ESI Bulletin

ENERGY STUDIES INSTITUTE
National University of Singapore

ESI Bulletin on Low Carbon Technologies for the Energy Transition

Low-carbon technologies are on the horizon. Photo by Hans from pixabay.com (Permission under Pixabay License)

INTRODUCTION

The theme of this issue is the role of low-carbon technologies in the energy transition given the changing energy landscape.

Halving emissions from peak by 2050 and then reaching net zero later this century has been a consensus by most key economies in the world. Clean energy is critical for achieving this target and is at the forefront of the global agenda. Technology plays an increasingly important role in producing and using clean technology. The emerging technologies, such as solar, wind and geothermal power, as well as carbon capture, utilisation and storage (CCUS), are expected to contribute to substantial reductions in the pathway to energy transition. Successful adaptation of technologies depends on not only on the availability of technology per se, but also on financing, which is particularly important for developing countries. This edition of the ESI Bulletin discusses the role of low-carbon technology in energy transitions in industrialised and developing economies; technology transfer through channels such as foreign direct investment and trade; and the overall energy transition landscape in the process of phasing out fossil fuels.

The first article, written by Esin Serin, is an overview of the role of technology for global net zero.

In this issue ...

Electrifying energy demand can translate into emissions savings when the electricity comes from low-carbon sources. The main low-carbon technologies adopted at present are renewables, such as wind and solar power. According to IEA, renewables could bring 35% of the cumulative emissions reductions by 2050. In contrast, countries may be more conservative when using nuclear given the costs and safety issues. CCUS is a multipurpose decarbonisation technology as it captures CO2 from large point sources across a variety of sectors. Hence, many countries are now incorporating CCUS into their decarbonization plans. Looking forwards, several industrialised countries such as UK, Germany and France have invested in a portfolio of low-carbon technologies. It is expected that renewables, nuclear and CCUS all together could contribute to up to 70% of the emissions reductions by 2050.

The second article is written by Malte Kueper, on the issue of an energy transition when energy supply is constrained across many countries around the world, particularly in Europe. It points out the possibility that increases in energy prices may push power stations back towards using cheap coal. However, some mechanism such as the emissions trading scheme and binding coal phase-out plans may help to accelerate the coal exit despite the energy shortage. It highlights that a more resilient and diversified supply portfolio should be created and green energy cooperation should be strengthened. During a piped-gas shortage, it is crucial to prevent supply-demand gaps by scaling-up LNG supply and renewable energy capacity. Looking forward, it is still hopeful that higher oil and gas prices feed through into an accelerated energy transition, although energy shortages may occasionally interrupt the process.

Do Huynh-Son authored the third article, discussing low-carbon technologies in Vietnam, one of the most economically promising countries in Southeast Asia. Heavily dependent on coal for power generation, the country aims to reduce coal generation capacity to 30.1 GW, contributing to 20% of the electricity mix by 2030. Besides reducing coal, low-carbon technologies will contribute to a large extent the country's decarbonization. In addition to solar and wind power, hydrogen and power storage are also targeted as important technologies for decarbonizing the economy. The Vietnamese government is confident that further increases in national competitiveness and resilience to external shocks will be enabled by transitioning towards a new green growth model of development, making low-carbon technologies central to the country's energy policy.

The last article is on collaboration between Southeast Asia and Northeast Asia in CCUS technology, produced by Son Minhee. As one of the fastest growing economic regions in the world, electricity demand has soared in recent years. That nearly 50% of the power plants in the region are fossil based makes it challengeable for the region's decarbonization. CCUS hence offers a solution to help mitigate carbon emissions. However, technical and financial obstacles may hinder its development. The two Northeast Asian countries, Japan and Korea, are actively exploring CCUS technology, not only domestically, but also overseas. Some Southeast Asian countries host Japanese and Korean CCUS/CCS projects. Given that the oil and gas sector in Southeast Asian countries are mostly state-owned, it is less difficult to adopt CCUS. Japan and South Korea enter the Southeast Asian market as not only an investment destination but also as a testbed for new markets as well.

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Unlocking the role of technology for global net zero

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To reduce or capture emissions? Photo by Peggychoucair from pixabay.com (Permission under Pixabay License)

Technology has already been a key enabler of reducing emissions from energy systems around the world but given that global net zero requires going much further and faster, its role needs to grow. Fortunately, despite differences in the prospects for individual technologies, the pathway to net zero for the global energy system is broadly clear. It involves accelerating the deployment of technologies required for achieving two broad objectives: electrifying as much of the energy demand as possible, and fully decarbonising electricity supply. Electrifying demand is made possible by technological switches such as electric vehicles replacing internal combustion engine vehicles on the roads and heat pumps replacing incumbent technologies like natural gas or oil boilers to heat buildings. In industry, electricity can be used instead of fossil fuels to provide low- and medium-temperature heat or to power certain steel production processes.

Of course, electrifying demand only translates into emissions savings if the electricity is coming from low-carbon sources. Decarbonising existing supply will not be enough either, as the world's demand for electricity is likely to more than double from current levels by 2050.[1] Substantial amounts of wind power and solar PV have been deployed around the world over the past decade while costs have fallen – solar PV unit costs by 85% and wind power by 55% in the period from 2010 to 2019.[2] This was not by luck but a product of innovation policy packages involving deliberate technology choices made by governments in many countries over decades.[3] The global energy crisis in the aftermath of the COVID-19 pandemic has also led countries to seek ways to reduce their reliance on imported fossil fuels, reinforcing the case for an accelerated uptake of renewables. Renewables (and in particular, wind and solar) could bring 35% of the cumulative emissions reductions along the net zero transition of the energy system through 2050.[4]

In contrast to broad agreement on a greater role for renewables, countries have widely varying views on the role that nuclear should play in the energy mix. Safety has become the primary concern about nuclear for many countries following the Fukushima disaster triggered by the tsunami of March 2011 in Japan. Globally, 48 GW equivalent of nuclear capacity is estimated to have been lost since 2011 due to plants that were either permanently shut down or did not have their operational lifetimes extended following Fukushima.[5] Nuclear is also commonly criticised on cost grounds as unlike renewables, the cost of electricity from nuclear has risen rather than fallen in the past decade.[6] But this might be more about the policy environment that has surrounded nuclear rather than an inherent aspect of nuclear technology: the world has not built many nuclear power plants in recent years, leaving supply chains small, uncompetitive, and unable to benefit from economies of scale.[7] The fact that some countries are able to deliver nuclear projects at lower costs than others could suggest that some costs are context-specific and, in theory, avoidable.[8]

Many jurisdictions are taking a refreshed look at nuclear with an aim to reduce both their emissions and reliance on imported fossil fuels. For example, the EU included nuclear in its REPowerEU plan; the US introduced tax credits for nuclear plants in its Inflation Reduction Act; and the UK committed to progressing up to eight new nuclear reactors by 2030 in its British Energy Security Strategy, all within last year. Furthermore, continued investment into innovation in the sector can bring advanced nuclear technologies to market, in turn enabling nuclear to deliver emissions reductions not just in the electricity sector but also in heat and industry. Switching from coal and oil to lower carbon fuels including nuclear is set to enable 5% of the emissions reductions under a pathway that takes the global energy system to net zero by 2050.[4]

Electricity-based solutions are set to deliver majority of the savings on the way to global net zero but they are not the full story. Some aspects of energy demand might be either technologically infeasible or too expensive to electrify. Carbon capture, usage and storage (CCUS) is a multipurpose decarbonisation technology in the sense that it can enable the capture of CO_2 from large point sources across a variety of sectors including power generation, hydrogen production and industrial facilities. Certain CCUS applications can also remove existing CO_2 from the atmosphere. Many governments are now looking at CCUS as part of their national decarbonisation strategies. Although carbon capture is not a new concept (as it has been used in certain industrial and fuel processing applications for decades), its explicit use for emissions reductions is relatively new. This means that many related technologies are still at an early stage of commercialisation and therefore at a high point in the cost curve. Policies such as the 45Q tax credits[9] in the US have the potential to change that by rapidly increasing deployment and driving down costs through learning between successive projects. CCUS is included in most of the projected pathways to global net zero and is expected to deliver 11% of the necessary reductions in energy-related emissions by 2050.[4]

Investing in a diverse portfolio of low-carbon technology could also unlock a new growth model for the world's economies. In the past few decades, many countries including the UK, Germany and France have shown signs of decoupling their economic growth from emissions, even when taking offshored production into account.[10] That means even though some of these countries have shifted away from manufacturing to less carbon-intensive, service-based industries, that cannot be the only explanation for the decoupling. The transition away from fossil fuels, uptake of low-carbon energy technologies and efficiency improvements have also contributed, enabling the same or even higher levels of economic activity to be sustained without the emissions that have historically been tied to it.[10] Low-carbon technology itself can become a growth opportunity for countries that act early to build comparative advantage and capture parts of the global supply chain for which demand is growing.

Electrification, renewables, nuclear and CCUS combined could deliver up to 70% of the emissions reductions needed to bring the global energy system to net zero by 2050.[4] With the environmental *and* economic case for low-carbon technology well-established, it is now down to more ambitious and decisive policy from governments around the world to make this reality.

1 International Energy Agency (2021) Net Zero by 2050: A Roadmap for the Global Energy Sector. Paris. https://www.iea.org/reports/net-zero-by-2050

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4 International Energy Agency (2021) Cumulative emissions reduction by mitigation measure in the Net Zero Scenario, 2021-2050. Paris. https://www.iea.org/data-and-statistics/charts/cumulative-emissions-reduction-by-mitigation-measure-in-the-net-zero-scenario-2021-2050

5 Paillere H and Donovan J (2021) Nuclear Power 10 Years After Fukushima: The Long Road Back. International Atomic Energy Agency. https://www.iaea.org/newscenter/news/nuclear-power-10-years-after-fukushima-the-long-road-back

6 Roser M (2020) Why did renewables become so cheap so fast? Our World in Data. https://ourworldindata.org/cheap-renewables-growth

7 Fitzpatrick M (2017) Nuclear power is set to get a lot safer (and cheaper) – here's why. The Conversation. https://theconversation.com/nuclear-power-is-set-to-get-a-lot-safer-and-cheaper-heres-why-62207

8 Berthélemy M and Rangel L E (2013) Nuclear reactors' construction costs: The role of lead-time, standardization and technological progress. Interdisciplinary Institute for Innovation, Working Paper 14-ME-01. https://hal.science/hal-00956292/document

9 Section 45Q of the Unites States Internal Revenue Code provides a tax credit for CO_2 storage which is intended to incentivise the deployment of CCUS. A variety of CCUS applications are eligible. The passage of the Inflation Reduction Act in 2022 has increased the value and expanded the scope of 45Q tax credits.

10 Ritchie H (2021) Many countries have decoupled economic growth from CO_2 emissions, even if we take offshored production into account. Our World in Data. https://ourworldindata.org/co2-gdp-decoupling

Emerging stronger from the energy crisis

Mr. Malte Kueper, Researcher for Energy and Climate Policy at the German Economic Institute (IW)

Russia's war in Ukraine was a turning point in the global energy landscape. The attack by the world's largest fossil fuel exporter has thrown energy markets into turmoil, faced consumers with supply gaps and price shocks and put many countries into an ongoing energy crisis. With fossil fuels pushing back into the center of the political and societal discussion, concerns are arising that short-term fossil fuel supply policies could undermine long-term decarbonization goals. On the contrary, the soaring prices for oil and gas could in fact become a catalyst for the world's transition towards clean energy. Recent figures from the IEA show that despite the energy crisis, clean energy investment has grown and been able to extend its lead over fossil fuels. At the same time, however, investment in fossil fuels continues to rise as well and is close to its pre-Covid level.[1] It is hopeful that with the right policy measures the energy crisis can be overcome without neglecting the global energy transition.

Turn the global electricity transition into an energy transition

International cooperation can help deal with supply disruptions. Illustration by Mohamed_Hassan from pixabay.com (Permission under Pixabay License)

The energy transformation often focuses strongly on the electricity sector while neglecting efforts in other sectors. While there is no doubt that fully decarbonizing the electricity sector will be one of the most crucial steps towards a green energy system, it alone will not be enough to achieve zero emissions as it also requires a fast ramp-up of those technologies that will utilize this green electricity in the end, electric vehicles or heat pumps for example.

Furthermore, there are hard-to-abate sectors, which cannot eliminate their emissions solely with renewable electricity. Examples include primary steel production, which will have to rely on the use of low-carbon hydrogen, or cement production, which will require CCS to get rid of otherwise unavoidable process emissions. In reality, most of the needed technologies for the decarbonization of these sectors are not yet commercially available on a large scale and will take time to roll-out. Analyses of the currently globally announced electrolysis projects, for example, indicate that green hydrogen will continue to be a scarce commodity in the next upcoming years.[2] Policymakers therefor ought to provide the suitable framework conditions for their market rollout.

Prevent a comeback of coal in global electricity generation

Coal is the largest single source of CO_2 emissions and its global phase-out is one of the top priorities for limiting global warming. Two-thirds of global coal consumption are used for electricity and heat, making it the largest source of electricity generation.[3] Despite an increasing electricity demand, the share of coal in global power generation declined from 40.8% in 2013 to 36.5% in 2021. At the same time, the share of wind and solar power tripled from 3.4% to 10.3%. While the rate of wind and solar scale-up is highly likely to increase due to technical and economic improvements, it alone will not be fast enough to push coal out of the market as quickly as required. Hence, the fuel-switch from coal to less polluting natural gas remains an important transitional step.

The increased gas prices could, however, once again favor the use of coal compared to gas in certain price-sensitive countries, especially in Asia. While such a reversion to coal can be politically endorsed as done in the European Union last year to temporarily dampen the gas price shock, it can be detrimental to long-term climate goals if gas is permanently replaced with coal. Carbon pricing such as the EU's emissions trading scheme (ETS) and binding coal phase-out plans with international support particularly for developing and emerging countries can help to accelerate the coal exit despite the current energy crisis.

Strengthen international energy cooperation

Understandably, skepticism towards a dependence on energy and raw material imports has grown in many countries since the beginning of the war. The overall lesson from the crisis, however, should not be to swap energy imports for energy protectionism, but to create a more resilient and diversified supply portfolio and increase green energy cooperation. This includes also international coordination to create a level playing field for carbon pricing to prevent carbon leakage into regions with less stringent climate policies which would not benefit the climate. Overall, the global energy crisis requires a global response, if it is not to result in unintended increases of emissions or geopolitical shifts in the long-term. A good example for this is the global LNG market.

When Russia stopped most of its pipeline gas supplies to the West over the course of the last year, large quantities of gas had to be replaced in the EU. As a response, the EU countries reduced their gas consumption, promoted fuel-switching and bought vast amounts of LNG to avoid more severe supply shortages. Within a year, the share of LNG in total EU gas imports rose from 21 to 36%. However, with global LNG export capacity utilization already over 80% before the war, there is a considerable risk that the increasing LNG demand from financially solvent customers could lead to a squeezing out of more price-sensitive buyers in developing and emerging countries. In June 2022, Bloomberg covered a story on electricity shortages in Pakistan as a result of the skyrocketed LNG prices.[4]

With global gas demand expected to increase by 2030, especially due to the growth in Asia where replacing coal with gas in electricity production is a key policy for reducing CO_2 emissions, it will be crucial to maintain the global perspective, even during the crisis, and to prevent supply-demand gaps by scaling-up LNG supply and renewable energy capacity.

2023 – what is in for the energy transition?

While fossil fuels pushed back into the center of the political and societal discussion, the price shock for oil and gas could in fact become a catalyst for the world's transition towards clean energy in the long-term. If the expansion of low-carbon alternatives like wind, solar, hydrogen or nuclear power can be accelerated, while at the same time recognizing the importance of natural gas as a bridging technology, the year 2023 has the potential to be considered an accelerator for the phase-out of fossil fuels in retrospect.

1. World Energy Investment 2023, https://iea.blob.core.windows.net/assets/8834d3af-af60-4df0-9643-72e2684f7221/WorldEnergyInvestment2023.pdf
2. Zukunft Erdgas: Wie viel brauchen wir noch und was kommt dann?, https://www.iwkoeln.de/fileadmin/user_upload/Studien/policy_papers/PDF/2023/IW-Policy-Paper_2023-Zukunft-Erdgas.pdf
3. Government of Canada, Coal facts, https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/coal-facts/20071
4. https://www.bloomberg.com/news/articles/2022-06-24/pakistan-faces-deeper-power-crisis-as-lng-becomes-too-expensive?leadSource=uverify%20wall

The Orientation of Low-Carbon Technologies to 2050 in Vietnam

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Introduction to 2023

The long-awaited National Power Development Master Plan 8 for 2021 – 2030 with a Vision up to 2050 was finally approved on the 15th of May in 2023 by Deputy Prime Minister Trần Hồng Hà with Decision 500/QĐ-TTg (2023). The two-year delay on how to realise Vietnam's 2050 Net-Zero objectives in power generation largely stemmed from critical decisions on the role of coal and renewables; in the end, low-carbon options prevailed due to the determination to achieve the country's climate targets and changes in the financial calculus and means around coal and renewables finance.

Optimisations to 2030

The headline target for the total power generation capacity serving domestic demand is set at 150.5 GW for 2030 (this excludes power exports, existing rooftop solar, and renewable energy converted to other forms of energy such as hydrogen).[1] Up 117% from 69.3 GW in 2020, this is already the 2nd highest in ASEAN behind Indonesia, and 23rd in the world.[2] The 2030 mix by renewables type is 21.9 GW (14.5% of total capacity of power plants) for Onshore Wind; 6 GW (4%) for Offshore Wind; 12.9 GW (8.5%) for Solar (excludes existing rooftop solar); 29.3 GW (19.5%) for Hydropower; 2.4 GW (1.5%) Pumped-Storage Hydroelectricity; and 2.3 GW (1.5%) for Biomass. In total, renewables are targeted to make up 30.9 – 39.2% of the power generation mix in 2030. Critically for Vietnam's Net-Zero commitments, generation capacity from coal will be limited to 30.1 GW (20%), reduced from an earlier October 2021 draft which had it at 40 GW. Explicitly recognised in the final text is that Vietnam is likely to encounter serious financing problems from abroad for any generating capacity from coal beyond this limit. This is true for both promulgated domestic policy and signed international commitments, the most critical of which is the Just Energy Transition Partnership (JETP) with the G7 countries plus Denmark and Norway, whereby Vietnam will unlock US$ 15.5 bn on better-than-private-capital-market terms over the next three to five years.[3]

The majority of remaining power generation capacity will be made up of natural gas: 14.9 GW (9.9%) will be from thermal plants running on gas from domestic fields, and 22.4 GW (14.9%) from LNG. Further into the future, the only other options to meet Vietnam's continually increasing energy demands to 2050 with the above constraints are low-carbon technology options.

Innovations to 2050

The scale of the challenge, if the past decade is anything to go by will be immense. Total Electricity Produced and Demanded increased between 2011 – 2019 at an average of 10.2% per annum. In 2020, demand still increased by 2.9%, totalling 248 billion kWh for the full calendar year. From the near-term socio-economic development planning perspective, this was just about covered by an increase in installed capacity in the same period of 13% on average per annum.

Due to the already high share of variable energy resources and limitation on the expansion hydropower baseload power in Vietnam's power generation mix, further increases in the buffer generation and transmission capacity are deemed necessary. To 2050, installed capacity targets for existing renewables options are as follows: 60.1 – 77.1 GW (12.2 – 13.4% of total capacity of power plants) for onshore wind; 70 – 91.5 GW (14.3 – 16%) for offshore wind; and 168.6 – 189.2 GW (33 – 34.4%) for solar.[4] Hydropower, already near its full technical potential, will only see very modest increases from 2030 onwards. In total, renewable energy is targeted to make up 67.5 – 71.5% of the power generation mix in 2050.

Vietnam's journey towards a low carbon economy. Photo by ThuyHaBich from pixabay.com (Permission under Pixabay License).

The more interesting difference between 2030 and 2050 targets however lay Vietnam's selection of new technologies for its 2050 power generation mix, which in 2030 are only on a small scale or not yet included. Selected installed capacity targets for these technologies are: 30.7 – 45.6 GW (6.2 – 7.9%) for power storage; 4.5 GW (0.9%) for co-generation electricity using residual heat, blast furnace gas, and by products of technological lines in industrial facilities; and 25.6 – 32.4 GW (4.5 – 6.6%) for thermal power using biomass and ammonia.

This is in addition to the detailed role for hydrogen in the above picture which deserves special mention. The installed capacity targets involving hydrogen are: 7 GW (1.5%) for power plants originally running on gas from domestic fields converted to run entirely on hydrogen; 4.5 – 9 GW (0.8 – 1.8%) for power plants running on a mix of LNG and hydrogen; and finally 16.4 – 20.9 GW (3.3 – 3.6%) for power plants originally running on imported LNG, converted to run entirely on hydrogen.

Conclusion

The objective of low-carbon technologies is in the decoupling of economic growth and emissions growth. In Vietnam, this is defined in detail in the National Green Growth Strategy for 2021 – 2030 with a vision up to 2050 1658/QĐ-TTg (2021) with the working assumption that further increases in national competitiveness and resilience to external shocks will be enabled by transitioning towards a new green growth model of development.[5] This places low-carbon technologies such as those targeted above at the centre of climate policy, and its place is now more secure with the approved Power Development Plan 8.

The National Green Growth Strategy (2021) also attaches importance to the reduction of greenhouse gas emissions, and for the power generation, these are now promulgated targets: assuming fully realised JETP financial support, under 170 million tonnes of C02 in 2030 (204 – 254 million tonnes without JETP support); and 31 million tonnes by 2050. As for the role of low-carbon technologies in Vietnam's other sectors such as oil and gas, petrochemicals, industry and transportation, the upcoming National Energy Master Plan for 2021 – 2030 with a vision up to 2050 will be similarly important in defining their contribution to emissions reduction.

1 Deputy Prime Minister of Vietnam, 'Decision of the Prime Minister No. 500/QĐ-TTg of 2023 on Approving the National Power Development Master Plan for the Period 2021 - 2030, with a Vision to 2050' (Prime Minister's Office, Vietnam, 15 May 2023), 8.

2 Institute of Energy, 'The National Power Development Master Plan for the Period 2021 - 2030, with a Vision to 2050' (Vietnam Ministry of Industry and Trade, April 2023), 33.

3 Ha-Duong, Minh. 'Vietnam's Just Energy Transition Partnership: CIRED/VIETSE background report'. (HAL, 2023)

4 Deputy Prime Minister of Vietnam, '500/QĐ-TTg of 2023', 9.

5 Deputy Prime Minister, 'Decision of the Prime Minister No. 1658/QĐ-TTg of 2021 on Approving the National Green Growth Strategy for the Period 2021 - 2030, with a Vision up to 2050' (Prime Minister's Office, Vietnam, 1 October 2021).

Collaboration between South-East Asia and North-East Asia in CCUS

Son Minhee, Research Associate, ESI

Introduction

South-East Asia, one of the most rapidly growing regions in the world, has seen a significant rise in energy demand, which has largely been met through the heavy reliance on fossil fuels.[1] Nearly 50% of the fossil-based power plants in the region, which contribute significantly to greenhouse gas emissions, were established more than a decade ago. CCUS (Carbon Capture, Utilisation, and Storage) offers a solution for one of the most challenging sources of emissions: heavy industry, which currently accounts for almost 20% of energy-sector emissions in South-East

How to capture? At what cost? Photo by shogun from pixabay.com (Permission under Pixabay License)

Asia. Moreover, South-East Asia, with its oil and gas fields, possesses an optimal geographical advantage for implementing CCS, which can lead to increased value by introducing CCU technology to thermal power plants and industries with high greenhouse gas emissions in the future. However, South-East Asia still faces technical limitations in implementing CCUS technology, prompting companies from various countries to explore opportunities for collaboration. Specifically, Japan, and South Korea are actively seeking cooperative ventures.

Opportunities and Challenges for CCUS projects in South-East countries?

South-East Asian nations benefit from competitive CCUS technology costs and advantages in the upstream oil and gas sector. The area gains from established operations and maintenance procedures, solid health, safety, and environmental standards, mature local supplier chains, effective well delivery, and these factors.[2] The compression costs were 20% cheaper, transportation costs were 38% cheaper, and storage costs were 67% cheaper compared to the McKinsey's benchmark cost. State-owned businesses in South-East Asia are in a good position to drive CCUS projects, as opposed to private sector players as has traditionally been the case in the US and Europe. While the framework for development of CCUS has not yet developed fully, PETRONAS of Malaysia has emerged as a regional leader, with the focus on its Kasawari project. Closely behind is Indonesia at the 'white paper' stage, recently releasing new basic regulation for CCUS on March 2023.[3]

Moreover, there is no carbon market yet in South-East Asia. Therefore, governments and businesses must look beyond local point-source-to-sink initiatives and begin considering the specifications of a potential cross-border CO_2 transit and storage market.[4] However, the price of CCUS for developers is unknown. Projects will stagnate in the absence of income visibility and cost savings from reduced emissions. CCUS is still a nascent technology and is expected to consume large budgets.

Transporting carbon across seas is challenging, and most South-East Asian countries are not Contracting Parties to the London Protocol. It prohibits international CO_2 transport for subaerial storage.[5] However, amendments to Article 6 of the LP introduced changes regarding waste export, sharing subsea structures, and CO_2 exports for subsea storage. Compliance involves submitting declarations to the IMO Secretary-General and informing involved parties. South-East Asian countries involved in CCS projects would likely follow relevant international agreements and their national laws.

Strategies of North-East Asian countries in the CCUS project

Two North-East Asian countries, Japan and Korea are actively exploring the adoption of CCUS technology, with a specific focus on industries that contribute significantly to greenhouse gas emissions, as part of their efforts to achieve carbon neutrality. Both countries are considering the comprehensive value of South-East Asia, including storage exploration, carbon material production, and carbon hydrogen, to facilitate the implementation of CCUS in the region.

Japan early initiated bilateral agreements with partner countries through the Joint Crediting Mechanism (JCM) in 2013 to develop carbon reduction projects in developing countries. Throughout this South-East Asian's rising energy demand, Japan is aware of how critical it is to spread CCUS technology. Through the establishment of the Asia CCUS Network, Japan is actively exploring avenues to introduce CCUS technology to South-East Asian countries and Australia.[6] Currently, there are nine

CCS and CCUS projects underway in Thailand, Malaysia, and Indonesia. This draws on from deep experience collaborating with NRG Energy in the United States to transform the Petra Nova CCS project in USA into a successful venture with the help of tax deductions and government financing.[7]

South Korea is actively seeking to secure gas fields that are scheduled for discontinuation and can be converted into carbon storage sites. Major engineering, procurement, and construction (EPC) companies and refineries are pursuing carbon storage projects overseas, particularly in Malaysia and East Timor.[8] Furthermore, the Korean government is preparing for the Carbon Contracts for Differences (CCfD), which will be linked with the emission trading system to reduce investment uncertainty in carbon-neutral technologies. Through CCfD, the government will guarantee companies a fixed carbon price for a certain period, specifically for CCUS technologies that may have low economic feasibility.
Source: Authors' summery

Conclusion

South-East Asian nations benefit from competitive CCUS technology costs and advantages in the upstream oil and gas sector which are mostly state-owned. It could be in a good position to powerfully drive CCUS projects. However, there are insufficient regulations for construction and CO_2 transportation and carbon economic frameworks for these projects. The North-East Asian countries are entering the South-East Asian market as targets for their energy plans and as testbeds for new markets. Japan has experience on how to see through these projects and to make collaboration with partner countries. The Korean energy and construction companies are also exploring to undertake CCUS projects in this area.

1 International Energy Agency. "Carbon Capture, Utilisation and Storage: The Opportunity in South-East Asia." (2021).

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3 Baker McKenzie. "Indonesia and Japan: Indonesia introduces CCS/CCUS Regulation", https://insightplus.bakermckenzie.com/bm/projects/indonesia-introduces-ccsccus-regulation/ (accessed June 5 2023).

4 Thomson, Gavin, "MAKING CCUS WORK IN ASIA PACIFIC " Natural Gas World, October 6 2022, https://www.naturalgasworld.com/making-ccus-work-in-asia-pacific-ggp-101243 (accessed June 10 2023).

5 IEA, 2021

6 Nithin Coca, "Why Japan is pushing CCS in South East Asia." *Energy Monitor*, July 28 2022, https://www.energymonitor.ai/tech/carbon-removal/why-japan-is-pushing-ccs-in-South-East-asia/ (accessed June 10 2023)

7 Ministry of Economy, Trade and Industry. "Promotion of overseas CCS" (2022), https://www.meti.go.jp/shingikai/energy_environment/ccs_choki_roadmap/jisshi_kento/pdf/004_05_02.pdf (accessed June 5 2023)

8 Korea Chamber of Commerce and Industry, "Domestic Carbon Capture, Utilization, and Storage (CCUS) Status and Challenges." April 17 2023, http://www.korcham.net/nCham/Service/Economy/appl/KcciReportDetail.asp?SEQ_NO_C010=20120936280&CHAM_CD=B001 (accessed June 10 2023)

Country	Location	Project name (Actors)	Note
Japan	Thailand	FS of CCS business in Thailand (INPEX, JGC, PTTEP)	CCS
	Thailand	CCS Study at Archit Gas Field (MOECO, PTTEP, Chevron)	CCS
	Malaysia	FS of liquefied CO_2 marine transport for CCUS (Mitsui O.S.K. Lines, PETRONAS)	CCUS
	Malaysia	Bintulu LNG Terminal CCS Joint Study (JAPEX, JGC, Kawasaki Kisen, PETRONAS)	CCS
	Indonesia	Feasibility study (Mitsui & Co., Pertamina) to build a CCUS value chain in the Lokan Block	CCUS
	Indonesia	CCS joint research for clean ammonia production (Mitsubishi Corporation, JOGMEC, ITB, PAU)	CCS, CCU for ammonia production
	Indonesia	Study of CCS+EGR in Tangguh gas field (INPEX, JX Oil Exploration, Mitsubishi Corporation, Mitsui & Co., Sumitomo Corporation, Sojitz, JOGMEC, BP, CNOOC)	LNG expansion project for CCUS.
	Indonesia	Study of CCS+EGR in Tangguh gas field (INPEX, JX Oil Exploration, Mitsubishi Corporation, Mitsui & Co., Sumitomo Corporation, Sojitz, JOGMEC, BP, CNOOC)	CO_2-EOR/CCS
	Indonesia	Gundi gas field CCS/EGR commercialization study (JGC, JANUS, Electric Power Development, Pertamina, ITB)	CCS
South Korea	East Timor /Australia	Bayu-Undan gas field CCS (SK E&S, Australia, and East Timor)	CCS
	Malaysia	Shepherd CCS (Petronas, SK Energy, SK earthon, Samsung Engineering, Samsung Heavy Industries, Lotte Chemical and GS Energy,)	CCS
	Malaysia	Kasawari (Petronas, POSCO International)	CCS

Source: Authors' summary

Staff Publications *(01 April 2023 to 30 June 2023 period)*

Internationally Refereed Journal Articles

Zedi Lu, Kanxin Hu, and Tsan Sheng Ng. "Improving Additive Manufacturing Production Planning: A Sub-Second Pixel-Based Packing Algorithm." *Computers & Industrial Engineering* 181 (2023): 109318. https://doi.org/10.1016/j.cie.2023.109318.

Ya-Fang Sun, Shiwei Yu, Yue-Jun Zhang, and **Bin Su**, "How Do Imports Change the Energy Consumption of China? An Analysis of Its Role in Intermediate Inputs and Final Demands", *Energy* 270 (2023): 126947. https://doi.org/10.1016/j.energy.2023.126947 Ibrahim Ahmed Eldowma, Guoxing Zhang, and **Bin Su**, "The Nexus Between Electricity Consumption, Carbon Dioxide Emissions, and Economic Growth in Sudan (1971-2019)", *Energy Policy* 176 (2023): 113510. https://doi.org/10.1016/j.enpol.2023.113510.

Yingzhu Li, Yingchao Lin, and **Bin Su**, "Time-Series Analysis of the Contributors and Drivers of Zhejiang's Carbon Emissions and Intensity Since China's Accession to the WTO", *Environmental Science and Pollution Research* 30 (2023): 46913-32. https://doi.org/10.1007/s11356-023-25550-3.

Alberto Costa, Tsan Sheng Ng, and **Bin Su**, "Long-Term Solar PV Planning: An Economic-Driven Robust Optimization", *Applied Energy* 335 (2023): 120702. https://doi.org/10.1016/j.apenergy.2023.120702.

Guoxing Zhang, Yang Yang, **Bin Su**, Yan Nie, and Hong-Bo Duan, "Electricity Production, Power Generation Structure, and Air Pollution: A Monthly Data Analysis for 279 Cities in China (2015-2019)", *Energy Economics* 120 (2023): 106597. https://doi.org/10.1016/j.eneco.2023.106597.

ESI Policy Briefs

Kendra Ho, **Keerthana Gopinath**, and **Alvin Ee**, "The Implications of Incentives for Private Electric Vehicle Ownership in Singapore" *ESI Policy Brief* 66 (28 June 2023). https://esi.nus.edu.sg/docs/default-source/esi-policy-briefs/the-implications-of-incentives-for-private-electric-vehicle-ownership-in-singapore.

Staff Presentations and Moderating

20 June Roger Fouquet presented "The Digitalisation, Decarbonisation and Dematerialisation of the Global Economy in Historical Perspective: The Relationship between Energy and Information since 1850" via internet at the *Oxford Symposium on Technology and Global Change*, organised by St Catherine's College of Oxford University, Oxford, UK.

9 June Ojasvee Arora moderated the ESI Public Seminar on Sustainability and Energy Transition, organised by Energy Studies Institute (ESI), Singapore.

3 June Su Bin presented "Impacts of Investments on Economy-Energy-Environment (3E)", at the *6th International Conference on Climate and Energy Finance*, organised by ISETS Energy Finance Network, Changsha, China.

1 June Kim Jeong Won presented "Who Pledges Net Zero: Pioneers and Laggards" via internet at the 8th AP-PPN Conference, organised by Asia Pacific Public Policy Network (AP-PPN) and Hong Kong University of Science and Technology, Hong Kong.

31 May Yao Lixia moderated the *7th ASEAN Energy Outlook (AEO7) Dissemination Seminar*, organised by ESI, Singapore.

31 May Nur Azha Putra presented "The Global Governance of Nuclear Energy" via internet at the *International Energy Symposium*, organised by the NTU Clean Energy Club, TUDelft Energy Club, and the Energy Club IIT Bombay.

13 May Kim Jeong Won presented "Carbon Neutral Policies of ASEAN and the Possibility of Cooperation with Japan toward AZEC" at the Workshop on Asia Zero Emission Community (AZEC), jointly organised by Meijo University Faculty of Economics, Otemon Gakuin University Faculty of Economics, and Yamaguchi University Faculty of Economics, Osaka, Japan.

12 May Kim Jeong Won presented "Carbon Neutral Policies of Singapore and the Possibility of Cooperation with Japan toward AZEC" at the *Workshop on AZEC*, jointly organised by Meijo University Faculty of Economics, Otemon Gakuin University Faculty of Economics, and Yamaguchi University Faculty of Economics, Nagoya, Japan.

10 May Zhong Sheng presented "Singapore's Revised LEAP Model" via internet at the *2nd Meeting of ERIA Working Group on Preparation of Energy Outlooks and Analysis of Energy Saving Potential in East Asia Region*, organised by the Economic Research Institute for ASEAN and East Asia (ERIA), Jakarta, Indonesia.

5 May Kim Jeong Won presented "Climate Ambitions in Southeast Asian Countries" at the *ESI-KEI Joint Workshop on Pursuit of the 1.5°C Target – Global and National Responses to Climate Change*, organised by ESI and Korea Environment Institute (KEI), Singapore.

5 May Zhong Sheng presented "Climate Change, Environment Policy and Global Value Chains" at the *ESI-KEI Joint Workshop on Pursuit of the 1.5°C Target – Global and National Responses to Climate Change*, organised by ESI and KEI, Singapore.

Staff Media Contributions

Kim Jeong Won *was quoted in "Proposed Special Economic Zone Could Strengthen Special Singapore – Malaysia Ties", Southeast Asia Globe, 20 June 2023. See https://southeastasiaglobe.com/singapore-johor-economic-zone/.*

David Broadstock was quoted in "Volatile Singapore Power Prices Push It to Finally Embrace Solar", *Bloomberg News*, 19 June 2023. See https://www.bloomberg.com/news/articles/2023-06-20/wild-singapore-power-prices-push-green-laggard-to-embrace-solar#xj4y7vzkg.

Alvin Ee was quoted in "Stop Structural Gymnastics, Avoid Demolishing Buildings, Singapore Urged", *The Business Times*, 7 June 2023. See https://www.businesstimes.com.sg/esg/stop-structural-gymnastics-avoid-demolishing-buildings-singapore-urged.

David Broadstock was quoted in "Power Demand Zaps New Peak Amid Soaring Mercury Levels", *The Business Times*, 18 May 2023. See https://www.businesstimes.com.sg/companies-markets/power-demand-zaps-new-peak-amid-soaring-mercury-levels.

David Broadstock was quoted in "Sun Cable: Why Australia's Two Richest Men Are Battling to Control an Unbuilt Solar Farm", *ABC News*, 4 May 2023. See https://www.abc.net.au/news/2023-05-04/sun-cable-solar-andrew-twiggy-forrest-cannon-brookes-elliott/102295152.

David Broadstock was quoted in "Electricity Retailers See More Demand from Businesses for Longer-Term Contracts", *The Straits Times*, 3 April 2023. See https://www.straitstimes.com/singapore/electricity-retailers-see-more-demand-from-businesses-for-longer-term-contracts.

Alvin Ee was quoted in "Going Green from the Inside Out", Joint Report of Schneider Electric and Singapore Green Building Council, April 2023. See https://www.se.com/sg/en/download/document/SGBC_Report/.

Recent Events

19 April, Taking valuation for granted? Assessing the links between commercial, policy and economic valuations of natural capital in the UK and Singapore (Seminar) Dr Sam Beatson

Dr. Sam Beatson (Senior Tutor, Finance, Risk and Banking Department, Nottingham University, UK) presented on assessing the links between commercial, policy and economic valuations of natural capital in the UK and Singapore. There exist some shared characteristics between the UK and Singapore which make for interesting comparison. Moreover, both need to continue to provide housing to meet demand and a commercial lobby, yet badly need to control pollution and protect species and habitats. Both governments are committed to reaching carbon net-zero. Both are seeking solutions to the gap between the commercial funding of the needs of the environment, and the climate change policy agenda. An area which needs more attention is valuation of natural capital, which links environmental science to both policy decision-making and business, due to an increasing trend towards securitisation of natural capital assets. Environmental and economic research demonstrates the potential value of such assets' service capabilities. Their size, location, habitat and ecosystem service functions, like carbon storage, flood risk reduction, biodiversity and the provision of hydropower suggest intrinsic and extrinsic economic value. An in-depth review of multi-disciplinary literature including valuation approaches, a series of cross-discipline interviews and the development of an economic valuation tool will assist policymakers, researchers and practitioners aiming to stimulate vibrant ESCG-linked securities and energy markets.

3 May, Transition-critical materials, financial risks and the NGFS climate scenarios (Seminar) Dr. Simon Dikau

Dr. Simon Dikau (Research Fellow, Grantham Research Institute on Climate Change and the Environment at the London School of Economics and Political Science (LSE)) presented on the risks associated with critical minerals needed for the transition to low carbon energy sources. Several 'critical' raw materials are needed to expand the deployment of low-carbon technologies and thus play a central role in the low-carbon transition. They include metals, minerals and rare earth elements. However, the reliable and affordable supply of these resources is subject to supply-side risks and demand-induced pressures. This talk presents estimates of the material demand requirements for so-called 'transition-critical materials' (TCMs) implied under two climate scenarios modelled by the Network for Greening the Financial System, namely 'Net Zero 2050', where the 1.5°C target is met, and 'Delayed Transition', where emissions do not start to fall until 2030, putting the 2°C target in jeopardy. It will show that several materials will be subject to significant demand-induced pressures under both scenarios. The evidence indicates potentially serious mismatches between supply and demand (i.e. supply 'bottlenecks') for three materials – copper, lithium and nickel – which are exacerbated if the transition is delayed.

17 May, Social Benefits of Clean Energy: Evidence from Bangladesh (Seminar) Prof. Gazi Salah Uddin

Prof. Gazi Salah Uddin (Senior Associate Professor of Financial Economics, Department of Management and

Engineering, Linköping University, Sweden) presented on the social benefits of clean energy in Bangladesh. Solar adoption exploded until 2015 in Bangladesh, setting a precedent for electrifying previously unconnected areas worldwide. This study tries to measure the welfare effects of solar adoption using the three rounds of the Bangladesh Integrated Household Surveys. We applied ordinary least squares and propensity score matching techniques to estimate the welfare effects of solar adoption. We found that solar adoption is associated with higher income, expenditure, asset value growth, and a massive reduction in kerosene expenditure than non-adopters. Other findings include solar households that leave sharecropping and pursue trading and poultry farming and children who benefit from solar adoption regarding education and nutrition.

31 May, The 7th ASEAN Energy Outlook (AEO7) Dissemination (Seminar) ASEAN Centre for Energy (ACE)

Researchers from the ASEAN Centre for Energy (ACE) presented their energy outlook for the ASEAN region. Since its inception, the ASEAN Centre for Energy (ACE) flagship publication, ASEAN Energy Outlook (AEO), has become one of the most important documents to support ASEAN energy policy and planning. AEO complements and supplements the APAEC, providing an overview of the current energy landscape and exploring pathways of the achievement of regional (and national) energy targets, and beyond. Especially, the AEO addresses the Programme Area No. 6 Regional Energy Policy and Planning, Outcome-based Strategy 1: To enhance the profile of ASEAN energy sector internationally, Action Plan 1.2: Publish regular regional energy outlooks and strategic reports on the thematic issue. Continuing the previous efforts, ACE launched the 7th edition of the ASEAN Energy Outlook (AEO7) at the 40th ASEAN Ministers on Energy Meeting (AMEM) in Cambodia. AEO7 marks the first ASEAN energy outlook, where ASEAN takes full leadership in data gathering, modelling, writing, and dissemination. It was developed by ACE in collaboration with national experts from ASEAN Member States (AMS) and guided by the ASEAN Regional Energy Policy and Planning Sub-sector Network (REPP-SSN). Support was provided by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH through the ASEAN-German Energy Programme (AGEP), Ministry of Economy, Trade and Industry (METI) of Japan, and ASEAN Climate Change and Energy Project (ACCEPT).

9 June, Sustainability and Energy Transition (Seminar) Dr. Harry Bradbury

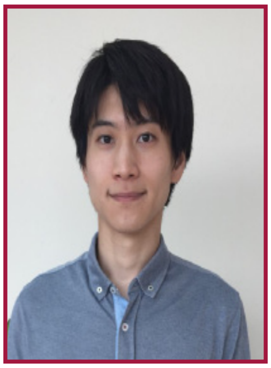
Dr. Harry Bradbury (Executive Chairman, The Heat Vault Company) outlined his work on various aspects of sustainable development including taking clean technologies from R&D to full commercialisation. One exciting example involves his company's work on pioneering large scale, long term energy storage in natural rocks, which could transform the deployment and usability of renewable energy systems.

New Staff

Dr. Joydeep GHOSH
Research Fellow

Dr. Joydeep Ghosh joined ESI in June 2023. He has more than 10 years of experience in the construction and application of CGE models for analysing energy, climate and sustainable development issues. He is also proficient in the construction of Social Accounting Matrices (SAMs) with energy and environmental accounts. His recent research has focused on the interplay between climate policy and technological progress, and on the economic impacts of the COVID pandemic. His past research focused on estimating the environmental and economic impacts of carbon pricing/trading policies consistent with the Paris Agreement target. Specifically, his research compared the cost implications of climate policies vis a vis agricultural productivity shocks, and the efficiency equity trade-offs of alternative carbon tax recycling mechanisms.

Kaitoh Hidano
Research Associate



Kaitoh Hidano joined Energy Studies Institute as a Research Associate in April 2023. He previously worked as an intern for the Centre for Tax Policy and Administration at the OECD and later as a consultant for its Environment Directorate where he contributed to the publication of a policy perspective on the nexus between trade and environment. Prior to that, he was a trainee at the United Nations Economic and Social Commission for Asia and the Pacific where he conducted econometric research. Before this, he worked at ZOE Institute for Future-fit Economies in Bonn and assisted proposing an overarching dashboard toward EU's sustainable development. He holds a Bachelor's and Master's degree in Economics specializing in European policies from the University of Strasbourg. His research interests lie in decarbonization strategies and climate policy in the context of energy transition.

Dr. Angel MAH
Research Fellow

With expertise in mathematical programming, Angel has a particular interest in optimizing renewable energy systems and supply chains. She has conducted extensive studies on the mathematical optimization of solar photovoltaic systems, hydrogen-based microgrids, hydrogen supply chains, and waste-to-resource value chains. Angel earned her PhD degree in Chemical Engineering from the University of Technology Malaysia. Prior to joining ESI in June 2023, she served as a Research Fellow at the NUS Environmental Research Institute (NERI), contributing to the Energy & Environmental Sustainability Solutions for Megacities (E2S2) program, a joint collaboration between NUS and Shanghai Jiao Tong University.

NG Zu Xiang
Research Associate

Zu Xiang joined ESI in June 2023 as a research assistant working on decarbonisation strategies in key economies. He graduated from the National University of Singapore with a Bachelor of Environmental Studies. His interest in social science brought him to take on a policy research role with the International Association of Labour Inspection where he worked on an occupational safety and health policy recommendation report. Before joining ESI, he was a research assistant at Nanyang Technological University working on a project studying sustainability in the palm oil sector. His research interests include political economy and examining human-nature relations.

Dr. Sita RAHMANI
Research Fellow

Sita joined Energy Studies Institute in June 2023 as a research fellow. Prior to this appointment, she was a research fellow at Tokyo Institute of Technology. She has worked as a research assistant in various projects of urban planning, including projects funded by foreign university, ministry, and various government agencies in Indonesia. Sita holds M.Eng and PhD degree in environmental planning and policy science at the School of Environment and Society, Tokyo Institute of Technology, Japan. She received her B.Eng in urban and regional planning from Universitas Gadjah Mada, Indonesia. During her graduate study, her research was about sustainable management of community-scale renewable energy project, particularly solar water pumping system in rural Indonesia. Her research interests include energy governance and policy, social dimension of energy, low-carbon development, energy transition, and regional development studies.

Dr. SUNG Jinseok
Research Fellow

Jinseok joined Energy Studies Institute in May 2023 as Research Fellow. Prior to his current appointment, he was Research Professor at the Center for International Area Studies and Lecturer at the department of BRICS, at Hankuk University of Foreign Studies. Before his experience at the university, he worked as Research Fellow at the department of Political Science and Diplomacy, at Hallym University of Graduate Studies, both located in Seoul, South Korea. He was also Visiting Researcher at the Institute for Emerging Economies (BOFIT), a research center at the Bank of Finland, in Helsinki. Jinseok participated in various research projects of organizations in different countries. His research mainly focuses on the natural gas market development, and energy markets in the Asia Pacific region and Eurasian countries. Jinseok holds a Ph.D. in World Economy and a M.Sc. in Oil & Gas Business from Gubkin Russian State University of Oil and Gas in Moscow, Russia. He received a B.A. in Economics from Hanyang University in South Korea.

Janani VENKATESH
Research Associate

Before joining ESI, she worked with the Sustainable Energy Lab at the Indian Institute for Human Settlements (IIHS), where she was involved in projects related to high-performance net-zero buildings. She has worked on sustainability assessments of the IIHS office buildings, and research using real time building data. She was part of the management team of Solar Decathlon India, a net-zero building challenge. Janani completed her Master's from SOAS University in London in International Studies with a focus on Global Energy and Climate Policy. She is a LEED Green Associate. At ESI, her research includes decarbonization strategies across sectors and driving the energy transition in Singapore.

Contact

- Collaboration as a Partner of ESI (research, events, etc.)
- Media Enquiries
- ESI Upcoming Events
- Join ESI Mailing List

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