Banking on Transition Technologies: Beware of Lock-In Traps

March 2023

ARE
ASIA RESEARCH
& ENGAGEMENT

Asia Research & Engagement (ARE)

ARE is a social enterprise with the mission to catalyse corporate change through investor backed engagement. We provide structured collaborative engagement programmes that emphasise dialogue between listed companies and institutional investors. Our current themes are energy transition and its financing, sustainable and responsible protein, and sustainable real estate. ARE is headquartered in Singapore and was founded in 2013.

Asia Transition Platform

The Asia Transition Platform was launched by Asia Research & Engagement (ARE) in September 2021. It has public support from eight global investors representing US$ 5 trillion in assets. The Platform aims to accelerate the energy transition in Asia to achieve the objectives of the Paris Agreement. The Platform's initial emphasis is on banks and power utility companies.

Authors

Ho Khinwai, with guidance from Kurt Metzger

Editing and comments

Benjamin McCarron, Tamara Singh, Manorama Singh

Design

The Candidate; Cover photo by Asian Development Bank on Flickr

Executive Summary

- Recent guidelines on transition technologies for Asia have been influenced by Japanese energy policies, which validate and promote CCUS and ammonia co-firing in the Power sector. These guidelines may be inappropriate for countries in Southeast Asia where the circumstances differ from Japan and investing in renewable power is viable.
- Banks seeking to achieve net-zero goals may face outsized negative outcomes associated with fossil fuel lock-in by following this guidance and financing such transition technologies. The guidelines also do not properly account for the life cycle emissions of the technologies.
- Banks should develop robust internal underwriting standards for financing transition technologies that consider their own country's economic, policy, and technological circumstances.

Introduction

This report cautions Asian banks from solely following the technology assessment approach in the ATF guidelines and Technology List

In September 2022, two important documents were published that sought to instruct how transition finance in Asia should develop.

These two documents are the *Asia Transition Finance (ATF) Guidelines (1st Edition)*[1] ('ATF Guidelines') published by the Asia Transition Finance Study Group as part of a Japan-led initiative, and the *Technology List and Perspectives for Transition Finance in Asia (1st Edition)*[2] ('Technology List') published by the Economic Research Institute for ASEAN and East Asia (ERIA).

Asia Research and Engagement and our supporting investors largely agree with the general frameworks and approach that the documents prescribe. However, we are concerned about the approach to assessing transition technologies in the Power sector.

The ATF Guidelines closely refer to the Technology List for assessing transition technologies. In its current iteration, the Technology List covers transition technologies deemed 'suitable' for the Power sector and related upstream fuel production activities.

We are concerned that Asian banks seeking to achieve their net-zero goals in their respective timelines may face outsized future negative outcomes such as fossil fuel lock-in should they solely follow these sources of guidance for the Power sector.

Such concerns have formed the bedrock of this short report.

---

[1] Asia Transition Finance (ATF) Study Group, *'Asia Transition Finance Guidelines 1st Edition',* [website], 2022, Asia Green Growth Partnership Ministerial Meeting 2022
[2] Economic Research Institute for ASEAN and East Asia (ERIA), *'Technology List and Perspectives for Transition Finance in Asia (1st Edition)',* [website], 2022, ERIA

Areas of Concern

Guidelines Do Not Consider Other Countries’ Circumstances

The guidance on transition financing at the corporate and project level is sound in the ATF guidelines

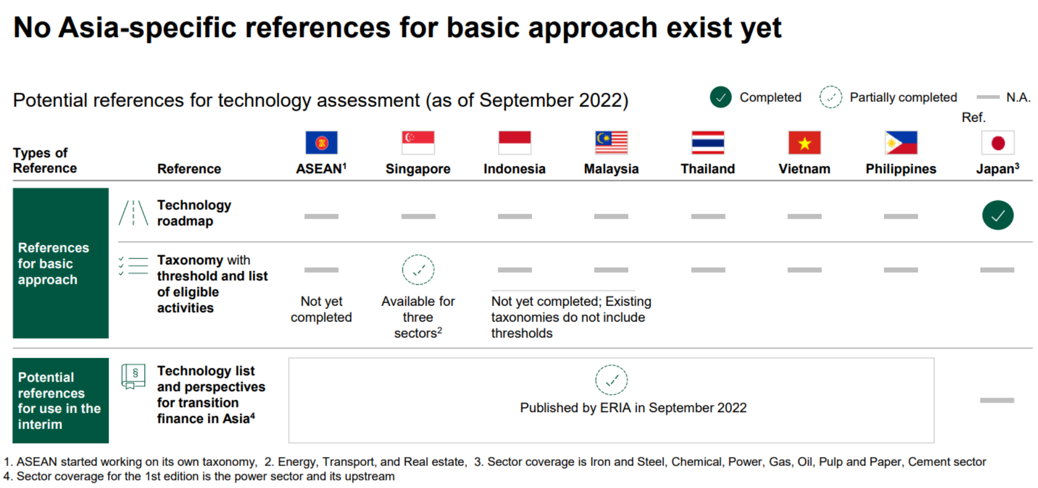
The ATF Guidelines provide sound guidance regarding transition financing assessments at the corporate and project level. The guidelines recommend that banks follow country or sector pathways, or in the absence of those, reference pathways and frameworks provided by Paris-aligned autonomous organisations such as the IEA and NGFS in the interim.

Where there is cause for concern, however, is on the technology-level assessments.

But the suggested approach for technology level assessment is concerning

The guidelines recommend that banks follow country- or sector-level roadmaps or taxonomies with thresholds and a list of eligible activities. In the absence of those roadmaps, banks are recommended to reference other literature to assess the suitability of technologies in the interim. However, the only one highlighted as available is the ERIA Technology List published in September 2022.

Fig. 1 ATF Guidelines’ collation of references for transition technology assessments



No Asia-specific references for basic approach exist yet

Potential references for technology assessment (as of September 2022)

✓ Completed   (✓) Partially completed   — N.A. Ref.

Types of Reference	Reference	ASEAN[1]	Singapore	Indonesia	Malaysia	Thailand	Vietnam	Philippines	Japan[3]
References for basic approach	Technology roadmap	—	—	—	—	—	—	—	✓
	Taxonomy with threshold and list of eligible activities	— Not yet completed	(✓) Available for three sectors[2]	— Not yet completed; Existing taxonomies do not include thresholds	—	—	—	—	—
Potential references for use in the interim	Technology list and perspectives for transition finance in Asia[4]	(✓) Published by ERIA in September 2022							—

1. ASEAN started working on its own taxonomy, 2. Energy, Transport, and Real estate, 3. Sector coverage is Iron and Steel, Chemical, Power, Gas, Oil, Pulp and Paper, Cement sector
4. Sector coverage for the 1st edition is the power sector and its upstream

Source: ATF Study Group, ATF Guidelines p.47

ATF guidelines provide a singular reference, ERIA Technology List, to assess transition technologies…

As few Asian countries have published a full technology roadmap or taxonomy with thresholds and a list of eligible activities, the Guidelines seem to highlight the ERIA Technology List as the go-to literature for banks to assess suitability for transition technologies.

…which promote transition technologies based on Japan’s policies. It is critical to consider other Asian nations’ circumstances

The Technology List published by ERIA, a Japan-led organisation, seems to validate and promote the use of transition technologies like CCUS and the co-firing of ammonia for the Power sector based on Japan’s own economic and technological circumstances, which may differ from the circumstances of other Southeast Asian nations.

Japan's Reasons for Pursuing Transition Technologies

Japan's energy policies highlight three main reasons for pursuing transition technologies

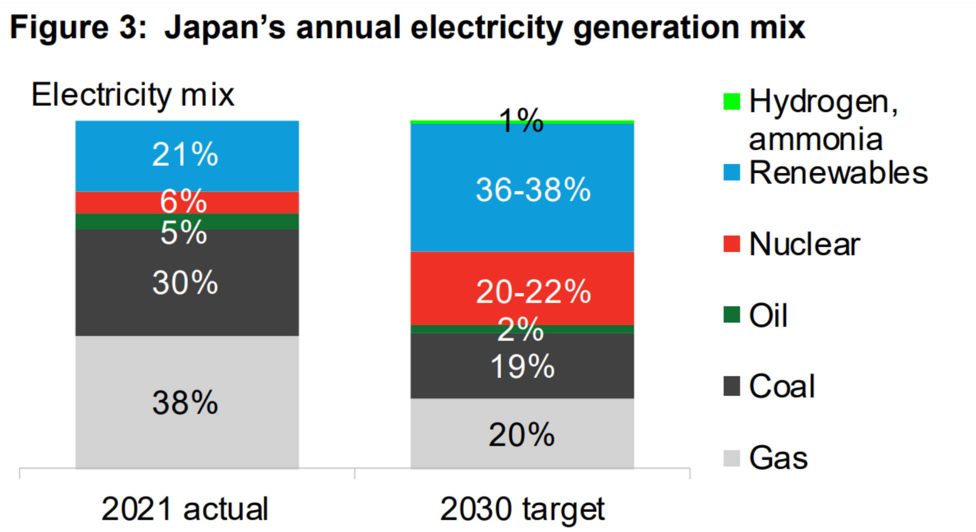
In many of Japan's energy policy documents such as the Sixth Strategic Energy Plan[3], there were several common threads as to why Japan is aggressively pursuing transition technologies such as the co-firing of ammonia and CCUS, instead of focusing on investing in renewables for power.

Energy Security and Diversity

1. Japan wants to maintain energy security and diversity, which deters policymakers to make a complete shift to renewables

Japan relies heavily on fossil fuels for power. It would be extremely costly to retire thermal power plants within global net-zero timeframes as Japan's thermal fleets are still relatively young. Furthermore, disruptions to the current energy mix will place huge stress on an already tight supply.

Fig. 2 Japan's heavy reliance on fossil fuels



Source: BloombergNEF (BNEF) report, 'Japan's Costly Ammonia Coal Co-Firing Strategy', p.2
Note: Years show Japan's fiscal year starting from April to March

According to a Wood Mackenzie report[4], policymakers prioritise the security and diversity of Japan's electricity supply and are more interested in having various policy options available. Japan would not rely on any single fuel or supplier for its power.

Therefore, Japan's ambitions for net-zero lean toward adopting retrofits like CCUS and ammonia co-firing, with some alternative renewable sources in the energy mix, rather than a full pivot where the bulk of electricity is generated from renewable sources as per the IEA net-zero roadmap.

[3] Agency for Natural Resources and Energy, 'Cabinet Decision on the Sixth Strategic Energy Plan," [website], 2021, Ministry of Economy, Trade and Industry
[4] Wood Mackenzie, 'Ammonia co-firing in thermal power plants could be worth US$100 billion in 2050,' [website], 2022, Wood Mackenzie

Limited Land Space

2. Limited land space makes it challenging for Japan to adopt renewables

Large-scale onshore wind and solar outfits are challenging in a population-dense country like Japan. Offshore wind turbines can and have been installed – but are too expensive to rely on as a main power source. Solar (including floating PVs or agrivoltaics) may be constrained due to other competing activities[5].

Thus, Japan claims to have maxed out its opportunities to decarbonise through renewables as the limited number of prime locations for solar installations have already been developed. Additionally, offshore deployment may be less cost-competitive in deeper waters than adopting transition technologies.

Grid Stability

3. Grid stability is affected by factors such as intermittency issue, higher frequencies of natural disasters and lower wind speeds

Renewable power sources face intermittency issues and are not dependable as a baseload power for Japan, a country with high energy consumption per capita. Higher frequencies of earthquakes and typhoons in Japan also affect grid stability.

Additionally, some sources[6] claim that Japan's renewable availability is not as strong due to lower wind speeds, leading to lower efficiency of renewables and a higher levelised cost of electricity (LCOE).

According to BNEF[7], Japan's grid infrastructure is not as efficient due to legacy contracts from older thermal and nuclear plants. Thus, the country would need to invest huge sums to connect to renewable power and implement balancing systems.

Japanese policymakers claim[8] that fossil fuels continue to be feasible as a baseload power at relatively lower costs compared to renewables in Japan, and if retrofitted with co-firing and/or CCUS technologies, can look increasingly attractive as carbon prices increase.

---

[5] Cheng, Blakers, Stocks, & Lu, '100% renewable energy in Japan', *Energy Conversion and Management,* 2022
[6] Mitsubishi UFJ Financial Group, *'Transition Whitepaper 2022'*, [website], 2022, Mitsubishi UFJ Financial Group
[7] BloombergNEF, *'Japan's Costly Ammonia Coal Co-Firing Strategy',* [website], 2022, BloombergNEF
[8] Agency for Natural Resources and Energy, *'Outline of Strategic Energy Plan'*, [website], 2021, Agency for Natural Resources and Energy

Other Asian Countries Do Not Have the Same Circumstances As Japan

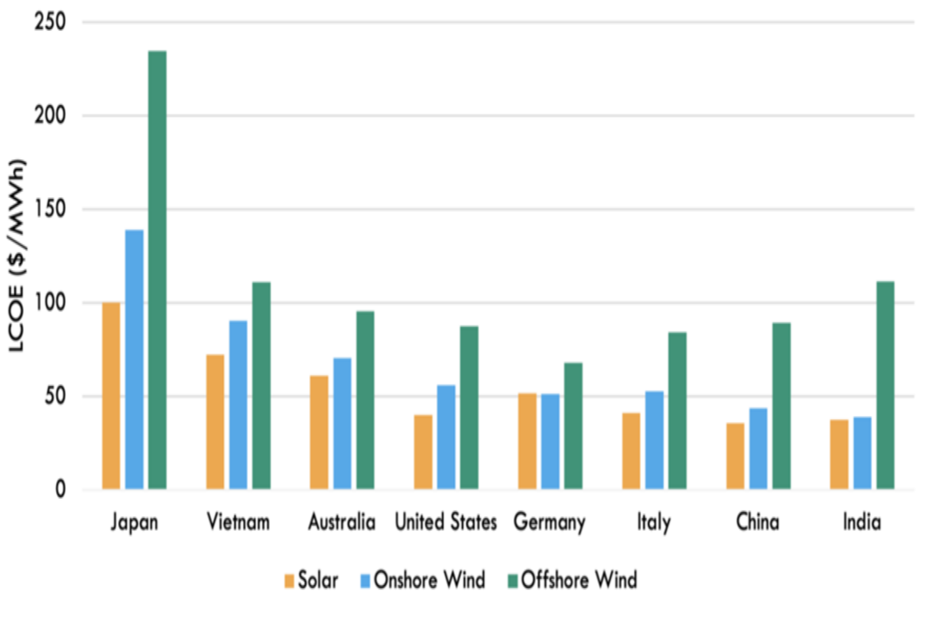
Both documents do not consider that other Asian countries do not face the same circumstances as Japan

The ATF Guidelines and the ERIA Technology List fail to highlight these important distinctions that may not hinder other Southeast Asian countries to focus on investing heavily in renewable power sources.

Such as having one of the highest constructions cost for renewables

For instance, because of the above circumstances, Japan has one of the highest construction costs for renewables in the world.

Fig. 3 Construction cost for renewables



Source: Carbon Tracker 2022, 'Put a price on it: The case for more effective carbon pricing in Japan,'

Other Asian countries may not face the same obstacles in their transitions. Banks participating in transition financing should consider that LCOE for renewables may be much more cost attractive than the CCUS or ammonia co-firing approaches favoured in Japan.

Vietnam can continue to prioritise wind power with its vast land availability; Indonesia can make use of its maritime area to deploy offshore solar PV or wind turbines

For example, land constraints or renewable availability may not be much of an issue for some countries. For instance, RSIS[9] notes that Vietnam should continue to prioritise wind power, with its vast land availability at an estimated total output of 27,750 MW, sufficiently meeting its national energy security goals. Indonesia, while having only a small land area of 1.9m km2, can make use of its uniquely large and fully accessible 6.4m km2 maritime area to deploy offshore solar PV or wind turbines which could generate sufficient electricity.

Malaysia, the Philippines, and Thailand do not face technical challenges to accommodate additional renewable capacity

In terms of grid infrastructure, grids in Malaysia, the Philippines, and Thailand currently do not face any technical challenges to accommodate additional renewable capacity due to low renewable penetration and robust grid requirements[10].

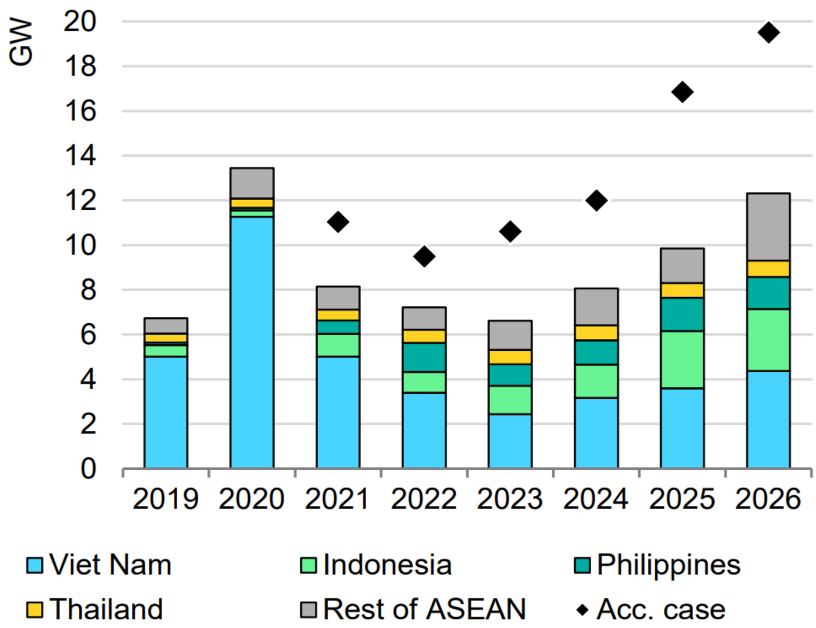
---

[9] Kembara & Kisyanto, 'ASEAN's Renewable Energy: Go for Country Advantage',[website], 2022, S. Rajaratnam School of International Studies (RSIS)
[10] Lee, *'Are Southeast Asian power systems ready for the rise of renewables?'*, [website], 2022, S&P Global Commodity Insights

ASEAN's renewable capacity is expected to grow by 65% or more in 2021-2026

According to the IEA[11], ASEAN countries are forecasted to grow their renewable capacity by 65% or higher in 2021-2026 with the expected implementation of new support policies (such as auction and feed-in tariff schemes) enabling improved grid integration.

Fig. 4 Renewable capacity additions forecast by country



Source: IEA, 'Renewables 2021 - Analysis and forecast to 2026', p.49.
Note: Rest of ASEAN comprises refers to Brunei, Cambodia, Laos, Malaysia, Myanmar, and Singapore. Acc. case refers to accelerated case.

ASEAN countries can benefit from regional interconnection of power systems and lower costs of grid upgrades

Furthermore, ASEAN countries will benefit from having a regional interconnection of power systems. By scaling renewable energy systems regionally, ASEAN countries can lower the overall costs of grid upgrades by planning the supply and minimising duplicate service provisions[12].

Banks may find it more economically attractive to finance grid capital expenditures that enable more renewable power

As grid infrastructure develops in Asia, banks may find it more economically attractive, and more aligned to both country and global decarbonisation pathways, to finance grid capital expenditures that allow for more renewable power.

The Risks of Technologies Failing to Live Up to Expectations

Several credible research sources have questioned the commercial viability, effectiveness, and cost competitiveness of transition technologies

Assessments over the advantages and disadvantages of different technologies should not be limited to simply referencing the summaries provided by the ERIA Technology List.

Numerous research has been published by creditable third-party research firms such as the Institute for Energy Economics and Financial Analysis (IEEFA) and Bloomberg New Energy Finance (BNEF) that question the commercial viability, effectiveness, and cost competitiveness of these transition technologies.

[11] International Energy Agency (IEA), *'Renewables 2021 - Analysis and forecast to 2026'*, [website], 2021, International Energy Agency
[12] International Renewable Energy Agency and ASEAN Centre for Energy, *'Renewable energy outlook for ASEAN: Towards a regional energy transition (2nd edition.)'*, [website], 2022, International Renewable Energy Agency, p.63

For many of these Asian economies heavily reliant on fossil fuels for power, investing in transition technologies like CCUS or ammonia co-firing may sound like a quick fix. However, these may result in a capex trap if they do not perform up to expectations as national and global decarbonisation timelines draw closer.

The below examples highlight some of the differing perspectives that have been published.

Emissions reduction from CCUS is unclear

ERIA notes that up to 90% emissions can be reduced using CCUS

The ERIA Technology List states that CCUS is a "deep decarbonisation" [13] technology for the Power sector and related upstream fuel production activities. It notes that up to 90% emissions can be reduced using CCUS retrofits on coal or gas plants, resulting in near-zero emissions.

But IEEFA's analysis shows an overall capture rate of no more than 72%

However, analysis from IEEFA found that a carbon capture installation at a New Mexico power generation facility would fulfil an overall capture rate (emissions from the plant and mine) of no more than 72% (or much lower), instead of the expected 90%. IEEFA mentions that such findings could be reasonably applied to other CCUS projects from coal and gas plants, as well as blue hydrogen projects[14].

And about 80-90% of the CO2 recovered has been used in Enhanced Oil Recovery projects

Additionally, IEEFA mentions that about 80-90% of the CO2 recovered throughout history has been used in Enhanced Oil Recovery (EOR) projects to produce more oil and gas, resulting in more greenhouse gas emissions[15].

Therefore, CCUS may not have the "deep decarbonisation" effects as intended, and banks should carefully consider the emission reduction benefits being proposed before underwriting.

CCUS has limited commercial viability

ERIA highlighted recent CCUS examples to show commercial viability

ERIA suggests that CCUS is in the early commercialisation stage and points to recent examples to show commercial viability. However, in this stage, IEA notes that the technology still "requires evolutionary improvement to stay competitive"[16].

But failed to highlight that there is only one small facility which is still operational in the world

Of the installation examples ERIA provided, it is noted that the Canadian example is the only coal power plant retrofitted with CCUS still in operation in the world (as of May 2022). Moreover, this is only a small facility producing 115 MW of power in Canada[17], not enough to show the feasibility of a large-scale operation.

Notably, the other successful project cited, Petra Nova, had been initially successful but was shut down in 2020 (less than four years of operation) due to high costs, despite tax credits and government financing[18].

Most CCUS projects in the past three decades have failed

A 2021 study found that most CCUS projects initiated in the past three decades have failed[19]. The study also indicated that larger plants increased the risk of projects failing or being put on hold.

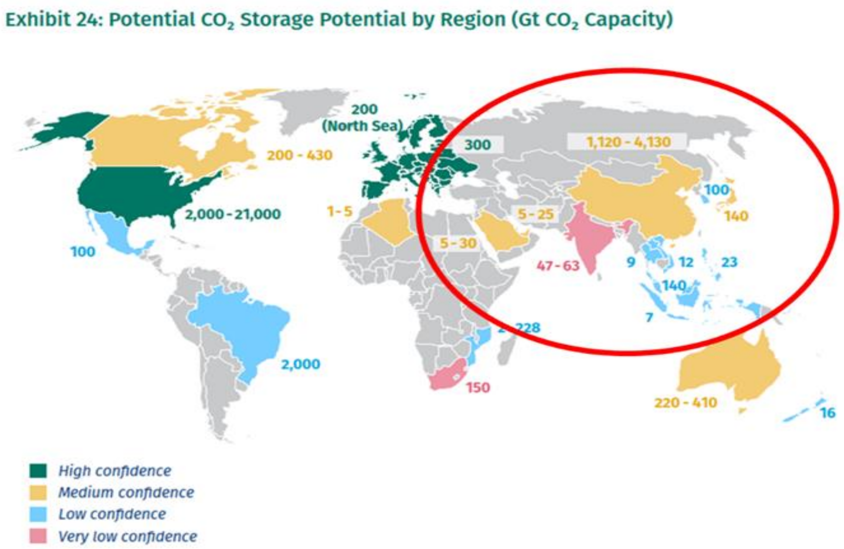
---

[13] ERIA, '*Technology List and Perspectives for Transition Finance in Asia (1st Edition)*', p.13
[14] Institute for Energy Economics and Financial Analysis, *'Carbon capture's methane problem: New report shows technology doesn't live up to the hype'*, [website], 2022, Institute for Energy Economics and Financial Analysis (IEEFA)
[15] Robertson, 'Carbon capture has a long history. Of failure.',[website], 2022, IEEFA
[16] ERIA, '*Technology List and Perspectives for Transition Finance in Asia (1st Edition)*', p.18
[17] Ohno, Okubo, & Hirose, 'Bottlenecks and Risks of CCS Thermal Power Policy in Japan', [website], Renewable Energy Institute, 2022, p.1
[18] Coca, 'Why Japan is pushing CCS in South East Asia', [website], 2022, Energy Monitor,
[19] Wang, Akimoto, & Nemet, 'What went wrong? Learning from three decades of carbon capture, utilization and sequestration (CCUS) pilot and demonstration projects,' *Energy Policy,* 2021

And even if CCUS achieves commercial scale, there may be insufficient domestic storage capacity in the long run

Even if CCUS achieves commercial scale, there may not be sufficient domestic storage capacity over the long term. Research from Wood Mackenzie and AIGCC suggest that there is low to very low levels of confidence for CO2 storage potential in much of Asia (apart from China). Even in Japan, where there is medium confidence in storage potential, analysis from TransitionZero estimates that CO_2 storage potential in Japan will be fully depleted in about a decade[20].

Fig. 5 Potential CO_2 Storage Potential by Region



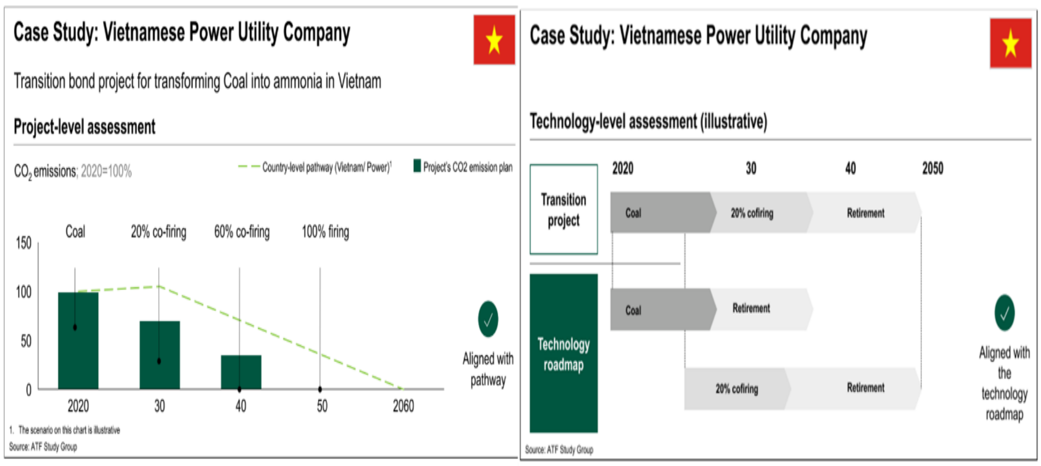
Source: Adapted from Asia Investor Group on Climate Change (AIGCC) Report, p.40

Ammonia co-firing likely to be costly with unclear emission reductions

While guidelines share ammonia co-firing's potential in emissions reduction, it may not deliver as expected and can be costly

The documents also indicate that coal co-fired with ammonia can serve as a "partial emissions reduction" technology in power generation, with the expectation that it will become a "deep decarbonisation" technology as co-firing percentages increase and eventually only burn ammonia for power.

Fig. 6 Case study of conversion of an existing coal power plant to ammonia co-firing



Source: ATF Study Group, ATF Guidelines, p.45-46

---

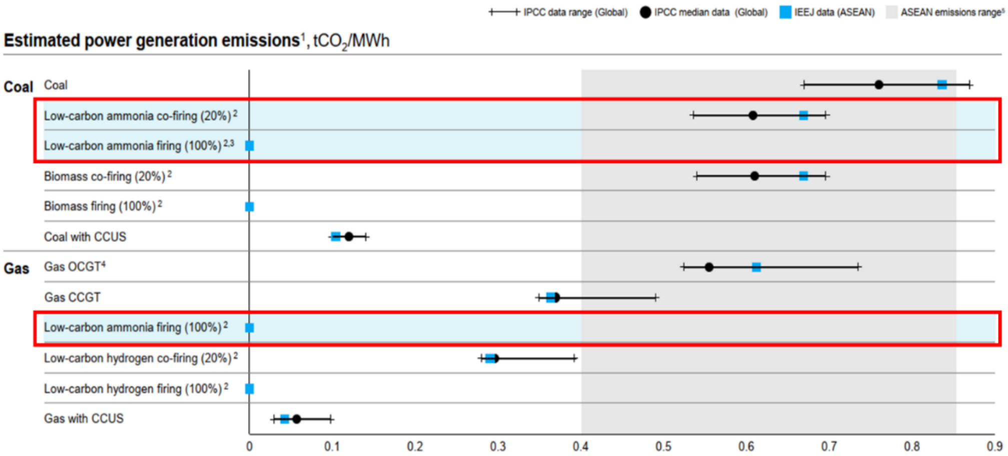
[20] TransitionZero, *'Coal-de-sac',* [website], 2022, TransitionZero, p.8

While these plans look good on paper, co-firing with ammonia may not deliver the emission reductions as expected and can be more costly.

Ammonia-fired technologies are still in prototype stage and not commercially proven

Presently, the ERIA Technology List indicates that both the 20% co-firing and 100% ammonia-fired technologies are still in prototype stages and not commercially proven[21]. Similarly, the emissions chart does not include any indication of emissions for 100% ammonia-fired power.

Fig. 7 Estimated power generation emissions



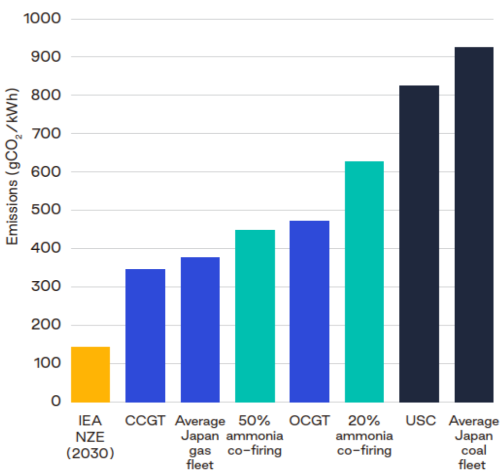
Source: Adapted from ERIA Technology List, p.49

BNEF's analysis show that ammonia co-firing emits more than twice the level of forecasted emission for power generation based on IEA NZE

Congruent with the above chart, BNEF's analysis "also found that a coal power plant retrofitted to co-fire ammonia at 50% or lower blend rates still emits more CO_2 than a natural gas-fuelled combined cycle power plant"[22].

Emissions only start to look similar to gas-power emissions at blend rates of 50% or more[23]. However, this is still more than twice the level of forecasted emissions for power generation based on the IEA NZE pathway.

Fig. 8 Emissions intensity of different power generation technologies



Source: TransitionZero, 'Coal-de-sac', p.20

---

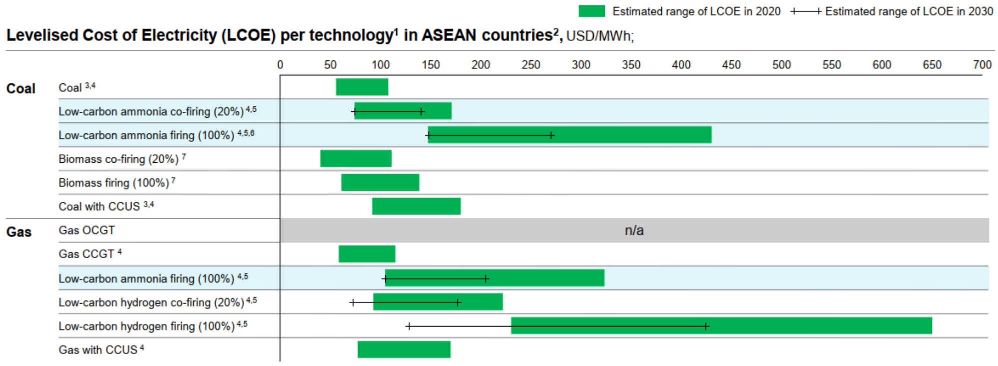
[21] ERIA, '*Technology List and Perspectives for Transition Finance in Asia (1st Edition)*', p.51
[22] BloombergNEF, *'Japan's Costly Ammonia Coal Co-Firing Strategy'*, [website], 2022, BloombergNEF, p.1
[23] TransitionZero, *'Coal-de-sac'*, [website], 2022, TransitionZero, p.20

And even if the co-firing rates can deliver low emissions, the cost of this technology may be too high

Even if the higher co-firing rates (or 100% ammonia firing) turn out to be technically feasible and deliver low emissions in line with accepted net-zero pathways, the cost of ammonia co-firing technology may be too uneconomical for power producers.

The ERIA Technology List shows the LCOE for the different transition technologies, and one can see that co-firing costs can quickly increase as blend rates go up.

Fig. 9 LCOE per technology in ASEAN countries



Source: ERIA Technology List, p.50

Furthermore, technical requirements to co-fire coal with 20% ammonia are distinct from co-firing with higher concentrations of ammonia or even burning ammonia exclusively[24]. Therefore, R&D, capex, or new retrofits may continuously be needed. NOx capture and removal equipment may also be needed to achieve the intended emission reductions.

These considerations can add heavily to the cost of producing energy using ammonia co-firing. And therefore, the current LCOEs for ammonia co-firing may be meaningfully understated.

Comparison with green technologies is absent

For a holistic evaluation, banks should compare transition technologies with green technologies

While the ERIA Technology List has outlined a list of technologies available for transition, banks should juxtapose them with green technologies such as renewable energy or green hydrogen when conducting suitability assessments. This will allow for a more holistic comparison to determine credit flows that achieve the most plausible and practical decarbonisation outcomes and alignment to the country or sector pathways.

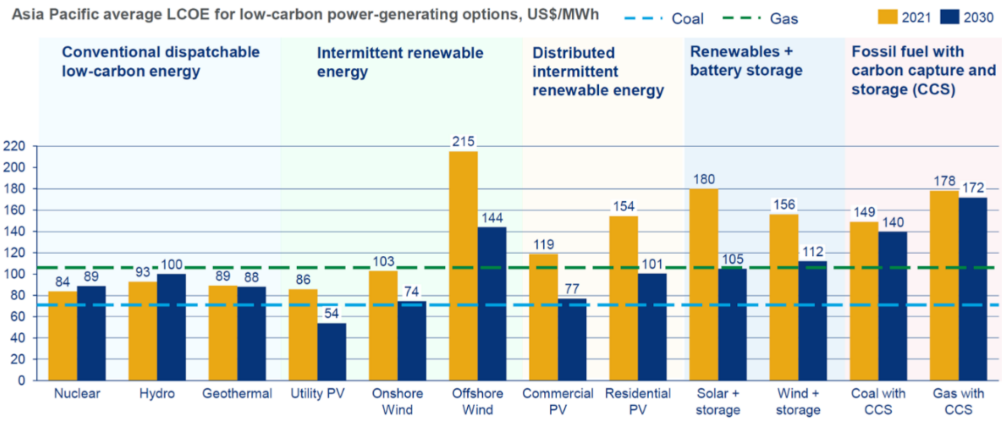
For instance, costs are a key factor in determining if a transition technology should be financed.

The Technology list does not include LCOE estimates for green technologies

While the ERIA Technology List showcases their LCOE estimates for the transitional technologies in ASEAN, it does not include a comparison with the LCOE estimates for solar and wind power.

[24] Mitsubishi UFJ Financial Group, *'Transition Whitepaper 2022'*, [website], 2022, Mitsubishi UFJ Financial Group, p.105

Fig. 10 Asia Pacific average LCOE for low-carbon power-generating options



Source: Wood Mackenzie, "Renewable power in Asia Pacific gains competitiveness amidst cost inflation"

Banks might find that financing for renewables greatly reduce portfolio risk

Depending on the large-scale availability of resources (i.e., renewable energy sources) and national decarbonisation objectives, banks might find that financing for renewable power generation would greatly reduce portfolio risk.

As it is expected to be cheaper than transition technologies in the future

Renewables are expected to be much cheaper in the future (even with storage) than transition technologies like CCUS and ammonia co-firing and is more likely to align with their own country's decarbonisation pathways.

Renewables also reduces dependence on imported fuels

Investments in renewables could also allow for reduced dependence on imported fuels. This is a notable benefit for many Asian countries concerned about energy security.

And projected to make up 90% of electric generation globally by 2050

A transition to renewables would also cut through issues of decarbonisation effectiveness and social opposition, as it is expected to make up the dominant share (90%) of electricity generation globally by 2050.

On balance, banks would benefit from understanding the economic viability of each possible configuration in its transition financing assessment.

Recommendations

Asian banks do not need to finance transition technologies to achieve net-zero goals

Asian banks do not need to finance technologies such as ammonia co-firing and CCUS in the Power sector to help them achieve a "just and orderly" transition and align to net-zero goals, contrary to what the ERIA Technology List and technology roadmaps developed by the Japanese government suggest as necessary[25] based on Japan's own transition.

Banks can finance green technologies such as renewable energy

Banks have the option to finance green technologies such as renewable energy (solar, wind, hydropower) as part of a transition strategy, even though it is not categorised as a "transition" technology.

While transition technologies should be limited to hard-to-abate sectors

Because of the abovementioned scale and effectiveness concerns, we strongly suggest that financing for solutions such as CCUS and ammonia co-firing should only be limited to hard-to-abate sectors such as cement and steel.

Banks need to build robust internal underwriting standards for each technology

Overall, banks should continue to seek out new research and evidence to build robust internal underwriting standards for each technology and evaluate them in the context of the borrower's country's decarbonisation goals and circumstances.

[25] Asia Transition Finance (ATF) Study Group, *'Asia Transition Finance Guidelines 1st Edition',* [website], 2022, Asia Green Growth Partnership Ministerial Meeting 2022, p.46

References

Agency for Natural Resources and Energy. (28 October, 2021). *Cabinet Decision on the Sixth Strategic Energy Plan*. Retrieved 8 December, 2022, from Ministry of Economy, Trade and Industry: https://www.meti.go.jp/english/press/2021/1022_002.html

Agency for Natural Resources and Energy. (October, 2021). *Outline of Strategic Energy Plan.* Retrieved 8 December, 2022, from Agency for Natural Resources and Energy: https://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/6th_outline.pdf

Asia Investor Group on Climate Change (AIGCC) . (December , 2021). *Carbon Capture and Storage in the decisive decade for decarbonisation - The case for Asia .* Retrieved 8 December , 2022, from Asia Investor Group on Climate Change (AIGCC) : https://www.aigcc.net/wp-content/uploads/2021/12/AIGCC-CCS-Report_final.pdf

Asia Transition Finance Study Group. (Sepetember, 2022). *Asia Transition Financing Guidelines 1st Edition*. Retrieved 8 December, 2022, from Asia Green Growth Patnership Ministerial Meeting 2022: https://www.aggpm2022.org/downloads/ATF_Guidelines_1st_Edition.pdf

BloombergNEF. (28 September, 2022). *Japan's Costly Ammonia Coal Co-Firing Strategy*. Retrieved 8 December, 2022, from BloombergNEF: https://assets.bbhub.io/professional/sites/24/BNEF-Japans-Costly-Ammonia-Coal-Co-Firing-Strategy_FINAL.pdf

Carbon Tracker. (26 October, 2022). *Carbon Tracker.* Retrieved 8 December, 2022, from Put a price on it: The case for more effective carbon pricing in Japan: https://carbontracker.org/reports/put-a-price-on-it/

Cheng, C., Blakers, A., Stocks, M., & Lu, B. (22 March, 2022). 100% renewable energy in Japan. *Energy Conversion and Management*. doi:https://doi.org/10.1016/j.enconman.2022.115299

Coca, N. (28 July, 2022). *Why Japan is pushing CCS in South East Asia.* Retrieved 8 December, 2022, from Energy Monitor: https://www.energymonitor.ai/tech/carbon-removal/why-japan-is-pushing-ccs-in-southeast-asia/

Economic Research Institute for ASEAN and East Asia. (September, 2022). *Technology List and Perspectives for Transition Finance in Asia (1st Edition)*. Retrieved 8 December, 2022, from ERIA: https://www.eria.org/uploads/media/2022_September_ERIA_Technology-List-and-Perspectives-for-Transition-Finance-in-Asia.pdf

Institute for Energy Economics and Financial Analysis. (1 August, 2022). *Carbon capture's methane problem: New report shows technology doesn't live up to the hype.* Retrieved 8 December, 2022, from Institute for Energy Economics and Financial Analysis: https://ieefa.org/articles/carbon-captures-methane-problem-new-report-shows-technology-doesnt-live-hype

International Energy Agency . (December, 2021). *Renewables 2021 - Analysis and forecast to 2026.* Retrieved 8 December, 2022, from International Energy Agency : https://iea.blob.core.windows.net/assets/5ae32253-7409-4f9a-a91d-1493ffb9777a/Renewables2021-Analysisandforecastto2026.pdf

International Renewable Energy Agency and ASEAN Centre for Energy. (2022). *International Renewable Energy Agency.* Retrieved 8 December, 2022, from Renewable energy outlook for ASEAN: Towards a regional energy transition (2nd ed.),: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Sep/IRENA_Renewable_energy_outlook_ASEAN_2022.pdf

Kembara, G., & Kisyanto, E. (24 June, 2022). *ASEAN's Renewable Energy: Go for Country Advantage.* Retrieved 8 December, 2022, from RSIS: https://www.rsis.edu.sg/rsis-publication/rsis/aseans-renewable-energy-go-for-country-advantage/

Lee, J. Y. (7 July, 2022). *Are Southeast Asian power systems ready for the rise of renewables?* Retrieved 8 December, 2022, from S&P Global Commodity Insights: https://www.spglobal.com/commodityinsights/en/ci/research-analysis/are-southeast-asian-power-systems-ready-for-the-rise.html

Mitsubishi UFJ Financial Group. (2022). *Transition Whitepaper 2022.* Retrieved 8 December, 2022, from Mitsubishi UFJ Financial Group: https://www.mufg.jp/dam/csr/report/transition/wp2022.pdf

Ohno, T., Okubo , Y., & Hirose, A. (May, 2022). *Bottlenecks and Risks of CCS Thermal Power Policy in Japan.* Retrieved 8 December, 2022, from Renewable Energy Institute: https://www.renewable-ei.org/pdfdownload/activities/REI-CCSbottlenecks-risks_EN.pdf

Robertson, B. (2 September, 2022). *Carbon capture has a long history. Of failure.* Retrieved 8 December, 2022, from Institute for Energy Economics and Financial Analysis : https://ieefa.org/resources/carbon-capture-has-long-history-failure#:~:text=The%20Institute%20for%20Energy%20Economics,%E2%80%94approximately%2080%E2%80%9390%20percent.

TransitionZero. (February, 2022). *Coal-de-sac.* Retrieved 8 December, 2022, from TransitionZero: https://static1.squarespace.com/static/605b4bcc5526904ff5589918/t/62066db231110622409e34eb/1644588483986/TransitionZero_Coal-de-sac_Report_final_full+report.pdf

Wang, N., Akimoto, K., & Nemet, G. F. (November, 2021). What went wrong? Learning from three decades of carbon capture, utilization and sequestration (CCUS) pilot and demonstration projects. *Energy Policy*. doi:https://doi.org/10.1016/j.enpol.2021.112546

Wood Mackenzie. (18 May, 2022). *Ammonia co-firing in thermal power plants could be worth US$100 billion in 2050*. Retrieved 8 December, 2022, from Wood Mackenzie: https://www.woodmac.com/press-releases/ammonia-co-firing-in-thermal-power-plants-could-be-worth-us$100-billion-in-2050/

Wood Mackenzie. (11 January, 2022). *Renewable power in Asia Pacific gains competitiveness amidst cost inflation.* Retrieved 8 December, 2022, from Wood Mackenzie: https://www.woodmac.com/press-releases/renewable-power-in-asia-pacific-gains-competitiveness-amidst-cost-inflation/

Disclaimer

ARE has taken all reasonable precautions to ensure that the information contained in this Report is current and accurate as of the date of benchmarking. No representations or warranties are made (expressed or implied) as to the reliability, accuracy, or completeness of such information. Although every reasonable effort is made to present current and accurate information, ARE does not take any responsibility for any loss arising directly or indirectly from the use of, or any action taken in reliance on any information appearing in this Report.

In viewing and/or printing any information available to you in this Report, you are solely responsible for bearing the relevant liabilities and risks. ARE does not warrant the accuracy of this Report or that it is free from any errors or defects. No content in this Report should be regarded as an offer or solicitation by ARE to sell investment products in any country to any person