&D/ trials/ partnership to build foundations	Rapid scaling up of commercial deployment	

Source: Summarized by NRI based on Singapore Maritime Decarbonization Blueprint

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Executive Summary

1. General Introduction

2. Ammonia Policy Trends

3. Ammonia Market Activities (Supply & Demand)

4. Maritime Decarbonization

Annex

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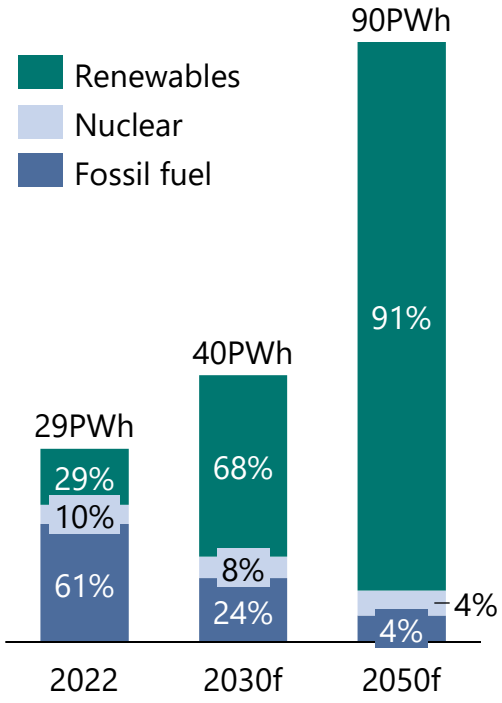
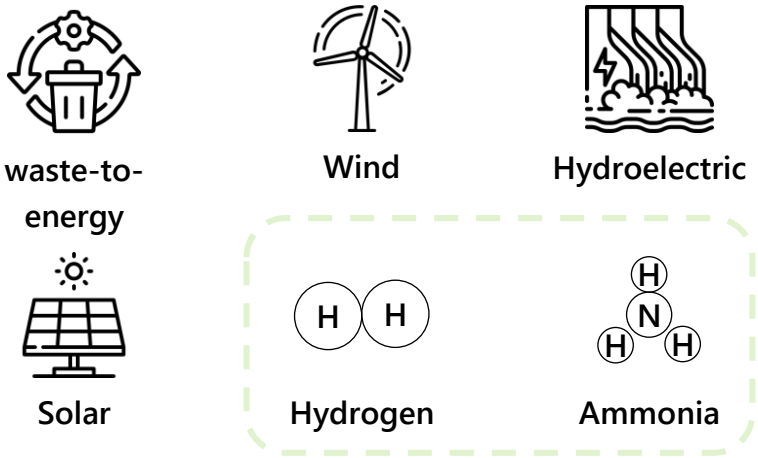
Growing global energy demand and the clean shift towards carbon neutrality have highlighted the use of Ammonia, including as a decarbonized fuel and Hydrogen carrier

Global energy mix



<Data from IRENA (2024), World Energy Transitions Outlook 2024>

Ammonia in the energy mix



- In the push for net zero, **renewables could account for over 90% of the world's power generation mix in 2050**
- **Ammonia can come in as a further Green Fuel option**, it can help balance the grid and strengthen energy security
- There are **two ways Ammonia can be used in power generation: via direct combustion, or via a cracking system that re-converts Ammonia into Hydrogen**, which is then used by a Hydrogen-enabled gas turbine

Source: Summary by NRI from IRENA

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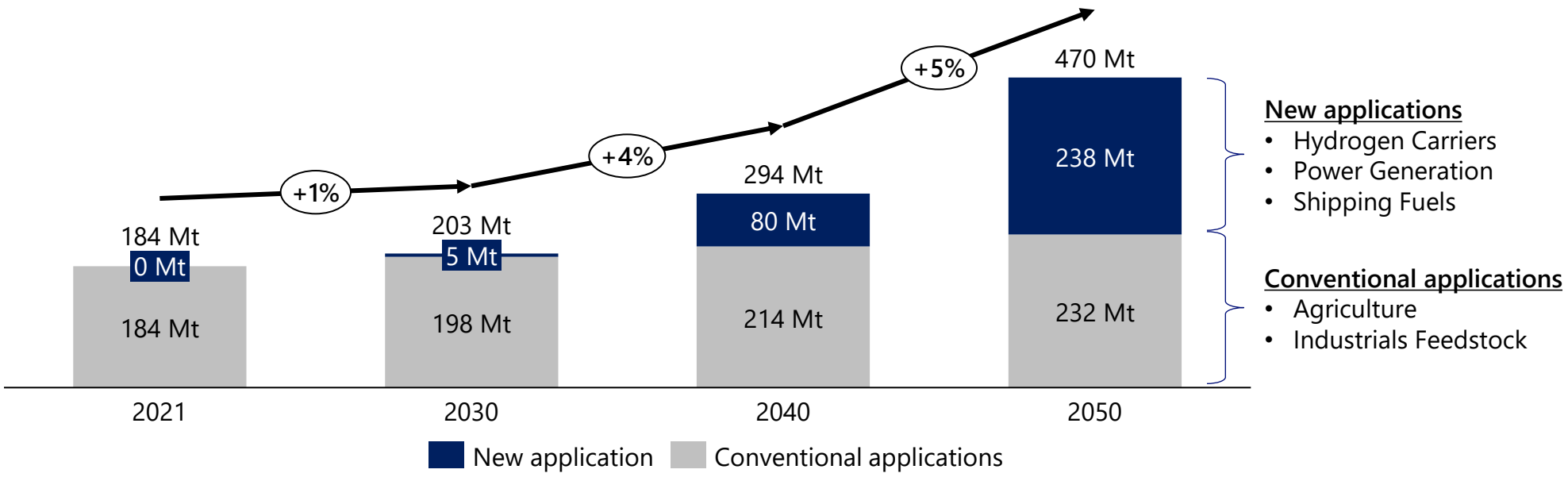
Global Ammonia demand is expected to pickup after 2030, and reach ~470 Mt in 2050, with new applications driving the growth

Global Ammonia Demand Forecast



<Data from Yara Clean Ammonia Report>

- **Conventional applications of Ammonia is mainly in the Agricultural/ Industrial areas** (e.g. fertilizers/ industrial feedstocks)
  - Moving forward, the majority of demand in this application is expected to be **served by a mix of grey and clean Ammonia**

- **New applications of Ammonia are mainly for Hydrogen Carriers, Power Generation and Shipping Fuels**
  - Moving forward, **100% of demand from new applications expected to come from clean Ammonia**
  - ~50% of 2050 demand is projected to come from new applications, with **shipping fuel as the main contributor**

Source: Summary by NRI from Yara Clean Ammonia

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ASEAN countries have also started initiatives on Ammonia which is aligned to the overall decarbonization movement globally (1/2)

Examples of Ammonia Activities in the ASEAN Region

Country	Activity	Overview
Singapore	Ammonia for Power Generation and Bunkering study	• **Main Parties Involved:** Energy Market Authority (EMA), Maritime and Port Authority of Singapore (MPA), Keppel, Sembcorp-SLNG, Itochu, Nippon Yusen, Sumitomo • **Description:** EMA and MPA to Further Study Viability of Ammonia for Power Generation and Bunkering
	Study to convert existing assets to Ammonia ready	• **Main Parties Involved:** Sembcorp, IHI Corporation • **Description:** the two companies will study the introduction of an Ammonia-Fueled gas turbine as well as the conversion of existing assets to Ammonia and mixed fuel within Sembcorp's facilities on Jurong Island
Indonesia	Garuda Hydrogen Hijau (Hydrogen) Project	• **Main Parties Involved:** ACWA Power • **Description:** The Project is expected to start commercial operations in 2026, will run on 600 MW of Solar and Wind power, and will produce 150,000 tons of Green Ammonia per year
	Ammonia Co-Firing in Coal-Fired Power Plants	• **Main Parties Involved:** PLN Nusantara Power • **Description:** MHI and PLN signed a MoU to commence three technical studies related to co-firing of less carbon intensive fuels at power plants owned by Nusantara Power
Malaysia	Green Ammonia and Hydrogen plant	• **Main Parties Involved:** Lotte, Samsung and Sarawak Economic Development Corporation Energy (SEDC) • **Description:** Lotte and SEDC has contracted Samsung Engineering to execute the FEED for the Green Hydrogen plant (150,000 tons/annum) and a Green Ammonia conversion plant (850,000 tons/annum) in Sarawak
	Green Ammonia Feasibility Study	• **Main Parties Involved:** IHI Corporation and Gentari (Petronas) • **Description:** IHI and Gentari sign MoU to explore Green Ammonia Production and Sales in Malaysia

Source: Various company website and announcements, NRI insights

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ASEAN countries have also started initiatives on Ammonia which is aligned to the overall decarbonization movement globally (2/2)

Examples of Ammonia Activities in the ASEAN Region

Country	Activity	Overview
Thailand	Green Ammonia Market Study	• **Main Parties Involved:** Thai-German Cooperation, DNV Energy systems • **Description:** Conducted comprehensive technical study exploring the future of Green Ammonia in Thailand's energy landscape
	Feasibility study on clean Hydrogen and Ammonia	• **Main Parties Involved:** Mitsui O.S.K. Lines (MOL), Electricity Generation Authority of Thailand (EGAT), Mitsubishi, and Chiyoda Corporation • **Description:** The consortium started a feasibility study on clean Hydrogen and Ammonia value chain in Thailand
Philippines	Hydrogen and Ammonia Utilization Study	• **Main Parties Involved:** AboitizPower, JERA • **Description:** assessment of the feasibility of co-firing Ammonia on coal plants and Hydrogen on LNG facilities to reduce carbon emissions during thermal power generation
Vietnam	Ammonia Co-Firing in Power Plants Study	• **Main Parties Involved:** Electricity of Vietnam (EVN), JERA • **Description:** JERA will support the roadmap for developing, researching and applying the technology for co-burning Ammonia and Hydrogen in EVN existing coal-fired power

Source: Various company website and announcements, NRI insights

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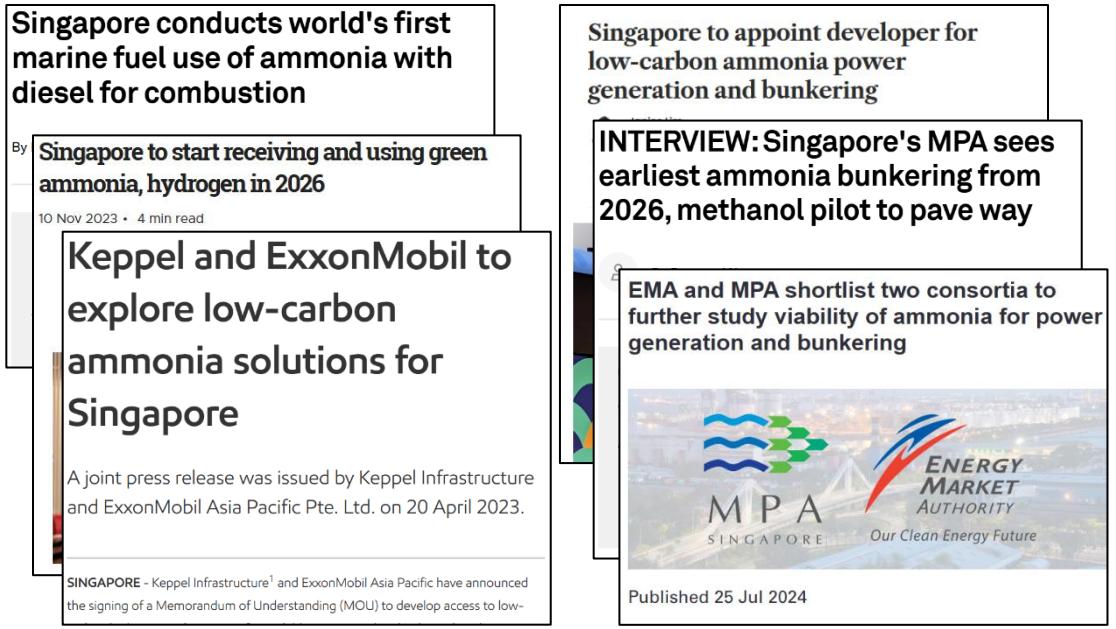
In Singapore, there is a positive approach to Ammonia. In particular, it aims to establish itself as a regional Ammonia supply hub

Singapore has been making headlines for its Ammonia activities



"Jurong Island might not be where Green Hydrogen or Ammonia is produced, but it could surely play a role regionally in aggregating supply, owing to its mature ecosystem of bunkering/storage, logistics and trade players"

Joint statement

Singapore Economic Development Board (EDB)
Surbana Jurong

Source: Summarized by NRI based on Public Articles

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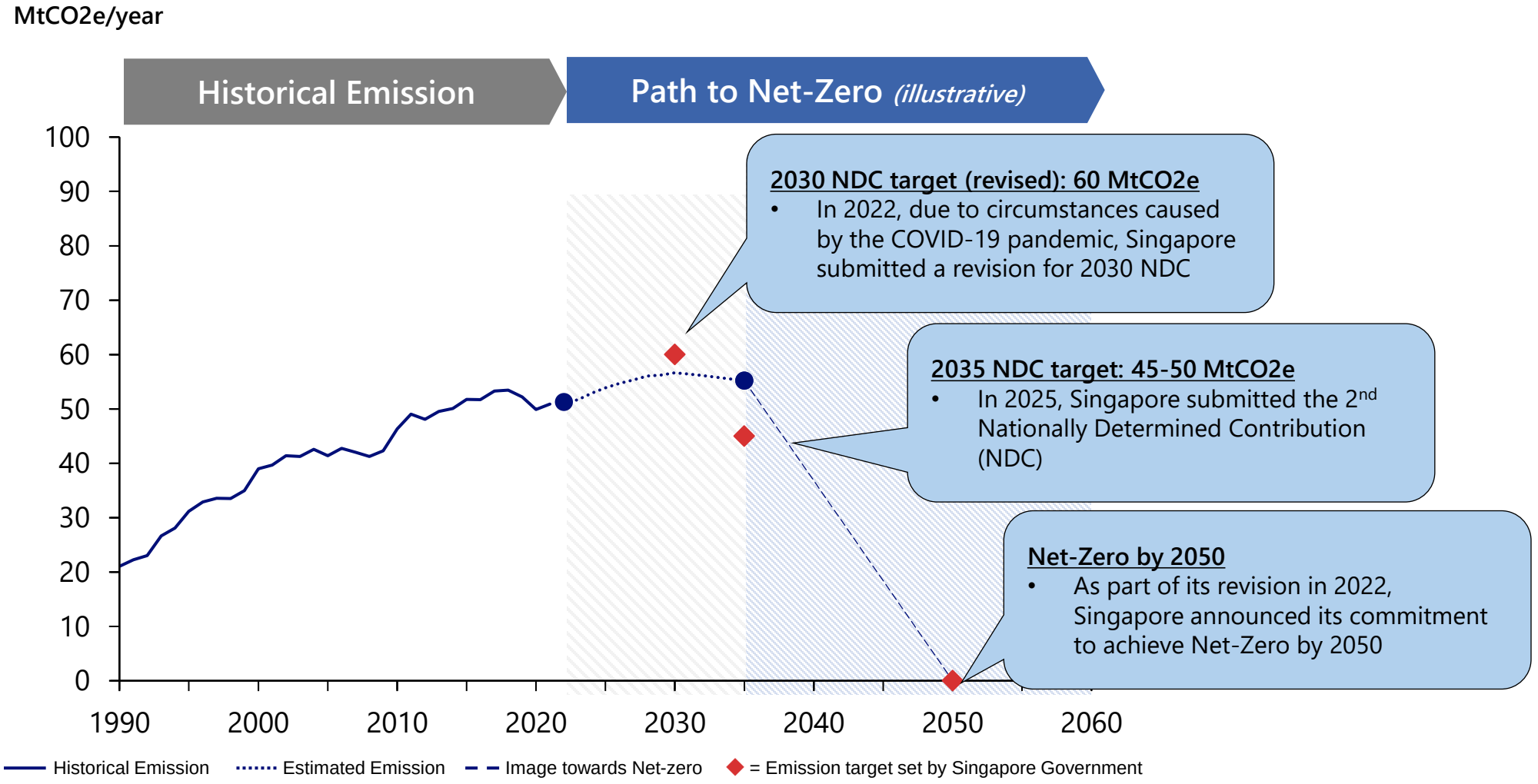
Similar to many countries, the Singapore has made its commitment for NDC target in 2030 and 2035, and targeting Net-Zero by 2050

Singapore Emission and Path to Net-Zero



Source: Summarized by NRI based on Climate Action Tracker

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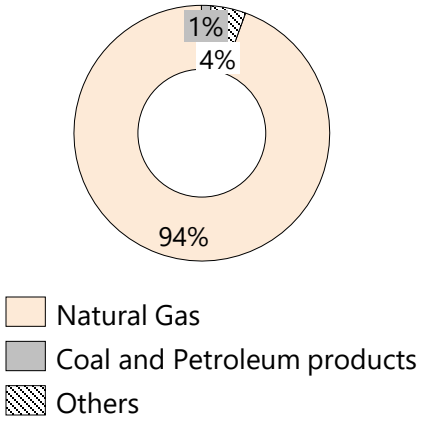
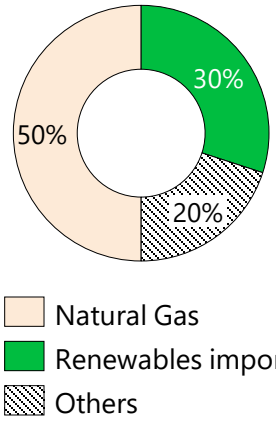
Singapore currently relies on natural gas but must shift to cleaner sources by 2035 to achieve net-zero emissions by 2050

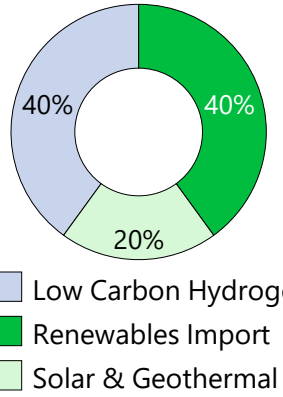
Singapore electricity mix 2023



Singapore electricity mix 2035F



Singapore electricity mix 2050F*



Singapore currently relies on natural gas for most of its electricity needs, but in an effort to reach its net zero carbon emissions target by 2050, the electricity mix will need to rely on more clean energy by 2035 and beyond

- **Solar:** Singapore aims to deploy at least 2 GWp of Solar energy by 2030, maximizing limited land space through rooftop installations, floating Solar farms, and advanced energy storage solutions
- **Hydrogen:** The government is investing in low-carbon Hydrogen as a future energy source, supporting research, pilot projects, and infrastructure development for Hydrogen import, storage, and usage
    - As part of Singapore's 2nd Nationally Determined Contribution (NDC) to future-proof the energy system, the Energy Market Authority (EMA)'s latest emissions standards require new Fossil Fuel generation units to be at least 30% Hydrogen-ready by volume, with the ability to be retrofitted to become 100% Hydrogen-ready in future
- **Ammonia:** Singapore is exploring Ammonia as a Hydrogen carrier and a potential direct fuel, particularly for maritime and power generation applications, with ongoing studies and industry trials
- **Methanol:** Green Methanol is being studied as a low-carbon fuel alternative, especially for shipping and industrial applications
- **Biofuels:** Singapore is scaling up biofuel adoption in aviation and maritime sectors
- **Others:** Singapore will continue importing renewable electricity (targeting 30% of supply by 2035), enhancing grid modernization, and investing in carbon capture and storage (CCS) technologies to reduce emissions

Note: *based on more desired scenario by EDB article where where Singapore is able to rely on low-carbon Hydrogen and import electricity from multiple countries
Source: Summarized by NRI based on EDB announcement and Singapore's 2nd NDC

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Executive Summary

1. General Introduction

2. Ammonia Policy Trends

Key Policies on Ammonia Development

- Other Related Policies
- Ammonia Related Research Organizations

3. Ammonia Market Activities (Supply & Demand)

4. Maritime Decarbonization

Annex

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Amongst the supporting policies of Singapore Green Plan, there are 3 main ones which touched upon the development of Ammonia in Singapore

Singapore's Green Plan is the national sustainability framework outlining the decarbonization pathway for the nation as a whole. It is **supported by sector-specific roadmaps to achieve net-zero by 2050**

- National Hydrogen Strategy
- Maritime Decarbonization Blueprint
- Sustainable Jurong Island
- Singapore EV Roadmap
- Enterprise Sustainability Programme
- ...

These 3 supporting policies have mentioned and outlined the strategy directions and development activities for Ammonia in Singapore

- **National Hydrogen Strategy:** Positions Ammonia as a Hydrogen carrier, driving investments in Ammonia cracking, storage, bunkering and direct power generation for Singapore's future energy mix
- **Maritime Decarbonization Blueprint:** Supports the development of Ammonia as a marine fuel, with trials and infrastructure for Ammonia bunkering in Singapore's port
- **Sustainable Jurong Island:** Facilitates industrial adoption of Ammonia for Hydrogen production, direct power generation and supports R&D in carbon capture and Ammonia cracking technologies

No specific mentions or initiatives that are targeting the development of Ammonia industry in Singapore

Source: Summarized by NRI based on public articles and reports

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It can be observed that decarbonization efforts of key policies can be broadly categorized into 3 phases with rapid commercial deployment expected to start 2030+

Summary of key milestone/timeline of Singapore decarbonization

Policy	Key milestone/timeline*			
	2020s	2030s		2050
SG Green Plan	Announce initial directions	1.5GWp of solar energy deployment	2GWp of solar energy deployment	All vehicles to run on cleaner energy by 2040
		Deploy 200 MWh of Energy Storage Systems	Reduce domestic GHG emission by 3Mt per year by 2030	Reduce GHG emissions from international shipping by 50%
		New registrations of diesel cars and taxis to cease from 2025	All new harbor craft to be fully electric or biofuel compatible	
Hydrogen Strategy			Jurong Island to be a sustainable energy and chemicals park	
			100% Hydrogen compatible CCGTs	Hydrogen to supply 50% of electricity demand
Maritime Decarb. Blueprint		Develop and commission world's first Ammonia-fueled tanker	Reduce port emission by 60% from 2005	Reduce GHG emissions from international shipping by 50%
			All new harbor craft to be fully electric or biofuel compatible	
Sustainable Jurong Island		Grow the base of Sustainable products and production	Jurong Island to be a sustainable energy and chemicals park	Increase the output of sustainable products by 4x from 2019 levels
			Increase the output of sustainable products by 1.5x from 2019 levels	Realize 6Mt of carbon capture per annum
			Realize 2Mt of carbon capture	
			Refineries and crackers to be top 25% globally (energy efficiency)	
		Conducting initial R&D/ trials/ partnership to build foundations	Start small-scale projects for commercial deployment	Rapid scaling up of commercial deployment

Net-Zero by 2050

Note: *only key activities related to energy/emission is showed above for high level illustration purpose
Source: Summarized by NRI based on public articles and reports; and NRI analysis

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The Singapore Green Plans outline whole of nation approach to Hydrogen/ Ammonia while the supporting policies provides sector specific targets and initiatives

Summary of Ammonia related focus in key policies

Policy	Target industry	Hydrogen/ Ammonia supply chain					
		Production	Import	Storage/Dist.	Bunkering	Power	Others
SG Green Plan	• Whole of nation	The SG Green Plan mainly **positioned Hydrogen and Ammonia as possible low-carbon alternatives which can help decarbonize Singapore in general** The **use case or development plan for application of Hydrogen and Ammonia is not mentioned here**, but instead elaborate in supporting policies below					
Hydrogen Strategy	• Industrials • Power • Transport		✓	✓		✓	
Maritime Decarb. Blueprint	• Maritime • Shipping • Port			✓	✓		
Sustainable Jurong Island	• Oil & Gas • Chemicals • Power		✓	✓		✓	

Note: *Only activities with concrete plan and initiatives are taken into consideration in the illustration above based on NRI's internal understanding
Source: Summarized by NRI based on public articles and reports

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Despite not having Ammonia specifics policies, there are 4 main policies in Singapore that are guiding Ammonia-related developments in Singapore (1/2)

Key policies supporting Ammonia				
Policy type	**Policy Name**	**Organization**	**Announcement Date**	**Description**
Strategic policy	**❶ Singapore Green Plan 2030**	• Ministry of Education • Ministry of National Development • Ministry of Sustainability and the Environment • Ministry of Trade and Industry • Ministry of Transport	2021	**Brief of Policy** • A national sustainability roadmap with targets for energy, transport, waste, and industry to achieve net-zero emissions by 2050 **Relevance on Ammonia** • Encourages low-carbon energy solutions, including Ammonia as a clean fuel for power generation, shipping, and Hydrogen transport
Strategic policy	**❷ National Hydrogen Strategy**	• Ministry of Trade and Industry Singapore • Energy Market Authority	2022	**Brief of Policy** • A roadmap to develop Hydrogen as a key energy source, focusing on imports, infrastructure, and technological advancements **Relevance on Ammonia** • Positions Ammonia as a Hydrogen carrier, driving investments in Ammonia cracking, storage, and bunkering for Singapore's future energy mix

Source: Summarized by NRI based on public articles and reports

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Despite not having Ammonia specifics policies, there are 4 main policies in Singapore that are guiding Ammonia-related developments in Singapore (2/2)

Key policies supporting Ammonia				
Policy type	**Policy Name**	**Organization**	**Announcement Date**	**Description**
Strategic policy	**❸ Maritime Decarbonization Blueprint (2050)**	• Maritime and Port Authority of Singapore (MPA)	2021	**Brief of Policy** • A strategy to reduce shipping emissions through alternative fuels, electrification, and Green port initiatives **Relevance on Ammonia** • Supports the development of Ammonia as a marine fuel, with trials and infrastructure for Ammonia bunkering in Singapore's port
Strategic policy	**❹ Sustainable Jurong Island**	• Economic Development Board • JTC Corporation	2021	**Brief of Policy** • A plan to decarbonize Singapore's energy and chemicals hub, focusing on cleaner feedstocks and low-carbon energy **Relevance on Ammonia** • Facilitates industrial adoption of Ammonia for Hydrogen production, direct power generation and supports R&D in carbon capture and Ammonia cracking technologies

Source: Summarized by NRI based on public articles and reports

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The Singapore Green Plan 2030 outlines Singapore's energy transition strategy, which highlighted key focus area such as using low-carbon alternatives

Policy Details	• **Policy Name**: Singapore Green Plan 2030 • **Policy Launch Year:** 2021 • **Policy Overseeing Organization**: Multi-Ministry Join Policy (Ministry of Education, Ministry of National Development, Ministry of Sustainability and the Environment, Ministry of Trade and Industry and Ministry of Transport)
Policy Background and Overview	• **Aims to achieve net-zero emissions by 2050** through sustainable development & climate resilience • It focuses on **transitioning to cleaner energy, enhancing Green transport and buildings, and fostering a low-carbon economy** • The plan also **strengthens climate adaptation measures, promotes sustainable living, and positions Singapore as a leader in Green innovation and solutions**
Key Policy Objectives	**The Singapore Green Plan 2030 is built on five key pillars to drive sustainability and climate resilience** • **City in Nature** enhances Green spaces and biodiversity • **Energy Reset** accelerates the transition to clean energy, Green transport, and efficient buildings • **Green Economy** fosters sustainability-driven growth • **Resilient Future** strengthens climate adaptation efforts • **Sustainable Living** promotes eco-friendly habits and waste reduction.
Key Timeline	• **2025:** Begin key sustainability initiatives, including park development, waste reduction, and transitioning to clean energy. • **2026:** Continued progress in Green spaces, waste management, and clean transport infrastructure. • **2030:** Major expansion of tree planting, energy-efficient buildings, and public transport, with a focus on sustainability. • **2035:** Expansion of Green spaces and further leadership in Green finance and sustainable infrastructure. • **2040:** Full adoption of clean energy, sustainable transport, and local food production.
Key activities	• Awarded **YTL PowerSeraya the right to build, own and operate a new Hydrogen-ready Combined-Cycle Gas Turbine (CCGT)** power plant and aims to commence operations of CCGT by 2027, making it the third Hydrogen-ready CCGT in Singapore
Ammonia specific info	**The policies encouraged Ammonia as a clean fuel for power generation, shipping, and Hydrogen transport** • **Committed $53 million to 16 Low-Carbon Energy Research projects** of low-carbon energy technologies such as Hydrogen (e.g. **some projects will look at developing Ammonia for Hydrogen transport**) • Launched request for proposals **for low/zero carbon Ammonia solutions for power generation and bunkering in 2024** to **test and deploy a direct Ammonia combustion power plant and support the holistic assessment of Ammonia bunkering**

Source: Summarized by NRI based on Singapore Green Plan 2030, Energy Market Authority, and related company's websites

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Under the Singapore Green Plan 2030 "Energy Reset" pillar, Singapore aim to use cleaner energy sources across all sectors such as Hydrogen and Ammonia

Key pillars of Singapore Green Plan

SG GREEN PLAN

City in Nature
Expanding Green spaces and enhancing urban biodiversity to create a more livable environment

Energy Reset
Transitioning to cleaner energy sources, improving energy efficiency, and reducing carbon emissions

Green Economy
Driving sustainable growth through Green jobs, innovation, and a low-carbon business ecosystem

Resilient Future
Strengthening climate resilience by improving water and food security, and enhancing flood protection

Sustainable Living
Encouraging eco-friendly habits, reducing waste, and promoting a circular economy in daily life

Green Energy
- **Singapore aims to transition towards cleaner energy sources by expanding Solar deployment, exploring Hydrogen and Ammonia, and improving energy efficiency**
- Key Target: Deploy at least 2 GWp of Solar energy by 2030, enough to power around 350,000 households annually

Green Transport
- Singapore is shifting towards cleaner transportation by promoting electric vehicles (EVs), enhancing public transport, and adopting sustainable fuels for aviation and **maritime (e.g. Ammonia bunkering and Ammonia-Fueled vessels)**
- Key Target: Phase out internal combustion engine (ICE) vehicles by 2040 and develop 60,000 EV charging points by 2030

Green Buildings
- Singapore is improving energy efficiency in buildings through stricter sustainability standards, retrofitting existing infrastructure, and promoting Green construction materials
- Key Target: Make 80% of buildings (by floor area) Green-certified by 2030 under the Green Mark certification scheme

Source: Summarized by NRI based on Singapore Green Plan 2030

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The National Hydrogen strategy highlights the importance of Hydrogen and Ammonia in providing up to half of Singapore's future domestic power demands by 2050

Policy Details	• **Policy Name**: Singapore's National Hydrogen Strategy • **Policy Launch Year:** 2022 • **Policy Overseeing Organization**: Ministry of Trade and Industry Singapore, Energy Market Authority
Policy Background and Overview	• Singapore's government has been studying various decarbonization pathways to achieve its 2050 net zero emissions target, while simultaneously strengthening energy security. • To achieve net zero by 2050, Singapore believes that low-carbon Hydrogen has the potential to steer Singapore's energy transition, complementing Solar, imported electricity and other potential low-carbon energy sources.
Key Policy Objectives	**To promote and develop Hydrogen adoption through** • Experimenting with the use of advanced Hydrogen technologies for commercial readiness through pathfinder projects, • Investing in research and development to unlock key technological bottlenecks, • Pursuing international collaborations to enable supply chains for low-carbon Hydrogen, • Undertake long-term land and infrastructure planning, and • Supporting workforce training and development of our broader Hydrogen economy
Key activities	• **Target for Hydrogen to potentially supply up to 50% of our projected electricity demand by 2050** (100% Hydrogen compatible Combined Cycle Gas Turbines (CCGTs), targeted for commercial availability in around 2030) • **Setting up of Global Centre for Maritime Decarbonization (GCMD)**, together with six other founding partners, as a non-profit organization based in Singapore to advance maritime decarbonization • Singapore has set aside an **additional SGD 129 million of research funding for Low-Carbon Energy Research projects** to support future development of low-carbon technologies such as Hydrogen
Ammonia specific info	**As part of the policy, Ammonia is positioned as a Hydrogen carrier, driving investments in Ammonia cracking, storage, and bunkering** • Maritime and Port Authority of Singapore (MPA) is working directly with various industry consortia to **study the feasibility of Ammonia as a bunkering fuel, and to accelerate its deployment in international shipping** • MPA is also collaborating with stakeholders to **define safety and operational envelopes that will be used to facilitate a regulatory sandbox for Ammonia bunkering trials** • The policy also highlighted the **high potential of Ammonia as Hydrogen carrier as part of future import plans**

Source: Summarized by NRI based on National Hydrogen Strategy

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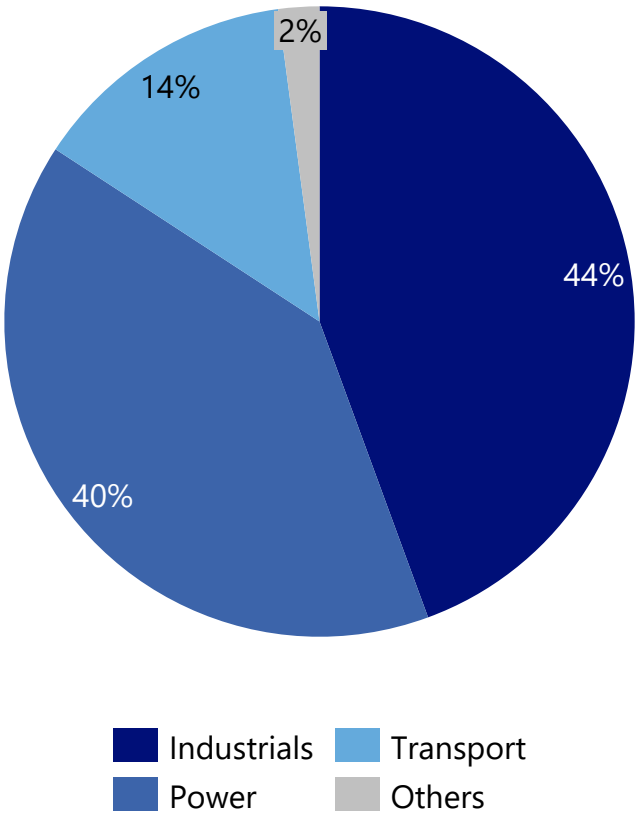
Power, Industrials and Transport sectors are the three largest emitting sectors which will utilize low-carbon alternatives such as Hydrogen and Ammonia solutions

Singapore Primary CO2 Profile (2020)



Initial plans for decarbonizations of key emission sectors

Industrials

- **The industrials sector is the largest contribution of Singapore's emission currently**
- **Low-carbon Hydrogen has been highlighted to be one of the key pathways in bringing down industrial emissions**
  - Used as feedstock for industrial processes
  - Used as fuel for heat, power, and steam generation

Power

- **The power sector is the 2nd largest contributor of emission in Singapore**
- **Four supply "switches" were identified to transform Singapore's fuel mix:** natural gas, Solar paired with Energy Storage Systems (ESS), regional power grids and low-carbon alternatives (Hydrogen/Ammonia)
- It is expected that By 2030, there will be at least 9 Hydrogen-ready power plants

Transport

The transport sector is the 3rd largest contributor of emission in Singapore. Each mode of transport has identified plans for Hydrogen

- **Maritime:** adoption and development of Ammonia/Hydrogen Fueled vessel
- **Aviation:** Increasing the adoption of SAF fuels and further development of Hydrogen-powered aircraft in the long-term
- **Land transport:** encouraging the adoption of electric vehicles, while continue to monitor developments in other clean energy alternatives (e.g. Hydrogen fuel cells vehicle)

The adoption of low-carbon Hydrogen have high synergies and relations to Ammonia

- E.g. sharing of key infrastructure to import and distribute Hydrogen/Ammonia

Source: Summarized by NRI based on National Hydrogen Strategy

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Ammonia is viewed as a promising technology in Singapore due to its matured technology, but there are still uncertainties and challenges in end-use applications

- Ammonia production, transportation and storage are technologically mature. There are also several low-carbon Ammonia projects in the pipeline worldwide, signifying the concrete steps to develop low-carbon Ammonia supply chains.
- The key uncertainties and challenges lie in end-use applications of Ammonia.

	Key Challenges	Proposed mitigation measures
Technology	**Nascent Hydrogen/Ammonia Technology Adoption** • Current Ammonia cracking technology has only been deployed at a small scale • Utilizing Ammonia as a Hydrogen carrier for power generation at national level requires cracking technology to improve	**Deployment of Ammonia pathfinder projects for power generation** • EMA is embarking on a pathfinder to test and deploy a direct Ammonia combustion power plant **Research studies and piloting nascent technologies** • Continue to explore new technologies to develop innovative solutions for Hydrogen and Ammonia • E.g. PSA will spearhead projects to develop advanced Ammonia marine bunkering capabilities
Supporting infrastructure	**Lack of infrastructure to support nation wide adoption** • E.g. Hydrogen will need to be stored and distributed to off-takers, requiring development of suitable import and storage facilities, and a distribution network. • E.g. Apart of the storage and bunkering, the current scale of Ammonia Fueled ships are still limited	**Continued private-public partnership to develop related infrastructure** • The government to provide support and collaboration to encourage further investments into related infrastructure
Regulatory	**Further development of regulations/ guidelines** • E.g. Establishment of safety and regulation guidelines for alternative fuels such as Ammonia for bunkering • E.g. Ammonia-Fueled power generation gas turbines is in its early stage – operating parameters and protocols need to be established	**Review and update of Ammonia bunkering standards and guidelines** • The Marine Port Authority (MPA) is collaborating with EnterpriseSG to develop Singapore standards for Methanol and Ammonia bunkering by end 2025

Source: Summarized by NRI based on National Hydrogen Strategy, National Determined Contributions

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The Maritime Decarbonization Blueprint (2050) aims to enhance environmental sustainability while maintaining the country's leadership in the maritime industry

Policy Details	• **Policy Name**: Maritime Singapore Decarbonization Blueprint • **Policy Launch Year:** 2022 • **Policy Overseeing Organization**: Maritime and Port Authority of Singapore (MPA)
Policy Background and Overview	• **Supporting the Singapore Green Plan 2030, the Singapore government launched the Maritime Singapore Decarbonization Blueprint** to enhance environmental sustainability while maintaining its leadership in the maritime industry. • The Blueprint outlines Singapore's initiatives on Ammonia adoption which includes **Ammonia bunkering and supply chain development** as well as **partnerships and research and development investments**.
Key Policy Objectives	**Port Terminal targets** • Achieve 60% emissions reduction based on 2005 emissions by 2030, Net Zero Emissions by 2050 **Domestic Harbor Craft targets** • Achieve 15% emissions reduction based on 2021 emissions by 2030, further 50% reduction based on 2030 emissions by 2050 **Maritime targets** • Supply low and zero-carbon marine fuels and enable Green technologies • Achieve 50% of Singapore Registry of Ships (SRS) fleet to be Green ships by 2050
Key activities	• Pilot Use of Biofuel Blends and Electrification and Biofuel Compatibility Study for Singapore Harbor Craft by MPA • MPA joined a multinational coalition (Castor Initiative) that aims to design, build, and commission the world's first Ammonia-Fueled tanker by 2025 • MPA is actively collaborating with like-minded industry partners to conduct feasibility studies and pilot trials for the deployment of future fuels and various low and zero-emission fuel solutions
Ammonia specific info	**Supports the development of Ammonia as a marine fuel, with trials and infrastructure for Ammonia bunkering in Singapore's port** • MPA supported and participated **partnerships with various international industry players to conduct trials and feasibility of Ammonia as a vessel fuel and bunkering** • MPA is also working to **develop regulatory sandbox for the application of Ammonia**

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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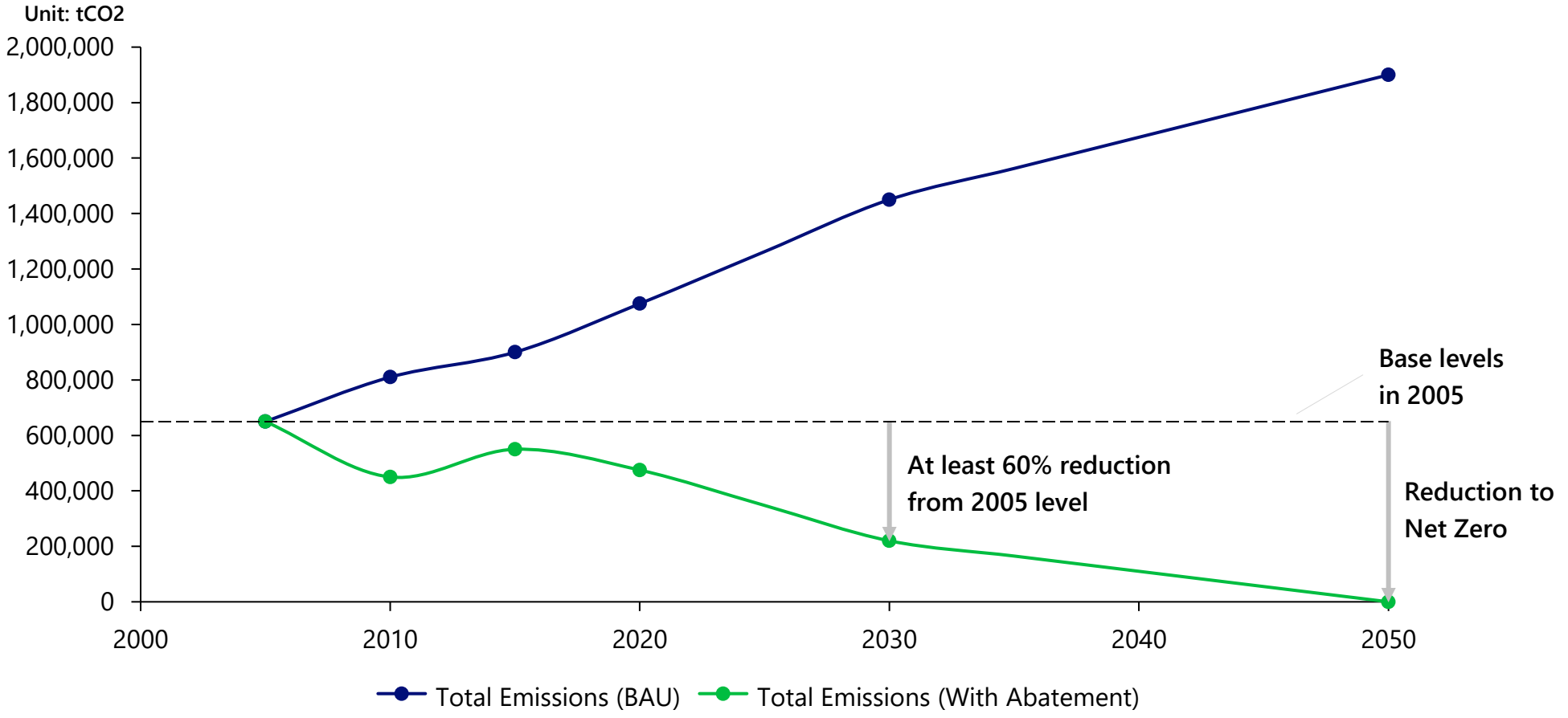
Maritime Singapore Decarbonization Blueprint (2050) aims to achieve >60% reduction of total emissions from port operations by 2030, and net zero emissions by 2050

Estimated BAU versus targeted emissions of port terminals from 2005 to 2050 by Jurong Port Pte Ltd ("JPPL") and PSA Corporation Limited ("PSAC")



<Data from MPA Decarbonization Blueprint>

Source: Summarized by NRI based on MPA Decarbonization Blueprint

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Based on current industry pilots and feasibility studies, MPA has identified Ammonia and E-Methanol as frontrunner fuels for decarbonization of international shipping

MPA's present assessment of low/zero-carbon fuels (specific to maritime application)

	Supply		Technology		Market Demand & Policies	Regulations/ Standards
	Availability	Infrastructure	Fuel Cell	Engine		
Biofuels	✓	✓	✓	✓	✓	✓
Electrification	✓	✓	✓	✓	✓	✓
E-Methanol	✓	✓	✓	✓	✓	✓
Ammonia	✓	✓	✓	✓	✓	✓
Hydrogen	✓	X	✓	X	X	X
Onboard CCSU	X	X	✓	X	X	X

Interim fuel choice for domestic harbor craft

Frontrunner fuels for international shipping

E-Methanol
- Easier to handle and store than ammonia, with existing infrastructure adaptability
- Emits CO2 when combusted
- Only emission free if carbon is from captured sources (very costly)

Ammonia
- Existing infrastructure availability is higher as compared to Hydrogen
- Ammonia vessels engines are expected to be available by 2025
- Toxic and challenging to handle, requiring strict safety measures

Hydrogen
- Lower energy density disadvantageous for longer-distance shipping
- Limited existing infrastructure
- Available at commercial scale before nearing 2030

Source: Summarized by NRI based on MPA Decarbonization Blueprint 2050 and Yara Clean Ammonia Report

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The Sustainable Jurong Island plan aims to transform Jurong Island (JI) and position it as a sustainable energy and chemicals park

Policy Details	• **Policy Name**: Sustainable Jurong Island • **Policy Launch Year:** 2021 • **Policy Overseeing Organization**: Economic Development Board (EDB), JTC Corporation (statutory board under Singapore's Ministry of Trade and Industry)
Policy Background and Overview	• The Sustainable Jurong Island plan was announced as a **supporting policy to Singapore's Green Plan 2030** • As Singapore's key hub for the energy and chemicals sector, **Jurong Island is being positioned as a sustainable energy and chemicals park, supporting the development of low-carbon solutions and circular economy initiatives**
Key Policy Objectives	• To **transform Jurong Island into a sustainable energy and chemicals hub** by promoting low-carbon solutions, increasing the production of sustainable products, and reducing carbon emissions • The plan aims to **support Singapore's long-term climate goals by driving innovation in cleaner energy, improving resource efficiency, and enhancing the competitiveness of the Energy & Chemicals sector in a low-carbon future**
Key Timeline	**By 2030** • Increase the output of sustainable products by 1.5 times from 2019 levels • Ensure that the refineries and crackers are in the top quartile of the world in terms of energy efficiency • Realize at least 2 million tons of carbon capture **By 2050** • Increase the output of sustainable products by 4 times from 2019 levels • Achieve more than 6 million tons of carbon abatement per annum from low-carbon solutions
Key activities	• A*STAR, EDB, and JTC are exploring a Carbon Capture and Utilization (CCU) test-bedding facility on Jurong Island • EDB will continue supporting companies in adopting decarbonization solutions, with enhanced REG(E) and IA(ER) schemes now covering carbon capture, utilization, and storage
Ammonia specific info	**The policies looks at development of infrastructure that will support transition to future energy source such as Ammonia an Hydrogen** • **Ammonia is one of the key sustainable products identified in the policy** • EDB and JTC will work with the industry to identify/plan for the necessary infrastructure to support the decarbonization and energy transition of Singapore, such as **specialised or shared infrastructure for future fuels such as Ammonia and Hydrogen**

Source: Summarized by NRI based on announcements and government release on Sustainable Jurong Island

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Singapore Jurong Island (JI) will be revamped as part of the Singapore Green Plan, with multiple projects focused on aggregating the supply of Green Hydrogen and Ammonia

"Jurong Island might not be where Green Hydrogen or Ammonia is produced, but it could surely play a role regionally in aggregating supply, owing to its mature ecosystem of bunkering/storage, logistics and trade players"

- Joint statement by EDB and Surbana Jurong

Jurong Island

<Images from JTC website>

- Jurong Island is a manmade island and industrial hub. It contributed around 3% of Singapore's GDP in 2020
- It is the **heart of Singapore's chemical and energy industry (>100 companies), acting as the operational base for global leading petroleum and chemical companies in Singapore**

List of planned Ammonia/Hydrogen projects in Policy*

Ammonia Powerplant and Bunkering	The Energy Market Authority (EMA) and the Maritime and Port Authority of Singapore (MPA) opened a tender for **developing an end-to-end Ammonia solution on Jurong Island (including direct Ammonia combustion powerplant)**
Ammonia cracking study	Air Liquide and Vopak have signed a Memorandum of Understanding to collaborate on the **development and operation of infrastructure for Ammonia import, cracking and Hydrogen distribution in Singapore**
Building Hydrogen ready power plant	Keppel to **develop Singapore's first Hydrogen-ready power plant**, with construction undertaken by Mitsubishi Power and Jurong Engineering consortium
Alkaline electrolysers for Hydrogen	Industrial gas firm Linde plans to **build a 9 MW Alkaline Electrolysers on Singapore's Jurong island** as part of a long-term Green Hydrogen supply deal with German chemicals firm Evonik

Note: Examples showed are non-exhaustive, based on Sustainable Jurong Island Policy Paper announced in 2021
Source: Summarized by NRI based on announcement and articles from EDB and various companies

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Apart from the carbon tax, Singapore government has announced grants to support the R&D and development of Ammonia in Singapore

Summary of Hydrogen/ Ammonia related focus (non-key policies)

	Policies	Hydrogen/Ammonia supply chain					
		Production	Import	Storage/Dist.	Marine Bunkering	Power	Others
Financial policies	Carbon Pricing Act					■	
	Future Energy Fund		↘ ■	↘ ■		↘ ■	
	Low-Carbon Energy Research Funding Initiative		🔬 ↘	🔬 ↘		🔬 ↘	
	CREATE Thematic Programme		🔬	🔬	🔬	🔬	
International collaborations	Singapore-Japan Ammonia Fueled Bulk Carriers Joint Study		↘ ■	↘ ■	↘ ■		
	Singapore-Vietnam partnership on Energy and Carbon Credits		🔬	🔬			
	Singapore-New Zealand Low-Carbon Hydrogen Agreement		↘ ■	↘ ■			
	Singapore-Australia Green Economy Agreement (GAE)		↘ ■	↘ ■			

Legends: 🔬 = R&D stage , ↘ = Trials/ Demonstration Stage, ■ = Project development Stage

Note: Understanding of focus along the supply chain is not absolute, it is only for illustration based on high level understanding of each policies

Source: NRI internal understanding

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Apart from the 3 main policies, Singapore has announced several other financial incentives/disincentives that supports the development of Ammonia industry (1/3)

Other related policies and government activities						
Policy type	**Policy Name**	**Stage of development**	**Supply chain involvement**	**Organization**	**Announced date**	**Description**
Financial (penalties)	**Carbon Pricing Act**	**Project development**	• **Power gen.**	• Ministry of Sustainability and the Environment (MSE) • National Environment Agency (NEA)	2019	**Brief of Policy** • The Carbon Pricing Act imposes a carbon tax on Greenhouse gas emissions to incentivize emissions reduction across emission heavy industries in Singapore (e.g. manufacturing, power, waste, and water sectors) **Relevance on Ammonia** • it encourages the adoption of cleaner technologies, (e.g. low-carbon Ammonia for power)
Financial (grants/ fundings)	**❶ Future Energy Fund**	**Trials/ Demos** **Project development**	• **Import** • **Storage/ Distribution** • **Power gen.**	• Energy Market Authority (EMA) • Ministry of Trade and Industry (MTI)	2023	**Brief of Policy** • A SGD 10 billion fund to improve the commercial viability of infrastructure investments for energy transition **Relevance on Ammonia** • Highlighted scope includes encouraging trials and development for Hydrogen and Ammonia related deployment
Financial (grants/ fundings)	**❷ Low-Carbon Energy Research Funding Initiative (LCER FI)**	**R&D** **Trials/ Demos**	• **Import** • **Storage/ Distribution**	• Agency for Science, Technology and Research (A*STAR)	2021	**Brief of Policy** • Research funding for R&D and demonstration projects on low-carbon energy technology solutions Over SGD 180 million has been allocated to this fund in the first 2 phases **Relevance on Ammonia** • Projects supported includes Hydrogen and Ammonia related infrastructure and technologies to decarbonize Singapore

Source: Summarized by NRI based on each organizations press release and announcements

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Apart from the 3 main policies, Singapore has announced several other financial incentives/disincentives that supports the development of Ammonia industry (2/3)

Other related policies and government activities						
Policy type	**Policy Name**	**Stage of development**	**Supply chain involvement**	**Organization**	**Announced date**	**Description**
Financial (grants/ fundings)	**❸ CREATE Thematic Programme**	**R&D**	• **Import** • **Storage/ Distribution** • **Bunkering** • **Power gen.**	• National Research Foundation (NRF)	2024	**Brief of Policy** • A SGD 90 million programme launched in 2024 that supports targeted initiatives that focus on sustainable solutions and technological advancements **Relevance on Ammonia** • Includes R&D projects on Ammonia as a Hydrogen carrier and its potential role in Singapore's clean energy ecosystem
International collaborations	**Singapore-Japan Green and Digital Shipping Corridor**	**Trials/ Demos** **Project development**	• **Import** • **Storage/ Distribution** • **Bunkering**	• Ministry of Transport (SG) • Ministry of Land, Infrastructure, Transport and Tourism (JP)	2023	**Brief of Policy** • this MoC marks the first Green and Digital Shipping Corridor established between Singapore and Japan to develop standards and best practices supporting the decarbonization, Digitalisation and growth of the maritime industry **Relevance on Ammonia** • MPA and the Japanese port partners aim to embark on pilot projects and trials for alternative marine fuels such as Ammonia and Hydrogen. The two sides will also work together to develop the necessary bunkering infrastructure, standards and training
International collaborations	**Singapore-Vietnam partnership on Energy and Carbon Credits**	**R&D**	• **Import** • **Storage/ Distribution**	• Ministry of Trade and Industry (MTI)	2022	**Brief of Policy** • Singapore has signed a MOU with Vietnam on R&D and deployment of low-carbon energy technologies **Relevance on Ammonia** • Key areas highlighted in the MoU included R&D and deployment of Hydrogen and Ammonia and other low carbon energy solutions

Source: Summarized by NRI based on each organizations press release and announcements

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Apart from the 3 main policies, Singapore has announced several other financial incentives/disincentives that supports the development of Ammonia industry (3/3)

Other related policies and government activities						
Policy type	Policy Name	Stage of development	Supply chain involvement	Organization	Announced date	Description
International collaborations	Singapore-New Zealand Low-Carbon Hydrogen Agreement	Trials/ Demos Project development	• Import • Storage/ Distribution • Power gen.	• Ministry of Trade and Industry (MTI)	2021	**Brief of Policy** • Singapore and New Zealand signed MoU to further collaboration on Electrolysers low-carbon Hydrogen development **Relevance on Ammonia** • The collaboration includes exploration of Ammonia as a Hydrogen carrier for cross-border energy supply between Singapore and New Zealand
International collaborations	Singapore-Australia Green Economy Agreement (GAE)	Trials/ Demos Project development	• Import • Storage/ Distribution • Power gen.	• Ministry of Trade and Industry (MTI)	2021	**Brief of Policy** • Australia and Singapore signed which lays the foundations for greater collaboration between two countries to drive growth while reducing emissions **Relevance on Ammonia** • The agreement includes collaboration for the growing use of clean Hydrogen and clean Ammonia

Source: Summarized by NRI based on each organizations press release and announcements

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❶ Future Energy Fund: SGD 10 billion fund to improve the commercial viability of infrastructure investments for energy transition

Policy details	• **Policy Name**: Future Energy Fund • **Policy Launch Year:** 2023 • **Policy Overseeing Organization**: Energy Market Authority (EMA) and Ministry of Trade and Industry (MTI)
Target stage	• **Trials/ Demonstrations** • **Project Development**
Area of focus	**The funds is mainly targets major investments in new infrastructure required for Singapore's energy transition** • **Infrastructure for importing low-carbon electricity** • **New infrastructure to support the generation, storage and delivery of Hydrogen** • **Other related major infrastructure investment to support Singapore's energy transition**
Grants overview	**The Future Energy Fund is an initiative by Singapore's Ministry of Trade and Industry (MTI) and the Energy Market Authority (EMA) to support infrastructure investments for the nation's transition towards a net-zero future** • Initially established **in 2024 with an injection of SGD 5 billion, the fund received an additional SGD 5 billion in 2025, bringing the total to SGD 10 billion** • **The fund primarily focuses on large-scale infrastructure projects – aiming to catalyze Singapore's energy transition by investing in critical infrastructure such as undersea cables for importing low-carbon electricity and developing Hydrogen terminals and pipelines** • These investments are designed to secure reliable and cleaner energy supplies, maintain energy security, and ensure long-term economic competitiveness
Example of relevant projects	• Currently there are no specific projects funded by Singapore's Future Energy Fund that has been publicly disclosed

Source: Summarized by NRI based on announcements on Future Energy Fund

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❷ LCER FI: Research funding for R&D and demonstration projects on low-carbon energy technology solutions

Policy details	• **Policy Name**: Low-Carbon Energy Research Funding Initiative (LCER FI) • **Policy Launch Year:** 2021 • **Policy Overseeing Organization**: Agency for Science, Technology and Research (A*STAR)
Target stage	• **Basic research/R&D stage** • **Trials/ Demonstration**
Area of focus	**The funds are aimed to support the development of nascent yet promising low-carbon technologies in** • **Hydrogen for power and energy** • **Carbon capture utilization and storage (CCUS)** • **Other related areas (i.e. geothermal-related technologies)**

Grants overview	**The Low-Carbon Energy Research Funding Initiative (LCER FI) is a Singaporean government program aimed at advancing low-carbon energy technologies to support the nation's decarbonization goals**
	• **Total of over SGD 180 million has been awarded to support R&D, and demonstration projects under the LCER FI** (Awarded projects shall receive funding support for a period of up to three years, capped at a maximum grant quantum of SGD 1.2 million per project)
	• The research funding were given to R&D projects **led by A*STAR, National University of Singapore and Nanyang Technological University**
	• Each of the 12 projects awarded in the first phase saw **strong collaboration with both local and foreign industry players**
	
	The LCER FI grants has completed Phase 1 in 2021 and the Calls-For-Proposal for Phase 2 has start in 2023
	• Phase 1 (2021)
	  ◦ R&D and demonstration projects on low-carbon energy technologies such as Hydrogen, and carbon capture, utilization and storage (CCUS)
	• Phase 2 (2023)
	  ◦ R&D and development of nascent yet promising low-carbon technologies like Hydrogen, carbon capture utilization and storage (CCUS) and related areas (i.e. geothermal-related technologies)

Source: Summarized by NRI based on announcements on LCER FI

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❷ LCER FI: In 2021, under Phase 1 of the LCER Programme, SGD 55 million has been awarded to support 12 projects on low-carbon energy technology solutions (1/2)

LCER Phase 1 Projects			
S/N	Research Theme	Project Description	Participants
1	Hydrogen	Ammonia Cracking: New Catalyst Development, Reaction Engineering and System Design	**NUS;** NTU; Surbana Jurong Infrastructure Pte Ltd
2	Hydrogen	Miniature Hydrogen leakage and purity sensors for downstream Hydrogen use	**A*STAR;** Hydrogen and Fuel Cell Association of Singapore (TAC)
3	Hydrogen	Methane Pyrolysis for Hydrogen and Carbon Nanotube Production via Novel Catalytic Membrane Reactor System	**NUS;** A*STAR; University of California@Davis; Curtin University; Université de Toulouse-Centre RAPSODEE-CNRS; Dyna Mac Engineering Services; Sembcorp Industries Ltd
4	Hydrogen	Liquid Organic Hydrogen Carriers (LOHCs) Technology for Singapore	**NTU;** NUS; Chiyoda Corporation; PSA Corporation Limited; Sembcorp Industries Ltd; City Gas Pte Ltd; Jurong Port Pte Ltd; Singapore LNG Corporation; Mitsubishi Corporation
5	CCUS	Alternative Sand from Carbon Dioxide and Waste Materials	**A*STAR;** NUS; NTU; Samwoh Innovation Centre Pte Ltd; EnGro Corporation Ltd
6	CCUS	Capturing waste with waste: Continuous carbon capture using highly efficient sorbents derived from incineration ashes	**NTU;** A*STAR; Surbana Jurong Infrastructure Pte Ltd; Mursun Pte Ltd; Tsinghua University; Kunming University of Science and Technology
7	CCUS	Towards Energy Efficient Electrochemical CO2 Reduction to Synthetic Chemicals: A Paradigm Shift in Sustainable Chemical Production	**NUS;** NTU; A*STAR; Stanford University; Tsinghua University and ExxonMobil
8	CCUS	Development and module scale validation of novel hollow fiber membranes for CO2 capture	**NUS;** NTUitive Pte Ltd; Chevron Singapore Pte Ltd; Surbana Jurong Infrastructure Pte Ltd

Bolded = Project Lead, **Blue** = Japanese Players

Source: Summarized by NRI based on announcements on LCER FI

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❷ LCER FI: In 2021, under Phase 1 of the LCER Programme, SGD 55 million has been awarded to support 12 projects on low-carbon energy technology solutions (2/2)

LCER Phase 1 Projects			
S/N	**Research Theme**	**Project Description**	**Participants**
9	CCUS	Stable and long term carbon dioxide hydrate based storage (CO2-HyStore) in deep ocean sediments	**NUS;** Purdue University and Lawrence Berkeley National Laboratory; ExxonMobil
10	CCUS	Process Systems Engineering for Guiding R&D on Low Carbon Technologies	**NUS;** ExxonMobil
11	CCUS	Adsorptive Carbon Capture Using Framework Materials	**NUS;** Northwestern University; ExxonMobil
12	CCUS	Nanostructured Catalysts for Direct CO2 Hydrogenation to Higher Alcohols and Fuels	**NUS;** NuStar Technologies Pte Ltd

Bolded = Project Lead, **Blue** = Japanese Players

Source: Summarized by NRI based on announcements on LCER FI

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❷ LCER FI: In 2023, under Phase 2 of the LCER Programme, SGD 129 million has been awarded to support 6 DHP projects and 10 ETGC projects (1/3)

LCER FI Phase 2: Directed Hydrogen Programme (DHP) and Emerging Technology Grant Call (ETGC)			
S/N	**Research Theme**	**Project Description**	**Participants**
1	Safety and Regulatory Standards	Post-Release Impact Mitigation Evaluation (PRIME)	**A*STAR;** University of Surrey; University of Newcastle; Singapore Institute of Technology; Malayan Daching Co Pte Ltd; S. K. Rosenbauer Pte Ltd; Air Products Pte Ltd; **Mitsubishi Heavy Industries Asia Pacific Pte Ltd**; Bureau Veritas Marine Pte Ltd; Eaglestar Marine Pte Ltd; Bluenergy Solutions Pte Ltd; Jurong Port Pte Ltd; Assets Training & Technical Services Pte Ltd; MPiCS Innovation Pte Ltd; Centre for Strategic Energy and Resources Ltd; **Itochu Singapore Pte Ltd**; Kellogg Brown & Root Asia Pacific Pte Ltd; American Bureau of Shipping; Vopak Terminals Singapore Pte Ltd
2	Ammonia Cracking	Energy efficient Ammonia Cracking by 3D printing and system optimization	**A*STAR;** Fudan University; Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences; Malayan Daching Co Pte Ltd; Kellogg Brown & Root Asia Pacific Pte Ltd; BNF Engineering Pte Ltd; Richz Holdings Pte Ltd; Vnergy Pte Ltd; CADFEM SEA; Measurement Advanced Engineering Pte Ltd; Fraction Technologies Pte Ltd; ST Engineering; Linde Gas Singapore Pte Ltd; KoolLogix Pte Ltd; Orient Technology Pte Ltd
3	Ammonia Cracking	Development of on-site, on demand Ammonia-to-Hydrogen e-cracking bench-top chemical mini-factory	**Nanyang Technological University (NTU);** University at Buffalo; **AGC Asia Pacific Pte Ltd**; Surbana Jurong Pte Ltd; Sydrogen Energy Pte Ltd; iSEACO Shipmanagement Pte Ltd; Synfuels China Technology Co. Ltd; China Hydrogen Energy Technology Co. Ltd; Jiangsu Mesocatalysis Materials Technology Co. Ltd
4	Ammonia Utilization	Development of an integrated system of Ammonia partially cracking and gas turbine combustion with cascade waste heat utilization	**National University of Singapore (NUS);** Cardiff University; **Tohoku University;** King Abdullah University of Science and Technology; Siemens Energy Pte Ltd; Keppel New Energy Pte Ltd, Sembcorp Industries Ltd, CADFEM SEA Pte Ltd
5	Hydrogen Transportation and Distribution	Light-weight, low leakage, high-pressure hybrid composite materials for Hydrogen transmission, distribution, and on-board storage	**A*STAR;** Polymore Materials Pte Ltd; SCG Chemicals Co Ltd; Aqua Power; ST Engineering; Halliburton Pte Ltd; TUV SUD; Cetim Matcor (Matcor Technology & Services Pte Ltd); BNF Industries Pte Ltd; New Universe Manufacturing Pte Ltd; Sunningdale Pte Ltd; Jurong Port Pte Ltd; SP Group; Measurement Advanced Engineering Pte Ltd; Omni Plus system; ECOPLUS International Pte Ltd; Cylinder Management Services

Bolded = Project Lead, **Blue** = Japanese Players

Source: Summarized by NRI based on announcements on LCER FI

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❷ LCER FI: In 2023, under Phase 2 of the LCER Programme, SGD 129 million has been awarded to support 6 DHP projects and 10 ETGC projects (2/3)

LCER FI Phase 2: Directed Hydrogen Programme (DHP) and Emerging Technology Grant Call (ETGC)			
S/N	**Research Theme**	**Project Description**	**Participants**
6	Hydrogen Transportation and Distribution	In-Service Structural Health Monitoring (IS-SHM) for Predictive Maintenance	**A*STAR;** Norwegian University of Science and Technology; Sun Yat Sen University; NUS; iFocus Pte Ltd; **Yokogawa Engineering Asia Pte Ltd**; DNV Singapore Pte Ltd; SIMTRUM Pte Ltd; Wavelength Opto-Electronics (S) Pte Ltd; Rain Tree Photonics Pte Ltd; Penguin Marine Offshore Services Pte Ltd; HiPA Photonics Pte Ltd; PetroLNG Pte Ltd; CIMC Offshore Co Ltd; Vopak Terminals Singapore Pte Ltd
7	CCUS / Capture	High-throughput screening of redoxactive adsorbents for electrochemically mediated carbon capture	**NUS;** Massachusetts Institute of Technology; Altara Infrastructure Services Pte Ltd
8	CCUS / Capture	A New Class of Two-Dimensional Covalent Organic Framework-Based Membranes for Competitive Carbon Capture	**NTU;** State University of New York
9	CCUS / Capture	High efficiency, direct CO2 capture using direct joule heating of conductive, porous solid absorbents	**NUS;** **SS-Alloy Co Ltd**
10	CCUS / Utilization	Plastic waste upcycling through polyolefin functionalization with carbon dioxide	**NUS;** A*STAR
11	CCUS / Utilization	Enzymatic CO2 utilization: towards efficient biocatalytic carboxylation of aromatics to produce useful chemicals	**NUS**
12	Hydrogen / Ammonia Cracking	Rational design of single-atom catalysts toward Ammonia electrooxidation	**NUS;** Huazhong University of Science and Technology

Bolded = Project Lead, **Blue** = Japanese Players

Source: Summarized by NRI based on announcements on LCER FI

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❷ LCER FI: In 2023, under Phase 2 of the LCER Programme, SGD 129 million has been awarded to support 6 DHP projects and 10 ETGC projects (3/3)

LCER FI Phase 2: Directed Hydrogen Programme (DHP) and Emerging Technology Grant Call (ETGC)			
S/N	**Research Theme**	**Project Description**	**Participants**
13	Hydrogen / Ammonia Cracking	Development of decentralized, on demand Ammonia-to-Hydrogen e-cracking chemical mini-plant using decoupled split pH fuel cell	**NTU;** CARES
14	Hydrogen / Hydrogen Transportation and Distribution	Coatings Development for the Prevention of Hydrogen Embrittlement of Large Infrastructural Components	**A*STAR**
15	Hydrogen / Hydrogen Transportation and Distribution	Enhancing Hydrogen Pipeline Connectivity with Novel Impermeable and Repairable Thermoplastic Composite Couplers	**A*STAR;** NUS; NTU; Hanyang University; Arkema Pte Ltd
16	Others / Energy Harvesting	Plug flow pattern for harvesting rain energy via solid liquid charge separation	**NUS**

Bolded = Project Lead, **Blue** = Japanese Players

Source: Summarized by NRI based on announcements on LCER FI

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❸ CREATE Thematic Programme: SGD 90 million programme launched in 2024 focus on R&D for sustainable solutions and technological advancements

Policy details	• **Policy Name**: CREATE Thematic Programme • **Policy Launch Year:** 2024 • **Policy Overseeing Organization**: National Research Foundation (NRF)
Target stage	• **Basic research/R&D stage**
Area of focus	• **Environmental Systems:** i.e. clean water, clean energy, solid waste disposal, environmental sustainability and energy conservation • **Energy Systems:** i.e. carbon capture and reduction, building efficiency and sustainability, harnessing solar energy and low energy electronic systems • **Human Systems:** i.e. inflammation, infectious diseases, biosystems and micromechanics • **Urban Systems:** i.e. energy and environmental sustainability, urban mobility, and urban design and territorial planning
Grants overview	**The CREATE Thematic Programme is a research initiative by Singapore's Campus for Research Excellence and Technological Enterprise (CREATE), focusing on interdisciplinary collaborations to address critical challenges** • In July 2024, **SGD 90 million programme was launched to advance research in Hydrogen utilization and the production of sustainable chemicals and fuels, such as sustainable aviation fuel** • The programme involves leading investigators from the National University of Singapore (NUS), Nanyang Technological University (NTU), CREATE partners like the University of Cambridge and Shanghai Jiao Tong University, and international experts from institutions such as Germany's Max Planck Institute and Japan's Tohoku University • The **research aims to develop solutions for decarbonizing Singapore's energy and industrial sectors, including building capacity in Hydrogen utilization, gaining insights into the combustion behaviors of zero-carbon fuel blends, and developing Ammonia-ready fuel cells for power generation**
Example of relevant projects	• Hydrogen utilization to Hydrogen combustion technologies • Green chemistry, such as the sustainable conversion of biomass to chemicals and biofuels • Synthetic biology, such as by engineering microbes to convert carbon dioxide into chemicals and biofuels • Chemical transformation, which involves developing net zero pathways of producing top molecules for pharmaceutical applications

Source: Summarized by NRI based on announcements on CREATE Programme

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Executive Summary

1. General Introduction

2. Ammonia Policy Trends

- Key Policies on Ammonia Development
- Other Related Policies

Ammonia Related Research Organizations

3. Ammonia Market Activities (Supply & Demand)

4. Maritime Decarbonization

Annex

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There is no Ammonia focused/specialised research organization in Singapore. However, related projects are still conducted by various research organizations

Summary of Hydrogen/ Ammonia related focus (Research Organization)

	Policies	Hydrogen/Ammonia supply chain					
		Production	Import	Storage/ Dist.	Bunkering	Power	Others
Research related organization	National Research Foundation (NRF)	National Research Foundation is the lead government agency that overseas the national research agendas. It may provide research fundings and grants but primarily does not conduct research					
	Agency for Science, Technology and Research (A*STAR)		R&D, Trials	R&D, Trials	R&D, Trials	R&D, Trials	
	National University of Singapore (NUS) – Centre for Hydrogen Innovations (CHI)		R&D	R&D		R&D	
	Cambridge Centre for Advanced Research and Education in Singapore (CARES)					R&D, Trials	
	Nanyang Technological University (NTU)				R&D	R&D	
	Singapore Maritime Institute (SMI)				R&D		

Legends: = R&D stage , = Trials/ Demonstration Stage, = Project development Stage
Note: Understanding of focus along the supply chain is not absolute, it is only for illustration based on readily available information
Source: NRI internal understanding

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There may be no specific research organizations dedicated to Ammonia, but related activities (especially with Hydrogen) are carried out by various organizations (1/3)

Research Institutes and Funding Organizations				
Organization	**Policy Name**	**Stage of development**	**Supply chain involvement**	**Description**
Funding Organization	**National Research Foundation (NRF)**	NA	• NA	**Overview of organization** • The NRF sets the national direction for research and development (R&D) by developing policies, plans, fundings and strategies for research, innovation, and enterprise **Example of related activities** • CREATE Thematic Programme: SGD 90 million programme launched in 2024 to support sustainable solutions and technological advancements (including Ammonia)
Research Institutes	**Agency for Science, Technology and Research (A*STAR)**	**R&D** **Trials/ Demos**	• **Import** • **Storage** • **Distribution** • **Bunkering** • **Power gen.**	**Overview of organization** • The Agency for Science, Technology and Research (A*STAR) is a statutory board under the Ministry of Trade and Industry of Singapore • The agency supports R&D that is aligned to areas of competitive advantage and national needs for Singapore **Example of related activities** • Low-Carbon Energy Research Funding Initiative (LCER FI): Hosted by A*STAR and funded by NRF, this initiatives offers SGD 55 million for 12 projects advancing low-carbon energy, including Hydrogen and Ammonia related technologies for power and industry decarbonization • E.g. Participated in a project to develop more efficient processes to release Hydrogen from Ammonia, by examining the development of robust and efficient Ammonia cracking technologies suitable for use in Singapore • E.g. Participated in project for exploration of new energies such as Hydrogen and Ammonia solutions, specifically tailored for offshore and marine applications. A*STAR and Seatrium were part of Singapore's first Ammonia fuel trial on the Fortescue Green Pioneer

Note: Understanding of focus along the supply chain is not absolute, it is only for illustration based on readily available information
Source: Summarized by NRI based on each organizations press release and announcements

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There may be no specific research organizations dedicated to Ammonia, but related activities (especially with Hydrogen) are carried out by various organizations (2/3)

Research Institutes and Funding Organizations				
Organization	Policy Name	Stage of development	Supply chain involvement	Description
Research Institutes	National University of Singapore (NUS) – Centre for Hydrogen Innovations (CHI)	R&D	• Import • Storage • Distribution • Power gen.	**Overview of organization** • NUS is a national public research university in Singapore • CHI is a publicly funded research center launched to help translate Hydrogen research and innovation into real-world applications for scaling and commercialization **Example of related activities** • SGD 25 million budgeted during initial establishment in 2022 to support R&D on the local production of Green Hydrogen, storage and transport capabilities. • Collaboration with industrial players to accelerate the adoption of Green Hydrogen as a fuel for power generation and electricity sectors
Research Institutes	Cambridge Centre for Advanced Research and Education in Singapore (CARES)	R&D Trials/ Demos	• Power gen.	**Overview of organization** • University of Cambridge's first research centre outside the UK • It brings together researchers from the University of Cambridge, Nanyang Technological University and National University of Singapore to work on problems relevant to Singapore and the world at large **Example of related activities** • E.g. Hydrogen and Ammonia Combustion in Singapore (HYCOMBS) project, which investigates the use of Hydrogen and Ammonia to generate power and minimize pollution. This research aims to aid the transition to these fuels in Singapore's energy system • E.g. CARES is contributing to two LCER projects under Directed Hydrogen Programme. The first is "Development of an integrated system of Ammonia partially cracking and gas turbine combustion with cascade waste heat utilization" and the second project is "Development of on-site, on-demand Ammonia-to-Hydrogen e-cracking bench-top chemical mini-factory" sub-awarded by NTU.

Note: Understanding of focus along the supply chain is not absolute, it is only for illustration based on readily available information
Source: Summarized by NRI based on each organizations press release and announcements

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There may be no specific research organizations dedicated to Ammonia, but related activities (especially with Hydrogen) are carried out by various organizations (3/3)

Research Institutes and Funding Organizations				
Organization	Policy Name	Stage of development	Supply chain involvement	Description
Research Institutes	Nanyang Technological University (NTU)	R&D	• Bunkering • Power gen.	**Overview of organization** • Nanyang Technological University is a public research university in Singapore **Example of related activities** • As part of the CREATE programme, NTU has collaborated with Imperial College London to advance Green Fuel cell technology. The project focuses on converting Ammonia directly into electricity through an electrochemical reaction, offering high energy efficiency and scalability • Three-year research collaboration with Hyundai Motor Groups, focusing on the areas of Hydrogen energy business and advanced energy system • In 2022, Nanyang Technical University, the Singapore Maritime Institute and the American Bureau of Shipping have released their long-awaited report into safety considerations for Ammonia bunkering
Research Institutes	Singapore Maritime Institute (SMI)	R&D	• Bunkering	**Overview of organization** • SMI promotes greater industry-academia R&D collaborations, and strengthens Singapore's research capabilities and impact to the industry **Example of related activities** • Conducted research on Ammonia bunkering, focusing on mitigation technologies and assessing environmental impact of potential Ammonia releases during bunkering operations • In 2022, Nanyang Technical University, the Singapore Maritime Institute, ASTI and the American Bureau of Shipping have released their long-awaited report into safety considerations for Ammonia bunkering

Note: Understanding of focus along the supply chain is not absolute, it is only for illustration based on readily available information
Source: Summarized by NRI based on each organizations press release and announcements

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A*STAR is Singapore's leading public agency driving R&D to support economic growth and industrial transformation. It bridges scientific innovation with industry applications

Organization Profile	
Name	Agency for Science, Technology and Research (A*STAR)
Year Estb.	1991
Website	https://www.a-star.edu.sg/
# Employees	5,200+
Overview	• The Agency for Science, Technology and Research (A*STAR) is a **statutory board under the Ministry of Trade and Industry (MTI) of Singapore** • (A*STAR) is **Singapore's lead public agency driving research and development (R&D) to support economic growth and industrial transformation**. • (A*STAR) bridges scientific innovation with industry applications, strengthening Singapore's position as a global hub for technology and innovation
Research Focus Area	• Biomanufacturing • Food and Consumer • Medical Technology • Pharmaceuticals & Biologics • Chemicals, Materials and GreenTech • Electronics • Engineering • Infocomms • Robotics and Automation • Security & Transport

*<Images from A*STAR website>*

Ammonia Related Research and Activity

Collaboration with Seatrium on Sustainable Ammonia Solutions

- Partnership to address challenges in the Ammonia supply chain, including bunkering, transportation, and storage.
- Aims to develop sustainable energy solutions for the offshore and marine sector, integrating Ammonia utilization with carbon capture technologies

Development of Ammonia plume model

- A*STAR's IHPC, along with other partners, developed an Ammonia plume model to assess safety, predict Ammonia dispersion in incidents, and support response planning for the Fortescue Green Pioneer, with ongoing enhancements as maritime fuel operations expand in Singapore.

Facilitation of Low-Carbon Energy Research (LCER) Programme

Source: Summarized by NRI based on A*STAR website and announcement

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3. Ammonia Market Activities (Supply & Demand)

- Ammonia Supply
- Ammonia Demand

4. Maritime Decarbonization

Annex

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Ammonia Market Activities (Supply & Demand) | Summary

The Ammonia industry may still be in its infant stages, but there are already announced activities/interest from the local government, local players and international players

Ammonia player mapping in Singapore

Supply chain	Production	Import	Storage/Distribution	Marine Bunkering	Power	Other applications
Regulatory Body		EMA		MPA	EMA	No Significant Activities announced
Public		Keppel Corporation Sembcorp				
Private (SG)				Pavillion Energy	Tuas Power	
Private (JP)			Mitsui O.S.K Lines	Itochu Sumitomo Mitsui Co.	IHI MHI	
Private (others)	Linde* *Hydrogen production facilities Air Liquide*	EDF ExxonMobile Vopak Total Energies Air Liquide		A.P. Moller - Maersk Fleet Management Ltd Fortescue	GE Vernova	
Research		A*STAR NUS-CHI		SMI NTU	NUS-CHI CARES	

Note: The above mapping is non-exhaustive and for illustration only (many of the cases are still in MoU stages and not fully developed/operating yet)
Source: Summarized by NRI based on case studied identified in this report

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MPA and EMA launched an EOI for end-to-end Ammonia power generation and bunkering in Singapore. Currently, 2 consortia has been shortlisted for final selection

Progress of EMA & MPA's tender for end-to-end clean Ammonia power generation and bunkering

Tender phases	❶ Expression of Interest (EOI)	❷ Closed Request for Proposal (RFP)	❸ Feasibility study for final selection		❹ Start project
Time period	December 2022	October 2023	July 2024		Mid 2025
Objective & Overview	EMA and MPA launched the **EOI to assess the feasibility of developing an end-to-end solution for Ammonia** • procurement, import, storage, distribution, and end-use for both **power generation and bunkering**	**The Closed RFP was to further evaluate the consortiums** • Each proposal was further developed and evaluated for shortlisting	The **shortlisted consortiums will proceed to conduct final feasibility/FEED study for final shortlisting** • Selected bidder will be lead developer of the project		To be announced
Project requirement	• **Ammonia/Hydrogen power generation of minimally 50MW**, with a minimum load factor of 75% • Storage and jetty designed for at least **0.1 MT/year capacity of Ammonia bunkering**	• **Direct combustion of Ammonia for power generation of 55-65MW** • **Ammonia bunkering at a capacity of at least 0.1 MT/year**, starting with shore-to-ship bunkering followed by ship-to-ship bunkering	**Direct combustion of Ammonia for power generation of 55-65MW**	**Ammonia bunkering at a capacity of at least 0.1 MT/year**, starting with shore-to-ship bunkering followed by ship-to-ship bunkering	
Participants	Total of **26 proposals were received** at the end of the EOI (identity not disclosed)	**6 consortiums was shortlisted** for RFP grom all the proposals received in EOI • Sembcorp Industries • Keppel Corporation • Jurong Port • Engie • Tuas Power • YTL PowerSeraya	**Consortium lead:** • Keppel Infrastructure Division • Sembcorp-SLNG	**Bunkering players** • Itochu Corporation • NYK Line • Sumitomo Corporation • Mitsui & Co. • Fortescue-Equatorial Marine Fuels	

Note: This status is updated as of February 2025
Source: Summarized by NRI based on EMA, MPA and related companies' announcement

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Ammonia Supply

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4. Maritime Decarbonization

Annex

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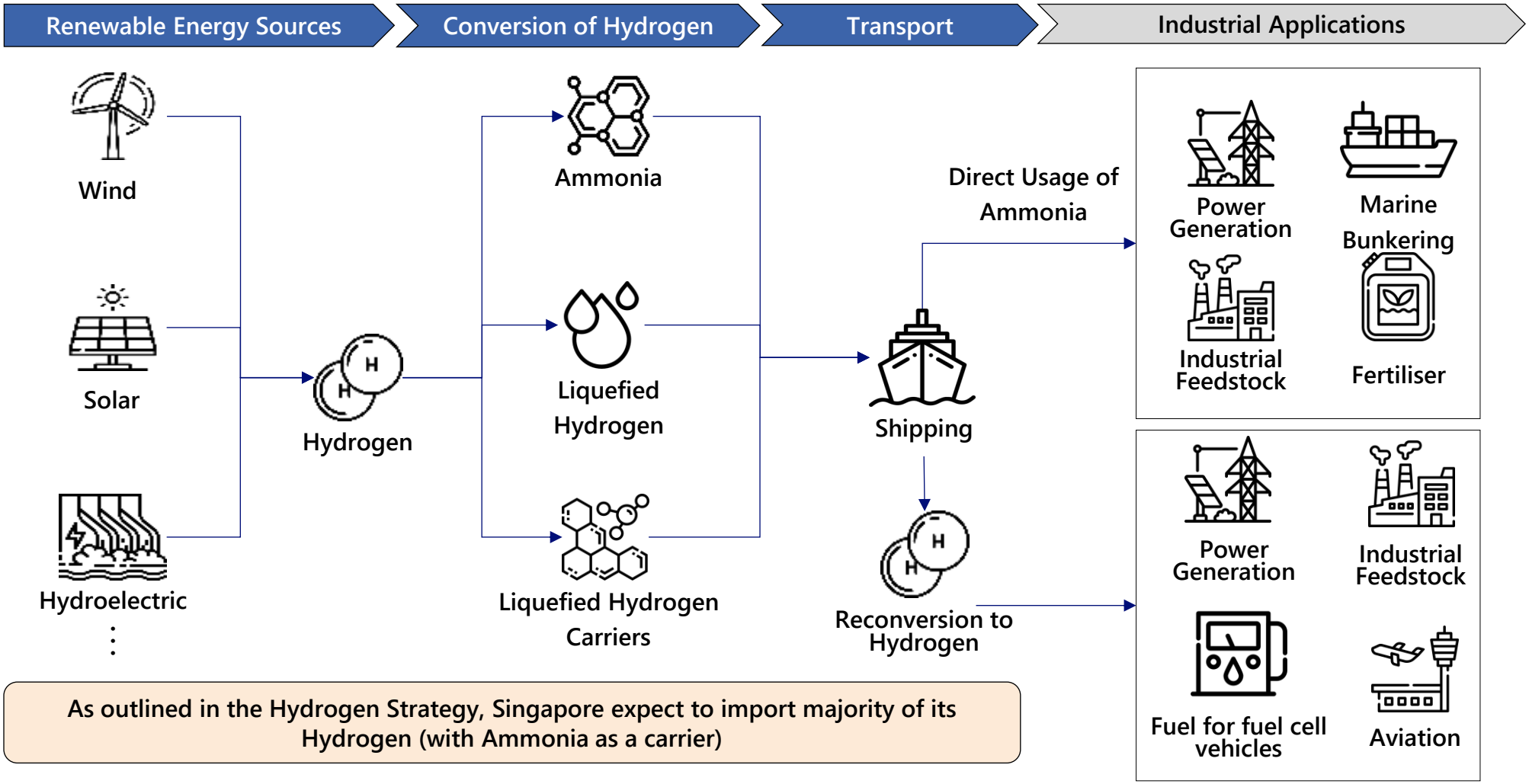
With limited/no production capacity in Singapore, majority of Ammonia need for Singapore in the future is expected to be imported



As outlined in the Hydrogen Strategy, Singapore expect to import majority of its Hydrogen (with Ammonia as a carrier)

Source: Summarized by NRI based on National Hydrogen Strategy

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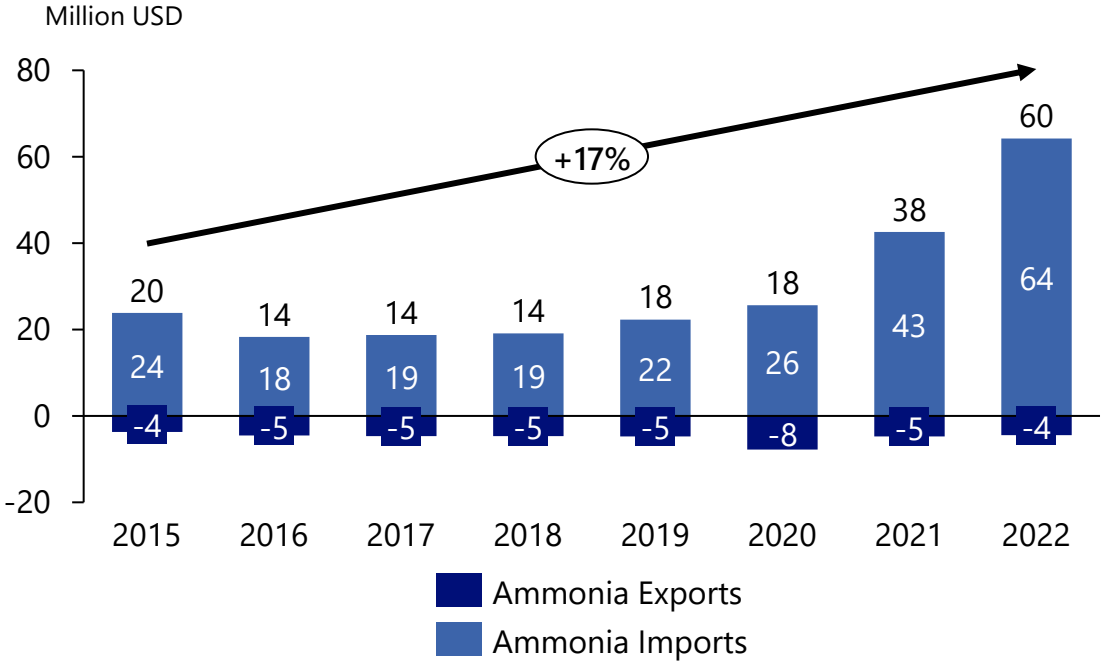
Singapore Ammonia's supply chain strategy focuses on primarily securing imported Ammonia from regional producers

Import/Export Trends and Domestic Demand for Ammonia in Singapore



- Currently, existing public and private partnerships are focused on securing future import supply of Green and blue Ammonia
- Singapore's government has announced a new project to develop an end-to-end Ammonia solution to generate up to 65 MW of electricity

"Jurong Island might not be where Green Hydrogen or Ammonia is produced, but it could surely play a role regionally in aggregating supply, owing to its mature ecosystem of bunkering/storage, logistics and trade players"

Singapore Economic Development Board (EDB)
Surbana Jurong

The Ammonia generation project would involve generating between 55 MW and 65 MW of electricity from imported low-carbon or zero-carbon Ammonia via direct combustion in a gas turbine or combined cycle gas turbine

Singapore Economic Development Board (EDB)
EMA, MPA

Source: Summarized by NRI based on data obtained from WITS, EDB & EMA announcements and public articles

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Following the policies, there has been activities and participations from both public and private sector to develop the Ammonia supply chain in Singapore (1/3)

	Activities related to development of Ammonia supply chain			
Type of Activity (Status)	Private organization	Government agency	Date	Description
Ammonia & Hydrogen infrastructure development (Joint Study and Asset development)	• Air Liquide Singapore • Vopak Singapore	None	2023	**Collaboration to develop Ammonia/Hydrogen infrastructure** • Air Liquide and Vopak sign MoU to collaborate on infrastructure for Ammonia import, cracking and Hydrogen distribution infrastructure • Vopak is considering the expansion of its existing Ammonia storage facilities to increase import and export volumes
❶ Ammonia supply chain development (Feasibility Study)	• Sumitomo Corporation • A.P. Moller - Maersk A/S • Fleet Management Limited • Keppel Offshore & Marine • Maersk Mc-Kinney Moller Center for Zero Carbon Shipping • American Bureau of Shipping ("ABS") • Kawasaki Kisen Kaisha, Ltd.("K"LINE)	• Maritime and Port Authority of Singapore ("MPA")	2022	**Project SABRE: Ammonia Bunkering in Singapore Joint Feasibility Study** • The study aims to cover the entire end-to-end supply chain of Ammonia bunkering, including the development of a cost-effective Green Ammonia supply chain, design of Ammonia bunkering vessels and related supply chain infrastructure • The project will assess the supply of Ammonia including potential synergies with Liquefied Petroleum Gas (LPG) as a starting point. Vessels or barges initially designed for LPG can also handle brown, blue, and Green Ammonia.

= Prominent cases in the industry that will be further elaborated in following slides

Note: *State owned or state related enterprise
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Following the policies, there has been activities and participations from both public and private sector to develop the Ammonia supply chain in Singapore (2/3)

	Activities related to development of Ammonia supply chain			
Type of Activity (Status)	Private organization	Government agency	Date	Description
❷ Import of Green Ammonia (Strategic partnership announcement)	• Gentari (Petronas) • AM Green	• GIC	2022	**Partnership to import Green Ammonia and Hydrogen into Singapore** • A partnership was formed between the three entities in 2023. AM Green, a Green Ammonia and Hydrogen producer, intends export them from India to Asian markets including Singapore • AM Green has plans to product up to 1 MT of Green Hydrogen annually by 2030
❸ Green Hydrogen supply chain (Feasibility Study)	• Tuas Power • EDF Group • Itochu Corporation	None	2022	**MoU to collaborate on establishing Green Hydrogen supply chain** • Conducting feasibility study to understand and quantify the demand and pricing level for the entire Green Hydrogen supply chain
Industry partnership (Strategic partnership announcement)	None	• Japan Bank for International Cooperation* • Sembcorp Industries*	2022	**MoU for promoting cooperation in industries that use Hydrogen and Ammonia as a fuel source** • JBIC aims to accelerate the structuring of projects for developing the supply chain between the 2 nations of Hydrogen and Ammonia as a fuel source

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Following the policies, there has been activities and participations from both public and private sector to develop the Ammonia supply chain in Singapore (3/3)

	Activities related to development of Ammonia supply chain			
Type of Activity (Status)	Private organization	Government agency	Date	Description
❹ Ammonia supply chain development (Feasibility Study)	• ITOCHU Corporation • TOKYO-Mitsui O.S.K.Lines • ITOCHU ENEX Co • Vopak Terminals Singapore • Pavilion Energy Singapore • Total Marine Fuels	None	2022	**MoU for joint development study on Ammonia fuel supply chain in Singapore** • Study the potential development of off-shore facility such as floating storage unit and/or Ammonia bunkering ship, and safety guidelines of Ammonia bunkering in Singapore

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Singapore companies such as Sembcorp and Keppel are participating in activities outside of Singapore related to the Green Ammonia supply chain development

	Singapore company activities related to development of Ammonia supply chain outside of Singapore			
Type of Activity (Status)	Private organization	Government agency	Date	Description
Ammonia supply from India to Japan (Commercial agreement)	• Kyushu Electric Power Co. • Sojitz Corporation • Nippon Yusen Kabushiki Kaisha (NYK Line)	• Government of Tamil Nadu • Sembcorp Industries*	2024	**Singapore company (Sembcorp) to supply Green Ammonia produced in India to Japan** • The project, with an investment of approximately USD 4.4 billion, aims to produce 200,000 MT of Green Ammonia annually for export to Japan.
❺ Hydrogen plant and export development (Project development)	• Keppel Corporation • Stanwell Corporation • Iwatani Corporation • Kansai Electric Power Company • Marubeni Corporation • Incitec Pivot Limited (IPL)	• Queensland Government	2023	**Keppel increases efforts in the development of Green Hydrogen and Ammonia production for use in Australia and export to Asia** • The Central Queensland Hydrogen (CQ-Hydrogen) project, involving Keppel and other partners, aimed to establish a large-scale Green Hydrogen and Ammonia production facility Australia • The Hydrogen and Ammonia will be for both domestic use and supply to rest of Asia

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❶ Project SABRE is a joint feasibility study for the development of Ammonia bunkering and supply chain by consortium of international players

Project name	**Project SABRE: Ammonia Bunkering in Singapore Joint Feasibility Study**
SG Ammonia supply chain focus	Production — Import — **Storage/ Distribution** — **Marine Bunkering** — Consumption
Private parties involved	• **Sumitomo Corporation:** Consortium lead. Manage end-to-end supply chain for Ammonia and LPG as marine fuels. • **A.P. Moller - Maersk:** Provide demand assumption Advice for relevant requirements • **Fleet Management Limited:** Provide technical advise and provide demand assumption Advice for relevant requirements • **Keppel Offshore & Marine:** Conduct all necessary engineering and design • **Maersk Mc-Kinney Moller Center:** Conduct Well-to-Wake Life Cycle Analysis. Provide the latest maritime industry-related updates on market outlook, sustainability efforts and regulations worldwide • **Kawasaki Kisen Kaisha, Ltd.("K"LINE):** Estimate transportation cost and provide technical advise • **American Bureau of Shipping ("ABS"):** Support the establishment of relevant regulations and operational guideline and conduct operational risk assessment
Government agencies involved	• **The Maritime and Port Authority of Singapore (MPA):** Providing insights on safety issues and Ammonia bunkering procedures, as well as allowing access to research capabilities in Singapore.
Announcement date	2021
Project type	**Feasibility Study for Ammonia Bunkering Supply Chain**
Project details	• The feasibility study to **establish a Green Ammonia bunkering supply chain** in Singapore focuses on: 1. **Development of cost-effective Green Ammonia supply chain** 2. **Design of Ammonia bunkering vessel** 3. **Development of related supply chain infrastructure (e.g. storage facilities)** 4. **Develop standards and regulations for bunkering operations** in Singapore

Source: Summarized by NRI based announcements from Maersk, Sumitomo and public articles

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❷ The project aims to export Green Ammonia to several markets, including Singapore, targeting from late 2025 (5 MT/per annum of Green Ammonia by 2030)

Project name	**Partnership to import Green Ammonia and Hydrogen into Singapore**
SG Ammonia supply chain focus	**Production** — **Transport** — Storage — Bunkering — Consumption
Private parties involved	• **AM Green:** Developing logistics and storage infrastructure to facilitate global export of green Ammonia**;** targets to produce 5 MT/per annum of Green Ammonia by 2030 • **DP World:** Jointly develop port infrastructure with AM Green at AM Green's Net-Zero Industrial Clusters to facilitate global exports of 1 MT/per annum of Green Ammonia • **Gentari:** Supplying 650 MW of round-the-clock, carbon-free energy to power AMG Ammonia's facilities, supporting production capabilities; Major investor with USD 1.6 billion invested into the project
Government agencies involved	• **Government of Singapore Investment Corporation (GIC):** Singapore's sovereign wealth fund investing in AM Green's project, funding the production and export of green Ammonia
Announcement date	2022
Project type	**Development of Ammonia Supply Chian**
Project details	• AM Green's Green Ammonia project focuses on establishing India as a leading global producer and exporter of Green Ammonia, supporting the **transition to clean energy** and contributing to **decarbonization efforts worldwide** • The project aims to **export Green Ammonia to several markets, including Singapore**, targeting from late 2025 • **Initial Phase:** 1 MT/per annum of Green Ammonia by 2026 • **Long-term goal:** 5 MT/per annum of Green Ammonia by 2030 which is equivalent to approximately 1 MT/per annum of Green Hydrogen

Source: Summarized by NRI based announcements from Gentari, MIDA and public articles

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❸ The partnership aims to establish green Hydrogen supply chain into Singapore where the 3 organizations collaborate on feasibility study proposing Ammonia as carrier

Project name	**Collaboration on establishing the supply chain required to import green Hydrogen into Singapore with Ammonia as the carrier**
SG Ammonia supply chain focus	**Production** — **Transport** — Storage — Bunkering — Consumption
Private parties involved	• **Tuas Power:** Singapore-based power generation company • **EDF Group:** France's largest power utility • **Itochu Corporation:** Japanese conglomerate trading and investment firm Each consortium partner will contribute its global strength and technical expertise through a feasibility study that seeks to understand and quantify the demand and pricing level for the entire supply chain
Announcement date	2022
Project type	**Feasibility study for development of Green Hydrogen (Ammonia as carrier) Supply Chian**
Project details	• Tuas Power partners EDF and ITOCHU to **establish green Hydrogen supply chain where the 3 organizations collaborate on feasibility study proposing Ammonia as carrier** • The consortium will **use the feasibility study as a platform to accelerate the production and consumption of green Hydrogen** • By remaining neutral to the sources of import and export, the **EDF-ITOCHU-Tuas Power consortium will have flexibility to explore diverse options to support the decarbonization of Singapore and beyond**

Source: Summarized by NRI based announcements from Tuas Power, EDF Group and Itochu

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❹ Feasibility Study for potential development and expansion of Ammonia cracking facilities, associated storage and import infrastructure

Project name	**Expansion of Ammonia storage infrastructure to increase imports**
SG Ammonia supply chain focus	Production — **Transport** — **Storage** — Bunkering — Consumption
Private parties involved	• **Itochu Corporation:** Consortium lead. Initiated Ammonia bunkering study • **Mitsui O.S.K. Lines:** Developing offshore facilities and safety guidelines • **ITOCHU ENEX Co:** Development of Ammonia fuel supply chain and safety guidelines of Ammonia bunkering in Singapore • **Vopak Singapore:** Developing onshore Ammonia storage and handling facilities • **Pavilion Energy:** Contributing to Ammonia supply chain development • **TotalEnergies:** Developing Ammonia fuel supply chain and bunkering infrastructure
Government agencies involved	• **The Maritime and Port Authority of Singapore (MPA):** Providing regulatory guidance and establishing safety standards for Ammonia
Announcement date	2022
Project type	**Feasibility Study for Ammonia storage infrastructure**
Project details	• The study includes potential development and expansion of Ammonia **cracking facilities**, **associated Ammonia storage and import infrastructure** at Vopak's Banyan terminal, and **the distribution of Low-Carbon Hydrogen through a Hydrogen Pipeline Network**. • The study will leverage on Air Liquide's industrial scale Ammonia cracking technology, to be tested in a pilot plant currently being built in Belgium and slated to become operational in 2024 • MOL will **promote the development of an offshore facility – either a floating storage unit or Ammonia bunkering vessel and the necessary safety guidelines**

Source: Summarized by NRI based announcements from Maersk, MPA and public articles

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❺ Keppel's Development of Green Hydrogen and Ammonia production in Australia by for use domestically and export to Asia

Project name	**Central Queensland Hydrogen Project (CQ-Hydrogen)**
SG Ammonia supply chain focus	Production — **Transport** — **Storage** — Bunkering — Consumption
Private parties involved	• **Keppel Corporation:** Expertise of Hydrogen and Ammonia production facility and regional supply chain (including potential off taking in Singapore) • **Stanwell Corporation**: Development of Green Hydrogen production, Hydrogen liquefaction and Loading plant • **Iwatani Corporation, Kansai Electric Power Company, and Marubeni Corporation:** Participation in FEED study and project development (including export and off taking to Japan) • **Incitec Pivot Limited (IPL):** Potential offtake of Hydrogen/Ammonia in Australia
Government agencies involved	• **Queensland Government:** Representative organization of Australia's government and project funding
Announcement date	2023
Project type	**Development of a Large-Scale Green Liquefied Hydrogen Supply Chain in Australia for supply regionally**
Project details	• CQ-Hydrogen will involve the **development of a Hydrogen Production Facility, Hydrogen Gas Pipeline, Hydrogen Liquefaction Facility, Ammonia Synthesis Plant, and ship loading facilities at Gladstone Port** (one of Australia's largest multi-commodity port) • Marubeni, Iwatani, Kansai Electric Power and Stanwell have been conducting a **feasibility study for large-scale green liquefied Hydrogen production and export to Japan since 2021** • Based on the results of this study, the five companies, including Keppel (a new potential green Hydrogen off-taker), **have now agreed to proceed with a FEED to conduct a full-scale study for a final investment decision** • CQ-Hydrogen aims to **produce and supply green Hydrogen targeting an initial capacity of ~70kt/year by around 2028 and 260kt/year by around 2031**

Source: Summarized by NRI based announcement and articles from CQ-Hydrogen and relevant companies websites

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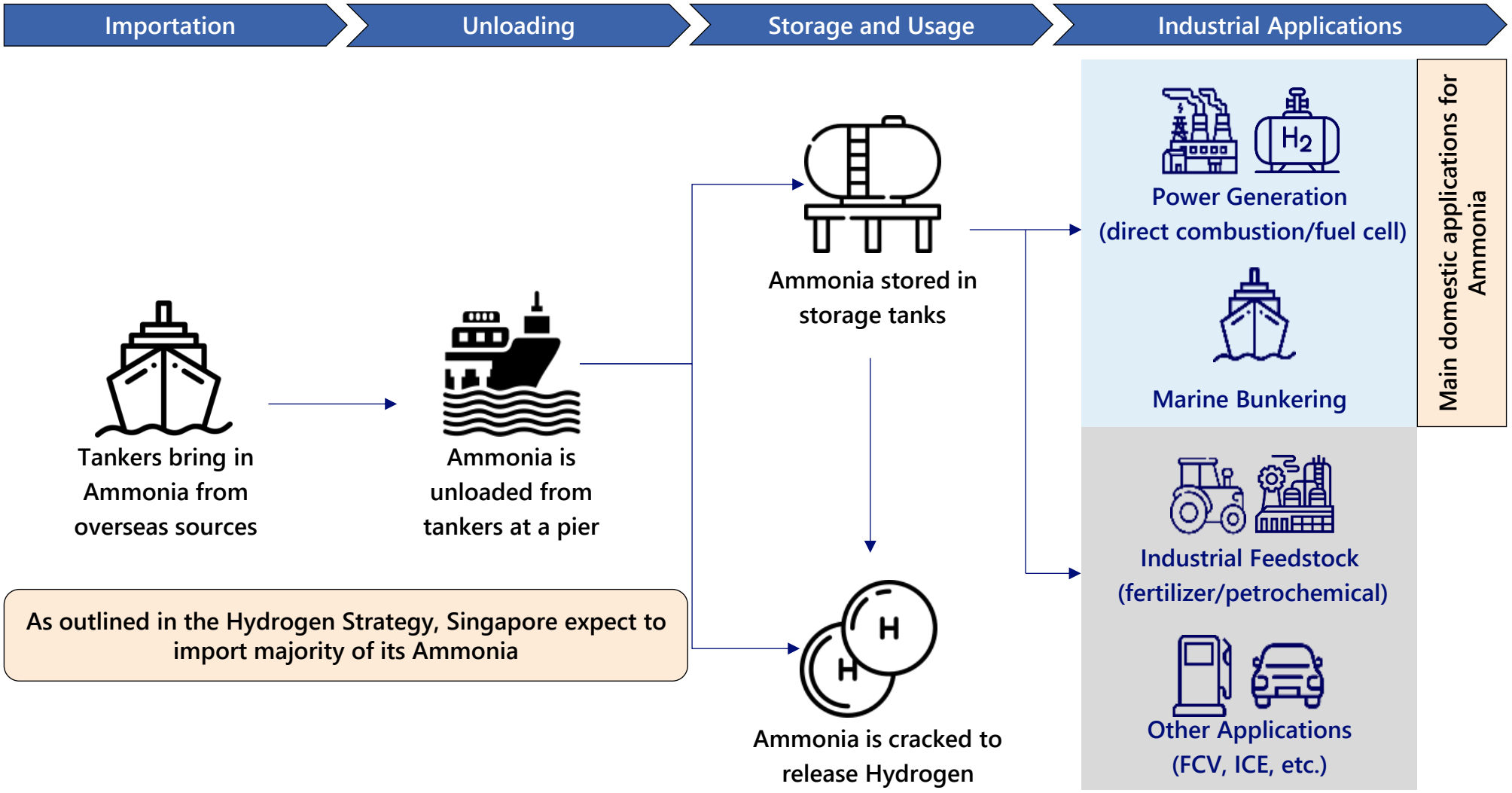
Ammonia is a clean energy resource can be utilized in multiple industrial sectors main future application/development is for Marine Bunkering and Power Generation



Source: Summarized by NRI based on National Hydrogen Strategy

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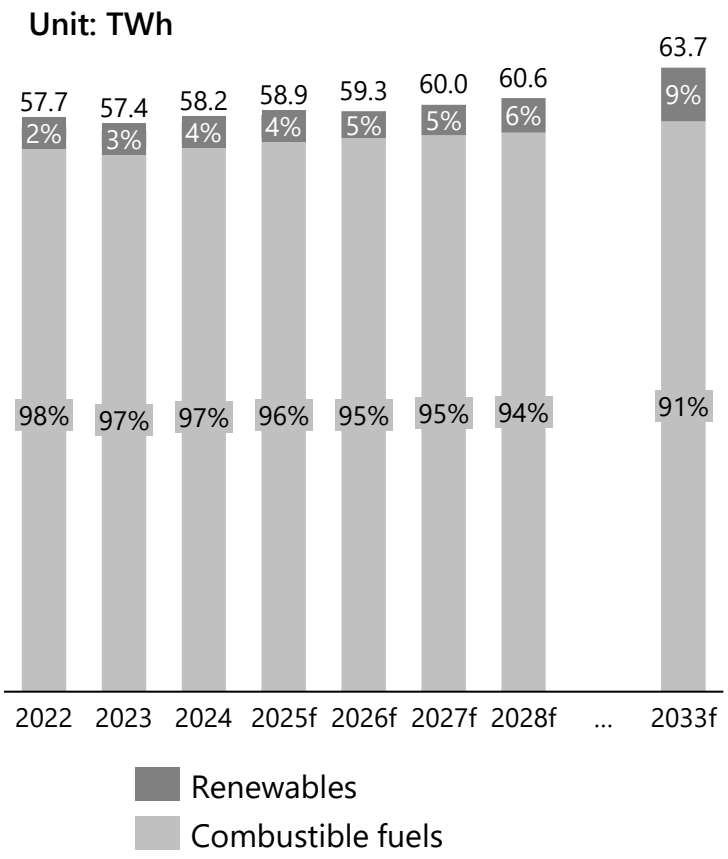
Majority of the Singapore's electricity generation will still be from conventional thermal in the short term but expected to replace to cleaner sources towards 2050

Singapore Electricity Mix Forecast 2033



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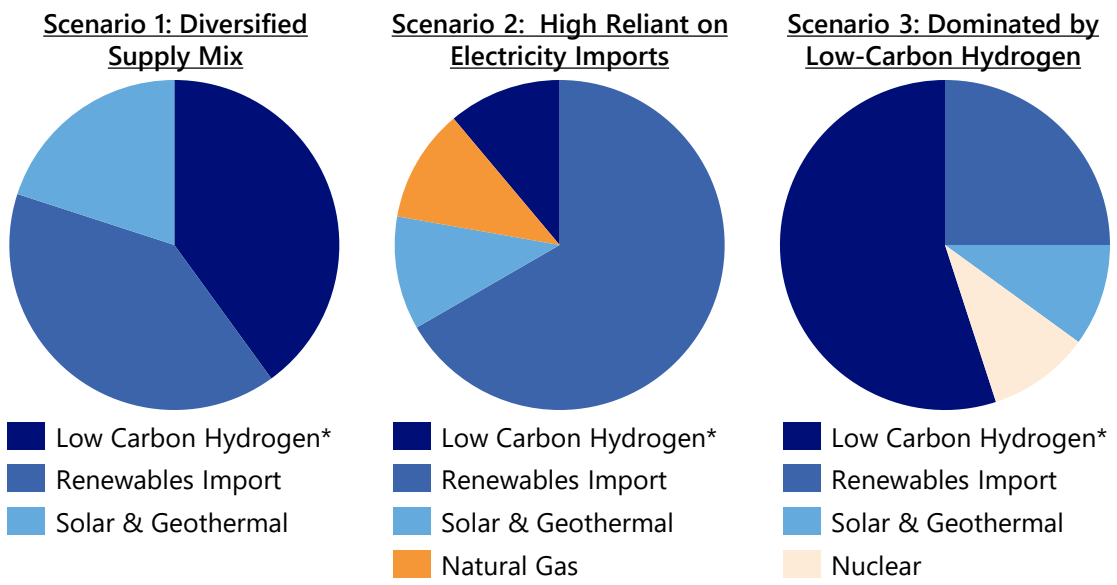
Singapore Electricity Mix Forecast 2050**



Ideally by 2050, **Singapore has a diversified electricity supply mix with 100% clean energy**

- Relying **on Renewable electricity imports and low-carbon Hydrogen as the two major contributors**
- Through a diversified range of import sources and local backup capacity, electricity imports are a secure and affordable supply option for Singapore
- Geothermal and solar are two key domestic renewable generation sources that add up to about a fifth of the supply mix

* Low-carbon hydrogen includes its derivatives such as ammonia
** Exact estimates are not available

Source: Summarized by NRI based on EIU Energy Report

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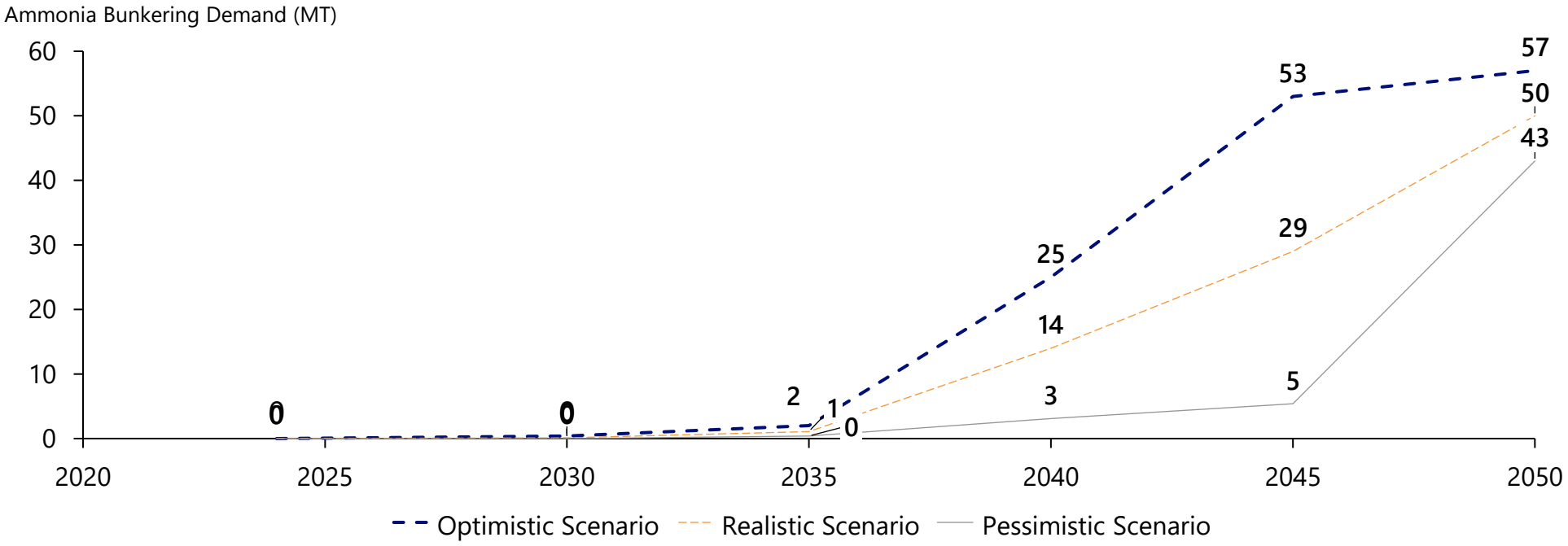
Ammonia Bunkering Demand is expected to pick up in 2035 with rapid growth to follow later in ~2040s onwards

Ammonia Bunkering Demand in Singapore



- **Currently in Singapore, Ammonia bunkering and application are still in its early development stage** with majority of the activities still focusing on the feasibility and trialing stage
- **Demand for Ammonia as a bunkering fuel is expect to only pick increase exponentially from 2040-2050**, with an estimated demand between 43-57 MT in 2050.
- **Ammonia is estimated to account for 30-40% of total marine fuel bunkering demand by 2050.**

Note: Demand potential for Ammonia will also be studied for other industrial activities, such as energy storage, fuel cells, Internal Combustion Engines (ICE) Engines (ICE)
Source: Online Publications, Expert Interviews, NRI Research & Analysis

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There are already multiple activities by both private and public organizations for utilization of Ammonia in Singapore (1/5)

	Activities related to development of Ammonia supply chain			
Type of Activity (Status)	Private organization	Government agency	Date	Description
Ammonia fueled ships development (Commercial Deployment)	• Nippon Yusen Kabushiki Kaisha (NYK) • Seatrium	• MPA	2025	**Joint Study Framework for Ammonia Bunkering Safety** • Nippon Yusen Kabushiki Kaisha (NYK) and its partners received Approval-in-Principle (AiP) from ClassNK for an ammonia-fueled bunkering vessel designed by Seatrium's LMG Marin
❶ Ammonia supply chain development (Feasibility Study)	• Keppel • Sembcorp-SLNG • Itochu Corporation, • Nippon Yusen Kabushiki Kaisha • Sumitomo Corporation • Mitsui & Co. • Fortescue	• The Energy Market Authority (EMA) • The Maritime and Port Authority of Singapore (MPA)	2024	**Development of Ammonia bunkering and Ammonia Fueled power plant** • EMA and MPA shortlisted Keppel's Infrastructure Division and Sembcorp-SLNG to develop a low- or zero-carbon Ammonia solution on Jurong Island for power generation and bunkering. The bunkering players include Itochu, NYK Line, Sumitomo.
❷ Ammonia fueled ships development (Commercial Deployment)	• Eastern Pacific Shipping (EPS) • Classification Societies, ABS • Lloyd's Register	• MPA	2024	**MoU for the commitment of Ammonia dual-fuel newbuilds to be registered under the Singapore Registry of Ships (SRS)** • EPS signs MoU with the MPA, and classification societies, ABS and Lloyd's Register, committing six of its Ammonia dual-fuel newbuilds to be registered under the Singapore Registry of Ships (SRS) upon delivery

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There are already multiple activities by both private and public organizations for utilization of Ammonia in Singapore (2/5)

	Activities related to development of Ammonia supply chain			
Type of Activity (Status)	Private organization	Government agency	Date	Description
❸ Ammonia fueled ships development (Trial/ Demonstration)	• Fortescue • Research Institutes • Industry Partners	• MPA	2024	**World's First Use of Ammonia as a Marine Fuel in a Dual-Fueled Ammonia-Powered Vessel in the Port of Singapore** • Fortescue conducted the world's first use of Ammonia, in combination with diesel, as a marine fuel onboard the Singapore-flagged Ammonia-powered vessel
❹ Ammonia for power generation (Project development)	• IHI Corporation • GE Gas Power	• Sembcorp Industries*	2024	**Signing of MoU to Develop Gas Turbines that Can Operate on 100% Ammonia** • The 3 companies will jointly explore the potential retrofitting of Sembcorp's Sakra power plant with Ammonia-firing capabilities
Pilot projects and trials for alternative marine fuels (Strategic Partnership announcement)	None	• The Ministry of Transport, Singapore (MOT) • The Ministry of Land, Infrastructure, Transport and Tourism of Japan (MLIT)	2023	**Singapore-Japan Green and Digital Shipping Corridor, embarking on pilot projects for alternative marine fuels** • MPA and the Japanese port partners aim to embark on pilot projects and trials for alternative marine fuels such as Ammonia and Hydrogen

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There are already multiple activities by both private and public organizations for utilization of Ammonia in Singapore (3/5)

	Activities related to development of Ammonia supply chain			
Type of Activity (Status)	Private organization	Government agency	Date	Description
❺ Ammonia fueled ships development (Commercial Deployment)	• Eastern Pacific Shipping (EPS) • MAN Energy Solutions • HD Hyundai Heavy Industries • ABS	• The China State Shipbuilding Corporation* • MPA	2023	**MoUs on development of world's first Ammonia dual-fuel vessels** • Ammonia dual-fuel engines will be fitted in a fleet of EPS's Newcastlemaxes and Very Large Ammonia Carriers (VLACs) slated for delivery from 2026 onwards
❻ Ammonia supply chain development (Feasibility Study)	• Keppel Infrastructure • ExxonMobil Asia Pacific	None	2023	**Keppel and ExxonMobil to explore low-carbon Ammonia solutions for Singapore** • MoU to develop access to low-carbon Hydrogen and Ammonia for scalable commercial and industrial applications in Singapore
Ammonia for power generation (Feasibility Study)	• Keppel New Energy • Mitsubishi Heavy Industries • DNV	None	2022	**Collaboration to explore the feasibility and implementation of an Ammonia-fired gas turbine on Jurong Island** • The three companies work together to perform a high-level Quantitative Risk Assessment to explore the use of 100% Ammonia as a fuel for a gas turbine or combined cycle gas turbine (CCGT)

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There are already multiple activities by both private and public organizations for utilization of Ammonia in Singapore (4/5)

	Activities related to development of Ammonia supply chain			
Type of Activity (Status)	Private organization	Government agency	Date	Description
Ammonia for power generation and marine bunkering (Feasibility Study)	• Mitsubishi Heavy Industries Asia Pacific • JERA Asia	• Jurong Port*	2022	**Collaboration to explore establishing a 100% Ammonia direct combustion power plant** • A joint study was be conducted, where a 60 MW class gas turbine combined cycle plant Fueled by Ammonia, as well as stimulate Ammonia demand to be ready for Ammonia bunkering in future
Ammonia fueled ships development (Design Development)	• Paxocean • Hong Lam Marine • Bureau Veritas	None	2022	**MoU to Pax ocean jointly develop an Ammonia bunker vessel design** • The collaboration aims to jointly develop an Ammonia bunker vessel design
Ammonia fueled ships development (Commercial Deployment)	• Ocean Network Express • Hyundai Heavy Industries • Nihon Shipyard	None	2022	**Ocean Network Express signed ship building contracts to construct 5 Ammonia and Methanol powered ships** • The vessels are designed with the highest efficiency standards as well as a variety of cutting-edge technology to reduce navigational impacts to the environment and are planned for the "Ready notation" or "AiP (Approval in Principle)" of Ammonia and Methanol as fuel, Carbon Capture and Storage

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There are already multiple activities by both private and public organizations for utilization of Ammonia in Singapore (5/5)

	Activities related to development of Ammonia supply chain			
Type of Activity (Status)	Private organization	Government agency	Date	Description
Ammonia fueled ships development (Design Development)	• Trafigura Group • MAN Energy Solutions	None	2021	**Trafigura Group co-sponsors the development of MAN Energy Solutions Ammonia-Fueled engine for maritime vessels** • The Ammonia engine is expected to be commercially available for large-scale ocean-going ships by 2024, followed by a retrofit package to make existing maritime vessels capable of running on Ammonia by 2025
Ammonia fueled ships development (Commercial Deployment)	• Lloyd's Register • MISC Berhad • MAN Energy Solutions • Samsung Heavy Industries (SHI)	• MPA	2021	**Partnership to build the world's first Ammonia-Fueled tanker by 2025** • a multinational coalition (Castor Initiative) that aims to design, build, and commission the world's first Ammonia-Fueled tanker by 2026

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❶ EMA and MPA has previous started an EOI in 2022 and has currently shortlisted two consortia to further study viability of Ammonia for power generation and bunkering

Project name	**Development of Ammonia solution on Jurong Island for power generation and bunkering**
SG Ammonia supply chain focus	**Power Generation** | **Marine Bunkering** | Industrial Feedstock | Other Applications
Private organization involved	• **Keppel's Infrastructure Division:** Consortium lead. Tasked conduct engineering, safety and emergency response studies for the proposed Project. • **Sembcorp-SLNG:** Consortium lead. Tasked conduct engineering, safety and emergency response studies for the proposed Project. • **Other plyers in the consortiums:** Itochu Corporation, Nippon Yusen Kabushiki Kaisha, Sumitomo Corporation
Government agencies involved	• **EMA:** Co-lead agency for development of the project • **MPA:** Co-lead agency for development of the project
Announcement date	2022-2024
Project type	**Tender for Ammonia for power generation and bunkering in Jurong Island**

Project details	• The lead developer will develop the end-to-end Ammonia solution comprising;
	  ○ Generating 55-65 MW of electricity from imported low- or zero-carbon Ammonia via direct combustion
	  ○ Facilitating Ammonia bunkering at a capacity of at least 0.1 MT/per annum
	• The two consortia were selected from a total of six that were earlier shortlisted in 2023 to participate in a restricted Request for Proposal (RFP), following an Expression of Interest (EOI) called in 2022.
	  • The bids were assessed based on the technical, safety and commercial aspects of their proposals. The two consortium leads are Keppel's Infrastructure Division and Sembcorp-SLNG, and the bunkering players in these consortia are Itochu Corporation, Nippon Yusen Kabushiki Kaisha (NYK Line) and Sumitomo Corporation

Source: Summarized by NRI based on announcements from EMA and MPA

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❷ MoU to develop Ammonia-fueled shipping, enhance safety standards, and establish Singapore as a hub for maritime decarbonization

Project name	**MoU to for the commitment of Ammonia dual-fuel newbuilds to be registered under the Singapore Registry of Ships (SRS)**
SG Ammonia supply chain focus	Power Generation | **Marine Bunkering** | Industrial Feedstock | Other Applications
Private organization involved	• **Eastern Pacific Shipping (EPS):** Provision and management of new Ammonia dual-fuel ships • **The American Bureau of Shipping:** Supporter of gas carriers and Ammonia expertise • **Lloyd's Register:** Not specified
Government agencies involved	• **MPA:** Representative government agency for development of the project
Announcement date	2024
Project type	**Development of Ammonia fueled ships and the accompanying standards/regulations**

Project details	• This **collaboration aims to advance the decarbonization of the shipping industry** through several key initiatives:
	  • **Ammonia Bunkering and Infrastructure Development:** The partners will jointly develop capabilities and infrastructure for Ammonia bunkering, facilitating the adoption of Ammonia as a marine fuel
	  • **Seafarer Training and Safety:** Emphasis will be placed on training seafarers in the management and safety protocols associated with handling Ammonia, ensuring a skilled and prepared workforce
	  • **Knowledge Sharing and Standards Development:** The MoUs encourage the exchange of expertise to explore Ammonia-related solutions and establish standards for power generation and bunkering
	  • **Pilot Trials for Alternative Fuels:** The agreements include considerations for conducting pilot trials of zero and near-zero emission fuels, contributing to the industry's environmental goals.
	• **This MoU is an addition to the MoU EPS signed with other organizations to develop and deploy Ammonia dual-fuel vessels**

Source: Summarized by NRI based on online publications

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❸ MoU to develop Ammonia-fueled shipping, enhance safety standards, and establish Singapore as a hub for maritime decarbonization

Project name	**MoU to develop and deploy Ammonia dual-fuel vessels**
SG Ammonia supply chain focus	Power Generation | **Marine Bunkering** | Industrial Feedstock | Other Applications
Private organization involved	• **Eastern Pacific Shipping (EPS):** Shipowner and manager leading the initiative to adopt Ammonia dual-fuel vessels • **MAN Energy Solutions:** Developer of the Ammonia-burning engines • **HD Hyundai Heavy Industries:** Shipbuilder involved in constructing Ammonia-fueled vessels • **The American Bureau of Shipping:** Classification societies ensuring regulatory compliance and safety standards
Government agencies involved	• **The China State Shipbuilding Corporation:** Parent company of shipyards building EPS's new vessels • **Maritime and Port Authority of Singapore (MPA):** Regulatory body supporting Ammonia adoption through safety guidelines and port readiness
Announcement date	2024
Project type	**Development of Ammonia fueled ships and the accompanying standards/regulations**

Project details	• EPS is partnering with key industry players to **develop and deploy Ammonia dual-fuel vessels**, driving the maritime industry's transition to zero-emission shipping.
	  • Collaboration with **MAN ES, HHI, and CSSC to equip Newcastlemaxes and VLACs with Ammonia-burning engines**, set for delivery from 2026
	  • **MPA, ABS, and Lloyd's Register are working on safety guidelines, port infrastructure, and compliance** for Ammonia-fueled ships
	  • **The project paves the way for Ammonia as a viable maritime fuel**, advancing the industry's net-zero emissions goals.

Source: Summarized by NRI based on online publications

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❹ IHI and GE Vernova collaborate to develop a new gas turbine combustor capable to use Ammonia for power generation, with separated MoU with Sembcorp

Project name	**100% Ammonia capable gas turbine combustion system**
SG Ammonia supply chain focus	**Power Generation** | **Marine Bunkering** | Industrial Feedstock | Other Applications
Private organization involved	• **IHI Corporation:** Provision of know-how of Ammonia combustion technologies • **GE Vernova:** Provision of expertise in engineering and manufacturing of gas turbine combustion systems and balance of plant systems
Government agencies involved	• **Sembcorp Industries:** Owner of one of the facilities (Sakra Power Plant)
Announcement date	2022-2023
Project type	**Development of Ammonia fueled power plant through retrofitting**

Project details	• This partnership is an extension of an earlier MOU between Sembcorp and IHI in 2022 to **explore decarbonization pathways for the power and industrial sector, in particular Ammonia direct combustion systems**
	  • The partnership also builds upon a separate cooperation between IHI and GE Vernova on **developing a retrofittable, 100% Ammonia-capable combustion system** that is compatible with specific GE Vernova turbine models
	• The MoU was extended with Sembcorp in 2023, to jointly explore the potential **retrofitting of Sembcorp's Sakra power plant in Singapore with Ammonia-firing capabilities**
	• The project will potentially assist **Sembcorp to generate low-carbon energy from its existing power plant assets** and support Singapore's efforts to diversify its energy sources and decarbonize the power sector
	  • This is also expected to **bolster industry confidence for the development of an Ammonia value chain in Singapore**

Source: Summarized by NRI based on announcements from EMA and MPA

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❺ Fortescue, with support from the MPA and its partners, conducted a trial using Ammonia-diesel as a marine fuel aboard a Singapore-flagged vessel

Project name	**Conducted World's First trial use of Ammonia as a Marine Fuel in a Dual-Fueled Ammonia-Powered Vessel in the Port of Singapore**
SG Ammonia supply chain focus	Power Generation | **Bunkering** | Industrial Feedstock | Other Applications
Private organization involved	• **Fortescue:** Led the Ammonia-fuel trials, operated the Fortescue Green Pioneer, and conducted tests on propulsion, emissions, and fuel efficiency • **Other research institutes and industry partners:** Supported fuel trials, safety assessments, and Ammonia plume modeling for risk management
Government agencies involved	• **MPA:** Provided regulatory support, secured test areas, set up an Emergency Operations Centre, and monitored safety and incident response • **Other government agencies:** Supported fuel trials, safety assessments, and Ammonia plume modeling for risk management
Announcement date	2024
Project type	**First trial use of Ammonia as a Marine Fuel in a Dual-Fueled Ammonia-Powered Vessel**
Project details	• Fortescue, with the support from MPA, government agencies, research institutes, and industry partners, has **successfully conducted the world's first use of Ammonia, in combination with diesel in the combustion process, as a marine fuel onboard the Singapore-flagged Ammonia-powered vessel**, the Fortescue Green Pioneer, in the Port of Singapore. • The Fortescue Green Pioneer was **loaded with liquid Ammonia from the existing Ammonia facility at Vopak Banyan Terminal on Jurong Island for the fuel trial**

Source: Summarized by NRI based on online publications

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❻ Keppel Infrastructure and ExxonMobil Asia Pacific have signed an MOU to develop low-carbon Hydrogen and Ammonia solutions for Singapore

Project name	**MoU to explore low-carbon Ammonia solutions for Singapore**
SG Ammonia supply chain focus	Power Generation | **Marine Bunkering** | Industrial Feedstock | Other Applications
Private organization involved	• **Keppel Infrastructure:** Developing Hydrogen and Ammonia solutions for power generation in Singapore, including a Hydrogen-ready power plant and feasibility studies for Ammonia-fueled power plants on Jurong Island • **ExxonMobil Asia Pacific:** Supplying low-carbon Hydrogen and Ammonia from its Baytown, Texas facility, leveraging carbon capture to reduce emissions
Announcement date	2023
Project type	**Develop access to low-carbon Hydrogen and Ammonia for scalable commercial and industrial applications in Singapore**
Project details	Keppel Infrastructure and ExxonMobil Asia Pacific have signed an **MOU to develop low-carbon Hydrogen and Ammonia solutions for Singapore's energy transition** • The collaboration **aligns with Singapore's National Hydrogen Strategy**, which aims to meet up to 50% of the country's power needs with Hydrogen by 2050, addressing the call for low-carbon solutions • **Keppel is developing Singapore's first Hydrogen-ready 600 MW combined cycle power plant on Jurong Island**, which will initially run on at least 30% Hydrogen and be capable of switching to 100% Hydrogen in the future • ExxonMobil is advancing the world's largest low-carbon Hydrogen project in **Baytown, Texas, which will produce Ammonia and low-carbon Hydrogen, to supply to Singapore**

Source: Summarized by NRI based on online publications

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Executive Summary

1. General Introduction

2. Ammonia Policy Trends

3. Ammonia Market Activities (Supply & Demand)

4. Maritime Decarbonization

Annex

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The Singapore Maritime Decarbonization Blueprint 2050 outlines a strategy to transition Singapore's maritime industry toward net-zero emissions built on 7 focus areas

Maritime Decarbonization Blueprint

Overview:

- The Singapore government launched the Maritime Singapore Decarbonization Blueprint in support of Singapore Green Plan
- The blueprint outlines the government's strategy to enhance the port for greater environmental sustainability while maintaining its leadership in the maritime industry

Key Implications

- Development of Ammonia for maritime applications and bunkering
- To maintain international leadership and competitiveness in maritime

Key focus areas

#1 – Port Decarbonization
- Reduce carbon emissions from port operations by improving energy efficiency and using cleaner energy sources

#2 – Greening Domestic Harbor Crafts
- Reduce carbon emission from domestic harbor craft fleet by using cleaner energy sources and incentivizing adoption

#3 – Develop Future Marine Fuels and Infrastructure
- Position Singapore as a key hub by establishing standards and guidelines, conducting pilot studies and supporting industry activities

#4 – Greening of Singapore's Ships
- Tackle GHG emissions from international voyages made by Singapore-registered ships by working with ship owners and operators

#5 – Active Participation at International Platforms
- Play key roles internationally on the decarbonization agenda

#6 – R&D and Talent Development
- Be a global hub for maritime decarbonization R&D solutions, enabled by a vibrant ecosystem, with the talent

#7 – Promoting Green Finance/ Accounting
- Strengthen Singapore's capabilities in carbon accounting, reporting and green finance

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint, NRI Analysis

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The Maritime Decarbonization Blueprint sets out multiple target between 2020s-2050 as a progressive step towards achieving Net-Zero by 2050

Summary of key milestone/timeline of Singapore Maritime Decarbonization Blueprint

Focus area	Key milestone/timeline*		
	2020s	2030s	2050
Port Decarbonization	Announce initial directions	Reduce absolute emissions by at least 60% from 2005 levels,	Net-Zero by 2050
Greening Domestic Harbor Crafts		Reduce absolute emissions from domestic harbor craft fleet by 15% from 2021 base levels; Halve 2030-level emissions	
Future Marine Fuels, Bunkering Standards and Infrastructure		Support provision of low and zero-carbon marine fuels and enable green technologies; Halve 2030-level emissions	
Greening of Singapore's Ships		Target 150 ships to be awarded SRS Green Notation; Increase SRS adoption of low/zero-carbon fuels; Target 50% of SRS fleet to be GSP ships	
Active Participation at International Platforms		Introduce a new flagship program on maritime sustainability and decarbonization	
R&D and Talent Development		Spearhead 20 technology projects; Train over 100 researchers, scientists and engineers; Target to create and upskill about 1,200 sustainability related jobs	
Promoting Green Finance/ Accounting		Develop a maritime sector-specific carbon accounting guide; Develop a standard taxonomy for sustainable assets and activities in the maritime sector	

Conducting initial R&D/ trials/ partnership to build foundations

Rapid scaling up of commercial deployment

Source: Summarized by NRI based on Singapore Maritime Decarbonization Blueprint

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#1 – Port Decarbonization: Reduce carbon emissions from port operations by improving energy efficiency and using cleaner energy sources

Focus area	**#1 – Port Decarbonization**
Overview	To support Singapore's national emissions target, **Maritime Port Authority (MPA) seeks to reduce emissions from port terminals and transit to a low-carbon future while keeping our port competitive** Port terminal operators – PSA Corporation Ltd (PSAC) and Jurong Port Pte Ltd (JPPL) – are committed to environmental sustainability and have **developed concrete strategies aimed at achieving net zero emissions by 2050** These strategies include the **greening of port handling equipment, port vehicles, and terminal buildings, as well as improving energy efficiency and adopting cleaner energy alternatives**
Key targets/ milestones	**By 2030** • Port terminals will **reduce absolute emissions by at least 60% from 2005 levels**, amidst projected growth in volumes **By 2050** • Port terminals aim to **achieve net zero emissions**

Key plans

Greening Port infrastructure
- Transitioning port equipment and vehicles to cleaner alternatives such as electric or low carbon fuel powered models to reduce direct emissions from port operations

Reducing Emissions from Grid Electricity
- Decarbonize existing grid, enabling port operators to reduce their indirect emissions
- Improve grid emission factor and source green electricity imported from regional grid

Greening port buildings
- Developing green buildings at port terminal that are more efficient and requires lower energy consumption (including deployment of rooftop solar)

Energy Efficiency Gains through Digitalisation
- Optimizing logistics, digitalizing operations, and streamlining cargo handling processes to reduce fuel consumption and emissions

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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Port Decarbonization covers 4 key areas: Greening Port Infrastructure, Reducing Emissions from Grid, Greening Port Buildings and Energy Efficiency through Digitalisation

Greening Port Infrastructure

<Images from tired Maritime Decarbonization Blueprint>

Example of initiatives taken:

- **Greening infrastructure**: Replacing diesel rubber-tyred gantry (RTG) cranes with **electric-automated rail-mounted gantry (RMG) cranes** at Pasir Panjang Terminal (PPT)
- **Greening infrastructure:** Replacing older diesel-operated prime movers with **cleaner alternatives like LNG-powered movers**
- **Deploying port infrastructure with full electric-automated rail mounted gantry cranes and electric AGVs** to support automated terminal operations for future Tuas Port

Reducing Emissions from Grid Electricity

<Images from tired Maritime Decarbonization Blueprint>

Example of initiatives taken:

- **Use electric balance cranes and conveyor belt systems** to unload and transfer aggregates from vessels to storage stockpiles
- **Establish a centralized inventory yard** for steel storage by 2028, which **utilizes electric overhead gantry cranes in plane of diesel-powered forklifts**, for the handling of steel cargo
- **Partner public agencies**: PSAC and JPPL are collaborating with public agencies and industry partners to **develop a Hydrogen-based ecosystem for the adoption of Hydrogen fuel to be commercially viable**

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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Port Decarbonization covers 4 key areas: Greening Port Infrastructure, Reducing Emissions from Grid, Greening Port Buildings and Energy Efficiency through Digitalisation

Greening Port Buildings

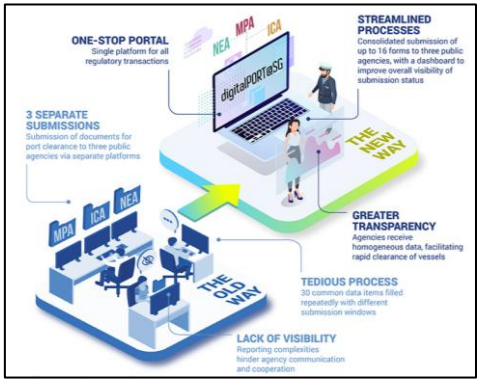
<Images from tired Maritime Decarbonization Blueprint and PSA website>

Example of initiatives taken:

- **Use of LED lightings**: **Improves building energy efficiency (e.g. PSA's Super Low Energy Building**
- **Optimize Air-conditioning and mechanical ventilation systems:** Optimized with smart devices to **enhance energy and water efficiency**
- **Install additional solar PV systems in new facilities** like ready-mix concrete and steel-handling buildings.
- **Include roof-mounted PV systems to maximize solar energy harvesting in** Tuas Port Maintenance Base

Energy Efficiency Gains Through Digitalisation

digitalPORT@SG™



<Images from tired Maritime Decarbonization Blueprint and MPA website>

Example of initiatives taken:

- **MPA's digitalPORT@SG platform: Helps to reduce or eliminate kinks in the supply chain**, leading more efficient supply chain with reduced vessel and vehicle idle times
- **Transshipment: Reduces emissions per container by consolidating cargo, minimizing service routes**, and allowing the **use of larger, more fuel-efficient vessels**

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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#2 – Domestic Harbor Crafts: Reducing emission from domestic harbor craft fleet by using cleaner energy sources and incentivizing adoption

Focus area	**#2 – Greening Domestic Harbor Crafts**
Overview	Domestic harbor crafts perform a range of essential marine services within the Port of Singapore, including the delivery of ship supplies and bunker as well as towage and launch services As part of Maritime Port Authority's (MPA) **efforts to mitigate national emissions,** the Maritime Singapore Decarbonization Blueprint outlines plans to **reduce emissions from its domestic marine transportation with a progressive and phased approach**
Key targets/ milestones	**By 2030** • Reduce absolute emissions from domestic harbor craft fleet by 15% from 2021 base levels, through adoption of lower-carbon energy solution such blended biofuel, LNG, diesel-electric hybrid propulsion, and full-electric propulsion **By 2050** • Halve 2030-level emissions by transitioning to a full-electric propulsion and net zero fuels

Key plans

Conducting R&D and Pilot Project Studies
- Pilot use of biofuel blends among existing harbor craft
- Support research and technology trials to ensure commercially viable transition to low and zero-emission solutions for domestic harbor craft

Providing Financial Support
- Collaborate with government stakeholders and financial institutions to develop Singapore's maritime financing ecosystem and provide financing support to harbor craft owners and operators

Establishing Regulatory Standards and Frameworks
- Progressively introduce new "green" licensing conditions and require licensed harbor craft to operate on low-carbon energy solutions

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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Domestic Harbor Craft efforts can be further categorized into 3 aspects where initial initiatives has started (1/2)

Conducting Research & Development (R&D) and Pilot Studies

<Images from tired Maritime Decarbonization Blueprint>

Example of initiatives taken:

- **Biofuel compatibility study for harbor craft:** Collaborated with Maritime Energy & Sustainable Development Centre of Excellence (MESD) to undertake a 'Biofuel Compatibility Study for Singapore Harbor Craft',
- **Feasibility trials at sea:** Assess compatible biofuels and blends and life-cycle assessment of carbon reduction
- **Pilot studies: Support pilot projects to research, design, build and operate a fully electric harbor craft** in the Port of Singapore by 2025

Providing Financial Support

Monetary Authority of Singapore | SOCIETE GENERALE | DBS | KFW IPEX-Bank | UOB | BNP PARIBAS

<Images from tired MPA website>

Example of initiatives taken:

- **Raising awareness of green financing solutions and tools**: Encourage harbor craft owners and operator to **tap on Singapore's growing maritime financing ecosystem** for renewal of assets
- **Develop schemes:** Aid first movers to **defray cost of investment into new green harbor craft**
- **Collaborate with financial institutions**: **facilitate risk management and catalyze lending** to harbor craft owners and operators

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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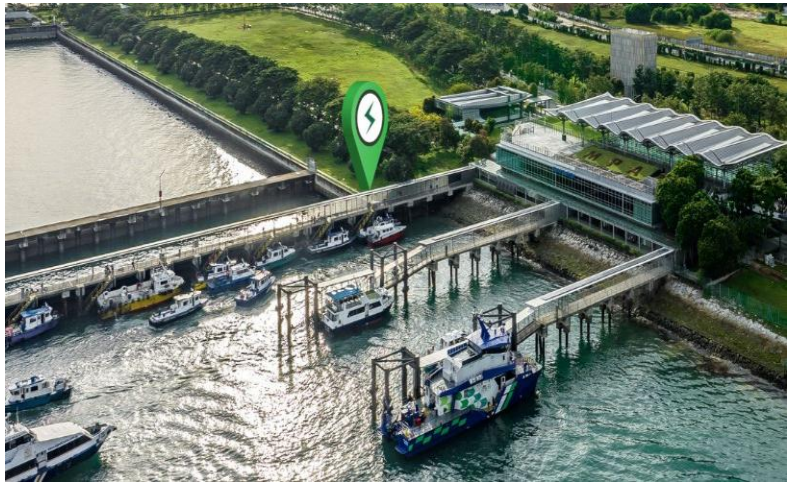
Domestic Harbor Craft efforts can be further categorized into 3 main areas where initial initiatives has started (2/2)

Establishing Regulatory Standards and Frameworks



Low-carbon energy solutions

Biofuel

Diesel-electric

LNG

Full-electric

Use of Biofuel in compliance with:

ISO[1] 8217

MSC-MEPC[2]

<Images from MPA website>

Example of initiatives taken:

- **Licensed harbor craft requirements**: Require all **licensed harbor craft to operate on lower-carbon energy solutions**, such as blended biofuel, LNG, diesel-electric hybrid propulsion or full-electric propulsion by 2030
- **Green licensing conditions**: Progressively introduce new "green" licensing conditions or requirements, such as the use of LNG, biofuel blends and eventually zero-carbon fuels, when harbor craft licenses are issued/renewed
- **Examine and develop standards** for the use of biofuels as bunkers in the domestic harbor craft fleet
- **MoU Signing**: In 2023, MPA and Shell Eastern Trading Pte Ltd signed a five-year MoU to collaborate on maritime decarbonization efforts in Singapore, including working together to advance the adoption of electric harbor craft and charging infrastructure

Note: [1]International Organization for Standardization, [2]Maritime Safety Committee-Marine Environment Protection Committee
Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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#3 – Develop Future Marine Fuels and Infrastructure: Position Singapore as a key hub by establishing guidelines, conducting studies and supporting activities

Focus area	**#3 Develop Future Marine Fuels, Bunkering Standards and Infrastructure**
Overview	Focus Area 3 centres on **establishing Singapore as a key hub for future marine fuels**, facilitating a **multi-fuel transition** for international shipping. Recognizing the current uncertainty in the industry, the strategy emphasizes both **transitional fuels and long-term solutions.** The approach supports the **trials and adoption of biofuels and LNG in the near term**, while actively exploring the **potential of Hydrogen, Ammonia, e-methanol, and bio-LNG as viable zero-carbon options**, including developing **bunkering standards and infrastructure.**
Key targets/ milestones	• Continue to support provision of **low and zero-carbon marine fuels** and enable **green technologies** • Continue to support the future of international shipping through a **multi-fuel transition**

Key plans

Research & Development (R&D), Pilot Studies and Talent Development

- **Conduct feasibility studies, pilot programs for future marine fuels (e.g. Ammonia) and infrastructure**
- Identify emerging needs and skillsets to equip maritime workforce

Supporting Industry Activities

- Engage various stakeholders to examine bunkering needs for global shipping industry
- Increase accessibility to green financing options for maritime industry players

Establishing Regulatory Standards and Guidelines

- Develop standards and guidelines for bunkering safety and alternative low/zero-carbon fuel adoption

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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Developing Future Marine Fuels and Infrastructure efforts is primarily done through collaboration on 4 key aspects (1/2)

Research & Development, Pilot Studies and Talent Development

<Images from Maritime Decarbonization Blueprint and Lloyd's Register's website>

Example of initiatives taken:

- **Collaborating with like-minded industry partners: Conduct feasibility studies and pilot trials** on the deployment of future marine fuels and enable the industry to assess the **operational and commercial viabilities of the various low and zero-emission fuel solutions.**
- **Launch LNG Bunkering pilot programs:** test operational protocols, gain operational experience, and strengthen Singapore's LNG Bunkering Capabilities
- **MOU Signing: Itochu's 2022 MOU with MPA supports advancing Ammonia fuel supply chains for future marine fuels and bunkering infrastructure.**

<Images from MPA's website and FueLNG's website>

Example of initiatives taken:

- **Pilot trials**: Support **pilot trials, testing bunkering procedures, development of bunkering infrastructure**, and honing of operational experiences and capabilities in Ammonia bunkering
- **Emerging roles and skills needs identification**: Identify emerging roles and skills needs for maritime decarbonization, and support enterprise to **equip maritime workforce with the necessary skills and knowledge to support the development of a low and zero-carbon bunkering hub** in Singapore

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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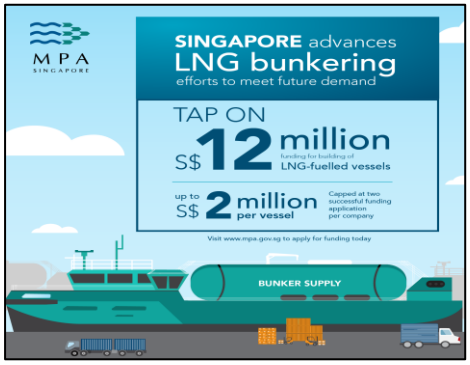
Developing Future Marine Fuels and Infrastructure efforts is primarily done through collaboration on 4 key aspects (2/2)

Supporting Industry Activities



<Images from Maritime Decarbonization Blueprint and MPA's website>

Establishing Regulatory Standards and Guidelines

<Images from MPA's website>

Example of initiatives taken:

- **Collaborating with value chain stakeholders: Support bunkering needs of global shipping industry** to ensure that Singapore can offer various low and zero-carbon fuel solutions
- **Partner government agencies: Examine infrastructure needs, demand projections, regulatory incentives and safety standards for future fuels** across different sectors
- **Expand suite of green financing options**: increase accessibility to sustainability-linked financing for the development of low and zero-carbon fuel solutions

Example of initiatives taken:

- **Establish regulatory standards:** Allow industry first-movers to **test-bed alternative low and zero-carbon fuel solutions**
- **Develop bunkering guides for future fuels in ports:** Enable the safe transport and bunkering of low and zero-emission fuels
- **Technical reference guidelines**: Jointly work with stakeholders to develop a set of technical reference guidelines on the safe bunkering of Ammonia, partner international partners to achieve harmonized global standards

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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#4 – Greening of Singapore's Ships: Incentivize Singapore-registered ships to reduce emissions and decarbonize SRS

Focus area	**#4 – Greening of Singapore's Ships**
Overview	The SRS is committed to tackling GHG emissions arising from international voyages made by Singapore-registered ships. The Green Ship Programme (GSP) incentivizes Singapore-registered ships to reduce emissions. **By the end of 2021, 11% of Singapore-registered vessels were enrolled**. **MPA aims to further decarbonize the Singapore Registry of Ships (SRS) by promoting energy-efficient technologies and low/zero-carbon fuels**, supporting shipowners in meeting IMO sustainability targets.
Key targets/ milestones	By 2027 • MPA expects 150 ships to be awarded the SRS Green Notation By 2050 • MPA aims to have at least 50% of the SRS fleet to be GSP ships In the long-term • MPA will have a larger fleet of Singapore-registered ships adopting energy efficient technologies and propelled by low or zero-carbon fuels

Key plans

Awarding Singapore-registered Ships with SRS Green Notation for Reducing Carbon Emissions

- Award the notation to ships that reduce their carbon intensity to a level exceeding the IMO EEDI Phase 3 requirements by at least 10% through the adoption of energy efficient technologies and/or adopt the use of alternative fuels.

Supporting Shipowners in Transition to Future Fuels

- Revise and enhance existing Green Ship Programme (GSP)
- Offer technical guidance and support to industry partners and shipowners
- Organize expert-led industry engagement sessions

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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Singapore Registry of Ships (SRS) efforts can be categorized into two main activities, recognizing the carbon emission reduction and supporting the transition of ships

Awarding Singapore-registered Ships with SRS Green Notation

<Images from Maritime Decarbonization Blueprint>

Example of initiatives taken:

3 different types of SRS Green Notation are awarded:

- **SRS Green Carbon Reduction (CR):** SRS that reduce carbon intensity to a level that exceeds IMO's EEDI phase 3 requirements by at least 10%.
- **SRS Green Low Carbon:** SRS that use low carbon fuel with conversion factor between fuel consumption and CO2 emission equal to or lower than LNG as primary fuel for their main engine and/or auxiliary engine(s).
- **SRS Zero-Carbon (ZC):** SRS that use zero-carbon fuel as primary fuel for their main engine and/or auxiliary engine(s)

Supporting Shipowners in Transition to Future Fuels

<Images from Maritime Decarbonization Blueprint and MPA website>

Example of initiatives taken:

- **Green Ship Programme Enhancement: Revising and enhancing existing program**
  - Short-term: granting zero-carbon fueled vessels maximum rebates or reduction on its IRF and ATT
  - Long-term: target 50% SRS fleet to be GSP ships by 2050
- **Supports for Alternative Marine Fuel: Offering technical guidance and support to industry partners and shipowners** to develop and undertake pilot trials for alternative future marine fuels, such as Ammonia and Hydrogen
- **Expert-led industry engagement sessions: Holding the sessions to exchange information** and best practices

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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#5 – Active Participation at International Platforms: Support IMO's targets and commit to inclusive climate action

Focus area	#5 – Active Participation at International Platforms
Overview	**Singapore actively participates at IMO and various international platforms to stay involve in the global level** **Singapore fully supports the targets that the Initial IMO Strategy sets out**. As a leading global hub port, bunkering hub and shipping registry, Singapore had contributed actively to the development of the Initial IMO Strategy. **Singapore is committed to strong, credible and inclusive climate action overall and at IMO**. Singapore seeks to play three key roles internationally on the decarbonization agenda
Key targets/ milestones	• Singapore remains committed to the current roles and contributions towards **building, facilitating, and supporting decarbonization standards in maritime** • Over the next few years, **MPA will introduce a new flagship program on maritime sustainability and decarbonization**

Key plans

Contributing to the Development of Global Standards

- Contribute to the discussions at IMO regarding the development of lifecycle GHG and carbon intensity guidelines for all alternative fuel types and preparation of implementation programs

Acting as a Bridge-builder for International Collaborations

- Support IMO's decarbonization measures
- Contribute expertise for evidence-based decisions
- Foster global maritime decarbonization through collaboration and knowledge-sharing

Spearheading and Guiding the Decarbonization of International Maritime Industry

- Support a global carbon levy on international shipping in the medium to long-term.

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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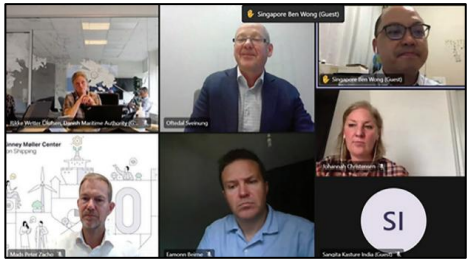
Active Participation at International Platforms efforts can be categorized further into 3 key activities (1/2)

Contributing to the Development of Global Standards



<Images from Maritime Decarbonization Blueprint and Mission Innovation website>

Example of initiatives taken:

- **Guidelines for Ships Using Ammonia: Proposing a new work output to develop non-mandatory guidelines for ships using Ammonia as fuel,** with Japan at the 104th meeting of the IMO's MSC in October 2021
- **Future Fuels Port Network (FFPN): Establishing the FFPN** with port authorities, the Port of Rotterdam and Japan's Ministry of Land, Infrastructure and Transport, to develop a roadmap to explore the harmonization of standards for clean marine fuels
- **Zero-Emission Shipping Mission: Participating** alongside other countries **as a "Core Member"** in the mission

Acting as a Bridge-builder for International Collaborations

NEXT GEN | Towards Green and Efficient Navigation

<Images from Maritime Decarbonization Blueprint and IMO website>

Example of initiatives taken:

- **Expertise Contribution:** Such as contributing expertise to the comprehensive impact assessment of short-term measures to reduce GHG emissions from ships.
- **NextGEN:** Fostering a global maritime decarbonization ecosystem through the platform that brings together the stakeholders to share ideas and collaborate
- **Support for Other Countries: Offering capacity building and technical assistance** to support SIDs and LDCs and providing leadership training for overseas port and maritime officials
- **The Silk Alliance:** MoU for 'The Silk Alliance', a regional green corridor cross-industry initiative to enable zero-emission shipping across the Indian and Pacific Oceans

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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Active Participation at International Platforms efforts can be categorized further into 3 key activities (2/2)

Spearheading and Guiding the Decarbonization of International Maritime industry

<Images from Ministry of Transport, IMO website>

Example of initiatives taken:

- **Carbon Price Mechanism Development:** Continuing to actively **contribute to global discussions on mid- and long-term measures at IMO**, with the view to develop a carbon price mechanism
- **USD 100,000 Pledge for IMO GHG Emissions Reduction: Pledging a sum of USD 100,000 to the IMO GHG Technical Co-operation – Trust Fund** seeking to deepen understanding of relevant technical issues pertaining to GHG emissions reduction and support Member States in their maritime decarbonization efforts
- **Support for the Purchase of Carbon Credits: Supporting first-mover maritime companies** who desire to do more, for example, by facilitating the voluntary purchase of carbon credits

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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#6 – R&D and Talent Development: Be a global hub for maritime decarbonization R&D solutions

Focus area	**#6 – R&D and Talent Development**
Overview	As a country with fulfilling landscape for technology and development, **Singapore will be a global hub for maritime decarbonization R&D solutions**, enabled by a vibrant ecosystem, **with the talent and expertise** to develop, trial, deploy and commercialize innovations.
Key targets/ milestones	**By 2027** • MPA will initiate, accelerate, or drive forward 20 technology projects • MPA will train over 100 researchers, scientists and engineers **By 2032** • Singapore's efforts will create and upskill a total of 1,200 sustainability-related jobs

Key plans

Initiating and Driving R&D and Innovation
- Commit to fund for maritime decarbonization R&D
- Co-fund decarbonization projects at various stages

Building Global Talent in Maritime Decarbonization
- Help companies defray manpower costs
- Provide co-funding support to employers and employees to ensure that the maritime workforce maintains the necessary relevant skills and knowledge for maritime decarbonization

Fostering an Enabling Environment for Collaboration and Innovation
- Collaborate with partners across value chains to jointly develop green technology capability development areas for the maritime sector in the upcoming decade

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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R&D and Talent Development can be categorized into 3 key activities fostering both innovation and skilled manpower (1/2)

Initiating and Driving R&D and Innovation

Port of Rotterdam

<Images from Maritime Decarbonization Blueprint>

Example of initiatives taken:

- **Project Catalyzation: Committing SGD 80 Million funding for maritime decarbonization R&D**, targeting to initiate, accelerate, and drive forward 20 technology projects, train over 100 researchers, scientists and engineers in the next 5 years
- **Project Funding: Continuing the co-funding of decarbonization projects at various stages** of R&D, pilot trials, translation and deployment, through a range of funds, programs and platforms
- **Conducting pilot trials of biofuels overseas:** The Rotterdam-Singapore Green and GDSC partners **have conducted a pilot for the bunkering of liquefied bio-methane (LBM)**

Building Global Talent in Maritime Decarbonization

<Images from Maritime Decarbonization Blueprint>

Example of initiatives taken:

- **Manpower Cost Support: Helping companies defray manpower costs** incurred in Singapore that are associated with qualifying maritime decarbonization activities
- **Support for Maritime Workforce Skills: Providing co-funding support to employers and employees** to ensure maritime workforce maintains the necessary relevant skills and knowledge for maritime decarbonization
- **MoU with Nippon Yusen Kabushiki Kaisha (NYK):** In 2024, MPA signed MoU with NYK to deepen their partnership and accelerate maritime decarbonization, digitalization, and manpower development efforts

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint and MPA Release

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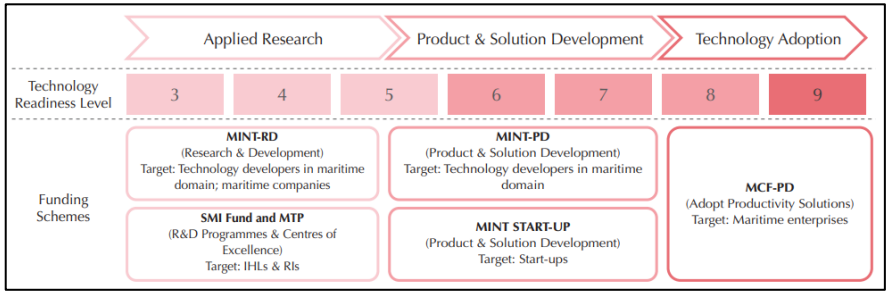
R&D and Talent Development can be categorized into 3 key activities fostering both innovation and skilled manpower (2/2)

Fostering an Environment for Collaboration and Innovation



<Images from Maritime Decarbonization Blueprint>

Example of initiatives taken:

- **Value Chain Collaboration: Collaborating with partners across value chains** to jointly develop and co-fund green technology capability development areas for the maritime sector in the upcoming decade. For example, MPA, SMI and industry stakeholders jointly outlined green technology **capability development areas for the maritime sector**
- **MoU with Mitsui O.S.K. Lines (MOL): MPA signed MoU in 2024, the mutual collaboration establishing a supply system for next-generation fuel sources** such as methanol, Ammonia, and Hydrogen

MPA Funding Schemes	
Maritime Transformation Programme (MTP)	• The MTP drives innovation in Singapore's Sea Transport Industry Transformation Map (ITM) by leveraging other NRF's Funds to enhance maritime R&D
SMI	• The Singapore Maritime Institute (SMI) Fund was established by MPA, A*STAR, and EDB to enhance maritime education and research in Singapore • It supports R&D programs, projects, infrastructure, and Centers of Excellence, fostering industry-academia collaboration and strengthening the country's maritime research capabilities.
MINT Fund	• The Maritime Innovation & Technology (MINT) Fund was established by MPA to supports maritime R&D and test-bedding in Singapore

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#7 – Promoting Green Finance/ Accounting: Strengthen capabilities in carbon accounting and promote green financing

#1 | #2 | #3 | #4 | #5 | #6 | **#7 Promoting Green Finance/ Accounting**

Focus area	**#7 Promoting Green Finance/ Accounting**
Overview	There is a lack of harmonized and accessible measurement system for maritime companies to progress in their carbon inventory and reporting efforts. To build Singapore as a green maritime finance hub, **MPA will continue to strengthen capabilities in carbon accounting and reporting and promote green financing** within the maritime industry.
Key targets/ milestones	• MPA will develop a maritime sector-specific carbon accounting guide • MPA will develop a standard taxonomy for sustainable assets and activities in the maritime sector

Key plans

Develop Guidelines for Carbon Accounting in the Maritime Industry
- Aim to develop a maritime sector-specific carbon accounting guide

Increasing Private Sector Participation
- Build awareness amongst SMEs through LowCarbonSG
- Support maritime companies in Singapore to study the voluntary use of carbon credits

Developing the Green Financing Landscape in Singapore
- Establish Singapore as a green maritime finance hub

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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Developing and Strengthening Carbon Accounting and Green Financing in Singapore efforts can be categorized into 3 key activities (1/2)

Develop Guidelines for Carbon Accounting in the Maritime Industry

<Images from Maritime Decarbonization Blueprint and MPA website>

Example of initiatives taken:

- **Maritime Carbon Accounting Guide: Developing a maritime sector's carbon accounting guide**, which will set out a harmonized carbon measurement system based on common carbon emissions classifications
- **Maritime Sustainability Reporting Guide: Launching the first sector-specific Maritime Sustainability Reporting Guide in 2019**, providing listed and non-listed maritime companies with a practical framework
- **Training: Collaborating with GCNS and SSA on training and sharing of best practices** to raise carbon accounting capabilities among maritime companies in Singapore.
- **MoU with UN Global Compact Network Singapore (GCNS):** In 2024, MPA signed MoU to develop training workshops for maritime companies for carbon accounting and management

Increasing Private Sector Participation

<Images from Global Compact Network Singapore and Jurong Port websites>

Example of initiatives taken:

- **LowCarbonSG:** Aiming to **build awareness amongst SMEs about the need to decarbonize**, the climate risks and impact to their businesses, as well as the opportunities available through LowCarbonSG
- **Carbon Offsets and Services: Exploring the potential of carbon offsets and services for the maritime industry**, by supporting maritime companies in Singapore to study the voluntary use of carbon credits

Source: Summarized by NRI based on Maritime Singapore Decarbonization Blueprint

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Developing and Strengthening Carbon Accounting and Green Financing in Singapore efforts can be categorized into 3 key activities (2/2)

#1 | #2 | #3 | #4 | #5 | #6 | **#7 Promoting Green Finance/ Accounting**

Developing the Green Financing Landscape in Singapore

MPA's Ambition – Green Ship Finance Centre of the East

Building a Green Financing Ecosystem
- Work with partners including SSA and MAS to raise awareness of green financing programs, leveraging Singapore's first mover position in green finance
- Tap on the GCMD's knowledge expertise as a catalyst to draw in financing interests
- Encourage existing banks in Singapore to provide green financing

Developing Solutions
- Support the development of a Maritime Green Taxonomy
- Encourage take-up of MAS schemes that defray expenses such as independent external reviews to facilitate access to green finance
- Leverage technology to (a) pool together verifiable data to support green financing decisions; and (b) support growth of independent verification companies

Growing a Diverse Suite of Financing Options
- Encourage the growth of alternative financing options in Singapore
- Promote growth through MSI-ML or MCF-BD schemes

Deepening Knowledge & Capabilities
- Leverage partners including IHLs to build competencies in maritime green finance
- Upskill maritime finance experts to gain sustainability-related knowledge

<Images from Maritime Decarbonization Blueprint>

Example of initiatives taken:

- **Building an Ecosystem:** MPA's vision is to build an ecosystem comprising diverse players offering both traditional and alternative sources of financing, as well as intermediaries that can connect shipping interests to such sources of financing
- **Developing Solutions:** MPA will work with MAS, GCMD and relevant partners to develop a standard taxonomy for sustainable assets and activities in the maritime sector
- **Building a Diverse Suite of Financing Options:** MPA seeks to attract green-focused shipping funds to operate out of Singapore. MPA will use its schemes – MSI-MLand MCF-BD – to facilitate the setting up of such funds and their subsequent expansion in Singapore.
- **Deepening Green Financing Skillsets & Capabilities:** MPA will work alongside government agencies, tripartite partners and IHLs to formulate curricula for courses and programs within relevant centers of excellence and institutes. MPA will continue to work with IHLs to develop maritime-relevant courses that have bespoke competencies applicable to green financing.

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Executive Summary

1. General Introduction

2. Ammonia Policy Trends

3. Ammonia Market Activities (Supply & Demand)

4. Maritime Decarbonization

Annex

Hydrogen/Ammonia Pricing

- Overview of Relevant government Organizations

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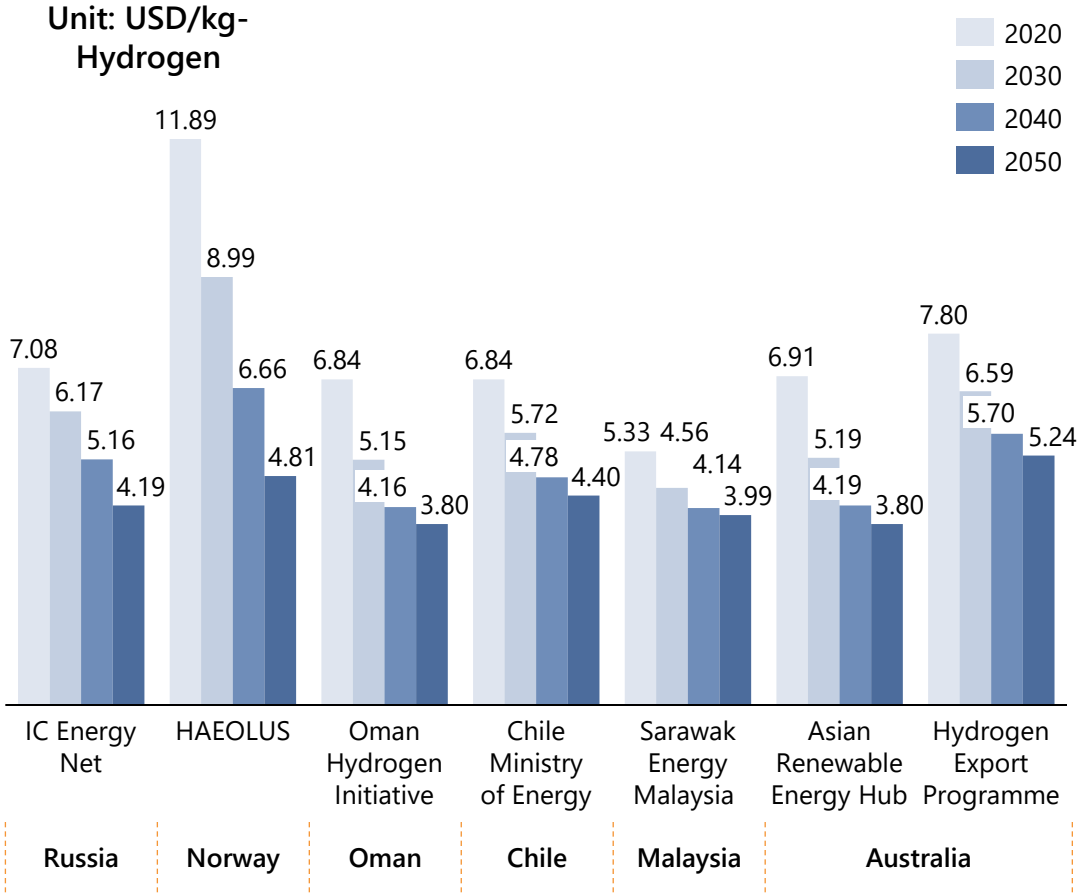
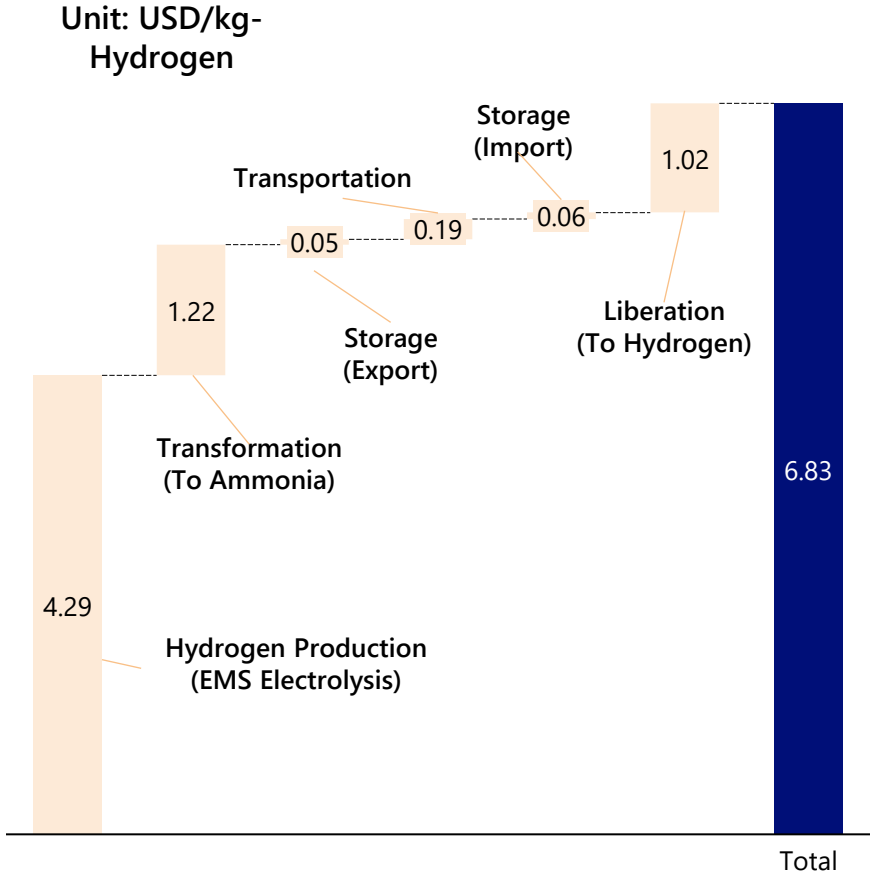
In a study done previously for Singapore's National Climate Change Secretariat, import price of Hydrogen from high potential hub was estimate to decrease in the long term

Singapore's Hydrogen Import Sources & Projected Costs of Import



Price component of imported Hydrogen (2020 estimates)



<data from KBR's report prepared for National Climate Change Secretariat, Strategy Group, Prime Minister's Office in 2020>

Source: Summarized based on KBR's report prepared for National Climate Change Secretariat, Strategy Group, Prime Minister's Office in 2020

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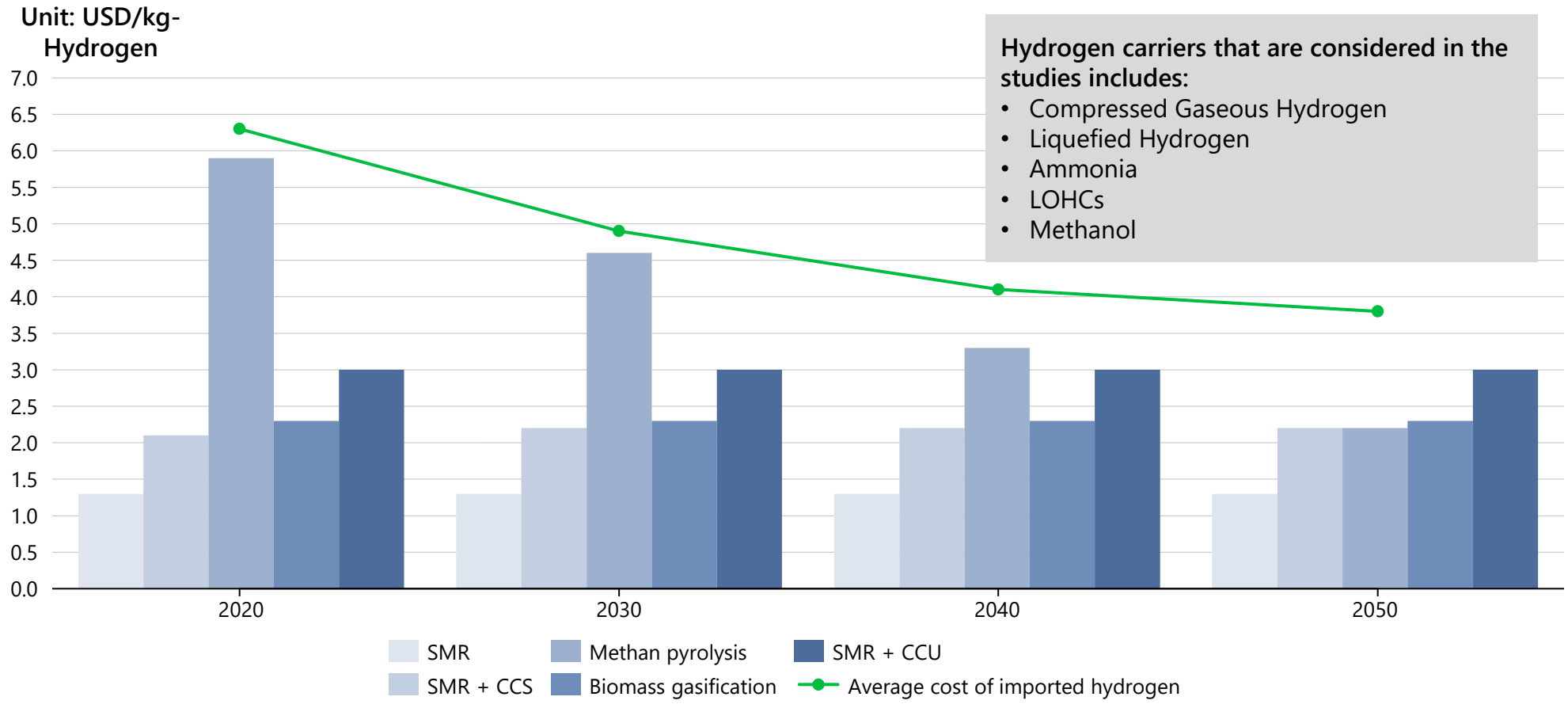
Despite imported Hydrogen having higher cost than local production in Singapore, due to limited production scale, majority of Hydrogen supply will be imported

Singapore's Hydrogen Import Cost vs. Local production cost



<data from KBR's report prepared for National Climate Change Secretariat, Strategy Group, Prime Minister's Office in 2020>

Source: Summarized based on KBR's report prepared for National Climate Change Secretariat, Strategy Group, Prime Minister's Office in 2020

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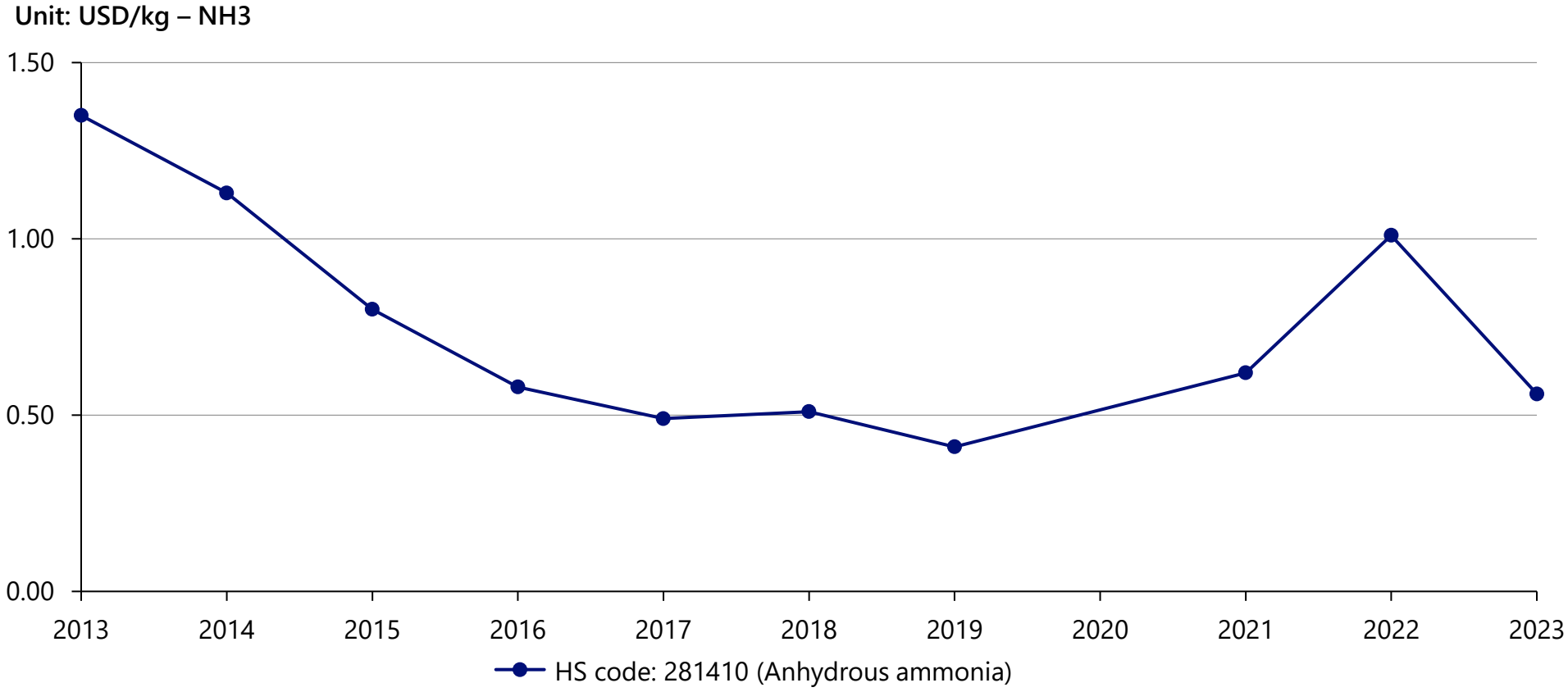
Reference)
Ammonia import price of Singapore

Historical Ammonia* Import Price of Singapore



<data from UN Comtrade>

* Note: Prices illustrated for grey ammonia

Source: Summarized based on data from UN Comtrade

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- Hydrogen/Ammonia Pricing

Overview of Relevant government Organizations

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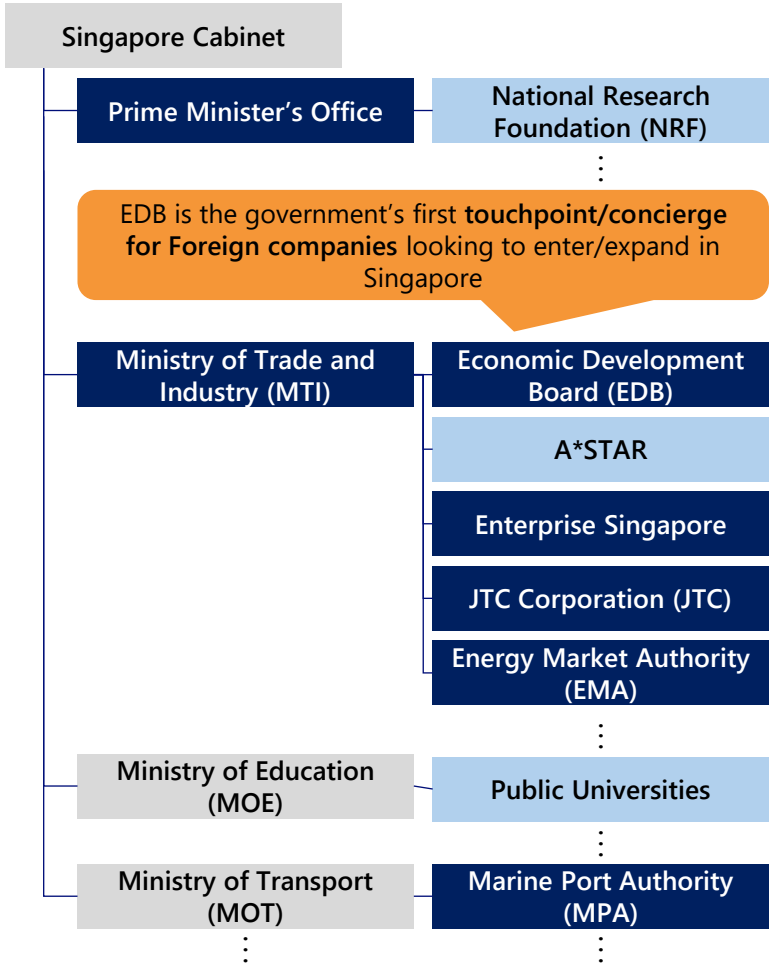
There are ~10 major ministries and agencies in Singapore that are more directly related to development of the Ammonia/Hydrogen industry and R&D

Singapore Government Agencies Map*



Ammonia/Hydrogen Industry development related organizations

- **Prime Minister's Office** – Oversees national policies, including Singapore's long-term energy transition strategy, which includes Hydrogen and Ammonia adoption.
- **Ministry of Trade and Industry (MTI)** – Develops policies to support the commercial viability of Hydrogen and Ammonia as future energy sources
- **Economic Development Board (EDB)** – Attracts investments in Hydrogen and Ammonia infrastructure, including production, storage, and export capabilities
- **Enterprise Singapore** – Supports local enterprises and startups involved in Hydrogen and Ammonia-related innovations and supply chain development
- **JTC Corporation (JTC)** – Develops industrial infrastructure, such as Hydrogen-ready industrial zones and storage facilities for Ammonia (i.e. Jurong Island)
- **Energy Market Authority (EMA)** – Regulates and plans for Hydrogen integration into Singapore's energy mix and power generation sector
- **Marine Port Authority (MPA)** – Develops policies and infrastructure to support Ammonia and Hydrogen as alternative marine fuels

Ammonia/Hydrogen R&D related organization

- **National Research Foundation (NRF)** – Funds research initiatives for Hydrogen and Ammonia technologies through national R&D programs
- **Agency for Science, Technology and Research (A*STAR)** – Leads research on Hydrogen production, storage, and Ammonia-based fuel technologies
- **Public Universities** – Conduct cutting-edge research on Hydrogen and Ammonia applications, including fuel cells, storage, and industrial usage.

Note: *Above ministries/agencies are non exhaustive and for illustration of relevant organization only
Source: Summarized by NRI based on local knowledge

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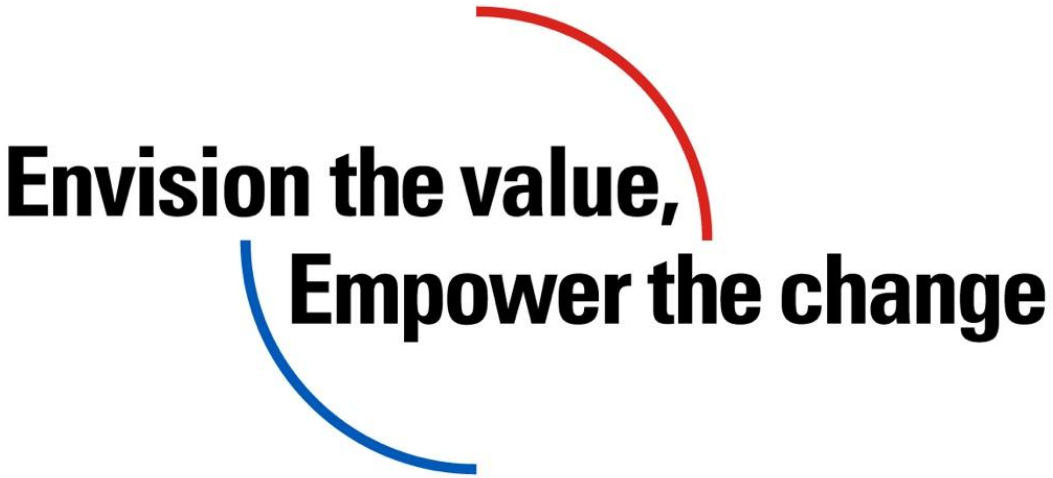
Envision the value,
Empower the change