Financing Singapore's Hydrogen Future

Bold Investment or Risky Gamble?

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Executive Summary

- Singapore's National Hydrogen Strategy appears to be meticulously conceived and well-situated within Singapore's decarbonisation plans. **Policy support will make hydrogen-related projects more bankable. However, financiers will still need to sort the wheat from the chaff.**

- "Low-carbon" or "clean" hydrogen definitions may not align with a credible net-zero pathway if fossil fuels are still being used to produce them, and projects relying on them face high risk of not meeting expected decarbonisation outcomes. **Financiers should require reputable certificates of origin and ensure they are internationally recognised, stringent, and comprehensive.**

- Using hydrogen for power generation in Singapore may not make economic sense and takes away capital that could have been used to develop and scale up lower-cost, lower-risk decarbonisation solutions that align with net-zero. **Hydrogen should be used for sectors that have no better substitutes in terms of cost and efficiency (e.g. oil refinery, shipping).**

- While hydrogen is certain to have a role to play in Singapore's sustainable future, informed scientific and technical knowledge has demonstrated that **it is not a panacea to address the climate challenge and is best coupled with other approaches.** Capital should be prudently directed to hydrogen projects that have low financing risks and are aligned with a credible net-zero pathway.

- Financiers can reduce financing risks by structuring additional protective covenants for projects with new or unproven technologies, or **rely on experts with technical knowledge and an understanding of economics to aid in the due diligence on these projects.**

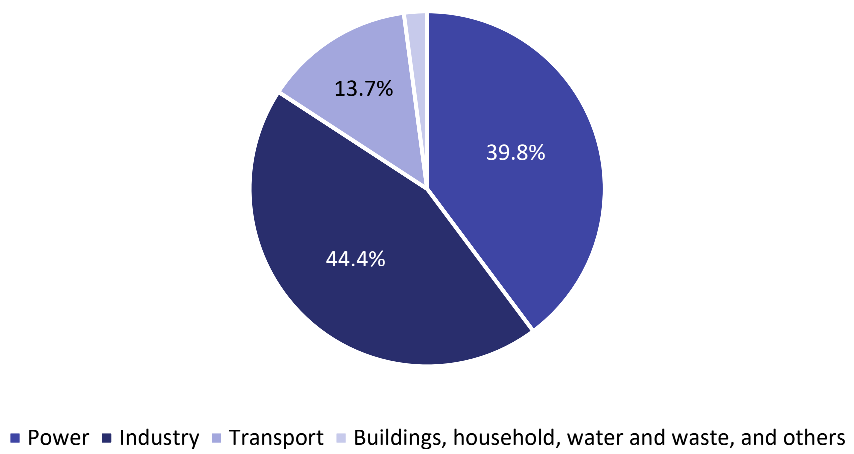
Introduction

This report serves to highlight the risks and additional considerations associated with financing or investing in hydrogen-related projects in Singapore

In October 2022, Singapore published its National Hydrogen Strategy, joining more than 30 other countries that had released their own.

The Strategy presumes that hydrogen can be a "broad-based and scalable decarbonisation pathway for Singapore and the world", outlining three important end-use areas where hydrogen has potential for their decarbonisation. The relevant sectors for these are: power generation, industry, and transportation, which formed almost 98% of Singapore's primary emissions in 2020.

Fig. 1 Singapore's primary emissions profile in 2020



Source: MTI, Singapore's National Hydrogen Strategy, p.15

The Strategy also highlights five key areas where Singapore plans to target its efforts to drive hydrogen adoption in the country:

1. Investing in R&D to overcome key technological bottlenecks
2. Experiment using hydrogen via pathfinder projects
3. International collaboration to enable low-carbon hydrogen supply chains
4. Long-term land and infrastructure planning to integrate hydrogen into Singapore
5. Supporting workforce training and development for a hydrogen economy

Singapore's approach to hydrogen adoption has been cautious and gradual

Singapore has done well to recognise not only the potential, but also the challenges and uncertainties associated with low-carbon hydrogen. For instance, Singapore commissioned a study in 2019 to look at hydrogen imports and its domestic downstream uses. The study provided an assessment of hydrogen in the different end-use sectors, noting the benefits and risks involved for each. As a result, the National Hydrogen Strategy appears to take a cautious and phased approach and notes the need to continually assess developments in technology and global supply chains.

However, few third-party analyses[1] have been done on the feasibility of Singapore's plans for hydrogen, and virtually none discuss the additional considerations and risks to financing or investment in its context.

While many of today's hydrogen-related projects are equity-driven or government-backed, the scale of decarbonisation required to meet net-zero goals suggests that private financial institutions will soon start looking at applications for such project financing.

Bankability of hydrogen-related projects will continue to grow…

Bankability of hydrogen-related projects will continue to grow. In the United States, the Inflation Reduction Act which became law in August 2022 contained provisions that included subsidies of up to $3 per kg of hydrogen produced that qualified as "clean". In Singapore, the Finance for Net Zero Action Plan that was launched in April 2023 will likely include blended finance schemes to reduce demand or cost uncertainties for hydrogen-related projects.

…but it does not mean all projects are feasible to fund

However, financiers should note that bankability and policy support does not mean that all hydrogen-related projects are feasible to finance, even if returns look attractive on the surface. Transition risks should be a key consideration as well. Financiers should remember the eventual objectives of these hydrogen projects, which is to accelerate global decarbonisation in order to reach net zero emissions by 2050.

Therefore, this report serves to provide financiers an introductory overview of these additional considerations when performing due diligence for financing or investing in hydrogen-related projects in Singapore.

[1] Hasan, 'Singapore's hydrogen strategy must go further', [website], 2023, The Business Times ;
Wang, S., 'Critiquing Asia's Hydrogen Power Ambitions', [website], 2023, The Breakthrough Institute

Issues for Financiers to Consider

1. Singapore's Definition of Low-Carbon Hydrogen Does Not Appear Wholly Credible

Singapore's National Hydrogen Strategy considers the use of blue hydrogen as a low-carbon energy source in the country's decarbonisation plans

Singapore's National Hydrogen Strategy touts low-carbon hydrogen as having potential to be "a major decarbonisation pathway to support Singapore's accelerated transition toward net-zero by 2050".

The National Hydrogen Strategy defines low-carbon hydrogen as being produced either from "electrolysis of water using renewable or low-carbon energy, or from fossil fuels with carbon removal technologies applied".

However, the effectiveness of blue hydrogen's contribution to net-zero is controversial

However, the latter, commonly known as "blue" hydrogen may currently be at odds with credible net-zero goals.

On Blue Hydrogen

Blue hydrogen has significant carbon lock-in risks at a time when credible net-zero pathways call for phaseout of fossil fuels

The production and consumption of blue hydrogen risks prolonging the use of fossil-based power as feedstock and would likely result in significant carbon lock-in risks at a time when credible net-zero pathways call for the phaseout of fossil fuels.

Performance and costs of CCS technologies for the production of blue hydrogen still do not align with expectations in a net-zero pathway

Additionally, carbon capture and storage (CCS) technologies are still considered controversial by many reputable institutions (e.g. IEEFA[2]) because of an underwhelming track record in terms of emission reduction as well as costs associated with deploying the technology.

There are very few currently operating blue hydrogen production projects of commercial scale, despite CCS being considered a mature technology.

Globally, only two facilities fit this bill – Air Products in Texas (United States) has been in operation since 2013, and Shell's Quest in Alberta (Canada) which has been in operation since 2015[3]. Both facilities failed to meet the carbon capture rates of 90-95% promised by the industry, with the Texas facility capturing less than 50% of the CO2 generated and the Alberta facility averaging 71%. These rates do not include the CO2 generated while operating the CCS equipment, or with compressing the captured carbon for transport and storage. Including these processes would further reduce the capture rate for onsite emissions.

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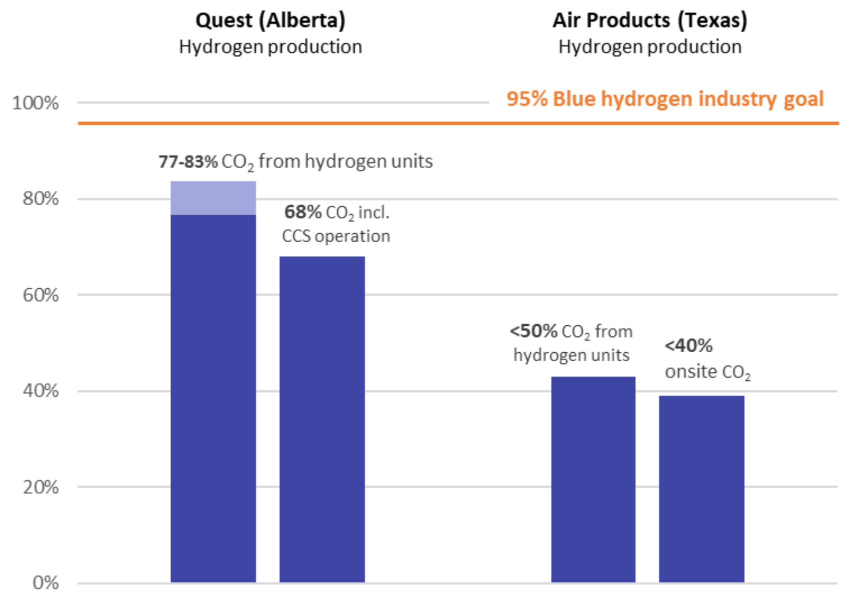
[2] Institute for Energy Economics and Financial Analysis (IEEFA), 'Carbon capture: a decarbonisation pipe dream', [website], 2022, International Renewable Energy Agency (IEEFA)
[3] Mattei, S. , Schlissel, D. , Wamsted, D. , 'The Energy Department's hydrogen gamble: Putting the cart before the horse', [website], 2023, Institute for Energy Economics and Financial Analysis (IEEFA)

Fig. 2 Real world CO2 capture far below promised rates



Source: IEEFA, 'Russia Sanctions and Gas Price Crisis Reveal Danger of Investing in "Blue" Hydrogen', p.4.
Note: "CO2 incl. CCS operation" refers to uncaptured CO2 from CCS operations, transport, and storage.

Production of blue hydrogen releases other GHG which are more damaging than CO2

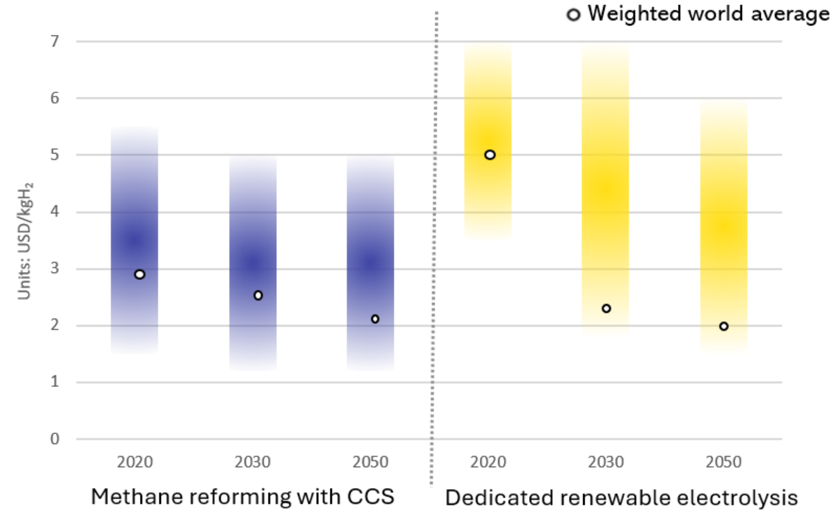
The production of blue hydrogen also results in the emitting of other greenhouse gases such as methane, which is not only 86 times more damaging to the climate than CO2 based on a 20-year global warming potential[4], but is also not captured by CCS technologies.

Blue hydrogen will be more costly in the longer term, despite being cheaper than green hydrogen in the shorter term

Moreover, while blue hydrogen seems to currently be much cheaper to produce ($1-2 per kg) when compared with green hydrogen ($3-8 per kg)[5], it requires producers to invest in equipment with very long lifetimes.

Marginal emission reduction benefits will cause these capital investments to become uneconomical, and result in inefficient assets even before 2030[6], as the cost of green hydrogen is expected to fall to reach parity with blue hydrogen within the next decade[7].

Fig. 3 Levelised cost of hydrogen production (after support)



Source: DNV, 'Hydrogen Forecast to 2050 – Energy Transition Outlook 2022', p.74.

[4] Howarth, R. & Jacobson, M. , 'How green is blue hydrogen?', 2021, Energy Sci Eng.
[5] International Energy Agency, 'Global Hydrogen Review 2021', p.7
[6] Mbuk, 'Clean Hydrogen's Place in the Energy Transition', [website], 2022, Carbon Tracker
[7] DNV, 'Hydrogen Forecast 2022-2050', [website], 2022, DNV

Blue hydrogen's unit costs may also be underestimated, as they may fail to consider other important costs and liabilities

Furthermore, the true costs of blue hydrogen production may be underestimated as many CCS cost projections rely on optimistic estimates of CO2 transport and storage, and generally do not take into account the cost of monitoring methane leaks and verifying capture rates[8]. CO2 leaks from the storage site may also create certain legal and financial liability, if not considered or priced at the outset.

To sum, blue hydrogen still has difficult technical and cost hurdles to cross. The following quote presents the hurdles we have described adeptly:

> *"Techno-economic analysis of fossil-fuel hydrogen produced with CCS has revealed a dilemma: if carbon-capture rates are low, there is a risk of lock-in by scaled high-emissions fossil-fuel hydrogen; if capture rates are high, there is a risk of stranded assets as hydrogen production with CCS may never become competitive."*[9]

On Certifications

Lack of universal standards on "clean" or "low-carbon" hydrogen labels opens up risk of transition-washing or green-washing

Presently, there are no universal standards on how the terms "low-carbon" or "clean" hydrogen are defined, and establishing international standards could take several years[10]. This opens up the possibility for transition- or green- washing to occur.

An example illustrates the potential for this risk: Sinopec, China's largest oil producer, recently started producing green hydrogen in its Xinjiang facility[11]. The plant is not only China's largest green hydrogen facility, but currently the world's largest, and is expected to produce up to 20,000 metric tons of hydrogen annually.

Just a year earlier, BloombergNEF[12] voiced its uncertainty as to how 'green' the hydrogen would be, as commitments about its renewable feedstock had been vague. Notably, if these renewable commitments fall short and the hydrogen production has to rely heavily on the grid, which is primarily coal-fired power, Sinopec can still call this hydrogen 'green' by simply purchasing credits from China's Green Electricity Certificate system.

Singapore may be complicit in such transition- or green- washing if it does not mandate certification of its hydrogen imports or if certification standards are weak

Singapore, which plans to import most of its low-carbon hydrogen, may be complicit in such transition- or green- washing if it does not certify the sources of its hydrogen imports.

Singapore is currently developing a Guarantee of Origin certification system that promises to be "interoperable" across jurisdictions. However, the National Hydrogen Strategy did not go into further details to indicate which jurisdictions or what certification standards Singapore intends to benchmark against.

The International Renewable Energy Agency (IRENA) notes that certificates of origin should be "rooted in a transparent and credible system"[13] and should take into account the important emissions throughout the supply chain, not only the emissions at production.

Particularly for Singapore, this could include emissions from the shipping, storage, and reconversion of hydrogen, depending on how stringent the carbon accounting boundaries are[14].

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[8] Longden, T. , Beck, F. , Jotzo, F. , Andrews, R. & Prasad, M. , ''Clean' hydrogen? – Comparing the emissions and costs of fossil fuel versus renewable electricity based hydrogen', 2022, ScienceDirect
[9] ibid.
[10] World Energy Council, 'WORKING PAPER | NATIONAL HYDROGEN STRATEGIES', p.14
[11] Reuters, 'Sinopec's first green hydrogen plant starts production in Xinjiang', [website], 2023, Reuters
[12] Parkes, 'Inside China's 260MW behemoth | How 'green' is the world's biggest green hydrogen project?', [website], 2022, RECHARGE news
[13] International Renewable Energy Agency (IRENA), 'Geopolitics of the Energy Transformation: The Hydrogen Factor', [website], 2022, IRENA
[14] Cheng W, Lee S., 'How Green Are the National Hydrogen Strategies?' Sustainability, 2022

The upcoming publication of the Singapore-Asia Taxonomy is expected to set high standards to qualify hydrogen imports as "Green"…

Looking at the proposals in the third GFIT Consultation Paper on the Singapore-Asia Taxonomy published in February this year, it seems the finance industry intends to follow closely with the carbon accounting boundaries and emission thresholds set by the EU Taxonomy.

Notably, the GFIT members had alluded that blue hydrogen (fossil-based with CCS) will likely fail to meet the 'Green' category by 2030-2035 and be downgraded to 'Red' (i.e. it should be phased out) due to three reasons:

(1) By the simple fact that natural gas, a fossil fuel, is still used as feedstock. The proposed 'Green' criteria does not allow fossil-based feedstock to be used after 2030.

…and potentially disqualifying imports of blue hydrogen (as currently allowed under the National Hydrogen Strategy)

(2) The proposed 'Green' criteria requires hydrogen production to emit below 3 kgCO2e per kg of H2 to qualify. The technical hurdles of CCS as well as emissions from shipping would indicate that blue hydrogen imported into Singapore would very unlikely meet this threshold.

Fig. 4 Hydrogen carbon intensity thresholds table

Asset Type	Criteria			
	2022	2030	2040	2050
Production of hydrogen	3 kgCO2e/kgH2*	1.5 kgCO2e/kgH2*	0.6 kgCO2e/kgH2*	0 kgCO2e/kgH2*
*To demonstrate compliance with any of the emissions intensity thresholds set in **Table 8**, the life cycle assessment in line with the methodological notes provided in the Appendix 5.				

Source: Green Finance Industry Taskforce, 'Identifying a Green Taxonomy and Relevant Standards for Singapore and ASEAN', p.31

(3) The proposed 'Green' criteria require a 90% minimum capture rate from CCS. The technical hurdles of CCS again indicate that blue hydrogen would be unlikely to meet this criteria.

It is also useful to point out that the Green Hydrogen Standard (GH2) is currently the only "global" certification scheme. The scheme validates hydrogen which emits <1 kg CO2e per kg of H2 as green, which only hydrogen produced from renewables (hydropower, wind, solar, geothermal, tidal, wave and other ocean energy sources) can achieve, and the only kind of hydrogen that aligns with a 1.5-degree pathway[15].

In this aspect, Singapore's National Hydrogen Strategy risks not being viewed credibly

Therefore, the National Hydrogen Strategy risks not being viewed as a 'credible transition' strategy[16] by considering fossil-based hydrogen with carbon capture as low-carbon hydrogen suitable for use in Singapore's decarbonisation efforts.

Financiers should therefore be cautious when financing or investing in projects that would rely on blue hydrogen, given the likely high risk of those projects not meeting expected decarbonisation outcomes.

In their due diligence, financiers should look at the certificates of origin of the hydrogen being sourced for a project and ensure that it meets credible guidelines (i.e. benchmarking against an existing credible Taxonomy such as the EU Taxonomy) and check if shipping, storage, and reconversion emissions are considered in the emissions accounting.

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[15] Green Hydrogen Organisation, 'The GH2 Green Hydrogen Standard', n.d.
[16] See, 'Common understanding of 'credible transition' needed to prevent transition-washing: Singapore minister', [website], 2023, Eco-Business

Additionally, while carbon offsets have generally not been discussed at length and are currently left out by most certification frameworks, financiers should also investigate the extent to which offsets have been used in order to provide a reliable assessment of the risks involved with a specific project.

2. Singapore's Intention to Use Hydrogen in Power Generation May Present Outsized Risks to Net-Zero Ambition

Hydrogen-for-power is costly and inefficient, and even more so in Singapore where the hydrogen has to be imported

According to the National Hydrogen Strategy, the power sector accounts for around 40% of Singapore's emissions and that hydrogen "is a promising low-carbon solution that can be scaled up and… has the potential to supply up to 50% of [Singapore's] projected electricity demand by 2050".

Numerous credible research points out that there are better ways of using hydrogen (and its derivatives e.g. ammonia) than as a direct fuel used for power generation.

The primary reason for this is that the economics of burning hydrogen for power does not make sense when compared to burning natural gas, especially in the Singapore context where the cost of imported hydrogen is even more unattractive due to transport and storage costs.

A Costly Endeavor

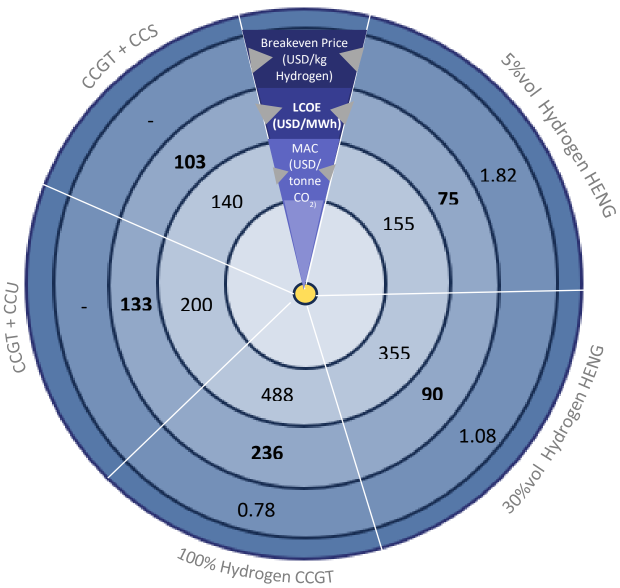
Singapore's own studies find that LCOE can increase by more than 3 times depending on the co-firing concentration of hydrogen

Analysis from KBR prepared for Singapore's Strategy Group on Climate Change[17] estimates that in 2050, the levelized cost of electricity (LCOE) could increase from USD 73/MWh using a traditional LNG Combined-Cycle Gas Turbine (CCGT), to USD 236/MWh for a 100% hydrogen-fired CCGT.

And may make electricity unaffordable for end-users

Barring any concessions or significantly higher carbon taxes, these increased costs would flow down and make it unaffordable for end consumers, especially if hydrogen should make up more than 50% of the energy mix in 2050.

Fig. 5 LCOE of hydrogen-fired power generation estimated up to USD 236/MWh in 2050



Source: KBR and Argus Media, 'Study of Hydrogen Imports and Downstream Applications for Singapore', p.53

[17] KBR, 'Study of Hydrogen Imports and Downstream Applications for Singapore', p.53

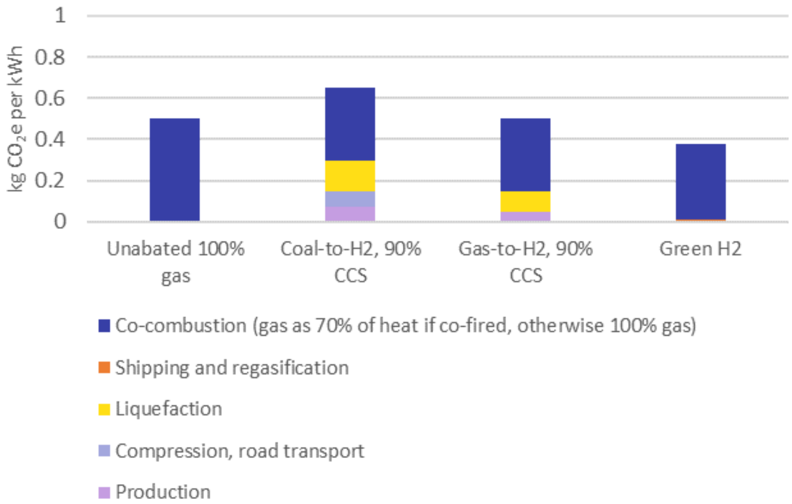
100% hydrogen firing is still unproven…

Additionally, capability for 100% hydrogen-firing is currently unproven and the emission reduction benefits of co-firing with hydrogen are marginal at best.

…and would likely only deliver marginal emission reduction benefits

According to projections[18] from an independent research group, The Breakthrough Institute, 30% co-firing with blue hydrogen assuming a 90% capture rate generates only a slight (4%) emission reduction compared with only burning natural gas for power. Even in the best-case scenario, co-firing with green hydrogen only yielded an emissions reduction of about 25% compared with natural gas-fired power generation.

Fig. 6 Supply chain emissions of hydrogen co-fired with gas for electricity



Source: The Breakthrough Institute, 'Critiquing Asia's Hydrogen Power Ambitions'

The risks of blue hydrogen discussed earlier are compounded when it is used in power generation

Additionally, the risks of low-carbon hydrogen (specifically blue hydrogen) mentioned in the previous section are compounded when it is used for power generation.

For instance, assuming hydrogen is produced using natural gas with current carbon capture rates, fugitive methane emissions are likely released when the hydrogen is being made and as well as when the hydrogen and natural gas are being burned. This may lead to larger overall fugitive methane emissions compared with only burning natural gas.

Such questionable emission reduction benefits could see capital investments in co-firing retrofits becoming uneconomical and result in stranded assets.

Importing hydrogen to Singapore adds another layer of costs and efficiency losses that make using it in power generation unattractive

Furthermore, importing hydrogen into Singapore adds another layer of costs (shipping and storage) and efficiency losses that make using it in power generation unattractive.

According to IEEFA[19], converting power to hydrogen and then using the fuel to generate power has a relatively low round-trip efficiency of 18-46%. In contrast, renewable energy storage technologies can range from 60-85% depending on their maturity.

If using blue hydrogen, high energy losses would also mean that more fossil fuels would need to be burned to produce the amount of hydrogen needed to generate a power output equivalent to simply burning natural gas.

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[18] Wang, S. , 'Critiquing Asia's Hydrogen Power Ambitions', [website], 2023, The Breakthrough Institute
[19] DiChristopher, 'Hydrogen technology faces efficiency disadvantage in power storage race', [website], 2021, S&P Global Market Intelligence

A Costly Trade-Off

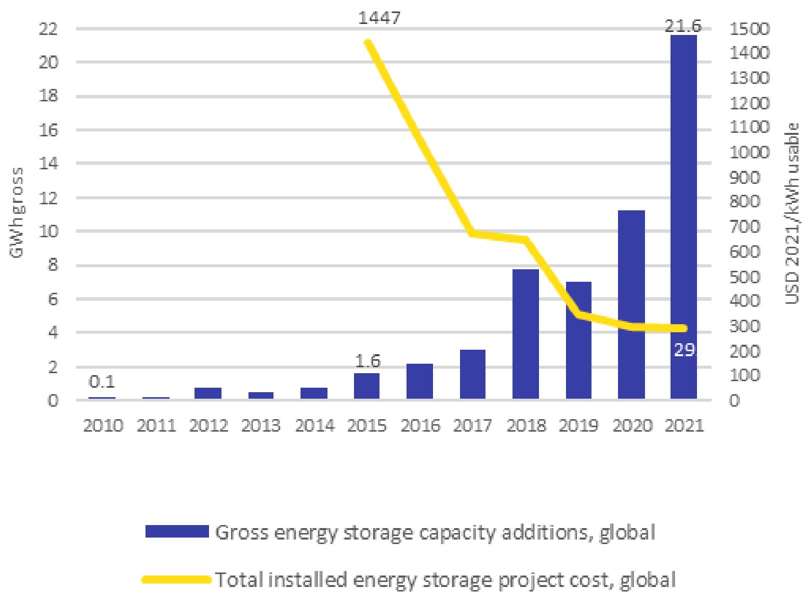
Funding hydrogen co-firing projects incurs huge opportunity costs in areas where proven, low-cost decarbonisation solutions already exist

By financing hydrogen co-firing, large opportunity costs would have been incurred where funds could have been used to develop and scale up already-proven decarbonisation solutions that currently make more economic sense.

These can include the following:

- **Scaling up renewable (solar/wind) capacity projects in countries neighboring Singapore that have high renewable power potential.** This can potentially create supply excesses that drive energy costs down and enable Singapore to import more renewable energy at lower rates.
- **Deploying battery technologies and grid-size battery storage systems** (see *Fig. 7*)
- **Investing in efforts to actualise the regional ASEAN power grid** by building more renewable electricity interconnections (e.g. Singapore-Laos hydroelectric interconnection)
- **Expanding investments for R&D and infrastructure for domestically-produced renewable energy and electrolytic (green) hydrogen, for local use in hard-to-abate sectors.** This also increases Singapore's energy security.
- **Broadening demand-management solutions including technologies that promote energy efficiency e.g. smart grid controllers and optimisers.** This will help drive down demand for electricity consumption and reduce pressure on energy imports. This also helps strengthen Singapore's energy resilience. Additionally, exporting these technologies might create market leadership and a revenue stream for Singapore.

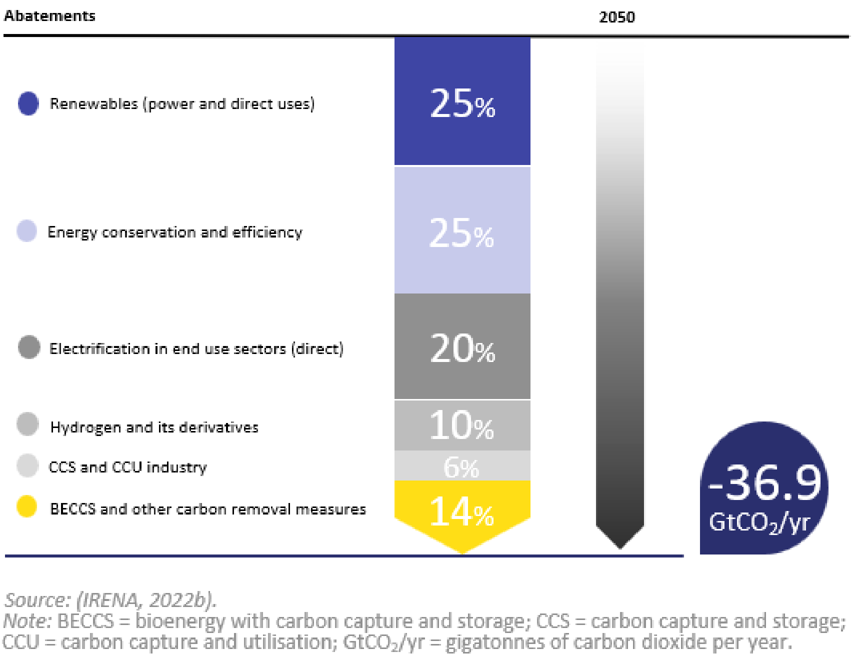
Fig. 7 Global battery storage capacity additions have had exponential growth and costs have come down dramatically



Source: IRENA, 'Low-Cost Finance for the Energy Transition', p.38.

These efforts would align with a credible 1.5-degree pathway. According to IRENA, a 1.5-degree scenario would see the use of renewable power, energy conservation and efficiency, and direct electrification comprising 70% of emission reductions, with green hydrogen and CCS contributing only 10% and 6% respectively.

Fig. 8 Energy-related CO2 emission reductions by category in the 1.5-degree Scenario by 2050



Source: *IRENA, 'Low-Cost Finance for the Energy Transition', p.52*.

Hydrogen co-firing still does not make sense even with green hydrogen. Renewable power can directly generate the same amount of power for cheaper

Even with green hydrogen, co-firing still does not make economic sense owing to the energy losses during its production mentioned above. Renewables should be used first to directly supplant fossil fuel power in the electricity mix.

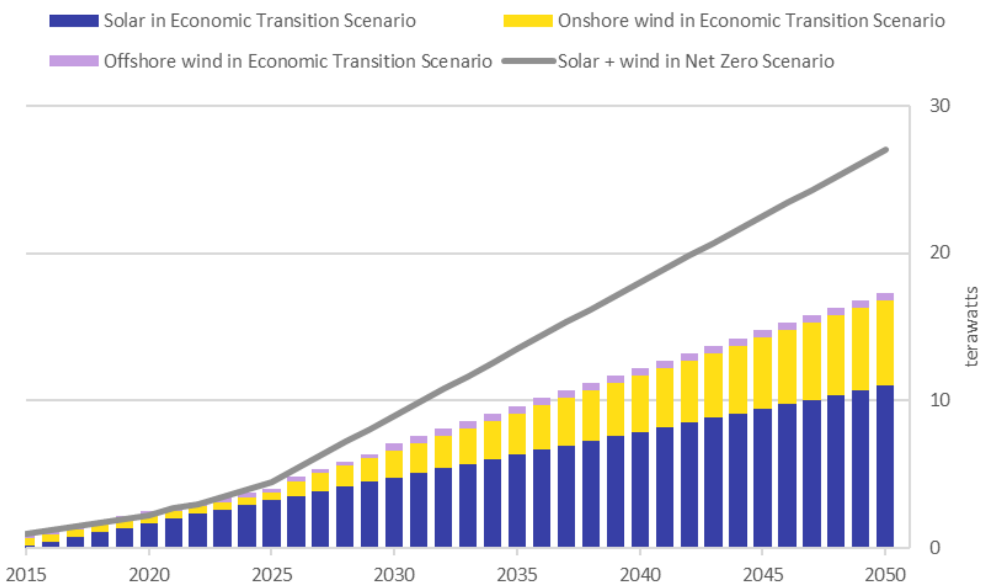
Using only surplus renewable electricity to produce hydrogen also means that the plant sits idle and is unproductive for much of the time, making hydrogen even more expensive.

Funds would be better used to expand renewable capacity, which is still well below the capacity needed for a 1.5 degree pathway

Once again, investing in green hydrogen for power means funds taken away and time delayed that could have been used to expand renewable capacity in renewable-rich regions, which are already at risk of not being able to meet global forecasted demand in 2050. BNEF's Economic Transition Scenario estimates that while wind and solar will see a sevenfold increase from current levels to around 16 TW in 2050, this would still be well short of the 28 TW needed for net zero[20].

[20] BloombergNEF, 'A Year of Breakthroughs and Setbacks for the Race to Net Zero, in Five Charts', [website], 2022, BloombergNEF

Fig. 9 Wind and solar cumulative installed capacity estimated to fall short



Source: BloombergNEF, 2022.
NOTE: The Economic Transition Scenario reflects an energy transition driven by the economic competitiveness of key technologies and assumes no new policies are introduced. The Net Zero Scenario reflects an energy transition pathway consistent with reaching net-zero emissions by 2050. See BNEF's New Energy Outlook 2022 for more.

These opportunity costs are real. Financiers who do not consider them would likely understate the transition risks in their credit models

Therefore, these opportunity costs are very real costs that are not reflected in conventional carbon accounting standards, but which would nonetheless frustrate the global ambition to reach net zero emissions, and therefore serve to understate the risks involved in the finance and investment of hydrogen projects. As a result, banks could underestimate the risks that impact credit models and transition risk scenarios of clients involved in hydrogen-for-power projects.

Hydrogen For Non-Power End Uses

Hydrogen can (and should) be used in hard-to-abate areas where renewables are not feasible

Due to the high costs of producing hydrogen, especially with added costs of importing hydrogen to Singapore, capital and resources should be prudently allocated to limit hydrogen use to areas where direct electrification is not possible or feasible ('hard-to-abate' industries).

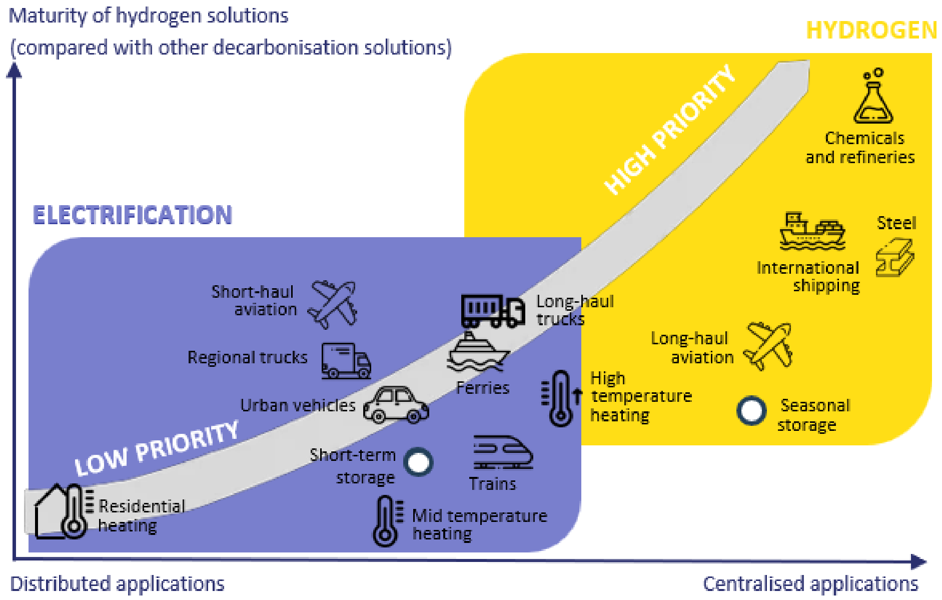
This is especially so when renewable power supply is already tight and higher interest rates have resulted in higher capital costs across the board.

Many credible third-party sources have already highlighted the end-use areas where hydrogen is most suited.

For instance, IRENA[21] points out that hydrogen should be prioritized for applications where there are currently no cost-effective alternatives and where demand already exists (e.g. the current use of unabated (grey) hydrogen for oil refining).

[21] International Renewable Energy Agency (IRENA), 'Geopolitics of the Energy Transformation: The Hydrogen Factor', [website], 2022, IRENA

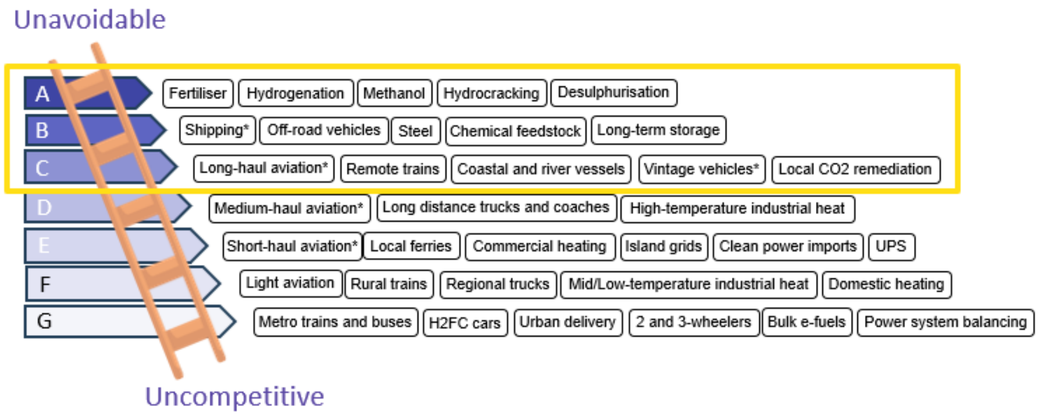
Fig. 10 IRENA's clean hydrogen policy priority



Source: IRENA, 'Geopolitics of the Energy Transformation – The Hydrogen Factor'.

Similarly, NEF (now BloombergNEF) founder Michael Liebreich's "Hydrogen Ladder"[22] points out the end-use areas where there is "no real alternative" except for hydrogen, and areas where other clean technologies like renewable electricity are likely to be more cost- and efficiency-competitive.

Fig. 11 Michael Liebreich's clean hydrogen ladder



Source: Adapted from Michael Liebreich/ Liebreich Associates, 'The Clean Hydrogen Ladder', 2021.

Financiers therefore should look to finance or invest in the "no-regret" type of projects in Singapore, to avoid risking their capital in potentially dead-end projects.

Example: Sarawak, Malaysia is currently trialing the use of hydrogen-powered public buses and proposing plans to assemble and bring hydrogen-powered passenger cars into the state. However, these hydrogen vehicles are more expensive and have higher refueling costs when compared to their battery-electric vehicle (BEV) counterparts. It remains to be seen if consumers are willing to pay more for such greener transport, or if fares have to be subsidised by the government. Moreover, they will face similar problems of high prices and low global demand if these hydrogen-powered vehicles are built for export.[23]

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[22] Michael Liebreich/Liebreich Associates, Clean Hydrogen Ladder, Version 4.1, 2021.
[23] Tham, 'Sarawak's Hydrogen Ambitions Constrained by Global Demand', [website], 2023, Fulcrum Analysis on Southeast Asia

Potential hard-to-abate activities in Singapore where hydrogen can be used: international shipping and aviation, oil refinery, chemicals manufacturing, semiconductor wafer fabrication

Potential hydrogen projects and sectors in Singapore that have low financing risk based on the above include:

- Increasing the capacity of green hydrogen derivatives (e.g. e-methanol and green ammonia) for Singapore's chemical and oil refinery industries, where there is an existing large hydrogen demand owing to Singapore's leading market positions in these activities.
- Expanding supply or building transport/storage infrastructure for sustainable aviation fuels (SAFs) or sustainable marine fuels (SMFs) as Singapore boasts leading air and maritime (bunkering) hubs.
- Developing green hydrogen as feedstock for semiconductor wafer fabrication activities, as Singapore is Asia's semiconductor powerhouse[24].
- R&D on electrolysis technologies and improving their energy efficiency
- R&D for process efficiencies on green hydrogen carriers (e.g. reducing the energy re-conversion losses of ammonia back into hydrogen)

[24] Tani, 'Chip industry doubles down on Singapore as production hub', [website], 2023, Nikkei Asia

Recommendations

Hydrogen is not a panacea to address the climate challenge and Singapore's energy transition problem

While hydrogen is certain to have a role to play in Singapore's sustainable future, informed scientific and technical knowledge has demonstrated that it is not a panacea to address the climate challenge and is best coupled with other approaches.

Financiers need to be discerning when funding hydrogen-related projects in Singapore, even though these projects are becoming more bankable due to policy support.

Banks and investors would fare better to allocate funds into hydrogen-related projects where: (1) the end activity and the hydrogen source aligns with a credible net-zero pathway; (2) hydrogen is the best or only low-carbon energy source

Capital should be prudently directed to hydrogen projects that have low financing risks and are aligned with a credible net-zero pathway.

Financiers can ask these questions when conducting due diligence on the projects including, but not limited to:

- How will the project ensure that hydrogen imports are sourced from truly low-carbon methods?
- To what extent will carbon capture and storage (CCS) technologies be relied upon?
- Are there alternatives to hydrogen that are at least as competitive in cost and technology terms, or more so, in specified end use areas?
- How will the project operators plan to mitigate or manage risks from external shocks or disruptions to hydrogen supply? (e.g. through fixed-price multi-year Power Purchase Agreements? Long-term offtake agreements with strong counterparties?)

For projects with new or unproven technologies, financiers can reduce financing risks by structuring additional protective covenants e.g. tracking progress of emission reduction or cost claims.

Financiers should also consider the "just" aspects of the projects, such as if the project adds to or decreases the affordability of energy in Singapore, or factor in safety considerations.

Alternatively, financiers can choose to rely on independent parties or external consultants with technical knowledge and an understanding of economics to aid in the due diligence on these projects.

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