

OPTIONS FOR DECARBONIZING MALAYSIA

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ABOUT ASEAN GREEN FUTURE

The ASEAN Green Future project is a collaboration between the Sustainable Development Solutions Network, ClimateWorks Australia, the Jeffrey Sachs Center on Sustainable Development at Sunway University, and research groups from Southeast Asia (Cambodia, Indonesia, Lao PDR, Malaysia and Thailand, with potential participation from Brunei, Myanmar, the Philippines, Singapore, and Viet Nam in the future). The Phase 1 report of each country team presents priorities and actions to date, and key technology and policy opportunities to further advance domestic climate action.

The Phase 1 regional report situates the region's path to low-carbon transition within a global context using the country reports and other studies. This series of reports, produced through a synthesis of existing research and knowledge, builds the case for advancing the region's climate agenda. Phase 2 of the ASEAN Green Future project will undertake quantitative assessments of the different options for decarbonizing the ASEAN countries. ■

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The JCI-JSC Working Paper series is published to disseminate preliminary research findings and stimulate intellectual discourse on wide-ranging public policy issues, ranging from security to sustainability. The views expressed herein are those of the author(s) and do not necessarily reflect the views of the Jeffrey Cheah Institute on Southeast Asia and the Jeffrey Sachs Center on Sustainable Development.

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Jeffrey Cheah Institute on Southeast Asia (JCI) is an independent public policy think-tank based at Sunway University on the outskirts of the Malaysian capital, Kuala Lumpur. The Institute's research programme is grouped around three core disciplines: economic development, governance, and social progress, including education. Its mission is to develop solutions to some of the region's most pressing development problems. JCI seeks to engage policymakers, scholars and ordinary citizens through regular public lectures and discussions, and to build lasting academic partnerships in the region and the wider Asia-Pacific.

Jeffrey Sachs Center on Sustainable Development (JSC) is a regional center of excellence that advances the achievement of the 17 Sustainable Development Goals (SDGs) in Malaysia and Southeast Asia, tackling the sustainability agenda through education, training, research and policy advisory. Launched in December 2016, the Center operates out of Sunway University and was borne out of a \$10 million gift from the Jeffrey Cheah Foundation (JCF) to the UN Sustainable Development Solutions Network (SDSN).

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PREFACE

By Woo Wing Thye

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All Association of Southeast Asian Nations (ASEAN) countries signed the Paris Agreement on 12 December 2015, to commit themselves to undertake actions that would limit global warming to no more than 2 degrees Celsius, preferably to no more than 1.5 degrees Celsius, above the temperature level in the preIndustrial Revolution period. Seven ASEAN countries – Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Thailand and Viet Nam – are participating in the ASEAN Green Future (AGF) project to conduct research and advocacy work on achieving net zero greenhouse gas emissions by mid-century. The primary objective of AGF is to encourage and support the strategic foresight of ASEAN policy makers for a sustainable future defined by the seventeen United Nations Sustainable Development Goals (SDGs), and to assist them in designing climate action programmes that are economically efficient and socially inclusive.

ASEAN Green Future is a multi-year project that started with its first online meeting of the teams on 23 February 2021. This report is the Malaysia component of Phase I of ASEAN Green Future. The remit of Phase I is to provide an overview of the present activities related to greenhouse emissions in each country, to take stock of the climate actions that have been implemented, and those scheduled for implementation in the future, and to assess the accumulated research on greenhouse gas emissions. Work on Phase I has proceeded rapidly despite the intensification of the COVID-19 rampage through Southeast Asia since February 2021, partly because of the synergism enabled, and inspiration generated by the monthly online meetings of the country teams, and partly because of the strong technical support provided by both the United Nations Sustainable Development Solutions Network (SDSN) and ClimateWorks Australia (CWA).

Team Malaysia is headed by Professor Leong Yuen Yoong, and its researchers are from the Jeffrey Sachs Centre on Sustainable Development (JSC) at Sunway University, and Institute for Environment and Development (LESTARI) at Universiti Kebangsaan Malaysia. Team Malaysia is working with government ministries and their agencies, private businesses and their associations, international organisations, other Malaysian research centres, distinguished universities in the world, and SDG advocacy groups. A large part of Phase I has been completed following the dictum that ‘good thinking is always based on good listening’.

In Phase 2 of the ASEAN Green Future project, Team Malaysia will embark on forward technology road mapping of selected decarbonization options. Each road map will undergo four complementary analyses: technical feasibility, financial feasibility, socio-economic impact and carbon footprint.

Team Malaysia welcomes your suggestions on ASEAN Green Future, and hopes for your participation in its work. ■

THINKING ABOUT MALAYSIA'S SUSTAINABLE FUTURE

By Leong Yuen Yoong, Michael James Platts and Amran Sofiyan

Malaysia is committed to the global movement of improving sustainability, resilience and competitiveness through decarbonizing key sectors in the economy. Phase I of the ASEAN Green Future (AGF) research project has identified key decarbonization options for carbon intensive sectors in Malaysia (Figure 1), which are then further elaborated on in this report.

Phase 2 of this research endeavour will involve forward looking technology road mapping on selected decarbonization options. Focussing on the 'how' is important for putting Malaysia on a path to net zero. Each technology roadmap will undergo four complementary analyses: technical feasibility, financial feasibility, socioeconomic impact, and carbon footprint. Subject experts will work with practitioners and stakeholders to define key questions, conduct research, and interpret the findings.

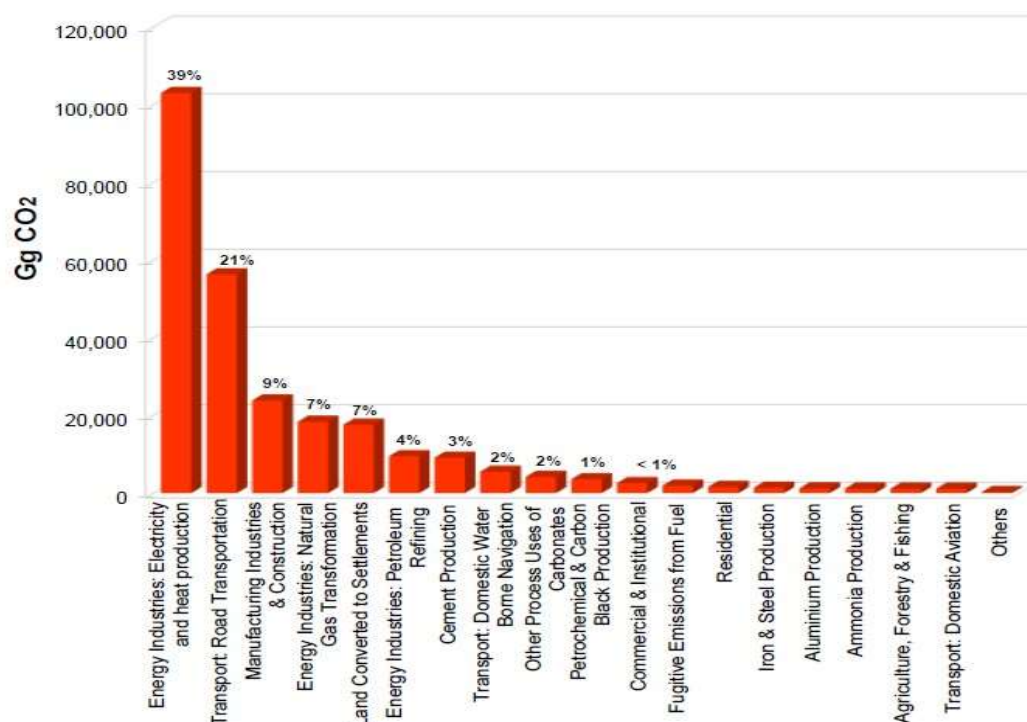


Figure 1: Major Sources of Carbon Dioxide in Malaysia in 2016

Source: Ministry of Environment and Water. Malaysia Third Biennial Update Report to the UNFCCC. Ministry of Environment and Water 2020.

This chapter is a prelude that digs deeper into some common but often overly simplistic perceptions used to frame the analytical questions that need to be asked, in order to develop evidence-based strategies that would be most useful to Malaysian policymakers.

1.1 Energy

Electricity and heat production are the largest contributors (39 percent) to CO₂ emissions in Malaysia.

According to the 2021–2039 Energy Generation Development Plan released by Malaysia’s Energy Commission on 24 March 2021, the retirement of coal power plants with a total capacity of 7GW is projected to be replaced by 2.8GW of new coal capacity.¹ The necessity for new coal generation capacity should be re-evaluated as part of the Economic Planning Unit’s work in formulating Malaysia’s National Energy Policy, which will be launched in the second half of 2021.

Natural gas, which emits half as much CO₂ as coal when combusted, has emerged as a transitional solution to climate change. Gas plants are more efficient than coal plants in converting heat energy into electrical power (55–60 percent vs. 34–42 percent efficiency). The value of natural gas in a world of renewable energy (RE) is its ability to balance intermittent electricity outputs and provide uninterrupted energy during peak hours with its flexible on-off cycles. On the other hand, investing in natural gas infrastructure might delay the transition to zero-carbon technologies and hinder emission mitigation in the long-term. How might policy actions in Malaysia prevent the negative long term consequences of natural gas?

The Malaysian government intends for RE to account for 31 percent of national power generation capacity by 2025. A total of 1,178MW of new RE capacity will be developed in Peninsular Malaysia from 2021 onwards. This consists of 1,098MW of solar and 80MW of non-solar. With solar being the dominant source of RE in the system, Malaysia is taking steps to improve grid resilience so that variable energy resources, such as solar, do not jeopardise the reliability of the electricity supply system. To ensure that the transition to RE and especially solar does not present a trade-off for grid reliability, Malaysia needs to establish a detailed understanding of the variability of the grid load with time and the possible generation of electricity with time. This will be essential to understanding the nature and scale of grid load and electricity generation variables and to developing a grid that is able to respond to that variability. Scenario planning using forward modelling of possible scenarios is an important first step in developing the tools to explore the needs—and options—for future infrastructure development.

The penetration limit² for grid connected solar is set at 24 percent of the estimated peak demand for the 2025 target. By 2035, the RE component in power capacity for Malaysia is projected to increase to 40 percent and solar penetration is expected to reach 30 percent of the projected peak demand. With more variable RE from solar being integrated into the electricity supply system, Malaysia’s Energy Commission and the Grid System Operator (GSO) plan to install five units of battery energy storage system (BESS) with a capacity of 100MW annually into the system from 2030–2034. These batteries are for grid stability, not energy storage.

¹ Two 700MW units in 2031, one 700MW unit in 2034 and another one in 2037.

² Maximum percentage of electricity generation sourced from solar facilities.

100MW is a rate,³ not a capacity.⁴ Storage is measured in MWH. What we will find—e.g. what Australia has done⁵—is that there is battery storage capacity with the ability to deliver 100MW, but only for about a minute. The value of battery storage in dynamic grid operation lies in keeping the grid stable during rapid transitions of load.

Batteries are many orders of magnitude too small and costly for storing solar energy for daily balancing and dispatch purposes. However, linking the solar in Malaysia with the hydropower in Thailand, Lao PDR, and/or Indonesia could reduce the need for battery storage, especially if ASEAN members continue to integrate their economies, following in the footsteps of the North American Free Trade Agreement (NAFTA) and the European Union (EU). This idea for ASEAN energy cooperation could be fleshed out by studying the long-time cooperation between Denmark and Norway in efficiently meeting RE demand.

For many decades, Denmark and Norway have had a cooperative agreement on energy supply based on the reality that Denmark has good wind resources and Norway has a lot of hydro energy. A high voltage direct current (HVDC) subsea cable⁶ was installed to link the two countries. When it is windy, Denmark exports electricity to Norway; when it is not windy, Norway exports electricity to Denmark. Norway has enough hydro facilities to store energy from winter (when the reservoirs fill up) to summer. Hydro is a historical energy storage option and often the cheapest way to store large amounts of dispatchable energy that can be turned on and off easily.

Further, Norway⁷ and Denmark have a high proportion of electric vehicles (EVs) due to abundant low cost electricity. A key detail to note is that Denmark and Norway had the HVDC link long before EVs were even conceptualized. Therefore the electrical infrastructure was already there, so it was possible for EVs to scale, rather than scaling in order to meet the demand for EVs.

Following the Denmark–Norway example of collaborative regional energy planning, the Lao PDR–Thailand–Malaysia–Singapore interconnection is a pilot multilateral trading project. Lao PDR has the potential to serve as the ‘Norway for Southeast Asia’, acting as a battery for the region with its large hydro energy potential.⁸ The interconnection between these countries currently exists at 300 MW and contributes one percent to Malaysia’s energy mix. While it is well known that different regions with different generation capacity mixes can cooperate to engender lower operational costs and emissions, the prerequisite for this cooperation is trust. Trust is important due to the increasing interconnectedness of infrastructure that has the potential to affect energy security and reliability.

Sarawak, one of the thirteen states in Malaysia, is already selling electricity to West Kalimantan. Sarawak’s abundant hydropower⁹ allows for more electricity to be supplied to Kalimantan as

³ Rated power capacity is the total possible instantaneous discharge capability (in kW or MW) of the BESS, or the maximum rate of discharge that the BESS can achieve, starting from a fully charged state.

⁴ Energy capacity is the maximum amount of stored energy (in kilowatt-hours [KWH] or megawatt-hours [MWH]). Storage duration is the amount of time storage can discharge at its power capacity before depleting its energy capacity. For example, a battery with 1MW of power capacity and 3MWH of usable energy capacity will have storage duration of three hours.

⁵ When grids run in terms of gigawatt days, Tesla’s battery in Hornsdale, which can deliver 189 MWH, is very small. The sole pumped hydro storage scheme on the UK grid – Dinorwic in Wales – can deliver 10GW for half an hour. It was built decades ago when the grid was significantly smaller. Even Dinorwic is only used for grid stability. One cannot isolate 30,000 houses and supply only them: The grid supplies everything within a designated area.

⁶ Transmission cable for carrying electric power below the surface of the water.

⁷ Norwegian plug-in electric car market share of new car sales is the highest in the world.

⁸ Hydro power project implementation in Lao PDR has been problematic due to socio-economic obstacles.

⁹ The Sarawak Corridor of Renewable Energy (SCORE), which involves twelve mega dams, has destroyed a lot of rainforest, biodiversity and displaced many indigenous people physically and culturally. Malaysia needs to work harder at making the UN Sustainable Development Goals relevant to the indigenous people. For the existing dams under

further socio-economic opportunities open up with the relocation of the Indonesian capital.¹⁰¹¹ This can also be supplied to Japan and Korea, both countries that bet heavily on the hydrogen economy.

Green hydrogen coupled with land availability and proximity to Indonesian iron ore open up a new industrial frontier for Sarawak—green steel.¹¹¹² This is an opportunity to revolutionise Malaysia's coal-based steel industry so that it will not lose out as environmental pressures increase globally. Malaysia exports nearly 60 percent

of all its iron and steel products to seven countries, including the EU (15 percent), South Korea (8.5 percent), Indonesia (8.5 percent) and the US (5.3 percent). These countries, which have set net zero carbon targets or substantial goals to cut carbon emissions, already have or are considering carbon taxes.

1.2 Transportation

Road transportation contributes to more than 20 percent of Malaysia's CO₂ emissions.

Rail-based freight transportation in Peninsular Malaysia covers a total track length of over 2,783 km, some of which form part of a regional rail network. For example, the Padang Besar–Johor Bahru rail (804km) is part of the Singapore-Kunming Rail Link network. The Padang Besar-Gemas electrified double-track has been operational since November 2015, while the 192km Gemas-Johor Bahru electrified double-tracking project is expected to complete by October 2022.

Given that the current movement of goods by rail represents only 30 percent of total railway track capacity, with <5 percent of land freight being transported by rail, rail-based freight transportation should be increased so that fewer large and hazardous trucks use the interstate highways. This will reduce heavy vehicle carbon emissions, road fatalities, congestion, and road repair needs due to overloaded lorries. However, running a greater number of freight trains requires larger unloading and loading depots to transfer goods from lorries onto trains and then in reverse. If this can be done at all the ports, it can be replicated in the main industrial areas, e.g. Rawang, Ipoh etc. Malaysia needs to plan for the infrastructure needed to make increasing rail-based freight transportation possible.

As roads become increasingly congested and carbon emissions rise with an increasing number of cars, shifting from road to rail is a way forward. Vehicles-on-train is also an option to consider. Nevertheless, roads remain important in a multi-modal approach towards transport decarbonization because the first and last miles need to be completed smoothly, and rural and isolated places need access. Civil engineers engaged by the government to plan infrastructure investment need to use scenario planning and look carefully at the human dimensions of travel. Understanding why people want to get from A to B will help engineers design practical, efficient and cost effective low-carbon solutions to support travel.

SCORE, we cannot turn back time to undo the destruction, but we can plan forward from where Malaysia is now; This requires steady, clinical, cold thinking, not emotionality. More understanding is required about these dams and their intended future use. There is a difference between wide, shallow dams, which can store a lot of water (and might be good for irrigation) and some power, and high dams, which can store significant energy because of the head of water they hold back.

¹⁰ Hydrogen is made by electrolysing water using electricity produced by hydropower. Sarawak Energy and Petroliaam Nasional Berhad (PETRONAS) entered a memorandum of understanding on 10 November 2020 to collaboratively explore the commercial production of green hydrogen and its value supply chain in Asia.

¹¹ Steel is produced by melting iron ore at high temperatures so that it reduces from iron oxide to iron. This process uses fossil fuels, which emit significant volumes of CO₂. If hydrogen is used as the reducing agent, >98 percent of the CO₂ normally released can be eliminated.

In decarbonization debates, countries tend to get confused between what they do as consumers, and what they do as developers and manufacturers that earn them their place in the global economy. Malaysia needs to identify this difference and address the two sectors separately. Differentiating between what Malaysia uses and what it manufactures (i.e. how it earns its living) is particularly important for transport.

In recent decades, manufacturing has gone completely global. Companies and industries can form big, international collaborations, whilst countries as individual markets are small. Malaysia needs to build very good relationships and earn its place as a producer in the global industry.

Putrajaya's customised incentives¹² discourage foreign automotive investors because they perceive unfair competition. This is one of the reasons¹³ global technology companies have bypassed the country to invest in Thailand and Indonesia for manufacturing and assembling EVs and EV-related technologies such as lithium-ion batteries and energy storage systems.

As a consumer, Malaysia does not have an automotive policy that eventually bans vehicles powered by fossil fuels. The National Automotive Policy 2020 promotes energy efficient vehicles, which are based on internal combustion engines (ICE). The categorisation of EVs is also bundled with hybrids and ICE vehicles that have connectivity and autonomous features (Next Generation Vehicles NxGVs).

The use of fossil fuels will reduce in the future, but ICE can continue to have an important ongoing role, as we shall see in the following discussion.

EVs seem to dominate mainstream thinking about decarbonizing transportation, despite the small number of EVs in Malaysia. However, there are numerous considerations that must be factored in if policies aimed at increasing EV deployment in Malaysia are pursued, including a completely new electricity infrastructure and completely different vehicles, based on different (and expensive) technologies that Malaysia does not currently have, along with complicated materials processing and recycling associated with EVs.

It is important to consider a life-cycle analysis when assessing the carbon footprint of key decarbonization technologies and solutions. One specific technology that must be closely analysed is the embodied carbon in light-duty electric cars. An electric car's weight is roughly a third higher than the conventional car, and the total carbon footprint of its production process is also around a third higher.¹⁴ A recent comparison of a new conventional car with a new battery powered car showed that because the carbon footprint of producing the battery powered car was significantly higher than the conventional car, even though it was cleaner to drive, it did not beat the lower carbon footprint of the conventional car until they had both driven 78,700 miles (126,655 kms), if the electricity to recharge the battery powered car comes largely from fossil fuels, for example in Malaysia, China and Poland.¹⁵ Under this power generation scenario, the breakeven

¹² Incentives are customised according to the level of localisation, vendor development programmes and Malaysian workers' salary.

¹³ Other reasons include Indonesia and Thailand having larger populations and cheaper labour than Malaysia

¹⁴ Choudhury, Saheli Roy. 2021. "Are electric cars 'green'? The answer is yes, but it's complicated." *Sustainable Future*. CNBC. July 26. <https://www.cnbc.com/2021/07/26/lifetime-emissions-of-evs-are-lower-than-gasoline-cars-experts-say.html>; Hall, Dale, and Nic Lutsey. 2018. Effects of battery manufacturing on electric vehicle life-cycle greenhouse gas emissions. The International Council on Clean Transportation.

¹⁵ Lienert, Paul. 2021. Analysis: When do electric vehicles become cleaner than gasoline cars? *Reuters*. July 8. <https://www.reuters.com/business/autos-transportation/when-do-electric-vehicles-become-cleaner-than-gasoline-cars-2021-06-29/>.

point for a new electric car will be in the range of hundreds of thousands of miles if one compares it with an already existing conventional car (no new carbon emissions due to vehicle production).

The carbon 'spend' needed to replace every conventional car on the planet is huge and the time taken to do it will also be huge. At least during transition—for a very long time—we are going to need to think about replacing fossil fuels with green fuels, rather than taking existing conventional vehicles off the road before their economic lifetime. People with old cars tend to drive a small mileage each year,¹⁶ and thus only contribute a small percentage to total transportation carbon emissions.

In addition, materials for EV manufacture are difficult to process and difficult to recycle compared to a conventional vehicle. Furthermore, EV battery life is only around eight years before it has to be replaced.¹⁷ New mines will be needed for the production of raw materials required for EV batteries.

Unlike in Northern China where wind energy is stronger at night than during the day, Malaysia and other tropical countries do not have the option of charging electric buses at night then using them during the day. The only way to do it is to have buses, each with two interchangeable battery packs, one in use and the other being charged. This solution requires a significant investment in batteries.

For these reasons, it would be wise for Malaysia to evaluate hydrogen-powered vehicles (HPV). Hydrogen can be used as a fuel in petrol engines only with a different fuel control algorithm in the computer control system. For decades BMW has been running ordinary petrol cars with an internal switch that can change the fuel to hydrogen and continue running.¹⁸ It is easy and safe. One does not have to change the basic car technology, rather to develop the engine management system (by designing a new cylinder head for existing engines), along with a new fuel management system, then add a hydrogen tank without needing a heavy and expensive battery to store electricity. These components can all be made in Malaysia. Vehicle engines can thus be converted, and allowing everything to remain as it was. This type of transition is expected to be more economical and easier to implement than the EV replacement route. The real challenge lies in developing a hydrogen delivering infrastructure, not in purchasing new EVs.

A key issue in using hydrogen as a fuel is whether hydrogen is stored at high pressure—as construction equipment giant JCB is currently exploring (Appendix 1)—or if it is better, as BMW has done, to store hydrogen as liquid hydrogen at very low temperatures. The former involves high pressure containers at every stage of hydrogen production, distribution and use, as with gas supply, e.g. oxygen to hospitals. However, high pressure storage presents a particular set of problems.

Another option is to cool hydrogen into liquid form. This would require all containers to have high quality insulation, but hydrogen can be moved about as a liquid, just as transportation fuels are

¹⁶ Hearst Autos Research. n.d. What is Average Mileage Per Year? Prod. Car and Driver. Accessed September 8, 2021. <https://www.caranddriver.com/research/a32880477/average-mileage-per-year/>.

¹⁷ Hardesty, Chris. 2021. "How long will my EV battery last? Here's what to know." Autotrader. Prod. Market Watch. July 13. Accessed September 8, 2021. <https://www.marketwatch.com/story/how-long-will-my-ev-battery-last-heres-what-to-know-11625774475>.

¹⁸ See https://en.wikipedia.org/wiki/BMW_Hydrogen_7. The German car industry has been spending the least on the development of hydrogen propulsion because it is considered costly. This might be change in the future. The German federal government will make available €7 billion to speed up market rollout of hydrogen technology, and €2 billion for fostering international partnerships. Furthermore, hydrogen production will not be subjected to the energy production levy, according to the law on renewable energies. Electrolysis facility will deliver 5GW by 2030 and another 5GW by 2035. Germany will also have a federal innovation commissioner for green hydrogen.

moved around now. BMW has a liquid hydrogen pump at Munich Airport¹⁹ where they fill their demonstration hydrogen powered cars to show they can be used in a completely normal way like other cars. Either of these technical roads is possible, but they have completely different infrastructure requirements. Both need exploring as the better option is not yet clear.

Whether it is battery EVs, plug-in hybrid EVs, fuel cell EVs or hydrogen powered vehicles (HPVs), Malaysia should not be focusing entirely on the cars themselves, rather, we should also think about the necessary infrastructure to facilitate the transition. Infrastructure issues are usually (a) very large and complex and (b) involve immense problems that are far from simple to solve. In developing a strategy, we need to consider with whom (which countries, which organisations) Malaysia might usefully collaborate, to develop both the understanding and the technology the country needs.

If we leave the emotive debate between electric and hydrogen alone, two points are clear: One is that 'electric' does some things well and other things not at all; and the same is true for hydrogen. This is not an 'either/or' issue; the future will be 'both/and'. There is widespread consensus that batteries will never suffice for long distance air travel, but a clean fuel such as hydrogen can work. Hence, Airbus is developing designs for hydrogen fuelled passenger aircraft. Similarly, batteries are unlikely to serve either heavy off-road earth-moving equipment or long distance lorries, but hydrogen can do so.

The second point to make regards an important development zone, which includes work at Oxford University to develop iron-based catalytic ways to make sustainable aviation fuel from green hydrogen and carbon dioxide.²⁰ This high value product has the potential to defray the cost of carbon capture and storage, and mitigate concerns about underground storage.

1.3 Manufacturing and Construction

Manufacturing and construction contribute 9 percent of Malaysia's CO₂ emissions, the third largest after electricity and heat production, and road transportation. It is not clear whether the 9 percent includes some or all of (i) emissions from onsite fuel combustion; (ii) emissions from manufacturing processes; and (iii) indirect emissions associated with purchased electricity and heat.

Energy inefficiency and high emissions are serious business liabilities. A large portion of CO₂ emissions are from the cement, chemicals, and iron and steel industries. Hence, huge reductions in industrial GHG emissions are possible by targeting certain product and process improvements.

Key options for decarbonization include industrial heat recovery²¹ and fuel switching. The right policies can make investment in cleaner industrial processes more profitable, accelerating both delivery and scale-up. Government, academia and industry need to work together to help industry transit to low carbon while maintaining competitiveness. A framework for decarbonization and energy efficiency improvements from now to 2050 needs to be developed with inputs from stakeholders. Commitments required by all parties to enable this low carbon transition need to be identified. Neither party can do it alone, rather, it is the combination that will be powerful.

The chemical industry produces the basic chemicals used in many final products and manufacturing processes. Capital investment in a chemical plant is high, with a slow payback rate.

¹⁹ https://www.press.bmwgroup.com/usa/article/detail/T0021884EN_US/world-s-first-public-hydrogen-fuel-station-to-open?language=en_US

²⁰ <https://www.greencarcongress.com/2020/12/20201228-oxford.html>

²¹ Capturing hot gas exiting industrial equipment such as incinerators, oxidisers, turbines, and gasifiers, and utilising its energy for other industrial processes. This reuses heat energy that would otherwise be expelled and wasted.

Parts of the industry will transition to more sustainable sources of feedstock for chemical production. In some cases, the development of a completely different industry will be required to achieve sustainability.

The construction industry creates society's infrastructure – roads, railways, ports, airports, the water supply network, the sewerage system, electricity supply – and constructs all buildings. Much of this involves the use of large and powerful off-road mobile machinery, e.g. for earth moving, which is likely to remain diesel powered because of the high power-to-weight ratios required for such machinery. Battery power can be impractical for many heavy vehicles. An operational hydrogen combustion engine has been developed by JCB, which could hasten the shift to zero emissions off-road machinery (Appendix 1).

Building construction, however, is likely to see the development of more factory-based modular construction, reducing the amount of work and waste produced on-site during construction.

1.3 Oil and Gas

On 26 May 2021, the Dutch court ruled that Royal Dutch Shell is partially responsible for climate change, and that the company must reduce its carbon emissions by 45 percent by 2030 as compared to 2019 levels. This ruling is a first-of-its-kind and may have a significant effect on the oil and gas industry for years to come. Investors and stakeholders are becoming increasingly conscious about the environment and how human activities impact it.

Since oil and gas are key energy resources that have fuelled rapid growth globally over the last few decades, it is natural to consider them as key contributors to greenhouse gas (GHG) emissions. One GHG which is particularly emitted by the oil and gas industry, is methane. With a higher global warming potential than CO₂,²² it is definitely a concern. The highest volume of methane emissions in Malaysia comes from fugitive emissions of the oil and gas industries (44 percent).²³ However, using GHG emissions as a measure of this industry's impact is insufficient. Oil spills that have occurred in recent years, including the 2010 Deepwater Horizon accident,²⁴ have caused irreversible damage to the environment, affecting natural ecosystems and ultimately, human activity.²⁵ Nevertheless, since the COVID-19 pandemic in 2020, the industry has pivoted towards decarbonization and supports initiatives that foster good environmental practices.

²² Based on GHG Protocol's "A corporate accounting and reporting standard, revised edition" (2004), global warming potential (GWP) is a factor describing the radiative forcing impact (degree of harm to the atmosphere) of one unit of a given GHG relative to one unit CO₂. In the words of the US Environmental Protection Agency, GWP is "a measure used to compare how much energy the emissions of 1 ton of gas will absorb over a given period of time, relative to the emissions of 1 ton of CO₂. The larger the GWP, the more that a given gas warms the Earth compared to CO₂ over that time period, which is normally 100 years." Based on estimates the GWP of methane (CH₄) is 28–36 over 100 years. Even though methane lasts about a decade on average, it absorbs much more energy than CO₂. Thus, the net effect of the shorter lifetime and higher energy absorption is reflected in the GWP.

²³ Ministry of Environment and Water. Malaysia Third Biennial Update Report to the UNFCCC. Ministry of Environment and Water, 2020.

²⁴ Other oil spill examples in Southeast Asia include: oil spill off the coast of North West Java; in July 2019, oil spill in Thailand in July 2013 due to a pipeline leak; oil spill in Philippines in July 2013 due to a pipeline leak; unidentified oil spill (at time of the report) on west coast of Malaysia, affecting coasts of states of Negeri Sembilan and Melaka. Based on a review of oil spills in Malaysia from 2014–2016, 43 percent of oil spills are vessel discharge, while 39 percent from unidentified sources, 6 percent from pipeline leaks, 8 percent from ship collisions, 2 percent respectively for sunken vessel and engine trouble. (Ismila Che Ishak and Aminuddin Md Aro (2019) "The review of oil spill incidents in Malaysia between 2014 to 2016", *Conference: 2nd International Conference on Contemporary Issues In Economics, Management and Business* in Hanoi, Vietnam)

²⁵ Human activity affected by oil spills include tourism and fisheries, especially offshore oil spills. Disruptions to the economic activities of tourist spots and fisheries suffer due to lower haulage. Human activity is further impacted by the health threats from oil spills as the oil spills may contaminate food and drink.

Importance of the oil and gas industry to Malaysia

Oil and gas history in Malaysia has its beginnings in Miri, Sarawak where the first oil well was discovered on Canada Hill, in 1910. Despite limited production in early days along with two World Wars that hampered production and expansion of oil and gas exploration, the experience taught us much about oil and gas reserves in the region. Fast forward to the 1960s, and the oil and gas industry in Malaysia started to grow. In 1974, the Petroleum Development Act stipulated the formation of Malaysia's national oil company, Petroliaam Nasional Berhad (PETRONAS). Through the Act, PETRONAS was granted ownership, exclusive rights and powers over Malaysia's hydrocarbon resources and comes under the direct purview of the Prime Minister.

Today, PETRONAS has expanded its operations globally and contributes about 20 percent of Malaysia's gross domestic product (GDP). As of 2020, Malaysia is reported to have proven oil reserves of 3.6 billion barrels and a refining capacity of about 880,000 barrels per day at seven facilities across the country. While this seems to indicate that the oil and gas industry will still play an important role to the nation, the impending decline of oil and gas reserves in the country—which, it is estimated, will be exhausted around 2040 and 2060 respectively—would mean that the industry needs to take a hard look at maintaining economic well-being and sustainability.

As a major national company, PETRONAS has lent its support to Malaysia's commitment in the Paris Agreement to reduce the GHG emissions intensity of its GDP by 45 percent by 2030 relative to 2005 levels, by pledging a net zero carbon emission commitment by 2050. This has caused a ripple effect in the local oil and gas industry as all parties concerned move to support PETRONAS in achieving the target. It represents an important step taken by PETRONAS to lead the local oil and gas industry to decarbonize. PETRONAS is also the first national oil company in Asia to pledge such a commitment. Despite growing decarbonization pressure on the oil and gas industry, other national oil companies like Saudi Aramco, Gazprom, Sonatrach, National Iranian Oil Co. and Kuwait Petroleum Corporation have yet to set emission targets.

Decarbonization options for the oil and gas industry

Sustainability reporting requirements and the recent landmark ruling against an oil major are encouraging factors for the oil and gas industry to decarbonize. PETRONAS embarked on sustainable practices two decades ago. To assess effectiveness, the company has calculated its carbon footprint, which enables PETRONAS to measure, manage and seek options to reduce carbon emissions further.

The first step is to assess existing platforms and operations, and find ways to improve efficiency. While efficiency improvement has been a standard practice, it is rather new to view it from a carbon emissions perspective.

There is an opportunity for PETRONAS as a regulator of Malaysia's oil and gas industry to advocate and steer the industry – especially PETRONAS's contractors – to lower GHG emissions from their activities.

Decarbonization options available to the oil and gas industry, as listed by the International Association of Oil & Gas Producers (IOGP), include:

- Reduce emissions in operations;
- Invest in renewable energy;
- Carbon capture, utilisation and storage;
- Reduce flaring;

- Coal to gas switch;
- Clean hydrogen.

Organisations that have been established to support the oil and gas industry in decarbonization include the International Petroleum Industry Environmental Conservation Association (IPIECA) and International Renewable Energy Agency (IRENA).

Challenges to decarbonizing the oil and gas industry

The biggest challenge in decarbonizing the oil and gas industry may lie within the industry itself. There is a pressing need to educate all players in the value chain on the impact of GHG emissions from each activity, and the importance of reducing them. Typical decarbonization challenges include:

- Lack of understanding about energy transition and value chain decarbonization;
- Some of the available technologies are expensive and experimental;
- The country lacks a high level decarbonization framework, which is important for measuring, monitoring and reporting GHG emissions;
- Since decarbonization is a voluntary action, companies tend to take decarbonization actions based on market requirements.

1.5 Waste

In nature, there is no waste. Everything is not only used, but is used both efficiently and effectively, without loss, symbiotically within the entire ecosystem, which is maintained as a living whole by the symbiotic nature of every detailed activity within it. What is key is that a network supports its weakest link, whereas a chain breaks at its weakest link. The meaningful difference in collaborative behaviour is enormous.

Within a balanced ecosystem, the emission and absorption of methane has daily, seasonal and annual rhythms. Hence, when methane is emitted, it is a sign that a natural process is out of balance. Industrial waste water contributes 24 percent of methane emissions in Malaysia, while 99 percent of methane emissions from industrial waste water treatment and discharge are from paoil mill effluent (POME). The conventional treatment of POME uses a series of open ponding systems and anaerobic digestion emits a biogas that consists of 65 percent methane.

To encourage biogas capture, new mills and existing palm oil mills requiring throughput expansion have been mandated to install full biogas trapping or methane avoidance facilities since 1 January 2014. As of December 2019, 125 biogas plants were in operation. This corresponds to a 28 percent implementation rate, given that there are 451 palm oil mills in Malaysia. Thirty of these biogas plants are connected to the national grid and three to the local grid for external users.

Biogas capture implementation has not achieved nationwide success in Malaysia due to shortcomings in the supporting framework design,²⁶ interconnectivity issues, poor return on investment, heavy fuel subsidy, and crop season and milling capacity.

Solid waste disposal contributes 29 percent of Malaysia's methane emissions. 80 percent of the country's solid waste is dumped into landfills and dumpsites. Solid waste in Malaysia consists of 50 percent food waste at the source, and 70 percent at landfill sites. Landfill and incineration are the

²⁶ RE fund, quota demand, feed-in tariff, displacement cost, e-bidding etc

more common methods for food waste disposal. However, landfills are reaching their limits in Malaysia and incineration is costly, pollutes the environment, and damages public health.

The Solid Waste Management & Public Cleansing Corporation (SWCorp) identified food waste as a key issue in its 2015–2020 Action Plan. Pilot schemes were introduced at the collection and composting stages. A challenge in implementing new schemes is that types of waste requiring similar treatment are regulated by different bodies, e.g. food waste by the National Solid Waste Management Department and sewage by the Ministry of Environment and Water.

The National Solid Waste Management Department has a Food Waste Management Development Plan for Industry, Commercial and Institution Sectors (2016–2026). The Ministry of Housing and Local Government (MHLG) and the Ministry of the Environment Japan (MOEJ) have also collaborated on developing the National Strategic Plan for Food Waste Management in Malaysia in 2018. Despite all these national efforts, food waste remains a major source of methane in Malaysia. These observations highlight the importance of not only creating helpful policies, but in reviewing their effectiveness and developing them appropriately to increase effectiveness.

Palm biomass waste is ten times the amount of municipal solid waste.²⁷ The former, however, receives a tiny amount of attention despite the fact that the soil needs palm biomass ‘waste’ to be recycled organically and fed back into itself, to restore soil fertility.

1.6 Agriculture

The relationship between the oil and gas industry and our food goes beyond powering the agricultural machinery and transportation that deliver crops from farms to grocery stores. Natural gas is used as a feedstock to produce large quantities of nitrogen-based fertilisers—ammonia and urea.²⁸ Malaysia manufactures and uses chemical fertiliser at ten times the rate of application of some neighbouring ASEAN countries,²⁹ yet achieves a lower agricultural yield.³⁰ It has been understood for over a decade that the reason is the degraded, severely poor fertility of Malaysia’s soil, i.e. the microbiological life that is the soil’s fertility has been seriously damaged, and applying more-of-the-same chemical ‘answer’ cannot work, as it is actually causing the problem. What is needed is a biological solution, based on a thorough understanding of the microbiological ecosystem that is the soil’s fertility, then working to regenerate it.

Modern composting is a biologically based manufacturing process that has been demonstrated to do this. It not only rejuvenates the soil’s highly productive microbial ecosystem and significantly increases agricultural yields, it also enables the soil to sequester large amounts of carbon during its production, thus becoming valuable in two ways, simultaneously.³¹ Developing a fertility-creating composting industry in place of a chemical ‘fertiliser’ industry is a necessary part of achieving sustainability.

1.7 Forestry

Before 2004, Malaysia had negative carbon emissions, because land use, land use change and forestry contributed significantly to Malaysia’s carbon emissions removal. To expand the carbon sink, the Malaysian government has launched a campaign under the 12th Malaysia Plan to

²⁷ Estimated palm biomass waste in Malaysia in 2020: 129 million tonnes per annum. Estimated municipal solid waste (MSW) in Malaysia: 13–14 million tonnes per annum.

²⁸ 80 percent of the gas is used as feedstock for fertiliser; 20 percent is used for heat and electricity production

²⁹ <https://knoema.com/>

³⁰ FAO 2019; FAOSTAT <https://documents1.worldbank.org/curated/en/617611574179512389/pdf/Agricultural-Transformation-and-Inclusive-Growth-The-Malaysian-Experience.pdf>

³¹ Platts, Michael James: Leong, Yuen Yoong. “Soil Fertility Is a Productive Capital Asset.” *Agricultural Sciences* 11, no. 8 (August 2020).

rehabilitate 20,000–80,000ha of degraded areas across Malaysia by replanting 100 million trees from 2021 to 2025. The key to success will lie in taking good care of saplings, especially those planted in rough terrain and on steep slopes, so that they develop healthy roots and grow to maturity. In the fervour to maintain rainforest as carbon sinks for the world, we sometimes risk constraining ourselves to a static view of stable ecosystems. This could lead to an over emphasis on forests' supposed fragility and low adaptability to withstand human activity and resource exploitation. The key to managing tropical rainforest is to focus on its resilience, not to eliminate all uses of it.

The role of forestry in decarbonization is two-pronged. One way is through developing certified carbon credits from gazetted forest. Here, sub-national frameworks to develop nature-based climate solutions are urgently needed.

The other is through developing new economic value from forest. Fossil fuel based industrial chemistry creates products (e.g. paints, plastics, pesticides, detergents etc.) that modern society uses and is reluctant to give up. Shifting the lifeblood of industrial chemistry away from fossil fuels requires bio-refining.³²

1.9 Moving Forward

In order to address these sectoral challenges, future studies must adopt the following approach to achieve well developed and clear strategic thinking across Malaysian sectors, and allow evidence based decision making at every step:

- Analyse the strategic decarbonization challenges faced across sectors;
- Carefully develop a set of possible forward technology roadmaps and establish key technical feasibility and costing issues, so that detailed clarifying explorations can be initiated within an overall plan. Everything can then be evidence based, both concerning technical possibilities – detailed products and infrastructural issues. This will provide a clear sight of not only the risks, but where we should focus work to explore and clarify those risks.

The article on the construction equipment giant JCB in Appendix 1 is a good example of such strategic thinking and model approach. JCB first analysed the problem to understand it fully, and then developed a set of possible forward technology roadmaps on the basis of technical feasibility and financial cost. When they finally settled on using hydrogen to power their products, they began in-house research and development (R&D) activities to solve remaining technical issues.

Undertaking strategic research is about knowing how to explore, efficiently and effectively, what can become not only possible, but valuable. Any models should be developed from a foundation in engineering, to allow understanding of what is possible and what is valuable to do.

When whole sectors are looking at decarbonization, we not only need to look at and explore technical roadmap scenarios, but also to discuss planning and infrastructure development bottlenecks, and the institutional and political developments needed to make progress. In both these areas, it is not computer models that matter, rather, the quality of the minds considering what it all means and what needs creating. This applies both technically and in relationships. The growth of collective technical understanding and the development of long lasting collaborative

³² Bio-refining produces multiple products from biomass as a feedstock much like what a petroleum refinery does with crude oil.

relationships of deep respect, friendship, and trust underpin the social process of industry development.

One cannot 'solve' a strategic problem simply by choosing a silver bullet technology and buying your way out of that problem. This comes from a model of strategic decision making that assumes that strategy is simply about choosing, not about developing any kind of understanding. For large-scale systems transformation to be successful, one must conduct vigorous and robust analysis to assess benefits and trade-offs within any path forward. It is only through systems thinking and an integrated approach that Malaysia will be able to embrace the full suite of economic benefits to society in the transition to a sustainable future.

Well over a decade ago, South Korea realised that developing the road to sustainability was not a single decision but a long term process; they needed to establish a way of developing a civil service with a coherent and highly developed competence to steadily grow their understanding and continue guiding the country throughout a decades-long transition. Every year, South Korea awards a coordinated set of scholarships to their most talented and mature civil servants, enabling them to complete 3-year PhD programmes at leading universities across Europe. Each PhD student works with their Korean supervisor to identify a PhD topic that will be useful for developing their overall understanding of sustainability.

South Korean embassies across Europe keep in contact with these PhD students. Each year, there is a two-day gathering of these students across Europe, where they share what they are doing and their findings. This allows each student to have a far wider development of their understanding, and to develop contacts across Europe for their research. It also means that when they go back to South Korea, they join a growing network of high level civil servants in different departments who all know each other, have shared learning experiences, and are able to think and plan together at a very high level.

This is an astounding piece of thinking and forward planning by South Korea, well worth emulating. ■

SECTOR DEEP DIVES AND DECARBONIZATION OPTIONS

2.1 Energy

By Fun Woh Peng

Malaysia is unique among developing nations in that it has a power generation capacity far exceeding peak power demand, which stood at around 18GW in 2019. In contrast, power generation capacity is estimated to be in excess of 30GW. Coal and gas contribute around 82 percent and renewable energy (RE), which includes all hydropower, contributes around 17 percent. RE sources like solar photovoltaic (PV), biogas and biomass account for a mere few percent. Additionally, Malaysia provides coverage to 99.9 percent of its population, with only extremely remote areas in East Malaysia unable to access grid connected power.

Currently, gas and coal will continue to feature heavily in Malaysia's energy mix through to 2050 with natural gas being touted as the solution to the low carbon energy transition. Is this necessary and sustainable?

The carbon dioxide emission profile of a cutting-edge gas power plant is estimated to be in the neighbourhood of 350–400g/KWH. For coal, an ultra-super-critical plant emits about 550g/KWH. Regardless of the technology, carbon dioxide emissions cannot be reduced to an acceptable level if fossil fuels are included in the generation profile. For reference, the Sustainable Energy Development Authority (SEDA) reported an emissions level of approximately 700g/KWH (2019). In the same year, total generation was reported to be about 150,000 GWH. It seems like Malaysia's CO2 reduction plan will hit a high lower limit, if it does not move away from fossil fuels.

The remaining viable alternatives are solar PV and hydro. Solar PV suffers from intermittency and low utilisation capacity. In Malaysia solar PV has a capacity utilisation of no more than 18 percent, compared to over 90 percent for fossil fuel plants. The challenge is how to provide a stable baseload, even if there is enough generation capacity, given that solar energy is intermittent. It becomes immediately obvious that some form of storage or interconnection must be included in the equation. Currently, the most advanced, accessible, and economical storage solutions are lithium-ion and flow batteries. Although the Levelized Cost of Storage (LCOS) is still not at grid parity, technology advancement will soon make them commercially viable.

Malaysia is endowed with an abundance of hydro generation potential. This RE source can act as a baseload or be used as storage (like a large battery).

Sector background and context

By Teh Ah Kau

Malaysia has the good fortune of being an energy-abundant country. Background information about the country is shown in Table 1.

Per Capita	Per Annum
GDP at Current Prices (RM)*	42,263
Primary Energy Supply (toe) ³³	3.070
Final Energy Consumption (toe)	1.951
Electricity Consumption (kwh)	4,576

Table 1: Key Economic and Energy Data

Source: Energy Commission 2019

Malaysia is supportive of climate action. In 2017, the government endorsed a Green Technology Master Plan (2017–2030) that includes target timelines to complete initiatives in five main sectors: (a) energy, (b) transport, (c) building, (d) waste and (e) water. Planning criteria takes into consideration (a) supply reliability, (b) diversity to reduce risk, (c) affordability and (d) sustainability related to carbon emissions.

The main pathways to decarbonization include (a) increase renewable energy (RE) source for electricity generation, (b) improve energy efficiency of industrial processes and product utilisation (c) conserve forest resources, (d) electrify transport and use vehicles with low carbon technology, and (e) reduce waste and loss.

Malaysia does not have wind or geothermal. Its main sources of RE are hydro and solar power. The plan is to increase Peninsula Malaysia's RE to 31 percent of total generation capacity by 2025, and 40 percent by 2035. This RE quantum does not include solar at distribution or behind the meter, such as rooftop solar. Above 30 percent, the reliability of the grid system supply in Malaysia suffers due to the intermittent nature of solar. To compensate for this shortcoming, additional equipment such as battery storage is required, thus increasing supply cost. Additionally, dispatchable thermal plants may be required to address the risk of prolonged lower production of solar plants during the cloudy monsoon period.

A power generation development plan up to 2039 has been put forward in 2021.³⁴ The plan complies with Malaysia's COP21 commitment on carbon intensity per GDP. The proportion of solar, combined cycle gas turbines (CCGT) and coal plants will change from 17 percent, 45 percent and 37 percent in 2021 to 31 percent, 47 percent and 22 percent in 2039 respectively, ensuring that power generation is less carbon intensive. Coal plant reduction and additional power generation development will be shifted to RE and natural gas.

The solar power initiative to increase total solar plants up to about 31 percent of system demand appears to be on track. In the last Large Scale Solar 3 (LSS3) tender called by ST in 2020, the average tender price was about 20 cents per kwh, which was close to parity price and had a good take off rate. Battery storage will improve reliability of supply due to intermittencies, but the price

³³ Tonne of oil equivalent (toe) is defined as 107 kilocalories (41.868 gigajoules). This quantity of energy is, within a few per cent, equal to the net heat content of one tonne of crude oil.

³⁴ Energy Commission. "Report on Peninsular Malaysia Generation Development Plan 2020 (2021–2039)." 2021.

is still high. Battery storage ancillary services will be added from 2030 onward. This will allow greater penetration of solar energy in the system. Technology solutions for mitigating intermittent supply will be required.

Hydro increase will be slow in the future, as most of the good hydro potential has been utilised. Gas usage will be increased further. The COVID pandemic has caused economic slowdown which has, in turn, reduced electricity consumption and carbon emissions but this effect is likely to be short-term.

At COP21 in 2015, Malaysia pledged to reduce its carbon emission intensity per GDP by 35 percent 2030 relative to the 2005 level or 45 percent with support from developed countries.

Reinforcing the COP21 commitment, the Government has revised the national RE capacity mix target from 20 percent to 31 percent by 2025 for Malaysia. The Government has also included large hydro resources as part of the RE definition for Malaysia, consistent with practices adopted by other countries internationally. Current large hydro capacity in Malaysia stands at 5684MW with Peninsular Malaysia contributing about 2232MW.

Key insights from existing decarbonization analysis include:

- Malaysia does not have wind and most of hydro have been utilised. Depending too much on solar RE reduces the reliability of supply due to the intermittent nature of solar. There will be a limit of around 30 percent with the current infrastructure, according to our experts.
- Another 10 percent increase may be possible if battery storage ancillary service is added. RE raises the cost of supply and gives uncertainty to reliability if pushed to the limit.
- ASEAN is different from Europe where the transmission network is well interconnected and network pricing mechanisms are available.
- From the national perspective, conventional fossil fuel power plants have a lower levelised cost. To reduce carbon emissions towards the limit of 30 percent or higher, system costs increase and system reliability decreases.
- Production hours for solar energy are only about 8 hours per day—and it is not available when cloudy, especially during the monsoon period. Electricity generation can vary suddenly and within the span of minutes or hours. The system must have sufficient dispatchable reserve to perform frequency control and power regulation. This uncertainty needs to be mitigated by standby thermal units. Could countries share standby generators to reduce costs, with a good interconnection and a price sharing mechanism?
- Malaysia will meet its pledge on targeted energy intensity per GDP, as it declared in its COP21 commitment.
- Beside RE, the remaining source supply comes from fossil fuels – either gas or coal.

Key gaps in current decarbonization analysis include:

- Ultimately, a large proportion of generation still depends on fossil fuels and the technology of carbon capture is still not economically available or mature.
- RE alone helps to reduce carbon emissions, but cannot achieve net zero without low cost and long duration energy storage.

The economic case for stronger climate ambition

Benefits for strengthening climate ambition include:

- Protection and scaling of natural ecosystem services provides resilience for human civilization and well-being, especially in the face of climate change;

- Preventing climate-related risk and avoiding stranded infrastructure assets;
- Attracting sustainable industries that protect the local environment and improve quality of life;
- Reducing carbon taxation of products and enhancing green branded products;
- Attracting investment from climate responsible investors;
- Lowering financial borrowing rates for projects funding;
- Creating new industries and jobs to strengthen the national economy.

2.2 Transportation

By Fun Woh Peng

Transportation accounts for more than 20 percent of carbon dioxide emissions in Malaysia. This number is increasing, with an average of over 600,000 vehicles produced each year over the last 10 years. The department of statistics reported 15 million private automobiles, 15 million motorcycles, 1.3 million commercial vehicles, 0.2 million public service vehicles and 0.6 million other vehicles in 2019.³⁵ As Malaysia does not practice a vehicle end-of-life policy, older vehicles will contribute to substantially greater emissions than estimated. Hence, any discussion by the government on reducing carbon dioxide emissions must include a plan to remove internal combustion engine vehicles that are no longer roadworthy from service.

From the 1980's onward, Malaysia has supported the automotive industry with various subsidies given to manufacturers as well as to component makers. It was expected that the industry would spearhead growth and bring about new indigenous technological innovations. This aim however, was never realised because local companies did not acquire the know-how required for manufacturing, development, design and innovation. The current automotive scene is dominated by Perodua (Daihatsu/Toyota) and Proton (Geely) as special incentives were given to them, afforded through their status as 'national' car makers. The vehicles they manufacture however, are 'build-to-design', with little input from local engineers and designers. Other foreign transplants like Honda, Toyota, Nissan, Mitsubishi, and others, build vehicles from kits imported from global sources. Hence, their technology contribution is even less.

The Malaysian National Automotive Policy 2014 promoted 'Energy Efficient Vehicles' or EEVs, yet these were nothing more than internal combustion vehicles that achieved a higher efficiency in terms of kilometres per litre. Resulting emissions from the transportation sector continue to increase, due to the growing number of vehicles on the road.

The Malaysian National Automotive Policy 2020 was introduced last year with the intention of supporting the country's drive towards a lower carbon economy. The specific objectives of NAP 2020 are as follows:

- Turn Malaysia into a regional hub for NxGV technology systems and vehicles production
- Expand the domestic industry in the sector of Mobility-as-a-Service (MaaS) particularly for the development of an integrated transport ecosystem
- Ensure the advancement of the domestic automotive industry is in line with the developments of Industrial Revolution 4.0
- Reduce carbon emissions in-line with the ASEAN Fuel Economy Roadmap of 5.3 Lge³⁶/100km by 2025

³⁵ <http://www.maa.org.my/statistics.html>; <https://www.ceicdata.com/en/indicator/malaysia/number-of-registered-vehicles>; <https://paultan.org/2020/04/02/vehicles-registrations-in-malaysia-31-2-mil-as-of-2019/>

³⁶ Litres of gasoline equivalent.

- Ensure the country benefits from the spin-off economy from the overall implementation of NxGV.

Although this is a step forward, it will be very difficult for the industry to bring about any changes in reducing carbon dioxide emissions as long as ICEs continue to play a role. Malaysia must adopt a new mindset and move towards zero tailpipe vehicles. The most promising options are electric battery vehicles and hydrogen fuel cells. The next Automotive Policy should include the following elements:

1. A ban on all production of ICEs by 2035. This should give local manufacturers enough time to scale down and build new infrastructure
2. A special excise duty given to early adopters, to accelerate the development of zero tailpipe vehicles
3. A tax on ICE vehicles after 2030 to encourage the transition
4. An income Tax Allowance (ITA) given to vehicle and component manufacturers, investment in infrastructure like charging and services.

Given that enormous resources are needed to develop the complete automotive infrastructure required, from design/development upstream to service and infrastructure downstream, a natural question to ask is 'Can Malaysia continue to support the automotive manufacturing industry?'

2.3 Manufacturing and Construction

By Andrew Fan and Leong Yuen Yoong

Globally, the manufacturing and construction sector directly³⁷ contributes around 19 percent of GHG emissions. The two sub-sectors that contribute the greatest global GHG emissions are cement, iron and steel.

For Malaysia, manufacturing and construction contributed 9 percent of Malaysia's CO₂ emissions, the third largest after electricity and heat production, and road transportation.³⁸ Consistent with the global scenario, Malaysia can achieve significant reductions in industrial GHG emissions by focusing on product and process improvements within the two highest CO₂ emitting sectors, i.e. cement, iron and steel.

Malaysia can use the following policy levers to encourage firms in the manufacturing and construction sector to decarbonize: 1) Implement a carbon pricing mechanism similar to Europe, UK or China, so there are financial incentives for firms to invest in low carbon production technologies; 2) Identify and implement industrial waste heat recovery projects because these projects result in greater energy efficiency which will yield a profit over the long run; 3) Encourage greater use of biogenic fuel to displace fossil fuels because Malaysia's oil palm and agriculture sectors produce large quantities of biomass by-products that can be processed into renewable fuel; 4) Plan and implement industry clusters to facilitate greater industrial symbiosis (e.g. use of waste, bioenergy and CO₂ as downstream feedstock); 5) Map available decarbonization technologies to existing industrial processes; 6) Capture carbon and utilise it to produce high value products.³⁹

³⁷ Direct contribution refers to direct-energy use and industrial process. It excludes electricity sourced from the energy sector which will be decarbonized with strategies described in chapter 2.

³⁸ Ministry of Environment and Water. Malaysia Third Biennial Update Report to the UNFCCC. Ministry of Environment and Water, 2020.

³⁹ UK Climate Change Committee. "The Sixth Carbon Budget: Manufacturing and Construction." 2020.; UK Department for Business, Energy and Industrial Strategy. "Chemicals Sector: Joint Industry-Government Industrial Decarbonization and Energy Efficiency Roadmap Action Plan." 2017.

Cement

The most common cement produced in Malaysia is Ordinary Portland Cement (OPC). OPC is produced when limestone (CaCO_3) is heated and reduced to lime (CaO). Lime is then combined with gypsum, iron, and aluminium silicates to form clinker. The clinker is then cooled and ground to form cement. The calcination process to form clinker contributes around 60 percent of total GHG emissions, while the remaining 40 percent is in the form of energy to heat the kiln and mechanical energy.⁴⁰

In 2016, the Malaysian cement industry had a total installed capacity of 38.8 million MT. Between 2011 to 2016, the amount of cement produced increased from 20.9 million MT to 22.3 million MT. The top 3 producers are Malayan Cement YTL, CIMA and Hume with market shares of 52 percent, 18 percent and 10 percent respectively. In 2017, Malaysia imported one million MT and exported 0.5 million MT of cement.⁴¹

The Malaysian cement industry can reduce GHG emissions via two ways. First, Malaysia's clinker to cement ratio is 0.89. This is high compared with other developing countries such as Brazil (0.65) and China (0.75). Malaysia can reduce GHG emissions by substituting clinker with biogenic materials such as palm oil fuel ash, rice husk and sawdust ash.⁴² Second, Malaysia's cement industry is highly reliant on fossil fuels, with biomass fuel accounting for only 2 percent of the fuel mix.⁴³ The industry can switch to fuels which are cleaner and more sustainable. In the long run, cement producers in Malaysia will need to deploy carbon capture and utilisation technology and/or low carbon cement alternatives⁴⁴ to reach net zero emissions by around mid-century.

Iron and Steel

Steel is a globally traded and small margin commodity. The industry is characterised by high capital intensity, dependence on bulk raw materials, cyclical growth and profitability trends, and periodic over-capacity. These factors hinder the adoption of emissions reduction technologies that will increase production cost significantly (>120 \$/ton).⁴⁵ The core issue around decarbonizing is not the lack of technological solutions, but the high abatement costs that will affect market share, trade, and labour.

To make steel, iron ore is melted at a high temperature and reduced from iron oxide to iron. The process usually involves burning fossil fuels, which releases significant CO_2 . The three key processes used to manufacture steel in Malaysia and their decarbonization potential are summarised in Table 2.

BF-BOF is here to stay in the near future because:

Raw material cost for scrap steel (USD430/MT CIF) is higher than iron ore (USD180–190/MT CIF). The steel yield from iron ore is higher than scrap steel. These factors affect profit margins. For

⁴⁰ Risman, Jeffrey, Chris Bataille, and Eric Masanet. "Technologies and policies to decarbonize global industry: Review and assessment of mitigation drivers through 2070." *Applied Energy* 266, no. 114848 (2020).

⁴¹ Malaysian Competition Commission. "Market Review of Building Materials in the Construction Industry under Competition Act 2010." 2016.

⁴² Müller, N., and J. Harnisch. "A blueprint for a climate friendly cement industry." WWF Lafarge Conservation Partnership, 2008.; Gazipur, B. "Necessity and opportunity of sustainable concrete from Malaysia's waste materials." *Australian Journal of Basic and Applied Sciences* 5, no. 5 (2011): 998-1006.

⁴³ Müller, N., and J. Harnisch, "A blueprint".

⁴⁴ Examples of low GHG alternatives to cement are geopolymers /alkali activated binders, magnesium silicate.

⁴⁵ ETC. Mission Possible: Reaching net-zero carbon emissions from harder-to-abate sectors. 2018. <https://www.energy-transitions.org/publications/mission-possible/>.

example, a deformed steel bar is priced at USD460/MT, which leaves little room for profit if scrap steel is used as the raw material.

Security of supply is higher for iron ore than scrap steel. This is an important factor in steel plant planning.

Steel Production Pathways	Decarbonization Potential
Blast furnace – basic oxygen furnace (BF-BOF)	<ul style="list-style-type: none"> • Dominates global production (71 percent); predominant production method in Europe • Stubborn to decarbonization technology; efforts are focussed on improving efficiency and/or decreasing production loss
Electric arc furnace (EAF)	<ul style="list-style-type: none"> • Secondary steel production that uses electricity to heat scrap steel to create new products (24 percent) • Lowest energy consumption; EAF-scrap is 36 percent less emission-intensive than BOF • Technically simplest to decarbonize through electrification • Limited in market share to recycled steel capacity
Direct reduced iron to electric arc furnace (DRI-EAF)	<ul style="list-style-type: none"> • DRI-based reduction emits less CO₂ than the integrated method and enables the production of high- quality products in the EAF • DRI-EAF production is 5 percent and growing • Requires cheap and readily available natural gas. Regions with low natural gas prices like the Middle East or North America are big DRI producers.

Table 2: Decarbonization Potential of Different Steel Production Pathways

Source: Hoffmann, Hoey and Benedikt 2020, Fan and Friedmann 2021, Moody's 2018

EAF can only process scrap steel, which is insufficient to supply all the steel demand in the world. In other words, BF-BOF is here to stay.

What governments can do is consolidate BF-BOF plants so that efficiency improves. Besides that which is described in Table 2, the technology landscape for decarbonizing steel production includes biomass and green hydrogen⁴⁶ reductants, carbon capture and usage. Locations that have cheap hydropower, available land and proximity to iron ore are ideal for green steel production.

2.4 Oil and Gas

By Low Wai Sern

Malaysian state of affairs

Malaysia is the second largest oil and natural gas producer in Southeast Asia and is the fifth-largest exporter of liquefied natural gas (LNG) in the world as of 2019 (U.S. Energy Information Association 2021).⁴⁷ Fossil energy exports continue to make up a substantial bulk of revenue and economic

⁴⁶ Replacing fossil fuels with green hydrogen as a reducing agent eliminates more than 98 percent of CO₂ usually released. Green hydrogen comes from electrolysing water, using electricity produced by hydro power.

⁴⁷ U.S. Energy Information Association. Country Analysis Executive Summary: Malaysia. U.S. Energy Information Association, 2021.

growth despite the drop in oil prices during 2014–2016 as well as recent instabilities due to the COVID19 pandemic.

Production volume for liquid petroleum fuels has been in slow decline since 2016.

Conversely, natural gas output has risen within the same timeframe, mostly driven by rising export volumes as the world moves from coal and oil to natural gas because the latter's global warming emissions from its combustion are much lower.

As of 2021, policymakers and PETRONAS⁴⁸ maintained an optimistic outlook on the future of the sector in the hope that the oil and gas industry will continue to be a significant contributor to government revenue.⁴⁹ PETRONAS is actively seeking to reverse the decline by attracting investment for marginal fields and newer oil recovery methods, developing the Trans-ASEAN Gas Pipeline System (TAGP) and expanding oil storage capacity.

The National Oil & Gas, Services and Equipment (OGSE) Industry Blueprint 2021–2030 was released by the Economic Planning Unit (EPU)⁵⁰ in late April 2021, outlining the initiatives and goals set out to revitalise an industry that is troubled by shale, excessive oil supply, and poor returns on investment.

Global state of affairs

A majority of economic estimates and projections predict a decline in demand in oil and gas in coming years, with the downturn expected to begin by 2025–2030. The gradual shift towards clean energy and technologies worldwide is expected to replace demand for traditional fossil fuels, especially coal and oil. The prospect for natural gas still hangs in the balance, with some segments of the industry investing in natural gas as a low- carbon alternative while others would prefer to replace it wholesale with renewables, particularly for the purpose of electricity generation.

The global pandemic in 2020 further exacerbated the issue as demand fell worldwide. While the prices of oil and gas have recovered somewhat since, the crisis has accelerated transitions in energy systems as economies worldwide are forced by circumstance to adapt. Within the industry, the larger players have also begun to shift focus, with major companies looking for low carbon solutions and setting carbon reduction goals for the near future.⁵¹

State of decarbonization research

The subject of decarbonization is a thorny one, especially in an industry that is based on the extraction of carbon- based fuels. Usually however, this is discussed in tandem with the usage of these fuels in energy generation, transportation and industrial processes. Within the industry itself, emissions represent a much smaller percentage of the total (Table 3).

⁴⁸ PETRONAS holds exclusive ownership rights to all oil and natural gas exploration and production projects in Malaysia through the Petroleum Development Act 1974. Malaysia Petroleum Management (MPM) is responsible for managing all upstream licensing procedures. PETRONAS holds stakes in most of the oil and natural gas blocks in Malaysia.

⁴⁹ PETRONAS' contribution in the form of taxes, dividends, and cash payments comprised about 35 percent of total government revenue in 2019

⁵⁰ Energy policy in Malaysia is set and overseen by the EPU and the Implementation and Coordination Unit. Both report directly to the Office of the Prime Minister.

⁵¹ Fiori, Luciano Di, Elif Kutsal, and Pawel Wilczynski. Global oil supply-and-demand outlook to 2040. McKinsey. 26 February, 2021. <https://www.mckinsey.com/industries/oil-and-gas/our-insights/global-oil-supply-and-demand-outlook-to-2040>; Dickson, Duane. 2021 oil and gas industry outlook: Exploring oil and gas trends and impact of COVID-19. Deloitte. 2021. <https://www2.deloitte.com/us/en/pages/energy-and-resources/articles/oil-and-gas-industry-outlook.html>.

		CO ₂	CH ₄	N ₂ O	NO _x	CO	NMVOCs	SO ₂
1A	Fuel Combustion Activities	226,728.76	24.08	4.24	1,026.84	4,619.62	847.26	589.09
1A1b	Petroleum Refining	8,624.04	0.35	0.07	7.41	4.62	0.3	0.03
1A1c	Manufacture of Solid Fuels and Other Energy Industries	25,509.63	0.45	0.05	40.47	17.73	1.18	0.13
1B	Fugitive emissions from fuels	1,728.93	927.78	NA	0.16	0.66	4.5	0.03

Table 3: GHG Inventory Year 2014

Note: All values in GG. Source: MESTCC 2018.

The IPCC Fifth Assessment Report (AR5) lays out several trends that provide opportunities in mitigating emissions from the extraction, transport and conversion of fossil fuels. These are (1) new technologies that make accessible substantial reservoirs of shale gas and unconventional oil;⁵² (2) a renewed focus on fugitive methane emissions, especially those associated with gas production; and (3) improved technologies for energy efficiency and the capture or prevention of methane emissions in the fuel supply chain.⁵³ Newer technologies also involve methods of carbon capture.

Among those applicable to Malaysia would be prospecting for unconventional sources, reducing fugitive methane emissions, implementing energy efficiency strategies⁵⁴ and technologies,⁵⁵ and adopting energy improvement technologies.⁵⁶ Locally, PETRONAS is seeking to (1) reduce hydrocarbon flaring & venting, capture methane emissions and optimise production and operations, (2) mitigate GHG emissions from operations through energy efficiency improvement and use of low carbon or renewable energy, and (3) minimise waste and promote recycling throughout the value chain.⁵⁷

Recommendations

As the costs of renewables drops and the industry becomes increasingly competitive, any effort to expand extraction of fossil fuels stands at odds with efforts to decarbonize.⁵⁸ Malaysia, as a net exporter of oil and gas products, is in a precarious position as global efforts to reduce reliance on fossil fuels continue in earnest. While fuel prices at the moment may still favour continued extraction, signs have begun appearing, pointing to the eventual decline of the industry. Indeed, as mentioned, larger producers (SHELL, BP, etc.) have all announced shifts away from traditional oil and gas production. Given the timeframes involved, there remains only a decade or so to make the shift or risk being left behind. For Malaysia, given its reliance on oil revenue, this could result in a heavy toll on the economy. There does not seem to be a viable long-term plan in place to mitigate the potential economic ramifications should demand drop significantly, especially if ASEAN, a major trading partner for Malaysia in this sector, begins to push for a low carbon future in earnest.

⁵² Crude oil that is obtained through methods other than traditional vertical well extraction. Examples include developing oil sands, directional drilling, fracking etc.

⁵³ Bruckner, T., I. A. Bashmakov, and Y., Chum, H., De la VegaNavarro, A., Edmonds, J., Faaij, A., Fungtammasan, B., Garg, A., Hertwich, E. Mulugetta. "Energy Systems." IPCC, 2014.

⁵⁴ Energy management practices, energy saving programs, maintenance programs etc.

⁵⁵ Replacing inefficient appliances and machinery with efficient ones

⁵⁶ Technologies that improve the generation, supply and use of energy

⁵⁷ PETRONAS. Net Zero Carbon Emissions. 2020. <https://www.petronas.com/sustainability/net-zero-carbon-emissions> (accessed 11 May, 2021).

⁵⁸ IEA. "Net Zero by 2050: A Roadmap for the Global Energy Sector." International Energy Agency, 2021.

2.5 Waste

By Agamutu Pariatamby

Malaysian waste management is relatively better than other developing countries, for it has a sound regulatory framework for the majority of waste streams including municipal solid waste (MSW),⁵⁹ agriculture waste, wastewater and others. However, when compared with developed countries, Malaysia falls behind in effective implementation of respective regulatory frameworks throughout the country. For instance, the Solid Waste and Public Cleansing Management Act 2007 or Act 672 is only implemented in selected states in Peninsular Malaysia and thus, source separation is only applicable to limited states as well. Regardless, source separation is not widely practised in states where Act 672 is applicable, despite the regulatory framework and provisions of fines, thereby resulting in highly heterogeneous generation of MSW. In addition to this, other factors that hamper the sustainable management of MSW include:

1. Lack of awareness of resource circulation and waste related activities among public;
2. Lack of participation of waste related initiatives such as source separation;
3. Overlapping responsibilities among ministries or other waste managing authorities;
4. Lack of coordination among relevant managing agencies;
5. Less developed and less advanced recycling infrastructure which mainly focuses on highly recyclable waste streams such as rigid plastics;
6. Role of informal sector in MSW management landscape.

Due to these issues hindering effective management of MSW, recycling of MSW has been as low as 17.5 percent in 2016. Ironically, even the numbers around MSW recycling are based on estimations and not calculated empirically. On the other hand, remaining MSW is disposed of in mainly non-sanitary landfills or open dumps, whereas a lesser quantity is disposed of in sanitary landfills. While there are three landfill flaring and six landfill gas collection projects running in Malaysia under the Clean Development Mechanism (CDM), the release of methane from solid waste disposal sites is high. Food waste (about 44 percent of MSW) which degrades more rapidly than other MSW streams, is a source of methane generation in landfills. Yet there is less possibility of Malaysia banning biodegradable waste streams from landfills in the light of the government's recent policies and regulations. For example, the 11th Malaysian Plan aimed at increasing recycling to 22 percent in 2020. Similarly, the Green Technology Master Plan highlighted that Malaysia aims to increase its recycling from 22 percent

in 2020 to 28 percent in 2030 and have 80 percent of sanitary landfills for disposal sites. Hence, there is no indication in policies, around banning the disposal of organics in landfills.

In addition to MSW, approximately 129 million tonnes of biomass are generated from the oil palm sector in Malaysia.⁶⁰ The biomass generated from oil palm include empty fruit bunch (EFB), fibre, shell, palm oil mill effluent (POME), trunk and fronds. POME is a major agricultural waste and has low resource circulation rate as only 92 palm oil mills with biogas capture facilities exist in Malaysia as of 2016. Bio-gasification converts organic waste into methane, which can be used for energy generation, and compost, which is a biofertiliser. There is a ban on open burning of agricultural waste as it is detrimental to the environment, therefore the palm industry has been looking at

⁵⁹ Estimated at 13–14 million tonnes per annum

⁶⁰ Agamuthu, Pariatamby, and S. B. Mehran. "Waste Management Challenges in Malaysia." In *Sustainable Waste Management Challenges in Developing Countries*, edited by P. Agamuthu, S.H. Fauziah and S.B. Mehran. Hershey, Pennsylvania: IGI Global, 2020.

resource circulation alternatives.⁶¹ Nevertheless, MESTECC reported that 100 percent of methane is released into the atmosphere from POME.⁶² Additionally, approximately 85 percent of palm oil mills deploy a ponding system for the treatment of POME. The remaining 15 percent use open digesting tanks for POME treatment.⁶³ According to the Green Technology Master Plan (2017–2030), 250 palm oil mills will provide electricity to the national grid and 233 mills will provide electricity to own boilers by 2030, hence improving resource circulation in waste from palm oil mills and reducing the release of GHG.

In order to improve the management of waste in Malaysia and decarbonize the waste sector, several recommendations are listed below:

1. Improve data collection in the waste sector to devise better management technologies and to establish required infrastructure;
2. Increase awareness among the public and other relevant stakeholders regarding waste management;
3. An effective and urgent implementation of an Integrated Waste Management policy, especially 3R (reduce, reuse, recycle) inclusive, is required in Malaysia;
4. Execution of waste segregation must be enforced throughout the country uniformly and non-compliance must be dealt with fines as stated in Act 672;
5. The utilisation of agricultural waste should be increased since there is great potential in its utilisation for bioenergy, bio-chemicals, and others. Stringent implementation of current regulations, and creation of awareness among stakeholders especially related to palm oil mills and tax subsidies are vital;
6. Formalisation and subsequent coordination of the role of informal recyclers should be carried out. Their contributions ought to be recognised and recycling data should be included in the national reports.

Please see Appendix 2 for more information.

2.6 Agriculture

By Chen Jit Ern and Low Wai Sern

The primary agricultural crop for Malaysia is oil palm, with roughly 2.6 million ha of new oil palm plantations established throughout the country between 2000 and 2020 alone, the vast majority being in the Borneo Island states of Sabah (0.5 million ha) and Sarawak (1.3 million ha). This increase in crop acreage has led to total oil palm plantations reaching almost 6 million ha in 2020 compared to 3.4 million ha in 2000.⁶⁴ By harvested area, this far outstrips the land-usage of other crops, with rubber plantations and rice cultivation covering 1.08 million ha and 0.7 million ha respectively in 2018.⁶⁵ Agricultural land is quite evenly spread across Peninsula Malaysia, but has a higher concentration along the coast of Sabah and Sarawak partly due to infrastructural conditions, especially access to sea ports. While palm oil has been a crucial component of economic wealth generation in Malaysia, this comes at a significant cost to the nation's natural

⁶¹ Shafie, S.M., T.M.I. Mahlia, H.H. Masjuki, and A. Ahmad-Yazid. "A review on electricity generation based on biomass residue in Malaysia." *Renewable and Sustainable Energy Reviews* (Elsevier) 16, no. 8 (2012): 5879–5889.

⁶² MESTECC. Malaysia Second Biennial Update Report to the UNFCCC. Putrajaya: Ministry of Energy, Science, Technology, Environment and Climate Change, 2018.

⁶³ Kamyab, H., S. Chelliapan, M.F. Md Din, and S. Rezanía. "Palm Oil Mill Effluent as an Environmental Pollutant." November 2018.

⁶⁴ FABLE. "Pathways to Sustainable Land-Use and Food Systems." 2020 Report of the FABLE Consortium, International Institute for Applied Systems Analysis (IIASA) and Sustainable Development Solutions Network (SDSN), 2020.

⁶⁵ FAOSTAT. 2018. <http://www.fao.org/faostat/en/#data/QC>.

and biodiversity resources as these plantations are usually established at the expense of large-scale conversions of forests and peatlands which are rich in carbon stock. In 2012, Malaysia was covered by 21 percent cropland, 64 percent forest, 15 percent urban and 1 percent other natural land.⁶⁶

The Agriculture, Forestry and Other Land Use (AFOLU) sector is a key contributor to carbon sequestration in Malaysia due to large areas of forests and peatlands. Officially, the Malaysian government reports a large net removal of CO₂ mostly due to the large remaining tracts of forestland in the country Table 4.

		Net CO ₂ Emissions/ Removals	CH ₄	N ₂ O	NO _x	CO ₂	NMVOCS
3	AFOLU	-263,263.50	166.04	20.58	0.39	17.82	NA
3A	Livestock		77.15	0.42	NA	NA	NA
3B	Land	-263,847.86	NA	NA	NA	NA	NA
3C	Aggregate sources and non-CO ₂ emissions sources on land	584.35	88.89	20.16	0.39	17.82	NA

Table 4: Abridged AFOLU Sectoral Table for GHG Inventory Year 2014

Note: All values in GG. Source: MESTCC 2018.

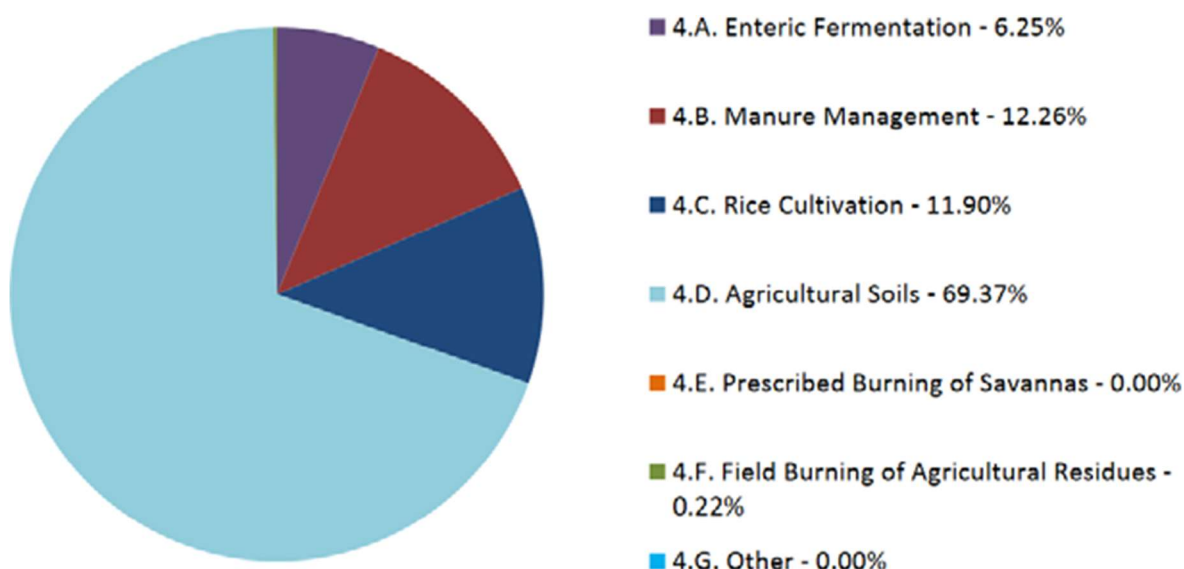


Figure 2: Breakdown of GHG Emissions Within The Agriculture Sector

Source: UNFCCC 2020.

In recent decades, Malaysia has deliberately moved from an agriculture-based economy to a manufacturing and services centered economy. The contribution of the agricultural sector to total GDP had more than halved from 44 percent in 1960 to 15 percent in 1990. This contribution fell

⁶⁶ FAO. "Global Forest Resources Assessment 2015 Country Report, Malaysia." 2014.

further to only 7 percent of total GDP by 2018 whilst the services sector rose in significance, contributing 53 percent of GDP.⁶⁷

In recent years, palm oil has been contributing >50 percent crop export by tonnage for Malaysia. From 1990 to 2010, palm oil production has grown at a rate of 3.1 percent per year. However, scenarios based on current trends project that annual growth will slow down to 1.8 percent from 2010 to 2050 due to less enthusiastic global demand.⁶⁸

Despite this, Malaysia is still heavily reliant on palm oil exports to maintain its balance of trade as well as a method for social engineering and wealth distribution.⁶⁹ In the light of environmental concerns about oil palm, it is important for Malaysia to diversify plantation crops that have a global market, and develop them in a sustainable manner.

Another agricultural consideration that Malaysia will have to deal with is the issue of food self-sufficiency. To maintain current agricultural acreage and not replace more forests, the nation will have to improve soil fertility or convert its export-oriented cash crop plantations to food crops, in other words rethinking its land-use strategy.

2.7 Forestry

By Gopalasamy Reuben Clements and Leong Yuen Yoong

Due to human population growth, the conversion of natural forests to plantation has been rising at alarming rates, especially for developing countries in tropical regions. For example, Malaysia was ranked as having the world's highest rate of tree cover loss (14.4 percent) between 2000 and 2012.⁷⁰ In Peninsular Malaysia, forest areas have declined from about 6.1 million ha in year 2010 to around 5.9 million ha in 2015 due to conversion of forests to other land uses, which translates to a deforestation rate of 0.66 percent/yr and a CO₂ emission of around 22.1 million Mg CO₂/yr.⁷¹

Negative environmental impacts from forestry activities

Despite the economic benefits, forestry sector activity has resulted in substantial negative impacts on Malaysia's environment as it involves logging of natural forests. This has hampered important ecosystem services such as carbon sequestration, precipitation regulation, air and water purification, flood control and soil stabilisation. In addition, the conversion of natural forests for timber harvesting, agriculture and infrastructure development also destroys wildlife habitat and biodiversity and increases GHG emissions.⁷²

⁶⁷ World Bank. "World Development Indicators." 2018.

⁶⁸ FABLE, "Pathways to Sustainable Land-Use and Food Systems."

⁶⁹ Platts, Michael James; Leong, Yuen Yoong. "Soil Fertility Is a Productive Capital Asset." *Agricultural Sciences* 11, no. 8 (August 2020).

⁷⁰ Hansen, M. C., et al. "High-Resolution Global Maps of 21st-Century Forest Cover Change." *Science* 342, no. 6160 (November 2013): 850-853.

⁷¹ Hamdan, Omar, Abd Rahman Kassim, and Mimi Samsudin. "IOP science: Quantifying rate of deforestation and CO₂ emission in Peninsular Malaysia using Palsar imageries." *IOP Conference Series Earth and Environmental Science*. 2016. 45-57.

⁷² Clements, Gopalasamy Reuben, Darmaraj Mark Rayan, Ahmad Zafir Abdul Wahab, and Arun Balu Venkataraman. "Trio under threat: Can we secure the future of rhinos, elephants and tigers in Malaysia?" *Biodiversity and Conservation* 19, no. 4 (April 2010): 1115-1136.; Agus, Fahmuddin, Ian E. Henson, Bambang Heru Sahardjo, Nancy Harris, Meine van Noordwijk, and Timothy J. Killeen. "Review of emission factors for assessment of CO₂ emission from land use change to oil palm in Southeast Asia." *Roundtable on Sustainable Palm Oil*, 2013: 7-27.

Is forestry a sunset industry?

Unsustainable logging practices have placed immense pressure on the forestry sector in Malaysia. However, the forestry sector still claims that forest harvesting will continue to generate more revenue for Malaysia. In 2019, the export of timber and its downstream products brought in RM 22.5 billion in revenue due to high demand for tropical forest products from India and new markets created in Oceania.⁷³ Despite Malaysia's ambition in timber trading, a continuous decline in tree cover poses a major problem for the forestry sector. In fact, the forestry sector is considered a sunset industry given the dwindling supply of natural tree resources. In business terms, a sunset industry is defined as one that continues to be important to an economy but is losing competitiveness. It will be challenging for the forestry sector to keep thriving due to the hidden costs and poor enforcement of forestry regulations.⁷⁴ Unregulated forest harvesting has negatively impacted forest industries in Malaysia as several plywood mills were forced to halt production due to a shortage of logs; the Japan Lumber Report also stated that high cost of logs and low sales price has placed plywood mills in a 'life or death' situation in Malaysia.⁷⁵

The role of the forestry sector in decarbonization

Before 2004, Malaysia had negative carbon emissions due to land use, land use change and forestry (LULUCF) removals.⁷⁶ To maintain Malaysia's rainforests as significant carbon sinks for the world, the utilisation of Malaysia's forestry assets needs an urgent reset. The current logging and minimal processing model attracts logging operators with no motivation to move up the value chain; forests being licensed and tradable leases; low value job creation; minimal replanting; no value added products; low revenues for state governments (royalties and cessions only; hard to audit royalties at gate); and minimal societal benefits.⁷⁷

We recommend a two-pronged strategy for the forestry sector in decarbonizing Malaysia: 1) develop new bio-economic value from forests; and 2) develop sub-national frameworks to facilitate private sector investments into nature-based climate solutions that generate revenue⁷⁸ from intact forests.

Circular bio-economy

A forest circular bio-economy is Malaysia's next economic wave that has the potential to exceed agriculture and petroleum.⁷⁹ In this model, any available abandoned/degraded land identified from remote sensing and ground truthing should be utilised for industrial timber plantations, and wood processing and bio-refineries.

Natural forests should be protected, value added products should be produced, reforestation should be organised, new technologies in bio-plastics and enzymes should be developed. All these developments will attract greater private sector investment and this will lead to greater

⁷³ Malaysian Timber Council. "Annual Report 2019." 2019.

⁷⁴ Habibu, Sira. "Cosmetics millionaire cuts a pretty picture in sawmill business." 16 August, 2017. <https://www.thestar.com.my/news/nation/2017/08/16/logging-in-to-success-cosmetics-millionaire-cuts-a-pretty-picture-in-sawmill-business/>;

⁷⁵ Wong, Jack. "Log shortage forcing some plywood mills to stop production." 10 December, 2018. <https://www.thestar.com.my/business/business-news/2018/12/10/log-shortage-forcing-some-plywood-mills-to-stop-production/>.

⁷⁶ Ministry of Environment and Water. Malaysia Third Biennial Update Report to the UNFCCC. Ministry of Environment and Water, 2020.

⁷⁷ Lax Global Resources. "The Paradigm Shift: Building a Future Together - Creating New Economic Value from Forest." 2018.

⁷⁸ Includes claiming carbon credit.

⁷⁹ Lax Global Resources, "The Paradigm Shift: Building a Future Together".

revenues for cash-strapped state governments, which are ultimately the owners of Malaysia's most valuable carbon sinks.

Sub-national frameworks to develop nature-based climate solutions

Under the Paris Agreement, countries commit to efforts which include reporting biennially emission levels, removal of GHG and emission reduction targets. Malaysia's Nationally Determined Contribution (NDC) is to reduce emissions intensity by 45 percent by 2030. To achieve NDC targets, a national Reduced Emissions from Deforestation and Degradation+ (REDD+) strategy, linked to a reduced GHG emissions from forest management compared to a 'business as usual' baseline scenario, has been proposed. However, the strategy currently does not identify specific national emission reduction frameworks or how sub-national governments will be engaged. The current REDD+ strategy outlines policy alignment at the national and state level, but the specifics around implementation, monitoring and reporting at the project level is undefined.

There is an urgent need to develop sub-national frameworks that would provide policy guidelines, forest GHG baseline for state governments, and structures to implement nature-based climate solutions to help state governments generate revenue from intact forests. These three outputs would allow the state governments to contribute to NDCs more effectively and autonomously because they are guided by a framework that caters to the specific needs of a state government. Ultimately, there needs to be sub-national guidelines that would allow state governments to contribute to NDCs that meet the requirements of international carbon offsetting standards, in line with the UNFCCC requirements to ensure transparency and safeguards of the reduced GHG emissions.

For example, a preliminary assessment in the Kenyir watershed in the State of Terengganu has determined the potential for a carbon offset project to reduce 8,318,879 tCO₂ emissions over 30 years within a ~100,000 ha landscape of production forest reserves in. This directly translates into State's contribution towards achieving the NDC through the forestry sector besides generating other co-benefits such as biodiversity protection and community empowerment. Such carbon financing opportunities in the Kenyir watershed can result in higher emissions reduction possibilities and contribute towards achieving Malaysia's NDC target over a 30-year period.

2.8 Coral Reefs

By Chen Jit Ern

Malaysia possesses substantial coral reefs within its territorial waters, particularly off the coast of Sabah state, an area that is part of the Coral Triangle. As such, Malaysia has a stake in the health and continuing stability of the coral reef ecosystem. The Department of Primary Resources and the Environment of Malaysia estimated that in the period of 2011 to 2015, coral reef areas under the management of Marine Park authorities alone contributed around RM8.7 billion in Total Economic Value.⁸⁰

It is therefore unfortunate that coral reefs have the dubious distinction of being the first whole ecosystem expected to become extinct as a direct result of climate change. Official estimates mentioned in the IPCC's Special report on Global Warming of 1.5°C, 2018, Chapter 3, states that "Warm water (tropical) coral reefs are projected to reach a very high risk of impact at 1.2°C (Figure 3.18), with most available evidence suggesting that coral-dominated ecosystems will be non-

⁸⁰ Department of Marine Park Malaysia. Total Economic Value of Marine Biodiversity: Malaysia Marine Parks. Department of Marine Park Malaysia, n.d.

existent at this temperature or higher (high confidence)".⁸¹ Given that we are currently on track to projected temperatures of 2°C or higher, it would not be a stretch to assume even in the best-case scenario, coral habitat regions will suffer high levels of coverage loss in the coming few decades.⁸²

As such, it will become increasingly important to develop plans to mitigate or slow down the impact of climate change on coral reef ecosystems. These would include restrictions on intensive developments near coral reefs and greater enforcement of destructive fishing methods (e.g. blast and cyanide fishing).⁸³ Such developments would not replace serious action on climate change nor would these scientific efforts be able to stem the full impact of unrestrained temperature increase, but rather, we expect these efforts would buy time for certain portions of the coral reef ecosystem to survive, while international action attempts to stabilise the global climate system.

In terms of their importance to Malaysia's carbon emissions targets, coral reefs consist structurally of layers upon layers of calcium carbonate (CaCO₃), deposited by corals as their exoskeleton.⁸⁴ These carbonate deposits are effectively large blocks of solidified carbon dioxide, which are maintained and sustained by living corals (see Figure 3 and Figure 4).

It should be noted that generally, living coral reefs contribute to the ocean carbon cycle through photosynthesis, respiration, calcification, and dissolution, but the process of calcification both captures (at geological time scales) and releases (at annual time scales) CO₂. This has led to the observation that coral reefs are not carbon sinks, but are in fact sources of atmospheric CO₂ in the short term. However, it is likely that the carbon released by calcification⁸⁵ is consumed through other biological processes on the reef, such as photosynthesis by associated macrophytes and sequestered within the system.⁸⁶ The cycling of carbon on coral reefs is thus more complex than that of other shallow coastal ecosystems and their actual role as blue carbon repositories would benefit from further investigation.⁸⁷ ■

⁸¹ Hoegh-Guldberg, O., et al. "Impacts of 1.5 C global warming on natural and human systems." In *Global warming of 1.5 C. An IPCC Special Report*. 2018.

⁸² Tolleson, Jeff. "How hot will Earth get by 2100?" (*Nature*) 580, no. 7804 (April 2020): 443-446.; Climate Action Tracker. *The Climate Action Tracker 2100 warming projections*. 4 May, 2021.

<https://climateactiontracker.org/global/temperatures/>.

⁸³ Praveena, Sarva Mangala, Siti Shapor Siraj, and Ahmad Zaharin Aris. "Coral reefs studies and threats in Malaysia: a mini review." *Reviews in Environmental Science and Bio/Technology* (Springer Link) 11, no. 1 (n.d.): 27-39.; Geraldine, Avila, and Olivia Miwi. *Fish bombers drawn to easy profits, says state minister*. 22 July, 2019.

<https://www.nst.com.my/news/nation/2019/07/506152/fish-bombers-drawn-easy-profits-says-state-minister>.

⁸⁴ Mollica, N.R., et al. "Ocean acidification affects coral growth by reducing skeletal density." *Proceedings of the National Academy of Sciences (PNAS)* 115, no. 8 (2018): 1754-1759.; McDermott, A. "Inner Workings: A microscopic mystery at the heart of mass- coral bleaching." *Proceedings of the National Academy of Sciences* 117, no. 5 (2020): 2232-2235.

⁸⁵ Lønborg, Christian, Maria LI Calleja, Katharina E. Fabriciusa, Joy N. Smith, and Eric P. Achterberg. "The Great Barrier Reef: A source of CO₂ to the atmosphere." *Marine Chemistry* 210 (2019): 24-33.; Ware, John R., Stephen V. Smith, and Marjorie L. Reaka-Kudla. "Coral reefs: sources or sinks of atmospheric CO₂?" *Coral Reefs* 11 (1992): 127-130.

⁸⁶ van der Heijden, L. H, and N. A. Kamenos. "Reviews and syntheses: Calculating the global contribution of coralline algae to total carbon burial." *Biogeosciences* 12 (2015): 6429-64 Coral polyp growth.jpg 41.; de Goeij, Jasper M., et al. "Surviving in a Marine Desert: The Sponge Loop Retains Resources Within Coral Reefs." *Science*, October 2013: 108-110.

⁸⁷ Macreadie, Peter I, Oscar Serrano, Damien T. Maher, Carlos M. Duarte, and John Beardall. "Addressing calcium carbonate cycling in blue carbon accounting." *Limnology and Oceanography Letters*, 2017: 195-201.

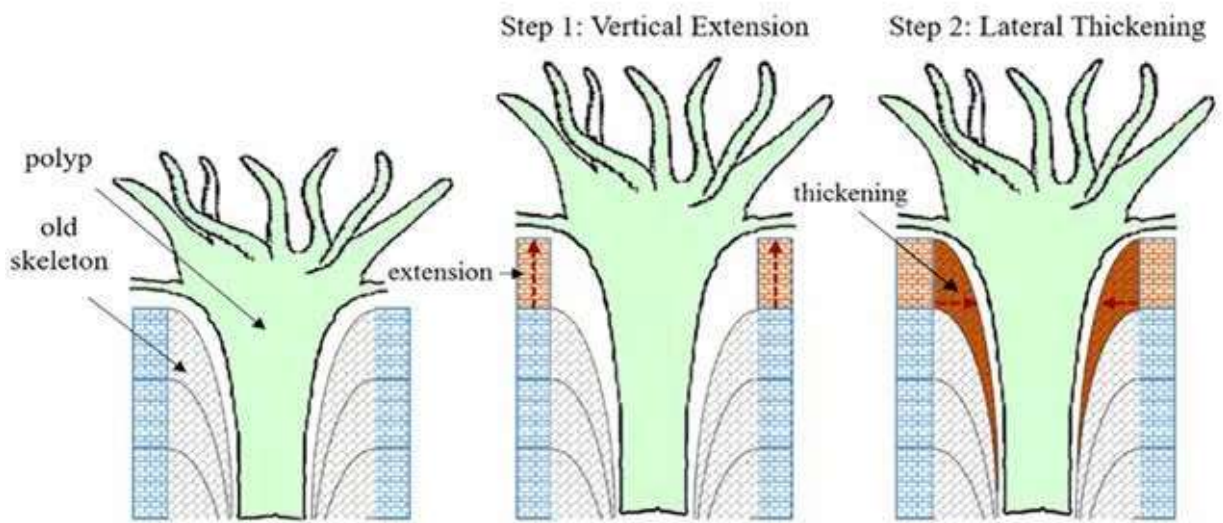


Figure 3: Diagrammatic Representation of the Formation of Multiple Layers of Calcium Carbonate Skeleton by Coral Polyps

Source: Image adapted from Nathaniel R. Mollica et al. PNAS 2018;115:8:1754–1759



FIGURE 4: Image of Dead Coral Calcium Carbonate Skeletons from the 2016 Great Barrier Reef Mass Coral Bleaching Event, with Human Diver for Scale

Source: Photo taken from Amy McDermott PNAS 2020;117:5:2232–2235.

RECOMMENDATIONS

1. Industrial decarbonization and energy efficiency roadmap action plan—how might government and industry collaborate?

1. Draw out constructive inputs from the stakeholders to develop a framework for decarbonization and energy efficiency improvements, from now to 2050
2. Framework will cover specific technological solutions (e.g. industrial heat recovery, fuel switching), and wider themes that are key to an industrial strategy (e.g. innovation, skills development and investment)
3. Identify commitments required by all parties to enable the low carbon transition. Commitments are built on industrial roadmaps that inform the carbon savings which industry could expect under different decarbonization scenarios.

Looking for: *cement, iron & steel, and chemical manufacturers; industrial process experts; Ministry of International Trade and Industry*

2. Develop Malaysia's understanding of energy and transportation systems decarbonization and socio-economic impacts

- Decarbonization of energy and transportation systems;
- A modelling analysis of the socio-economic impact of various decarbonization pathways;
- Impact on income growth and composition of employment;
- Impact on international competitiveness of different sectors;
- Impact on income distribution and poverty;
- Impact on economies of the thirteen states.

Looking for: *technology road-mapping and modelling experts*

3. Develop new green industries that will be dynamic drivers of high- quality growth for Malaysia to accelerate its transformation into a developed economy

- Discussion with the private sector to identify a few high priority industries which Malaysia has the potential to transform into internationally competitive green industries (e.g. Malaysia is a leading producer of solar panels and has the potential to become a global industry leader along the entire solar equipment and batteries value chain);
- For identified high priority industries, develop suitable incentives to attract strategic foreign technology partners to collaborate with the Malaysian private sector to build internationally competitive green industries;
- Create an enabling human capital development ecosystem to supply talent at the required scale, to drive knowledge intensive green industries forward.

Looking for: *collaboration with the Economic Planning Unit and the Ministry of International Trade and Industry to develop a National Green Industry Action Plan*

4. Develop Malaysia's action plan to decarbonize the organic fraction of municipal solid waste via large scale

- Windrow composting;
- Anaerobic digestion, followed by composting.

Looking for: *funders and collaborators*

5. Other waste suggestions:

- Improve data collection in the waste sector to devise better management technologies and to establish required infrastructure;
- Increase awareness among the public and other relevant stakeholders regarding waste management;
- An effective and urgent implementation of an Integrated Waste Management policy, especially 3R (reduce, reuse, recycle) inclusive, is required in Malaysia;
- Execution of waste segregation must be enforced throughout the country uniformly and non-compliance must be dealt with through fines, as stated in Act 672;
- The utilisation of agricultural waste should be increased since there is great potential in this for bioenergy, bio-chemicals, and other uses. Stringent implementation of current regulations, and creation of awareness among stakeholders especially related to palm oil mills and tax subsidies are vital;
- Formalisation and subsequent coordination of the role of informal recyclers should be carried out. Their contributions ought to be recognised and recycling data should be included in national reports.

6. Develop sub-national frameworks to facilitate private sector investments into Nature-Based Climate Solutions (NBCS) to fund the long-term protection of natural forests

- Develop sub-national GHG forest inventories that are credible and transparent
- Develop a social and environmental baseline to ensure safeguards can be designed into potential NBCS projects;
- Assess existing state policies and legal frameworks that would allow NBCS projects to be implemented in the state, in line with international standards requirements which demonstrate safeguards to ensure project benefits are credible;
- Identify a forest area and develop a project structure that outlines stakeholders of an NBCS project: e.g. landowners, project developers, carbon credit offtakers, investors and local communities;
- Develop a business case which shows the flow of finance through the NBCS project to ensure income fund forest protection activities;
- Engage potential investors to ensure NBCS projects meet their requirements.

Looking for: *funders and collaborators*

7. Coral research and refuges

At the moment Malaysia does not have major coral tank facilities like the National Sea Simulator (SeaSim), run by the Australian Institute of Marine Science (AIMS). There are large-scale saltwater aquarium facilities in Kuala Lumpur in the form of the KLCC Aquaria oceanarium, but for now, those tanks and facilities are mainly dedicated to public displays of animals. Malaysia should capitalize on its current infrastructure to develop KLCC Aquaria and other large tank aquarium facilities, in order to incorporate research work on the effects of climate change on marine organisms as well as to prioritise the maintenance of threatened local coral and fish species. Aside from the importance of having local research capabilities for simulating the impact of climate change on local corals, it should also be emphasized that these facilities may become the last refuges for local coral species and their associated ecosystems if future climate change remains on its current trajectory.

Note that this plan will require the buy-in of the operators of these facilities and we expect there will be a need to provide compensation. The plan would also ideally be facilitated by the development of official research collaborations with AIMS and other large research aquarium institutes, like the Centre Scientifique de Monaco (Scientific Center of Monaco). Please see Appendix 3 for more information.

8. Coral rehabilitation and restoration

While long-term predictions for the survival of coral reefs are grim, additional national support should be provided to current coral rehabilitation and restoration efforts, such as those carried out by NGOs including Reef Check Malaysia (<https://www.reefcheck.org.my/>) and corporations such as Petronas (<https://www.yayasanpetronas.com.my/better-care-for-the-ocean/>). A national decision to coordinate these efforts and determine how best to increase the local effect of multiple restoration projects in specific locations could be a good start. ■

APPENDICES

Appendix 1

THE TIMES | Saturday May 22 2021

Zero-emission hydrogen engine given a test drive

Graeme Paton Transport Correspondent

An operational hydrogen combustion engine has been developed in Derbyshire that could speed the shift towards zero-emission transport.

The construction equipment giant JCB said that the engine would be capable of powering heavy machinery and vehicles without producing carbon dioxide. The company said that the technology — a modified version of its latest diesel engine — would deliver green transport at about a tenth of the cost of other zero-emission solutions. This includes battery power, which can be impractical for many heavy vehicles, and hydrogen fuel cells, which are relatively expensive to develop and maintain.

2050. It is expected that the shift will be achieved through battery technology — almost 14 per cent of new cars sold since the start of this year were pure electric or hybrid models.

However, the transition will be harder to achieve in large vehicles where the size, weight and charging time of batteries can be impractical. Some buses and cars are powered using hydrogen fuel cells, when electrical power is generated through a chemical reaction, although there are extensive technical challenges.

JCB is developing a working hydrogen motor. Like a conventional diesel engine, it relies on the combustion of fuel to generate power. Hydrogen gas, which has a high energy density, is carried in pressurised tanks on the vehicle and injected into the engine with compressed turbocharged air.

Burning hydrogen at high temperatures in a combustion engine can cause toxic nitrogen oxides (NOx), a pollutant. To combat this the JCB engine uses a low level of hydrogen — about one part to 100 parts of air — to control the combustion temperatures. Burning hydrogen and oxygen also produces water, requiring engineers to develop systems to manage the steam released through the process.

The company said that its prototype piston engine produced no CO₂ and “practically zero” levels of NOx.

It is thought that the hydrogen engines will cost about £10,000 each, and costs will be kept down by using the same production lines and many of the same components as diesel engines.

By comparison a prototype hydrogen fuel cell system, which is being adapted for a 20-tonne excavator as part of another JCB trial, will cost about £100,000. The batteries needed to power such a machine would probably cost in the region of £60,000, the company said.

Bamford, a Conservative Party donor, said that the Department for Transport appeared to have a “pretty closed mind” on the benefits of hydrogen, placing more energy and money into the development of battery power.


“The use of hydrogen motors will provide the quickest way to reach the target of zero carbon dioxide emissions,” he said.

“The use of fossil fuels in machinery may be phased out in the future but that shouldn’t mean that internal combustion engines don’t have an important ongoing role.”

How it works

(modified diesel combustion engine)

- 1 Pressurised hydrogen gas tanks are fitted to the side of the JCB
- 2 Gas and a small amount of air is injected into the cylinders at 5 bar (73psi)
- 3 Spark plugs on each cylinder ignite the gas, which drives the pistons
- 4 Burning hydrogen and oxygen creates H₂O (water), but no other emissions



Appendix 2: Waste Sector Summary

I. SECTOR BACKGROUND & CONTEXT

1.1 Sector profile and state of play in climate action

The waste sector in Malaysia, which includes Municipal Solid Waste (MSW) management, wastewater treatment and Palm Oil Mill Effluent (POME), has been incrementally contributing Greenhouse Gas (GHG) emissions since 2005 and is the second biggest contributor of GHG emissions (9 percent) in Malaysia after the energy sector. In 2014, the waste sector released 50.5 million tonnes of CO₂-e of GHG emissions. Solid waste disposal sites (SWDS) released 31 percent of total GHG emissions from the waste sector, which makes up 3 percent of national GHG emissions. On the other hand, approximately 91 percent of methane is generated from SWDS, 8.6 percent from POME and 0.4 percent from bio-effluent. Overall, the majority of MSW is disposed of in some form of landfills. There are currently 92 palm oil mills with biogas capture facilities in Malaysia as of 2016.

1.2 Overview of sector development priorities

The 11th Malaysian Plan had set a MSW recycling target of 22 percent by 2020. In terms of policy, it had aimed at sustainable consumption and production where the dependence on renewable energy sources should also increase. MSW recycling is aimed for 25 percent and 28 percent by 2025 and 2030. For palm oil mills, it is aimed that 250 mills will provide electricity to the national grid and 233 mills will provide electricity to own boilers by 2030.

II. THE ECONOMIC CASE FOR STRONGER CLIMATE AMBITION

2.1. Current state of decarbonization analysis

Key insights from existing decarbonization analyses	Approximately 17.5 percent of MSW was recycled and 1 percent is of organic MSW was composted in 2016. On the other hand, 92 palm oil mills captured biogas in 2016.
Key gaps in current decarbonization analysis	MSW data is estimated – lacks empirical data collection
Key challenges that decarbonization faces in the Malaysian context	<ul style="list-style-type: none"> Generation of unsegregated MSW Continued increase in MSW generation Lack of public awareness; less public participation in MSW management Lack of big scale infrastructure for decarbonization activities such as recycling plants, materials recovery facility (MRF), biogas plants etc. Lack of coordination among relevant managing agencies

2.2. Strengthen climate ambition is imperative for economic development and social progress

Evidence-based insights on key climate-related risks (physical and transitional risks) to Malaysia's socio-economic development	<ul style="list-style-type: none"> Water and soil stress due to unsustainable production and consumption patterns Lack of participation of relevant stakeholders in transitioning to decarbonization activities
Evidence-based insights on key opportunities for accelerated socio-economic development in Malaysia in the sector concerned	Decarbonization activities such as recycling results in job creation and generation of revenue
Evidence-based insights on key incentives for finance and investment flows to finance the transition to carbon neutrality	<ul style="list-style-type: none"> Decarbonization activities generate revenue in the form of recycled products, energy generation etc Savings from avoided negative environmental impacts
Key gaps and challenges that decarbonization of the sector faces in Malaysia, especially in the context of COVID19 crisis	<ul style="list-style-type: none"> Generation of potentially infectious waste (face mask, gloves etc.) in MSW could hamper recycling activities Disruptions in value chains could lead to ineffective management
Key government agencies to engage	<ul style="list-style-type: none"> Ministry of Housing and Local Government Solid Waste Management Corporation National Solid Waste Management Department of Environment and Water

III. KEY COUNTRY SPECIFIC AND REGIONAL RECOMMENDATIONS FOR DECISION MAKERS FOR UNFCCC COP26

Improve data collection of waste sector to devise better management technologies and to establish required infrastructure
 Increase awareness among public and other relevant stakeholders of waste management

Appendix 3: Coral Research and Refuges

By Chen Jit Ern

The experience of mass coral bleaching events in the Australian Great Barrier Reef in the past five years has proven that predictions of large-scale loss of coral reef areas are fairly accurate and should be acted on. As a member nation of the Coral Triangle, particularly thanks to the state of Sabah, Malaysia has a direct stake in the health and future maintenance of coral reefs, especially within its national waters.

While research into coral reef biodiversity and conservation occurs independently in various universities in Malaysia, at the moment Malaysia does not have major coral tank facilities like the National Sea Simulator (SeaSim), run by the Australian Institute of Marine Science (AIMS). There are large-scale saltwater aquarium facilities in Kuala Lumpur in the form of the KLCC Aquaria oceanarium, but for now those tanks and facilities are mainly dedicated to public displays of animals.

One step that could be considered is the development of KLCC Aquaria and other large tank aquarium facilities to incorporate research work on the effects of climate change on marine organisms as well as to prioritise the maintenance of threatened local coral and fish species (even if these species might be more difficult to keep in captivity compared to more popular exhibit species). The advantage of this, as opposed to developing an independent marine research center, is that it will leverage existing local know-how in terms of running these facilities as well as help diversify operational usage of these facilities which are currently primarily focused on walk-in/physical tourism. However, since this will require the buy-in of the operators of these facilities, who have their own priorities, we expect there will be a requirement to provide some form of compensation for their contribution. This plan would also ideally be facilitated by the development of official research collaborations with AIMS and other large research aquarium institutes, like the Centre Scientifique de Monaco (Scientific Center of Monaco), particularly in terms of technical capabilities and research training.

Aside from the research aspects, it should also be emphasised that these facilities may become the last refuges for local coral species and their associated ecosystems if future climate change remains on its current trajectory. As mentioned earlier in this report, coral reefs are estimated to become extinct in almost all current habitat ranges by 2100, with mass bleaching events like the ones that have occurred in the GBR expected to hit parts of the coral triangle in the near future. As such, in the coming decades, Malaysian aquarium facilities may have to play the role of biodiversity refuges, similar to the role zoos have taken up as breeding and conservation centres for animal species extinct in the wild.



AIMS SeaSim (Source: SeaSim Twitter account)



KLCC Aquaria exhibit tanks (Source: <https://www.fatindays.com>)



Centre Scientifique de Monaco research aquariums (taken by Eric Tambutte, CSM)



The Jeffrey Cheah Institute on Southeast Asia is an independent public policy think tank, based at Sunway University on the outskirts of the Malaysian capital, Kuala Lumpur. The Institute's research programme is grouped around three core disciplines: economic development, governance and social progress, including education. Its mission is to develop solutions to some of the region's most pressing development problems. JCI seeks to engage policymakers, scholars and ordinary citizens through regular public lectures and discussions, and to build lasting academic partnerships in the region and the wider Asia-Pacific.

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The Jeffrey Sachs Center on Sustainable Development is a regional center of excellence that advances the achievement of the 17 Sustainable Development Goals (SDGs) in Malaysia and Southeast Asia, tackling the sustainability agenda through education, training, research and policy advisory. Launched in December 2016, the Center operates out of Sunway University and was borne out of a \$10 million gift from the Jeffrey Cheah Foundation (JCF) to the UN Sustainable Development Solutions Network (SDSN).

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