SECURING OUR FUTURE: NET ZERO PATHWAYS FOR MALAYSIA

November 2021

About WWF

WWF is one of the world's largest and most experienced independent conservation organisations, with over five million supporters and a global network active in more than 100 countries. WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

About BCG

Boston Consulting Group (BCG) partners with leaders in business and society to tackle their most important challenges and capture their greatest opportunities. BCG was the pioneer in business strategy when it was founded in 1963. Today, we help clients with total transformation – inspiring complex change, enabling organisations to grow, embedding sustainable business practices, building competitive advantage, and driving bottom-line impact. Our diverse, global teams bring deep industry and functional expertise and a range of perspectives to spark change. BCG delivers solutions through leading-edge management consulting along with technology and design, corporate and digital ventures – and business purpose. We work in a uniquely collaborative model across the firm and throughout all levels of the client organisation, generating results that allow our clients to thrive.

Publication Date: November 2021

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Foreword

We live in truly unprecedented times. Climate change is no longer a distant concept. Every year, the lives and livelihoods of millions around the world are affected by the effects of climate change. Our actions have put us on the brink of climate crisis. If we carry on our current emissions trajectory, we risk setting off climate tipping points which will be irreversible and catastrophic. We will face a future fraught with extreme weather, natural disasters, food insecurities, and unimaginable biodiversity loss.

Altering the trajectory of climate change requires nothing less than a large-scale transformation of the global economy. We will need to decarbonise across all sectors of the economy, step up our protection of our natural assets, invest in adaptation and resilience, and make a difference by incorporating sustainability in our everyday choices. This is no longer an option, but an imperative, to secure our futures.

The Securing Our Future: Net Zero Pathways for Malaysia report is a collaborative effort between WWF Malaysia and the Boston Consulting Group (BCG) to chart a pathway to achieve net zero emissions for Malaysia by 2050, supported by progressive decarbonisation milestones in the short and medium term. This is a journey that has already begun in earnest, and the report acknowledges the progressive efforts and announcements already made by the Government and various institutions across Corporate Malaysia.

The report offers insights into practical pathways for us to achieve net zero, anchored on equitable transition for Malaysia. Achieving net zero by 2050 will be a momentous task, one which will require a whole-of-nation approach, with coordination and collaboration across government, businesses, investors, and civil society. The study offers ideas for green policies and actions to protect our megadiverse natural assets, decarbonise key sectors of the economy, enhance our green enabler foundations, and strengthen holistic environmental and social safeguards for a just transition.

The study finds that Malaysia is well endowed to achieve net zero with our extensive forest cover, access to sustainable and cost competitive renewable energy, green policy foundations, and strong green industry adjacencies. Net zero will do far more than address climate concerns: it will unlock huge economic opportunities through growth of the green economy, creating millions of new jobs and strengthening the country's future with sustainable global competitive advantage.

To unite stakeholders across Malaysia on the climate agenda, ten key priorities are highlighted. These priorities represent the building blocks towards a net zero transition. In designing these priorities, careful balance was made between the green agenda, financial wellbeing for businesses and society, and a mitigation of socioeconomic impacts arising from these shifts.

We strongly urge policymakers, captains of industries, and leaders of civil society to embrace the recommendations within the pages of this report for a safer and better world for us and our future generations.

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SECURING OUR FUTURE: NET ZERO PATHWAYS FOR MALAYSIA

Objectives of the Study

The need to address climate change is more urgent than ever with a growing need for decisive climate mitigation and adaptation action to secure our futures.

The WWF-BCG Net Zero study explores potential climate mitigation pathways for Malaysia to achieve Net Zero emissions along various time horizons, and the social and economic impact of these pathways. The findings of the study aims to serve as a resource for both public and private sector stakeholders, and to inform climate transition pathway options. Moreover, the study aims to enhance widespread awareness on climate transition, to catalyse progressive climate actions across a broad range of stakeholders in Malaysia.

The potential climate mitigation pathways has been developed through a bottom-up sector-by-sector view covering key sources of Greenhouse Gas (GHG) emissions and removals in the country. These sectors include the energy, transport, industry, agriculture, waste as well as the land use, land-use change and forestry (LULUCF) sectors. For each of these sectors, potential decarbonisation levers are explored and prioritised with a view of technical feasibility and commercial viability, factoring in key environmental and social safeguards. The impact of these pathways on key socioeconomic outcomes are also assessed and used to inform the optimal Net Zero pathway for the country. Finally, a view on the priority actions and enablers required to facilitate the journey to Net Zero is outlined to highlight potential focus areas for cross-stakeholder collaboration.

The study also aims to highlight the importance of an equitable climate transition in Malaysia, where the country's climate mitigation pathway contributes to strong total societal and environmental impact. This includes ensuring rights-based climate solutions, equitable workforce transitions, protection of vulnerable populations, and the fair distribution of costs and benefits of transition across various constituents, both globally and domestically. In addition, efforts to ensure climate adaptation and resilience are equally important and will need to be pursued in conjunction with climate mitigation efforts of the country.

The study builds on a global partnership between BCG and WWF since 2012. Through this partnership, BCG and WWF have embarked on numerous projects – globally, regionally, and locally – in support of its mission to stop the degradation of the planet's natural environment and build a future in which people live in harmony with nature. This includes collaboration towards a New Deal for Nature and People, and on various other topics ranging from forests to oceans, from sustainable finance to environmental policy, and from advocacy climate to biodiversity. Through these joint efforts, strong impact has been created including preventing deforestation with early warning systems, enhancing supply chain transparency through digital platforms such as OpenSC, and catalysing world-changing partnerships such as the Science-Based Targets initiative.

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The climate imperative

In 2018, the Intergovernmental Panel for Climate Change (IPCC) issued a landmark report warning of the catastrophic and irreversible effects of climate change if global warming is not limited to a maximum of 1.5^{0}C above pre-industrial levels[1]. These irreversible effects are associated with the surpassing of "tipping points", which would result in irreversible chain of reactions including melting of glaciers and major ice sheets, thawing of the Arctic permafrost, forest diebacks, and more, affecting fundamental life support systems and habitats globally

To limit global warming below the 1.5^{0}C threshold, global net human-induced carbon emissions will need to fall by about 45% from 2010 levels by 2030 and reach Net Zero around 2050. Moreover, changes are needed now. At the beginning of 2020, to have a 67% chance of limiting global warming to 1.5^{0}C, the remaining global carbon budget was 400 $GtCO_2e$. With the global rate of emissions of around 40 $GtCO_2e$ per year including land use showing no signs of reversing, this carbon budget is on course to be exhausted in slightly over 10 years.

Currently, global climate policies and pledges are falling short. Even if all countries fulfilled their unconditional climate pledges under the 2015 Paris Agreement, global warming of 3.2^{0}C above pre-industrial levels is expected by the end of the century[2]. Critically, the latest *IPCC 6th Assessment Report* published in 2021 found that in almost all emission scenarios, global warming is expected to exceed the 1.5^{0}C threshold in the early 2030s[3]. Without immediate, rapid, and large-scale reductions in emissions and a shift to promoting well-being, limiting global warming to 1.5°C will soon be beyond reach.

Humanity has a limited and rapidly closing window of time to alter the trajectory of global warming and limit temperature rise and develop sustainably for the benefit of current and future generations. The call to action to address climate change is more urgent than ever, and each country will need to contribute based on common but differentiated responsibilities towards the global climate science driven target of achieving global Net Zero[4] emissions by 2050.

The economic imperative

Climate transition is not only a global climate imperative, but also an economic imperative. The rapid rise of Environmental, Social and Governance (ESG) in the decision-making of investors, corporations, and consumers has large and far-reaching economic implications:

- *Investors* are increasingly institutionalising ESG considerations, with ESG assets under management globally projected to climb to USD 53 trillion, more than a third of the total USD 140 trillion global investment assets under management by 2025[5].

- *Corporations* have also increased their climate ambitions. Over 3,000 corporations have committed to achieve net zero carbon emissions by 2050, under the Race to Zero initiative[6].

- *Consumers and civil society* awareness on the importance of climate change and environmental activism has also been growing. In a recent global survey, 87% of survey respondents want corporations to integrate environmental considerations into products, services, and operations[7].

Megatrends of shifting capital and demand will increase the size of demand in the green economy, catalysing economies of scale, which further increases the commercial attractiveness of green products and services. This forms a virtuous cycle accelerating the shift of demand towards the green economy.

1. IPCC (2018). Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels.
2. United Nations Environment Programme (2019). Emissions Gap Report 2019.
3. IPCC (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the IPCC 6th Assessment Report.
4. Net zero emissions are achieved when anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period.
5. Bloomberg Intelligence Research and Analysis (2021). ESG assets may hit $53 billion by 2025, a third of global assets under management.
6. United Nations Framework Convention on Climate Change, Race to Zero.
7. BCG Global Survey on COVID-19 and Environment (2021).

Whilst climate transition and the rise of the green economy present large, new growth opportunities, it also equally poses an existential threat to the survival of companies, sectors, and nations which do not adapt rapidly and decisively to climate transition.

If we continue in the BAU manner where we continue with intensive consumption patterns, continuous loss of biodiversity, land use change and rising GHG emissions, the cumulative loss between 2011-2050 will be almost USD 10 trillion. Alternatively, if we shift to a "global conservation scenario" which includes sustainable consumption and production, protection of nature, stabilisation of land use and the peaking of GHGs, an improvement of 0.23 trillion is noted compared to the baseline.

Positioning of countries globally on Net Zero

Spurred by both global climate and socioeconomic imperatives, an increasing number of countries are committing to Net Zero emissions. In 2019, only one-sixth (16%) of global GDP was covered by Net Zero targets. In 2021, Net Zero pledges cover over two-thirds (68%) of the global GDP.

Overall, 54 countries and the European Union (EU) as a bloc, covering approximately 61% of global emissions and over two-thirds of global GDP, have committed to Net Zero[8]. Most of these countries have targets to achieve Net Zero by 2050, with notable exceptions, such as China and Indonesia, which have committed to Net Zero by 2060. Commitments to Net Zero have not exclusively been made by developed countries, with an increasing number of developing countries committing to Net Zero, incentivised by both increasing economic feasibility and new green growth opportunities associated with a progressive climate mitigation pathway.

Malaysia's competitive advantage for Net Zero journey

Historical context and starting foundation

Over the years, Malaysia has made progressive commitments towards climate transition. The country is a signatory to the Paris Agreement, under the United Nations Framework for Climate Change Convention (UNFCCC). In 2015, in conjunction with the Paris Agreement, Malaysia committed to unconditionally reduce economy-wide GHG emissions intensity of GDP by 35% in 2030 compared to 2005 levels, and a further conditional 10% reduction with the support of financial allocation, technology transfer, and capability building from developed countries[9].

In 2021, Malaysia enhanced its NDC targets to reduce economy-wide emissions intensity of GDP by 45% in 2030, compared to 2005 on an unconditional basis[10]. In the revision, the scope of GHG coverage was also expanded from the original three types of GHG to seven types of GHG.

Besides commitments to the NDCs, various policies have been established to enhance environmental sustainability, including various initiatives outlined over multiple Malaysia Plans. In addition, the Shared Prosperity Vision 2030 highlights sustainability as a key enabler accentuating the importance of development through green growth, which emphasises on low carbon development, resource efficiency, resilience, and inclusivity, as well as the preservation of the environment and ensuring sustainability of natural resources in the country.

Reflecting the importance of climate change in the national agenda, the Malaysian Climate Change Action Council (MyCAC) was established as the platform to discuss and set the direction on climate change issues and the green development agenda in the country. Progressive climate ambitions have also been set by major Malaysian corporations, including PETRONAS, Hibiscus Petroleum, Tenaga Nasional, Maybank, CIMB, Bursa Malaysia, and the Malaysian Aviation Group, as some examples.

8. Energy & Climate Intelligence Unit and Oxford Net Zero (2021). Taking Stock: A Global Assessment of Net Zero Targets.
9. UNFCCC (2015) Intended Nationally Determined Contribution of the Government Of Malaysia.
10. UNFCCC (2021) Malaysia's Update Of Its First Nationally Determined Contribution.

Natural advantages on Net Zero journey

In addition to the strong starting foundation of preceding climate policies and efforts across both the public and private sectors, Malaysia has several natural advantages which positions it strongly for the Net Zero pathway.

Malaysia's large carbon sinks, such as its natural forests, contributed to the removals of over three quarters (77%) of total emissions in 2016, a unique advantage for the country[11]. In addition, Malaysia is also in a strong position to leverage multiple decarbonisation technologies, such as the high potential of solar, bioenergy, and sustainable hydropower as sources of renewable energy, which also enables the production of green hydrogen. Moreover, the strength of various industry clusters, such as the electrical and electronics industry and automotive clusters, positions the country well to capture added local value from increased electrification and low carbon mobility.

Perspectives on Net Zero 2050 for Malaysia

On the 27th of September 2021, the target for Malaysia to achieve carbon neutrality as early as 2050 was announced[12]. Various supporting measures, such as the implementation of carbon pricing and the commitment to stop building new coal power plants were also highlighted.

The study views the announcement as a highly positive and progressive step for Malaysia. The findings of the study further demonstrate that Net Zero 2050 is not only technically feasible, but also socioeconomically positive, providing further validation and confidence for policymakers and citizens to embark on this journey.

However, to enable this pathway, action is needed across all stakeholders on the green agenda along with strong government leadership to implement coherent, progressive, and effective green policies and enablers in collaboration with the private sector including civil society. Multilateral support on climate finance and funding, capability and capacity development, and technology transfer from developed countries also represent key enablers to achieve Net Zero.

From a technical perspective, the path to Net Zero is feasible based on proven technologies which have been adopted globally and are highly relevant to Malaysia's specific context. Moreover, future breakthroughs in innovation and technology can further enhance the economics of the Net Zero pathway, and the technical pathway should be periodically updated to reflect these developments.

From a socioeconomic perspective, with effective orchestration, the Net Zero 2050 pathway is shown to have strong benefits in terms of net GDP and job creation compared to less ambitious climate transition pathways. The Net Zero 2050 pathway has the potential contribute up to an incremental RM 50-60 billion in GDP per annum and 200,000 to 300,000 jobs over and above the current forward-looking plans. Based on the starting point advantages of the country, the investment costs required to achieve a Net Zero 2050 pathway is less than 1% of GDP.

The Net Zero 2050 ambition will also serve to enhance the future economic resilience of the country by catalysing the move towards future green economy sectors. Currently, 20-30% of Malaysia's economy[13] is concentrated in sectors which face large transition risks[14]. Catalysing timely transition in these sectors will be the key to long-term economic resilience. Moreover, given Malaysia's position as a key trading economy, the country will need to rapidly adapt to shifts in global demand, ESG-driven Foreign Direct Investment (FDI), and international trade megatrends such as potential carbon border adjustment mechanisms. Finally, catalysing progressive climate transition can unlock early mover advantages in the green sectors, spurring new growth and investments into the country.

11. Ministry of Environment and Water (2020) Malaysia's Third Biennial Update Report submitted to the UNFCCC.
12. Parliament of Malaysia (27 September 2021) YAB Prime Minister RMK-12 Speech.
13. Department of Statistics Malaysia (2020) GDP by Kind of Economic Activity at Current Prices.
14. S&P (2019) Sectoral ESG Risk Scores 2019.

Ten priorities for an equitable Net Zero transition

Whilst there are a wide range of initiatives required to achieve the Net Zero 2050 pathway, there are 10 large-scale priorities which are crucial for Malaysia. These priorities will need to be acted on in a timely and coherent manner in order to unlock socioeconomic benefits associated with the Net Zero pathway. In addition, priorities will ensure an equitable and balanced transition with smooth workforce and sector transitions as well as strong environmental and social safeguards.

In addition to climate priorities which focus on the climate mitigation to achieve Net Zero, urgent action on climate adaptation and resilience priorities are equally needed. Even with the best global efforts in climate mitigation, the pace of climate change which has already been set in motion will inevitably result in increased adverse impacts from climate change. This demands quick responses from an adaptation and resilience perspective to protect lives, livelihoods, and the economy, which will complement the climate mitigation efforts of the country on the pathway to Net Zero 2050.

While Loss and Damage will inevitably be experienced even if we undertake maximum efforts in mitigating and adapting to climate change, the scope of this report does not factor that in. Loss and Damage due to climate change however can be reduced and it is thus imperative that we take sufficient climate mitigation and adaptation action to do so now

1. Protect and enhance Malaysia's natural assets
2. Decarbonise the energy sector
3. Accelerate low carbon transportation
4. Price carbon
5. Mobilise climate finance
6. Spur innovation and scale high potential technologies
7. Strengthen safeguards for total societal and environmental benefit
8. Enhance human capital and ensure equitable workforce transition
9. Behavioural change and consumer action
10. Public and private sector climate leadership and governance

Description of the ten Net Zero priorities for Malaysia (I/II)

1 | Protect and enhance Malaysia's natural assets

Strengthen the country's natural assets and carbon sinks for climate change mitigation, adaptation, resilience, and disaster risk reduction. This includes safeguarding forest cover, rehabilitating degraded forests, enhancing forest landscape continuity to promote biodiversity, eradicating illegal logging, enhancing agroforestry and agroecology, as well as protecting our ocean and coastal ecosystems.

2 | Decarbonise the energy sector

Decarbonise energy as the largest source of emissions through enhanced energy efficiency and demand-side management, fuel switching, fugitive emissions reduction, and power mix optimisation. Phase out coal and scale-up renewable energy with the support of grid enablers and energy storage as well as key social and environmental safeguards such as recycling and end-of-life management policies, sustainable value chains, mitigated land use impact, and holistic socio-environmental impact assessments.

3 | Accelerate low carbon transportation

Scale-up public transport infrastructure and shared mobility solutions, facilitate electric vehicle (EV) penetration with a vibrant local EV manufacturing and supply chain industry and timely charging infrastructure roll-out. Enhance fuel economy standards, adopt sustainable biofuels and other emerging zero carbon fuels in heavy transport, aviation, and maritime sectors, and ensure Environmental, Social, and Governance (ESG) safeguards in low carbon mobility supply chains.

4 | Price carbon

Introduce carbon tax or emission trading scheme (ETS) to price in the negative externality of carbon emissions and to signal positive and progressive climate action in the country. This includes building the foundations of carbon accounting and disclosures, deploying an equitable and transparent carbon pricing mechanism, and ensuring material impact by phasing the implementation of carbon pricing towards a target of USD 50-80 per tonne of CO_2e by 2030.

5 | Mobilise climate finance

Unlock RM 350-450 billion of climate finance by mobilising private capital enabled by market regulations such as disclosures, reporting, and others. Implement climate catalysts to create a pipeline of bankable projects to attract green investments with supportive frameworks and campaigns. Strategically deploy catalytic public capital, enhance blended finance, and secure international funding and financing to support climate transition.

Description of the ten Net Zero priorities for Malaysia (II/II)

6 | Spur innovation and scale high potential technologies

Enhance funding and develop the ecosystem for climate innovation to scale promising climate innovations in the country. Harness academia and key stakeholders to step up climate solution R&D and commercialisation in emerging technologies where Malaysia has competitive advantages (e.g., green hydrogen, algae, bioenergy) with key enablers (e.g., funding, human capital).

7 | Strengthen safeguards for total societal and environmental benefit

Ensure holistic screening and monitoring of climate solutions for total societal and environmental impact, promote rights-based climate solutions, exclude false climate solutions which deliver negative long-term impact, act against corporate "greenwashing", avoid unjust transitions which exacerbate inequalities between countries, regions, or people groups, and mainstreaming environmental and climate considerations in decision making process.

8 | Enhance human capital and ensure equitable workforce transition

Equitable job transition and proactive workforce reskilling factoring in regional nuances where relevant, reorientate education towards green economy skills, institute targeted social safety net programs to protect livelihoods of households suffering job losses through transition.

9 | Behavioural change and consumer action

Shift consumer and corporate choices towards responsible consumption and production, circular economy, and low carbon practices with strengthened climate awareness, information provision, education, government incentives and regulations. Activate civil society participation to hold government accountable on climate transition commitments.

10 | Public and private sector climate leadership and governance

Demonstrate public sector leadership with clear climate ambition, progressive and harmonised policies, incentives, and regulation, catalytic investment to spur green economy, as well as green public sector procurement and budgeting practices. Harness public-private collaboration to close key climate knowledge gaps underpinned by a transparent, participatory, inclusive approach, enhance corporate governance and disclosures which factor in climate risks, and facilitate open data sharing to ensure widespread solutioning on climate challenges.

Securing Our Future:
The Case for Change

The Case for Change

The global climate imperative

The unequivocal evidence of human-induced global warming

Climate change is widespread, rapid, and intensifying. Changes in the Earth's climate are being observed in every region and across the whole climate system. Many of these changes are unprecedented in hundreds of thousands of years.

There is now unequivocal evidence of human-induced GHG emissions that have resulted in the steady warming of the atmosphere, oceans, and lands. Global warming has led to a widespread retreat of glaciers, rise in sea levels, growth in frequency and intensity of hot extremes and heavy precipitation, as well as many other adverse climate events. Climate change is expected to have a large impact on lives and livelihoods, from floods due to intense rainfall; or from rising sea levels in coastal areas; from increased droughts to amplified heat waves in cities; and the loss of forest and ocean ecosystems which we rely on as essential food sources.

Risk of catastrophic and irreversible climate damage based on current trajectories

In 2018, the IPCC issued a landmark report warning of the catastrophic and irreversible effects of climate change if global warming is not limited to a maximum of 1.5⁰C above pre-industrial levels. Critically exceeding the 1.5⁰C warming threshold significantly increases the likelihood of surpassing climate "tipping points", which represent critical thresholds that when exceeded, will result in abrupt, irreversible, and catastrophic damages to the global climate system. These "tipping points" include the thawing of the Arctic permafrost which represents a large store of carbon and methane, melting of the Greenland and Antarctic ice sheets, widespread bleaching of coral reefs, and forest diebacks, such as in the Amazon and Boreal forests.

However, timely, strong, and sustained reductions in the emissions of carbon dioxide and other greenhouse gases will limit climate change. To remain within the carbon budget required to limit global warming to below the 1.5⁰C threshold, global net human-caused emissions of carbon dioxide will need to fall by about 45% from 2010 levels by 2030, and reach Net Zero around 2050.

Currently, global climate policies and pledges are falling short of these targets. Even if all countries fulfilled their unconditional climate pledges under the 2015 Paris Agreement, global warming of 2.9⁰C above pre-industrial levels is expected. Critically, the latest *IPCC 6th Assessment Report* published in 2021 found that in almost all emission scenarios, global warming is expected to exceed the 1.5⁰C threshold in the early 2030s. Furthermore, the report also shows that a 1.1⁰C rise has already been recorded in the last decade, relative to 1850-1990 levels, highlighting the urgent case for change.

The urgent global call to action to avert climate crisis

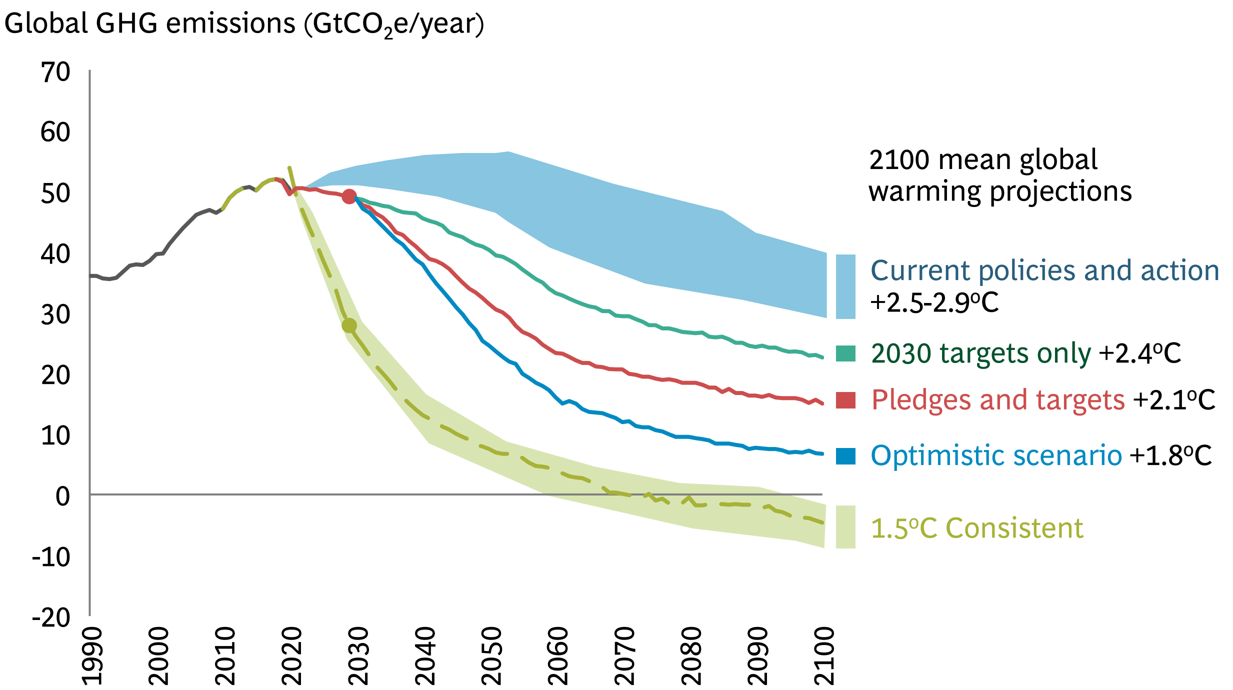
Without immediate, rapid, and large-scale reductions in emissions, limiting global warming to close to 1.5°C will soon be beyond reach. In Southeast Asia, compared to the 1.5°C pathway, the 2°C pathway is expected to result in a 4% to 10% increase in continuous precipitation levels, significantly increasing the risk of flooding, a 0.5°C to 2.5°C increase in average maximum daily temperatures, and sea level rises of 0.3m to 1.0m, which poses significant risks to the large amount of low-lying coastal communities in the region.

Humanity has a limited and rapidly closing window of time to alter the trajectory of global warming and mitigate the worst effects of climate change and protect the well-being of current and future generations. In parallel, urgent efforts on climate adaptation and resilience efforts will also be required to prepare for the unavoidable adverse impacts of climate change.

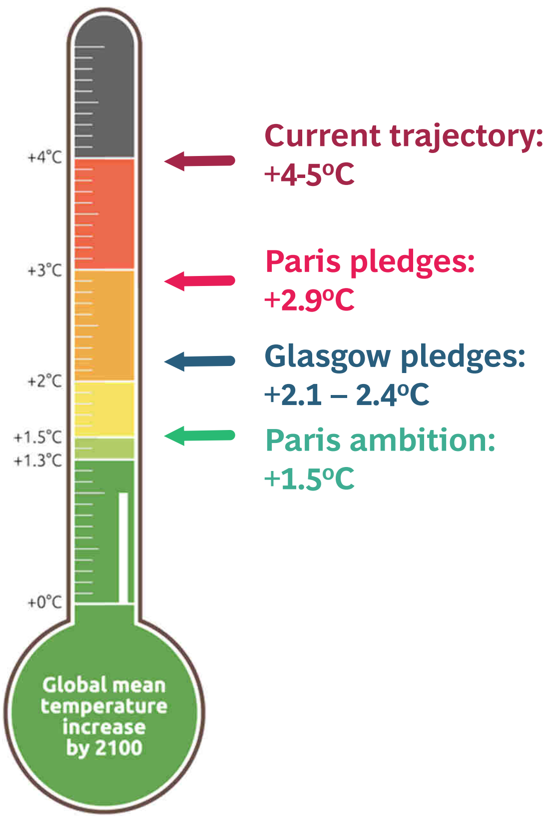
13. IPCC (2018). Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels.
14. United Nations Environment Programme (2019). Emissions Gap Report 2019.
15. IPCC (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the IPCC 6th Assessment Report.

Figure 1: Global carbon emission pathways under various scenarios

Despite progress in COP-26, current global GHG trajectory still insufficient to limit global warming to a maximum of 1.5⁰C



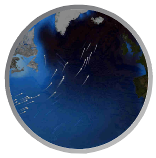
Temperature scenarios in 2100



Climate "tipping points"

Large release of stored emissions from the thawing of the **Arctic permafrost**

Ocean level rise from the **melting of glaciers and large polar ice sheets**



Slowdown of the **Atlantic Meridional Overturning Circulation (AMOC)**

Diebacks in the Amazon and Boreal forests turn carbon sinks into carbon sources

Coral reef bleaching caused by warming ocean temperatures

1. Current policies assumes countries decarbonise further at same annual rate required to achieve NDCs between 2020 and 2030; 2.0°C path and 1.5°C path based on emission reductions required by respective 2018 average IPCC scenarios
Source: IPCC, COP26 announcements, Climate Action Tracker, Press releases

The economic imperative

Climate transition is not only a global climate imperative, but also increasingly an economic imperative. The rapid rise of ESG in the decision-making of investors, corporations, and consumers has large and far-reaching economic implications. Globally, the collective pressure from demand and capital are compelling corporations to act on climate transition. A progressive climate ambition, such as Net Zero, will position the country to benefit from international trade linkages, global investment flows, and new sources of economic growth.

International Trade Linkages

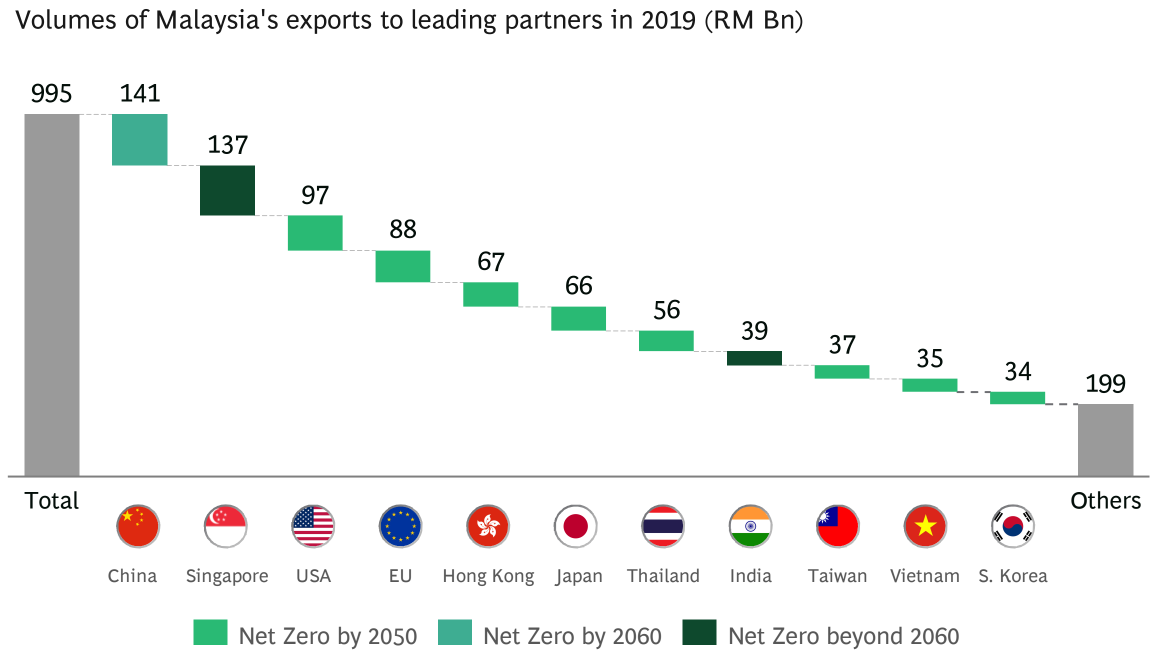
Malaysia is one of the most open economies in the world, with a trade to GDP ratio averaging over 130% since 2010. Openness to trade and investment have been instrumental in employment creation and income growth, with about 40% of jobs in Malaysia linked to export activities[16]. Given the degree of international exposure and extensive trade linkages, global ESG-related megatrends will have a significant impact on the national economy.

- A large majority of Malaysia's key trading partners have committed to Net Zero, with over 50% of current trade to trade partners which have a Net Zero 2050 goal. These countries include the United States, European Union, Japan, Thailand, Taiwan, Vietnam, and South Korea.
- Aligned to their Net Zero ambitions, many trading partner countries have adopted domestic carbon prices. However, domestic carbon prices are subject to carbon leakage, and countries are increasingly exploring carbon border adjustment mechanisms (CBAM), where imports will also be subject to carbon pricing, to equalise the playing field with domestic producers.
- The EU aims to establish CBAM as early as 2023, where imports into the bloc for selected high emission sectors will need to comply with emission accounting and reporting standards. By 2026, the CBAM prices are likely to increase, converging with carbon prices of the EU Emission Trading Scheme and expanded to a broader range of import products into the bloc[17].
- With the adoption of CBAM, emissions along the supply chain will increasingly become a key source of competitive advantage for nations. Countries with lower emission footprints in export-oriented industries subject to CBAM, will benefit from enhanced trade competitiveness. To capture economic advantages from the adoption of CBAM, exporting countries will need to adopt recognised carbon accounting standards, decarbonise key export sectors, and establish mechanisms to account for and price-in imported supply chain emissions, where Malaysia are intermediate producers of goods.
- Even without border adjustment mechanisms, demand-driven shifts from global consumers and corporations due to ESG will have a large impact on trade demand. Over 3,000 corporations have committed to achieve Net Zero carbon emissions by 2050, under the Race to Zero initiative[18]. Moreover, it is estimated that a fifth of the world's 2,000 largest public companies amounting to nearly USD 14 trillion in sales now have Net Zero targets[19].
- Increasingly, corporate Net Zero targets are being expanded to not only cover Scope 1 and 2 emissions, but also Scope 3 emissions[20] (full supply chain emissions). With the introduction of targets on Scope 3 emissions, corporations will be incentivised to shift procurement and supply chains from high emission to low emission countries and supply chains.
- Moreover, sustainable supply chains are increasingly becoming important for export market access, such as the need to comply with sustainable palm oil standards, which prevent deforestation and ensure human rights protection for palm oil exports to the European Union.

16. World Bank (2021) Malaysia Country Overview.
17. European Commission (2021) Carbon Border Adjustment Mechanism: Questions and Answers.
18. United Nations Framework Convention on Climate Change, Race to Zero.
19. Energy and Climate Intelligence Unit and Oxford Net Zero (2021). *Taking stock: a global assessment of net zero targets.*
20. Scope 1 Emissions is defined as direct GHG emissions as a result of the company's operations; Scope 2 emissions is defined as the indirect GHG emissions associated with the generation of electricity, steam, heat and cooling purchased or acquired by the supplier; Scope 3 emissions is defined as all indirect GHG emissions in the company's supply or value chain not directly owned or controlled by the company

Figure 2: Economic imperative to future-proof trade as major trading partners commit to Net Zero

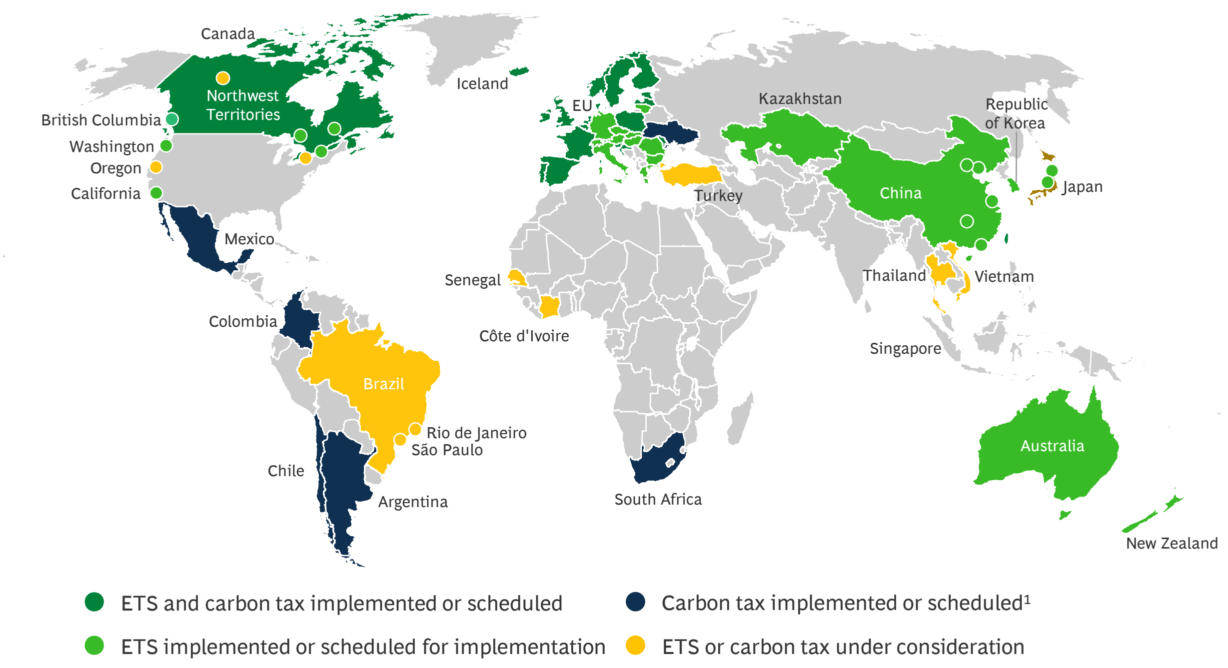
>50% of Malaysia's major exports markets have Net Zero 2050 targets



1. For Taiwan, Net Zero pledge being considered by policymakers 2. Singapore pledge to achieve Net Zero by second half of the century
Source: MATRADE, European Commission

Figure 3: Economic imperative to ensure readiness for carbon border adjustment mechanisms

Growing number of countries and jurisdictions with carbon prices



1. The circles represent subnational jurisdictions 2. ETS = Emission Trading System
Source: World Bank, WRI

Global Capital Flows

Besides shifting demands, the growing incorporation of ESG and specific climate considerations across global investors are strengthening the need for timely climate transition. It is imperative for Malaysian economy to continue being an attractive destination for DDI and FDI, to ensure continuous job creation and growth of household incomes.

- Investors are increasingly institutionalising ESG considerations, and particular climates, into investment decisions. Negative screens, exclusions, and ESG overlays[21] have withdrew capital from specific industries or companies with negative ESG impact, impacting valuations and constraining capital in non-environment friendly companies and economy sectors.

- Overall, ESG assets under management globally are projected to climb to USD 53 trillion, more than a third of the total USD 140 trillion global investment assets under management by 2025[22]. Increases in ESG-centric funds have also been on the rise, with impact investing or thematic funds aligned with specific themes, such as the environment.

- Moreover, active investors are also making their voices heard in boardrooms. Using dialogue, voting, and other shareholder actions, investors are using their influence to drive positive climate disclosures and actions in corporations. For example, BlackRock, the largest asset manager globally, voted against 255 board directors across various portfolio companies, for failing to act on climate issues in the first half of 2021 alone[23].

- Long-term FDI is also increasingly being influenced by ESG factors. For example, RE100 companies, a group of over 300 major companies committed to 100% offtake of renewable energy[24], are now actively influencing decisions on where to locate manufacturing operations or corporate centres, based on the ability to access renewable energy.

New Sources of Economic Growth

A large portion of the Malaysian economy is concentrated in lower-growth, mature sectors of the economy, and in major extractive industries such as Oil and Gas, which are facing the prospects of natural decline, with depleting natural resources.

New growth in high-value areas of the economy is critical to achieve high-income nation status. A strong climate ambition has the potential to catalyse transition from mature, at-risk, and declining sectors of the economy towards emerging, future-proof, and growing green economy sectors, to unlock new sources of economic growth for the nation.

- Global value pools are rapidly shifting, with accelerating demand-driven changes by consumers, corporations, and investors towards green products and services. In 2018, the global green economy was measured to be 6% of the global stock market, at USD 4 trillion; growing at an annualised growth rate of 8% since 2009. By 2030, it is expected that this will increase to 10% of the global market value by 2030, with USD 90 trillion of investments over the period[25].

- The rapid growth of the green economy presents opportunities for early-mover corporations and countries, built on sustainable competitive advantage, to capture large new sources of growth in the green economy. Moreover, progressive move towards the green economy reduces transition risks for the economy. It is estimated that around 21% of GDP and 26% of BURSA Malaysia market capitalisation is concentrated in companies seen to face high transition risks[26].

- Progressive climate action, galvanised through a forward-looking Net Zero ambition, has the potential to spur new sources of economic growth, which contributes to immediate COVID-19 economic recovery, whilst future-proofing and reducing transition risks for the economy.

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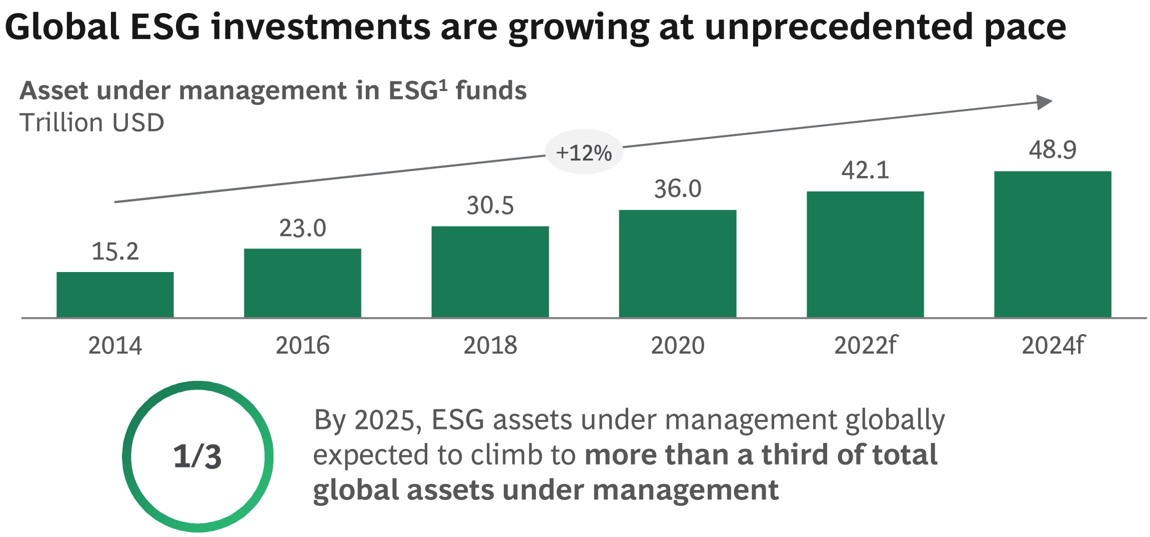
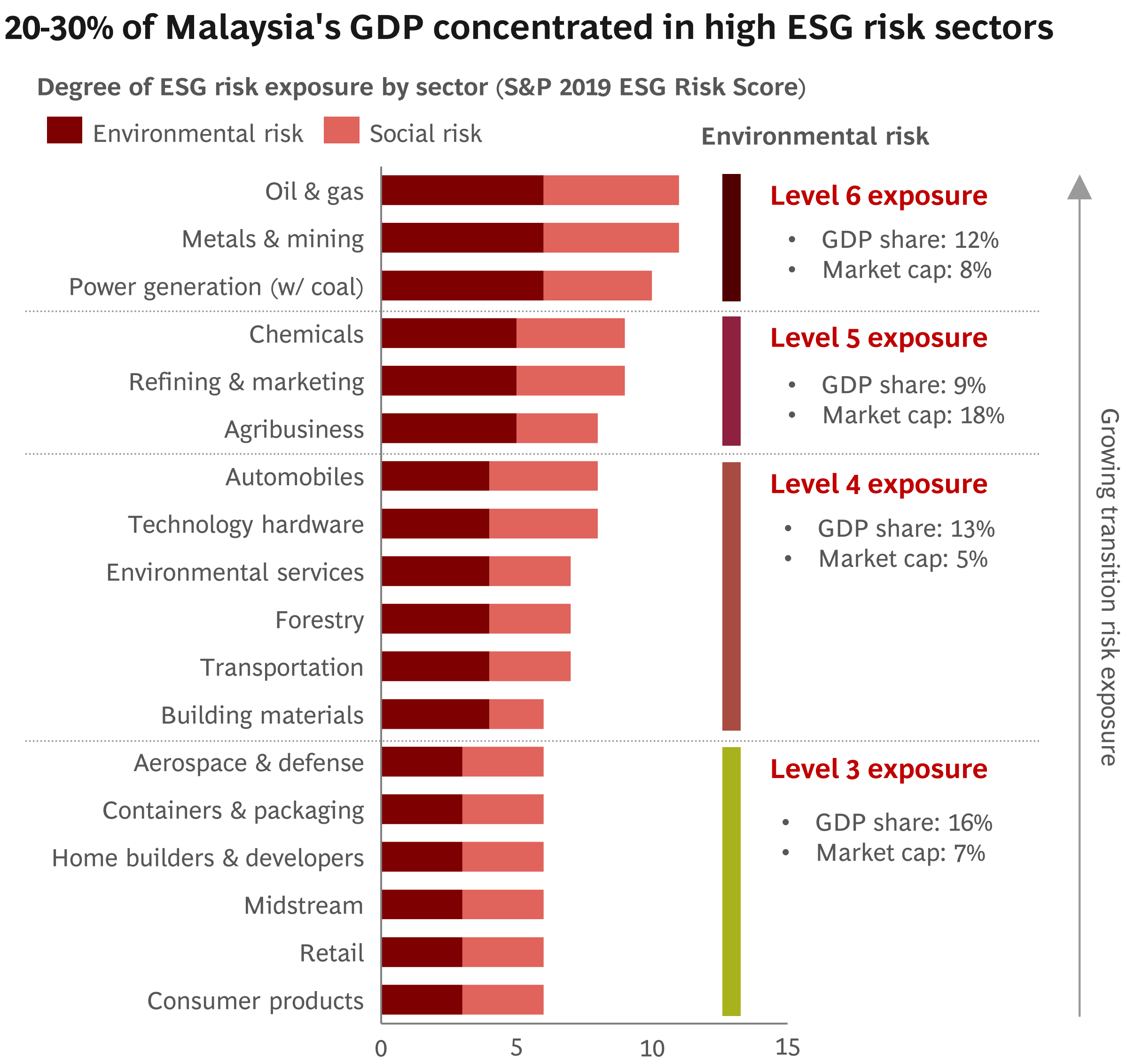
21. Negative screens involve excluding specific industries or companies with negative ESG impact from investments, and ESG overlays represent selecting companies or tilting entire investment portfolios towards higher ESG performance.
22. Bloomberg Intelligence Research and Analysis (2021). ESG assets may hit $53 billion by 2025, a third of global AUM.
23. Bloomberg (21 July 2021) *BlackRock voted against 255 directors for climate issues.*
24. RE 100 (2021) Annual Report 2021.
25. FTSE Russell (2019) Investing in the Green Economy: Busting Common Myths.
26. S&P ESG Risk Scores 2019 mapped against DOSM sectoral GDP statistics (2019) and BURSA Malaysia market capitalisation (6 October 2021). Level 5 and Level 6 transition risks scores considered as high transition risks.

Figure 4: Economic imperative to position to capture growing ESG investments



Source: Bloomberg Intelligence Research and Analysis (2021)

Figure 5: Economic imperative to future-proof high transition risk sectors



Source: S&P ESG Risk Scores 2019, DOSM GDP Data (2019), BURSA Malaysia Market Cap – based on Capital IQ (6 Oct 2021)

Country commitments to Net Zero

The acceleration of country commitments to Net Zero

Motivated by both climate and economic imperatives, the pace of countries committing to Net Zero has accelerated significantly over the past few years. In 2019, only one-sixth (16%) of global GDP was covered by Net Zero targets. In 2021 following the COP-26, Net Zero pledges cover approximately 90 percent of the global GDP[27].

The majority of countries have established Net Zero targets around several landmark timeframes, including 2050 and 2060. Net Zero targets of notable countries and blocs which constitute major sources of trade demand include the United States (2050 target), the European Union (2050 target), Indonesia (2060 target), China (2060 target), and most recently India (2070 target). There also has been momentum in Southeast Asia with key economies such as Malaysia, Thailand, and Vietnam committing to Net Zero in lead up to the COP-26. Some countries have already achieved Net Zero such as Bhutan, Suriname and Panama are carbon negative countries, meaning they absorb more emissions each year than they produce. Malaysia was net negative in GHG emissions until 2004, showing that net zero commitments are feasible and achievable.

The momentum of countries committing to Net Zero is expected to continue, with 80 countries actively considering Net Zero targets. Notably, commitments to Net Zero have not exclusively been made by developed countries, as there is an increasing number of developing countries committing to Net Zero. A key contributing factor which has enabled more developing countries to commit to Net Zero is the rapid progress of green technologies, which have increased the commercial viability of Net Zero pathways.

The difference between Net Zero carbon and Net Zero greenhouse gas (GHG)

A key facet of Net Zero commitments is the scope of emissions coverage of these commitments. Specifically, whether these commitments cover only carbon dioxide emissions or broader GHG emissions:

- **Net zero carbon:** Net zero carbon emissions are achieved when anthropogenic carbon dioxide emissions are balanced by anthropogenic carbon dioxide removals over a specified period. Carbon dioxide is estimated to account for around 76% of total GHG emissions[28] .

- **Net zero emissions:** Net zero emissions focuses on the broader GHG emissions, in addition to carbon dioxide. Net zero GHG emissions is achieved when anthropogenic GHG emissions are balanced by anthropogenic GHG removals over a specified period[29].

- Where multiple GHGs are involved, the quantification of Net Zero emissions depends on the chosen time horizon and climate metric, to compare emissions of different GHGs, such as global warming potential, global temperature change potential, or others.

- For example, carbon dioxide has a global warming potential (GWP) of 1, compared to methane with a GWP of 25 over a 100-year period[30]. Whilst methane emitted today lasts about a decade on average, which is a much shorter time horizon than carbon dioxide, methane also absorbs much more energy than carbon dioxide- therefore contributing more greatly to global warming within its time horizon than carbon dioxide. This net effect of the shorter lifetime and higher energy absorption is reflected in the GWP[31] such as nitrous oxide which has a GWP of 298.

In assessing potential Net Zero pathways for Malaysia, this study accounts for all economy wide emissions covering sectors such as energy, transport, LULUCF, waste, agricultural and industrial processes emissions as outlined in the country's latest national inventory and includes all GHGs namely carbon dioxide, methane, nitrous oxide, and other IPPU-related GHG emissions[32]

27. Energy & Climate Intelligence Unit and Oxford Net Zero (2021). Net Zero Tracker, World Bank GDP data (2020)
28. Center for Climate and Energy Solutions
29. IPCC Special Report: Global Warming of 1.5^{0}C Glossary
30. Based on the IPCC Fourth Assessment Report for consistency with Malaysia's BUR3 UNFCCC submission. The study notes the update in GWP values in the IPCC Fifth Assessment report (e.g., methane GWP increase from 25 to 28)
31. US Environmental Protection Agency (2021) Understanding Global Warming Potentials
32. Namely hydrofluorocarbons (HFCs), perfluorocarbons (PFC), sulphur hexafluoride (SF4), nitrogen trifluoride (NF3). GWP values are derived from the IPCC Fourth Assessment Report were used in the CO2 equivalent calculations.

Figure 6: Overview of Net Zero commitments by country (I/II)

Timeline of Net Zero commitments by countries

Pre-2050

Benin *(achieved)*	Bhutan *(achieved)*	Cambodia *(achieved)*	Liberia *(achieved)*
Madagascar *(achieved)*	Antigua & Barbuda (2040)	Austria (2040)	Bangladesh (2030)
Barbados (2030)	Finland (2035)	Germany (2030)	Iceland (2040)
Maldives (2030)	Nepal (2045)	South Sudan (2030)	Sweden (2045)

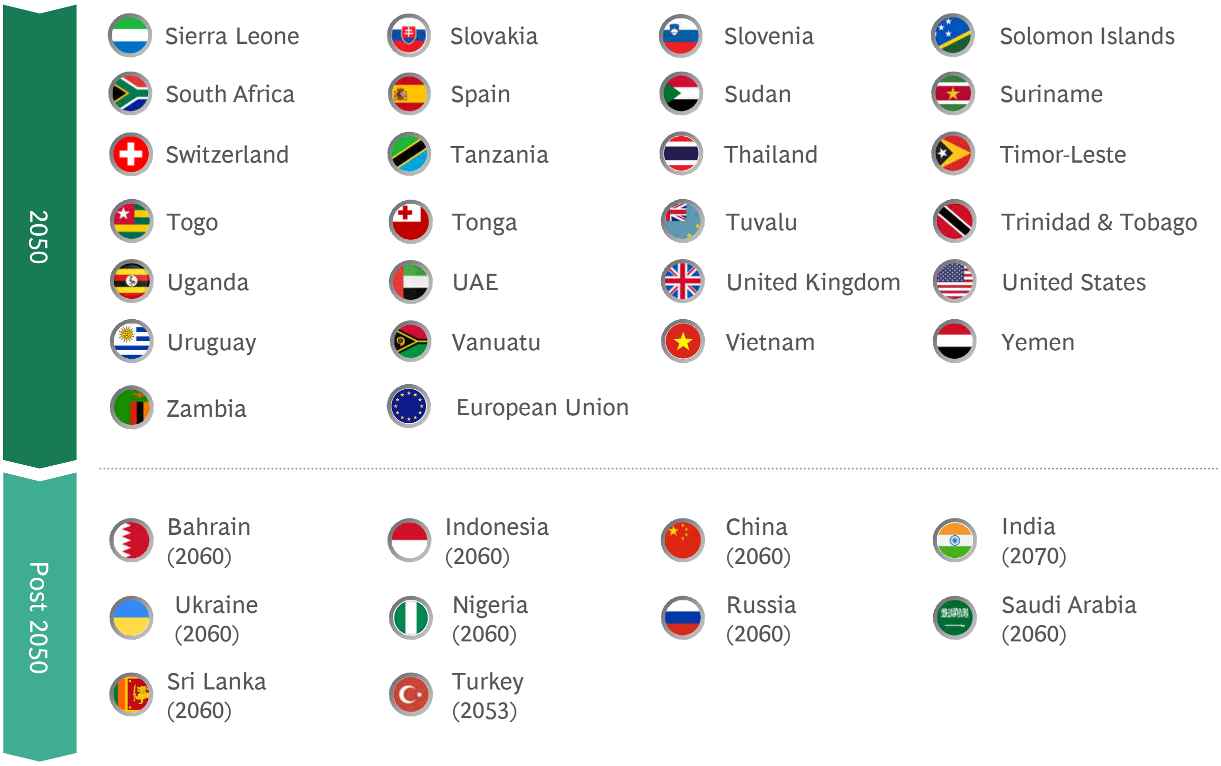
2050

Afghanistan	Andorra	Angola	Argentina
Armenia	Australia	Bahamas	Belgium
Belize	Brazil	Bulgaria	Burkina Faso
Burundi	Canada	Cape Verde	CAR
Chad	Chile	Colombia	Comoros
Costa Rica	Croatia	Cyprus	Dominican Republic
Denmark	Eritrea	Estonia	Ethiopia
Fiji	France	Gambia	Greece
Grenada	Guinea	Haiti	Hungary
Ireland	Israel	Italy	Jamaica
Japan	Kazakhstan	Kiribati	South Korea
Laos	Latvia	Lebanon	Lesotho
Lithuania	Luxembourg	Malawi	Malaysia
Mali	Malta	Marshall Islands	Mauritania
Mauritius	Micronesia	Monaco	Mozambique
Myanmar	Namibia	Nauru	New Zealand
Nicaragua	Niger	Niue	Pakistan
Palau	Panama	Papua New Guinea	Peru
Portugal	Romania	Rwanda	Vincent & Grenadines
Samoa	São Tomé & Príncipe	Senegal	Seychelles

1. Official statement made in Parliament – carbon neutrality earliest by 2050; subsequently clarified to be Net Zero GHG emissions in the MY CAC announcement
Source: Energy & Climate Intelligence Unit, Al Jazeera – What has your country pledged at COP26?

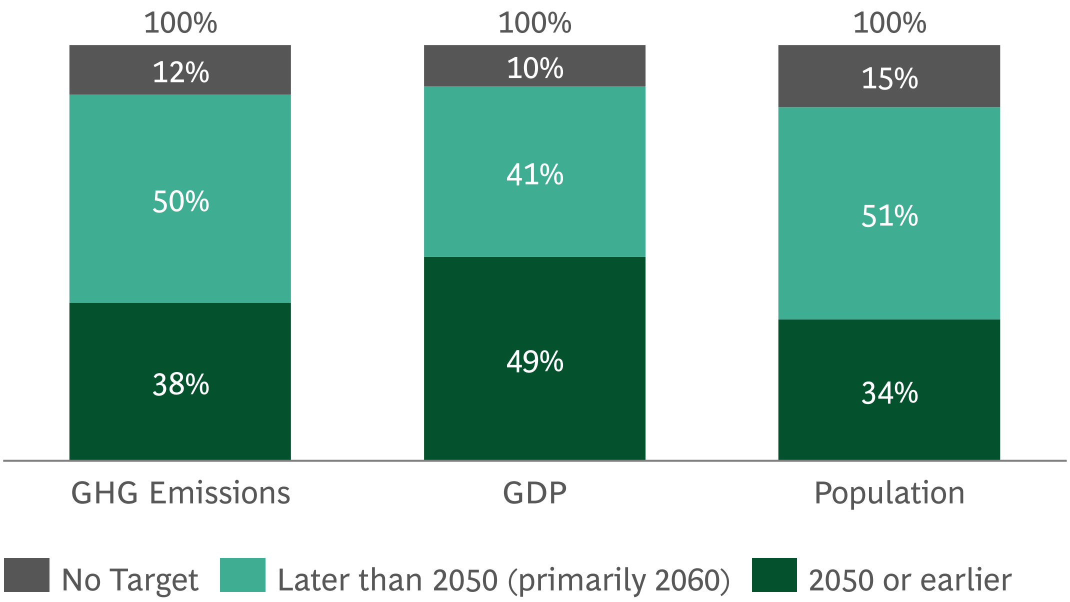
Figure 6: Overview of Net Zero commitments by country (II/II)

Timeline of Net Zero commitments by countries



Source: Energy & Climate Intelligence Unit, Al Jazeera – What has your country pledged at COP26?

Coverage of Net Zero commitments globally



Source: Energy & Climate Intelligence Unit, World Bank, Al Jazeera – What has your country pledged at COP26?

The increasing commercial viability of Net Zero pathways

The pace of technological progress also enhances the commercial and economic viability of Net Zero pathways globally. In the energy sector, which represents one of the largest sources of global emissions, rapid cost improvements in renewable energy technologies, such as solar and wind power, as well as enablers, such as battery storage and smart grids, have significantly improved the economics of transition. In the transport sector, unprecedented declines in the cost of electric vehicles (EVs), from technology improvements in battery storage, to economies of scale of production, will see the 5-year total ownership cost of EVs fall below international combustion engine (ICE) vehicles within a decade, for most countries[33]. The rapid decline in the costs of Internet of Things, such as sensors, has the potential to enable the mass adoption of energy efficiency technologies across the industrial, commercial, and residential sectors.

Moreover, with increased R&D and innovation funding focused on climate solutions, technology breakthroughs are also expected to shift the cost curves of green solutions. Accelerating demand-side shifts towards green products and services will also enable costs to decline, as corporates benefit from economies of scale and moving down the experience curve.

The importance of common but differentiated responsibilities

The growing economic imperative for climate action and the increasing commercial viability do not diminish the importance of the "common but differentiated responsibilities and respective capabilities" principle, for countries embarking on climate mitigation paths.

Some developing countries have been stepping up with ambitious Net Zero targets, with some even beyond their fair share[34] and in line with the horizons of developed countries, like Bhutan. It is critical that equitable support is provided from developed nations to developing nations, anchored on the principles of "common but differentiated responsibilities and respective capabilities", to support these progressive transitions. Even with the increasing long-term economic and commercial viability of Net Zero pathways, investments costs for transition remain large. These include capital investments into infrastructure development, upskilling the workforce to ensure equitable transition, building awareness, and many other key areas of upfront investment needed.

Support from developed countries to developing countries on transition financing and funding, such as through global multilateral or bilateral climate funds, technical support for capacity and capability building, and others, will be critical to help developing countries do their part for climate mitigation. This also includes climate funding and financing by developed countries for developing countries, such as accountably delivering on prior commitments of at least USD 100 billion annually of climate finance. Besides funding and financing, technology transfer and access from developed to developing countries will be important to enable developing countries to leapfrog the technology curve on decarbonisation solutions.

Given the historical trend whereby goals are generally not met, for example with the 1st and 2nd Kyoto Protocol Commitment periods, it is imperative that the 2050 commitments seek to aim higher than what is actually required. Furthermore, collectively, even this is not sufficient as the developed world should be aiming for net zero emissions within this decade rather than by 2050.

Furthermore, developing countries that commit to emissions reduction greater than their fair share should be equitably enabled with adequate financial assistance, technology, and capacity support in line with the principle of common but differentiated responsibilities and capabilities.

> "The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their **common but differentiated responsibilities and respective capabilities**. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof."
>
> *- UNFCCC 1992, Article 3 paragraph 1*

33. Boston Consulting Group (2020) *Who Will Drive Electric Cars to the Tipping Point?*
34. Fair share accounts for the equitable distribution of decarbonisation responsibilities factoring in a country's historical responsibility associated with cumulative emissions over time and individual capabilities and countries to act given their stage of development to inform share of climate mitigation responsibilities.

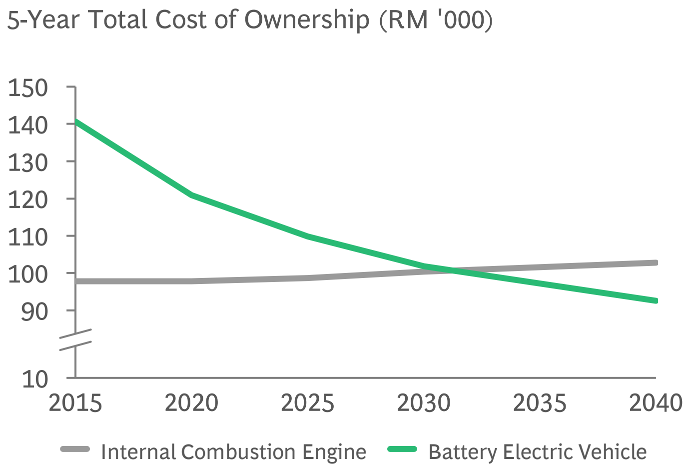
Figure 7: Technology-driven inflection points are reducing the cost of decarbonisation

Rapid improvement in economics of key decarbonisation technologies will increase the affordability of climate mitigation

Mobility

5-year Total Cost of Ownership of Electric Vehicles (EVs) to fall below Internal Combustion Engine (ICE) vehicles by 2030 with mass production and rapidly falling battery costs.

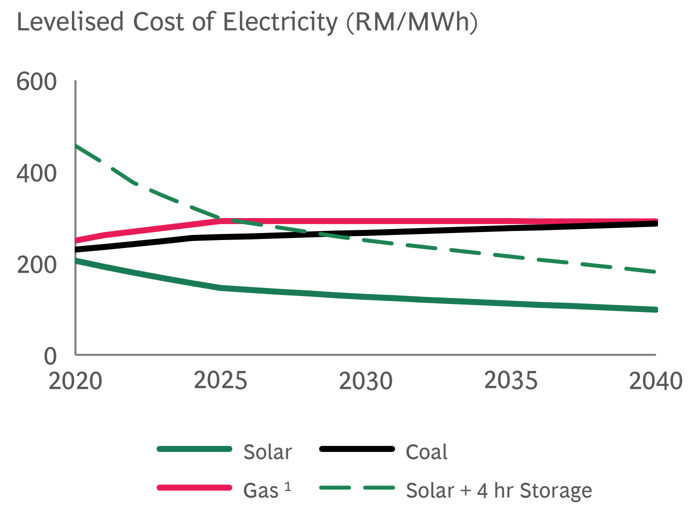
Mobility is approximately 10 – 15% of total household expenditure of Malaysians today.



Electricity

Levelised cost of generation from solar already lower than fossil fuels; solar and storage system will be cheaper by 2030.

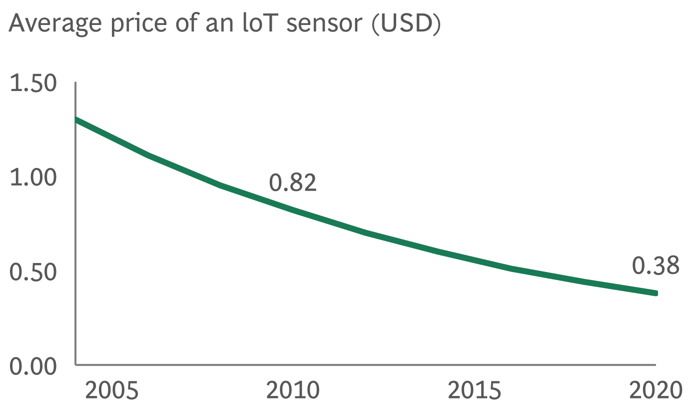
Given rise in capital costs and potential carbon pricing on fossil fuels, renewables are more affordable even after accounting for system integration costs.



Energy efficiency

Over 50% reduction in cost of sensors have over the last 10 years, unlocking affordability of energy efficiency with Internet of Things.

Significant applications across industry, commercial and residential sector (e.g., smart factories, smart homes, etc.).



1. TCO = Total cost of ownership, ICE = Internal Combustion Engine, EV = Electric Vehicle, IOT = Internet of Things
Source: BCG Powertrain model, IEA, BCG Power Model analysis for Malaysia, Microsoft

Why Malaysia is uniquely positioned

Malaysia has several unique advantages which position it strongly for progressive climate transition and to achieve Net Zero. These include:

- **Natural carbon sinks** from the abundant forest cover in Malaysia, which acts as a key source of carbon removals, offsetting a large part of the country's emissions.
- **Other natural advantages** due to the country's geographical position and natural landscape endowments, such as cost-effective renewable energy.
- **Industry adjacencies** which position the country well to capture domestic economy benefits from green economy growth.
- **Strong legacy of environmental policies and initiatives** which have set strong foundations and frameworks, upon which the country can build on in its Net Zero pathway.

Collectively, these factors provide the country a strong starting position and platform to realise significant socioeconomic benefits from the Net Zero pathway. Each of these areas will be explored further in the following sections:

Advantages from the country's natural carbon sinks

Based on the latest national GHG inventory[35], Malaysia emitted a total of 344 $MtCO_2e$ in 2016. Over three quarters (77%) of this emissions were offset by the country's carbon sinks, where removals from the land use, land use change, and forestry (LULUCF) sector amounted to 259 $MtCO_2e$, resulting in an overall net emissions of 75 $MtCO_2e$.

In terms of emissions, the energy and transport sectors are primary contributors, totalling to 75% of the national emissions. The remaining 25% of emissions were contributed by industrial processes and product use (IPPU), waste, agriculture, and LULUCF emissions.

The country's removals are primarily contributed by its extensive forest lands, which cover approximately 55% of the country's land mass. These carbon sinks provide Malaysia with an advantage on its Net Zero journey over many other countries, as total forest cover globally is estimated to be approximately 30% of total land mass[36].

Prior to 2004, Malaysia's carbon sinks absorbed more than 100% of total emissions, making Malaysia a net negative emissions country. However, the increasing emissions from population growth and economic development has led Malaysia to become a net positive emissions country. Whilst emissions have been growing steadily, removals from carbon sinks has remained relatively flat over the period, indicating a relatively stable forest cover.

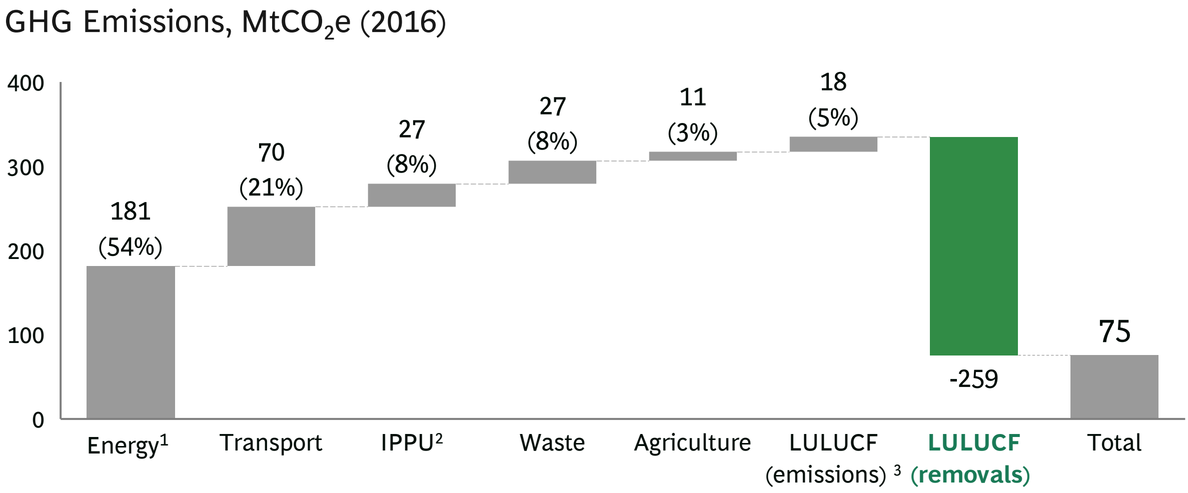
Although the country has been successful in maintaining a stable level of carbon removals through its natural assets, these natural assets are expected to come under increased pressure in the future. For example, forest land is expected to face increasing demand from competing land uses, such as cropland to meet the country's growing food needs, as well as settlements to meet population growth and economic development needs.

Malaysia's forests represent a key natural advantage, not only as carbon sinks, but also due to the rich mega-biodiversity and extensive environmental services these forests provide. Moreover, forests are central to the adaptation and resilience to climate change, as they are key sources of climate and water cycle regulation, protection of soil stability, flood mitigation, providing varieties for food security, and others. Retaining these natural advantages by preserving, conserving, and restoring forests are important for climate transition, whilst ensuring equitable solutions for other land use needs.

34. Ministry of Environment and Water (2020) Malaysia's Third Biennial Update Report submitted to the UNFCCC
35. UN Climate Change News (March 2019) *A Look at REDD+ on International Day of Forests*

Figure 8: Snapshot of Malaysia's GHG emissions and removals breakdown by sector

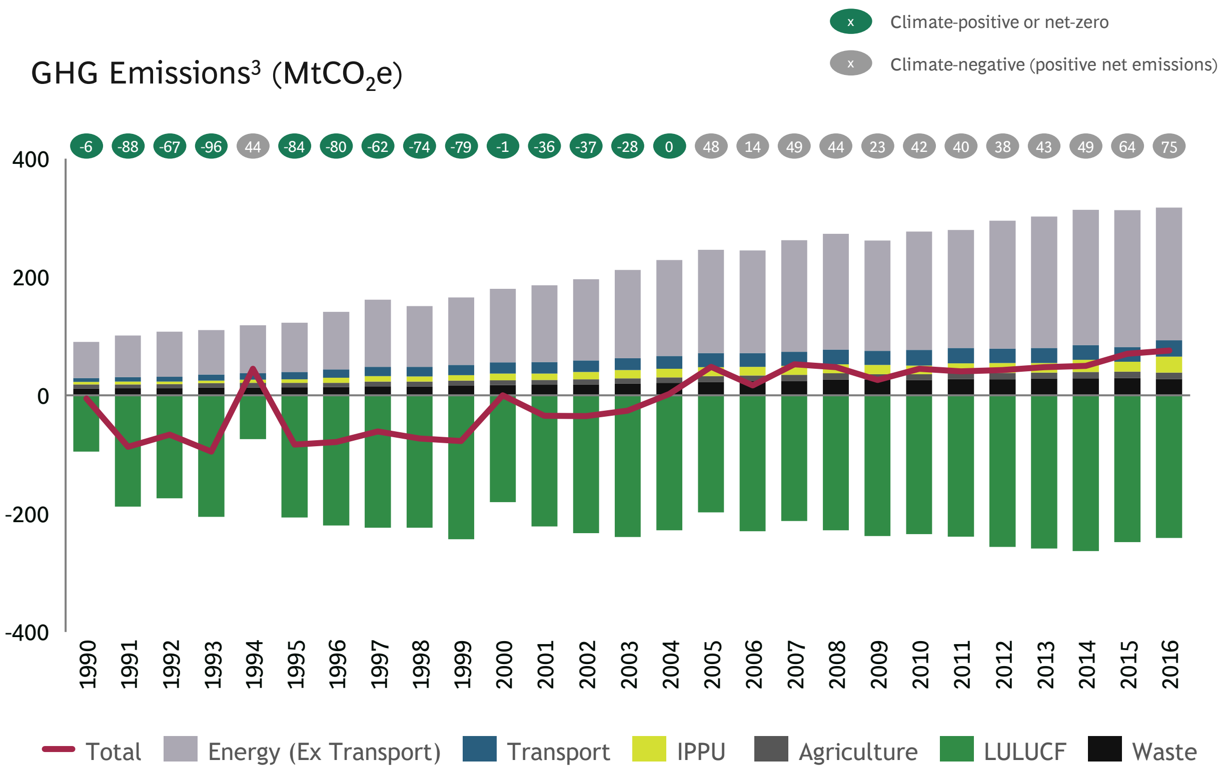
77% of GHG emissions are removed by Malaysia's carbon sinks - giving Malaysia a strong starting position to achieve Net Zero



1. Excluding transport 2. IPPU: industrial processes and product use 3. LULUCF: land-use, land-use change, and forestry
Source: Malaysia's Third Biennial Update Report to the UNFCCC (2020)

Figure 9: Malaysia has been a net emitting country since 2004

Steadily growing emissions has shifted Malaysia from being a net negative to a net positive emissions country since 2004



1. IPPU = Industrial Processes and Product Use 2. AFOLU = Agriculture, Forestry, and Other Land Use 3. GHG emissions taking into account emissions and absorptions of GHGs.
Source: Malaysia's Third Biennial Update Report to the UNFCCC (2020)

Advantages from natural resource endowments

Besides the advantages from carbon sinks, Malaysia's natural endowments also provide it with a strong starting position for the Net Zero pathway, especially in the adoption of cost-competitive renewable energy.

Due to the country's geographical proximity to the equator, Malaysia benefits from strong year-round solar irradiance, which allows cost-competitive solar energy production. The country's hydroelectric production provide significant regional advantages for green hydrogen production. Moreover, the country is also well positioned to benefit from bioenergy. This includes both second-generation bioenergy from biogas and biomass production from abundant agricultural waste feedstock, and third-generation bioenergy from algae.

Advantages from industry strengths and adjacencies

The country's strengths in key industry sectors, which are key enablers to a variety of decarbonisation technologies, positions the country well to capture economic benefits and strong local value-added benefits related to the green economy. Currently, Malaysia is the top 3 producer of photovoltaic cells and modules globally[37], positioning it well to capture the rapidly growing local and international demand, with the increased penetration of solar energy. The strength of the country's electrical and electronics (E&E) sector can enable the successful capture of economic multipliers, from the increased electrification and adoption of energy efficiency technologies.

Malaysia's agriculture sector can also benefit from new sources of value creation, with revenue streams from bioenergy, especially with circular economy and waste-to-value practices. With increased awareness on the contribution of forests to biodiversity, carbon removals, and environmental services, the country’s forestry sector stands to benefit with revenues from domestic carbon markets, and in areas such as eco-tourism. Finally, with timely transition of the automotive manufacturing and supply chain, Malaysia has large potential to benefit from low carbon mobility trends, such as the electrification of passenger vehicle fleets across the region.

Advantages from green policy foundations and governance platforms

Environmental sustainability has been featured in the country's national development plans. The concept of protecting the environment, as part of the development planning process, was first given prominence in the 3rd Malaysia Plan (1976-1980), where the importance of balancing the objectives of development and environmental conservation was stressed, to ensure the benefits of development are not negated by adverse environmental impact.

In recent decades, the 9th Malaysia Plan (2006-2010) highlighted the need to increase the use of non-fossil fuel energy, to enhance fuel diversification and environmental sustainability. The 10th Malaysia Plan (2011-2015) emphasised the importance of renewable energy adoption and outlined key initiatives, such as the Central Forest Spine (CFS) and the Heart of Borneo (HOB), to enhance sustainable forest management. The 11th Malaysia Plan (2016-2020) emphasised initiatives to enable green growth, promote sustainable consumption and production, conserve natural resources, and strengthen resilience against climate change and natural disasters.

Most recently, the 12th Malaysia Plan (2021-2025) identifies *Advancing Sustainability* as one of its three focus themes. Within the theme, the importance of advancing green growth, enhancing energy sustainability, and transforming the water sector, as well as moving towards a low-carbon nation, was emphasised to ensure sustainability and resilience. Furthermore, the imperative of addressing climate change, promoting sustainable consumption, production practices and circular economy, safeguarding biodiversity, as well as the holistic and sustainable management of energy and water systems, was also highlighted in the plan. Various targets, such as increasing government green procurement to 25%, increasing recycling rate of household waste by 40%, and scheduled waste by 35%, were also outlined. Additionally, the target of carbon neutrality as early as 2050 was highlighted. This target will be supported by enablers, such as carbon price adoption and restriction on new coal power plant builds in the country.

37. Malaysian Investment Development Authority (2020) Malaysia's Electrical & Electronics Industry

The 11th and 12th Malaysia Plans are also designed to implement the Sustainable Development Goals in Malaysia with the 13th Plan to provide the framework for the last 5 years of the SDGs. The plans can be seen to progressively integrate environmental sustainability principles across the different areas of development covered.

In addition to the Malaysia Plans, the Shared Prosperity Vision 2030 also highlights sustainability as a key enabler. This accentuates the importance of development through green growth, which emphasises on low carbon development, resource efficiency, resilience, inclusivity, preservation of the environment, and ensuring the sustainability of natural resources in the country.

Over time, progressive cross-sectoral green policies and regulations have been established to cascade the Malaysia Plan aspirations. For example, the Environmental Quality Act (1974) was developed to enhance the prevention, abatement, control of pollution, and enhancement of the environment. This was followed by the National Policy on the Environment (2002), National Green Technology Policy (2009), National Policy on Climate Change (2010), and Low Carbon Cities Masterplan (2021). Supporting enablers have also been established over time, such as the Green Technology Financing Schemes (GTFS), Green Investment Tax Allowances (GITA), and Green Income Tax Incentives (GITE) schemes.

Sectoral policies were also established to promote environmental sustainability. In the energy sector, these include policies to enhance renewable energy adoption and energy efficiency[38]. In the transport sector, these include policies to enhance public transport modal share, encourage the take-up of energy efficient vehicles, and mandate biofuel blending[39]. For the waste sector, plans and policies for recycling and waste management have been established[40]; whilst in the agriculture sector[41] directions on sustainable agriculture land use and practices have been highlighted across multiple policies and plans. Finally, in forestry and land use, legislation and policies on sustainable land use, physical urban and rural development planning, protection of wildlife and biodiversity, the conservation of forests and oceans, and others, have been developed since the 1960s[42].

Malaysia has also made various international commitments related to the environment. To ensure sustainable land use and protect the country's national assets, commitments were made during the Rio Earth Summit to maintain forest cover above 50% in Malaysia. In support of forest cover goals, announcements to limit total palm oil land to 6.5 million hectares were made. Beyond land use commitments, Malaysia is also party to a range of multilateral environmental agreements on a range of topics, including the protection of biological diversity, important wetlands, biosafety, transboundary movement of hazardous waste, and others.

On climate mitigation, in conjunction with the Paris Agreement, Malaysia submitted its nationally determined contributions (NDC) to unconditionally reduce economy-wide GHG emissions intensity of GDP by 35% by 2030, compared to 2005 levels; and a further conditional 10% reduction with the support of financial allocation, technology transfer and capability building from developed countries. In 2021, Malaysia further enhanced its NDC targets to reduce economy-wide emissions intensity of GDP by 45% by 2030, compared to 2005, on an unconditional basis. In the revision, the scope of GHG coverage was also expanded from three to seven types of GHG.

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38. Key environment-related energy policies – National Energy Policy (1979) and New Energy Policy (2010) outlining objectives of efficient, secure, and environmentally sustainable supply of energy; for renewable energy – Five Fuel Diversification Policy (2000), National Renewable Energy Policy and Action Plan (2010), Renewable Energy Act (2011), Sustainable Energy Development Act (2011); for energy efficiency – National Energy Efficiency Action Plan (2016)
39. Key environment-related transport policies – National Transport Policy 2030 (2019) across all transport types; for public transport – National Land Public Transport Masterplan (2013); for energy efficient and next gen vehicles – National Automotive Policy (2014, 2020), Green Technology Master Plan 2030 (2017); for heavy transport – National Logistics and Trade Facilitation Master Plan 2015-2020; for biofuels – National Biofuel Policy (2006) and Biodiesel Programs
40. Key environment-related waste policies – for agriculture waste National Biogas Implementation (EPP5); for waste management – National Solid Waste Management Policy (2016), National Physical Plan 3 (2016), Malaysia Smart City Framework (2018), Rural Development Policy (2019), National Cleanliness Policy (2019), Food Waste Management Development Plan (2016-2026); for waste-to-energy – Renewable Energy Act (2011)
41. Key environment-related agriculture policies – National Agrofood Policies (2011-2020, 2021-2030), National Commodity Policy (2011), Third National Agriculture Policy (1998-2010), and palm oil land area cap announcements
42. Key environment-related land use and forestry policies – Land Conservation Act (1960), National Land Code (1965), Wildlife Conservation Act (1972), National Parks Act (1980), National Forestry Act (1984), Fisheries Act (1985, National Policy on Biological Diversity (2016-2025), National Forestry Policy (1978, 1992, 2021), National Policy on the Environment (2002)

Overview of potential climate mitigation pathways

Methodology and approach

A view on potential climate mitigation or GHG emission reduction pathways for Malaysia was developed in the study, as a reference for stakeholders to understand the envelope of possibilities for climate transition and the trade-offs associated with each potential pathways.

Firstly, a view of the current forward-looking trajectory of net GHG emissions was developed. This trajectory was based on the country's GHG inventory starting position, as defined in the Malaysia's Third Biennial Update Report to the UNFCCC. From the starting position, the forward-looking trajectory of GHG emissions and removals was projected based on underlying drivers, such as demographic growth and industrial development, as well as the expected impact of the nation's current forward-looking plans. The trajectory was also developed using the best publicly available data and supplemented by assumptions obtained and verified through various expert inputs and discussions, using methodologies consistent with the IPCC national GHG emissions[43] inventory accounting standards and guidance. The methodology and data sources used are covered in the respective sector deep dives.

A bottom-up sector-by-sector view was taken across major sources of GHG emissions and removals to estimate the current trajectory of the country's net GHG emissions. Notably, the *Current Trajectory* pathway is different from a status quo or "no action" scenario, as the pathway embeds current forward-looking plans which have been established, such as existing policy measures which contribute to emissions reduction. To assess the potential of reducing net emissions from the *Current Trajectory* pathway, a range of levers were identified, through an extensive global scan of potential levers, which either reduce GHG emissions or enhance GHG removals. For each lever, the technical feasibility, commercial viability, and lever interdependency was assessed, factoring in Malaysia's specific context.

Box 1 | Methodology to assess Malaysia-specific technical feasibility, commercial viability, and interdependency of each decarbonisation lever, illustrated with the example of EVs

Technical feasibility and decarbonisation potential

To assess the technical potential of EV decarbonisation for the country, Malaysia-specific customisations were applied, by including the emissions pool of the country's light vehicle fleet, average driving distance (VKT), the replacement rate and average vehicle lifetimes, the fuel economy of the existing fleet, EV charging infrastructure and regulation, and the emission factors of the power sector as fuel inputs for EVs.

Commercial viability

In addition, to assess Malaysia-specific commercial viability of EV decarbonisation, the total cost of vehicle ownership for Malaysian consumer was assessed. These include the current and future expected evolution of Malaysia-specific vehicle purchase and maintenance costs, factoring in local manufacturing content, domestic taxes, import taxes, and historic vehicle prices; as well as domestic vehicle fuel input costs, such as domestic petrol pump prices and assumptions on vehicle charging electricity tariffs.

Lever interdependency

Finally, the interdependency of various decarbonisation levers, such as the interlinked effect of various levers, including public transport, light vehicle electrification, power system decarbonisation on each other, were assessed. Energy system modelling tools, such as TIMES and PLEXOS, were also leveraged to capture energy-related interdependencies, to ensure holistic energy system and power system modelling.

43. IPCC (2006) Guidelines for National Greenhouse Gas Inventories

Pathway description and considerations

To dimensionalise potential climate mitigation directions for the country, four net GHG emission reduction pathways were developed. The pathways are based on the current best available outlook of various decarbonisation levers and technologies. Levers were screened for technical viability and evidence of successful implementation, as pre-requisite criteria to be included into the pathways. High potential but nascent levers, which lack an implementation track record, are highlighted but excluded in the four defined pathways. Accelerated progress or the emergence of new decarbonisation technologies will likely alter the GHG emission reduction pathways of the country. Hence, the pathways will need to remain dynamic, and revisited over time, to capture these trends.

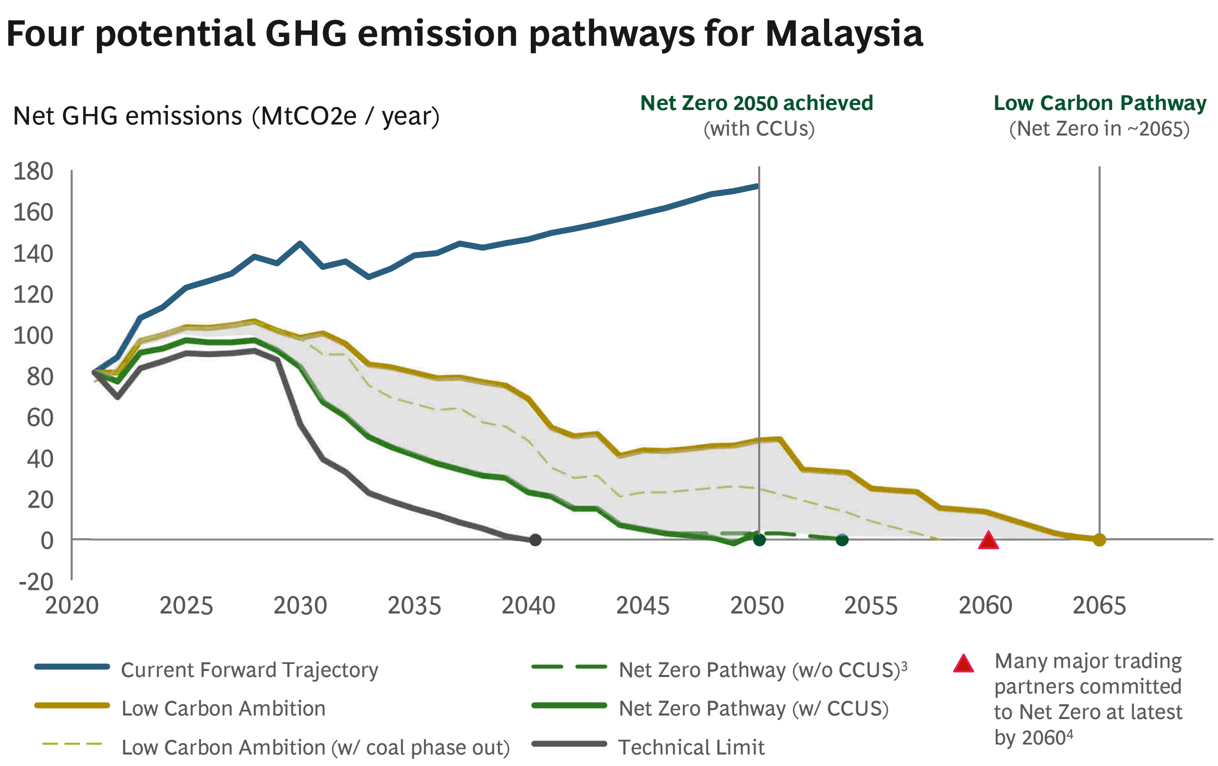
01 **Current Trajectory**
Deliver planned carbon reductions with continued policy trajectory and timely execution of current forward-looking stated plans.

02 **Low Carbon Ambition**
Deliver current plans and adopt a fast follower approach to adopt highly mature and commercially attractive decarbonisation levers as the economics evolve.

03 **Net Zero 2050**
Achieve target of Net Zero by 2050, with progressive green policies, early adoption and scale-up of high potential decarbonisation levers, prioritised based on commercial viability.

04 **Technical Limit**
Delivering Net Zero in the nearest possible timeframe by utilising all proven, technically feasible decarbonisation levers available.

Figure 10: Potential GHG emission reduction pathways for Malaysia



1. Under JPPPET 2020, coal power plants planned for 2031 (1400 MW), 2034 (1400 MW), 2037 (1400 MW) in Peninsular Malaysia. In current forward-looking plans, assumed that JPPPET 2020 plan is followed, and same energy mix is retained onwards from the final year of the JPPPET. For original low carbon ambition, planned coal power plants are built but phased out following the expiry of the PPAs and any emissions associated with the replacement fuel has been included. For Net Zero ambition, any coal power plant which is not committed (PPA not signed) is phased out.
Source: Project Team Analysis

Findings of GHG emission reduction pathways

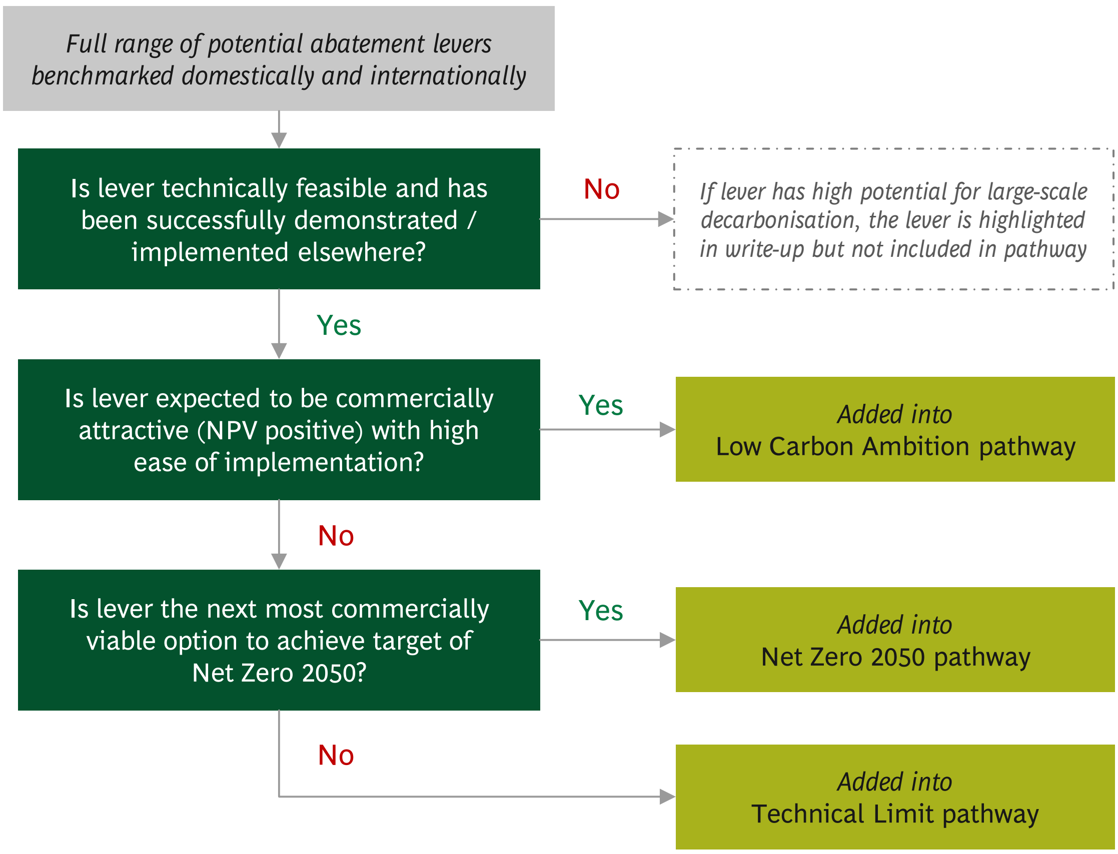
In **the Current Trajectory**, whilst emissions intensity is expected to decline, the total absolute emissions of the country continues to increase, as the growth pace of emission-related activities exceeds the improvement pace of emissions intensity reduction. In this pathway, Net Zero is not achieved, as net GHG emissions increase over time.

In the **Low Carbon Ambition pathway**, absolute GHG emissions continue to increase, reaching a peak around 2028, before gradually declining and reaching Net Zero around the 2065 period. Notably, a Net Zero 2065 ambition will represent a later target, as compared to a large majority of the country's trading partners, which primarily have Net Zero targets by 2060 or earlier. Several high impact levers were also found to have the potential to considerably shift the low carbon ambition. For example, adopting a coal phase out policy, instead of following through on medium-term power development plans, which involve the building of coal plants in the 2030s, will enable the Low Carbon Ambition pathway to achieve Net Zero seven years earlier in 2058. In this case, the planned coal power plants are substituted by renewables and gas. Overall system cost is also progressively lowered from current trajectory to low carbon pathway and further to net zero pathway.

In the **Net Zero 2050 pathway**, absolute GHG emission plateaus between 2025-2029, prior to a strong decline towards Net Zero by 2050. Based on the current technology outlook, decarbonisation technologies will bring the country close to the Net Zero line. Nevertheless, there may be a need to adopt carbon removal technologies, such as carbon capture and storage (CCS), for the last mile of net GHG emission reduction for Net Zero by 2050. Without the adoption of these carbon removal technologies, Net Zero will still be achieved towards 2055. However, if new high potential decarbonisation technologies emerge or existing technologies experience breakthroughs, the need for carbon removal technologies to achieve Net Zero 2050 may eventually be replaced.

Finally, the **Technical Limit pathway** was developed to demonstrate the maximum technical potential for decarbonisation in the country, by leveraging all known technologies which are technically feasible. This includes at-scale adoption of emerging technologies, which are technically viable but is not expected to be commercially viable in the foreseeable future. In this pathway, the country has the theoretical technical capacity to reach Net Zero around 2040.

Figure 11: Decision tree for inclusion of GHG abatement levers into pathways



Socioeconomic implications of the pathway

The socioeconomic impact and investment outlay of various GHG reduction pathways was assessed to inform potential trade-offs across the various technical pathways. This includes detailed bottom-up assessments to quantify the impact of the pathways on net GDP and jobs. In addition, high level assessments of pathway impact on key areas of household spending, and overall cost of living were made. Potential regional development opportunities from new green growth were also identified, factoring in the unique competitive advantage of various regions across Malaysia.

GDP and jobs impact

The impact of GHG emission reduction pathways on GDP was estimated through the bottom-up analysis of the impact of each lever, on direct and indirect GDP, using the income method of GDP estimation. Historical data on GDP breakdown by sector was obtained from the Department of Statistics Malaysia (DOSM) as the baseline. Based on the projected forward-looking demand impact of each lever, forward-looking spend and revenue were estimated, while also factoring in the distribution of spend over time (e.g., spend across the lifecycle during build stage vs. stable operations and maintenance stage). Spending by each stage of the lifecycle was disaggregated into various factors of production. This includes profits and various components of capital and operational expenditure, such as labour costs, equipment costs, material input costs, and other costs, based on detailed cost structure benchmarks. In addition, the extent of local value capture was factored in for various expenditure components. Through this methodology, direct GDP was estimated at a granular level; and indirect GDP impact estimated through GDP multipliers from national input-output tables. A similar methodology was applied for job impact estimates, factoring in Malaysia-specific employment multipliers.

Analysis of the GHG emission reduction pathways showed that the Net Zero 2050 has an overall positive impact on net GDP and job creation, compared to lower ambition pathways, such as the low carbon ambition or the current trajectory. The net positive GDP and job impact are derived from a few key sources:

- **Domestic substitution.** Green transition provides an opportunity for the country to capture a higher share of local value, for key products and services. For example, in the power sector, the coal to renewables switch has a large and sustained positive impact on GDP and jobs in the country. Currently, there is limited local value capture in the end-to-end coal value chain, as Malaysia relies strongly on international expertise for coal power plant builds and coal imports. In contrast, renewables, such as solar and bioenergy, have significantly more GDP and job spillover effects, with greater local value capture along the end-to-end value chain, which can be further enhanced with the build-up of local supply chain capabilities. Localising key technologies for climate transition will also be important to enhance domestic value capture, reduce import reliance and improve trade balance.

- **New green growth industries.** Another key source of GDP and job contributions is emerging new green growth industries, which are spurred by a strong climate ambition. This includes industries around hydrogen, where Malaysia is well positioned to capture due to cost advantages; energy efficiency, as the demand for both energy efficiency related products (e.g., smart devices) and services (e.g., energy service companies) increase; and the growth of bioenergy adoption across sectors (e.g., next generation biofuels in marine, aviation, heavy transport, and industry). Timely green transformation of existing sectors, such as repositioning the automotive industry from Internal Combustion Engine (ICE) vehicle manufacturing to Electric Vehicle (EV) manufacturing, are also critical to capture large demand growth.

- **Unlocking new sources of value.** With an enhanced circular economy principle and waste-to-value practices, new sources of value will be unlocked from existing practices. For example, the use of waste agricultural products to produce energy such as biogas and bioenergy, unlocks new revenue streams with GDP and job spillovers. Increased efforts on forest preservation and restoration, results-based payments related to carbon sequestration and environmental services of forests, and revenue-generating agroforestry practices, will unlock new sources of value for local communities, contributing to GDP and jobs spillovers.

- **Infrastructure development and public transport maintenance.** The build-up of green infrastructure will lead to GDP and job creation, primarily in the build-out phase, but also in the stable-state with the operations and maintenance of the developed infrastructure. This includes road and rail-based public transport infrastructure, charging infrastructure build-out for electric vehicles, bioenergy production and distribution infrastructure, upgrades to the power system, such as smart grids or other enablers to accommodate the greater penetration of renewables, and others. The timing effect of infrastructure development is one of the primary drivers for net GDP and job creation impact fluctuations observed over time.

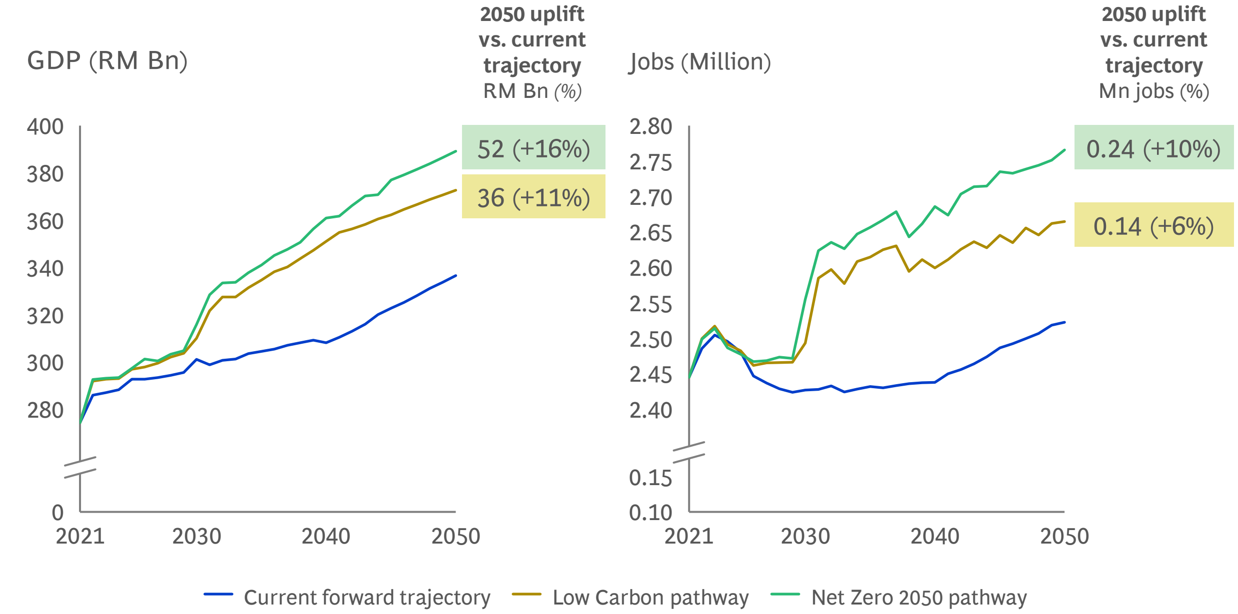
- **Enhanced disposable income effects.** Lastly, enhanced GDP and jobs are created by reducing the costs of key goods and services, which free up resources and increase disposable income to be spent in higher multiplier sectors of the economy. For example, the lower costs of electricity and mobility enabled by strong technology progress will enable household and industry expenditures to be directed elsewhere, providing greater spillover multiplier effects.

A breakdown of the net GDP and job impact also shows that whilst net GDP and job creation are larger with a higher climate ambition such as Net Zero 2050, the degree of GDP and job transition is also the greatest. The successful transition of economic sectors, from declining domestic sectors to emerging green economy sectors, as well as workforce reskilling and transition, will be required to capture spillover GDP and job benefits from climate transition. During climate transition, social protection is also critical for the workforce to ensure a just and equitable climate transition for Malaysians and should not create new inequalities in the society.

Moreover, with the natural depletion of natural resources, such as oil and gas over time, spurring future economy GDP and jobs will be critical for economic resilience and sustainability. Investing to build-up infrastructure foundations and enablers to support green economic transition will have strong pay-offs in the long run, through strong net GDP and job creation. Successful transition will also be crucial for public finances, to grow future-proof sources of fiscal revenue to offset future declines in fiscal revenue, derived from the oil and gas sector and other extractive industries.

Figure 12: Net GDP and job impact comparison across GHG emission pathways

Net Zero pathway has the potential to deliver strong net GDP and jobs creation for the country

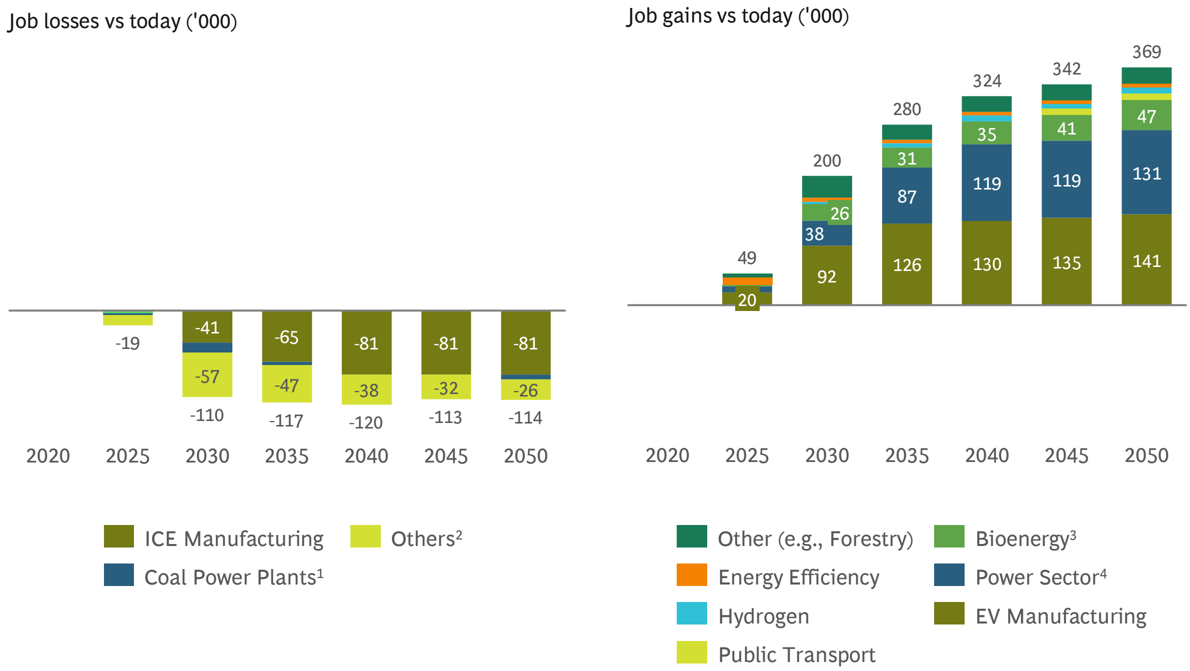


1. Excluding GDP and job impact of depleting oil and gas resources on Oil & Gas and OGSE sector 2. Jobs contribution was derived through the application of multipliers on the respective CAPEX and OPEX values associated with the growth areas (adjusted based on import content), 2. Jobs contribution multipliers were assigned to CAPEX and OPEX values based on their appropriate categories, 3. Multipliers were derived based on the input-output tables of Malaysia
Source: DOSM, Input-Output Multipliers, UNEP, Project Team Analysis

Figure 13: Breakdown of job losses and job gains across key economic sectors

Job transitions need to be managed between declining sectors and new green growth sectors

Net job losses are lower than … … net job gains from Net Zero pathway



1. Job losses from coal power plants are minimal due to low labour-intensity and low portion of local content across fuels and EPC value chain 1. 2. Primarily job losses from fuel value chain (e.g., refineries, fuel retail); excludes impact to any industry from border adjustment mechanisms 3. Includes both agriculture sector and bioenergy from refineries required for biodiesel 4. Includes jobs related to grid upgrades as well as power plants; but excludes solar manufacturing for export
Source: DOSM, UNEP, ILO

New job opportunities can also help offset potential decline in Oil and Gas and OGSE sector with gradual natural resource depletion

Current Oil & Gas direct and indirect contribution to the national economy

7 – 9	2 - 4	70 - 80	55 - 60	20-30
% Direct GDP Contribution of Oil & Gas Sector[1]	% Direct GDP Contribution of OGSE Sector[2]	'000 Workers Employed in Oil & Gas Sector[3]	'000 Workers Employed in the OGSE Sector[2]	% O&G Direct Contribution to Fiscal Income[4]

*Potential **reduction of Oil and Gas production** by up to **60-80%** by 2040 vs. 2020 based on forward-looking outlook of producing, sanctioned, and unsanctioned resources[5]*

1. Based on DOSM GDP and Employment Statistics – Table 2: GDP by Kind of Economic Activity at Current Prices (2015-2019) 2. Based on National OGSE Industry Blueprint 2021-2030 3. Based on DOSM GDP and Employment Statistics – Table 11a: Annual Employment by Economic Activity (2015-2019) 4. Based on Shared Prosperity Vision 2030 corroborated with Ministry of Finance statistics 5. Based on Wood Mackenzie (gas) and Rystad data (oil) on producing and sanctioned, unsanctioned, and yet-to-find estimates corroborated by industry experts
Source: DOSM, National OGSE Blueprint, Shared Prosperity Vision 2030, Wood Mackenzie, Rystad

Investment impact

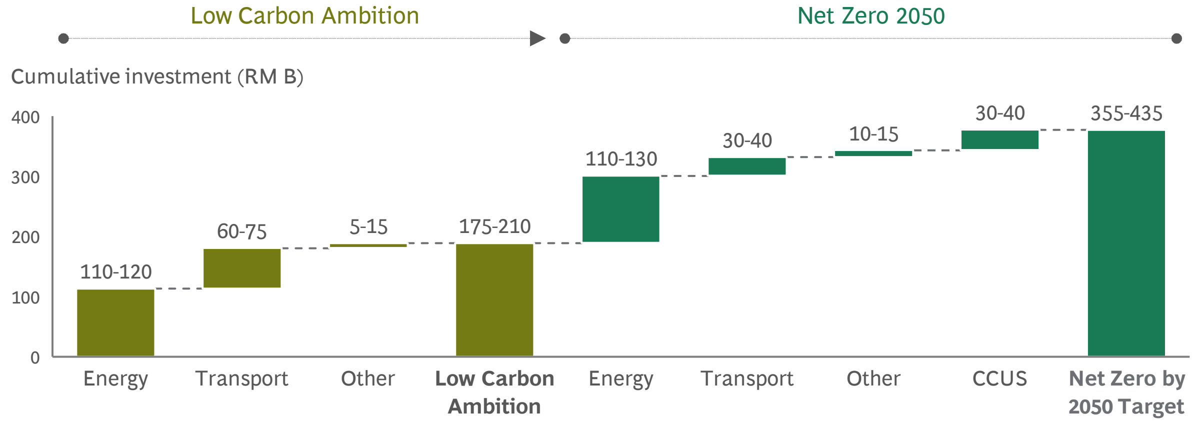
In order to capture net benefits from GDP and jobs associated with climate transition, investments are required to develop the necessary infrastructure enablers, incentivise early adoption of green technologies, and support transitions from declining to emerging sectors. Investments related to developing the necessary infrastructure enablers include capital expenditure required to develop public transport, EV charging networks, grid infrastructure upgrades, biofuel blending facilities, and others. At the same time, investments are required to incentivise the early adoption of select green technologies, including for consumer adoption of EVs, before inflection points where these green technologies are commercially attractive relative to incumbent technologies, are reached.

To enable the Net Zero pathway 2050, the study estimates that a total of RM 350 – 400 billion of investments are needed over a 30-year period. Approximately 80% of these investments are associated with the energy and transport sector. On an annual basis, these investments equate to less than 1% of GDP, and will need to be funded from a combination of private, public, and multilateral climate funding support.

Figure 14: Cumulative investments required for Net Zero 2050 pathway for Malaysia

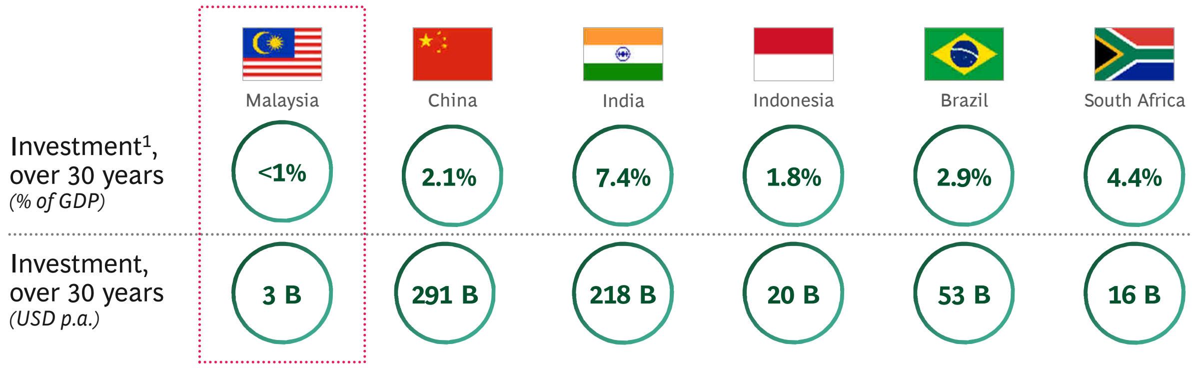
Estimated investment of RM 350 - 450 billion for Net Zero pathway

Cumulative investment 2021-2050 for Low Carbon Ambition and Net Zero 2050 (RM Bn)



1. Investment represent CAPEX expenditure across various abatement levers but exclude any investments for Adaptation and Resilience (A&R). Power investments include power plants, energy storage, smart grid, audit and retrofits, green building investments, etc. 2. Transport investments include EV charging infrastructure, automotive facility upgrades, public transport investments, hydrogen infrastructure development, biorefinery capacity addition 3. Other investments include industry abatement initiatives such as steel recycling, hydrogen DRI, investments in agriculture and forestry (e.g., precision agriculture investments, degraded forest restoration, etc.), and waste investments (e.g., WtE plants)
Source: Project Team Analysis

Investments required to achieve Net Zero in Malaysia relatively attractive compared to selected other developing countries



1. Mitigation & adaptation cost of RM350-400bn over 30 years 2. 2050 GDP in Malaysia assumed to be ~USD 1,300 Bn accounting for Y-o-Y nominal GDP growth of 4% with GDP USD398 (constant 2010 US$) Bn in 2019 used as baseline
Source: World Bank, 'China Net Zero: Clean Tech Revolution' - Goldman Sachs; 'Net Zero for South Africa' – PWC ; 'Building a sustainable financial system to serve India's development needs' – FICCI; 'Deep decarbonisation of Indonesia's energy system: A pathway to zero emissions by 2050' - Institute for Essential Services Reform, Project Team Analysis

Regional opportunities impact

For all Malaysians to share in the benefits of climate transition, it is critical that GDP and job creation benefits are well distributed across various regions. Natural resource endowments or existing industry clusters provide potential sources differentiated competitive advantage for various regions to benefit from green growth opportunities. For example, regions with advantages with strong solar irradiation and access to sustainable hydropower resources, are positioned to benefit strongly from GDP and job creation related to renewable energy and green hydrogen production. Regions with existing electric and electronics, solar component manufacturing, automotive clusters, and other green technology adjacencies are positioned strongly to benefit from new green growth opportunities. Moreover, with agriculture and forestry endowments distributed well across the country, regions across Malaysia stand to benefit from economic opportunities associated with bioenergy, agroforestry, and nature-based solutions.

Broad mapping of green economic opportunities point towards the potential of green transition strongly benefitting all regions across Malaysia, building on the unique advantages of each region, with effective planning and coordination. Lower income regions also have the potential to leapfrog and converge with higher income regions in Malaysia, as natural assets and advantages are increasingly valued in green transition.

Cost of living impact

Besides regional equitability, the impact of climate transition on cost of living was assessed. Green transition will likely affect multiple areas of household expenditure, particularly in areas such as mobility and utilities expenditure, as well as consumer goods, food products, and others. Strong technological progress is expected to reduce the low carbon mobility and power system costs in the long-run, even after accounting for infrastructure development costs and integration costs. However, green requirements are expected to be inflationary in certain areas of spend such as in consumer goods due to the costs of decarbonising the supply chain and incorporating sustainability considerations, but this is expected to reduce over time as economies of scale are achieved.

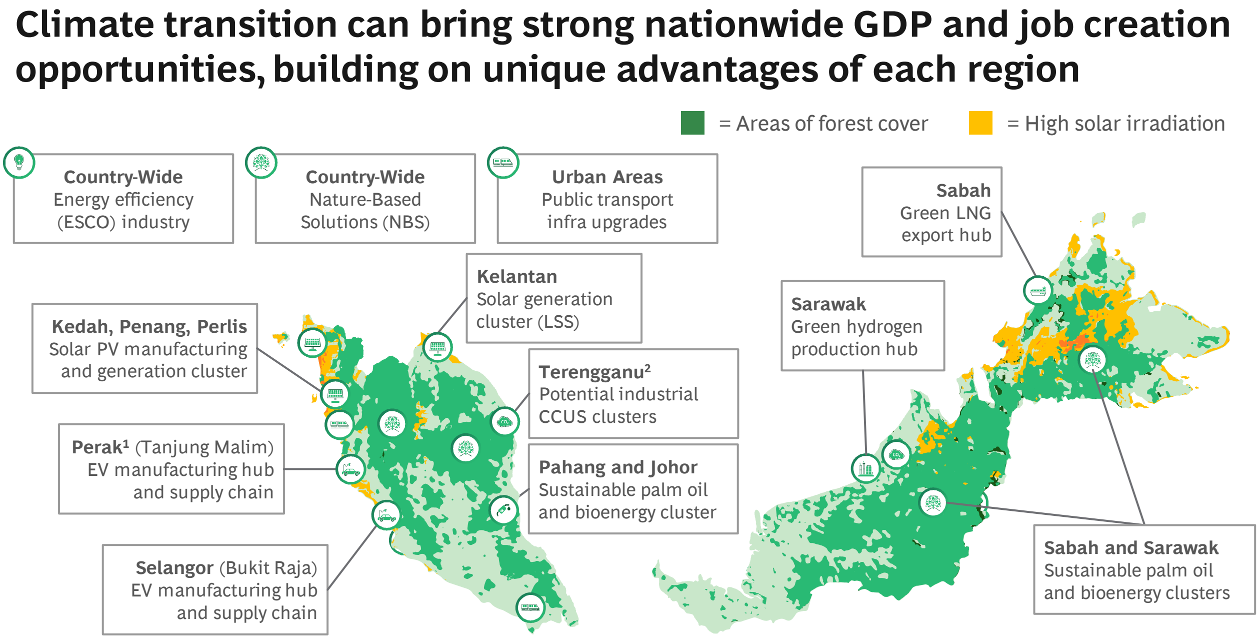
Accounting for the impact of cost of living increases on households of various income levels will also be critical. For example, B40 households spend a larger proportion of their expenditure on housing and utilities as well as food and beverage products compared to M40 and T20 households. Reducing costs of mobility through affordable public transport and equitably passing through lowered power system costs has the potential to reduce the cost of living for lower income households. Safeguards will also needed to ensure that mechanisms such as carbon pricing do not have adverse impact to lower income households through effective redistribution policies.

Overall socioeconomic impact

A highly progressive climate transition ambition, such as the Net Zero 2050 pathway, is estimated to bring higher GDP and job impact compared to less ambitious climate pathways. These GDP and job benefits are expected to be well distributed across regions in Malaysia, building on the unique competitive advantages possessed by each region. Green transition is also not expected to be inflationary for households, if cost advantages of rapid technology progress particularly in the areas of energy and mobility can be captured to increase affordability in key areas of household spend.

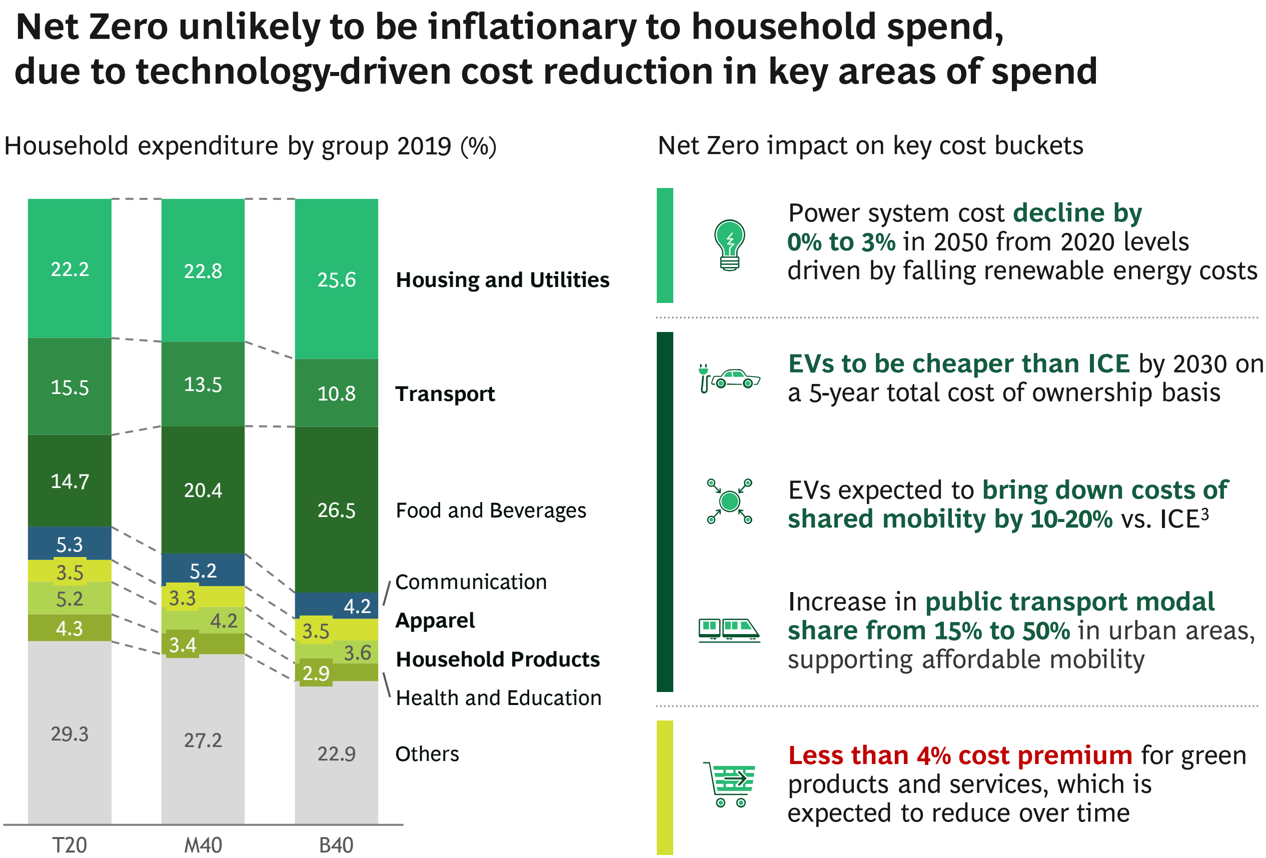
Whilst the potential socioeconomic benefits are large, the level of progressive effort, action, and coordination to ensure the country's readiness for the Net Zero 2050 pathway should not be underestimated. All stakeholders in the country will need to be activated from public sector leadership with progressive and coherent green policies, regulations, and incentives to the private sector stepping up to champion the green agenda and acting decisively to reduce its carbon footprint. Consumers will also have a large role to play by shifting behaviours to more sustainable and responsible consumption, being conscious of the environmental impact of their decisions in day-to-day decision making. Multilateral international support from climate funding and financing, technology transfer, and capacity and capability building will also be needed to enable Malaysia to embark on an ambitious climate transition pathway, and to unlock the socioeconomic benefits for the country.

Figure 15: View of regional economic opportunities catalysed by green transition



1. Proton facility in Tanjung Malim, UMW-Toyota factory in Bukit Raja 2. Based on lowest cost CCUS (carbon capture, utilisation, and storage) potential 3. Non-exhaustive list
Source: Expert Discussion, World Bank Group, Solar GIS for solar irradiation, Global Forest Watch for forest cover, Project Team Analysis

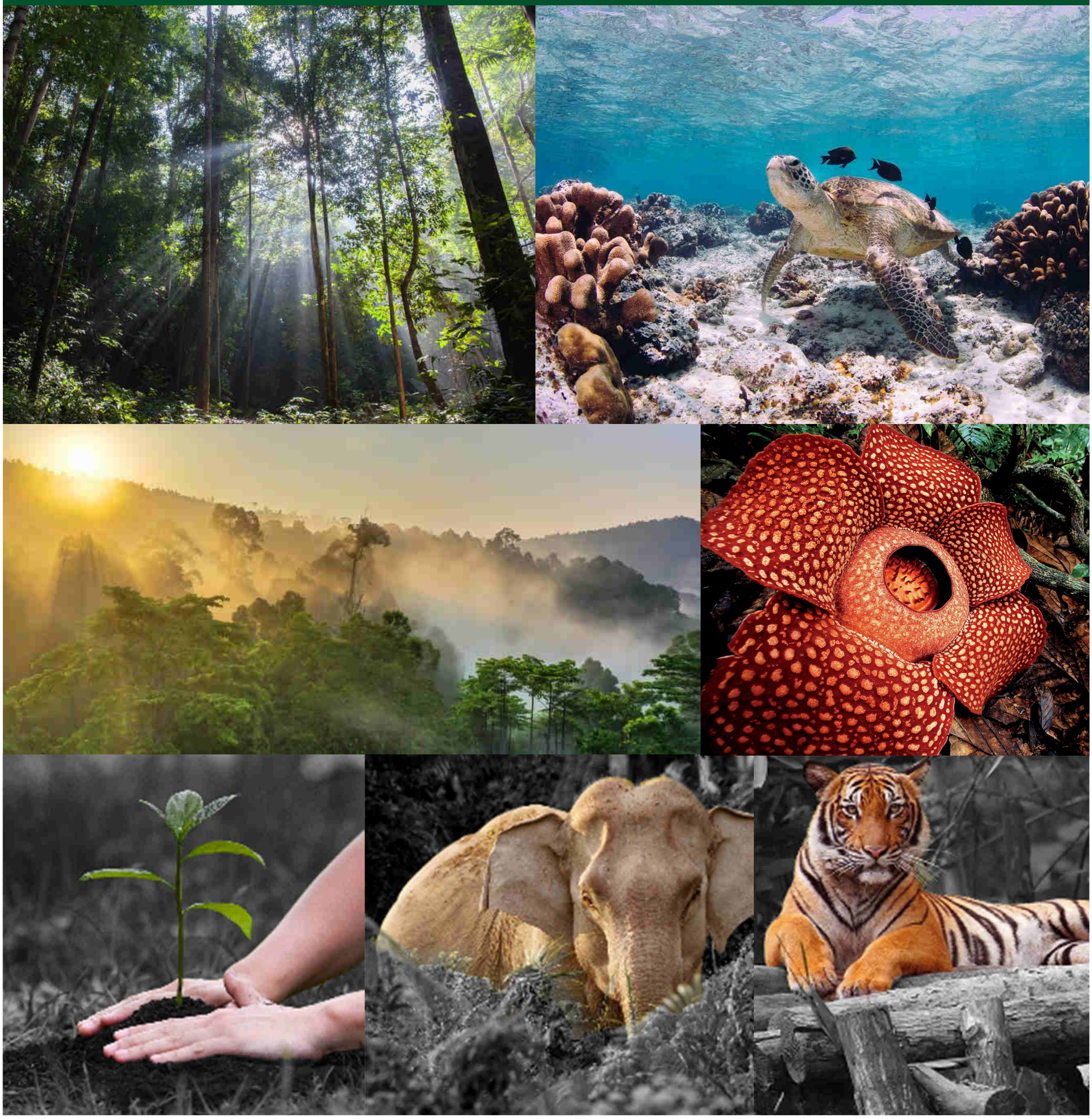
Figure 16: Green transition unlikely to be inflationary and potentially cost advantageous to households



1. Includes restaurants and hospitality, services and miscellaneous 2. Split based on income groups - T20 refers to top 20% income group, M40 refers to middle 40% and B40 refers to bottom 40% 3. Operating costs of EVs are lower with high utilisation due to lower relative fuel costs to ICE; reducing operational expenditure of ridesharing / shared mobility 4. TCO = Total Cost of Ownership, ICE = Internal Combustion Engine
Source: DOSM, Project Team Analysis

Priority #1:

Protect and enhance Malaysia’s natural assets



Overview

Malaysia has been endowed with a rich variety of natural assets, from the country's vast rainforests to its coastlines and oceans, which are home to an extensive array of plant and wildlife species. Our natural assets constitute an extraordinary natural capital that maintains our natural environment and the life-support systems that give us food, water and numerous economic benefits. Malaysia is recognised as one of the world's seventeen mega biodiverse countries globally, which collectively provide habitats for the majority of the Earth's species and a high number of endemic species.

There are an estimated 15,000 species of vascular plants in Malaysia, 307 known species of mammals, 30 of which are endemic to Malaysia, 785 species of birds, 242 species of amphibians and 567 species of reptiles, as well as 2,068 species of freshwater and marine fishes. Beyond supporting mega-biodiverse habitats, Malaysia's natural assets are key for various ecosystem services including regulating climate, temperatures, and air quality, supporting healthy water cycles, maintaining soil quality, providing flood and disease control, and many others. It is critical that our natural assets are protected to secure our futures, as key sources of climate mitigation, adaptation, and resilience and socioeconomic benefits including livelihoods for indigenous communities, competitive advantages for sectors such as tourism, and many others.

Malaysia's natural assets such as its forests will face increased pressures over the coming decades, with increased competition for land use driven by growing populations, food needs, and other economic development pressures. The need to protect and enhance Malaysia's natural assets is greater then ever before and will need to be a key priority across stakeholders to ensure resilient and sustainable development in Malaysia.

Historical trajectory

Focusing on the contribution of the country's natural assets to GHG removals, the land use, land use change, and forestry (LULUCF) sector was assessed. The land use, land use change and forestry (LULUCF) sector covers GHG emissions and removals from the use and change in use of different land types. The main land categories are forest land, cropland, settlements, grassland, and wetlands. The contribution of oceans to carbon removals is not included in the national GHG inventory. Whilst oceans are recognised as a source for carbon removals, given the lack of concrete data the potential carbon removals from oceans are not explored in the study's climate pathways.

Of the total landmass of 33 million hectares in Malaysia, forest land constitutes the majority of landmass (55%), followed by cropland (24%) and settlements (20%). Forest lands[44] contributed 244 $MtCO_2e$ of net removals, croplands[45] contributed 15 $MtCO_2e$ of net removals, whilst settlement contributed 18 MtCO2e of net emissions. Collectively, net carbon removals from forests and croplands abated approximately 75% of Malaysia's total GHG emissions[46].

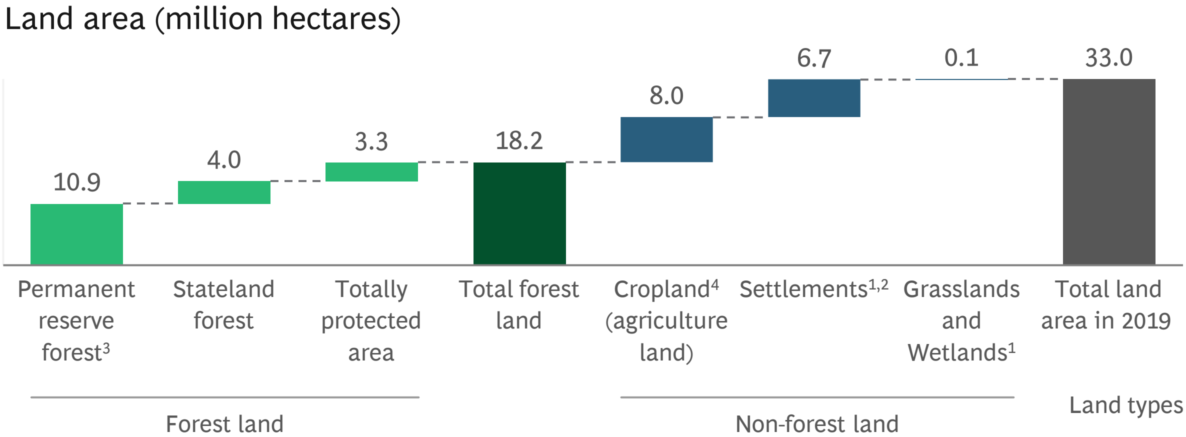
In terms of historical trajectory, net GHG removals from forest lands have been gradually increasing between 1990 to 2016, at a rate of around 1.1% per annum. One of the key drivers of this improvement is the steady decline in wood removals at approximately 3.2% per annum, reducing annual carbon losses. The reversal of biomass loss due to forest loss has also contributed to enhanced GHG removals. Between 1990 to 2009, biomass stock gains were declining steadily at 0.3% per annum, but has since been growing at 0.4% per annum[47] , contributing to increased carbon removals. Over the period, the country has also successfully retained its forest cover around 18.3 million hectares or at approximately 55% of land mass, with slight fluctuations between 53% and 57% of forest cover over the 1990-2016 period.

For cropland, net GHG removals have been deceasing by 1.5% per annum, but has largely stabilised over the last few years at 15 $MtCO_2e$ of removals. Finally, GHG emissions from conversion of forest or croplands to settlements have stabilised at a low level of approximately 3 $MtCO_2e$[48] .

44. Combined view of Forest Land remaining as Forest Land and Land converted to Forest Land.
45. Combined view of Cropland remaining as Cropland and Land converted to Cropland
46. Malaysia's 3rd National Communication and 2nd Biennial Update Report (2018), UN Framework Convention on Climate Change.
47. Ministry of Water, Land and Natural Resources, Press Releases
48. Malaysia's 3rd National Communication and 2nd Biennial Update Report (2018)

Figure 17: Breakdown of Malaysia total land mass by land us type

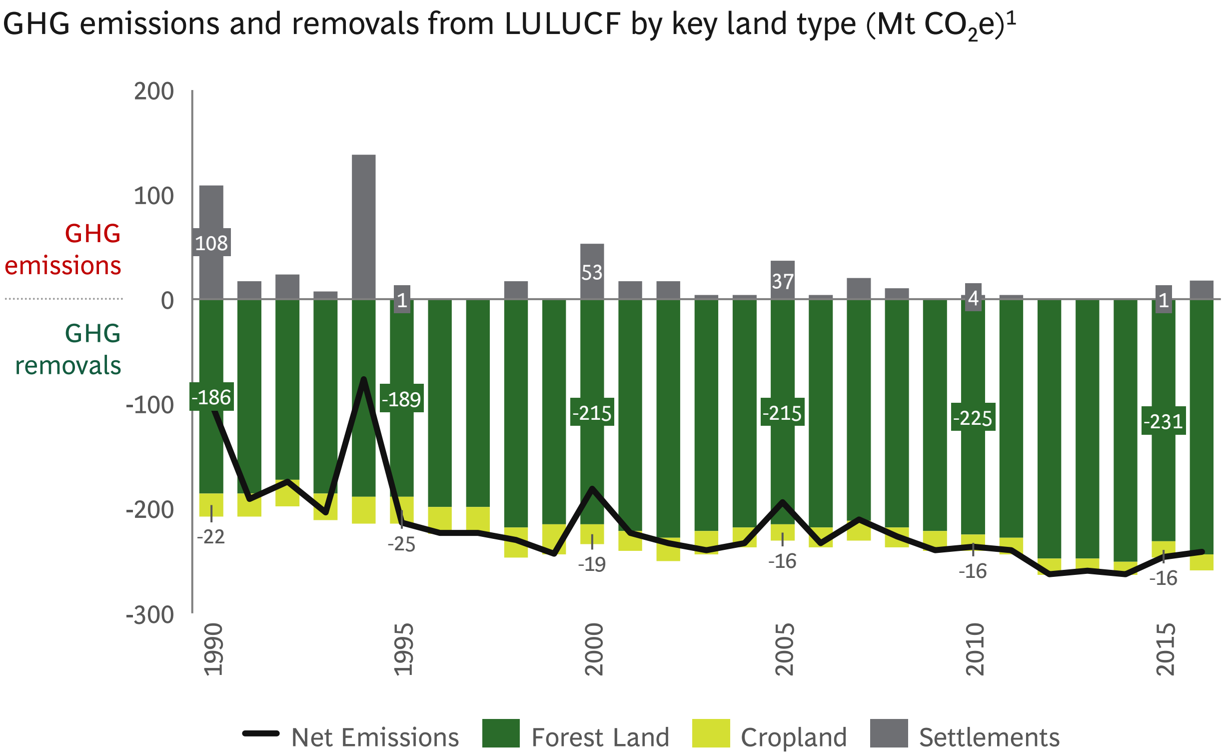
Forests constitute 55% of total land mass, with cropland and settlements making up bulk of remaining 45% of land area



1. Estimated grasslands and wetlands using 2016 grasslands and wetlands areas as proxy for 2019 (BUR3), settlement is calculated as a difference between total land area and the sum of forest, cropland, grassland and wetland; 2. Incl. all developed land like transport infrastructure and human settlements of any size, graveyards, mining and golf courses as well as unmanaged areas due to abandoned development projects 3. Permanent reserve forest consist of 9.5 Mn ha of inland forest, and 0.4-0.5 Mn ha of peat swamp, mangrove, and plantation forest 4. Cropland consists of 5.9 Mn ha of oil palm, 1.1 Mn ha of rubber, 0.4 Mn ha of paddy, and 0.4 Mn of fruit plantations
Source: Malaysia's Third Biennial Update Report to the UNFCCC (2020), KeTSA, Department of Agriculture, Malaysia, Malaysian Palm Oil Board (MPOB), Malaysian Cocoa Board, Malaysian Pepper Board, Rubber Industry Smallholder Development Authority (RISDA), PLAN Malaysia

Figure 18: LULUCF sector contribution to GHG removals has been growing over time

Gradual improvements in GHG removals from forest land observed, the major driver of net LULUCF removals



Source: Malaysia's Third Biennial Update Report to the UNFCCC (2020)

Box 2 | Overview of forest land in Malaysia and existing forestry policies and initiatives (I/II)

Currently, there are 18.2 million hectares of forest land in Malaysia, comprising 10.9 million hectares of permanent forest estate, 4.0 million hectares of stateland forest, and 3.3 million hectares of totally protected areas (TPAs)[49].

- **Permanent forest estate (PFEs)** are legally designated as reserved forest. PFEs consist mainly of inland forests (9.5 million hectares) as well as mangroves, peat swamps, and plantation forests (0.4 – 0.5 million hectares each). A portion of PFEs are forests designated to produce timber on a sustained yield basis.

- **Stateland forests** represent current forest land which long-term use has not been decided and can be co-opted into the PFE system or converted to some alternative form of land development, under the jurisdiction of state authorities[50].

- **Totally protected areas (TPAs)** represent national parks, wildlife sanctuaries, and nature reserves which have been gazetted under national parks and wildlife protection ordinances for conservation and protection of biodiversity, wildlife and habitats, or the preservation of specific natural features.

The Federal Constitution empowers each state to enact laws on forestry and to formulate forestry policy independently for the state[51]. Forestry revenues, such as logging rents, are accrued to the state government. However, the Constitution also empowers the federal government to formulate forestry legislation as necessary to promote uniformity across states.

To facilitate enhanced policy coordination across federal and state governments related to the development and land use across forestry, agriculture, mining, and other purposes, the National Land Council was established in 1972. Subsequently, the National Forest Policy 1978 (revised in 1992) was established, enshrining key legislation to conserve and manage the nation's forests based on the principles of sustainable management as well as to protect the environment, conserve biological diversity, genetic resources, and to enhance forest research and education. The thematic objectives of the National Forest Policy 1978[52] are also reflected in state-level policies, such as the Sabah Forest Policy (2018)[53] and the Sarawak Forest Policy (2019)[54].

More recently, the Malaysia Forestry Policy was also launched and jointly adopted by all 13 states in 2021[55]. The policy outlines the direction for the forestry sector to meet challenges at both the domestic and international level, including fulfilling the commitment pledged by Malaysia during the Rio Earth Summit in 1992 to maintain forest cover of at least 50% of total land mass[56].

49. Total Forested Areas in Malaysia statistics (2020) Ministry of Energy and Natural Resources (KeTSA).
50. Malaysia: Forestry Subsector Review (1991) World Bank.
51. As provided under Article 74 (2) of the Federal Constitution which empowers each state to enact laws on forestry and to formulate forestry policy independently for the state. Forestry revenues (e.g., rents from logging) are accrued to the state government. However, the Constitution, under Article 94 (1) empowers the federal government to formulate forestry legislation as necessary to promote uniformity between two or more states.
52. Malaysian Forestry Policy 2020 (2020) Ministry of Energy and Natural Resources (KeTSA).
53. Sabah Forest Policy 2018 (2018) Sabah Forestry Department.
54. Sarawak Forest Policy 2019 (2019) Forest Department Sarawak.
55. Precedence to policy include the National Forest Policy (1978) which was revised in 1992; and the National Forestry Act (1984) which was amended in 1993.
56. Statement by the Minister of Natural Resources and Environment, United Nations Conference on Sustainable Development, 22 June 2012, Rio De Janeiro.

Box 2 | Overview of forest land in Malaysia and existing forestry policies and initiatives (II/II)

In addition, the National Policy on Biological Diversity 2016-2025 was established to guide biodiversity management in the country, reflecting Malaysia's international commitment to the Convention on Biological Diversity (CBD)[57] and other multilateral environmental agreements. Among other objectives, the policy aims to safeguard key ecosystems, species, and genetic diversity with targets around conservation and sustainable management of the country's forests.

In support of the policies above, the REDD Plus Strategy[58] was developed as the framework for forest sink and biodiversity conservation, including the reduction of emissions from deforestation and forest degradation, conservation, enhancement of forest carbon stocks, and sustainable management of forests. Various other initiatives such as the Central Forest Spine (CFS) [59] and Heart of Borneo (HOB)[60] have also been established to gazette and maintain key forest areas to ensure the continuity of forest landscapes through ecological corridors.

57. Sixth National Report of Malaysia to the Convention on Biological Diversity (2019) Ministry of Water, Land and Natural Resources.
58. National REDD Plus Strategy, Malaysia (2015) Ministry of Natural Resources and Environment.
59. CFS1: Master Plan For Ecological Linkages (2009) Department of Town and Country Planning Peninsular Malaysia.
60. International Conference On Heart Of Borneo (2019) Sabah Forestry Department.

Case Study 1 | The Heart of Borneo Initiative

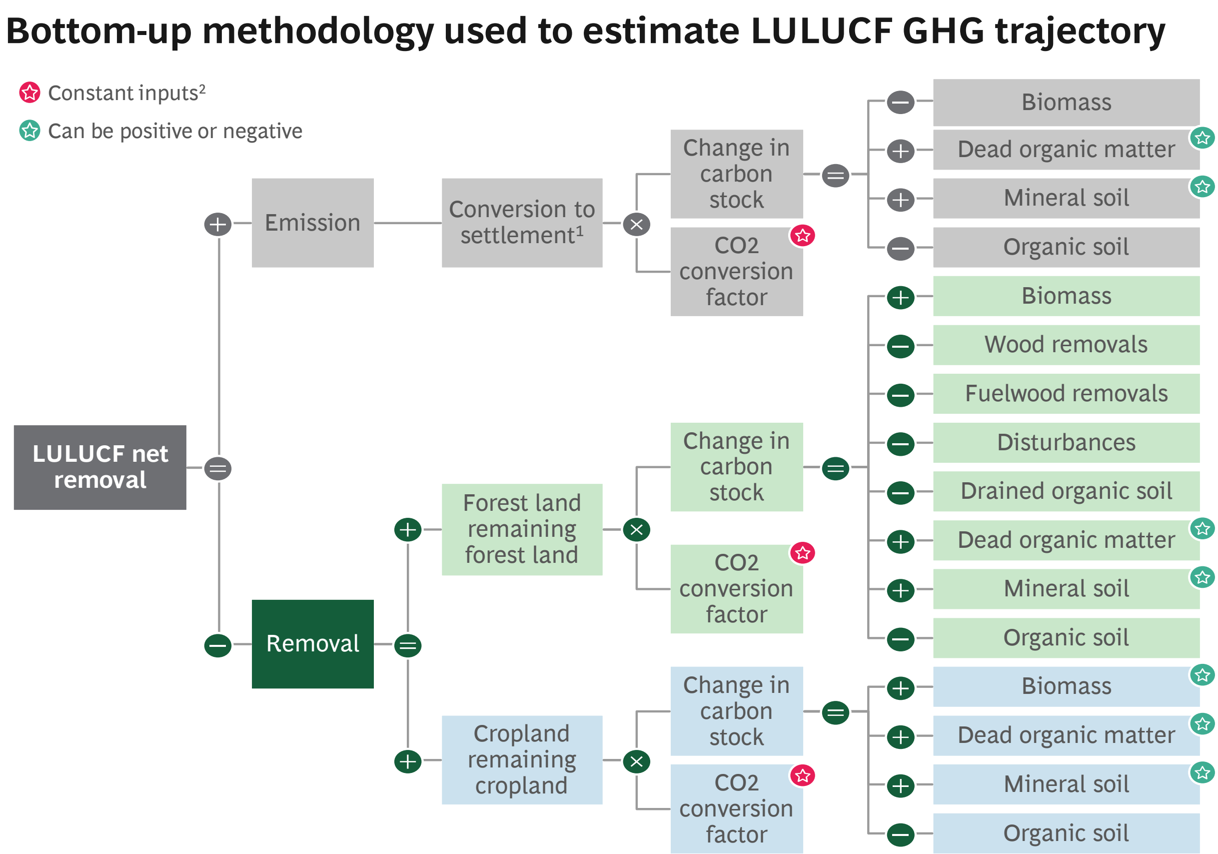
The Heart of Borneo (HoB) Initiative is joint Declaration of Brunei Darussalam, Indonesia and Malaysia that is supported by Civil Society. It straddles 23 million hectares of the most pristine rainforest in Borneo, the world's third largest island that covers 74 million hectares. At the turn of the 20th Century, 96% of Borneo was forest covered. By 2015, with forest opened up for settlements, agriculture, plantations and development, only 55% of the island remains under forest cover, and much of this found in the HoB. Being a treasure trove of biodiversity, the HoB is a source of life and livelihood for 11 million people.

The goal of the HoB Initiative is to conserve biodiversity for the benefit of people through five core areas: Transboundary Management, Protected Area Management, Sustainable Nature Resource Management, Ecotourism and Capacity Building. The three countries and partners converge during the annual HoB Trilateral Meeting to report on progress and discuss proposals on enhancing conservation and sustainable development.

In Malaysia, the five core areas are defined by the Heart of Borneo Strategic Plan of Action for Sabah and Project Implementation Framework for the Heart of Borneo Sarawak. The state governments implement various projects with the support of Five Year Malaysia Development Plans. Private concessionaires are required to manage the natural resources in compliance with principles of sustainability including adherence to certification standards. Civil Society such as WWF-Malaysia undertakes conservation projects in collaboration with government agencies, private sector and local communities. The activities include establishing protected areas and High Conservation Value areas as wildlife habitats apart from supporting local communities and Indigenous Peoples manage their conservation areas.

Covered by vast intact tropical rainforest, the Heart of Borneo is an important carbon sink, and concerted efforts must be made to conserve it.

Figure 19: Driver tree depicting methodology for LULUCF sector net removals



1. Forestland or cropland converted to settlement; 2. Conversion from carbon to carbon dioxide by multiplying carbon stock with 44/12;
Source: IPCC guidelines, Malaysia's Third Biennial Update Report to the UNFCCC (2020)

Brief description of projection methodology for key LULUCF removals and emissions drivers

For forest land, carbon removals are calculated using the IPCC Tier-1 method[61] (biomass gain-loss method) where the change in carbon stock is calculated from the gain of carbon stock from above-ground and below-ground biomass, as well as the loss of carbon stock from wood removal, disturbance, and drained organic soil. For cropland, carbon removals are calculated based on the evolution of perennial cropland area multiplied with the historical average of carbon sequestration of cropland.

The forest land of any given year is calculated as the sum of existing forest land, forest land gain (e.g., through afforestation), and forest land loss (e.g., through deforestation driven by commercial agriculture, commercial logging, extractive industries or urban and infrastructure development). For land use change, such as conversion from forest land or cropland to settlements, carbon emissions are calculated based on the area converted to settlements multiplied with the default emission factors outlined in Malaysia's Third Biennial Update Report to the UNFCCC (2020) report. Carbon change in dead organic matter, mineral soil, and organic soil are not calculated due to data limitations.

Land use change estimations were made based on a detailed bottom-up view of planted area required to meet food security levels outlined in the National Agrofood Policy 2.0, factoring in yield improvements, utilisation of idle land, and forward-looking population growth estimates. Conversion from forest land for settlements were made based on historic land use change trajectory, reference benchmarks for forest land to settlement conversion, and factoring in impact of decisions of build-out of large scale solar on land. These plans should be updated with further developments in land impact assessments of various policies, such as the Framework Plan for Transforming the Mineral Industry 2021-2030 for extractive industries. The study assumes strong protection for forest retention where policy conflict exists as a baseline, such as in relation to deforestation for mineral extraction. Moreover, the land impact of key infrastructure and urban area developments will need to be incorporated, such as the development of infrastructure in Sabah and Sarawak.

61. IPCC Guidelines for National GHG Inventories (2006), Volume 4: Agriculture, Forestry, and Other Land Use; Annex 1.

Forward trajectory

There are five key drivers for the estimated current trajectory pathway of the LULUCF sector, if additional levers are not adopted beyond those outlined in existing plans. As a result of the drivers below, the total GHG removals of the LULUCF sector decreases from 272 $MtCO_2e$ to 259 $MtCO_2e$ from 2020 to 2050 in the current trajectory pathway:

1. **Cropland demand increase to meet growing population and food security targets**
   For commodity crops, palm oil cropland continues to grow on its historic trajectory up to the cap of 6.5 million hectares cap. Rubber planted area is expected to stagnate driven by lower return attractiveness. The conversion of rubber planted area to meet future food crop land needs over forest land conversion is considered in the Low Carbon and Net Zero 2050 pathway. Planted areas for cocoa and pepper are expected to stabilise around the 0.01 million hectare mark, stabilising historic declines observed.

   For food crops, demand increase to meet population growth and self-sufficiency levels (SSL) in the National Agrofood Policy 2.0[62] represents a key driver. Planted area for fruits and vegetables are expected to increase by 0.35 million hectares. For paddy, despite growth in demand, no growth in planted area is assumed given the large potential for paddy yield improvement. In total, cropland land use is expected to grow to 8.85 million hectares from current 8.05 million hectares, requiring land use conversion to croplands. The growth in perennial crops land area will also result in cropland GHG removals increase.

2. **Utilisation of idle land to partially meet cropland demand expansion**
   Approximately 0.18 million hectares of idle land is estimated, consisting of 0.11 million hectares of idle agriculture land and 0.07 million hectares of idle ex-mining land. Ongoing efforts such as the Idle Land Development Program by the Department of Agriculture[63] the utilisation of idle land will reduce the quantum of increase in forest land conversion to cropland[64]. The potential to repurpose ex-mining land for cropland following rehabilitation and environmental, health, and safety is also included in the current trajectory pathway.

3. **Growth of settlement land demand**
   Land demand for settlements is expected to grow influenced by urban expansion, infrastructure growth, as well as sectoral land demand needs such as from the energy sector (e.g., large scale solar build-out) and extractive industries. Over the 2020-2050 period, a total of 200,000 hectares of settlement land demand increase is projected, or approximately 6,000 hectares a year. This projection is informed by the historic trajectory of land use conversion to settlements and based on global benchmarks which indicate that settlement-driven deforestation typically accounts for less than 1% of total deforestation.

4. **Decline of forest cover, but forest cover remains above Rio Summit pledge**
   Influenced by the combination of factors above, forest cover is expected to decline from 18.2 million hectares to 17.4 million hectares, or from 55.1% to 52.6% forest cover in the current trajectory pathway. Malaysia continues to adhere to its Rio Earth Summit pledge to retain forest cover above 50% of total land mass.

5. **Lower carbon stock due to forest cover decline and stabilising wood removals**
   The major drive for lower forest carbon stocks is expected to be the decline in forest cover. Furthermore, commercial wood removals (i.e., timber) is expected to stabilise going forward, a deviation from its previous decline over time which has contributed to growth in GHG removals over the last decade. Whilst efforts to restore degraded forests will improve carbon stocks, given the size of forest cover reduction, a net negative impact on forest carbon stocks is expected. Other contributors such as loss of carbon from drained organic soil at peatlands or disturbances such as forest fires are expected to remain constant at current levels.

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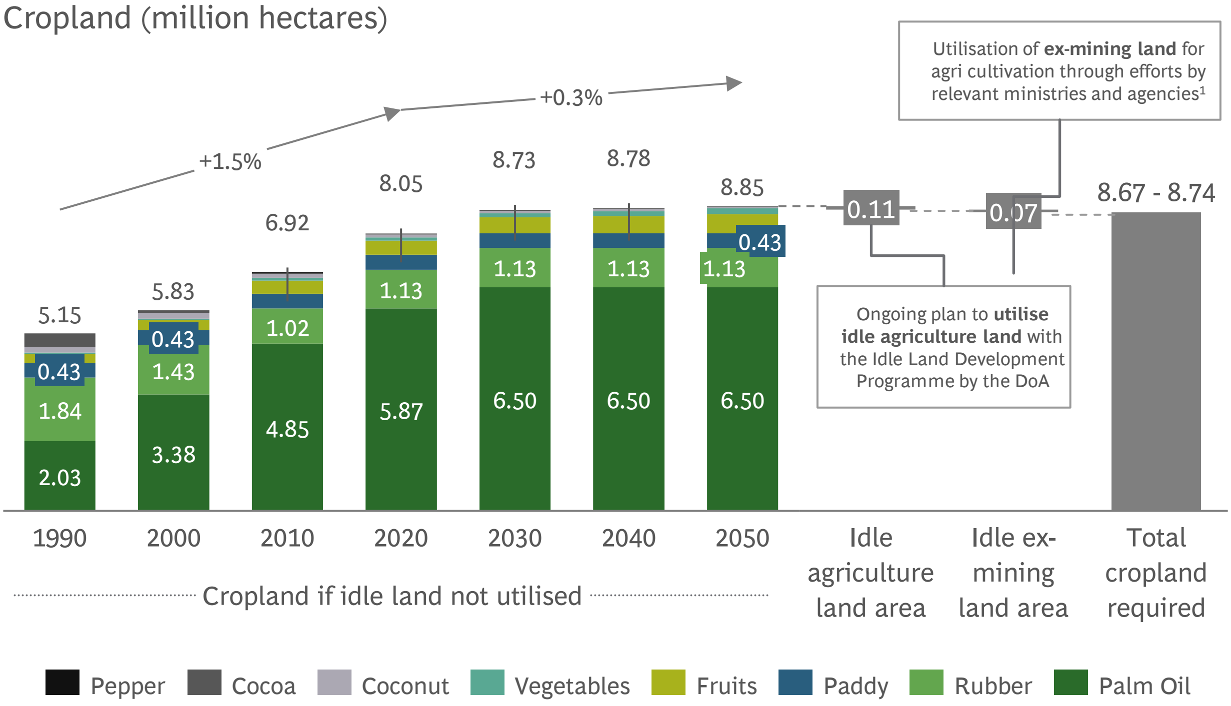
62. National Agrofood Policy 2.0, Draft Policy Report (2021) Ministry of Agriculture and Food Industries.
63. Department of Agriculture lands a helping hand to develop idle land, The Malaysian Reserve, 16 May 2019.
64. Unlock potential of idle land to reduce food imports, The Malaysian Reserve, 15 May 2019.

Figure 20-: Agriculture cropland land use growth projections

Cropland land use growth expected to slow over time

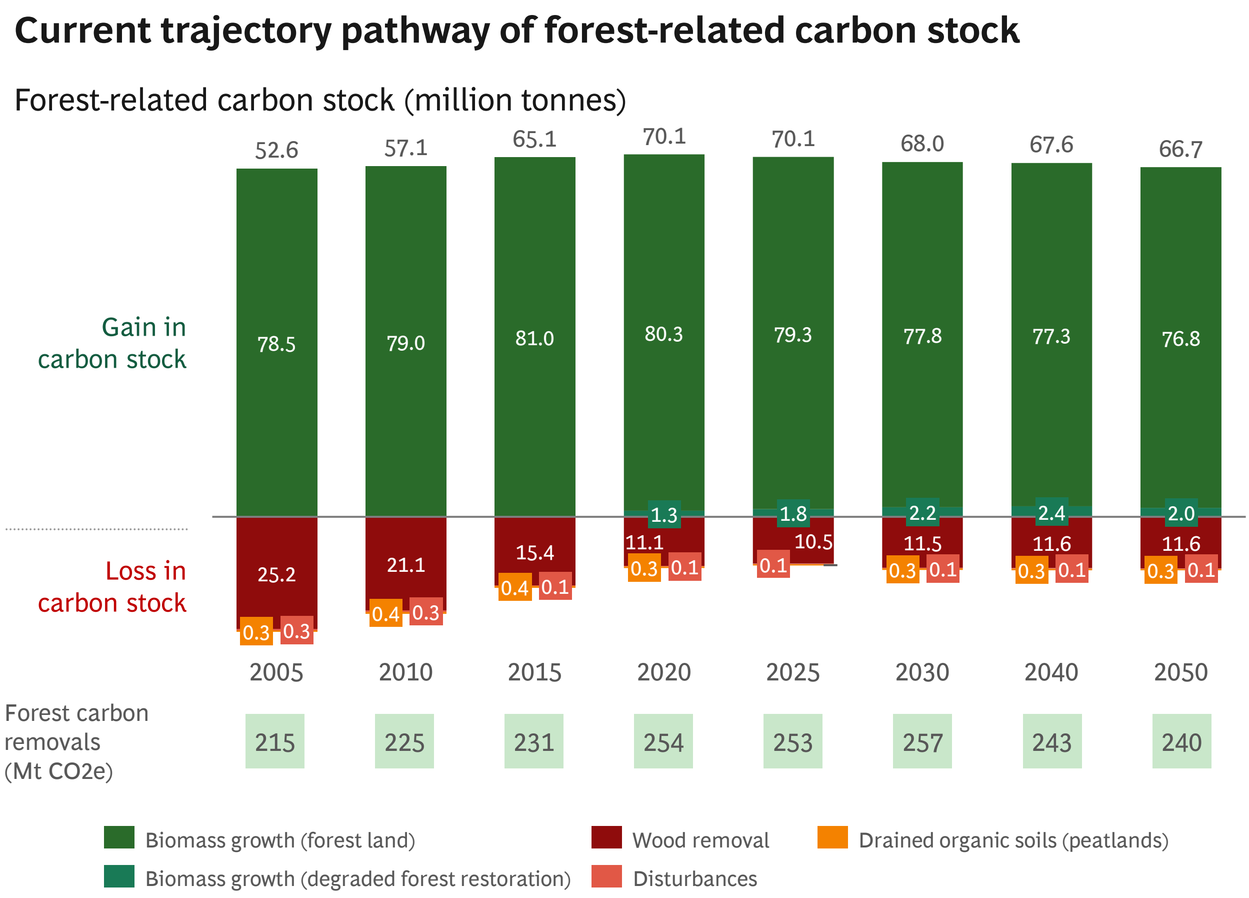


1. Based on ~110k ha of idle agriculture land and ~70k ha of ex-mining land
Source: Ministry of Primary Industry, Department of Agriculture, Department of Minerals and Geoscience

Crop type	Total cropland space required (ha) 2015	2020	2025	2030	2040	2050	2015-2020 CAGR	2020-2025 CAGR	2025-2050 CAGR	Projection assumptions
Oil palm	5.64	5.87	6.17	6.50	6.50	6.50	0.8%	1.0%	0.2%	Historic land use growth, up to 6.5 Mn ha limit
Paddy	0.43	0.43	0.43	0.43	0.43	0.43	0.0%	0.0%	0.0%	SSL of 80% met with improved yields
Fruits	0.39	0.41	0.43	0.46	0.50	0.55	1.0%	1.0%	1.0%	SSL of 83% met with 1.48% CAGR of planted area
Vegetables	0.09	0.10	0.11	0.12	0.14	0.17	2.1%	1.9%	1.8%	SSL of 79% met with 2.46% CAGR of planted area
Rubber	1.08	1.13	1.13	1.13	1.13	1.13	0.9%	0.0%	0.0%	Planted area stabilises, based on expert input
Coconut	0.08	0.08	0.08	0.07	0.06	0.05	0.0%	0.0%	-1.9%	Planted area change follows historic CAGR
Cocoa	0.02	0.02	0.02	0.01	0.01	0.01	0.0%	0.0%	-2.7%	Decline in planted area levels flattens out at 0.1 ha
Pepper	0.02	0.01	0.01	0.01	0.01	0.01	-12%	0.0%	0.0%	Decline in planted area levels flattens out at 0.1 ha
Total Area	7.75	8.05	8.38	8.73	8.78	8.85	0.8%	0.8%	0.2%	Assuming current idle land remains unoccupied
Required Area	-	8.05	8.25	8.56	8.61	8.67	N/A	0.5%	0.2%	After utilising 0.18 Mn hectares of idle land (agri and ex-mining)

1. 2020 assuming same rate of growth between 2019-2020 as 2014-2019 2. Based on actual land area for paddy cultivation. Planted area is higher than actual land area due to certain areas possessing more than 1 crop cycle 3. SSL = Self Sufficiency Level of local production relative to local consumption factoring in target food security levels outlined in the National Agrofood Policy 2.0 4. Based on MPIC announcement 5. Prior to considering idle agriculture land 5. Existing agriculture or ex-mining land which is un-utilised
Source: National Agrofood Policy 2.0 Draft, Ministry of Primary Industry, MARDI, Industry Expert Interviews, Project Team Analysis

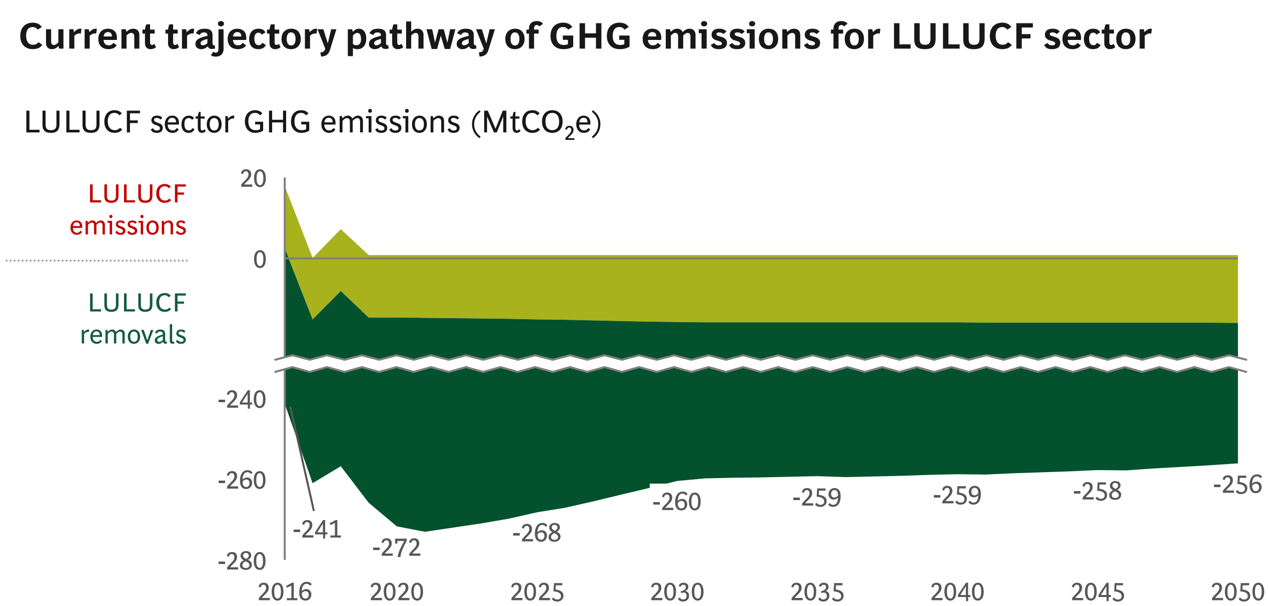
Figure 21: Summary impact of various drivers on carbon stock and emissions



1. 2020–2050 values projected based on projected evolution of forest land, deforestation, and degraded land restoration 2. Loss of carbon stock projections for disturbances follow 2000-2013 average values; loss of carbon stock from drained organic soils follow 2016 values (latest recorded) representing 3% of forest

Source: Project Team Analysis

Figure 22: Time series breakdown of GHG emissions in LULUCF sector in current trajectory

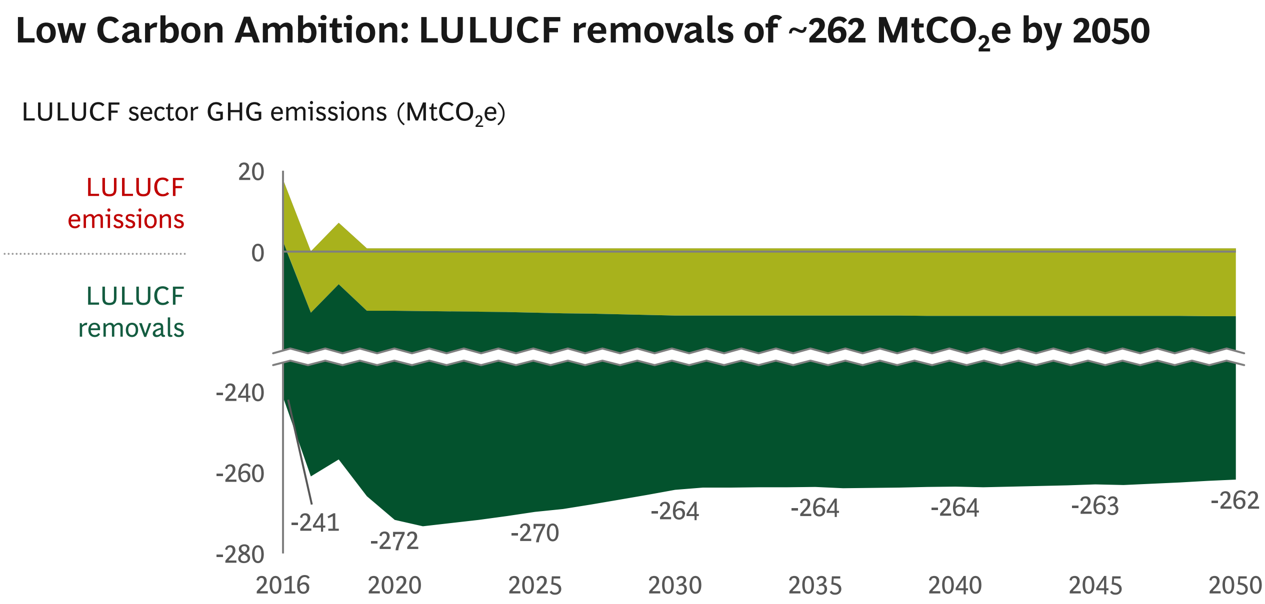


Source: Project Team Analysis

Collective impact of levers on GHG emissions pathway

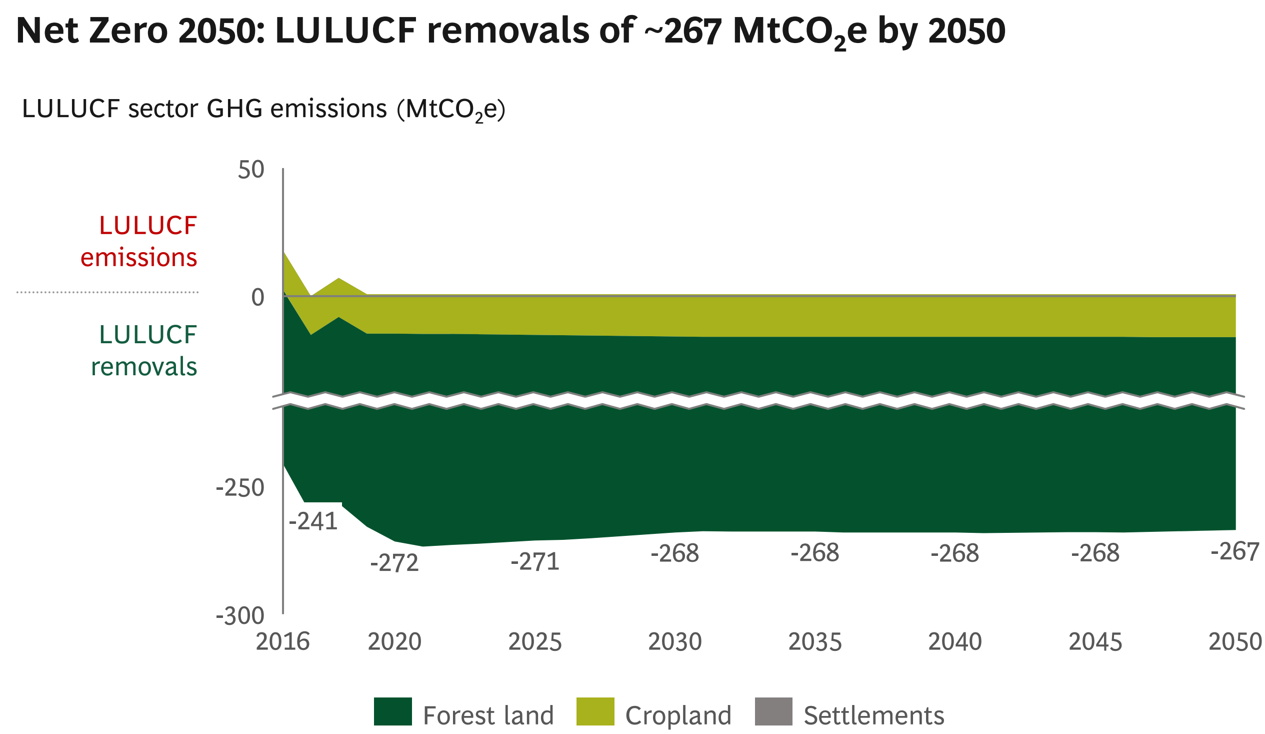
Based on the LULUCF abatement levers explored, approximately 6 $MtCO_2e$ of emissions can be reduced by 2050 in the *Low Carbon Pathway* from the *Current Trajectory Pathway*. In the *Net Zero 2050* pathway, emissions are reduced by approximately 11 $MtCO_2e$ compared to the *Current Trajectory Pathway*, equating to a 4% increase in GHG emissions removed from LULUCF. The contribution of various abatement levers to both these pathways are outlined overleaf.

Figure 23: Overall profile of GHG emissions for LULUCF sector in Low Carbon scenario



Source: Project Team Analysis

Figure 24: Overall profile of GHG emissions for LULUCF sector in Net Zero scenario



Source: Project Team Analysis

Overview of potential abatement levers

A range of abatement levers were considered for the LULUCF sector in order to shift the current trajectory pathway. These levers can be broadly grouped into four categories:

- Increasing GHG removals from forest lands
- Increasing GHG removals from cropland
- Reducing deforestation from forest land use change to cropland or settlement land
- Enhancing supporting enablers and safeguards to protect natural assets

Increasing GHG removals from forest lands

Various abatement levers to enhance carbon stock from biomass growth, optimise wood removals, and reduce drained organic soils emissions were considered to increase net GHG removals:

- **Identification and restoration of degraded forest areas**

  Degraded land areas are where forest carbon stock has been reduced due to human-caused processes, resulting in a decline of forest productivity in providing forest ecosystem services, such as carbon removals. Restoration of degraded forest areas, as a result of sub-optimal restoration following commercial wood removal or disturbances. Several regional studies have been conducted to sample the size of degraded forest areas in Sabah and Sarawak.

  For example, it is estimated that in Sabah close to 1 million hectares of total forest land has some degree of degradation, which is mostly very low degradation (20%), low degradation (3%), and moderate to extreme degradation (2%). Efforts to restore degraded areas, prioritising from the most degraded areas, can enhance GHG removals from forest and restore ecosystem service value of forests. Beyond restoring identified degraded efforts, enhancing mapping of degraded forest and preventive practices to avoid forest degradation will be key such as effective replanting and reforestation following commercial logging activities.

- **Enhanced carbon improvement practices in post-felling reforestation**

  Based on expert interviews, it is estimated that 1% of post-felling natural forest area can benefit from enhanced carbon improvement practices based on the area in the selective Forest Management Units (FMUs) with low carbon stock thresholds.

  The management of harvesting and reforestation of productive forests can be enhanced with carbon improvement practices such as silviculture or enrichment planting. This measures will increase overall biomass stock and long-term GHG removal capacity of reforested areas and enhance future commercial wood harvests[65].

  Carbon improvement practices during harvesting have lasting effects on forest structure, composition, and functioning. For example, harvesting with good technical control which minimises harvesting costs and reduces environmental effect such as on residual forests. Reduced-impact logging procedures and techniques are a series of pre- and post-logging practices designed to protect seedling and saplings, minimise soil damage, prevent damage to non-target species important for wildlife and non-wood forest products.

  This is complemented by post-logging silviculture practices which aims to enhance the regeneration of desirable tree species and to control competing vegetation. This will ensure sufficient potential crop trees with appropriate level of density and distribution over the entire area to facilitate healthy regeneration. The specific carbon improvement measures applied will be dependence on the unique requirements of specific forest land.

65. Krisnawati, H., and Wahjono, D. (2010) Effect of Post-Logging Silvicultural Treatment On Growth Rates of Residual Stand In A Tropical Forest, Journal of Forestry Research 7 (2): 112-124..

- **Eradication of illegal logging with technology adoption**

  Whilst Malaysia has significantly reduced instances of illegal logging over time with enhanced detection and enforcement, illegal logging has not been fully eradicated. For example, close to 30 cases of illegal logging were identified in Kelantan alone, with encroachment in 16 of the state's 37 permanent reserves in 2020[66]. Moreover, illegal logging measures are also typically reactive, after the damage of illegal logging has already occurred. Whilst exact estimations of illegal logging are not disclosed, inputs provided by subject matter experts indicate that illegal logging contributes to less than 0.1 million tonnes of CO_2e of emissions in the country.

  Scaling-up technologies which prevent and rapidly detect illegal logging instances can support the move towards the full eradication of illegal logging in Malaysia. For example, in Indonesia, algorithms have been leveraged to enhance the prediction of illegal logging hotspots, to better inform cost effective and preventive illegal logging actions in the country.

- **Enhanced restoration and management of drained organic soils**

  Organic soils are characterised by high levels of organic matter, which accumulate in the presence of water, and are found in abundance in tropical peatlands. Peatlands or peat swamps hold approximately 10 times the carbon stock of tropical forests on mineral soil per hectare[67]. When drained, deforested, or degraded peatlands release carbon faster than the rate of sequestration, turning these forest lands into net GHG emitters. Currently, it is estimated that around 143,000 ha of peatland is subject to drained organic soil[68].

  Restoration of drained or degraded organic soils is a key priority to reduce LULUCF emissions. This involves preventing further drainage or organic soils by halting intensification of artificial drainage, enhancing monitoring and mitigation schemes to restrain uncontrolled fires and soil erosion, and halting expansion of agricultural practices that require drainage or involve uncontrolled logging. After further damage is prevented, restoration will need to be a key priority where rewetting and reforesting and subsequent conservation will enable the restoration of peatlands to reduce emissions and improve water regulation.

Increasing productivity and GHG removals from cropland

- **Agroforestry to enhance soil carbon sequestration**

  Agroforestry represents the intentional integration of trees and shrubs in cropland, interspersed with agricultural crops, to create environmental, economic, and social benefits. This integration or intercropping increases the capacity of the soil for above-ground and below-ground carbon sequestration. Several key benefits from agroforestry include the increase in soil organic matter and biological activity which enhances soil fertility, enhanced soil erosion and runoff control which enhances retention of water, soil material, organic material, as well as increasing the carbon stock of a given area.

  Several studies on tropical agroforestry has been conducted, including in Malaysia. In a study done in Sabah[69], a combination of oil palm and agarwood was able to realise a significantly higher total ecosystem carbon stock[70] of 85.4 tonnes of carbon per hectare compared monoculture oil palm plantations of about 60.3 tonnes of carbon, enhancing the carbon sequestration capabilities of cropland.

  Whilst agroforestry holds significant potential to contribute towards enhanced carbon sequestration of cropland, there are limitations in data in determining the split of current cropland between monoculture plantations and agroforestry systems. Based on this constraint, the GHG abatement potential of this lever is not quantified for this study, but may provide additional upside to enhance GHG removals of cropland.

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66. Malay Mail (2020). Illegal logging detected in 16 Kelantan forest reserves
67. Harenda, K., Samson, M., Lamentowicz, M., Chojnicki, B. (2018) The Role of Peatlands and Their Carbon Storage Function in the Context of Climate Change, GeoPlanet: Earth and Planetary Sciences.
68. Malaysia's 3rd National Communication and 2nd Biennial Update Report (2018) UN Framework Convention on Climate Change.
69. Besar, N., Suardi, H., Phua, M., James, D., Mokthar, M., Ahmed, M. (2020) Carbon Stock and Sequestration Potential of an Agroforestry System in Sabah, University Malaysia Sabah.
70. Total ecosystem carbon stock represents the sum of above-ground (e.g., trees, shrubs) and below-ground carbon stocks (e.g., soil)

Case Study 2 | The Living Landscape approach

The Living Landscape Approach provides a framework to achieve and maintain a delicate balance between economic development and to protect natural ecosystems and its inhabitants. This conservation approach protects forests, wildlife and freshwater ecosystems, supports a movement towards the sustainable production of palm oil through credible certification, and restoration of forests. The three areas of work are called the three pillars of Protect, Produce and Restore.

This initiative is in support of national government policies to maintain 50% of Malaysia under forest cover and a mandatory MSPO certification of all oil palm plantations by 2019. This includes the Malaysian state of Sabah's forestry policy to keep 30% of Sabah's land mass under full protection, and the adoption of a Jurisdictional Approach to oil palm production that requires 100% RSPO certification by 2025.

In Sabah, WWF-Malaysia is implementing a 5-year programme in three priority landscapes to showcase the living landscape approach, namely at the Lower Sugut, Tabin, and Tawau Landscapes. They will also be working with government agencies, private companies and local communities to protect forests and wildlife, produce RSPO certified palm oil and restore degraded forests and wildlife corridors.

The living landscape approach is also being carried out by WWF-Malaysia on several important ecological corridors, as outlined by the Central Forest Masterplan in Peninsular Malaysia. The overall plan is to ensure connectivity between the large forest complexes of Belum-Temenggur in the North to Taman Negara in the Central Eastern side of Peninsular Malaysia, while ensuring sustainable oil palm production in the landscapes between and around the corridors. It is also currently being conceptualised for the state of Johor.

The Living Landscape approach with the three pillars of Protect, Produce and Restore can be a landscape model for Malaysia in supporting the journey towards Net Zero emissions.

Photo credit: Tan Hao Jin / WWF-Malaysia

Case Study 3 | Sustainable biofuel production through reforestation

The global community, through the Bonn Challenge, seeks to restore 350 million hectares of degraded and deforested landscape by 2030. This is a monumental challenge as restoration is costly and requires long gestation. For Malaysia alone, it is estimated that 1.8 million hectares of forest require some form of restoration. Assuming the need to restore 1 million hectares with the cost ranging from RM6,600 ha to RM8,300 ha per year, the total amount needed would range from RM6 billion to RM8 billion annually.

The goal of this project is to defray the high cost of restoration by producing biofuel in reforestation. The following R&D strategies will be undertaken:

- Develop the conditions required for planting tapioca and starch crops in forest restoration through agroforestry.
- Process the starch into bioethanol for further refinement into biofuel that fulfils the technical requirement of the transportation and energy sectors.
- Develop a supply chain protocol to provide safeguards to rural communities and Indigenous Peoples as well as prevent deforestation.

The project's outcome is to combat climate change through the restoration of our carbon sink. In turn, this restored forest will serve as a natural habitat to prevent biodiversity loss. By generating multiple benefits and impacts, this project will attract multilateral collaboration support. This includes the European Union's Long-Term Budget and Next Generation EU (amounting to 400 billion Euro from natural resources and environment and 110 billion Euro for the Neighbourhood and the World). A grant from the Government of Malaysia serves as a seed fund to initiate this project. Based on 1 person undertaking 10 hectare of forest restoration, a 1-million ha forest restoration project can potentially create long term jobs for 100,000 people in the rural areas.

Photo credit: Mazidi Abd Ghani / WWF-Malaysia

Reducing deforestation from forest land use change to cropland or settlements

Based on the current trajectory pathway, 0.62 million hectares of deforestation is expected from 2021-2040 for conversion into cropland. The conversion of forest land to cropland is the main driver in the reduction of forest cover from 55% to 53% of land mass. Several levers to reduce forest land conversion are considered below:

- **Market-based mechanisms to price-in positive externalities of forest land**

  In the absence of any regulatory barriers preventing land use change (e.g., reserve forests), the return generating ability of different land use options is a key factor in influencing a landowner's decision on land use change. Profit-oriented landowners are financially incentivised to convert forest land to cropland if the net present value of agriculture land exceeds the net present value of forest land, after accounting for land use conversion costs.

  A key challenge today is that the full economic value of forest land does not translate into equivalent financial return for the landowner, as positive externalities from forest land such as the environmental contribution of carbon sequestration, biodiversity, water and soil systems, and the social contribution towards forest peoples are not fully compensated by the market. The disparity between true economic value and financial returns results in the undervaluation of forest land relative to other land use options.

  Domestic carbon offset markets represent a first key step in narrowing the gap between true economic value and financial returns, by factoring in the externality of carbon emissions and removals. Where domestic carbon offset markets have been established, landowners have higher incentives to convert cropland into forest land or to retain current forest land due to financial return obtained based on the amount of carbon sequestered.

  To assess the impact on carbon offset markets which enable the monetisation of the positive externalities of carbon sequestration, net present value (NPV) analyses were run to compare forest land use and commodity crop land use, under various carbon price scenarios. Commodity crops were chosen for comparison as these crops are not constrained by food security targets of the nation and can be optimised based on net economic value contribution.

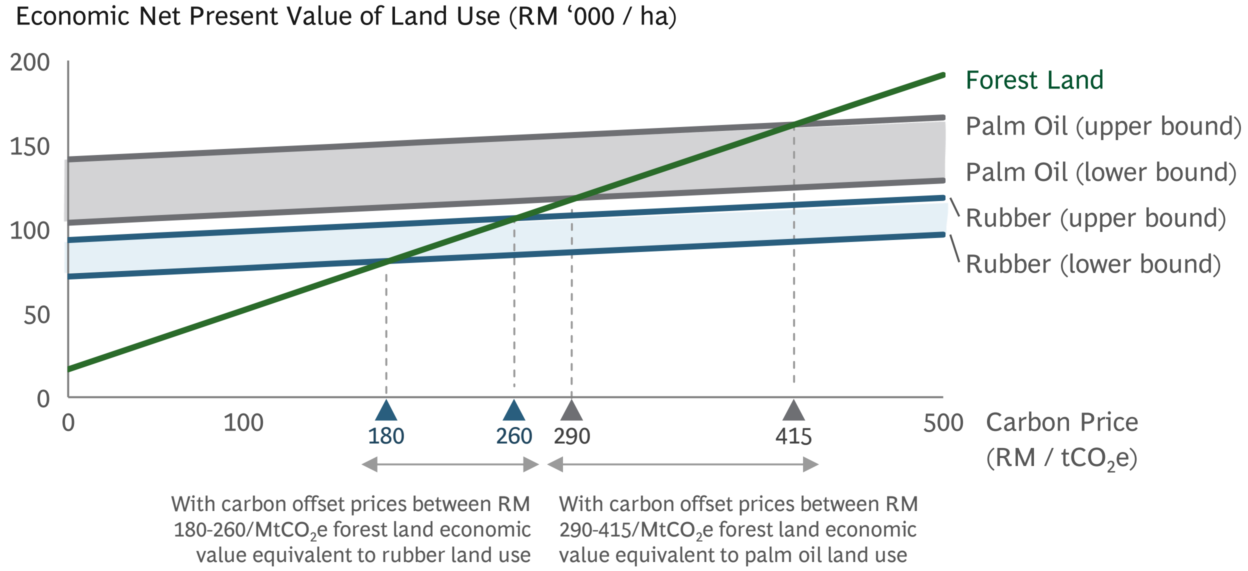
  Without a carbon price, the net present economic value of forest land use consists of commercial, social, and other environmental value. Commercial value comprises of income from wood products, non-wood products and fibre. Social value comprises of forest people subsistence use and recreational benefits. Environmental value excluding carbon sequestration includes disturbance regulation, watershed services, and air purification.

  Holistic factoring commercial, social, and other environmental dimensions, the economic value of forest is estimated at approximately RM 16,500 per hectare. This is significantly lower compared to the net present economic value of palm oil land even after accounting for land use conversion costs which amount to approximately RM 103,700 – RM 141,200 per hectare. For rubber plantations, the net present economic value amounted to approximately RM 71,700 – RM 93,500 per hectare.

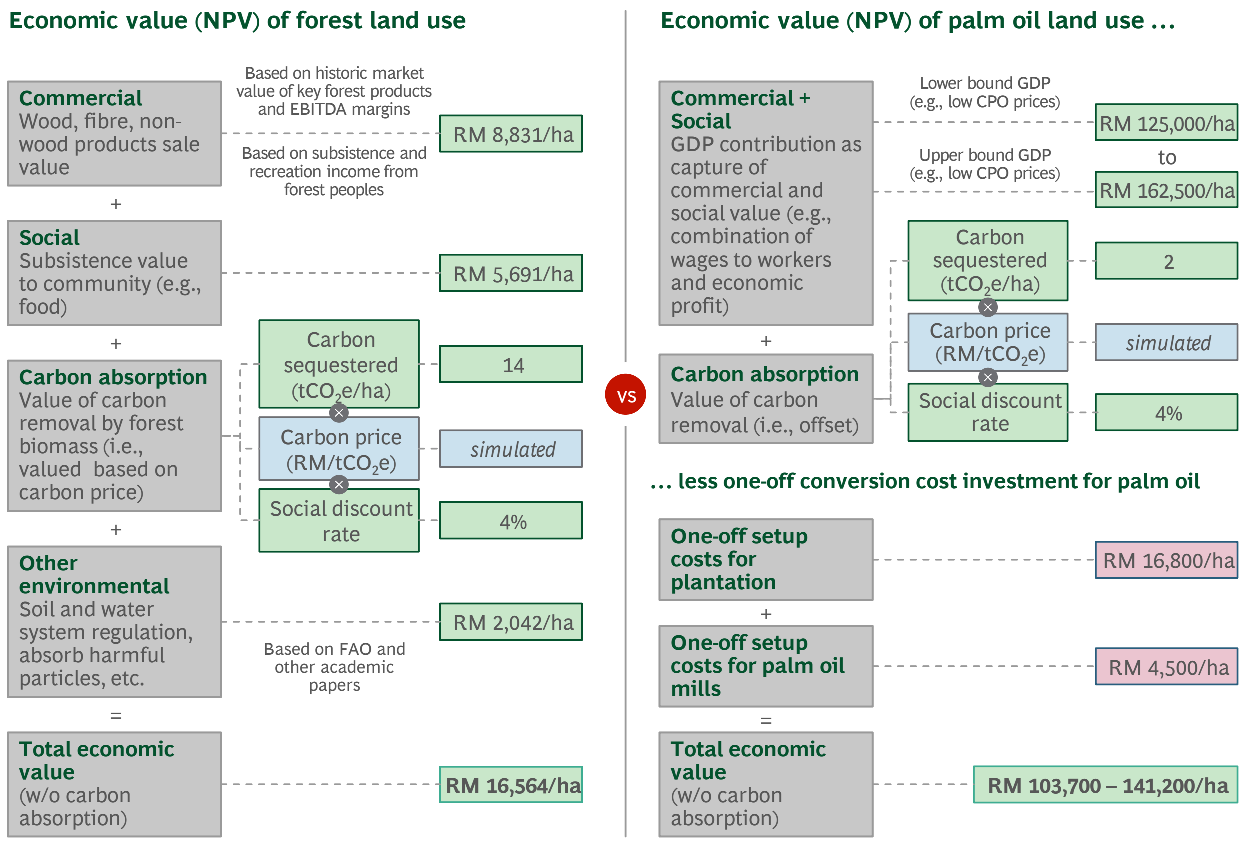
  As the level of carbon price increases, the economic value of forests increases, first exceeding the economic value of rubber plantations and subsequently palm oil plantations. At a carbon price of RM 180 – RM 260 / MtCO_2e the economic value of forests converges to the economic value of rubber plantations, which may incentivise landowners to afforest agriculture land to capture value from carbon offset markets. Out of the total of 1.13 million hectares of rubber plantation, afforestation of 50% of existing rubber plantation land area will reduce deforestation for cropland conversion by approximately 90% from current forward-looking projections. If the carbon price offered on carbon offset markets increases to the RM 290 – RM 415 / MtCO_2e range, the economic value of forests converges with the economic value of palm oil plantations.

Figure 25: Comparison of economic net present value of forest land vs. agriculture land

Accounting for positive externalities of forests, such as through carbon prices, can financially incentivise reforestation of cropland



1. Annual average GDP for palm oil at RM 5000-6500/ha and for rubber at RM 2500-3250/ha (DOSM) which drives difference between upper and lower bound values, value of environmental disturbance regulation valued at RM 77.25/ha based on De Groot et. al. and applicable to 0.04% share of area protected for erosion, particle purification value from Bottalico et. al. and Nowak et. al. and Ven Essen EEA studies, watershed services from FAO and Ernst et. al. 3. Current EU ETS prices taken as EUR 50/tonne based on May 2021 values; with EUR: MYR exchange rate of 4.5:1
4. Due to highly extensive list of sources and data inputs used, calculation available on request from project team
Source: FAO, DOSM, academic journals, expert interviews, Project Team Analysis



1. Does not price in value of biodiversity, temperature regulation, and precipitation regulation in forests due to challenge of isolating effects
Source: Neale, D. et. Al. (2016) *Global Forest, Paper & Packaging Industry Survey;* Chao, S. (2012) *Forest Peoples: Numbers Across The World;* Chiabai, A. et. al. (2009) *Economic Valuation of Forest Ecosystem Services;* de Groot, et. al. (2012) *Global Estimates of the Value of Ecosystems and Their Services*. Ernst, C., et. al. (2004) *Protecting the Source: Conserving Forests To Protect Water;* Aquastat Water Withdrawal By Source 1990-2017 (2018) UN FAO; Nowak, D. et. al. (2018) *Air pollution removal by urban forests in Canada and its effect on air quality and human health;* Global Forest Resources Assessment (2010) UN FAO; Derived from average palm oil and rubber GDP over 2016-2019 period, *Buku Tahunan Perangkaan Malaysia 2019* (2019) DOSM

Moreover, carbon removal is only one form of positive externality of forest lands. There are further positive environmental externalities of forests such as biodiversity support, lowering temperatures, and precipitation regulation. As these externalities are holistically factored in, such as through biodiversity offsets[71], landowners will be increasingly incentivised by market-based mechanisms to reduce deforestation and increase afforestation, beginning with the conversion of lowest commercially yielding croplands.

- **Reduce cropland demand with demand-side management with behavioural change**

  With increasing population size and food security needs, demand for agricultural produce is expected to increase in the baseline, resulting in a knock-on effect on cropland demand. Behavioural driven demand-side measures such as switching towards healthier diets and away from the most carbon-intensive foods as well as reducing food waste will have a large impact on overall crop land demand. Changes in demand for agricultural or livestock produce due to change in behaviour have a material impact on land use demand, as both the total quantity of food product and the type of food product (e.g., type of meat) demanded shifts. Various types of agriculture or livestock produce have various land use intensities or requirements per unit of food output and switching to enhanced plant-based alternatives and by moving away from the most carbon intensive food sources.

- **Enhance yields of cropland to meet food security needs with lower land area**

  Enhancing the productive yield of agriculture land will enable the country to achieve target self-sufficiency levels for key food crops, with reduced land area. For example, large yield gaps have been highlighted for paddy where current yields of 3.5 tonnes per hectare is significantly below targets yields of 5.3 tonnes per hectare by 2030. If the full potential of yield improvements are realised, not only will paddy land expansion be unnecessary, but a lower amount of land would be required to achieve the country's 80% SSL target.

  Unlocking benefits from economies of scale and enhancing the capacity, know-how, and technology access will be critical to increase productivity of the large number of agriculture smallholders in Malaysia. In Malaysia, about 80% of vegetable farms are less than two hectares, two-thirds of paddy farmers have plot sizes of less than one hectare, and only one-third of fruit farms can be considered commercial farms, as a majority of farms are less than a hectare[72]. Given low production volumes, smallholders may face challenges in justifying fixed costs of acquiring yield-improving technologies, adopting advanced yield-improving farming techniques, or training of workers at-scale to uplift knowledge of agriculture best practices. Orchestrated collaboration across smallholders to support overcoming some of these barriers will be critical to achieve better economies of scale and yield productivity.

- **Unlock alternative sources of cropland with reduced land use requirements**

  In addition to directly enhancing the yield of agriculture land, alternative supply sources such as urban farming and vertical faming can reduce the need for cropland expansions. Illustrative of the potential food production capacity of urban farming, it is estimated that 15% of the overall population's fruit and vegetable needs in the United Kingdom[73] can be met by leveraging 10% or current urban green spaces.

  Besides food crops, alternate supply sources with reduced land use requirements can be used to substitute agriculture grown for biofuel production. Alternate supply sources of biofuels such as algae have significantly higher yields per area and can be grown in non-arable land reducing cropland demand. The commercial viability of these solutions are explored further in the energy sector, recognising the potential positive impact on land use requirements.

71. Harnessing Markets for Biodiversity: Towards Conservation and Sustainable Use (2003) Organisation for Economic Cooperation and Development (OECD).
72. The Edge Markets (2020). Special Report: The State of the Nation: Bridging the gap between agriculture and food security
73. Urban land could grow fruit and vegetables for 15 percent of the population, Institute for Sustainable Food, University of Sheffield, 2020.

Enhancing supporting enabler and safeguards to protect natural assets

- **Scale-up adoption of agroecology practices across the country**

  Agroecology or regenerative agriculture, is a holistic and integrated approach that applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems[74]. Agroecology is not merely a set of agricultural practices; it focuses on optimising social relations, empowering farmers, and enhancing value capture to bring various socio-environmental benefits such as strengthened adaptation and resilience to climate change, conservation of natural resources, and protection of biodiversity.

  Scaling up the adoption of agroecology in Malaysia will require supportive policies, education and awareness building, as well as funding and financing support to enable farmers to mainstream agroecology into their everyday agriculture operations and practices. Leveraging on global efforts such as the Food and Agriculture Organisation's (FAO) Scaling-Up Agroecology Initiative, which aims to support local and national efforts to deliver context-specific solutions by co-creating knowledge and conducting capacity building and training will also be critical to accelerate the take-up of agroecology in the country.

- **Anchor climate and nature-based solutions on rights-based approach**

  Nature-based solutions efforts and actions often coincide with areas where the lowest income and most vulnerable people groups live, with potential unintended adverse consequences. This include the infringement on the rights of vulnerable groups to forest resources, implementing solutions without prior and informed consent of these groups, and criminalising everyday subsistence activities of forest communities. Increased awareness of right-based solutions and anchoring climate solutions on these principles will be critical, with safeguards set in place to prevent these adverse impacts.

  This is especially pertinent in the design of carbon or nature-based solution markets. For example, key safeguards are needed to avoid low quality carbon credits which do not promote additionality and do more harm than good with the social impact of forest communities. Similar screening will be required for international carbon or nature-based solution arrangements, ensuring safeguards to protect rights of developing countries and specific vulnerable groups within them to ensure climate justice and equitable climate transitions.

- **Strengthening data foundations for better natural asset data, including for blue carbon**

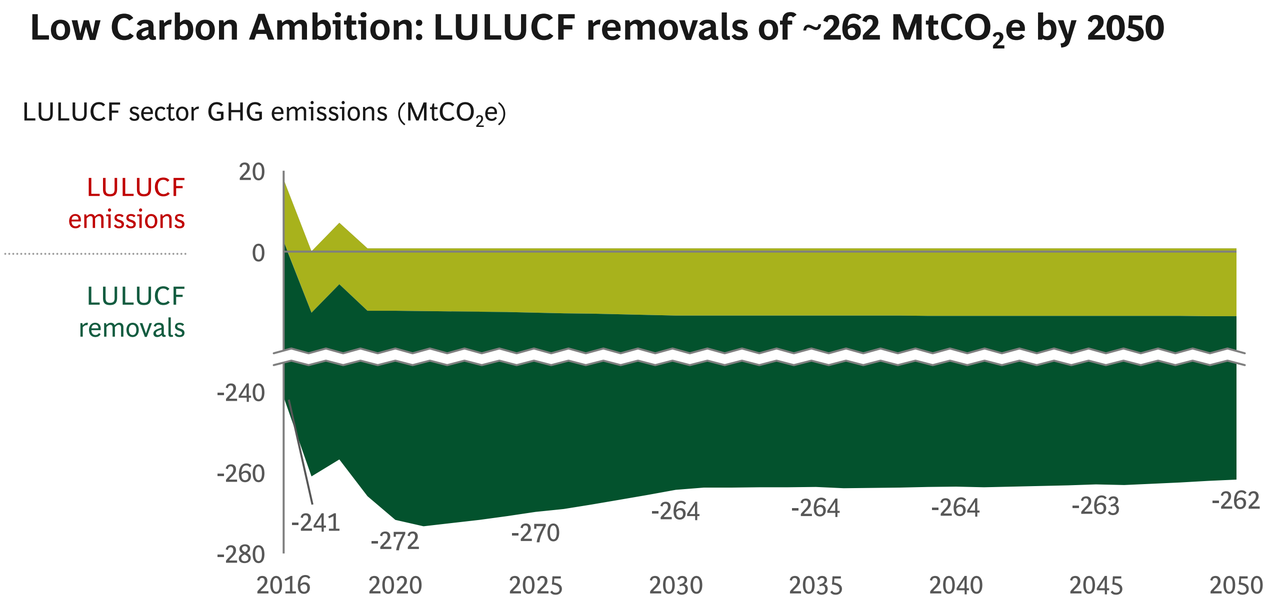
  Building on strong progress already being made, strengthening foundations to enhance optimal data-driven decision making for the protection and conservation of natural assets will be key. Besides deepening our understanding of the forest landscapes, deepening the understanding of blue carbon, and the potential of Malaysia's coastlines and oceans in climate mitigation, adaptation, and resilience are key. Enhanced data will enable more targeted high impact solutions, such as full clarity on degraded forests areas in Malaysia. Furthermore, enhancing data transparency and open access will be critical in democratising solutioning for climate mitigation, adaptation, and resilience which will accelerate climate innovation and awareness across the country.

74. Food systems (FS) encompass the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products that originate from agriculture, forestry or fisheries, and parts of the broader economic, societal and natural environments in which they are embedded. (FAO)

Collective impact of levers on GHG emissions pathway

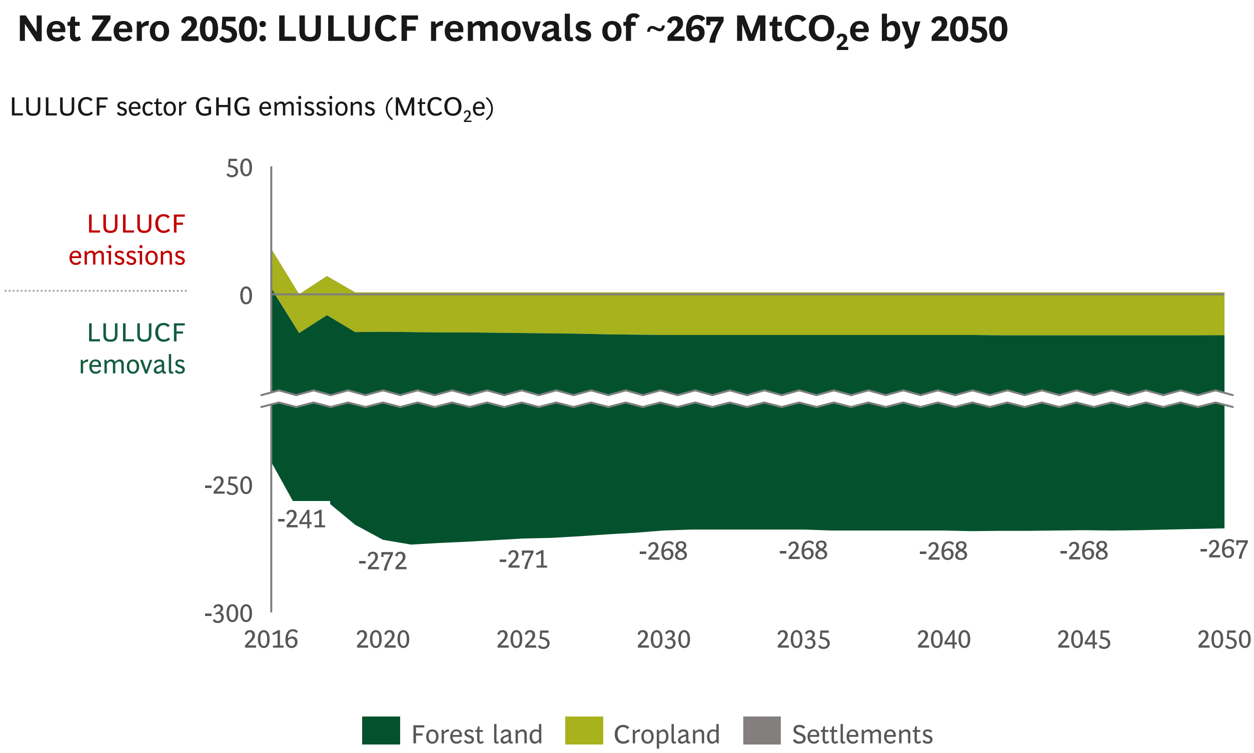
Based on the LULUCF abatement levers explored, approximately 6 $MtCO_2e$ of emissions can be reduced by 2050 in the *Low Carbon Pathway* from the *Current Trajectory Pathway*. In the *Net Zero 2050* pathway, emissions are reduced by approximately 11 $MtCO_2e$ compared to the *Current Trajectory Pathway*, equating to a 4% increase in GHG emissions removed from LULUCF. The contribution of various abatement levers to both these pathways are outlined overleaf.

Figure 26: Overall profile of GHG emissions for LULUCF sector in Low Carbon scenario



Source: Project Team Analysis

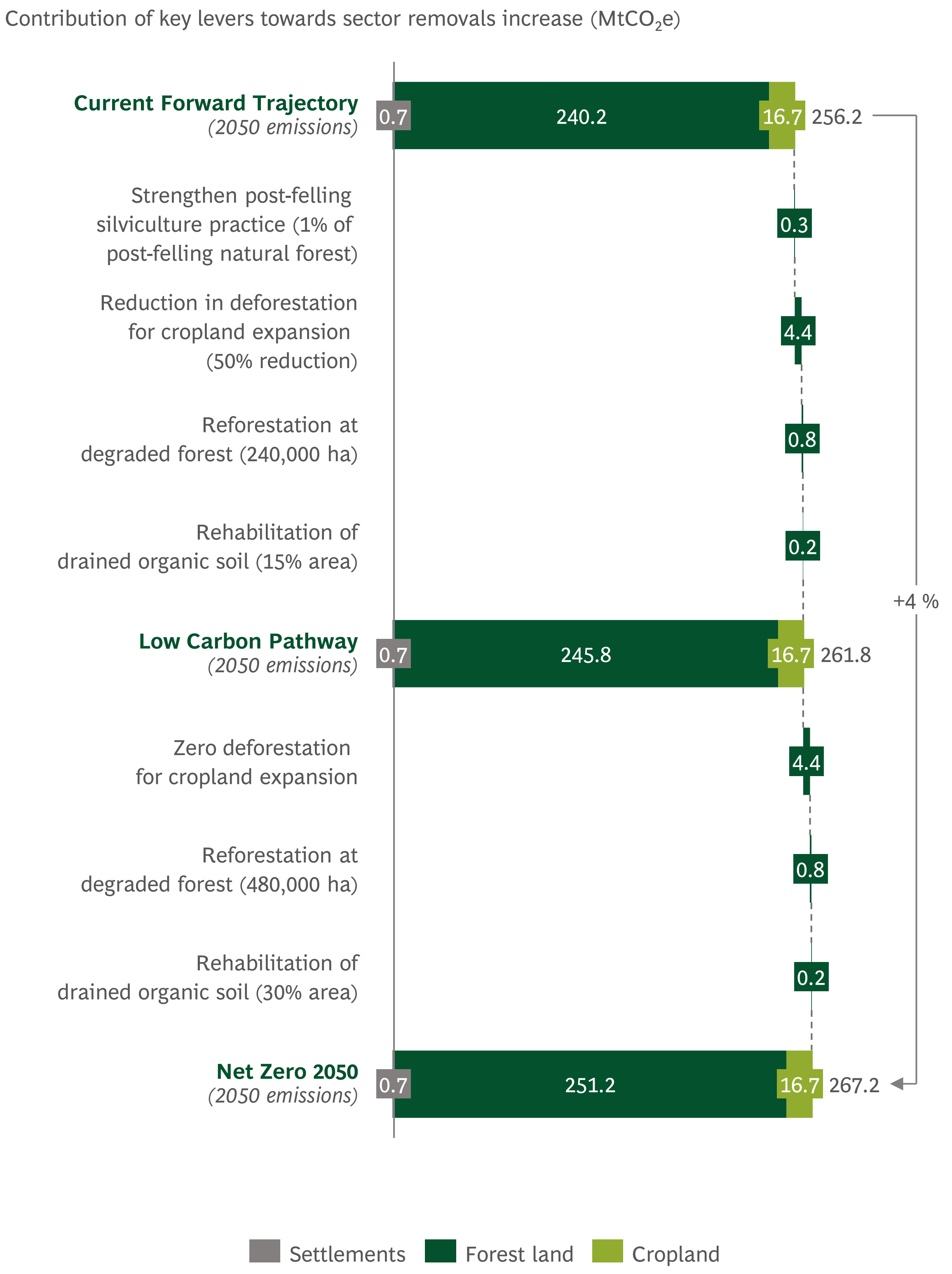
Figure 27: Overall profile of GHG emissions for LULUCF sector in Net Zero scenario



Source: Project Team Analysis

Figure 28: Breakdown of lever contribution towards sectoral decarbonisation in LULUCF sector

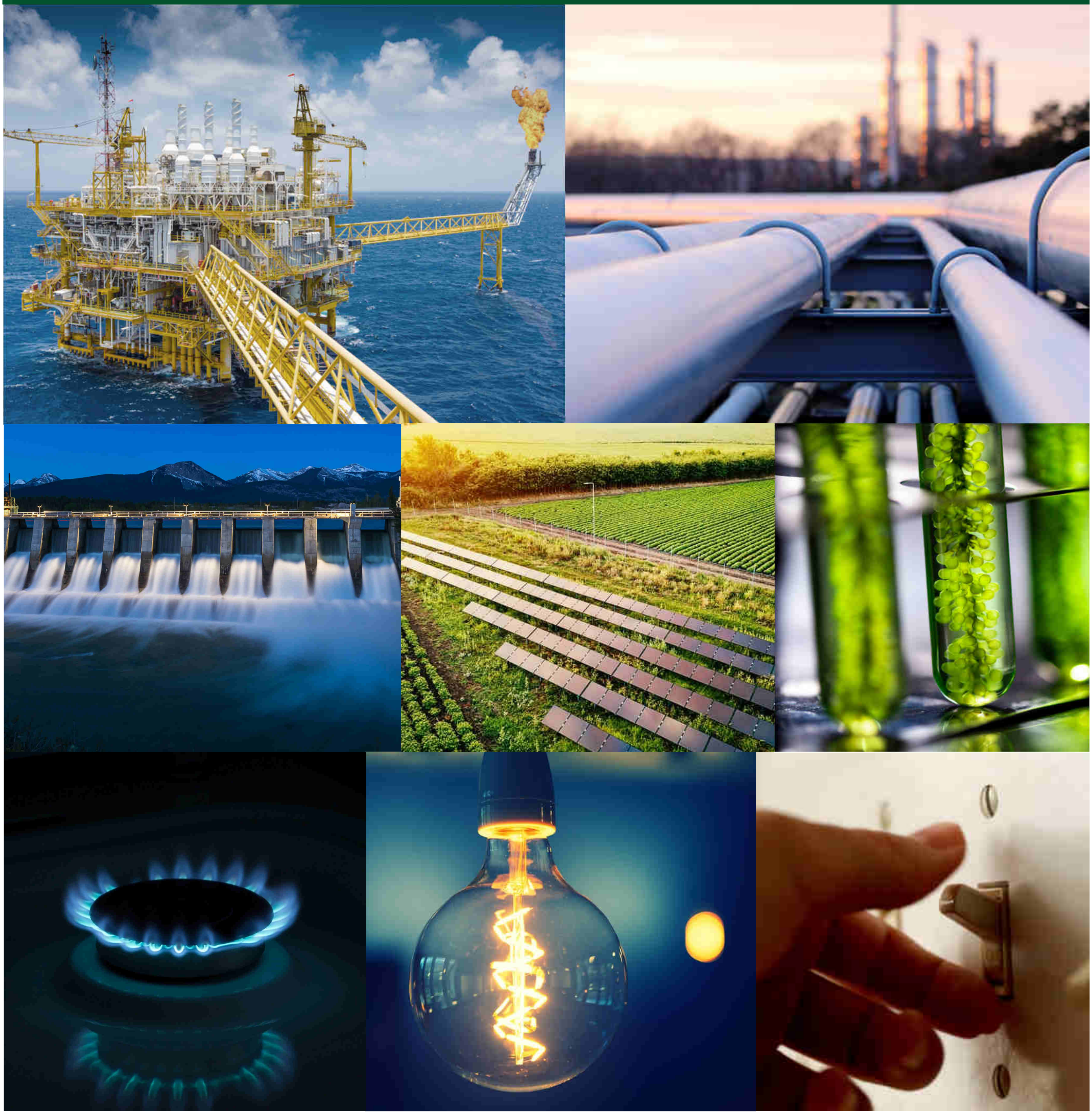
~4% increased reduction in GHG emissions from current forward trajectory in Net Zero by 2050 scenario for LULUCF sector



Source: Project Team Analysis

Priority #2:

Decarbonise the energy sector



Overview

The energy sector has been a key in supporting the lives and livelihoods of Malaysians for decades, providing electricity for our homes, key factors of production for our industries, fuel to enable our mobility, key sources of job creation and household incomes, and many others. The energy sector will continue to be critical in the country's socioeconomic development going forward with the access to affordable, reliable, and sustainable energy as a key sustainable development goal.

The need to enhance the environmental sustainability of the country's energy sector is critical, whilst balancing against other dimensions of the energy trilemma including energy equity and energy security. The energy sector is the largest source of emissions, contributing around 75% of total emissions. These emissions derive from a few key sub-sectors including:

- **Fuel combustion in energy industries** (e.g., emissions from energy transformation process in power generation, petroleum refining, gas transformation, and other solid fuels)

- **Fuel combustion in manufacturing industries and construction** (e.g., direct emission at the point of fuel consumption by industry sector)

- **Fuel combustion in transport** (e.g., direct emission at the point of fuel consumption in the transport sector, consisting of land transport, and domestic marine and aviation transport)

- **Fuel combustion in other sectors** (e.g., direct emissions at the point of fuel consumption by commercial, residential, agriculture, and other sectors)

- **Fugitive emissions from fuels** (e.g., intentional or unintentional release of GHG during the extracting, processing, and delivery of fossil fuels to the point of end use)

Emissions from fuel combustion in the transport sector, representing 21% of total national GHG emissions, has been carved-out in a separate chapter. Despite the carve out of chapters for better focus, energy use in the transport sector and all other demand sectors were evaluated in a holistic manner, factoring in the interdependencies across the country's energy demand-supply balances.

Historic trajectory

Emissions from the energy sector has been growing at a steady pace of 5% per annum since 1990. The main driver of overall energy emissions is fuel combustion in energy industries which has been growing at 6% per annum and represents the largest emission sub-sector comprising 70% of ex-transport energy emissions. Over 75% of energy industries emissions derive from fuel combustion in electricity generation, with the remaining 25% of energy industries emissions deriving from petroleum refining and other energy transformation activities, such as natural gas transformation.

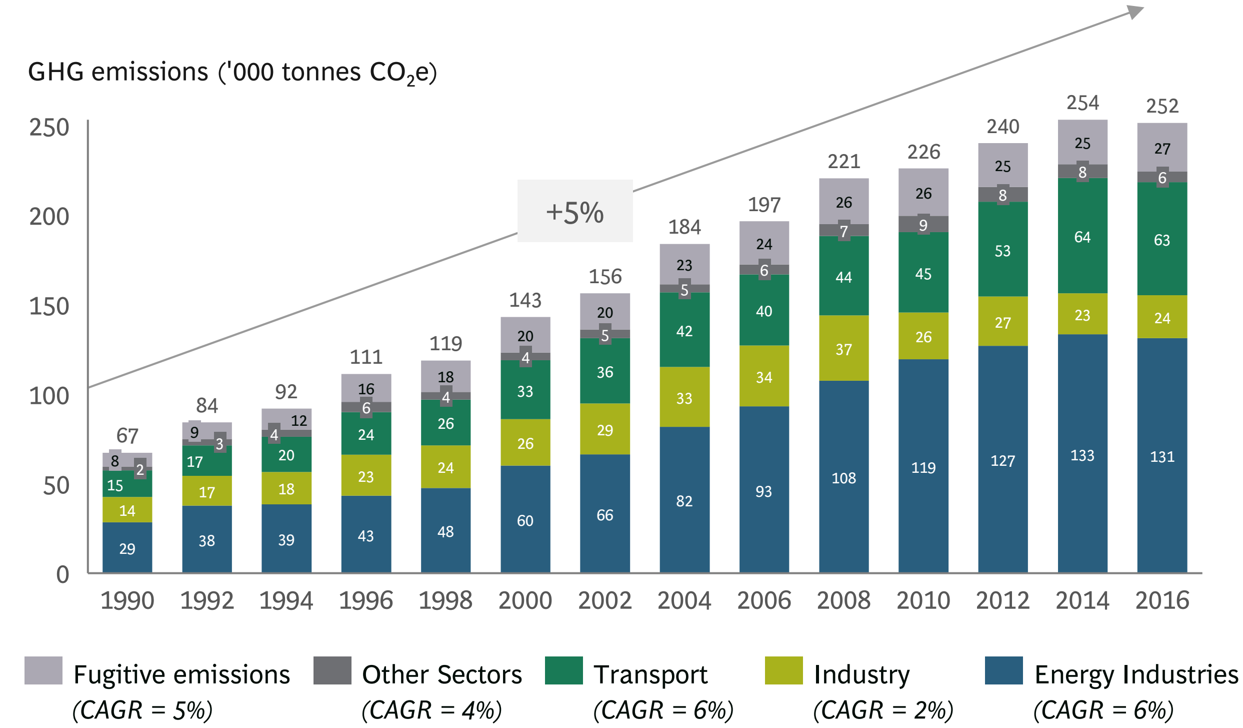
A key factor behind the growth in energy industry emissions is the steady increase in final energy demand associated with population growth and economic development. This has contributed to energy demand increase in the power sector as well as the non-power sector. However, as countries develop and diversify economically towards the service sector, the growth of energy demand typically decouples from GDP growth. This has also been observed in Malaysia, where energy demand continues to grow in absolute terms, but at an increasingly lower rate than GDP growth.

A second key factor has been the evolution of the energy mix, and in particular the power mix. The increase in coal share of the power mix, driven by energy affordability and energy security reasons in the past, has tilted the power mix towards higher carbon emitting fuels. In the last 20 years, the share of coal fuel inputs into power stations has increased from less than 10% to over 50%.

Besides end use energy demand, fugitive emissions have also experienced strong growth, tripling in size between 1990 and 2016. Fugitive emissions are intentional or unintentional release of GHGs which occur during the upstream extraction, production, processing, storage, and delivery of fossil fuels to the point of final use. Notably, fugitive emissions from oil and gas industries is the largest contributor of the country's methane emissions, with a 44% share of total methane emissions, which have 25 times the global warming potential (GWP) impact of carbon dioxide.

Figure 29: Historic evolution of emissions from the energy sector (including transport for reference)

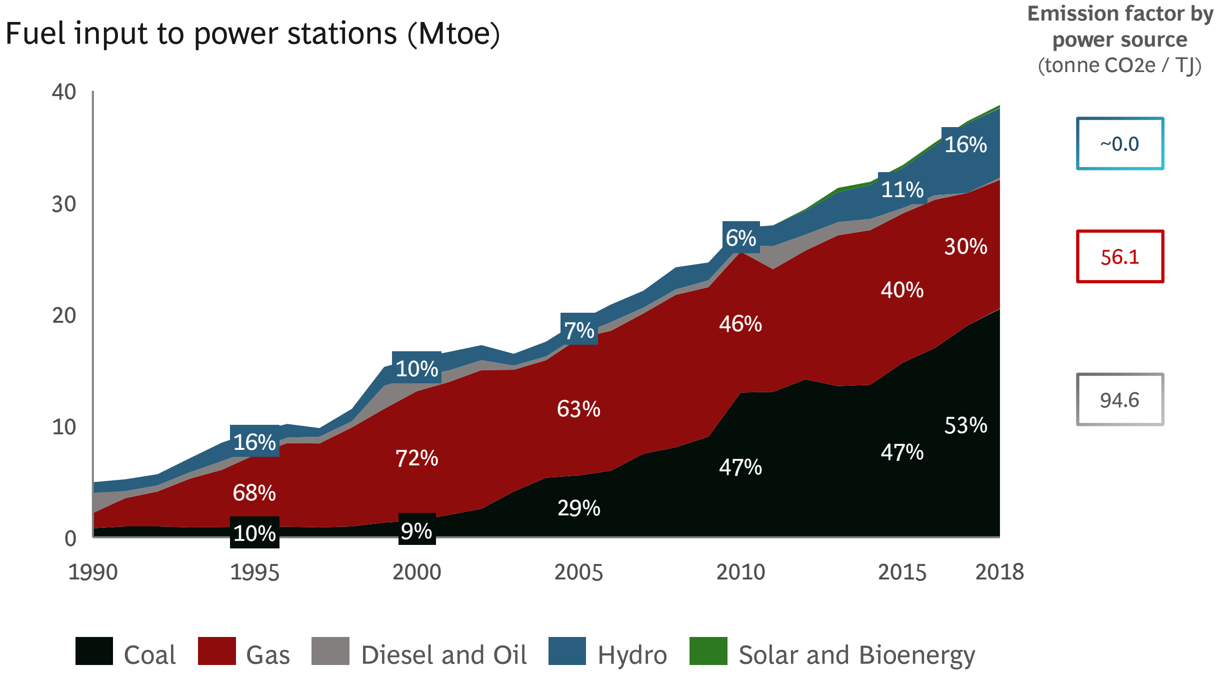
Energy-related emissions has been growing steadily over time



1. Energy industries consists of electricity and heat production, refining, and other energy industries 2. Transport consists of light vehicles, heavy vehicles, and domestic shipping and aviation 3. Industry consists of construction and manufacturing 4. Other sectors includes non-specified sectors 5. CAGR is from 1990-2016 6. Transport energy emissions for reference, detailed in next section 7. GHG included: CO2, CH4 and N02
Source: Malaysia's Third Biennial Update Report to the UNFCCC (2020)

Figure 30: Increasing emissions intensity of power generation with coal share increase

Coal share increase in the power mix driven by affordability, at the trade-off of GHG emissions



Source: Suruhanjaya Tenaga National Energy Balance 2018, IPCC emission factors

Forward trajectory

To estimate the forward trajectory of energy system emissions, energy system modelling was conducted using the TIMES (The Integrated MARKAL-EFOM system) model generator and PLEXOS which was used for granular power system modelling and simulations.

As inputs into the energy system models, key energy demand drivers were identified. This included population growth forecasts which have historically proven to be strongly correlated with residential and commercial energy demand. For industry energy sector, a sector-by-view was taken to account for forward-looking production and capacity outlook of each energy-intensive industry. Energy demand from various energy-intensive sectors are forecasted to have different growth trajectories, such as limited energy demand growth in overcapacity sectors such as in the cement industry as one example in the near term, in contrast to rapid growth in pulp and paper energy demand associated with the strong projected capacity additions driven by foreign direct investments.

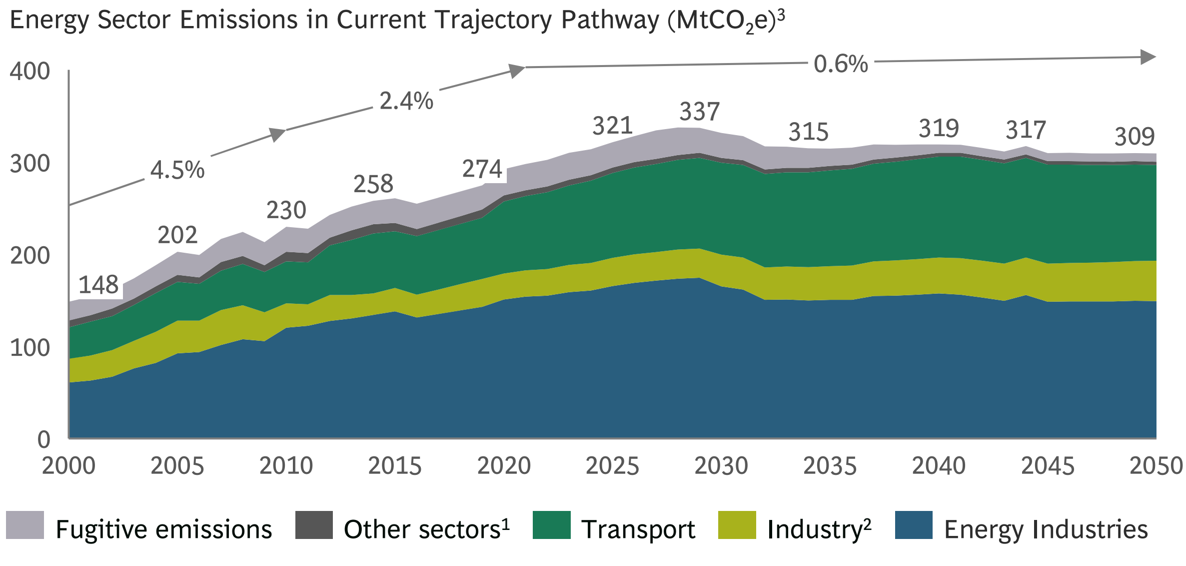
Current plans were also incorporated, such as power sector development plans outlined in the *Mesyuarat Jawatankuasa Perancangan dan Pelaksanaan Pembekalan Elektrik dan Tariff* (JPPPET 2020) or the Forum for Policy and Planning for Electricity Supply and Tariffs and other regional plans. Energy efficiency improvements outlined in the National Energy Efficiency Action Plan (NEEAP) were also incorporated. Where projection horizons exceed that of current plans, extrapolations were made, matching the level of ambition of existing plans.

Based on these projections, energy demand overall is expected to grow in absolute terms but with declining energy intensity driven in part by energy efficiency measures adopted. Emissions intensity is expected to decline, driven by current power development plans which outline the reduction in coal share and increase in renewable share of the power mix. For example, in Peninsular Malaysia, the latest power development plans include the reduction in coal share of the capacity mix from 37% to 22%, and the rise in renewables from 17% to 31% between 2021 and 2050. Whilst the stance on no new coal power plant has been made in recent announcements, the official power development plans have been taken as reference for the country's current trajectory pathway, which include several planned coal power plants builds in the 2030s.

Other emissions such as fugitive emissions are forecasted based on volumetrics incorporating the outlook of domestic oil and gas supply going forward, whilst emissions from energy industries such as refineries are made based on forward-looking capacity and fuel demand-supply balances.

Figure 31: Current trajectory pathway projections of energy emissions

Energy sector emissions growth expected to slow over time



1. Other sectors include Residential, Commercial, Agriculture 2. Includes Industry and Construction 3. Values from 2016 onwards are projected
Source: Malaysia's Third Biennial Update Report to the UNFCCC (2020), National Energy Balance 2018, JPPPET 2020, NEEAP, IPCC, Project Team Analysis

Box 2.1 | Overview on TIMES energy system modelling methodology

The Integrated MARKAL-EFOM System (TIMES) model generator was developed as part of the IEA-ETSAP (Energy Technology Systems Analysis Program) to support in-depth energy and environmental analyses. TIMES is a technology rich, bottom-up model generator, which uses linear-programming to produce a least-cost energy system factoring in user constraints, over medium to long-term time horizons. Through TIMES, scenarios various potential energy futures can be explored to support policy decision making related to the energy sector.

In summary, there are several key features of TIMES:

1. **End-to-end energy system modelling.** TIMES captures the end-to-end energy value chain through the chain of processes that transform, transport, distribute and convert primary energy supply to final energy demanded by energy consumers. The model holistically captures the mathematical, economic, and engineering relationships between "producers" which affect the supply-side of energy and "consumers" which affect the demand-side of energy.

2. **Least cost energy system optimisation criteria.** TIMES is designed to solve for the energy system that meets the energy service demands over the entire time horizon at the lowest possible cost. It does this by optimising equipment investment decisions based on technology curves, primary energy supply, and energy trade decisions at a regional level. TIMES assumes perfect foresight, where all investment decisions are made in each period with full knowledge of future events. The optimisation is conducted across all sectors and across all time periods for which the time limit is imposed.

3. **Scenario analysis.** TIMES allows for the development of a reference energy scenario by running the model in absence of any policy constraints for a least cost model. Against this scenario, policy constraints (e.g., minimum share of renewable energy, maximum amount of GHG emissions, energy security constraints) are defined to simulate the impact of various policy scenario constraints on the energy system and on energy system costs.

Box 2.2 | Overview on PLEXOS power system modelling methodology

PLEXOS was leveraged as a tool to supplement TIMES with granular power system modelling for the country. PLEXOS leverages a simulation engine to analyse zonal and nodal energy models ranging from long-term investment planning to medium-term operational planning and down to short-term, hourly, and intra-hourly market simulations.

To build confidence in system stability and adherence to energy security parameters in a power system with a high degree of renewable penetration, various stress test scenarios were run to simulate the response of the power system in extreme demand and supply situations, such as extended periods of low solar irradiation which reduces solar power output.

To ensure that total system cost impact of integrating renewables into the power system was also simulated, factoring in total costs associated with incorporating intermittent renewable energy such as costs for complementary energy storage requirements, balancing costs, system interaction costs, and other grid and enabler costs based on Malaysia's specific context.

Overview of potential abatement levers

Description of categories of abatement levers

A range of abatement levers were considered to develop alternate net GHG emissions pathways to the current trajectory. The key energy sector abatement levers can be categorised into:

- **Demand-side management and energy efficiency:** Reducing final energy demand from end users through combination of behavioural changes, technology-driven solutions, incentive and regulatory frameworks, and key energy efficiency industry enablers.

- **Emission-reducing fuel switching or substitution:** Reducing emissions by switching from higher emissions to lower emissions fuel use by end users, including enhancements in alternative fuel access to enable fuel switching, such as diesel to natural gas or coal to biomass switching in industry.

- **Optimisation of the power mix and enablers:** Reducing emissions in fuel combustion for electricity generation by optimising power development plans, such as decreasing the share of coal power and increasing the share of renewable power in the capacity mix, with the right supporting grid infrastructure and energy storage enablers.

- **Energy transformation process efficiency:** Reducing energy losses and conversion efficiency in key energy transformation processes, such as in the power generation, crude oil refining, and natural gas transformation.

- **Fugitive emissions reduction:** Reducing emissions across the end-to-end fuel value chain, from upstream oil and gas flaring and venting, to emissions in production, storage, transmission, and distribution of fossil fuels.

Demand-side management and energy efficiency

Demand-side management and energy efficiency covers a wide range of sub-initiatives which have the potential reduce energy demand across residential, commercial, and industrial sectors.

Malaysia has precedent initiatives to enhance demand-side management and energy efficiency, primarily focused on the electricity sector through the National Energy Efficiency Action Plan (NEEAP). The NEEAP targets to achieve 8% electrical efficiency savings over a 10-year period between 2016-2025 through energy efficiency labelling, minimum efficiency performance standards (MEPS), energy audits and energy management, promotion of co-generation, and energy efficient buildings. These initiatives are supported by various enablers, including the Energy Audit Conditional Grant (EACG) which supports voluntary energy audits by industry players and the introduction of Registered Electrical Energy Manager (REEM) in the 2010s.

Building on these strong foundations, there are several opportunities to step up demand-side management and energy efficiency to support an enhanced climate ambition along several themes:

- **Establish and enforce mandatory energy efficiency measures**

  Aside from the coverage of selected household appliances with MEPS and some enforcement of energy efficiency standards in buildings at the local government level, mandatory energy efficiency measures are limited in Malaysia today. A range of mandatory measures supported by regulations can support the scale-up of energy efficiency measures, many of which are net present value (NPV) positive for businesses.

  This includes mandatory energy audits for large energy consumers covering both electrical and thermal energy as practiced in Indonesia and Thailand, mandatory cost-benefit assessments on combined heat-and-power (CHP) for greenfield industrial plants as practiced in Europe, and minimum energy efficiency and green building standards for new purpose-built commercial buildings as practiced across many countries. Mandatory minimum energy performance standards (MEPS) can be enforced for key energy-intensive commercial and industrial equipment and a broader range of household appliances than currently covered.

- **Shift end user behaviour**

  Beside mandatory measures, enhanced voluntary demand-side management and energy efficiency practices can be encouraged. Broadening the coverage of energy efficiency labelling to cover a larger range of products, updating energy ratings to ensure that consumers are supported to make informed decisions between products, and increasing the effectiveness of energy labelling to nudge consumer behaviours are all key levers to increase energy efficiency. For example, in selected countries, consumers are provided with information on potential monetary energy cost savings they can obtain by purchasing higher energy efficient equipment through labels at point of purchase. Guidelines on recommended building temperatures for commercial buildings and shopping centres can also encourage energy savings behaviour.

  Other measures include enhancing awareness of the benefits of energy efficiency and energy conservation and enhancing energy efficient habit formation through education. This can range from platforms among industry players which allow for sharing of energy saving measures to encouraging habit formation in schools such as switching off appliances or lights when not in use. Moreover, going forwards, behavioural nudges will be needed. Looking forward, end user behaviour to optimise the timing of energy consumption, such as the time of day when electric vehicles are charged, can unlock key benefits such as smoothing energy consumption to avoid highly costly spikes in demand to the power system.

- **Scale-up the energy service ecosystem**

  Energy service companies (ESCOs) play a critical role in the scale up of energy efficiency in the commercial and industrial sectors. The development of the ESCO industry in Malaysia has been encouraging, but large potential still exists to scale-up the use of ESCOs. Efforts should be made to mainstream ESCO offerings such as with increased awareness of the benefits and trust in Energy Performance Contracting (EPC) with enhanced measurement and verification standards and model template contracts suited to the country's context. Training to enhance human capital across ESCOs, such as the development of industrial process expertise in addition to building services, will also need to be enhanced.

  Enhanced support for ESCOs such as with supportive project financing such as with revolving energy efficiency funds, risk-sharing facilities, or dedicated energy efficiency credit lines can be established accommodating a range of models such as shared savings, guaranteed savings, or energy supply contracting fit to the appetite of the end users. A thriving ESCO industry will also contribute to significant energy reduction as well as GDP and job creation. The IEA estimates that on average ESCO projects are delivering energy savings upwards of 25%[75] and that the rapidly growing ESCO industry is valued close to USD 30 billion. In the United States as an example, energy efficiency related jobs employ more than 3 million people, around 1-2% of the country's overall labour force.

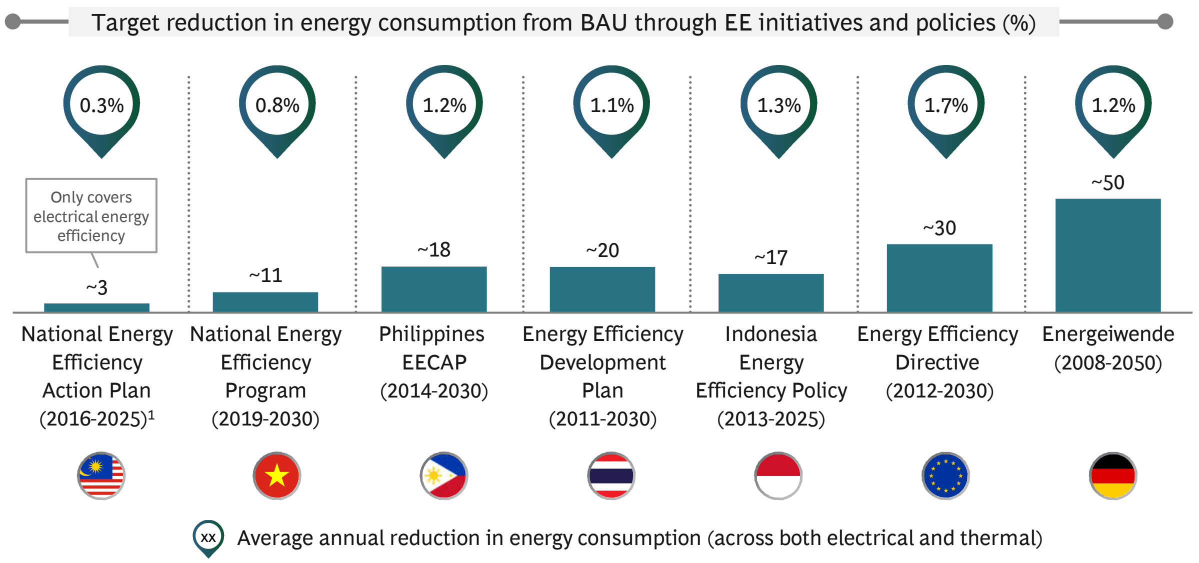
- **Catalyse adoption of advanced energy efficiency technologies**

  Adoption of energy efficiency technology solutions which are rapidly developing and are reaching inflection points of commercial viability will be key. With the cost of sensors halving just in the last 10 years, smart devices which can contribute to energy efficiency reduction are becoming increasingly mainstream. Coupled with the adoption Artificial Intelligence and Machine Learning under Industry 4.0, industrial players have potential to optimise their energy inputs, reducing energy input costs, and achieving competitive advantage.

  Building strong awareness of developments in energy efficiency technology, such as through ESCOs, will be key for the timely scale-up of commercial energy efficiency technology solutions. Incentives can further encourage early adoption of technologies, with successes shared on industry platforms to catalyse confidence amongst other industry players to adopt emerging energy efficiency technologies.

Figure 32: Comparison of current energy efficiency savings programs by country

Taking a higher ambition and scope on energy efficiency will converge Malaysia with regional peers



1. Energy savings across residential, commercial, and industrial. In contrast to peers, Malaysia energy efficiency program only covers electrical energy and not thermal energy (8% electricity consumption decrease vs. BAU over 10-year period) and hence when assessed as proportion of total energy is lower compared to regional counterparts
Source: World Bank, IEA, Ministry of Energy equivalent websites

Figure 33: List of energy efficiency measures for adoption based on Malaysia's context

Key high impact energy efficiency initiatives to support Net Zero

#	Initiative	Relevant sectors
1	Expand current coverage of **energy efficiency plans** from electricity to include thermal energy	R C I
2	**Mandatory energy audits** for energy-intensive industry and commercial players	C I
3	Move from voluntary to **mandatory equipment MEPS** for key industry and commercial equipment	C I
4	Develop **long-term roadmap for MEPS** across all equipment and appliances, to enhance industry preparedness	R C I
5	Promote **Industry 4.0 and digital** technologies (e.g., smart homes) which enable increased energy efficiency	R C I
6	Review **energy efficiency label five star-rating thresholds**, and improve information on labels to nudge consumer behaviour	R
7	Scale-up **energy efficiency in the public sector** (e.g., EPC contracts with ESCO for government buildings)	C
8	Mandate **cost-benefit analysis of combined heat-and-power solutions** for large industry players	I
9	Enhance **incentives, financing access and knowledge sharing** to promote energy efficiency retrofits	C I
10	Streamline **energy efficiency requirements across green buildings**, and enforce mandatory energy efficiency standards	R C
11	Reduce barriers to EPC contracts by creating **standards for M&V and EPC template** contracts	C I
12	Recommend **set temperature controls** standards for commercial buildings (offices, shopping centres)	C I

R = Relevant for residential sector C = Relevant for commercial sector I = Relevant for industry sector

1. MEPS = Minimum Energy Performance Standards; CHP = Combined Heat and Power; ESCO = Energy Service Company; EPC = Energy Performance Contract, M&V = Measurement and Verification

Emission-reducing fuel switching or substitution

End user fuel substitution from higher emission to lower emission energy sources represents another lever to reduce energy sector emissions. One key enabler to emission-reducing fuel switching is energy access. For example, industry clusters which lack direct access to natural gas resources rely on higher emission petroleum products such as diesel as sources of fuel. Enhancing industry access to cleaner fuels factoring in end-to-end value chain emissions including emissions in the transporting fuels to the end consumer, can reduce industry emissions. However, as enhancing access could entail large capital expenditure, the economics of energy access provision should also be thoroughly evaluated for long-term financial sustainability.

Fuel switching can also be encouraged where existing infrastructure is readily available. For example, natural gas has a lower emission factor than liquefied petroleum gas (LPG), which is a key fuel for cooking in both the residential and commercial sector. Where natural gas access is readily available to end users based on existing infrastructure, fuel switching can bring about strong benefits without incurring addition expenses.

Moreover, as more alternative lower carbon fuels become commercial, fuel switching should be actively encouraged to ensure timely green transition. For example, biomethane produced from upgrades of Palm Oil Mill Effluent (POME) biogas facilities can provide an alternative low carbon source to decarbonise natural gas use in industry, with improved commercial viability. Substitution of fossil fuels for sustainable bioenergy, such as that generated from agriculture waste or next generation supply sources such as algae, can also support reduction in industry energy emissions.

Optimisation of the power mix and enablers

The decarbonisation of the power mix represents the single largest lever in achieving the Net Zero pathway. Over 75% of energy industries emissions derives from fuel combustion in electricity generation. With growing electrification from existing demand sources and new demand sources such as electric vehicles, the potential impact of decarbonising the power mix grows.

In optimising the power capacity and generation mix, the Energy Trilemma needs to be effectively balanced – across energy equity and economic development, energy security, and environmental sustainability. Moreover, in decarbonising the energy mix various enablers and safeguards need to be put in place. Overall, to enable the Net Zero pathway, four key priorities within this lever exists.

Adopting commercial renewable energy at scale

With rapid cost improvements driven by technology, renewables have become highly economically attractive relative to fossil fuel power generation. In Malaysia, the cost of solar energy production is already below coal production and combinations of solar and energy storage solutions are expected to be cheaper than incumbent fossil fuels towards 2030. Whilst system integration and balancing costs are required to accommodate solar power as it grows as a share of the total power mix, these costs are rapidly falling due to battery storage technology improvements, making solar energy attractive even at high levels of power mix penetration. Moreover, from a trade perspective, domestic renewables reduce the reliance on imported fossil fuels, create larger domestic economic spillovers in GDP and jobs, and reduce exposure to volatile global fossil fuel commodity prices.

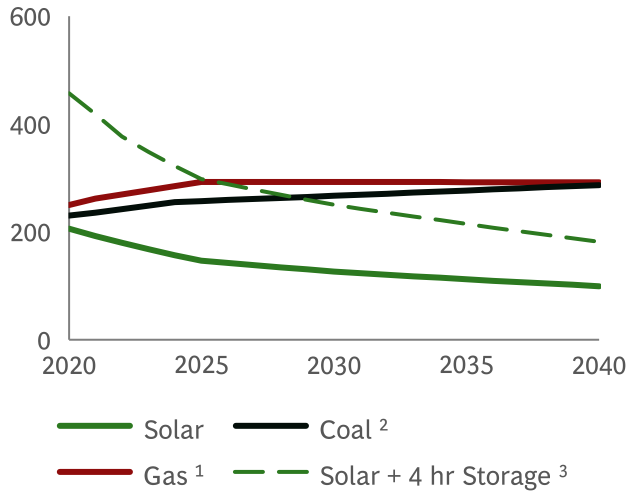
Corporates are also playing a key part in increasing the attractiveness of renewable energy. For example, RE 100 consists of over 300 large multinational companies which have committed to fully offtake renewable energy, influencing foreign direct investment (FDI) decisions. In addition, corporates are increasingly willing to pay premiums for renewable energy, such as through the purchase of renewable energy certificates (RECs) to decarbonise their own corporate footprint, which further increases the attractiveness of renewable energy adoption. Moreover, with advantages of highly cost competitive renewable energy, Malaysia can position as an attractive FDI and operations destination for global corporates with strong renewable commitments.

Figure 34: Simplified representation of the evolution of economics across power generation sources

Rapid tech improvement in solar and storage has shifted economics, even after accounting for integration costs

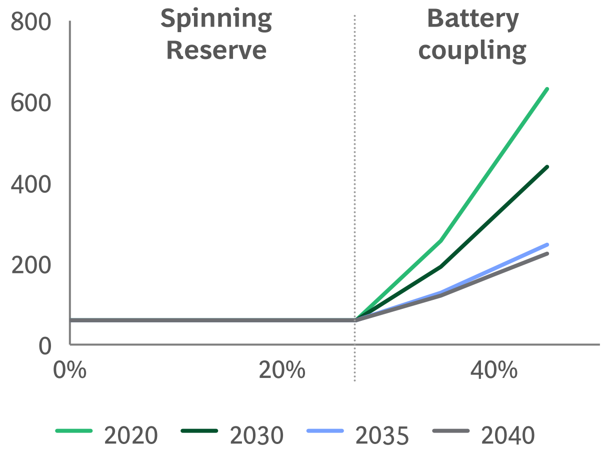
Solar-storage cost improvements, and rising coal financing costs are game changers …

Levelised Cost of Electricity (RM/MWh)



… even after accounting for energy storage, grid investments, and balancing costs

Variable RE[4] integration costs (RM/MWh)



… includes incremental grid costs, balancing costs, system interaction costs, and enabler costs

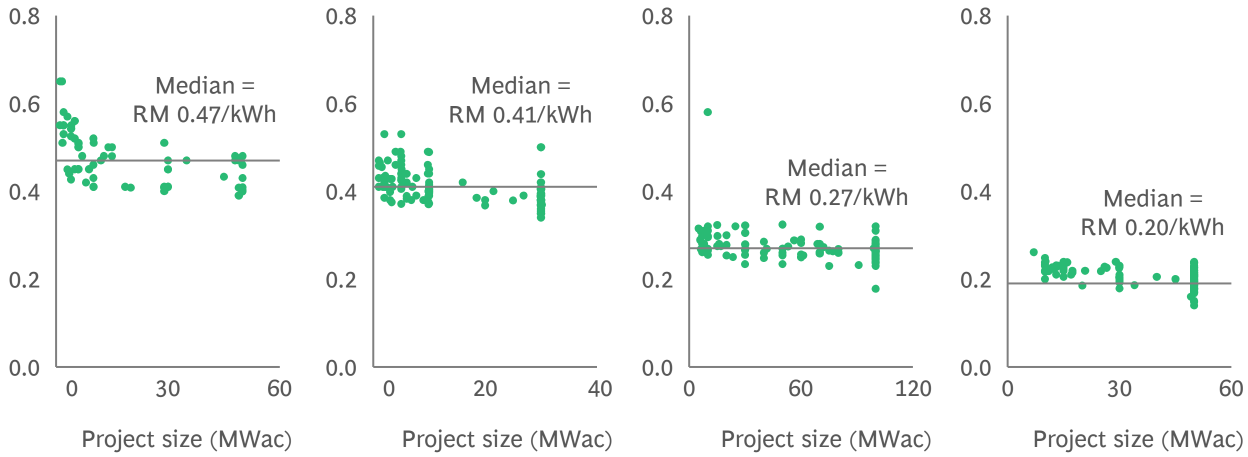
1. 700MW Single Shaft CCGT, ~50% Capacity Factor, ~55% efficiency, 2. Ultra Super Critical 700 MW, ~85% Capacity Factor, ~42% Efficiency, 3. For a 50 MW plant, 30 MW would be paired with 4 hr battery storage (e.g., 120MWh) 3. Levelised cost of energy (LCOE) is the cost of generating electrical power from different sources, excluding the balancing and interaction costs 4. Renewable energy
Source: IRENA, IEA, Wood Mackenzie, Lazard, EIA and BNEF

Figure 35: Historic trajectory of large-scale solar (LSS) auction bids

Rapid declining bids in each large scale solar auction round

LSS 1: Median bid price of RM0.47/kWh | **LSS 2: Median bid price of RM0.41/kWh** | **LSS 3: Median bid price of RM0.27/kWh** | **LSS 4: Median bid price of RM0.20/kWh**

Tariff bid (RM/kWh)



LSS 1 — Min bid: RM 0.39/kWh; Max bid: RM 0.65/kWh

LSS 2 — Min bid: RM 0.34/kWh; Max bid: RM 0.53/kWh

LSS 3 — Min bid: RM 0.18/kWh; Max bid: RM 0.58/kWh

LSS 4 — Min bid: RM 0.14/kWh; Max bid: RM 0.24/kWh

1. LSS1 award in 2016 for 2018 COD; LSS2 award in 2017 for 2020 COD; LSS3 award in 2019 for 2022/23 COD; LSS 4 award in 2021 for 2023 COD
Source: Suruhanjaya Tenaga bid announcements

Figure 36: RE100 companies FDI decisions are increasingly influenced by access to renewable energy

RE100 players have committed to 100% offtake of renewable energy

Companies deciding where to locate based on access to Renewable Energy

RE 100

RE100 is group of over 300 large global companies pledged to offset **100% of electricity demand with clean energy.**

Access to renewable energy a key factor in influencing FDI and deciding between manufacturing locations.

300+

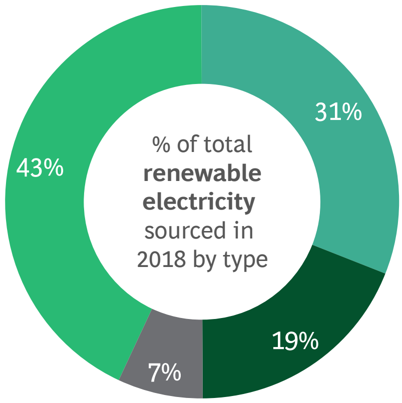
Members worldwide

330+

TWh / year electricity demand

Source: RE 100 Website

Range of models used by RE100 players to offtake 100% renewable energy



- Unbundled energy attribute certificate purchase
- Contract with suppliers (green electricity tariffs/products)
- Direct procurement from offsite grid-connected generators (PPA)
- Others[1]

1. Self-generation (4%); Purchase from on-site installations owned by a supplier (1.75%); Other options (0.75%); Direct line to an off-site generator with no grid transfers (0.50%)

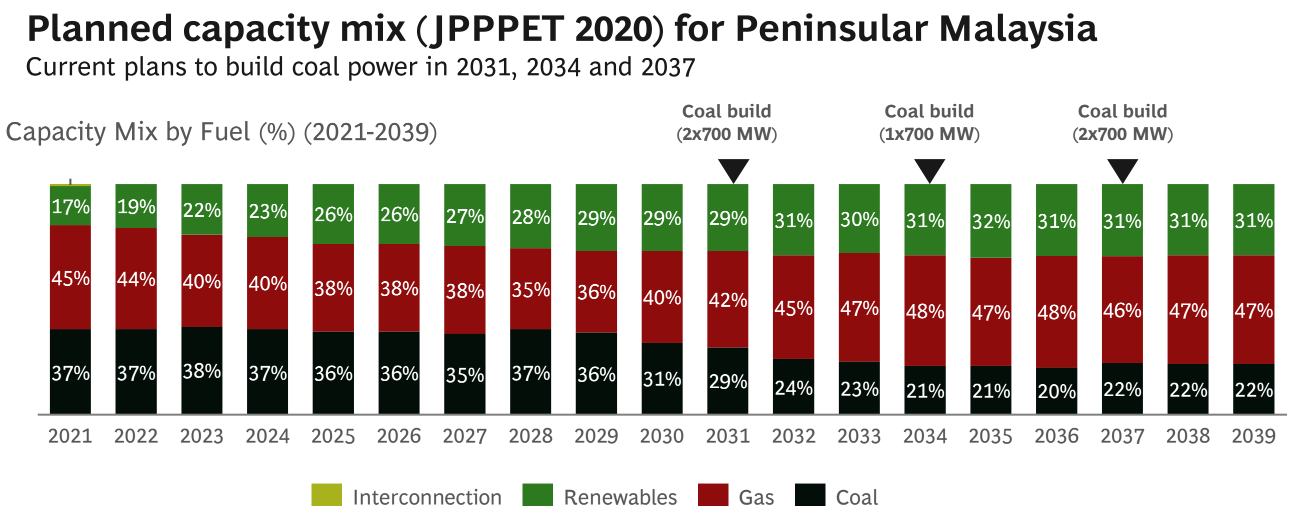
Phasing out coal power from the energy mix

In contrast to the rapid improving economics of renewable energy, the outlook for coal power has diminished significantly over the last few years. Growing number of institutional investors, financial institutions, and reinsurers have committed to stop the financing or reinsurance of coal. Countries supporting international financing of coal such as China and Japan have also recently announced overseas coal financing bans. As a result, capital availability is expected to be severely constrained making new coal power plant builds economically infeasible with high stranded asset risks.

If Malaysia adheres to its no new coal and coal phase out policy, the last coal Power Purchase Agreement (PPA) will expire by 2045. The high economic and financial risks of future coal build out represents a compelling reason to revisit the country's forward-looking power development plans, which currently outline plans for coal power plants in the 2030s. Moreover, with rapid technology improvement in renewable energy and energy storage solutions, the phase out of coal is not projected to adversely impact system costs, negating one of the key justifications for the presence of coal power in the country's power mix. To drive an even more decarbonisation path whilst within the construct of existing PPAs, retrofits of coal power plants for sustainable biomass co-firing can be considered, factoring in unique plant-specific conditions and configurations.

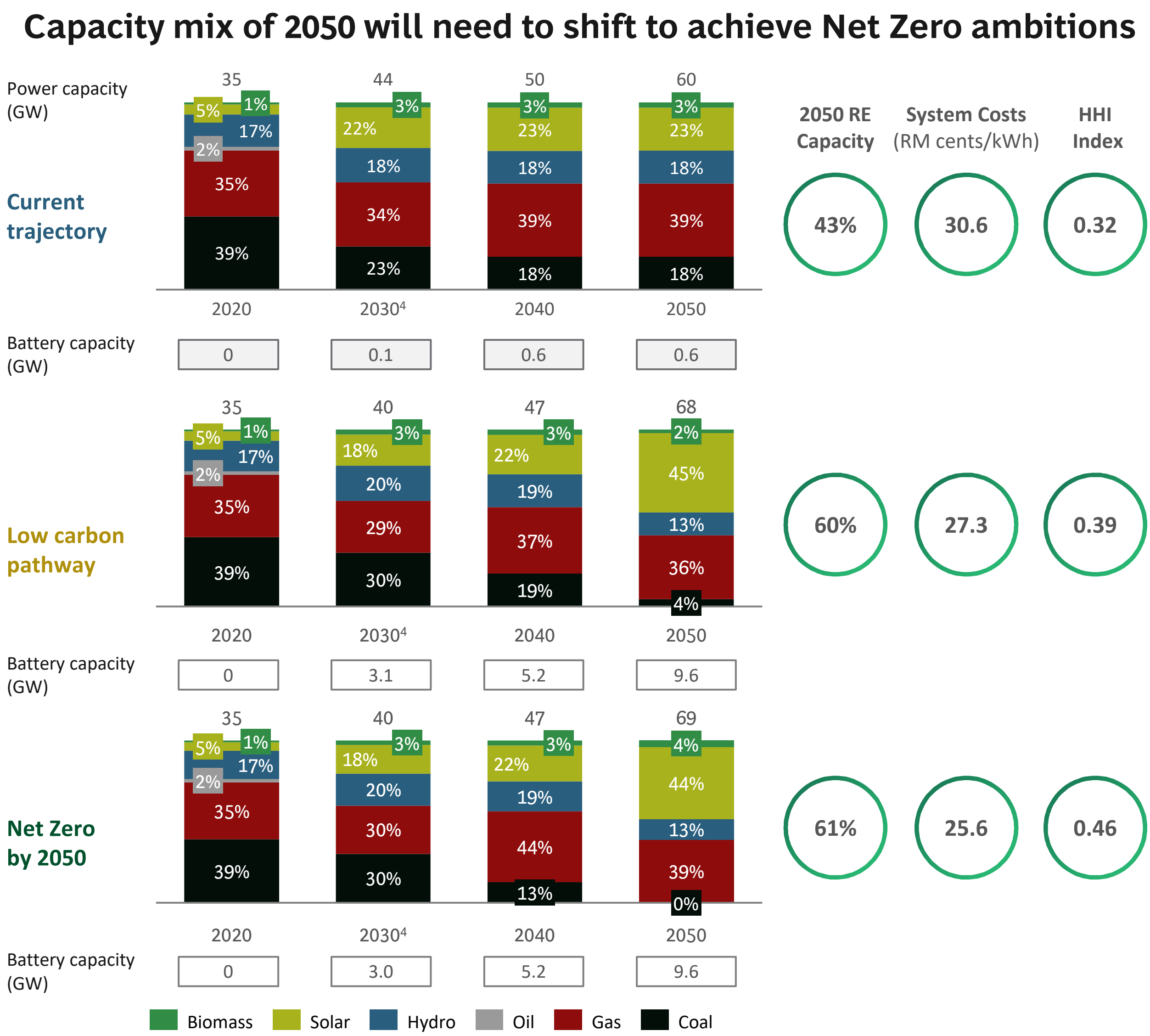
With the phase out of coal, natural gas will have a key role to play a key transition fuel, supported by its ability for rapid ramp up to complement intermittent renewable energy. However, natural gas is not a zero-carbon fuel and emits around half the emissions of coal for equivalent energy output. Over time, as new emerging renewable energy sources and energy storage improve in commercial viability, the share of natural gas in the energy mix can be gradually reduced over time, supporting further decarbonising the energy system.

Figure 37: Current official power development plans for Peninsular include coal power build-out



1. Renewables consists of solar, hydroelectric, and bioenergy (e.g., biomass, biogas)
Source: Mesyuarat Jawatankuasa Perancangan dan Pelaksanaan Pembekalan Elektrik dan Tariff (JPPPET 2020) for Peninsular Malaysia

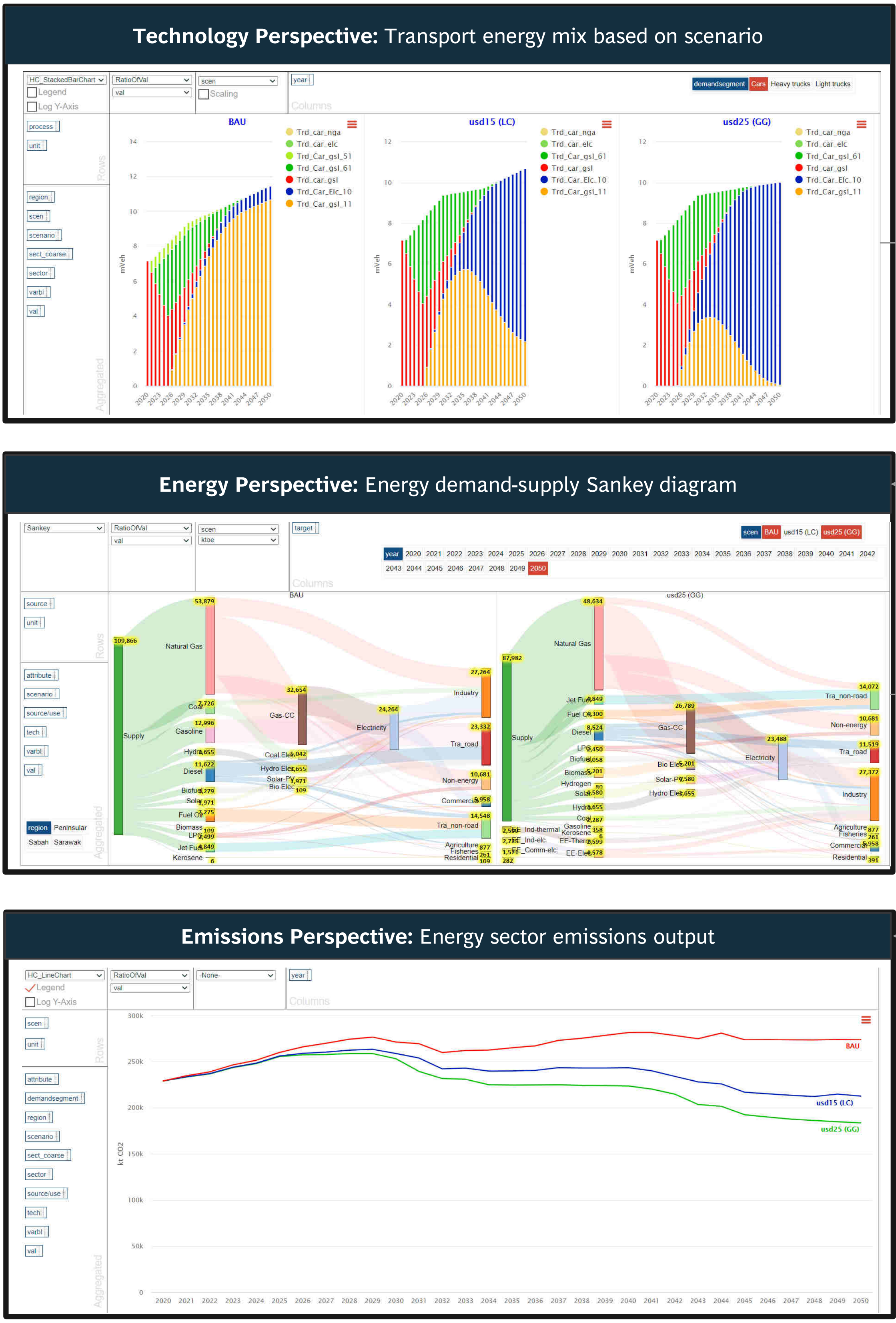
Figure 38: Power capacity mix scenarios



1. Current trajectory holds final power mix in 2040 constant to 2050; low carbon pathway assumes JPPPET 2020 plans are followed, and optimisation occurs following PPA expiry of current and planned plants; Net Zero 2050 assumes full coal phase out including no repowering of existing coal PPAs
2. HHI = Herfindahl–Hirschman index is a measure of concentration, used to assess fuel source diversification
Source: Output from PLEXOS Model, Project Team Analysis

Figure 39: Sample output from TIMES model of energy system balances

TIMES used as tool to support holistic energy system modelling

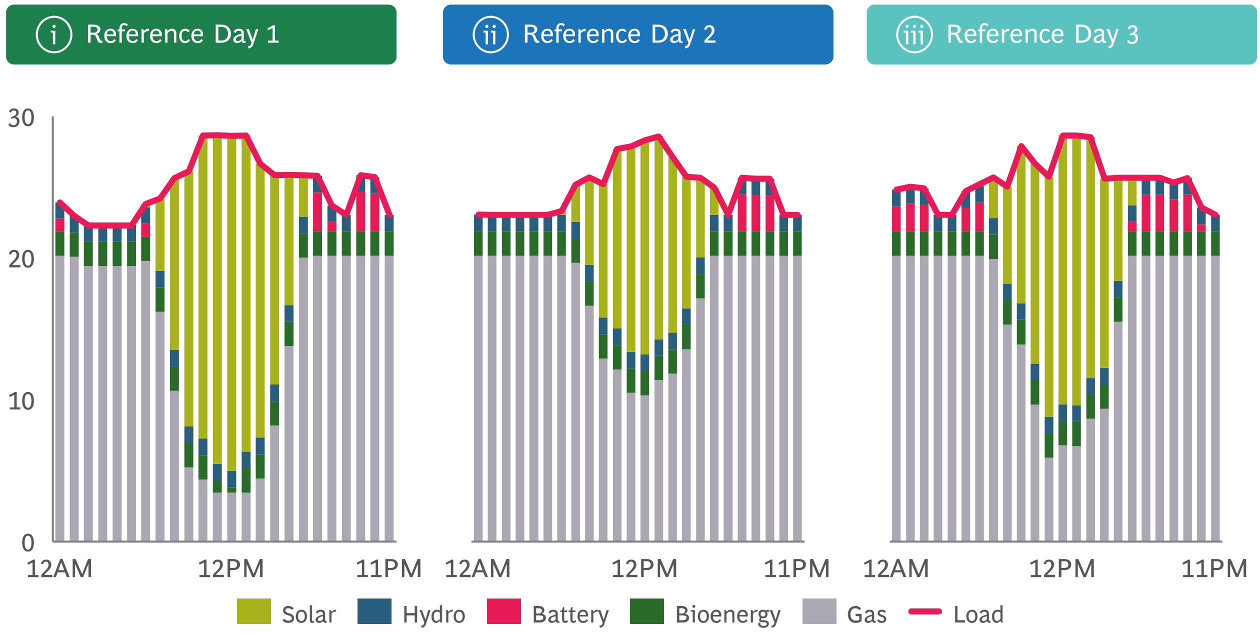


Source: Output from TIMES (The Integrated MARKAL-EFOM System) Model, Project Team Analysis

Figure 40: PLEXOS simulation of hourly time slices of power demand-supply system

Under Net Zero 2050, Peninsular power generation mix will have significant solar penetration; supported by gas and battery storage

Hourly distribution of power generation (GW)



Assumes gas power plants have 40 MW/min ramp-up/ramp-down feature by 2050
Source: Plexos model, Malaysia weather patterns (2019), Project Team Analysis

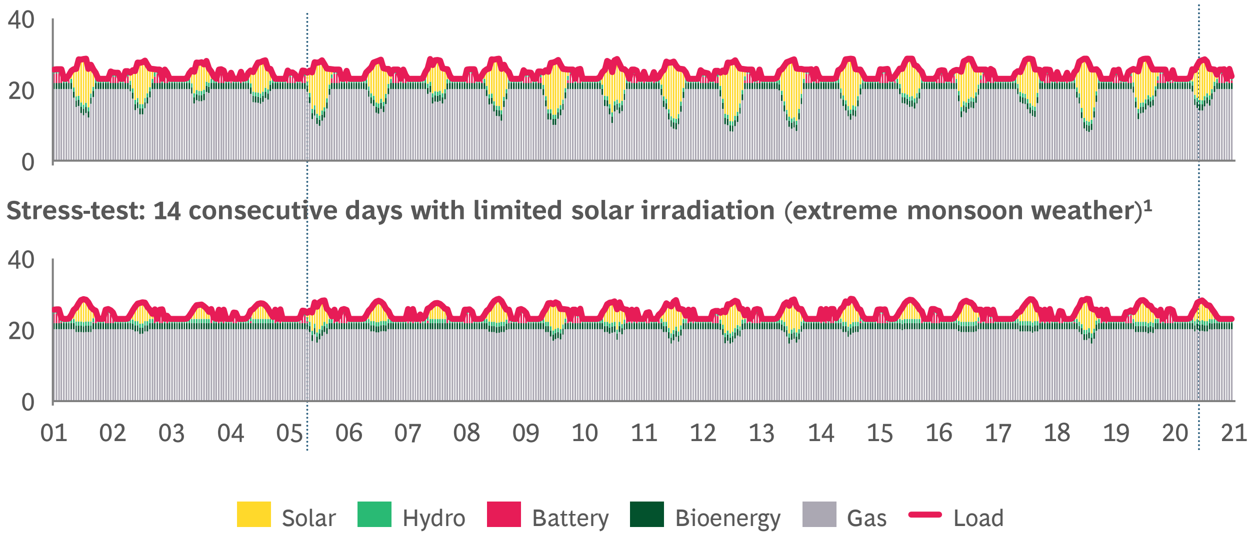
Figure 41: Stress test of power system stability under extended extreme weather conditions

Stress test used to assess energy security of power system in extended periods of limited solar irradiance

Hourly distribution of power generation (GW)

2-week snapshot: Normal monsoon season weather (simulates 2019 weather)

Stress-test: 14 consecutive days with limited solar irradiation (extreme monsoon weather)[1]



1. Assumes hourly capacity factor for the country is reduced by 50% solar
Assumes gas power plants have 40 MW/min ramp-up/ramp-down feature by 2050
Source: Plexos model; Project Team Analysis; Renewables Ninja (2019 weather patterns)

Timely development of energy system enablers

To unlock the benefits of increased renewable energy penetration in the power system, various power system enablers will need to be established. Timely grid transmission infrastructure upgrades will be needed to enhance connectivity between areas of high renewable energy supply to demand centres, and to accommodate increased to renewables into the power system. Upgrades to distribution grids will also be required to accommodate the scale-up of distributed renewable energy. Investments will need to be made into energy storage and demand response solutions to safeguard system stability with increased penetration of intermittent renewables.

Supporting domestic market regulation is also key to accommodate the equitable scale-up of renewables. For example, ensuring energy equity by optimising the tariff structure to ensure equitable distribution of system costs associated with growing prosumers and distributed energy resources will be critical. In addition, optimisation of regulation and market structures to accommodate new business models such as virtual PPAs (vPPAs) or peer-to-peer (P2P) electricity trading which can further incentivise the growth of renewable energy resources. For emerging renewable energy sources, continuing programs such as Feed-in-Tariffs (FiTs) and Net Energy Metering (NEM) will be critical to encourage further renewable energy penetration in the grid mix.

At a regional level, power system stability and energy security of individual member countries can be enhanced through regional grid interconnections, such as the ASEAN interconnected grid. Cross-border electricity markets which facilitate the commercial exchange and trading of electricity will enhance energy security safeguards of each member state through enhanced flexibility for power generation source diversification. This will enable individual member states to decrease their individual reserve margins, which improve power system costs without the compromise of energy security. Moreover, with an interconnected grid, countries will be able to optimise power demand-supply over a wider network, making full use of the time-of-day differences across various countries within ASEAN to reduce overall electricity system costs and to optimally leverage renewable energy endowments across the region.

Enhance safeguards to ensure end-to-end sustainability of power generation

Safeguards are also critical to ensure the end-to-end social and environmental sustainability of renewable energy solutions:

- For large scale hydropower, preventive safeguards will be needed against adverse environmental impact such as damage to river ecology, loss of forest areas or natural habitats from flooding, as well as social impact such as displacement of local populations.

- For solar power, ensuring sustainable land use such as through dual use solar farms which cultivate agriculture to reduce land use trade-off of solar farms and sustainability of the end-to-end manufacturing supply chain.

- For bioenergy, ensuring the sustainability of bio-based feedstocks by safeguarding against non-sustainable bioenergy solutions which increase pressure on land use and on deforestation, as well as factoring in end-to-end lifecycle emissions will be critical.

- For energy storage solutions such as batteries, socially and environmentally sustainable supply chains will be critical to protect labour rights and to ensure sustainable extractive and processing processes.

Moreover, effective end-of-life waste management and recycling policies will be key to ensure the sustainability of power generation. For example, European directives on solar waste since 2014 have ensured solar panel producer responsibilities and obligations for collecting recycling PV panels, including minimum collection and recovery targets. This has contributed to approximately 85% to 95% of solar waste being recycled. In addition, ensuring sustainable second-life use and sustainable end-of-life disposal for battery storage will also be critical.

Energy transformation process efficiency

Emissions are incurred in the conversion of primary energy to secondary and final energy output such as in the electricity generation, oil refining, and gas transformation process. Various levers exist to reduce energy losses and emissions in the energy transformation process.

For electricity generation, thermal energy losses in energy conversion between fuel to steam to electricity can be reduced by enhanced boiler, turbine, and generator efficiency. Measures such as enhanced waste heat recovery with combined cycle power generation, optimising key input and final steam parameters, and other operational levers can significantly improve conversion efficiency. As an example, sub-critical thermal power plants have efficiencies around 38% compared to ultra-supercritical thermal power plants with reach up to 44% efficiency.

For refineries and gas plants, levers such as process optimisation, waste heat recovery, and key equipment upgrades informed by optimised thermodynamic models can enhance fuel conversion efficiency. Continued improvements in equipment conversion efficiencies driven by technology progress will need to be tracked and incorporated, such as in new greenfield plant builds and major brownfield plant overhauls to reduce emissions in energy transformation.

Fugitive emissions reduction

In 2016, fugitive emissions contributed 27 $MtCO_2e$ of emissions, 90% of which originates from natural gas and 10% from oil. Fugitive emissions can originate from fugitive leaks from equipment (e.g., valves, pumps, compressors) or venting and flaring, which is the controlled release/burning of natural gas associated with oil-gas production mainly due to safety reasons.

In upstream, flaring and venting in oil and gas offshore platforms and fugitive emissions in the production process represent a key source of methane emissions, which has high global warming potential. Measures to eliminate routine and continuous flaring under normal operating conditions through the recovery of associated gas is critical, in line with the World Bank Zero Routine Flaring initiative. Whilst non-routine flaring for safety reasons will continue to be required, this should also nevertheless be minimised. The recovery of associated gas can be used to generate new revenues for Oil and Gas companies, further increasing the commercial viability and attractiveness of the abatement lever.

A key metric for upstream fugitive emissions is methane intensity, which is a measure of methane emissions relative to natural gas throughput. The Oil and Gas Climate Initiative (OGCI) has set a target to reduce methane intensity to "near zero", which is defined as between 0.25% to 0.2% over total volume of production[75]. It is estimated that through sustainability reports of key representative players of Malaysia's oil and gas industry that methane intensity levels are approximately 0.5%. Leveraging technology and enhancing processes to reduce these emissions to meet near zero ambitions will be important in the coming years.

In midstream and downstream, preventing fugitive gas leakages in storage, transmission, and distribution will be key. This includes enhanced leak detection with technology-driven optical gas imaging or predictive emission monitoring systems to ensure early detection and prevention of fugitive emissions. Besides enhanced monitoring, upgrade of key equipment such as seals and use of other technologies on recompression to recover methane gas, enclosed combustion units, or other technologies can be adopted factoring in the design of the compressor station and other site-specific variables to reduce fugitive emissions.

75. OCGI (2018). Oil and Gas Climate Initiative sets first collective methane target for member companies

Collective impact on GHG emissions pathway

Based on individual assessments of technical viability and commercial feasibility, levers were considered and included into the various GHG emission pathways. Details of the contribution of each lever to GHG abatement in the energy sector can be found overleaf for both the Low Carbon Ambition and the Net Zero 2050 pathway.

Of the total net emissions across all sectors in the current trajectory scenario in 2050 which is approximately 170 $MtCO_2e$, energy sector decarbonisation levers have the potential to decrease total emissions by 84 $MtCO_2e$ in the Low Carbon Pathway and by 104 $MtCO_2e$ in the Net Zero 2050 pathway. The largest three levers for the decarbonisation of the energy sector are the decarbonisation of the power mix, energy efficiency and demand-side management, and electrification of the light vehicle fleet.

Figure 42: Summary of energy sector levers under various pathways

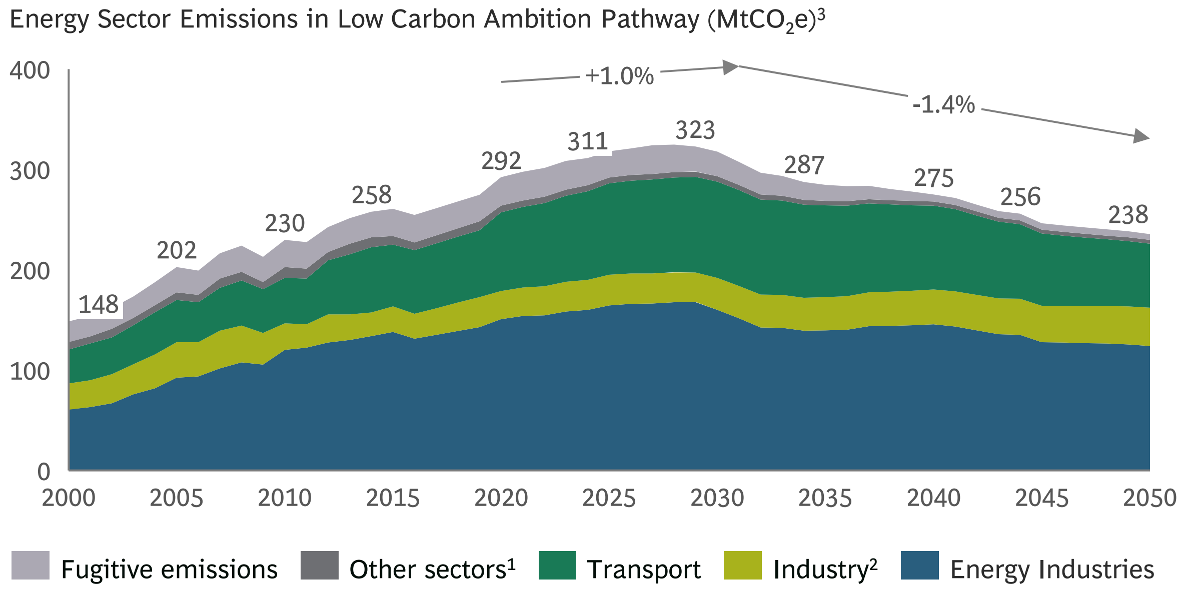
Energy sector parameters under each GHG pathway scenarios

Sector and Key Driver (values in 2050)		Current Forward-Trajectory	Low Carbon Ambition	Net Zero in 2050
Power	Total power capacity (GW)	60	78	78
	Total energy efficiency improvements	12%	26%	26%
	Capacity mix coal share	18%	4%	0%
	Capacity mix renewables share	43%	52%	54%
	CCGT gas plant efficiency	42%	50%	58%
Transport	Public transport modal share	40%	50%	60%
	EV share of fleet	7%	84%	100%
	Light vehicle fuel economy	~30%	~30%	~30%
	Biofuel blending in heavy transport	B20	B30	B30
	Hydrogen penetration	0%	0%	5%
Fugitive	Fugitive emissions intensity	0.72%	0.49%	0.25%

1. CCGT = Combined Cycle Gas Turbine

Figure 43: Low carbon ambition pathway projections of energy emissions

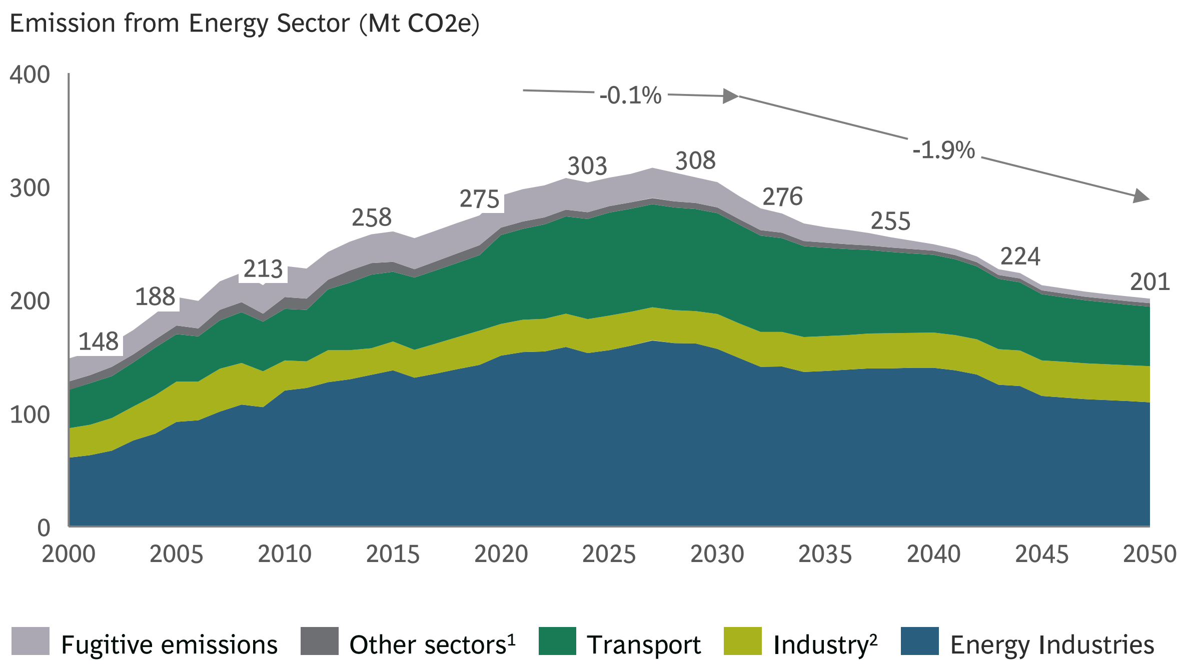
Low Carbon Ambition Pathway: Energy emissions expected to plateau between 2025-2030, before steady descent



1. Other sectors include Residential, Commercial, Agriculture 2. Includes Industry and Construction 3. Values from 2016 onwards are projected
Source: Project Team Analysis

Figure 44: Net Zero 2050 pathway projections of energy emissions

Net Zero 2050: Energy emissions will need to peak by 2025, before steady descent reaching around 200 $MtCO_2e$ towards 2050



1. Other sectors include Residential, Commercial, Agriculture 2. Includes Industry and Construction 3. Values from 2016 onwards are projected
Source: Project Team Analysis

Priority #3:

Accelerate Low Carbon Transport

Overview

The transport sector has been a vital enabler for the country's economic prosperity, unlocking connectivity across the country and beyond. The mobility of people and products are fundamental enablers to a thriving economy, and the strong development of transport systems in the country has also been a key ingredient to our economic successes. Looking forward, accelerating the adoption of low carbon transport represents a key contributing factor to a resilient, sustainable, and future-proof transport sector, as well as a key lever for the overall decarbonisation of the national economy.

Fuel combustion in transport currently accounts for around 21% of national GHG emissions. These emissions primarily derive from road transport, and to a significantly lesser extent from railways, domestic aviation, and domestic maritime or water-borne navigation. International aviation and maritime are not included in the country's national GHG inventory. From an energy demand perspective, the transport sector contributes to more than 35% of the final energy demand.

Under road transport, vehicle types covered include passenger vehicles, light-duty trucks, heavy-duty trucks, buses, and motorcycles. Emissions accounted under the transport sub-sector represent emissions released at the point of end use of the fuels, and not for emissions released through the supply chain of transport fuels or in the manufacturing of vehicles. However, in the evaluation of transport abatement levers, the end-to-end emissions and broader sustainability considerations in the supply chain were factored into the decision making.

Historic trajectory

Since 1990, transport sub-sector emissions have grown by approximately 6% per annum, multiplying four-fold from around 15,000 $MtCO_2e$ in 1990, to over 63,000 $MtCO_2e$ in 2016. Close to 90% of total transport emissions derive from road transport. There have been several key influencing factors for road transport emissions, including:

Demand growth

In 2019, there were 31 million motor vehicle units registered in Malaysia, with passenger cars and motorcycles each constituting around 45% of total motor vehicle units registered[76] . Over the 2010-2019 period, there has been an average of 1.1 million units of new vehicle registrations per year, reflecting the strong growth in end-use demand. However, not all registered vehicles are actively contributing to emissions. For example, of the 14 million registered cars, it is estimated that on-the-road car volume was around 6.7 million vehicles in 2019, recording an average of 28,000 km travelled distance per year. Strong growth of on-the-road vehicles has led to growth in fuel demand and transport emissions over the years. Relative to regional peers, Malaysia has one of the highest car ownership penetration when adjusted for nominal GDP per capita, whilst the modal share of public transport hovers around 20-25%[77]
.

Fuel economy improvements

As technology progresses, engine efficiency and fuel economy of vehicles have improved over time, reducing the energy and emission intensity of vehicles. Under the National Automotive Policy (NAP) 2014, specifications for energy efficient vehicles (EEVs) were developed based on the maximum carbon emission levels and fuel consumption. With strong execution of the NAP 2014, the penetration of energy efficient vehicles (EEVs) has been steadily rising, reaching 62% penetration in 2018 and likely over 80% in 2020, based on historic growth trends, reducing the energy intensity of the vehicle fleet. Currently, the average vehicle fuel economy is estimated to be around 7.96 litres per gallon equivalent (Lge) per 100 km.

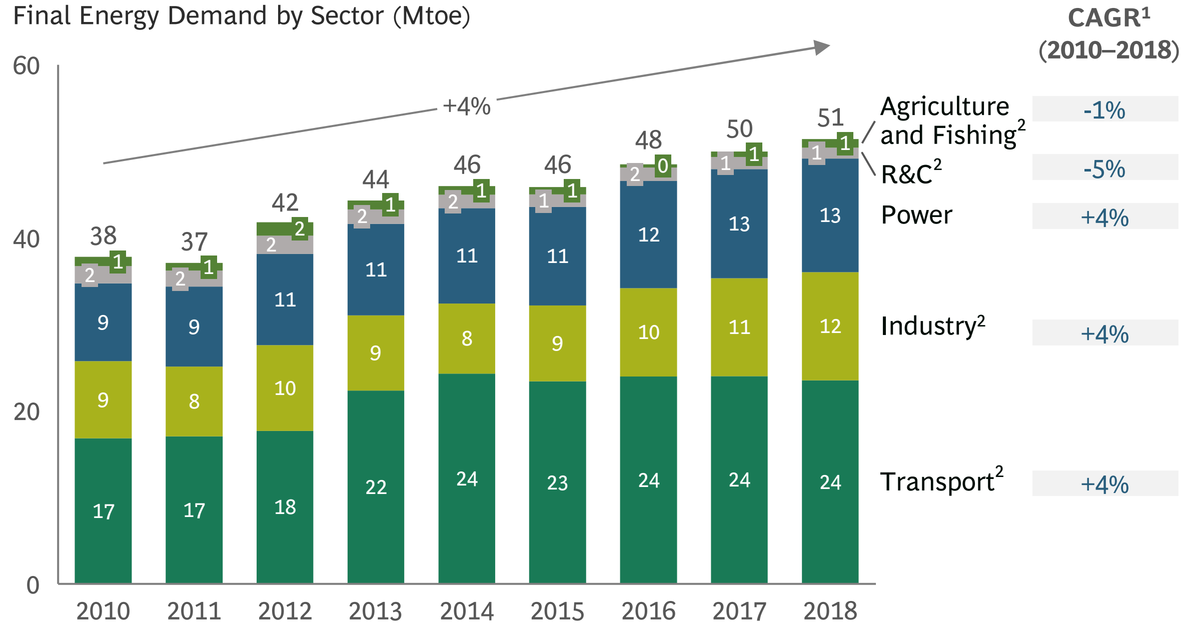
Fuel switching and fuel standards

Another key driver of emissions is fuel inputs. Mandatory B7 and B10 biodiesel blending was imposed in 2014 and 2019 respectively, contributing to emissions intensity reduction in the heavy vehicle segment. In addition, fuel standards have also been ratcheted up over time, reducing the level of sulphur content in fuels. Diesel fuel standards were enhanced from Euro 2 to Euro 2M standards to reduce sulphur, lead, benzene, and other environmentally damaging pollutants, resulting in sulphur dioxide and nitrogen oxide emissions. Moreover, voluntary adoptions of higher fuel standards, such as Euro 5, has been seen in Johor and the Klang Valley since 2014 and 2016, respectively.

76. JPJ (2018). JPJ motor vehicle registration data (2014-2018)
77. MGTC (2017). Green Technology Master Plan 2017- 2030

Figure 45: Breakdown of transport share in final energy demand

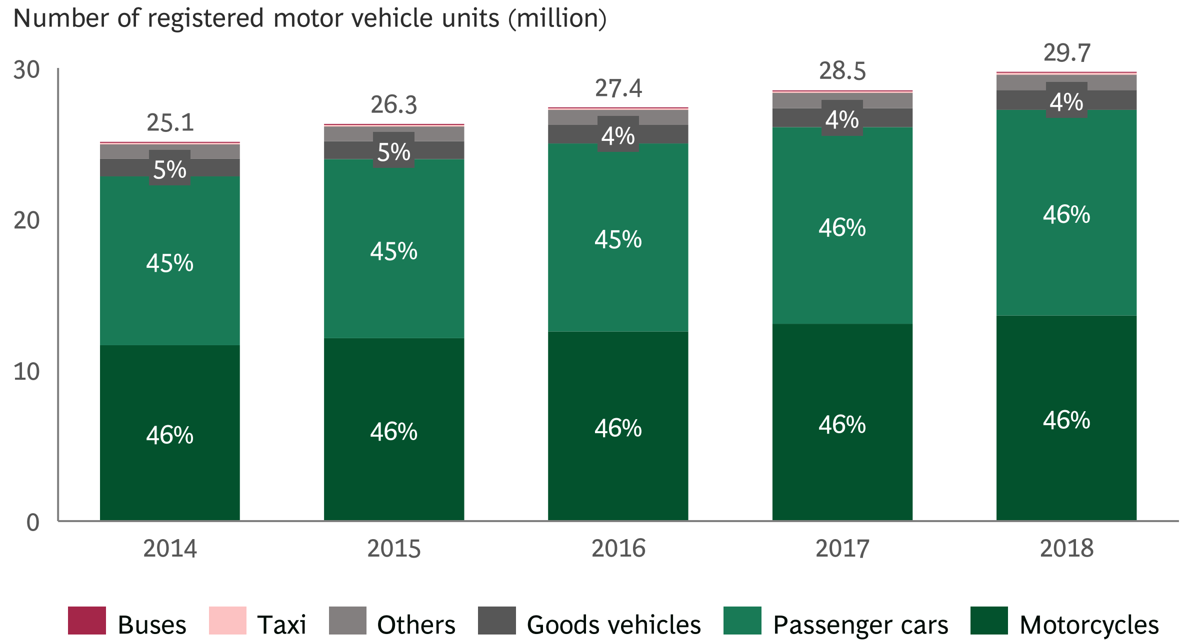
Transport constitutes the largest share of final energy demand



1. R&C = Residential and Commercial 2. Electricity excluded as electricity consumption of all demand sector is covered under Power sector
3. Use of products resulting from the transformation process for non-energy purpose (i.e., bitumen/lubricants, asphalt/greases) and as industry feedstocks have been removed from NEB as this is covered under IPPU emissions 4. Non-energy use has been removed
Source: Suruhanjaya Tenaga National Energy Balance Reports (2010-2018)

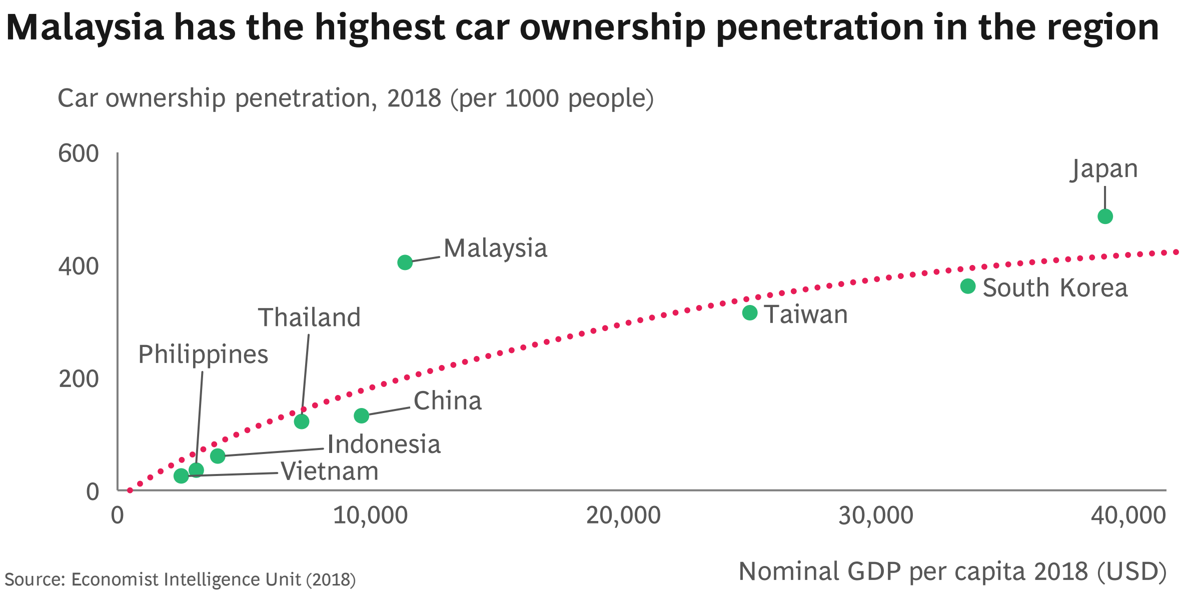
Figure 46: Growth rate of motor vehicle registrations in Malaysia

Steady growth in motor vehicle registrations over time



Source: JPJ motor vehicle registration data (2014-2018)

Figure 47: Country comparison of car ownership penetration against GDP per capita



Source: Economist Intelligence Unit (2018)

Light Road Transport

Forward-looking plans are expected to further reduce the energy and emissions intensity in the light vehicle segment, primarily through increased next generation vehicle penetration, enhanced fuel economy, and increased public transport modal share.

- **Next generation vehicles (NxGV) penetration** is expected to reduce energy demand and emission intensity of vehicles, going forward. Based on the NAP 2020, NxGV vehicles are defined as vehicles which meet both energy efficient vehicle specifications and intelligent mobility applications, such as vehicle automation. Alternative powertrains, such as hybrid, electric, or fuel cell vehicles will have significant impact on emission reduction, when coupled with decarbonisation of fuel sources (e.g., grid-drawn electricity for EVs, and clean hydrogen production for fuel cell vehicles). Autonomous Vehicles (AVs), when deployed at scale, can support the reduction of energy demand with optimised driving behaviour, enabling fuel savings. Given the objectives of positioning Malaysia as a NxGV hub, the local take-up of NxGV will have positive demand spillovers to the country's automotive sector.

- **Fuel economy targets** of 5.3 Lge / 100 km by 2025 has been a clear goal set in line with the ASEAN Fuel Economy Roadmap[78] , within the NAP 2020[79] . Given the starting fuel economy position of the fleet is around 7.96 Lge / 100 km in 2020, around 4% improvements in fleet fuel economy will be required per year, through strong penetration of EEVs. Longer-term fuel efficiency targets of 4.40 Lge / 100 km towards 2030, also represents a key reference point.

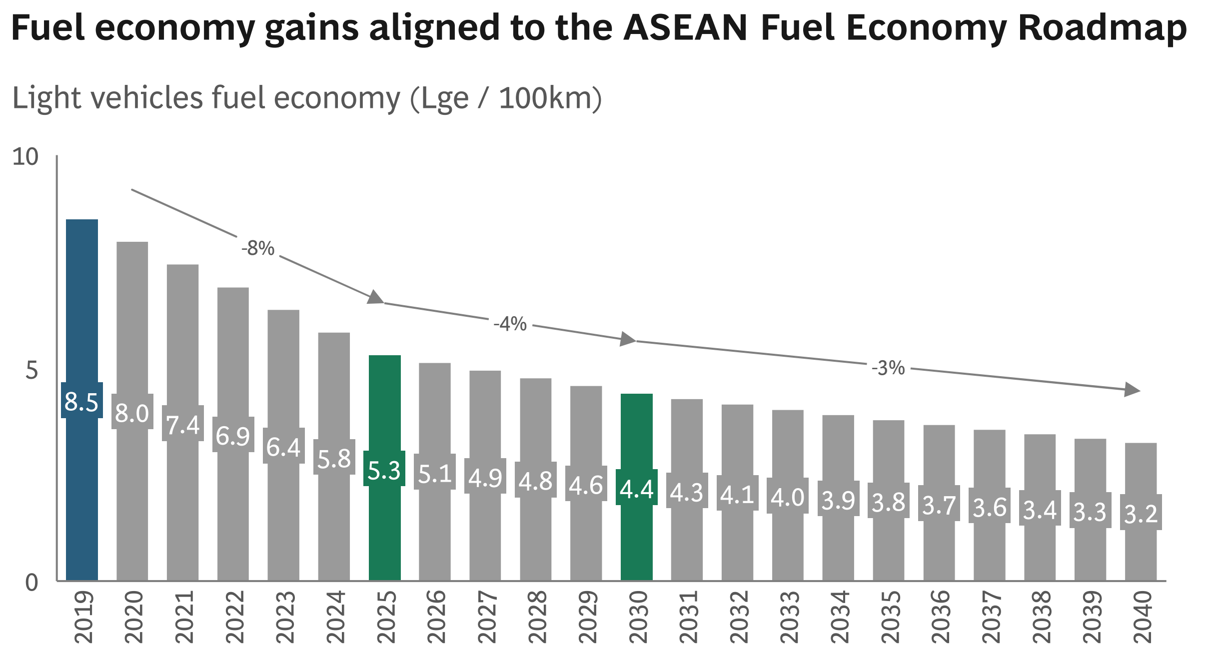
- **Public transport modal share** increase, outlined in the National Land Public Transport Master Plan (2013)[80] , proposes the goal to achieve 40% public transport modal share in urban areas by 2030, which will need to double from the current modal share levels of 20-25%. The current and upcoming LRT 3, MRT 2 and 3, as well as long-distance rail projects and bus projects (e.g., bus rapid transit), will contribute towards the public transport modal share increase. Efforts for green public transport, such as the adoption of electric buses or hydrogen buses in Sarawak, can reduce the public transportation’s direct emission footprint.

- **Fuel standards enhancements,** with the roll-out of Euro 4M for RON 95 petrol and plans for Euro 5 Petrol roll-out by 2025, will reduce the sulphur content of fuels and emissions, which will enhance air quality, aligned with the Clean Air Action Plan 2010.

- **Other measures** include B7 biodiesel blending in diesel-based luxury passenger vehicles and various behavioural shifting measures (e.g., vehicle energy efficiency labelling, end-of-life scrapping incentives, and eco-driving education programs) have the potential to enhance vehicle energy efficiency and emissions reduction.

78. Global Fuel Economy Initiative. (2021). ASEAN countries begin process of implementing Fuel Economy roadmap
79. MITI (2020). National Automotive Policy
80. SPAD (2013). Land Public Transport Master Plan Greater Kuala Lumpur / Klang Valley

Figure 48: Projected schedule of fuel economy improvements for Malaysia



Source: ASEAN Fuel Economy Roadmap

Heavy Road Transport

Emissions intensity is expected to decrease with increased biodiesel blending requirements, whilst freight modal share and fuel economy are expected to reduce the total energy demand.

- **Biodiesel blending mandates** under the B20 Biodiesel Program, with the planned roll out of B20 biodiesel blending limits by 2022 from the current B10 blending limits will reduce carbon emissions intensity from the heavy transport sector. Spillover effects from biodiesel blending mandates on the palm oil industry include stable demand offtake of over 1 million tonnes of CPO, and the development of the country's biodiesel industry, with over 530,000 tonnes of biodiesel. At the current level of consumption, approximately 3.2 million tonnes of emissions reductions are expected.

- **Rail freight modal share** increases, such as the development of the East Coast Rail Link (ECRL) and other freight connectivity projects, are expected to increase rail-based freight modal share targets. However, counteracting effects, such as the completion of the Pan Borneo highway and the connectivity of economic corridors across states, will likely result in uptake of heavy vehicle demand in the region.

- **Fuel economy improvements** are expected in the heavy transport segment, albeit at a slower pace compared to the light vehicle segment. A natural rate of 0.5% fuel economy improvement per annum is projected for heavy vehicles, from a starting position of approximately 14.35 Lge / 100 km.

- **Fuel standards improvement** with the roll-out of Euro 5 Diesel in 2021 will reduce sulphur content of fuels and contribute to pollutant reduction.

- **Other measures,** such as behaviour changes of increased eco-friendly driving aided by technology, (e.g., through driver monitoring systems) can have strong impact due to the long travel distances of trucks. In addition, end-of-life scrapping measures can be key to phase out the highest-emitting aged vehicles from the fleet.

Marine Transport

In the marine transport sector, only domestic marine transport activities are accounted for in the national GHG emissions inventory. Nevertheless, international maritime requirements, such as International Maritime Organisation (IMO) targets of near-term sulphur content reduction and longer-term decarbonisation are likely to have positive spillover effects in greening the domestic marine sector.

- For the international marine sector, the IMO has outlined clear targets for sulphur cap reduction in the near-term and decarbonisation goals in the long-term. By 2020, sulphur cap reduction from 3.5% to 0.5% will be required for non-emission control areas[81] . In the longer term, the focus of IMO will shift to decarbonisation, with targets to reduce fleet carbon intensity by at least 40% between 2023 – 2030, and by at least 70% between 2030 – 2050, compared to 2008 levels.

- To meet near-term sulphur cap reductions, viable options include switching from high sulphur fuel oil (HSFO) to low sulphur fuel oil (LSFO), marine gas oil (MGO), Maritime Diesel Oil (MDO) or installing scrubbers. However, switching away from petroleum products will be needed to decarbonise the sector. Options such as LNG bunkering represent attractive medium-term decarbonisation solutions, but other zero carbon fuels, such as next generation biofuels and e-fuels (e.g., e-ammonia, e-methanol), will be required to meet long-term ambitious decarbonisation targets.

- Whilst IMO regulations only apply to international marine transport, domestic marine sector spillovers are expected as low carbon fuels gain in cost competitiveness, compared to incumbent petroleum-based fuels. Incentives through green port policies will also catalyse the shift of the domestic maritime sector towards cleaner fuels. Moreover, as corporates set decarbonisation targets, such as Scope 1 targets by logistics or marine players, or Scope 3 targets by Oil and Gas players, pressure will be exerted on the marine sector to decarbonise.

Aviation

Similar to marine transport, international aviation decarbonisation requirements, as defined through Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)[82] are expected to have positive spillover effects to the domestic aviation sector, especially in relation to aviation energy efficiency and input fuels.

- The main reference point for aviation sector decarbonisation is the UN ICAO's CORSIA. CORSIA aims to reduce GHG emissions from airline operations by 590 Mn to 800 Mn of emissions by 2040. Over 80 countries have already pledged to participate in the voluntary pilot programme, including Malaysia, ahead of mandatory enforcement in 2027.

- Mature levers to decarbonise aviation include enhanced air travel efficiency with enhanced aircraft design, infrastructure improvements, and aviation operation improvements to reduce fuel consumption. On the consumer side, demand-side management and reduced air travel are also key emission reduction levers.

- In the medium to long-term, fuel switching to cleaner energy sources will likely gain momentum. This includes next generation biofuels or synthetic fuels, and potentially to even more nascent technologies, such as electric or hydrogen planes. Selected airports globally have started to blend biofuels into jet fuels supplied through the airport, encompassing both domestic and international flights, in order to enhance the scale of operations.

- Given Malaysia-specific advantages in biofuels production, demand from a combination of domestic and international aviation can support the scale-up of sustainable jet fuel production, including from emerging sources such as algae, to spur commercially-viable new green growth and to decarbonise the aviation sector.

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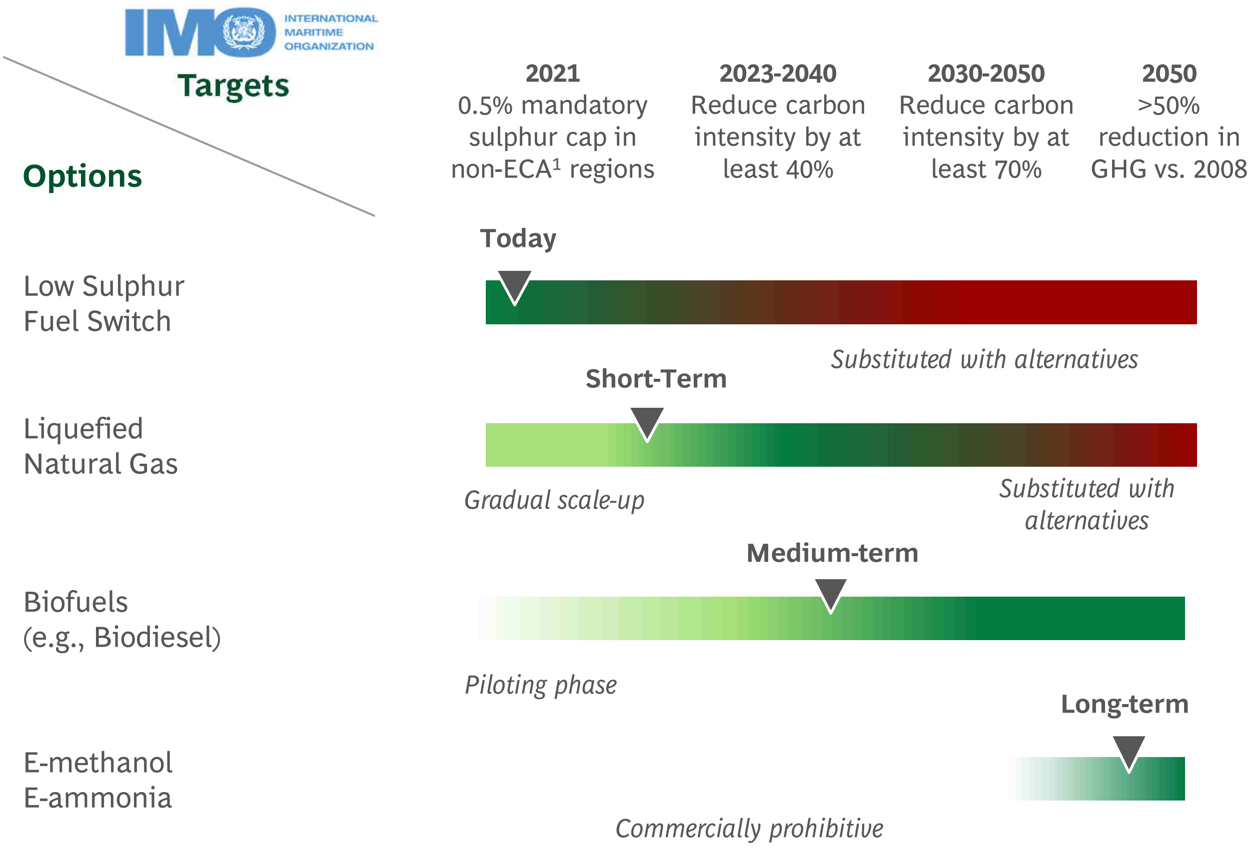
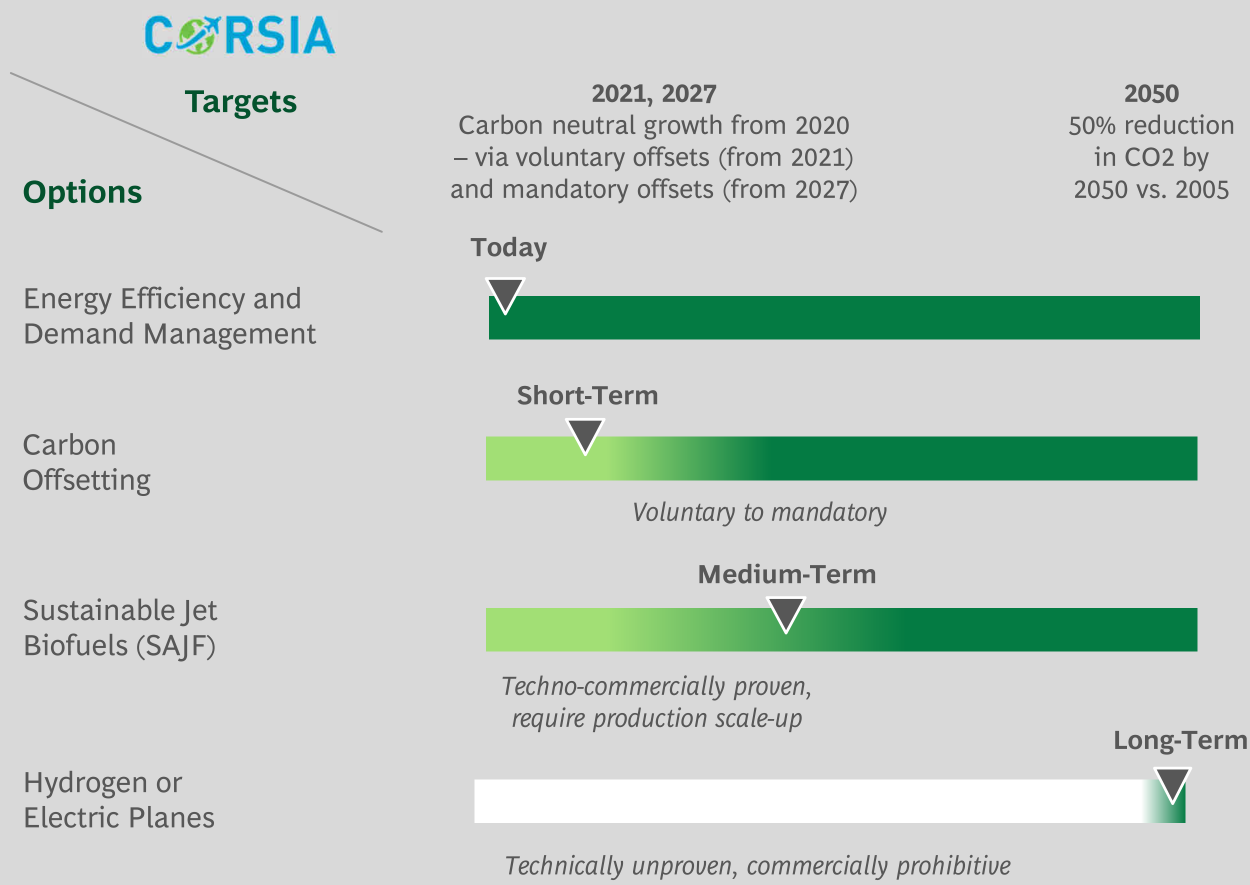
81. International Marine Organisation (2020). IMO 2020 – cutting sulphur oxide emissions
82. ICAO (2021). Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)





1. Reduction from 3.5% to 0.5% sulphur cap in non Emission Control Areas
Source: IMO, CORSIA, Project Team Analysis

Overview of potential abatement levers

Description of abatement lever categories

A range of abatement levers were considered to develop alternate net GHG emissions pathways to the current trajectory, specifically for the light vehicle segment. These levers build on strong current efforts and plans, to drive emissions reduction in the transport sector.

- **Increasing public transport modal shares**

  Building on progressive ambitions to achieve 40% public transport modal share in urban areas by 2030, public transport modal shares can be further increased over time to reduce emissions, enhance mobility affordability, and ease road congestion. Development of public transport infrastructure to support enhanced network reach and integration, last-mile connectivity, and service reliability, will be critical to shift consumers towards public transport. With one of the highest car ownership per capita, Malaysia stands to benefit strongly in terms of mobility affordability, with large-scale shifts towards public transport.

  The Net Zero pathway outlines targets of public transport modal share of 50% by 2040, and 60% by 2050, inspired by benchmarks of global cities with similar levels of urban density. High levels of public transport penetration, deep intermodal integration across rail, bus, and other alternative transport modes will be key to achieve proposed targets. In addition, the introduction of hydrogen or electric buses can further reduce carbon emissions, as public transport scales.

- **Strengthening shared mobility and alternative transport**

  Technology solutions have a key role to augment consumer convenience and confidence in adopting shared mobility. For example, dynamic ridesharing and carpooling solutions help to match highly synergistic carpooling demand across various users in real time. This supports an increase in passenger per trip, reduce congestion and emissions, while increasing mobility affordability. In some cities, ridesharing and carpooling consist of over 40% of total trips, with an average of 3.5 passengers per trip, compared to the average of 1.3 passengers per trip in non-carpooling or ridesharing.

  Non-technology levers can also support shared mobility and carpooling, through dedicated high-occupancy vehicle lanes, as seen in selected cities in Australia and New Zealand; or incentives for clean work commutes, including carpooling, as seen in selected states in the United States. Beyond passenger vehicles, shared micro-mobility solutions (e.g., bicycle-sharing), can also support the scale-up of alternative transport. However, this has to be supported by city planning measures to accommodate alternative transport, such as bicycle lanes.

  In the long-term, solutions such as shared autonomous electric vehicles (SAEVs) should be explored, given the large potential of these solutions to bring down the costs of shared mobility. Initial studies indicate that SAEVs have the long-term potential to reduce costs by up to five times of Internal Combustion Engine (ICE) rideshare costs.

- **Enhancing fuel economy**

  To comply with the ASEAN fuel economy roadmap target[83] , improvements of fleet fuel economy by 8% between 2020-2025 and 4% between 2025-2030 will be required. To phase out low fuel economy vehicles, schemes to incentivise end-of-life scrapping of low fuel economy vehicles, such as offering rebates on subsequent vehicle purchase, can be adopted. In parallel, Minimum Efficiency Performance Standards (MEPS) and mandatory energy labelling will promote strong fuel economy in new cars sales.

  Beyond light vehicles, driving fuel economy improvements in the heavy vehicle segment is equally critical. Whilst fuel of the future powertrains will quickly become commercial in the light vehicle segment, the runway for heavy vehicles is expected to be longer, increasing the importance on fuel economy in supporting emissions reduction.

83. Global Fuel Economy Initiative (2021). ASEAN countries begin process of implementing fuel economy roadmap

- **Scaling-up electrification of the light vehicle fleet**

  Shifting from ICE vehicles to EVs which offtake power from clean energy sources represents one of the most important decarbonisation levers to achieve the country's Net Zero ambitions. Moreover, with rapid technological improvements in battery technology and economies of scale in production of EVs, the switch between ICE to EV is expected to be highly commercially viable for consumers by the end of the decade, even without EV subsidies or carbon pricing.

  The rapid shift in EV economics is driven by global megatrends in policy, technology, and competition:

  From a policy perspective, country and city bans on both new sales and vehicles on road have accelerated, with many committing to bans in the 2030-2050 period. Countries have also stepped-up vehicle emission standards and consumer incentives to accelerate consumer take-up of EVs.

  From a technology perspective, the rapid decline in battery technology costs are driving steep reduction in EV costs. Batteries comprise between 30-40% of total EV costs, and the cost of batteries are expected to decline by 40-60% by 2030 from current levels. Moreover, technology advancements in EV electronic components manufacturing, as well as enhanced driving range and reduced battery sizes, are increasing the range of electric powertrain applications.

  From a competition perspective, major OEMs have announced the phase-out of ICE vehicles between 2025-2035 to enhance focus on EVs and other powertrains of the future, which are experiencing rapidly growing demand. Hundreds of electric vehicles are expected to enter the market by 2025 along the full spectrum of price points, providing consumers with extensive choices during new vehicle purchases.

  The rapidly improving economics of EVs are also catalysing demand, leading to economies of scale in manufacturing, supply chains, and even charging infrastructure build-out. Through a combination of these factors, the economics EVs will reach "tipping points" with ICE vehicles, where EVs will be cheaper on a 5-year total cost of ownership (TCO) basis, compared to EVs within the 2025-2030 period in most countries.

  Based on Malaysia-specific factors, such as fuel input costs (e.g., petrol prices, potential EV charging tariffs), local manufacturing costs and import content, tax rates, and other factors, the TCO inflection points for Malaysia was estimated. Even without any subsidies for EVs, the 5-year TCO of EVs will be lower than ICE by 2030. By 2035, the 2-year TCO of EVs will be lower than ICE, and by 2039, the 1-year TCO of EVs will be lower than ICE.

  > ***By 2030, the 5-year total cost of ownership of EVs will be lower than ICE vehicles. In the early 2040s, the vehicle purchase cost of EVs will be lower than ICE vehicles.***

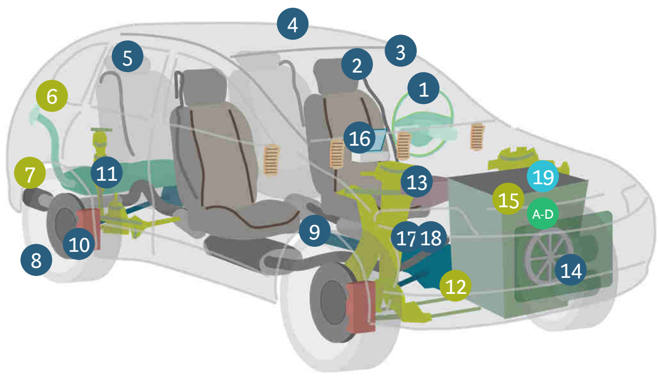
  With strong pre-requisite enablers for EV penetration, EV share of new car sales have the potential to reach 20% by 2030, 50% by 2035, and above 80% by 2040, even without demand-side incentives, based on global consumer vehicle purchasing behaviour. Supported by consumer incentives to accelerate EV take-up, ICE vehicles will be phased out from new car sales by 2040, and eventually across the fleet of vehicles towards 2050, based on natural vehicle replacement cycles, in the Net Zero 2050 pathway. For motorcycles, the economic tipping points which encourage switching from ICE motorcycles to electric motorcycles will occur before passenger cars. For example, the Indonesian government has established plans to phase out new sales of ICE motorcycles by 2040 and ICE vehicles by 2050[84] , reflecting the relative economics of electrification between 2-wheelers and 4-wheelers.

84. Reuters (2021). Indonesia aims to sell only electric-powered cars, motorbikes by 2050.

Figure 49: Component comparison and cost structure breakdown

EVs with fewer components, with battery the largest cost driver

Components of an ICE, Hybrid & BEV vehicle



Traditional components
- Common components
- ICE specific
- Hybrid specific

Emerging components
- BEV specific

Average component costs

Common Components
1. Steering ~$280
2. Passenger Restraints ~$350
3. Body Glass ~$150
4. Body & Structural ~$2,500
5. Interior ~$1,200
8. Wheels & Tires ~$270
9. Axles & Driveshafts ~$850
10. Braking ~$330
11. Suspension ~$490
13. Electronics ~$1,700
14. Climate Control ~$710
16. Audio & Telematics ~$310
17. *ADAS* *~$160*
18. *Software* *~$500*

ICE Specific
- 6 Fuel System ~$360
- 7 Exhaust ~$300
- 12 Transmission ~$1,400
- 15 IC Engine ~$2,700

ICE: $~14.5k/vehicle

Hybrid Specific
- 19 Add. Powertrain ~$1,300 (MHEV) ~$ 5,000 (PHEV)

HEV: $~16k–22k/vehicle

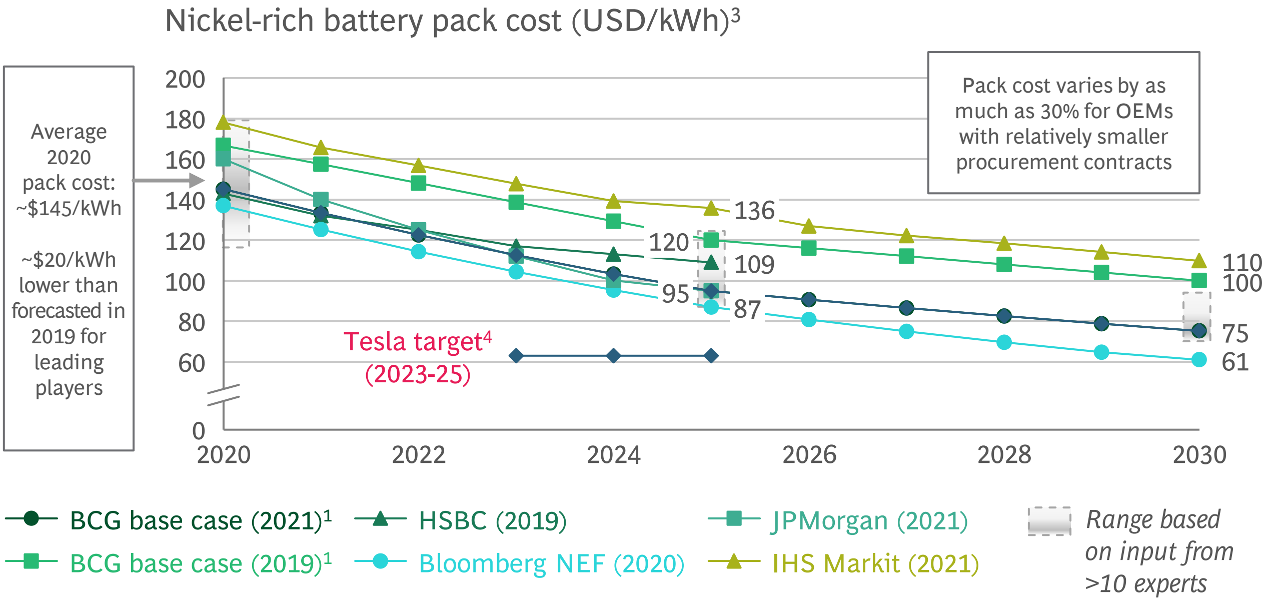
BEV Specific
- A Electric Motor ~$1,600
- B Battery Pack ~$9,000[1]
- C Power Electronics ~$2,000
- D Add. Parts ~$3,000

BEV: $~24k/vehicle

ICE = Internal Combustion Engine Vehicle; xEV = Electric Vehicles
1. Based on a capacity of 60kWh
Source: Merrill Lynch, UBS, Project Team Analysis

Figure 50: EV battery cost evolution projections

Battery costs expected to fall by 40-60% by the end of the decade

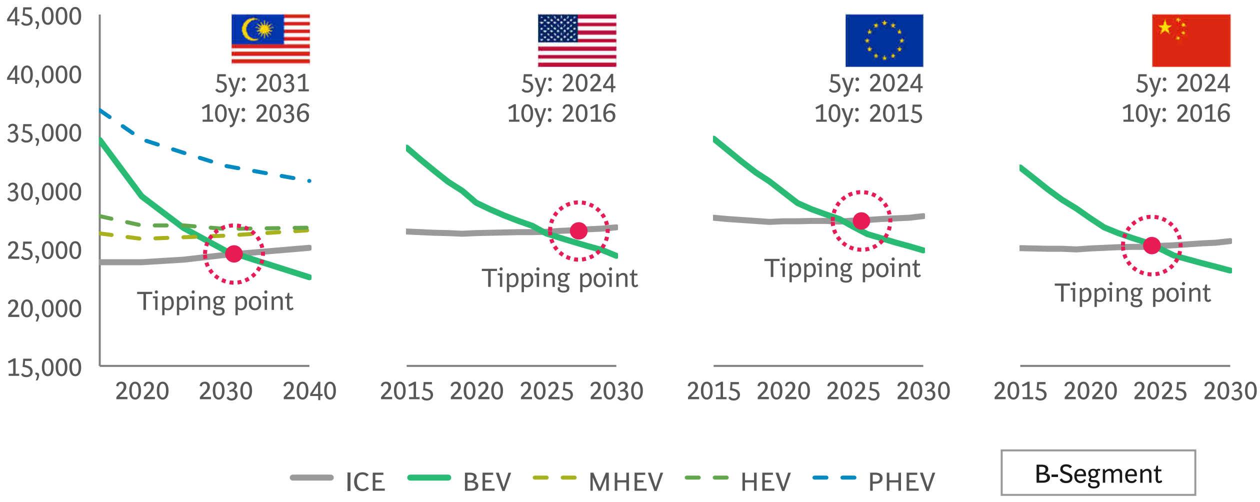


1. BCG forecast for automotive-grade BEV/Pouch cells, produced at automotive scale (>10 GWh/yr), and using the known innovation roadmap for NCM chemistry; different cell and pack designs, production scale, or chemistries will drive different costs 2. Cell cost is cost for OEM to procure, incl. cell mfgr. costs 3. Battery pack cost is cost for OEM to procure, includes BMS, BTM, housing, etc., 4. Limit assumes BEV/Cylindrical cells 5. Limit assumes volume-weighted average of different cell chemistries
Sources: Project Team Analysis and forecast; expert interviews; analyst reports (UBS, HSBC, Bloomberg New Energy Finance)

Figure 51: Total cost of ownership inflection points between ICE and EV vehicles

EVs in Malaysia will have lower 5-year TCO than ICE by 2030

5-year Total Cost of Ownership (USD)

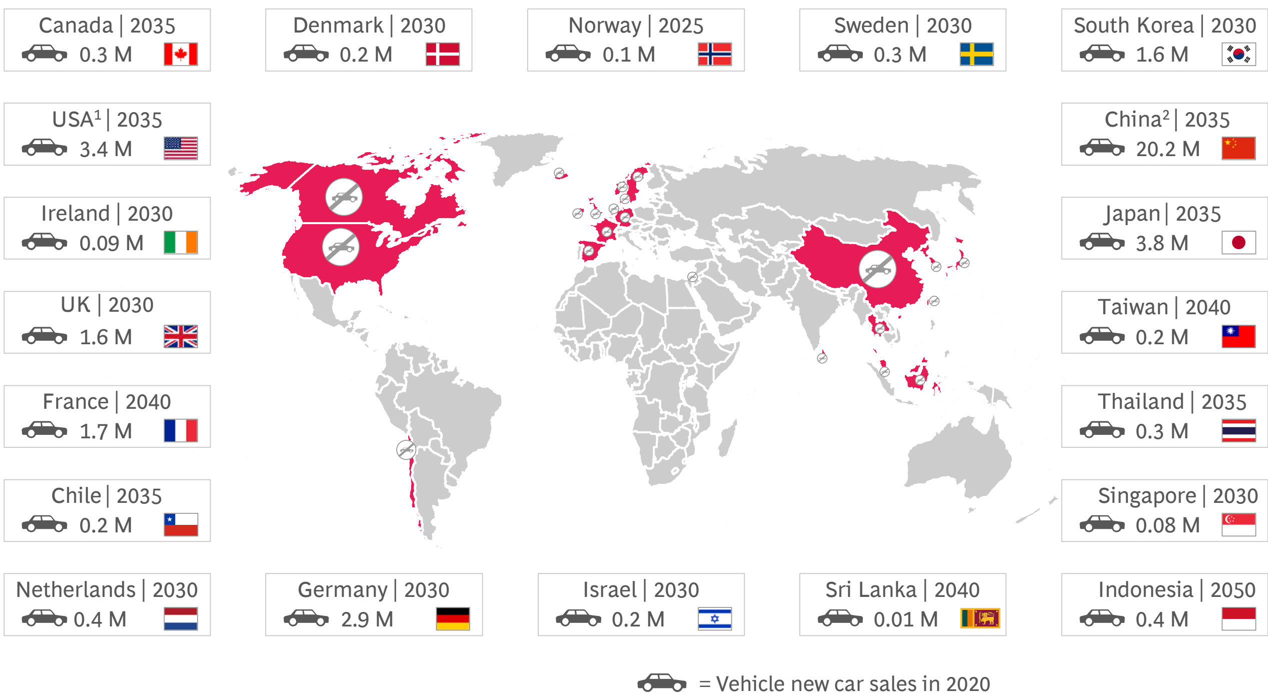


1. Assumptions for Malaysia: No subsidies, no payments received through vehicle to grid scenario, fuel price at RM 2.00 per litre in baseline, electricity price at RM 0.57 per kWh, same base price of vehicle for China is assumed for Malaysia, sales tax at 10%; Conversion rates used – USD:EUR at 1.13, USD:RMB at 0.14, USD:MYR: 0.23; EIA Technical Assessment Report (TAR) Battery costs are assumed as base case for all scenarios; Fuel price per litre at RM 3.04 (US), RM 6.71 (EUR), RM 4.13 (CHI); Electricity price per kWh at RM 0.56/kWh (US), RM 0.95/kWh (EUR), RM 0.34/kWh (CHI); Annual distance travelled for Malaysia at 28,000 km; Cost of maintenance considered in a scenario where no local EV manufacturing is present
Source: U.S. Energy Information Administration (EIA), BCG Analysis (Future of Powertrain)

Figure 52: Country bans on ICE vehicles to shift global demand towards EVs

Country bans on new car sales or on-road ICE vehicles to further catalyse lowering of EV costs, as economies of scale are reached

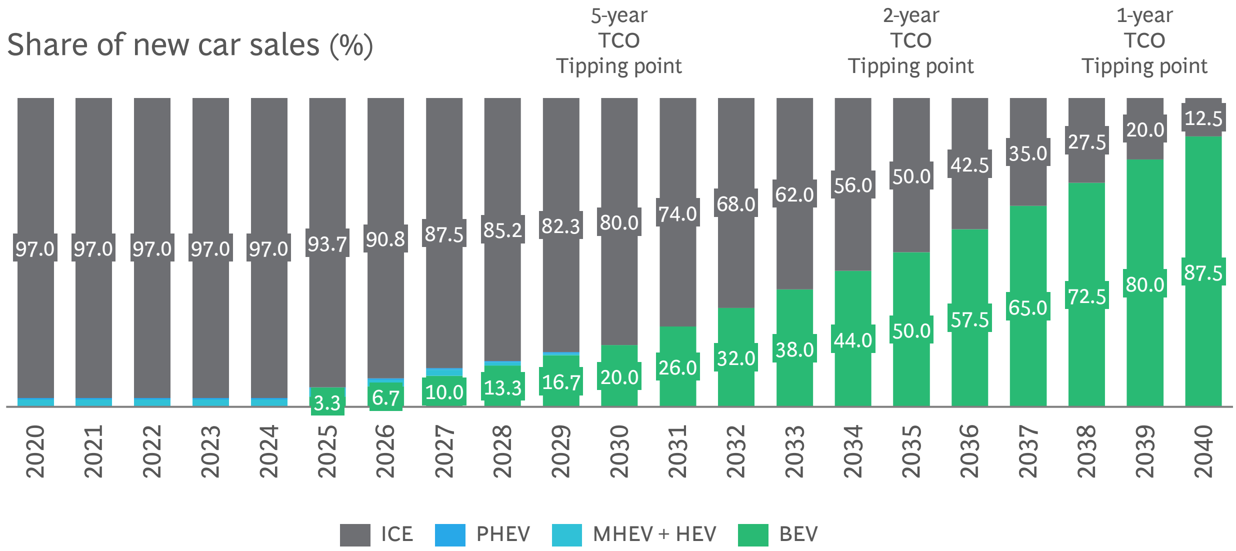
Year of ICE light vehicle new car sales bans across major cities and countries



1. Plug-in hybrids allowed , 2. Plans committed or being considered 3. Ban on traditional ICE vehicles, hybrids allowed
Source: Country Policy Announcements, Press Searches, Reuters, Morgunblaðið, The Driven, Charged , World Economic Forum, Taiwan News, CNN , Green Car Reports, Spiegel, RTL Nieuws, BBC, S&P Global Patts, Forbes, R&T, The Straits Times, OICA

Figure 53: Impact of total cost of ownership inflection points on new car sales of EVs

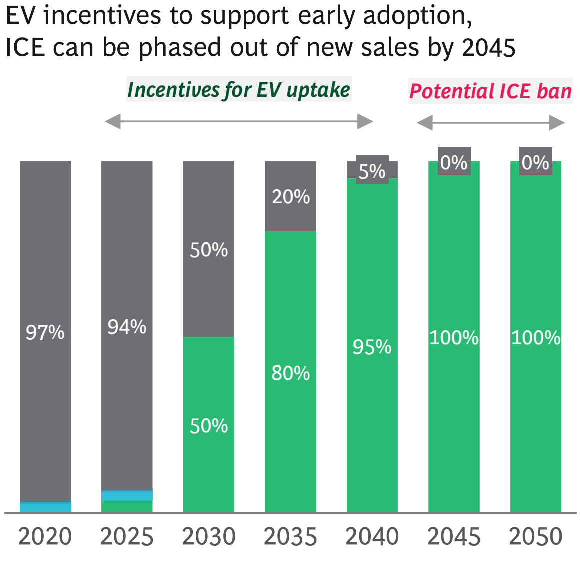
20% of new car sales can be EVs by 2030 and >85% by 2040 based on natural economics, even without consumer incentives

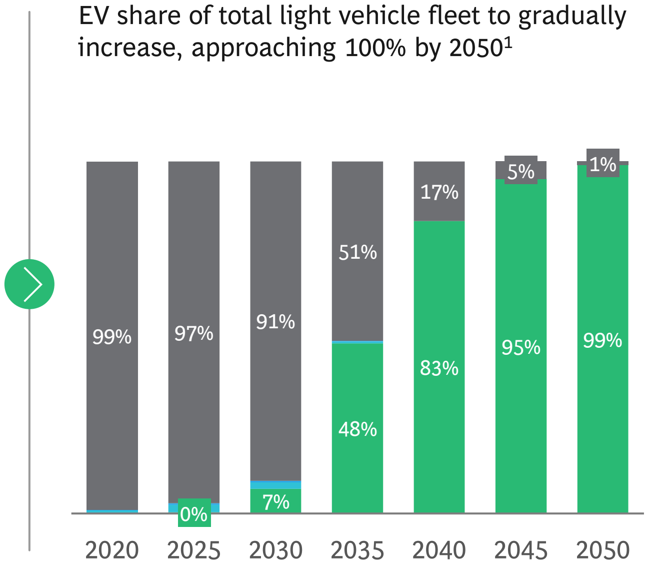


1. PHEV = Plug-in Hybrid Electric Vehicle, MHEV = Mild Hybrid Electric Vehicle, HEV = Hybrid Electric Vehicle; EV Penetration rates of new car sales are based on a scenario where lawmakers and automotive players actively push for the EV agenda in Malaysia (e.g., incentives, sufficient EV charging infra, development of locally produced EVs); Modelled based on B-Segment vehicles
Source: Project Team Analysis

Figure 54: Net Zero 2050 new car sales and fleet penetration of EVs, with government incentives

Net Zero 2050: EVs to penetrate close to 100% of total vehicle fleet with adoption incentives and new ICE vehicle car sales by 2045





1. Assumes ICE vehicles have a 10-year useful life on average 2. Incentives of 10% of vehicle costs from 2025 to 2032 and incentives to achieve 1-year TCO cost equivalence between ICE and EV between 2033 to 2039 (gradually decreasing over time). Costs of incentives / subsidies have been incorporated into Net Zero 2050 pathway investment costs
Source: BCG Global Powertrain Model with country customisation

- **Strengthening enablers to accommodate EV adoption**

  To accommodate timely EV take-up and to realise spillover socioeconomic benefits from EV adoption, enablers which unblock barriers to consumer adoption, capture industry growth opportunities, and safeguard against downside risks will be required.

  Unblocking barriers to consumer adoption

  Based on Malaysia-specific consumer surveys, the largest barrier to consumer adoption of EVs is the lack of charging infrastructure. Timely build out of charging infrastructure networks, with the right balance of charger types and distribution across highways and major road arteries, in addition to optimised network of charge points at homes and workplaces, will be critical to overcome range anxiety of consumers. In early stages of adoption, the role of public sector will be key to establish foundational infrastructure before these investments are attractive to private investors, due to the lack of scale. Over time, transition to public-private partnership and eventually to private sector infrastructure build-out will be needed to sustainably scale-up charging infrastructure across the country.

  In addition, policies and regulations for charging infrastructure interoperability, EV data usage and platforms, as well as safety standards which safeguard consumer interests will also be required. Over time, as the economics of EVs improve, barriers which may delay economic "tipping points" of EVs relative to ICE vehicles should be reviewed, such as fuel subsidies which artificially lower the TCO of ICE vehicles.

  Capturing industry growth opportunities

  To unlock strong GDP and job opportunities from ICE to EV megatrends, timely transition of the domestic automotive sector is needed. This will require timely build up of local EV manufacturing and supply chain capabilities, workforce reskilling for EV-specific requirements, and investments to ensure fit-for-purpose facilities for EV manufacturing. Developing a strong domestic EV manufacturing and maintenance hub can also support reduction of EV costs for consumers and mitigate adverse trade impact from a shift to EVs.

  With regional peers announcing strong EV manufacturing ambitions, Malaysia will need to decisively transition its automotive sector to secure competitive advantage in the automotive sector. Supportive supply-side policies and fiscal incentives will be needed to grow domestic capabilities, in specific portions of the supply chain critical for EV manufacturing competitiveness. Capitalising on strengths in adjacent industries such as the electrical and electronics sector and building new capabilities at pace through international partnerships and technology transfer, will be needed to capture industry growth opportunities in an increasingly competitive market.

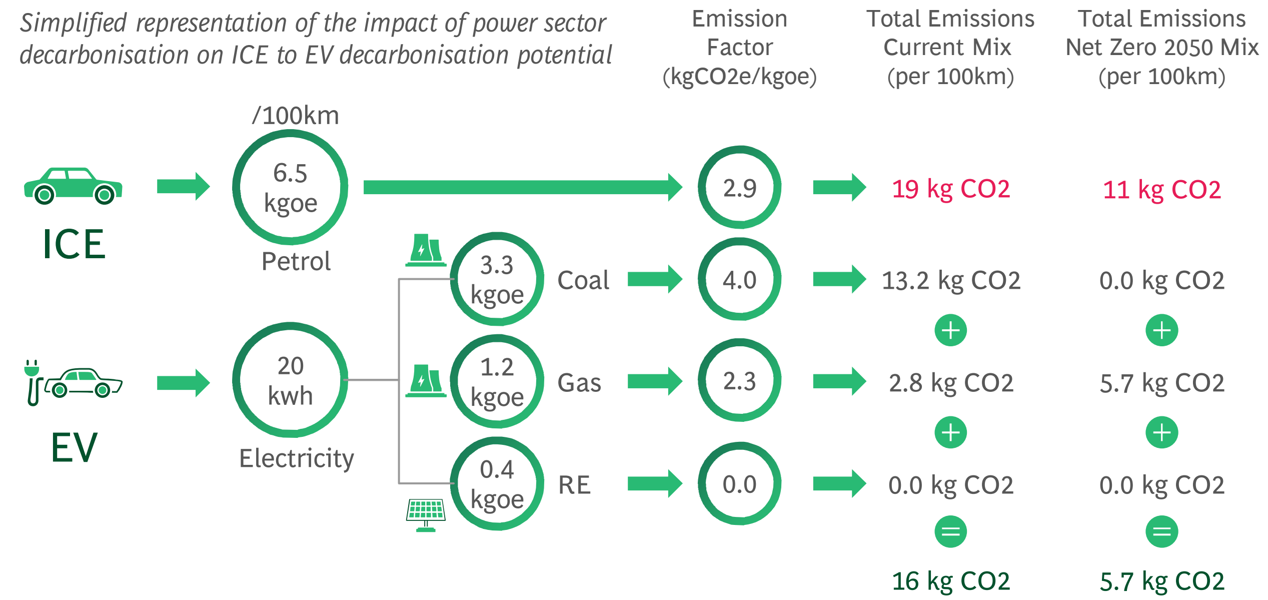
  Safeguarding against downside risks

  Advanced planning to mitigate key downside risks will also be required to ensure total socioeconomic benefits from ICE to EV transition. For example, the timely decarbonisation of the power grid and ensuring sustainable end-to-end supply chains will be critical to ensure that EV demand does not result in adverse social and environmental impact. This includes advocating strongly for sustainable social and environmental upstream practices in extractive industries for EV production, such as in battery manufacturing. In addition, ensuring strong frameworks are in place for EV component recycling or second-life use, and sustainable wastes disposal will be critical to reduce the environmental impact over the full cradle-to-grave cycle of EVs.

  Grid enablers will also be needed to support equitable scale-up of EVs. For example, uncontrolled charging behaviour risks a sharp increase of peak demand, which will come at the cost of detriment of power systems. Timely upgrades of grids to accommodate rapid chargers may also be required to avoid grid instability. By optimising power system investments, tariff structure, and other behavioural nudges, key risks in EV scale-up can be mitigated with optimised charging behaviour and facilitative power system enablers.

Figure 55: Interdependency of impact between electric mobility and power sector decarbonisation

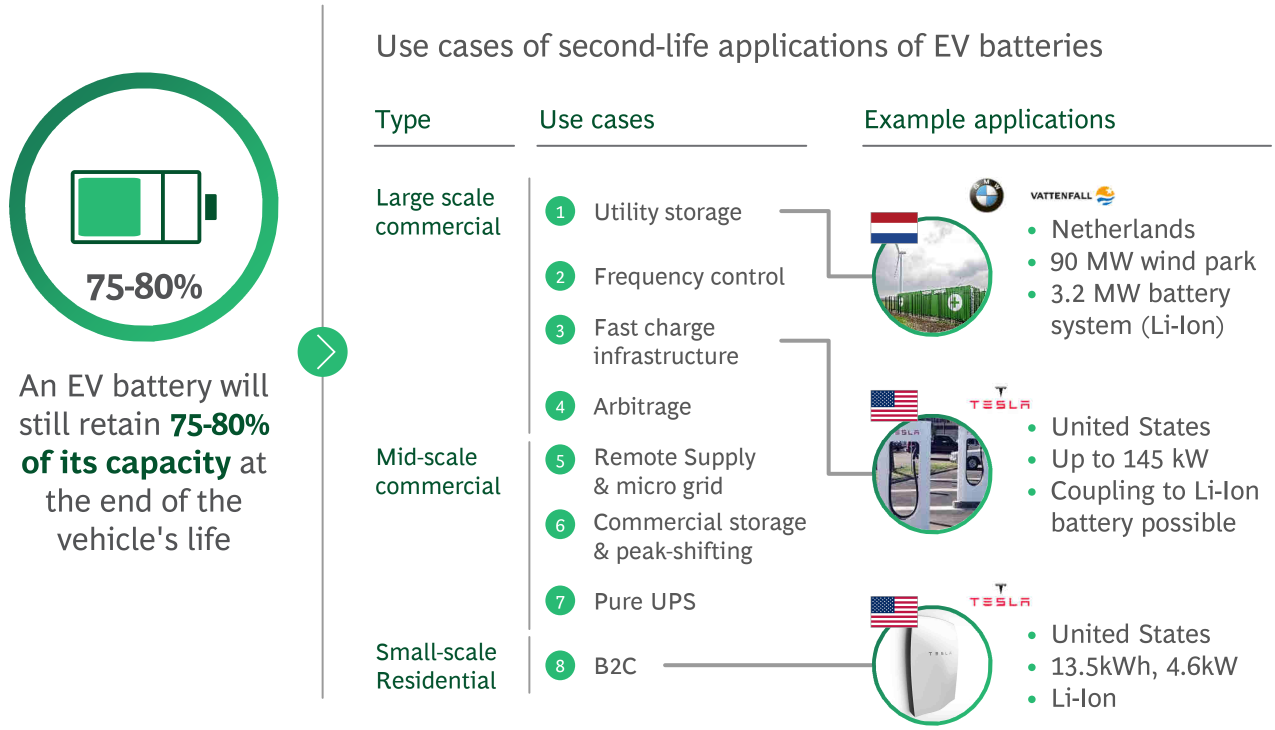
Greening of the power mix will need to be pursued in parallel to enable to maximise benefit from EVs



1. Assuming Power Plant efficiencies benchmarked against local power industry, 1 kgoe = 11.63 kWh, based on capacity mix of ~46% coal , ~38% gas, ~16% RE in 2020, 0% coal and ~44% gas and ~56% RE in 2050 2. Simulation representative of potential Peninsular Malaysia impact
Source: Single Buyer, MGTC, ASEAN Fuel Economy Roadmap, IPCC, Project Team Analysis

Figure 56: Second-life use options of EV batteries following vehicle end-of-life

Electric Vehicle batteries have significant second-life potential as Energy Storage Systems (ESS), with many case examples



Source: ICCT; IHS; Press Searches and Project Team Analysis

Figure 57: Factors influencing consumer vehicle purchase decisions

Charging infrastructure is the main barrier towards BEV take-up

Survey inquiring on consumers greatest concern in purchasing all battery-powered electric vehicles

#1 Lack of charging infra 33%

#2 Safety concerns 19%

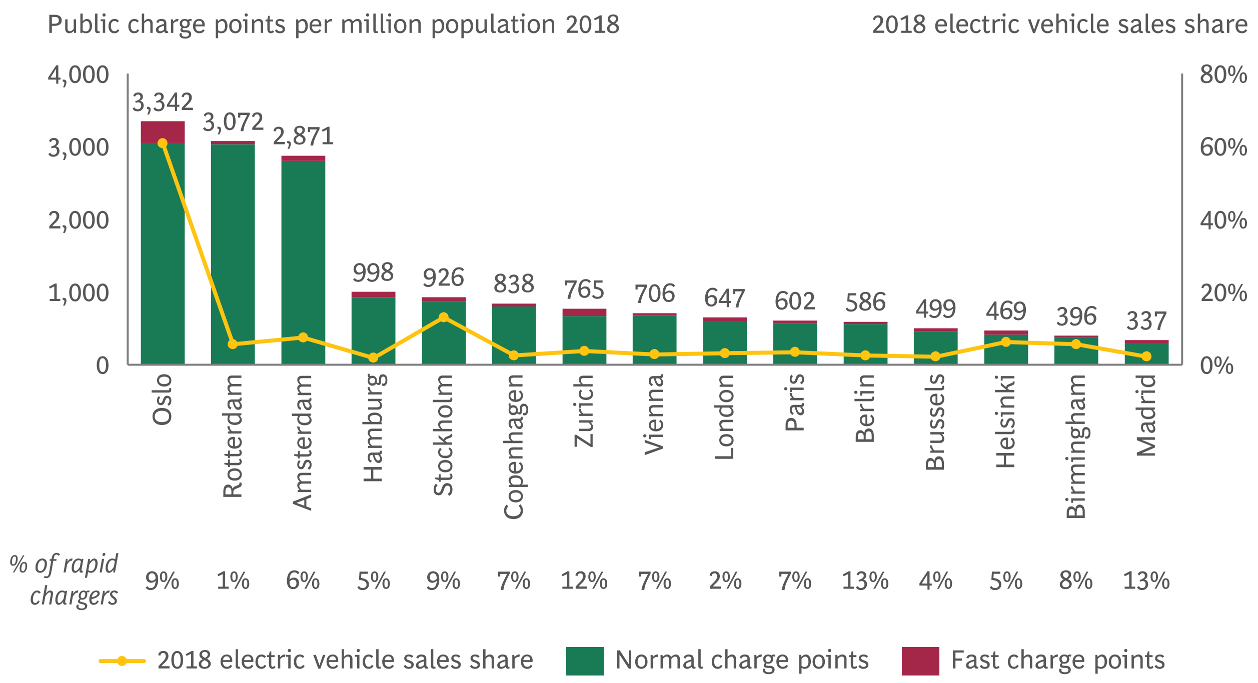
#3 Cost/price premium[1] 16%

Concern	Indonesia	Malaysia	Philippines	Singapore	Thailand	Vietnam
Lack of charging infra	39%	35%	31%	34%	19%	38%
Safety concerns	12%	18%	24%	18%	19%	22%
Cost/price premium	11%	21%	13%	20%	18%	12%
Time required to charge	15%	11%	12%	14%	16%	18%
Driving range	22%	12%	17%	10%	24%	7%
Lack of choice	1%	3%	3%	4%	4%	3%
Other	0%	0%	0%	0%	0%	0%

1. By 2030, the 5-year total cost of ownership of BEVs is expected to be comparable with Internal Combustion Engine, representing a key inflection point 2. Survey sample size of n > 1000 for each Southeast Asian market
Source: Deloitte 2021 Global Automotive Consumer Study

Figure 58: Volume of charging infrastructure required for initial EV take-up

500-1000 public charge points per million population to spur early take-up of EVs, with rapid chargers are less than 10% of all chargers



Source: International Council On Clean Transportation: Analysing Policies To Grow The Electric Vehicle Market In European Cities (2020)

A range of abatement levers were considered to decarbonise the heavy transport sector. Similar to the light vehicle segment, this includes levers such as optimising modal shares, enhancing fuel economy, and implementing emission reducing fuel switching:

- **Optimising rail-based freight modal share**

  In 2017, rail freight comprised 2.2% of total freight modal share, with road freight transport being the dominant form of goods movement with 97.5% modal share[85] . Upcoming projects, such as the East Coast Rail Link (ECRL) and others, are expected to uplift the rail freight modal share to approximately 5% by 2030.

  Rail-based freight modal share increases can result in strong improvements in emissions, whilst also reducing congestion on major highway arteries of the country. As a point of comparison, the rail freight modal share in Europe has been stable at around 17-20% over the last decade. Given the broader considerations of rail-based investments and modal share increase, further increases from 5% modal share were conservatively not considered for the study's climate pathways. However, this should be explored in depth, factoring in impact on emissions reduction, road decongestion, logistics demand requirements, and total investment costs.

- **Enhancing fuel economy**

  Current fuel economy of heavy transport is estimated to be around 14.35 Lge / 100km, with historical annual improvements of fuel economy averaging 0.5% improvement per annum. Whilst the ASEAN Fuel Economy Roadmap[86] set out targets for fuel economy for the light vehicle segment, there is limited national or regional guidance on targets for fuel economy in the heavy vehicle segment. Reflecting the importance of enhancing fuel economy not only for light vehicles, but also for heavy vehicles, fuel economy improvements of 3% per year is estimated for the heavy transport sector.

  In addition, various behavioural changes can also be adopted to reduce fuel consumption, such as eco-driving to conserve fuel per kilometres travelled. It is estimated that light commercial vehicles and heavy commercial vehicles have an annual distance travelled of approximately 20,753 kilometres and 79,400 kilometres, respectively. The increased awareness of eco-driving behaviours, supported by technology solutions such as central monitoring and algorithm-based assessments of individual driver eco-driving adherence can be a key lever in promoting fuel efficiency in the heavy transport sector.

- **Optimising biodiesel blending limits**

  Building on the roll-out of B20 biodiesel for heavy transport expected in the coming year, biodiesel blending with sustainable bio-based feedstocks can further decarbonise the heavy transport sector. As a reference, Indonesia, which shares the similarity of using palm-based biodiesel feedstocks, has implemented B30 biodiesel blending in 2020, and is planning for B40 biodiesel blending by the mid-2020s. Trials on higher biodiesel blends such as B100 are also being conducted to assess the impact on vehicle engine condition and performance.

  In the Net Zero 2050 pathway, an increase from B20 to B30 in Malaysia is assumed. One of the inhibiting factors for high levels of biodiesel blending is the abatement cost, which is directly influenced by the palm oil – gas oil (POGO) spread. Over the past 5-years, the POGO spread has averaged around USD 140 per tonne, which is indicative of a cost premium of biodiesel over diesel. Based on average POGO spreads, a B30 biodiesel program based on current volumes equates to either RM 1.1 billion of fiscal subsidies, or a RM0.06 retail diesel price increase for consumers. Given the financial outlay, further increase beyond B30 was not adopted. However, this may change with increased commercial viability of biodiesel, relative to the incumbent petroleum products based on shifts in POGO spread economics over time, reduction in supply aggregation costs, or with bio-based feedstock breakthroughs (e.g., algae), which decouple the POGO spread trade-offs with alternative cost competitive sources of biofuels.

85. Ministry of Transport (2019). National Transport Policy 2019-2030
86. Global Fuel Economy Initiative (2021). ASEAN countries begin process of implementing Fuel Economy roadmap

- **Tracking developments in fuel of the future powertrains**

  In contrast to the light vehicle segment where the electric powertrain is emerging as the predominantly accepted fuel of the future, various fuels of the future technologies are in competition for the heavy vehicle segment. This includes hydrogen fuel cell trucks, natural gas trucks (including Liquefied Natural Gas and Compressed Natural Gas trucks), and electric trucks.

  Based on current technologies, each of these solutions are not fully commercially competitive yet against the incumbent diesel powertrains and have various trade-offs. For example, electric and CNG powertrains currently have relatively lower average driving range, reducing the attractiveness for long-distance transport. Between hydrogen and LNG trucks, there is a trade-off between cost and emissions. Hydrogen trucks represent zero carbon emission options, with the use of blue or green hydrogen, but at significantly higher costs, when factoring in hydrogen fuel cell truck vehicle costs and the required hydrogen infrastructure build-out. Developments in various technologies will need to be tracked, and future decisions made on the focus fuel of the future for the country in due course, with better visibility on the commercial viability of each future powertrain option as technology progresses.

Figure 59: Comparison across potential heavy vehicle powertrains across range of dimensions

Trade-offs between competing future heavy vehicle powertrains

Powertrain	Range per refuel	OPEX (Fuel and Maintenance)	CAPEX (Vehicle Purchase Costs)	Fuelling Infrastructure	Tank-to-wheel CO_2 emissions
Diesel	1000–3000 km (average range of 1500 km)	~RM 50k/ year for maintenance and ~ RM 95k/year for fuel costs[1]	~RM 250k for cost of heavy vehicle (above the 15,000 kg category)	Well-developed refuelling infrastructure network	~135 $MtCO_2$ per year per truck[6]
LNG	Up to 1600 km (average range of 650 km)	~15% higher maintenance cost[2]; Fuel cost parity if LNG price ~70% of diesel[3]	~40–50% higher in upfront vehicle costs, but rate of tech progress lower than fuel cell	Infrastructure remains limited, but tech is mature (pipelines, VPS)	~115 $MtCO_2$ per year per truck[7]
Hydrogen	Up to 1200 km (average range of 625 km)	~17% lower maintenance cost[2]; ~ 60% higher fuel cost in 2020 improving to ~ 3% lower fuel cost vs. diesel in 2040[4]	1.7x higher cost, but cost reduction of ~15% p.a. based on fuel cell system and battery cost reductions; reaches parity in 2040	Highly costly build out of hydrogen transport and refuelling infra required	No direct GHG emissions produced (for green or blue hydrogen)
CNG	500 – 1000 km	Less popular due to shorter driving range; heavy vehicles typically used for long distance of 200 - 750km/day[8]			
Electric	400 – 800 km				

Legend
High relative advantage of fuel — Low relative advantage of fuel | Current position (2020) → ← Future position (2040)

1. Considers average fuel economy of 32 L/100km, annual distance travelled at 160,000 km and baseline price of diesel at RM 2.00, 2. Annual maintenance cost per truck according to powertrain: Diesel at ~ RM 48,000, LNG at RM 56,000, Hydrogen at RM 14,500, 3. Actual ratio of fuel cost varies by LNG and diesel market prices; due to Malaysia's low diesel prices, LNG cost parity with diesel is rarely achieved according to historical estimates, 4. Dependent on evolution of H2 prices according to production type (e.g., grey, green) and H2 transportation costs, 5. Tank to wheel CO2 emissions considered at point where energy is absorbed (fuelling station) to discharge of energy (on the road), 6. Diesel CO2 emissions considers average distance, fuel economy, CO2 emissions factor as guided by the 2006 IPCC guidelines (3,100 tonne per ktoe), 7. LNG CO2 emissions considered to emit ~ 15% less CO2 than diesel powertrains according to Iveco and Scania, 8. May be overcome with emerging technologies on hybrid CNG-electric heavy vehicles 9. CNG = Compressed Natural Gas, LNG = Liquefied Natural Gas
Source: Energies Journal, Expert Interviews, Oxford Energy, Project Team Analysis

Enhancement in supply feedstocks can benefit decarbonisation across multiple transport end uses, from road transport to marine transport, and aviation. One such example is sustainable biofuels, which are expected to have a key role in driving decarbonisation in the transport sector.

- **Scaling up sustainable biofuels**

  Initiatives to scale up sustainable biofuels adoption across demand sectors will be critical. This includes-maturing biofuel solutions for shipping and aviation, which is currently in its nascency, as well as improving economics of biodiesel blending in heavy transport, based on bio-based feedstocks suitable for Malaysia's specific context. There are a wide range of potential production pathways to produce biofuels which have unique economics, feedstock requirements, and fuel quality outputs, which need to be assessed to ensure optimal end use adoption of biofuels.

  Spurring new sources of bioenergy feedstock can unlock large potential benefits in terms of bioenergy cost competitiveness and long-term sustainability. Malaysia's biofuel production predominantly derives from first-generation biofuels. To enhance the long-term sustainability of biofuels with increased demand, increased focus on developing second and third generation biofuels will be needed.

  For second-generation biofuels, the use of selected agricultural waste in line with circular economy principles for bioenergy production or solutions can bring about new revenue streams and reduce food versus fuel and land trade-off impacts of first-generation bioenergy. Efforts to improve the cost of aggregation, select suitable second-generation feedstocks, and enhance the commercial viability of biofuel production along the value chain will be needed.

  For third-generation biofuels, crude algae oil is a high potential bioenergy source, which has been in development for an extended period, but has been historically inhibited by low commercial viability and high process energy intensity. However, technology developments and innovative breakthroughs have enabled the significant improvement in commercial viability and the energy intensity of production. For instance, coagulants are used to reduce the need for energy-intensive drying processes.

  Supporting the scale-up of sustainable third-generation biofuels such as algae, can unlock the potential of cost-competitive biofuels, with large improvements in the lifecycle environmental impact. This is because algae oil does not compete with food production, reduces resource impact with the use of sea water instead of freshwater, uses non-arable land, and produces greater carbon absorption impact over trees during the growth process.

  One key benefit of biofuel adoption compared to other low carbon alternatives is that bioenergy solutions represent drop-in fuels which can be scaled quickly, with limited changes or investments into infrastructure for fuel delivery, in contrast to electric or hydrogen solutions. Moreover, with proprietary domestic technologies and strong natural endowments such as year-round solar irradiance, Malaysia is well-positioned to capture early mover advantage from algae bioenergy production scale-up.

  Currently, the decarbonisation impact of crude algae oil has not been embedded into the current GHG emissions pathway, due to the strict criteria and need for established and proven at-scale reference examples for abatement levers to be considered. However, the game-changing potential of algae bioenergy is recognised, and can be incorporated into the pathway, replacing other higher cost abatement levers, with proven at-scale implementation and detailed assessments to verify the lifecycle emissions impact, abatement costs, and broader environmental impact benefits.

Box 4 | Description of various generations of bioenergy feedstock

There are currently four generations of biofuel, which are primarily differentiated by the source of feedstock. The four generations of biofuel vary in terms of technical maturity, commercial viability, and environmental impact, particularly on land use and water resource impact. A brief description of each biofuel generation is summarised below:

- First-generation biofuels, such as biodiesel or bioethanol, are produced from food crops grown on arable land, through the transesterification or yeast fermentation process. This includes biofuel production from crude palm oil in Malaysia.
- Second-generation biofuels are produced from lignocellulosic or woody biomass feedstock and agricultural by-products, residue, and waste. Examples include palm oil agricultural waste, jatropha, waste vegetable oil, and municipal solid waste.
- Third-generation biofuels, such as algae, are high-yield biofuels produced from non-food sources with high carbohydrate and lipid content, fast growth rate, and does not require arable crop lands or freshwater to produce biofuels.
- Fourth-generation biofuels derive from genetically engineered microorganisms, such as cyanobacteria, is used as catalysts to enable the direct production of high-yield and high-quality fuel from solar energy, with minimal land use impact.

Case Study 4 | Innovative algae biofuel production by Next Generation Oil Group

Next Generation Oil Group (NGOG) is a Malaysian-based company involved in the production of crude algae oil (CAO), derived from micro-algae which contains high levels of energy-rich oils, and uses carbon dioxide in its cultivation process, making it carbon neutral.

NGOG has developed its patented A-MAP™ technology, which is a fundamentally different process of microalgae cultivation and harvesting method from existing current technologies. The A-MAP™ system is able to deliver higher yields on an industrial scale at a commercially viable production cost. In terms of land use, A-MAP™ produced CAO is estimated to produce on average 400 times the yield of palm oil per acre and only 0.25% of the land requirements to produce the same volume of oil per acre compared to palm oil. Algae biomass is the only bio feedstock in the world that can be cultivated without the use of arable land and fresh water. CAO also has many applications for decarbonising energy, with the highest potential in the transportation sector specifically in aviation as the feedstock for producing sustainable aviation fuel. In addition, crude algae oil can be a direct substitute for certain petroleum products used in industry such as heavy fuel oil used in gensets.

NGOG is aiming to develop 38,000 acres of A-MAP™ plantations by 2030, producing approximately 38 million tonnes of CAO per annum. Algae consumes CO_2, and on a life-cycle basis has a much lower greenhouse gas emission profile than other energy crops. NGOG's patented system sequesters 2.2 tonnes of CO_2 for each tonne of CAO produced. The carbon sequestration potential of the planned acreage will also contribute significantly towards Malaysia's Net Carbon Zero Emissions commitment by 2030. Besides positioning Malaysia strongly to capture an early mover advantage into the high potential sustainable biofuels market, strong domestic spillover effects are expected from the project such as the creation of 76,000 high value jobs for Malaysians and contribution to the country's GDP.

Special Chapter

Decarbonise IPPU, Waste, and Agriculture

Overview

To support progressive climate transition and to achieve Net Zero, decarbonisation across all sectors of the economy will be required. Whilst a majority of the emissions reduction in absolute terms will derive from the energy and transport sectors which constitute around 75% of emissions, reducing emissions from IPPU (8% of emissions), waste (8% of emissions), and agriculture (3% of emissions) will also be required. For each of these sectors, the current trajectory of emissions was developed and a range of levers were explored based technical feasibility and commercial viability based on Malaysia's specific context, to formulate potential GHG pathways for the sectors.

Industrial Process and Product Use (IPPU)

The industry sector has played a vital role in Malaysia's development, contributing to economic growth, jobs, and producing key materials for infrastructure development in the country. During the production process, emissions are incurred both through energy consumption and through industrial process and product use (IPPU). IPPU emissions are by-products of processes that chemically or physically transform materials (e.g., in a blast furnace), product uses of GHGs such as in refrigerators, or non-energy uses of fossil fuels such as in feedstocks in the industrial processes.

Four key sub-sectors constitute the majority of IPPU emissions – minerals (e.g., cement, carbonate, lime, and glass manufacturing), metals (e.g., aluminium, iron and steel), chemicals (e.g., ethylene, methanol, ammonia), and electronics (e.g., semiconductors, photovoltaics). Collectively these four sectors contribute approximately 9% of Malaysia's GDP, and have been growing at 5.5% per annum.

Historic trajectory

IPPU emissions has grown by approximately 6% per annum between 2000 to 2016, with particularly strong uptake in growth since 2010[87]. The largest driver of the increase in absolute terms has been the mineral industry contributing to around 40% of emissions increase, followed by the metal sector at around 25%, and the chemical and electronics sectors at around 15% each. Over the period, the GDP contribution of the four sectors has grown along the same trajectory as IPPU emissions, pointing towards overall production growth as a key driver behind the increased emissions.

Historically, there has been several notable initiatives to encourage emission reductions in industry. For example, in support of the Environmental Quality (Clean Air) Regulations 2014, the Department of Environment published a series of guidance notes for best available techniques economically achievable (BAT) covering 9 key industries to support the reduction in pollution and emissions from industrial activities[88]. These documents covered a high IPPU emissions sectors including the minerals, metals, and petrochemical sectors. Many of the levers, including a large number of tactical operational levers, which are comprehensively outlined in the guidelines continue to be relevant to drive reduction in emissions in these sectors.

Forward trajectory

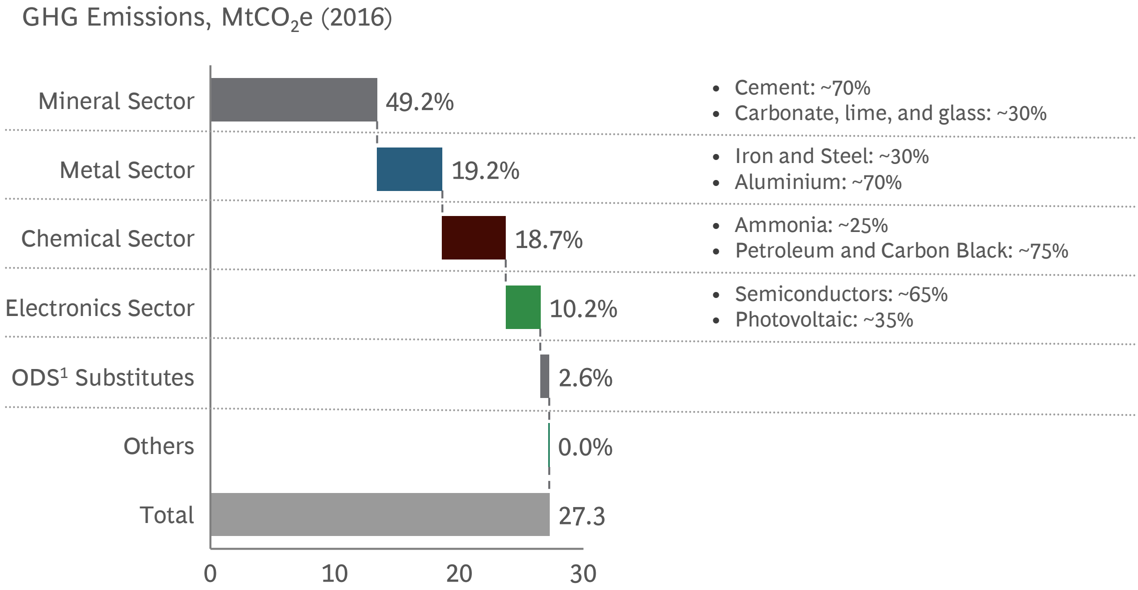
The forward trajectory of IPPU emissions was developed based on production forecasts of each category under the four key sub-segments. Production forecasts were developed based on a combination of industry outlook forecasts of production, historical trends and correlations between production numbers with sector emissions, and verification with independent topic experts. Other Malaysia-specific nuances were also considered such as the low utilisation in both the cement and steel sectors and large upcoming project developments which will have a large impact on demand.

Overall, IPPU emissions are expected to grow at approximately 2% per annum between 2020 to 2050. IPPU emissions from the electronics sector is expected to grow at the highest pace at 4% a year, driven by the strong continued growth of the sector. In contrast, IPPU emissions from the cement, metals, and chemicals sectors are expected grow at a slower pace between 1.5% to 2.5% over the period.

87. Department of Statistics Malaysia. (2019). Malaysia Statistical Handbook 2019.
88. Department of Environment (2014). Best Available Techniques Guidance Document On Iron and Steel Industry

Figure 60: Historic breakdown of IPPU sector GHG emissions

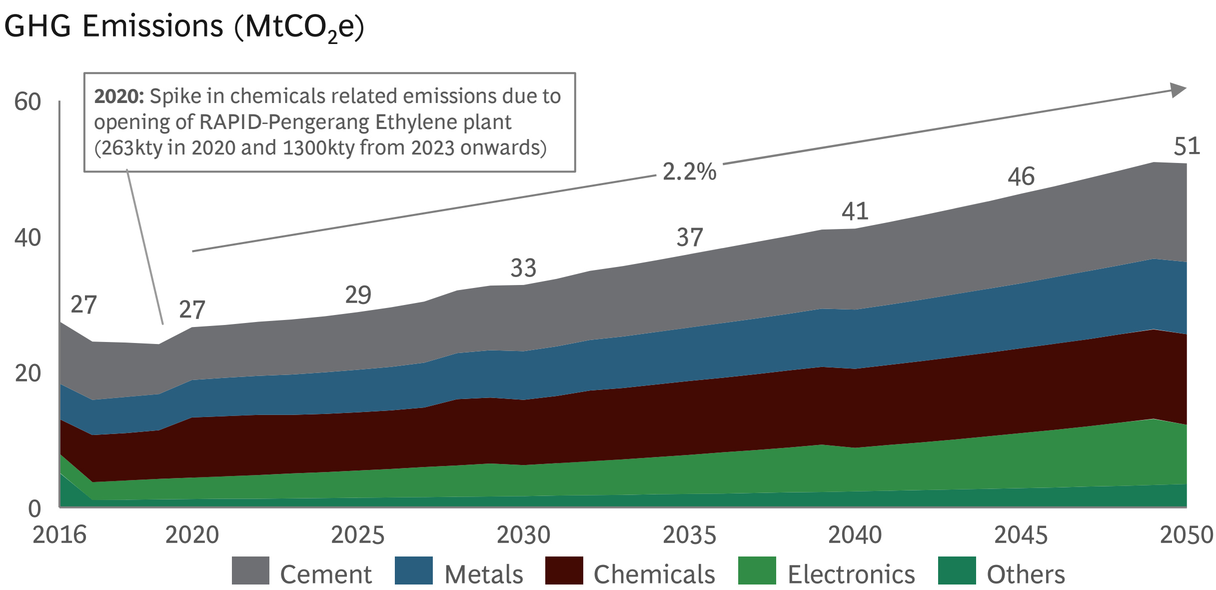
~98% of IPPU emissions driven by 4 sectors – minerals, metals, chemicals, and electronics production



1. Ozone depleting substance
Source: Malaysia BUR3 Submission

Figure 61: Current trajectory evolution of GHG emissions for IPPU sector

Current Trajectory: IPPU emissions grows to ~50 $MtCO_2e$, growing at ~2.2% p.a. over the 2020-2050 period



1. One time spike in other process uses of carbonates relative to 1990-2015 trend. Note: Cement emissions here do not account for removal of CKD due to lack of data availability; Other mineral emissions not accounted for due to lack of data availability; forecasts do not include CH4 emissions for steel (coke preparation) as should be covered under energy use based on IPCC guidelines
Source: Project Team Analysis, ChemCom, CW Research, IEA, Malaysian Steel Institute, World Steel Association, OECD Steel Outlook, Bureau of Metals Statistics, MIDA, Malaysia BUR3 Submission

Overview of potential abatement levers

Description of categories of abatement levers

A wide range of abatement levers are available to decarbonise IPPU emissions. The study focuses on the highest impact emission reduction solutions which can be deployed at scale to materially reduce GHG emissions for the country. Structural measures such as industry consolidation to increase capacity utilisation, grow economies of scale which allow for better adoption of latest high efficiency and low emissions technologies are not considered in this study, but can have significant impact on overall sector competitiveness and emissions.

The levers explored for each key IPPU emissions sector include:

- **Cement:** Substituting clinker use in cement mix with alternatives materials suited to Malaysia's context such as fly ash and steel slag. Alternative cements can reduce emissions between 20-80% from the cement sector. Other measures include demand-side measures to increase recycled building materials, reducing overall cement demand.

- **Iron and Steel:** For iron and steel, levers such as increasing the share of electric arc furnace (EAF) steel production and using hydrogen in direct reduced iron (DRI) production were considered. For aluminium, levers such as increasing aluminium recycling and implementing inert anodes as a replacement for existing carbon-based anodes in the aluminium smelting process.

- **Chemicals:** Feedstock switching to lower carbon solutions such as methanol, pyrolysis of waste materials such as plastics, and use of zero carbon hydrogen to substitute natural gas in the production of ammonia and methanol was considered. These levers each require high capital cost investments and currently have limited commercial viability, and hence were not included in the simulated GHG pathways.

- **Electronics:** Improvements in industrial gas handling and machine efficiency to reduce usage of gas during the cleaning and etching process, and industry-wide increase in wafer sizes to increase output of wafers, reducing the amount of gas used for equivalent amount of substrate produced. Given data limitations, the levers to reduce electronics IPPU emissions were not included in the simulated GHG pathways.

Cement

- **Clinker substitution in cement mix with alternatives materials**

  Clinker material used in cement manufacturing refers to a nodular material produced in the kilning stage and can be used as a binder for cement products. Majority of cement process-related carbon emissions are generated from the production of clinker. Portland cement, which is the main cement produced in Malaysia, and has a 90-95% clinker ratio.

  In order to reduce emissions, the use of clinker will need to be substituted with alternative materials as a replacement for cement production. Of the common cement substitutes, fly ash and granulated blast furnace slag (GBFS) are most widely used in Malaysia.

  Fly ash refers to the waste product from coal power generation and is generally the primary choice for clinker substitution in Malaysia due to availability of supply. GBFS is the by-product of blast furnace steel production and is generally the secondary choice for substitution in Malaysia due to limited domestic availability and the need to import at high prices. In the Net Zero pathway, the national average percentage of clinker in cement mix is expected to decline from 90% today to approximately 50% in the future.

- **Cement demand-side management**

  Cement demand will be largely driven by the evolution of domestic demand going forward, with significant regional overcapacity outlook. In the near term, large housing construction activities and major infrastructure projects will drive increase in cement demand, before stabilising to an estimated long-term growth rate of 2% per annum. One key lever to reduce cement IPPU emissions is to decrease the quantity of cement demand by substituting cement with alternative building materials. Enhance building material recycling will promote the circular economy and reduce demand for cement, reducing emissions in the sector.

Iron and Steel

- **Increased used of electric arc furnaces (EAF) in steel production**

  Electric Arc Furnaces (EAFs) have significantly lower emission factor compared to traditional blast furnace-basic oxygen furnaces (BF-BOF) and direct reduced iron (DRI). On average BF-BOF furnaces and DRI produce approximately 18 times and 8 times higher emissions that EAFs per unit of energy. Moreover, EAF steel production also has the added advantage of enabling increased use of recycled steel scrap within its production processes.

  Currently, EAF steel production currently makes up 62% of total steel capacity in Malaysia, with BF-BOF and DRI making up the remaining 12% and 25% of capacity, respectively. Whilst BF-BOF processes will be needed for highly specific steel manufacturing applications, given the ability for the BF-BOF process to produce higher purity steel, there is potential to further increase the share of EAF steel production. In the Net Zero 2050 pathway, EAF share of capacity increases to 85%, substituting BF-BOF and DRI shares which declines to 5% and 10%, respectively. Country benchmarks have shown several countries to have EAF proportion between 85-100% of total steel production.

- **Application of blue or green hydrogen in production of DRI steel**

  Natural gas is currently utilised as the reducing agent in the production of DRI steel. Replacing natural gas with green hydrogen enables the by-product of the iron ore reduction process to be water vapour instead of carbon dioxide. The use of this technology is contingent on the availability and accessibility of green or blue hydrogen, with appropriate hydrogen infrastructure.

  Use of blue or green hydrogen in DRI steel production is currently not yet competitive, but with rapid improvements in costs of renewable energy and with falling electrolyser costs, abatement costs are expected to decline over time. Furthermore, where DRI steel plants are in the proximity of key sources of zero carbon hydrogen production, transport and infrastructure costs can be further reduced. In the Net Zero 2050 pathway, zero carbon hydrogen in production of DRI steel is assumed to be a feasible towards 2050 and is scaled up to meet 100% of DRI production, representing 10% of total steel production.

Aluminium

- **Increased aluminium recycling (secondary production share of aluminium production)**

  Secondary production refers to the process of recycling aluminium scrap back into aluminium production. Secondary production has 20 times less emissions compared to primary production, which is the production of new aluminium. By increasing the proportion of recycled aluminium in aluminium production, secondary production of aluminium increases replacing primary production. Currently, more than 95% of aluminium production is primary production. In the Net Zero 2050 pathway, this is assumed to decrease to 85%, enabling an increase of secondary production share to 15% of overall aluminium production.

- **Use of inert anodes**

  Utilising inert anodes instead of carbon anodes in the smelting process represents another key lever to reduce aluminium IPPU emissions. Inert anodes do not react with oxygen, and hence reduce IPPU GHG emissions emitted during smelting.

  Primary aluminium production currently relies heavily on carbon anodes, to extract oxygen from raw alumina, which releases carbon emissions. Furthermore, carbon emissions are also produced in the production of carbon anodes. Inert anode technology provides opportunities to remove emissions from both the electrolysis and anode production process. In the Net Zero 2050 pathway, inert anodes account for 80% of total anodes in aluminium production.

Chemicals

There were several potential levers identified for chemicals, but impact was not quantifiable due to reliance on specific data points. These levers were not further pursued given the likely limited commercial viability of these abatement levers at the current point in time. However, given the large decarbonisation potential of these technologies, ongoing tracking of developments is recommended.

Broadly, this includes optimising feedstock for olefin production to reduce emissions with lower carbon feedstocks such as methanol, implementation of carbon capture and storage solutions (CCS) for chemical production, and the pyrolysis of waste materials such as plastics for recycling and reuse as raw materials. In addition, the use of zero carbon hydrogen as feedstock for ammonia and methanol production has the potential to eliminate carbon emissions related to input feedstock during the chemical production process.

Electronics

Similar to chemicals, several potential abatement levers were also identified for the electronics sectors, but data limitations inhibit a full sizing of potential for the Malaysia context.

This includes improvements in industrial gas handling and machine efficiency to reduce usage of gas during cleaning and etching processes, which can reduce up to 10% of emissions based on global benchmarks. In addition, industry-wide increase in wafer size that increases output of wafers, leading to reduced amount of gas used, can also reduce emissions. Based on global benchmarks, increases in wafer sizes can reduce emissions by up to 20-30% every 10 years.

Collective impact of levers on GHG emissions pathway

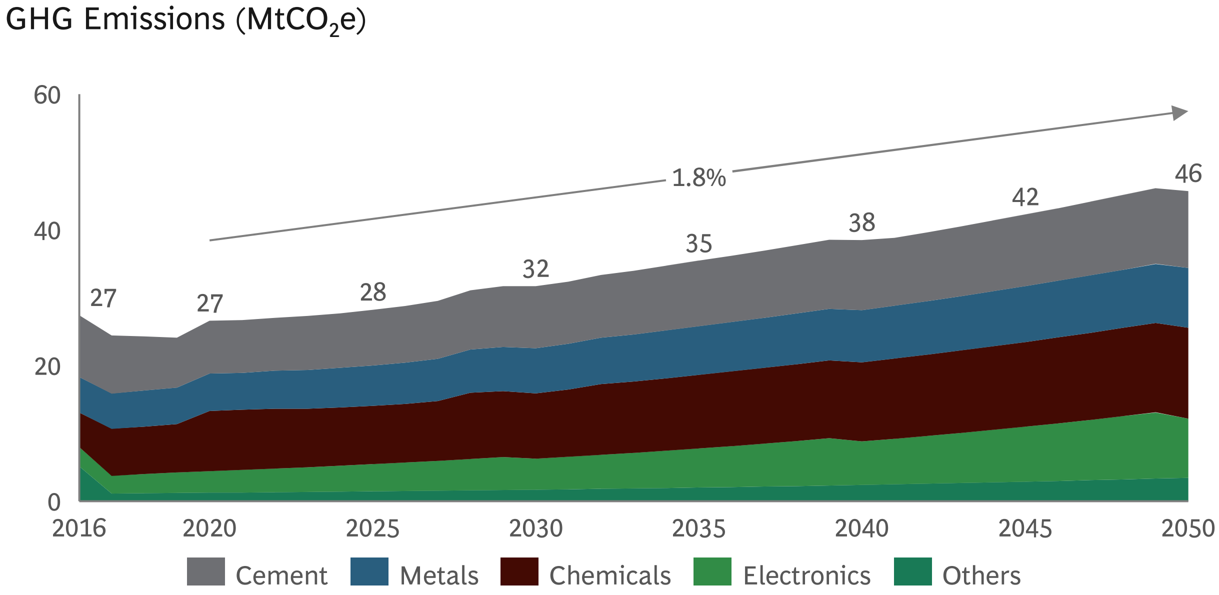
Based on the IPPU abatement levers explored, approximately 5 $MtCO_2e$ of emissions can be reduced from the current trajectory pathway in the low carbon pathway, which adopts highly feasible abatement levers with focus on commercial viability. These emission reductions derive from a degree of clinker substitution, increase in share of EAF, and aluminium recycling.

In the Net Zero 2050 pathway, these levers need to be scaled, with a larger share of clinker substitution and share of EAF. In addition, higher abatement cost solutions leveraging emerging technologies are also adopted, such as zero carbon hydrogen use to decarbonise DRI and inert anodes in aluminium production. This reduces emissions by pathway to approximately 10 $MtCO_2e$ compared to the current trajectory pathway, equating to a 20% decline in IPPU emissions intensity.

The study recognises that low utilisation particularly in the cement and metal industry may be inhibitors to large capital investments in emissions abatement technologies, especially in the near term. Hence, a first key step will be to enhance utilisation and improve financial performance through a range of levers including considering capacity consolidation for economies of scale, which can also increase the affordability of identified emissions abatement technologies.

Figure 62: Low carbon pathway evolution of GHG emissions for IPPU sector

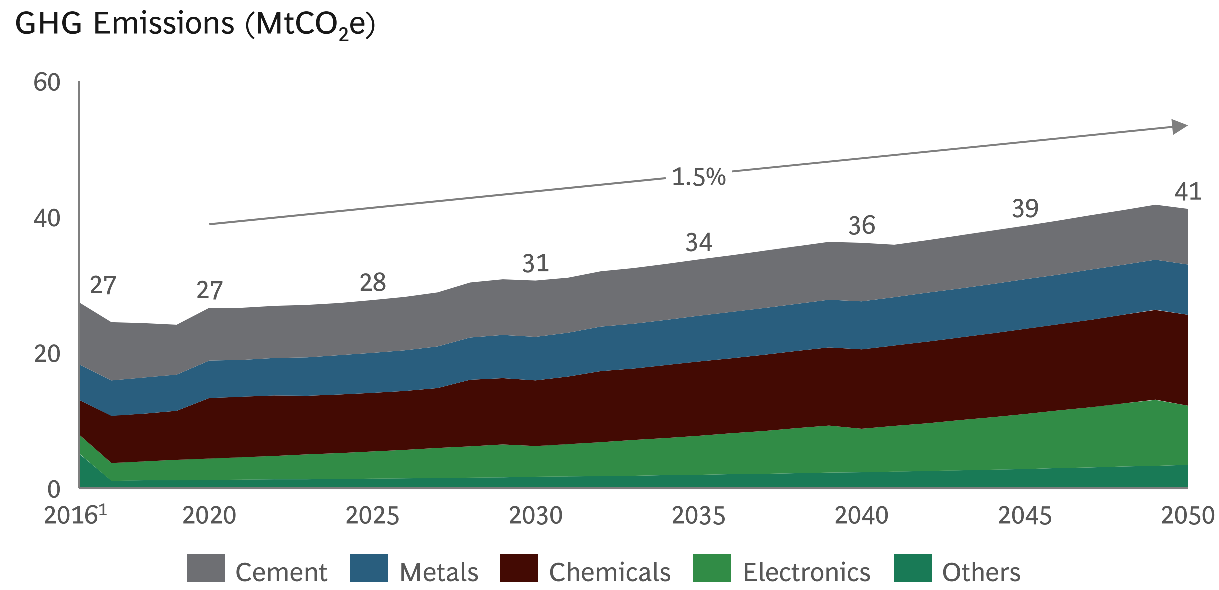
Low Carbon Pathway: IPPU emissions growth limited to ~46 $MtCO_2e$ at 2050, growing at a~1.8% p.a. over the 2020-2050 period



1. One time spike in other process uses of carbonates relative to 1990-2015 trend. Note: Cement emissions here do not account for removal of CKD due to lack of data availability; Other mineral emissions not accounted for due to lack of data availability; forecasts do not include CH4 emissions for steel (coke preparation) as should be covered under energy use based on IPCC guidelines
Source: Project Team Analysis, ChemCom, CW Research, IEA, Malaysian Steel Institute, World Steel Association, OECD Steel Outlook, Bureau of Metals Statistics, MIDA, Malaysia BUR3 Submission

Figure 63: Net Zero 2050 pathway evolution of GHG emissions for IPPU sector

Net Zero 2050: IPPU emissions growth limited to ~41 $MtCO_2e$ at 2050, growing at ~1.5% p.a. over the 2020-2050 period

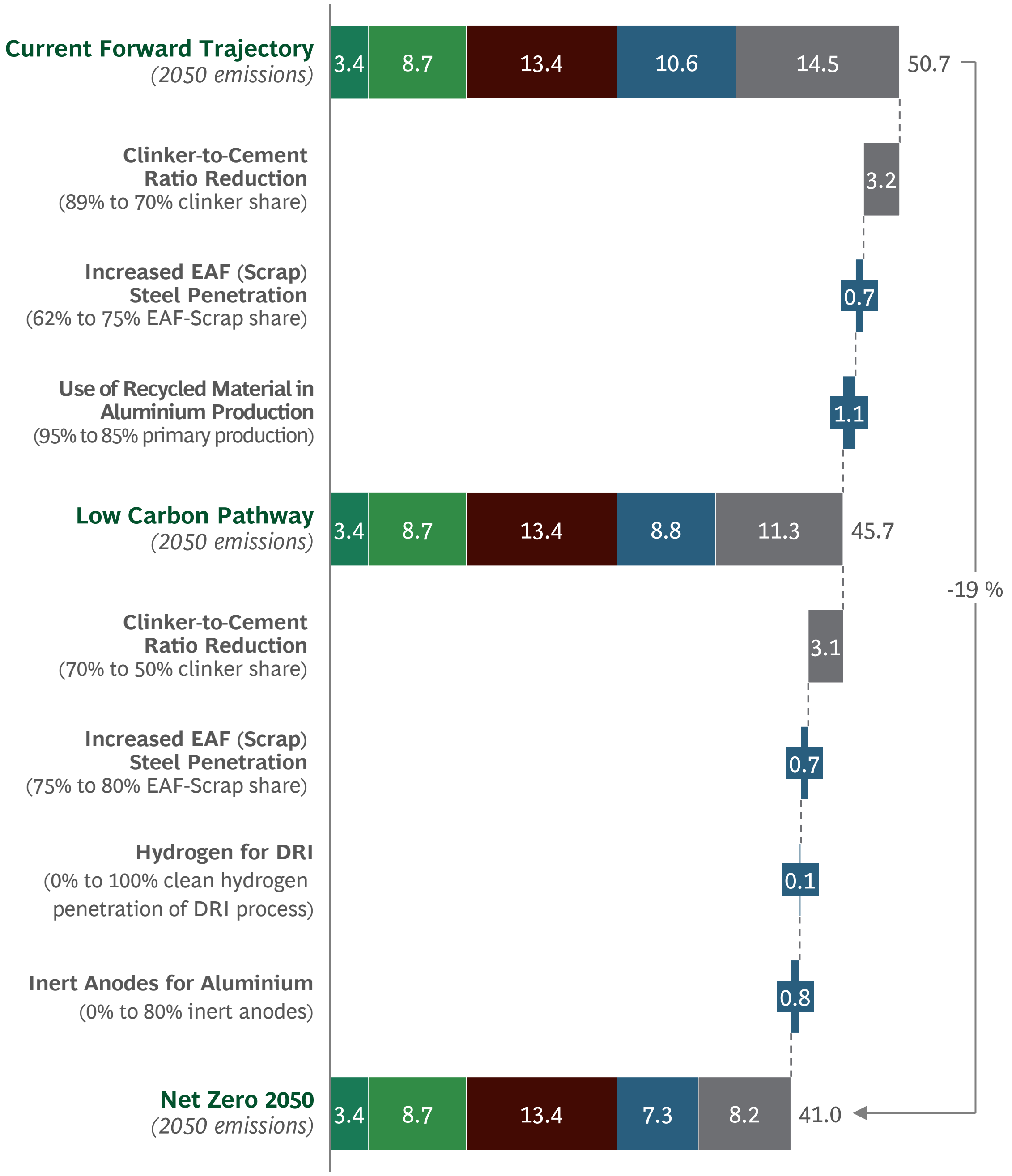


1. One time spike in other process uses of carbonates relative to 1990-2015 trend. Note: Cement emissions here do not account for removal of CKD due to lack of data availability; Other mineral emissions not accounted for due to lack of data availability; forecasts do not include CH4 emissions for steel (coke preparation) as should be covered under energy use based on IPCC guidelines
Source: Project Team Analysis, ChemCom, CW Research, IEA, Malaysian Steel Institute, World Steel Association, OECD Steel Outlook, Bureau of Metals Statistics, MIDA, Malaysia BUR3 Submission

Figure 64: Breakdown of lever contribution towards sectoral decarbonisation in IPPU sector

~19% increased reduction in GHG emissions from current forward trajectory in Net Zero by 2050 scenario for IPPU sector

Contribution of key levers towards sector decarbonisation ($MtCO_2e$)



Electronics: Nascent or high abatement cost levers

- Feedstock decarbonisation: Low carbon olefin feedstock substitution; hydrogen feedstock for ammonia and methanol
- Pyrolysis of waste materials (plastic)

Chemicals: Nascent or high abatement cost levers

- Reduced gas in cleaning and etching
  (10% one-off emission reduction)
- Reduced gas from wafer size reduction
  (20-30% emission reduction every 10 years)

Others[1] | Electronics | Chemicals | Metals | Cement

Source: Project Team Analysis

Waste

Waste produced across all sectors of the economy, from households to commercial, industrial, and agriculture sectors has been increasing steadily over time. The sustainable management of waste is critical for various socioeconomic outcomes, including the protection of the environment, health of the population, and overall quality of life. In line with the growth of overall waste volumes in Malaysia, emissions from the waste sector has been growing steadily. In the latest national GHG inventory, waste emissions amounted to 27 $MtCO_2e$, approximately 8% of the country's total GHG emissions[89].

Around 92% of waste emissions derive from two key sources. Industrial wastewater from palm oil mill effluent (POME) produced during palm oil production contributes 51% of waste sector emissions, whilst solid waste disposal contributes a further 41% of waste sector emissions.

Various plans have been established to enhance sustainable waste management in Malaysia. For example, the National Solid Waste Management Policy (2016) was developed to emphasise the holistic management of solid waste[90]. This was complemented by the National Physical Plan 3 (2016) which outlined the importance of establishing solid waste management facilities in line with low carbon requirements and the value recovery of solid waste to ensure spatial sustainability and resilience to climate change.

For urban areas, the Malaysia Smart City Framework (2018)[91] emphasised the importance of waste management in cities, including highlighting waste-to-energy solutions. For rural areas, the Rural Development Policy (2019) also emphasised the importance of innovative management of solid waste to enhance the living environment.

Finally, sectoral policies beyond the waste sector have encouraged various waste management solutions. One such as example is waste-to-energy. Through the Renewable Energy Act (2011) policies to encourage renewable energy through feed-in-tariffs (FiT) was established, including for electricity generated from biogas and waste-to-energy. This has provided long-term certainty in electricity offtake prices over a period of 16 years, encouraging investments based on greater long-term certainty of future revenue streams.

Historic trajectory

Emissions from the waste sector has been growing at a steady pace of 3% per annum. The main drivers of overall waste emission growth are from increased production of crude palm oil (CPO) and increased waste generation due to population growth.

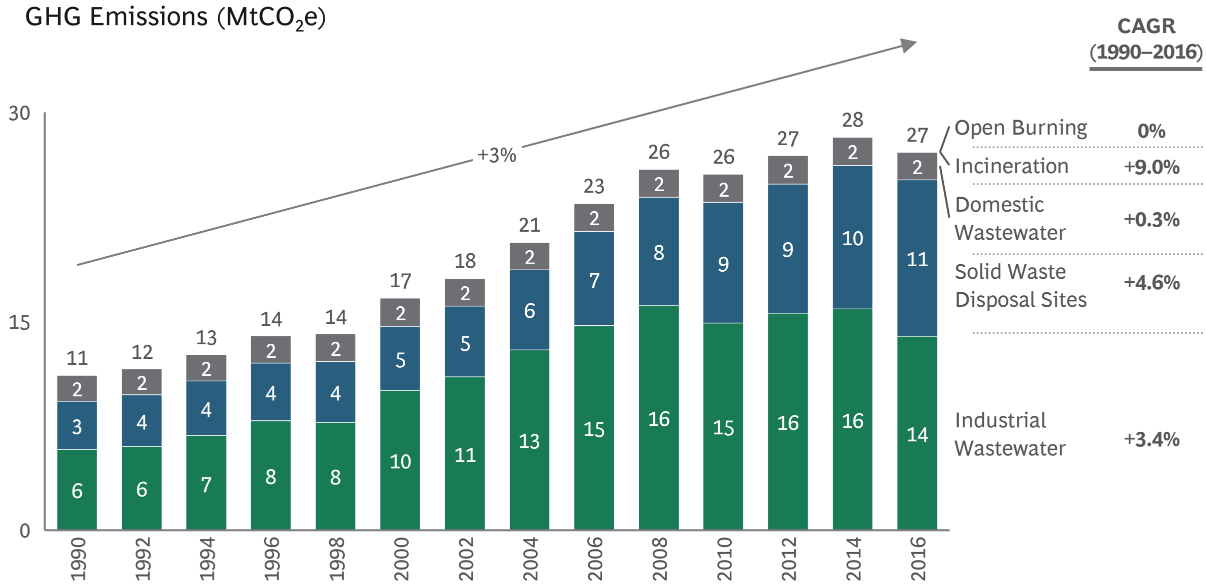
As the world's second largest producer of palm oil with over 5.9 million hectares of planted palm oil area, Malaysia produces over 19 million tonnes of CPO annually[92]. During palm oil production, fresh fruit bunches (FFB), the main harvest of palm oil trees, is processed into crude palm oil (CPO). POME is produced as by-product which can have an adverse effect on the environment, in the form of methane emissions, if not treated properly.

Malaysia currently generates over 38,000 tonnes of waste every day[93], with most of the waste currently being sent to landfills. Majority of GHG emissions from solid waste disposal sites originates from methane emissions during the decomposition of waste under conditions devoid of oxygen. Different types of waste have different amounts of degradable organic carbon (DOC) content which contributes to methane emissions at varying rates. The largest category of waste in Malaysia is food waste, making up ~45% of total waste generated[94].

89. Malaysia Ministry of Environment and Water (2020) . "Malaysia's Third Biennial Update Report to the UNFCCC (BUR-3)"
90. JPSPN (2016). National Solid Waste Management Policy 2016
91. Ministry of Housing and Local Government (2018). Malaysia Smart City Framework
92. MPIC (2021). Agri commodity Statistical Data
93. MIDA (2020). Sustainable Waste Management in Malaysia : Opportunities and Challenges.
94. Data from Solid Waste and Public Cleansing Management Corporation (SWCorp)

Figure 65: Time series breakdown of waste sector GHG emissions

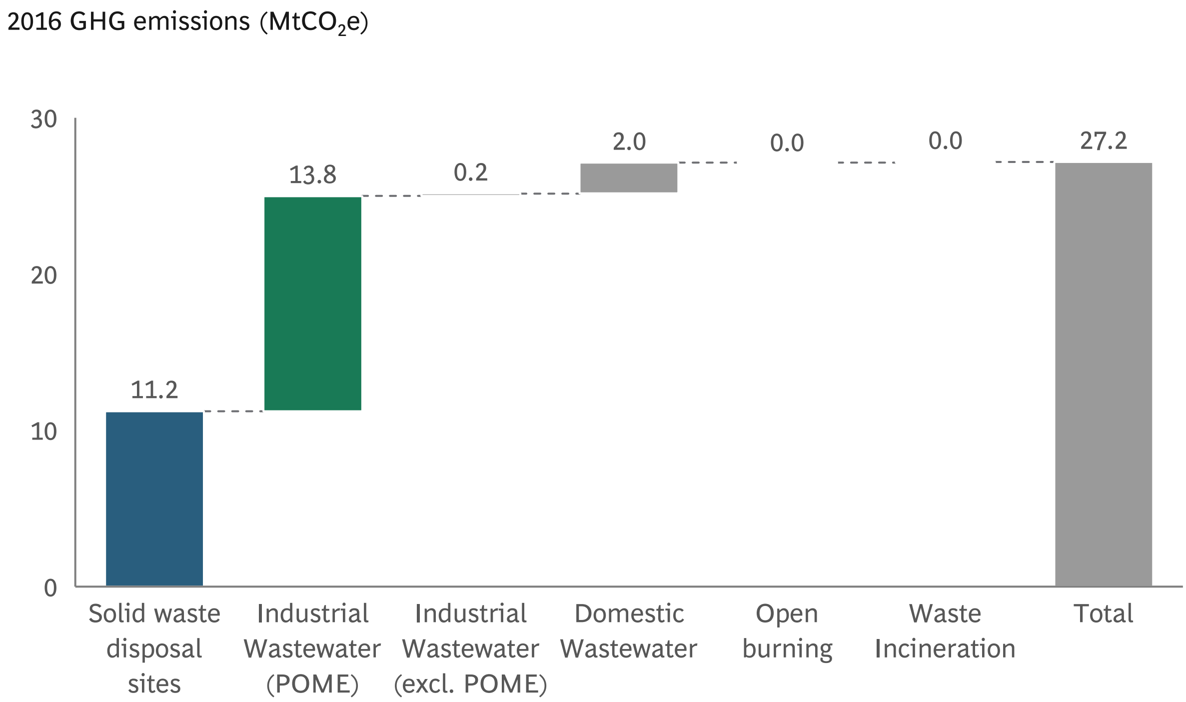
Waste sector GHG emissions growing at 3% per annum



Source: Malaysia's 3rd BUR to the UNFCCC

Figure 66: Annual decomposition of GHG emissions from the waste sector

Key focus on solid waste disposal and POME which constitutes 92% of GHG emissions from the waste sector



Source: 3rd Biennial Update to the UNFCCC

Forward trajectory

The growth of POME related waste emissions is strongly influenced by the planted area of palm oil, which expected to grow steadily at its current trajectory, up to the cap of 6.5 million hectares towards 2030. As palm oil planted area grows, the level of POME production will increase proportionately as a by-product of the production process.

In contrast, the growth in solid waste is primarily driven by the evolution of population growth and waste per capita. Waste per capita is typically higher in urban areas than rural areas due to increased consumption of goods. Malaysia's population is projected to grow from 33 million in 2020 and to 44 million in 2050[95]. Over the same period, the urbanisation rate is projected to grow from 77% in 2020 to 88% in 2050. As a result, Malaysia could see an increase of up to 70% in waste generated from 2020 levels.

In addition to overall demand growth, current policy positions and plans are expected to influence the forward trajectory of waste sector emissions:

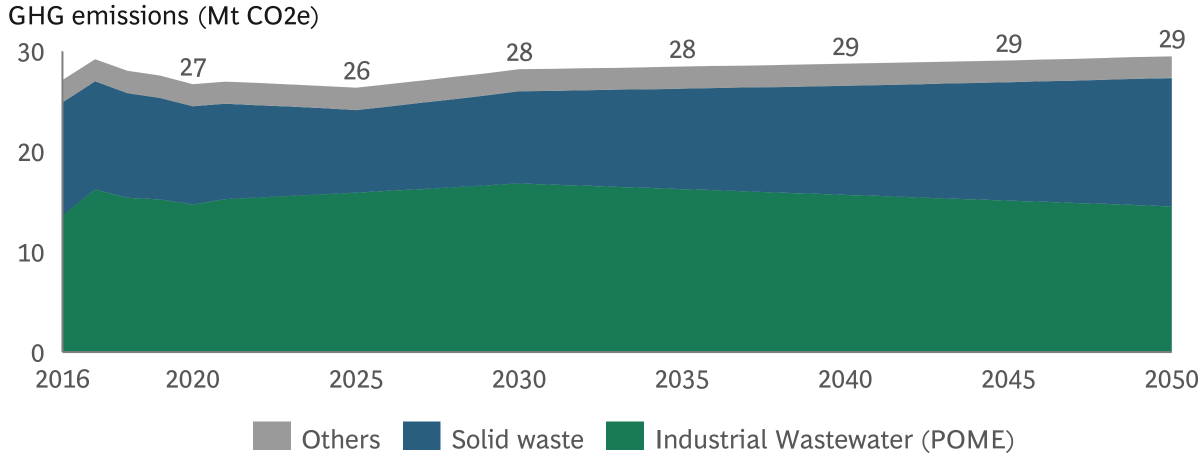
- **Biogas facilities for POME capture.** Since the 10th Malaysia Plan, the build-out of biogas recovery facilities at palm oil mills has been guided by the National Biogas Implementation entry point project (EPP5) under the Palm Oil National Key Economic Area (NKEA)[96]. Effective 1st January 2014, new mills and existing palm oil mills requiring throughput expansion have been mandated to install full biogas trapping or methane avoidance facilities. A reported 104 out of 454 palm oil mills currently have biogas capturing facilities, with an emissions reduction of ~2.4 $MtCO_2e$ achieved in 2016[97]. Based on the current trajectory, around 56% of total palm oil mills are projected to be equipped with biogas plant facilities by 2050, which equates to 5 new palm oil mills constructed on average per year until 2050.

- **Recycling rates.** In the 12th Malaysia Plan, the target of achieving 40% recycling rate of household waste and 35% recycling rate of scheduled waste was outlined. This follows the historic pattern of gradually improving recycling rates, which have resulted in growth of recycling rates from around 10% in 2012 to 28% of household waste in 2018. Recycling rates are defined as the sum of total recyclables divided by sum of total solid waste generated which commonly includes paper, plastic, steel, glass etc.

- **Measures for waste disposal sites and waste-to-energy development.** Besides targets for recycling rates, the Ministry of Housing and Local Government (KPKT) has also announced concrete plans for the construction of 6 waste-to-energy plants, the safe-closure of 14 non-sanitary landfills, and the construction of 5 sanitary landfills by 2025. The impact of these measures on waste GHG emissions was assessed and included in the current trajectory pathway.

Figure 67: Current trajectory evolution of GHG emissions for the waste sector

Waste sector emissions expected to flatten out over time



95. Department of Statistics Malaysia population and demographic projection statistics
96. Malaysia Palm Oil Board (2011). National Biogas Implementation (EPP5).
97. Energy Commission. (2020). Malaysia Energy Statistics Handbook 202

Overview of potential abatement levers

Description of categories of abatement levers

Abatement levers were identified for the largest sources of GHG emissions for the waste sector, deriving from POME industrial wastewater and solid waste disposal.

To further reduce emissions from POME industrial wastewater:

- Deepening coverage of biogas facilities across palm oil mills

To further reduce emissions from solid waste disposal:

- Setting up of key foundational enablers for effective solid waste management
- Significantly reduce food waste generated and enabling diversion away from landfills
- Further enhancing recycling rates
- Harnessing energy from waste

Palm Oil Mill Effluent (POME) waste emissions reduction

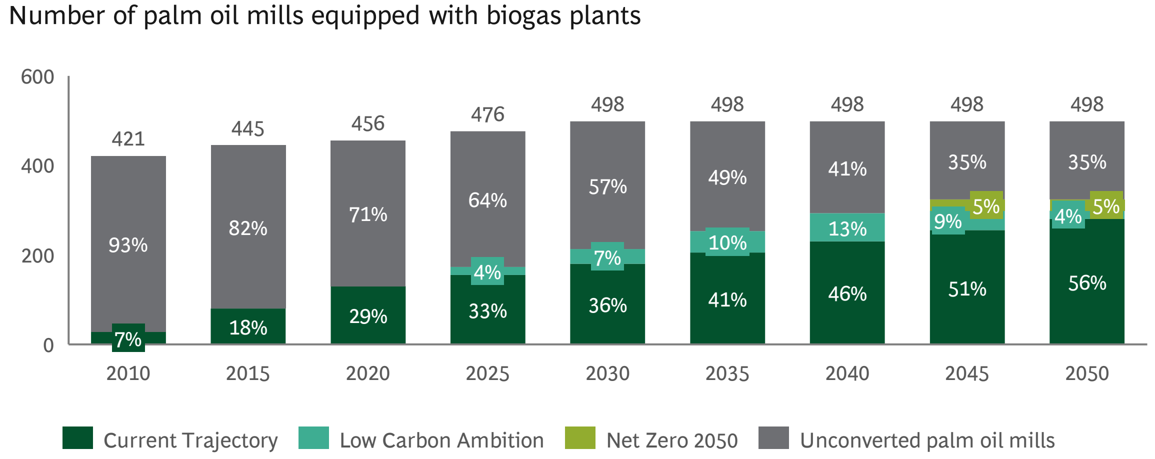
- **Deepening coverage of biogas facilities across palm oil mills from 56% to 65%**

  Treatment of POME begins with the extraction of residual oil, which is then placed into a closed digestor tank or covered lagoon to produce methane rich biogas produced during the anaerobic digestion of POME which can be a source of renewable energy. In the Net Zero 2050 pathway, biogas plant facilities penetration is assumed to reach 65% of total palm oil mills (324 equipped palm oil mills), higher than the 56% projected (280 equipped palm oil mills) in the current trajectory. The 65% penetration rate is assumed to be reached by 2043.

  Enabling support needs to be given to support the implementation of biogas recovery plants including continued support through feed-in-tariff (FIT) rates or renewable energy certificate (RECs) schemes, financing and funding support for initial capital outlays, grants for further R&D to increase the efficiency and to reduce costs in POME treatment, and others.

Figure 68: Changes in number of palm oil mills equipped with biogas plants from 2010-2050

324 cumulative biogas plants projected by 2043 in net zero pathway representing 65% of feasible palm oil mills



1. Construction of 5 biogas plants p.a. in BAU, and 8 biogas plants p.a. in Low Carbon and Net Zero pathway projected based on average of rate of construction for the past 5 years and MPOB forecast. Decrease in % in low carbon scenario due to "catching up" in BAU scenario
Source: Malaysia Palm Oil Board (MPOB), 3rd Biennial Update to the UNFCCC, Project Team Analysis

Solid waste disposal emissions reduction

- **Setting up key foundational enablers for effective solid waste management**

  Before waste can be effectively monitored, managed & treated, many key enablers are required along the waste process flow from production all the way to disposal to ensure end-to-end environmental sustainability, even if GHG emissions are not directly quantified from these measures in the national GHG inventory:

  Upstream waste segregation

  Effective early upstream waste segregation is crucial to help facilitate cost efficient waste treatment methods and to reduce downstream sorting costs as required for recycling and waste-to-energy processes. Strict enforcement and effective monitoring of waste segregation will need to be put in place, including deterrents and penalties for households that fail to separate waste at source.

  Reducing waste with the 3R's of Reduce, Reuse, Recycle and circular economy principles

  Public awareness is paramount to effectively combat GHG emissions from the waste sector. For example, there needs to be an increased awareness on the 3R initiative of reduce, reuse, and recycle, along with other initiatives which enhance the level of education on proper waste management. Beyond the 3R initiative, extra emphasis needs to be placed on the impact of food waste which is the largest source of methane emissions in the waste sector. Waste management curriculum should also be integrated into the school curriculum to ensure habit formation from an early age, highlighting the importance of proper waste management as well as the consequences of sub-optimal waste disposal.

  Complementing the 3Rs, enhancement of circular economy adoption will promote the enhanced refurbishing and re-using of materials along the value cycle, including design, production, distribution, use, collection, and recycling. Circular economy principles tackle both unsustainable consumption and also unsustainable production, such as measures to reduce waste generation from the product design phase.

  Legal enactment and structuring of collection contracts

  The Solid Waste Management and Public Cleansing Act 672 was set up to standardise the level of solid waste management and public cleansing across all local councils. However, to date, the Act has only been adopted by 2 federal territories and 6 states. Moving forward, there is an opportunity to extend Act 672 to include all states to ensure standardisation of waste collection and enhanced enforcement by the authorities.

  Furthermore, waste collection contracts should also be reviewed and restructured to incentivise upstream waste segregation, beyond compensation solely based on the amount of waste collected and transferred to landfills.

  Consistent measurements, reporting and centralisation foundations

  For effective waste treatment, consistent measurements, reporting, and centralisation foundations are required to develop a deep understanding into the volume, composition, and sources of waste. Consistent review on waste generation data and waste composition at landfills is needed to accurately assess the forward-looking trajectory on waste and to identify targeted mitigation measures which increase sustainability of solid waste management.

  Besides accurate data capture, waste data should ideally be centralised under a designated party responsible in waste data collection and timely reporting, establishing a single source-of-truth across stakeholders.

- **Significantly reduce food waste generated and enabling diversion away from landfills**

  Food waste constitutes around 45% of total waste in Malaysia and is the main contributor of methane emissions from the waste sector due to its abundance and high organic carbon content. Where possible, food waste should be avoided to reduce the volume sent for food waste processing. To maximize the value of food and mitigate the impacts of unsustainable disposal, the resilience and circularity of local food systems should be increased by supporting a diverse market of food waste processing solutions, including value-added systems. Below are a few initiatives to help tackle methane emissions originating from food waste:

  Food waste prevention and reduction campaigns

  Avoidable food waste, primarily driven by the wastage of food which is still edible, constitutes 24% of total food waste. Food waste prevention campaigns aim to raise awareness on the benefits of reducing food waste by changing how people perceive food, highlighting the environmental impact of food waste, and potential cost savings to households. Providing practical everyday solutions to enable changes in people's behaviour will be key to prevent and reduce food waste.

  Another potential measure is ensuring that excess or unmarketable but safe food across the supply chain are channelled to people with limited or insufficient access to food. Surplus food rescue at larger establishments across retail, groceries, and hotels, which is then redistributed through food security organisations, can serve as a important channel of food aid for low-income community members. Fiscal incentives, such as tax incentives for surplus food donating organisation can further support this practice such as seen in the United States[98] or penalties to disincentivise disposal of edible food such as seen in France[99] . Collectively, multiple benefits can be achieved through these measures, including reducing the cost of food aid, avoiding emissions from food waste channelled to landfills, improving nutrition through better access to fresh foods for low income households, and others.

  Anaerobic digestion

  Anaerobic digestion is the slow natural decomposition of biodegradable or organic waste using microorganisms to produce biogas which consists of methane and carbon dioxide. Anaerobic digestion is an ideal waste treatment method for food waste as the technology is best used on waste feedstock with high biodegradable matter (>50%) and high moisture content (>55%). Developing a clear forward-looking national plan to realise the potential of this technology, including increasing cost competitiveness of the technology and plans for adoption, will be important. Anaerobic digestion will also require enhancements in effective waste segregation at source to be effective. Currently, there are only a few small-scale anaerobic digestor plants across the country set up by local councils and individual organisations[100]. If planned at scale, anaerobic digestion has the potential to generate energy and reduce emissions from organic waste.

  Waste-to-animal-feed solutions such as Black Soldier Fly Larvae (BSFL) processing

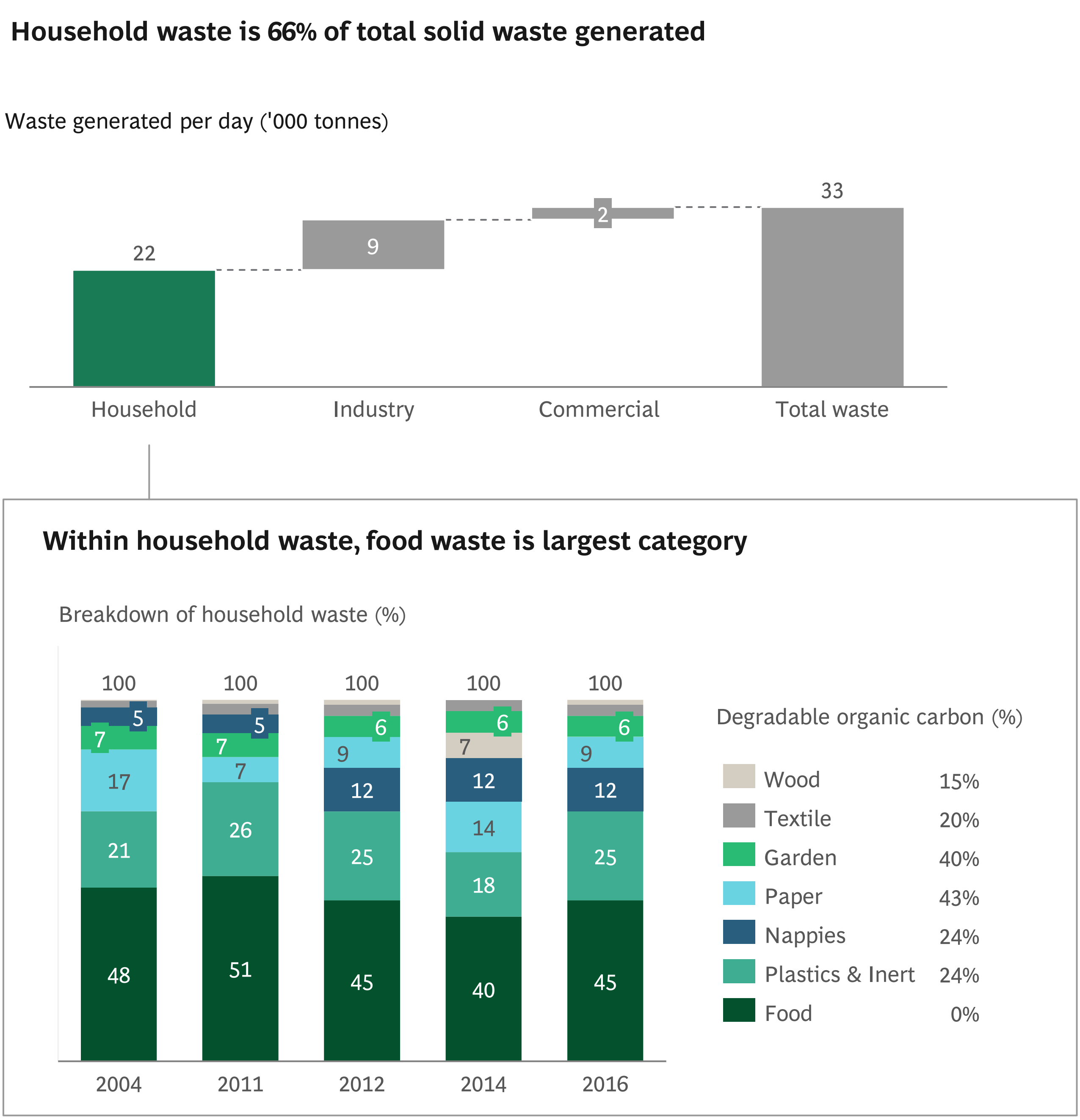
  Waste-to-feed-systems, such as black soldier fly larvae (BSFL) is a nascent technology that possesses high potential to support highly cost effective waste management whilst promoting the circular economy. The black soldier fly larvae decomposes various types of organic and food waste and converts them into fertilisers or rich sources of protein which can be used as animal feed for livestock. The added circular economy revenue stream contributes to the enhancement of commercial viability of BSFL. As a relatively nascent technology, further research and investments are required to adopt and scale the adoption of BSFL as a solution in solid waste treatment.

98. Environmental Protection Agency (EPA) data
99. Ministry of Ecological Transition, France
100. JPSPN (2016). "Food Waste Management Development Plan for Industry Commercial and Institution Sector."

Composting

Composting is an accelerated process of natural decomposition of organic matter into compost by microorganisms, such as bacteria and fungi, to produce fertilisers as a by-product of the process. Some of the main challenges with implementing composting at scale include the lack of effective waste segregation, and the limited economic viability due to high investments and operating costs, and relative lack of cost competitiveness compared to chemical fertilisers, thereby limiting the market creation for compost. However, opportunities to promote composting in specific niches exist, such as in a decentralised manner with household composting, or in selected areas where premium can be obtained from organic and sustainable circular economy farming principles, which justifies the higher cost of fertiliser inputs.

Figure 69: Waste generation & waste composition breakdown in Malaysia



Source: Survey on Solid Waste Composition, Characteristics & Existing Practice of Solid Waste Recycling in Malaysia (2012), JPSPN, IPCC

Case Study 5 | Circular food economies – Black Soldier Fly Larvae (BSFL)

End-of-life material systems must drastically improve to support the transition to the circular economy. To maximise the value of food and mitigate the impact of unsustainable disposal, municipalities should increase the resilience and circularity of local food systems by supporting a diverse market of food waste processing solutions, including value-added systems, like using food waste to animal feed systems.

Waste-to-feed systems, such as feeding food waste to black soldier flies' larvae (BSFL), produces valuable outputs, as explored in WWF-US's waste-to-feed market analysis. BSFL processing of pre- and post-consumer food waste and industrial by-products is a prominent and growing sector in Malaysia with an approximately 250+ tonnes per day of organic waste handled by less than a dozen bio-conversion facilities at present. Over the next 3-5 years, current expansion plans of existing facilities will increase capacity to 1100 tonnes per day. Industry players such as feed manufacturers and bioconversion facilities that specialise in BSFL processing of organic waste are already strongly interested in potential future collaborations to scale-up production and to cater for new domestic demand.

Supporting BSFL processing would address both the lack of concentrated efforts to implement and enforce separation of food waste at source for landfill diversion as well as the urgency to respond to environmental challenges such as over-reliance on wild fish stock in aquaculture feed. To fully realise BSFL's potential as a circular food economy, effective separation and collection of food waste is key. In addition, regular measurements to help businesses and people identify underlying waste hotspots and to address them at the source will remain crucial in the long-term.

Importantly, alongside any circular economy solutions, there should be legally binding principles, a "waste or food recovery hierarchy", upon which food waste management is based. Similar principles already exist in other countries and define a priority order for waste management intended to ensure that the waste management options create the most benefits for the environment, society, and the economy. Upstream food waste but also loss prevention and reduction measures also need to be prioritised and exhausted before unavoidable and remaining food waste is converted or considered for other use within a circular economy model.

Source: WWF-US study EPA food recovery hierarchy (USA), NEA food waste management hierarchy (SG), EC waste framework directive (EU)

- **Further enhancing recycling rates**

  Recycling is one of the most important measures in sustainable waste management to decrease the production of additional products from raw materials and their associated GHG emissions. Recycling rates are measured by summing total recyclables (which usually consists of non-organic wastes such as plastics, paper, glass, iron etc) over total waste generated. A closer review of some of the contributory factors of countries with high recycling performance reveals the following:

  - Comprehensive schemes to enable people to recycle (e.g., mandatory separated collection of dry materials and bio-waste)
  - Clear performance targets and policy objectives (e.g., tightened regulations and recycling laws to restrict waste produced per person, requirements to separate certain materials from residual waste, landfill bans)
  - Funding for recycling programs (e.g., government funding for increased societal engagement to encourage recycling, Extended Producer Responsibility schemes)
  - Financial and behavioural incentives to directly and indirectly encourage citizens to recycle (e.g., taxes on residual waste treatment and disposal, restrictions on residual waste bins, differential 'Pay As You Throw' and Deposit Refund Schemes)

- **Harnessing energy from waste**

  The majority of waste in Malaysia is disposed in non sanitary landfills or open dumpsites without gas recovery as this represents the lowest cost disposal technique to handle waste in large quantities. However, landfills are a growing environmental issue and with increased shortages of available land, and the negative externalities of environmental, health and safety issues for local communities. This includes release of methane gas produced during the anaerobic decomposition of solid waste at landfills.

  Given the prospects of continued waste volume growth, more sustainable solutions to waste management will be required, including exploring various waste-to-energy options. Many waste-to-energy solutions continue to lack commercial viability, but technology developments over time are expected to create more options in the future. Two of the more commercially viable waste-to-energy options are outlined below:

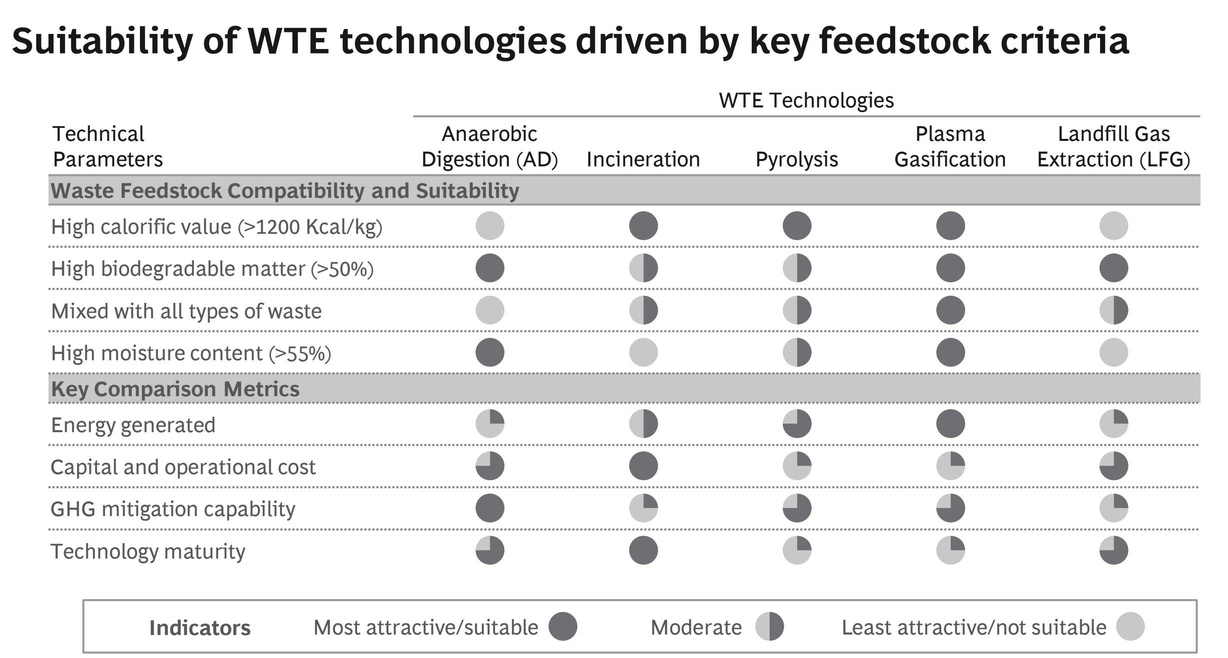
  Incineration

  Incineration is the primary approach of waste-to-energy treatment which involves combustion of organic material to generate thermal energy which are then used to generate power through steam generators. Scrubbers are then used as pollution removal techniques to capture particulate emissions from being emitted in the atmosphere. It is also crucial to have a stable source of feedstock to maintain a high optimal during incineration to reduce hazardous gas such as dioxins and furans. Incineration requires good waste segregation at source to filter out waste with high moisture content to increase efficiency. Whilst incineration is a better waste treatment option compared to open burning and landfilling, GHG emissions are still emitted from incineration plants. Hence, the presence of incinerators does not mitigate the need to focus on reducing waste generation or other waste diversion methods upstream.

  Landfill gas recovery

  Landfill gas recovery is the process by which methane gas is collected from solid waste deposited in a landfill. Instead of allowing for methane gas release into the atmosphere, sanitary landfills have a network of pipes to recover methane rich landfill gas that can be converted into a renewable energy source. Other superior options include reducing organic waste channelled to landfills to resolve the root cause of methane emissions, such as potential landfill bans of food waste and enhanced alternative treatment of food waste.

Figure 70: Comparison of different WTE technologies

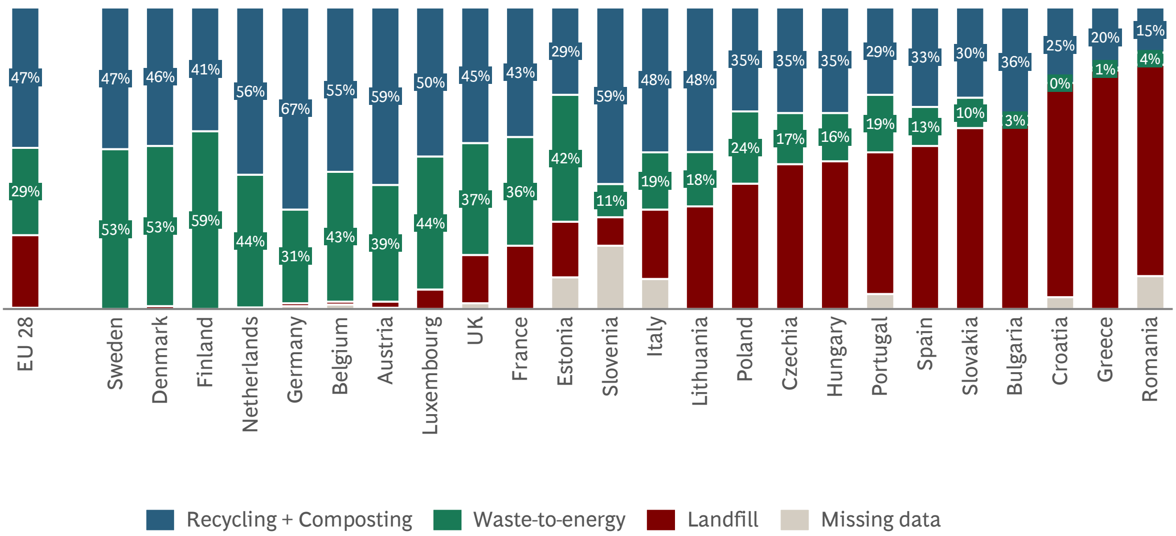


Source: Industry Reports, Expert Discussions, Project Team Analysis

Figure 71: Breakdown of waste treatment methods by European countries

Of total waste, 47% is recycled or composted; whilst 29% is channelled to waste-to-energy plants in Europe

Municipal waste by treatment (2017) (%)



1. Graph by CEWEP. Percentages are calculated based on the municipal waste reported as generated in the country
Source: Eurostat, Project Team Analysis

Figure 72: List of key enablers of countries with high performing recycling rates

Countries with high recycling rates supported by various legislative and policy enablers

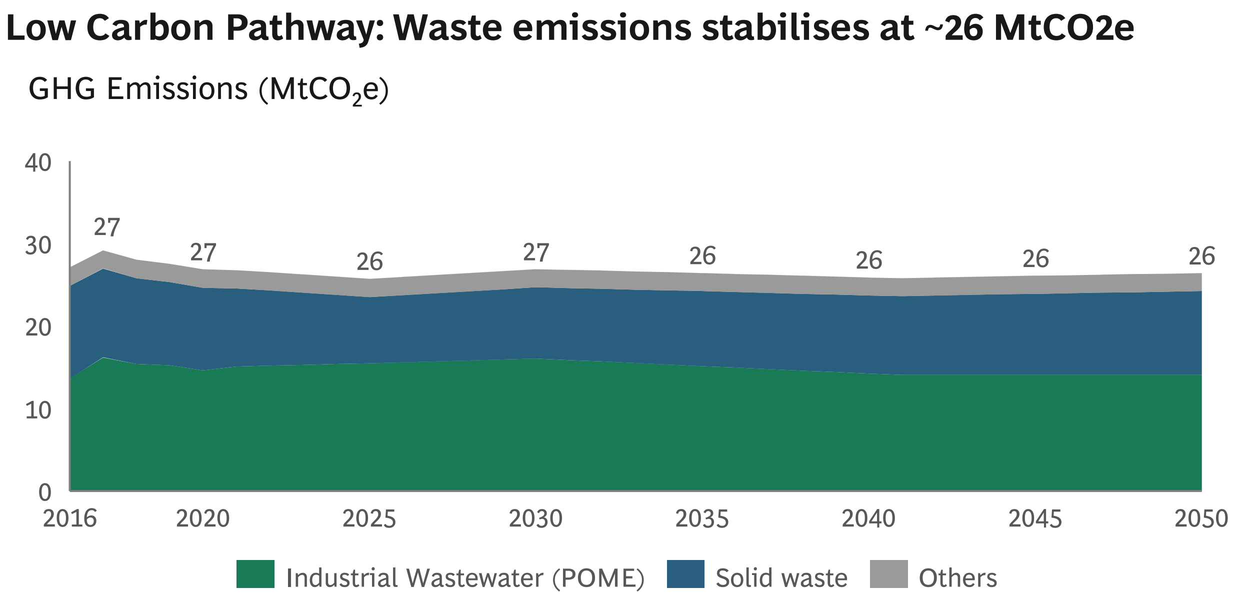
Legislative / Policy Enablers											
Widespread separate collection of key dry recyclable materials	✓		✓	✓	✓	✓	✓	✓	✓	✓	
Widespread separate collection of biowaste	✓		✓	✓	✓	✓	✓	✓	✓		✓
Landfill and/or incineration bans for selected materials	✓	✓	✓	✓	✓		✓	✓			
Statutory recycling rate/separate collection targets	✓	✓		✓	✓	✓	✓	✓	✓	✓	
Restrictions on collection of residual waste				✓			✓	✓	✓		
Variable-rate charging (e.g., Pay as you throw)		✓			✓	✓	✓	✓	✓		✓
Extended producer responsibility scheme(s)	✓	✓			✓	✓	✓	✓			✓
Deposit refund scheme(s) for packaging	✓	✓	✓		✓	✓	✓	✓			✓

Source: World Recycling League, Eunomia

Collective impact on GHG emissions pathway

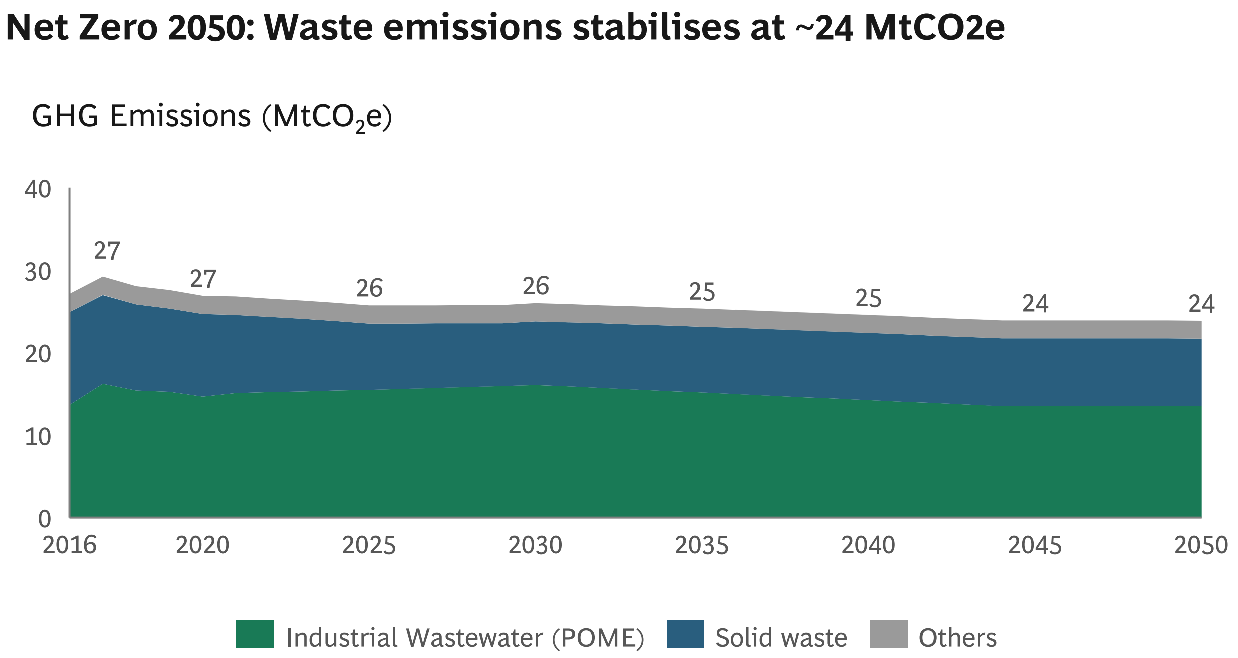
The waste sector is projected to increase from 27 $MtCO_2e$ in 2016 to 42 $MtCO_2e$ in 2050 primarily due to the increase in CPO production and population growth. With current forward-looking plans, waste emissions are forecasted to reduce by 12 $MtCO_2e$ to 30 $MtCO_2e$ in 2050. In the low carbon pathway, adoption of identified abatement levers can further reduce emissions by 4 $MtCO_2e$ in the low carbon pathway and 6 $MtCO_2e$ in the Net Zero 2050 pathway, decreasing total waste emissions to 26 $MtCO_2e$ and 24 CO_2e respectively

Figure 73: Low carbon pathway evolution of GHG emissions for the waste sector



Source: Project Team Analysis

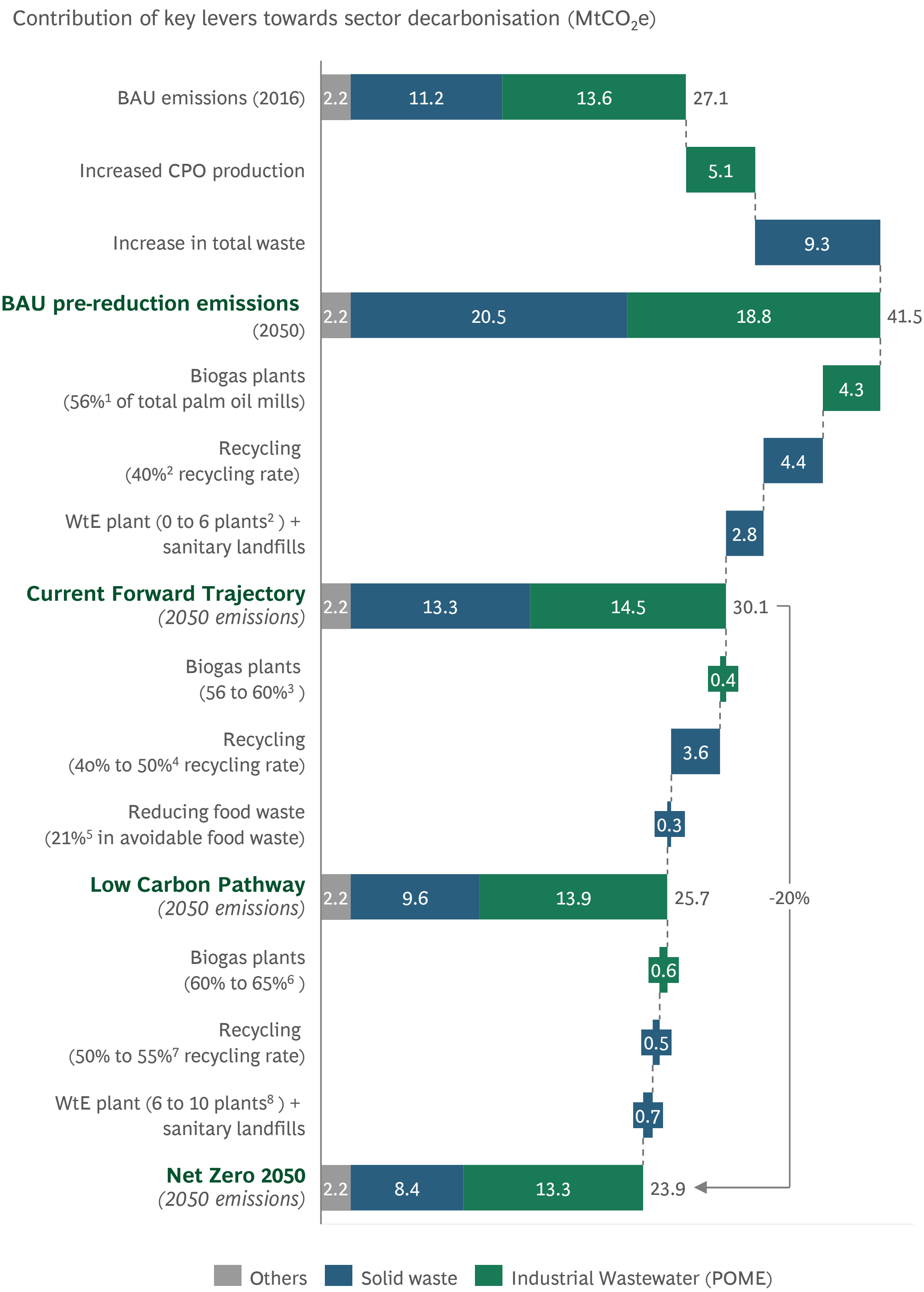
Figure 74: Net Zero 2050 pathway evolution of GHG emissions for the waste sector



Source: Project Team Analysis

Figure 75: Breakdown of lever contribution towards sectoral decarbonisation in the waste sector

~20% increased reduction in GHG emissions from current forward trajectory in Net Zero by 2050 scenario for the waste sector



1. Based on current projection of 5 biogas plants equipped per year; 2. Based on KPKT target of 40% recycling rate & 6 WtE plant by 2025; 3. Based on total % of palm oil mills within 20km of grid; 4. Extending KPKT's target from 2025 to 2050; 5. Based on WRAP Love Food, Hate Waste campaign; 6. Extending coverage of palm oil mills that are far from grids for rural electrification & to power workers' quarters; 7. Based on current best practice recycling rate from Germany at 55%. May require more ambitious targets based on new technologies/ innovations; 8. Based on previous KPKT plan to have 1 WtE plant in every state

Agriculture

The agriculture sector has been a key pillar for Malaysia's development over the years, promoting a range of socioeconomic outcomes for the country. The agriculture sector comprises of agriculture products which include both commodity crops such as palm oil and rubber as well as food crops such as rice, fruits, and vegetables as well as livestock products.

Beyond its direct contribution to meeting the country's food security needs, the agriculture sector has been a key driver of the country's overall economic growth. In 2019, the agriculture sector directly contributed to 7% of GDP with a further 3% of GDP created from highly related downstream industries such as food and beverage processing, rubber manufacturing, and others. Agricultural exports also accounted for over 6% of the country's total exports in 2019. From a social perspective, the agriculture sector has played a key role in poverty alleviation particularly in rural areas and supporting the livelihoods of smallholders through income and job opportunities.

Looking forward, the agriculture sector will continue to have a key role to play for the country and sustainable development of the sector factoring in economic, social, and environmental objectives are key. The agriculture sector will need to respond to the expanding food needs of a growing population and the growing importance of domestic food security, as highlighted by the supply chain impacts of the recent global pandemic.

With the growth in agriculture production over time, emissions from the agriculture sector has gradually increased. In the latest national GHG inventory, the agriculture sector was responsible for 11 $MtCO_2e$ of emissions, 3% of the country's total emissions. Notably, these emissions are direct emissions from the agriculture sector and exclude the emissions and removals from cropland and cropland-related land use change, which is accounted for under the LULUCF sector.

Historic trajectory

Agriculture sector emissions has been growing at approximately 2% per annum between 1990 and 2016. The largest source of emissions from the agriculture sector is managed agriculture soil, which contributed to 49% of total emissions and has been growing most rapidly at 3% per annum, relative to other agriculture emission sources[101]. Emissions from rice cultivation (22%), enteric fermentation from livestock (13%), and manure management (11%) are the next largest source of emissions for the agriculture sector. The remaining 5% of emissions is made up of urea and biomass burning related emissions.

Forward trajectory

For food crops and livestock, the National Agrofood Policy is a key reference to project the forward trajectory of production. Inputs from the draft National Agrofood Policy 2.0 (2021-2030) was leveraged to determine potential planted area impact for each crop, based on target self-sufficiency levels (SSL) for food security and identified potential yield improvements opportunities. The impact of SSL targets on livestock populations was also incorporated. The SSL targets defined for 2030 was assumed to hold until 2050.

The National Agrofood Policy 2.0 is focused on ensuring a sustainable, resilience, and technologically-driven agrofood industry[102]. The policy also highlights the need for a paradigm shift towards sustainable food systems, adapted to climate change as well as the reduction of GHG emissions per unit of food produced, thereby lowering the carbon footprint of the agrofood industry.
Several key strategies outlined in the policy, are complementary to climate mitigation and adaptation priorities of the country. This include the reduction of food waste, conservation of biodiversity and natural resources, planning and adaptation to climate change such as the impact of droughts, floods, and rising temperatures on crop yields. Beyond the agrofood policy, the impact of initiatives which have an impact on reducing agriculture emissions such as the Semi-Aerobic Rice Intensification (SARI) program, was also factored into consideration.

101. Ministry of Environment and Water (2020). Malaysia Third Biennial Update Report To The UNFCCC
102. Ministry of Agriculture and Food Industries (MAFI) (2021). Draft National AgroFood Policy 2.0

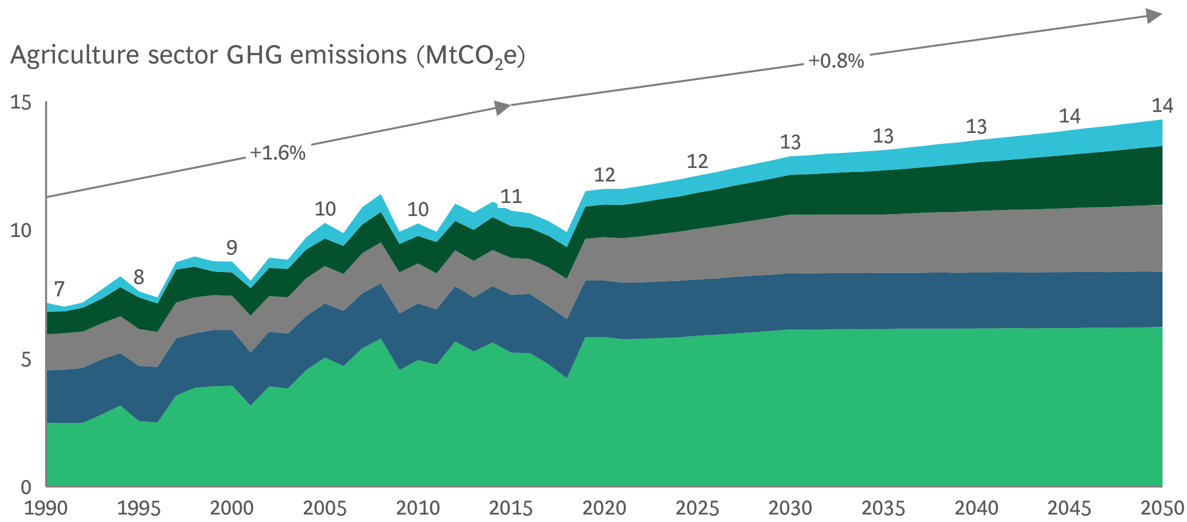
For commodity crops, the National Commodity Policy represents a key reference policy. In the last National Commodity Policy (2021-2020) the importance of modernising and transforming the commodity industry for enhanced competitiveness and sustainability was highlighted. Inputs from other announcements such as the palm oil cultivation cap of 6.5 million hectares were also incorporated into the forward trajectory.

Based on the combination of factors above in the current forward trajectory, emissions from the agriculture sector is expected to increase from 11 $MtCO_2e$ to 14 $MtCO_2e$ by 2050. The largest emissions sources continue to be managed agricultural soil at around 47% of total emissions, and enteric fermentation and rice cultivation at around 17% of total emissions each.

The increase in agriculture soil emissions is driven primarily by increased fertiliser application at planted area grows. Rice cultivation emissions are expected to stabilise as water management regimes remain constant and given that increase in production is expected to derive from yield improvements rather than expansion in planted area. Some improvements in emission reduction due to SARI adoption are expected, but not sufficient to materially shift overall emissions from rice cultivation. In contrast, enteric fermentation emissions are expected to increase by 1.5 times with growing livestock populations to meet the country's SSL requirements. The increase in livestock will also result in increased emissions from manure management over the period in line with the growth of livestock.

Figure 76: Current trajectory evolution of GHG emissions for the agriculture sector

Current Trajectory: Agriculture emissions to grow to 14 $MtCO_2$ by 2050, growing at ~0.8% p.a. over the 2020-2050 period

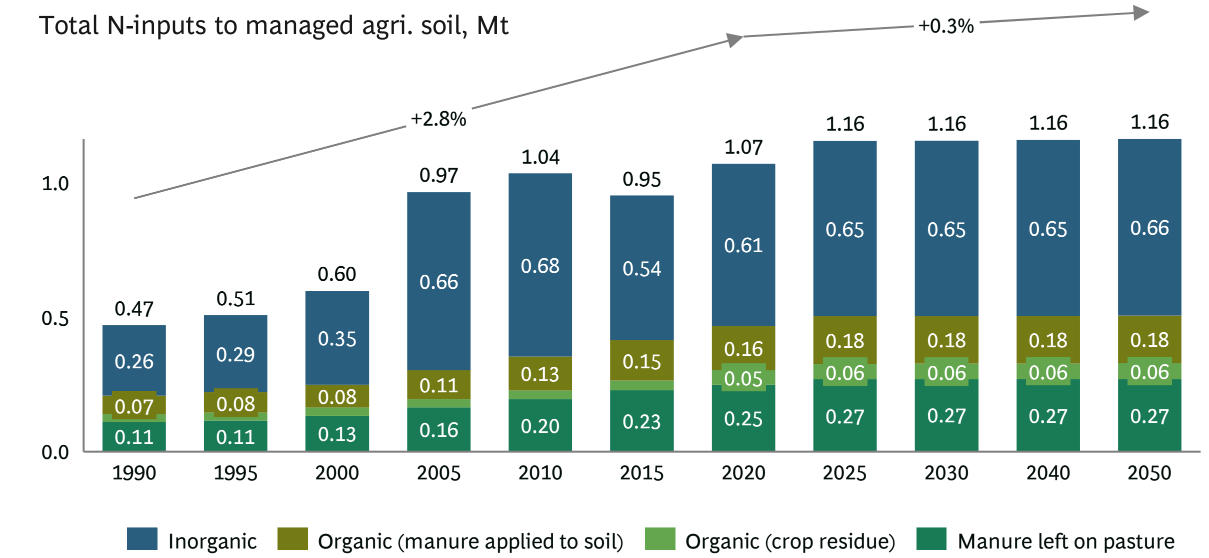


Sources of agriculture sector GHG emissions	2016 emissions ($MtCO_2e$)	1990-2016 CAGR (%)	2016-2050 CAGR (%)
Urea	0.6	+1.8	+1.8
Manure management	1.2	+1.3	+1.9
Enteric fermentation	1.4	-0.2	+1.9
Rice cultivation	2.3	+0.5	-0.2
Managed agricultural soil	5.2	+2.9	+0.5

Source: Malaysia's Third Biennial Update Report to the UNFCCC (2020), Project Team Analysis

Figure 77: Projected evolution of nitrogenous inputs into managed agriculture soil

Managed agri soils: Larger planted area will result in higher nitrogenous fertilisers usage and N-input to the soil



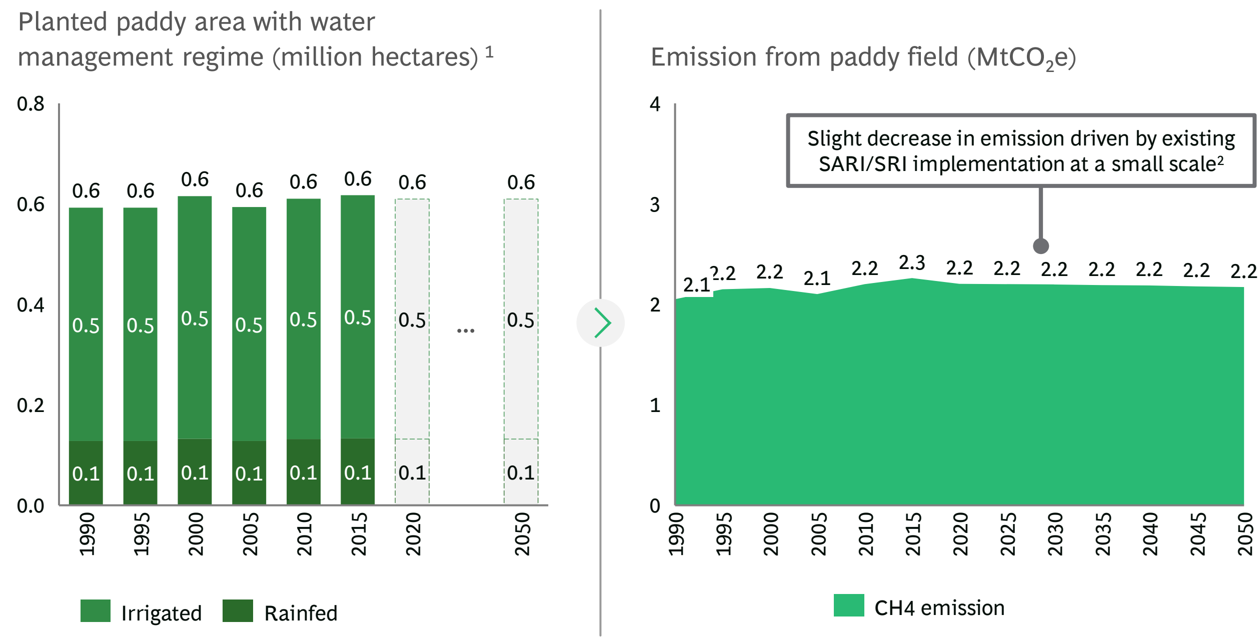
1. Expected to increase further due to the need to increase yield through increased fertilizer usage, as a result of palm oil expansion cap discussed in previous slide; 2. Palm oil mill effluent; 3. Empty fruit bunches 4. Numbers from 2020 onwards are projected
Source: FAO, Expert interview, press release, Project Team Analysis

Figure 78: Projected evolution of methane emissions from rice cultivation

Rice cultivation: emissions to stay flat with minimal change in planted area and water management regime

Total paddy planted area and split by water management regime

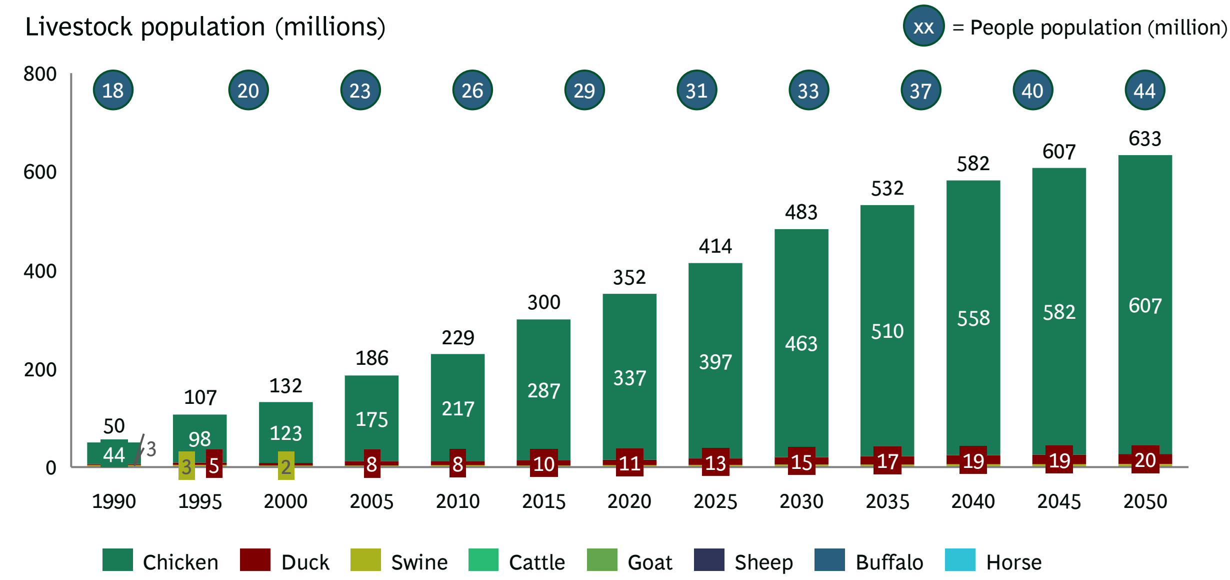
Evolution of rice cultivation emissions in baseline



1. Excludes upland rice field which is not flooded and does not have emission factor; 2. Based on SARI implementation by NESTLE, it is estimated that ~0.1% of planted paddy area has adopted SARI in 2020, and this is projected to increase ~5% of total planted area by 2050 in the BAU scenario; Source: MARDI, Department of Agriculture, Project Team Analysis

Figure 79: Projected evolution of livestock population by type

Livestock: Livestock population projected to increase by 1.8x by 2050 in line with government target self-sufficiency ratios



Note: Assuming same mix of livestock breeding as of 2020 in the future projection
Source: Ministry of Agriculture and Food Industries; Ministry of Plantation Industries and Commodities, Project Team Analysis

Figure 80: Projected evolution of enteric fermentation emissions from livestock

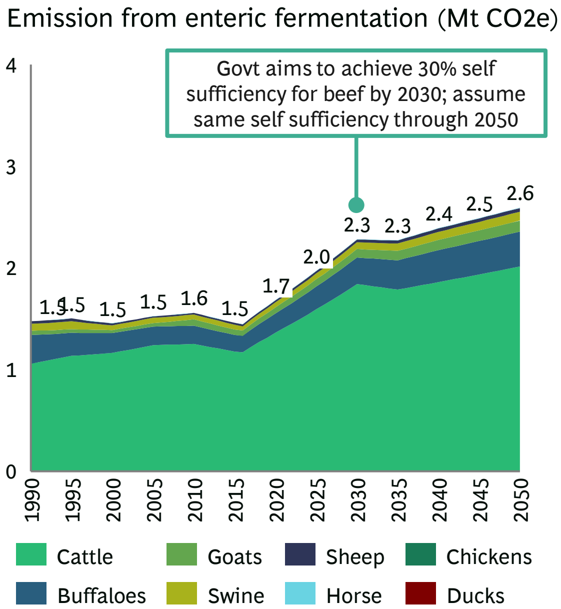
Emission from enteric fermentation projected to increase by 1.5x by 2050, mainly driven by the cattle population

Cattle contributes the highest emission among all livestock …

2050

Livestock	Population mix	CH4 emission/# ($MtCO_2e$)	Total CH4 emission ($MtCO_2e$)
Chicken	95.8%	0	0.00
Duck	3.2%	0	0.00
Swine	0.5%	0.03	0.09
Cattle	0.2%	1.6	2.01
Goat	0.1%	0.1	0.11
Sheep	0.0%	0.1	0.04
Buffalo	0.0%	1.4	0.34
Horse	0.0%	0.5	0.00

… contributing to rise in enteric fermentation



Source: Malaysia 3rd BUR, Press Releases, Project Team Analysis

Overview of the abatement levers

Description of categories of abatement levers

A range of levers were explored to optimise agricultural and livestock management practices in order to reduce GHG emissions from the sector. The three key levers to drive agriculture emission reduction are outlined below:

- Enhancing nutrient stewardship and precision agriculture
- Scaling alternative wetting and drying (AWD) techniques in rice plantations
- Altering feed composition to reduce livestock enteric fermentation

Enhancing nutrient stewardship and precision agriculture to optimise soil N-inputs

Nitrous oxide released directly and indirectly as a result of fertiliser N-inputs into agriculture soil has significant global warming effects, around 298 times the global warming potential of carbon dioxide.

By enhancing nutrient stewardship by applying the "4 R's" of right source (i.e., right fertiliser product), right rate, right time, and right place in fertiliser application, the level of nitrogenous soil inputs and consequently the amount of managed agricultural soil emissions can be reduced. The concept of nutrient stewardship is not new and has been promoted for decades within the agriculture industry in Malaysia. However, scaling up and ensuring universal applications of these techniques, especially across smallholders, and supported by latest technology enablers can have a sizable impact. Moreover, it is in the economic interests of farmers to apply the 4 R's, enabling fertiliser use to be decreased by up to 20% to 30% whilst retaining yield.

- **Controlled-release fertiliser:** Optimise the use of slow-release or controlled-release fertiliser over conventional fertilisers which currently has low penetration. Slow release of nutrient and optimised rates as required by plants enhances the demand-supply matching of nutrients and reduces nutrient leaching in the process. The rapid improvement in costs of controlled-release fertiliser, combined with growing labour shortages, will further increase economic upside of switching towards controlled-release fertiliser.

- **Reduce N-losses with inhibitors:** Application of inhibitors to fertiliser can reduce the rate at which urea is broken down into ammonium (e.g., with urease inhibitors) to reduce ammonia volatisation as well as the rate where ammonium is broken down into nitrites and nitrates (e.g., with nitrification inhibitors) to reduce leaching.

- **Precision agriculture to optimise granularity of application:** Improve area granularity of heterogenous fertiliser application based on specific area nutrient demand-supply needs, aided by technology solutions. This includes collating granular area data from soil or plant testing to inform optimum nitrogen fertiliser rates, and optimising planning and application in accordance with specific area needs. Incorporating weather forecasts data to identify risks of soil saturation, and optimising fertilising schedules accordingly, can also be conducted.

- **Cover crops:** Scaling and ensuring optimal application of suitable cover crops across agriculture sectors which can contribute to natural enhancements in soil nutrition and fertility. For example, cover crops such as *Mucuna Bracteata* which are already being widely used in palm oil plantations. Scaling natural sources of nutrient provision across agriculture sub-sectors and across farmer groups (e.g., scaling-up adoption across smallholders) will support the reduction of synthetic fertiliser and associated managed agriculture soil emissions.

Using a combination of nutrient stewardship levers, approximately 1.3 $MtCO_2e$ of emission reductions can be expected by 2050. This has been incorporated into the Net Zero 2050 pathway.

Scaling alternative wetting and drying (AWD) techniques in rice plantations

The primary driver for emissions from rice cultivation is from the anaerobic decomposition of organic material in flooded rice fields which produce methane during the paddy growing season. Around 60% of paddy fields in Malaysia's are continuously flooded, with irrigation through an embankment to ensure water supply. A further 30% of paddy fields are rainfed, where fields are flooded for part of the season. The remaining 10% of paddy fields are upland rice fields which are dry and not flooded.

Continuously flooded or irrigated paddy fields have an emission factor of 4.8 tonnes of CO_2e per hectare, significantly higher to partially flooded or rainfed paddy fields which have an emission factor of 1.3 tonnes of CO_2e per hectare. Upland paddy fields produce negligible emissions.

Optimised water management can reduce emissions from rice cultivation. Existing efforts in this area include the adoption of Semi-Aerobic Rice Intensification (SARI) paddy farming techniques, such as that being promoted by the Nestle Paddy Club amongst Malaysian farmers. With the use of SARI techniques, reduced irrigation water by 30% to 40% is realised, lowering methane emissions. SARI currently is being adopted in over 600 hectares of paddy fields in Malaysia, comprising around 1% of total paddy planted area.

Other water management techniques include Alternate Wetting and Drying (AWD) which involves farmers draining paddy fields two to three times a year during growing seasons. This has shown to reduce GHG emissions by 30% to 40%. In major rice producing countries such as Bangladesh, the government targets to scale up AWD rice production to 20% of its total rice cultivation by 2030. Leveraging a combination of water management techniques such as AWD and SARI can reduce methane emissions from rice plantations by up to 0.4 MtCO_2e if adopted by 60% of total harvested paddy area in Malaysia.

Altering feed composition to reduce livestock enteric fermentation

Methane emissions from livestock enteric fermentation derive primarily from cattle, which is expected to grow to 2 MtCO_2e based on the country's food self-sufficiency levels (SSL). Feed additives or supplements can reduce methane emissions from ruminant livestock, by inhibiting the microorganisms that produce methane in the rumen.

Case studies have showed that incorporating fats and oils into the diets of cattle population can suppress methanogenesis and methane emission from cattle by 15–20%, with high potential for widespread application. Various nascent solutions are also being explored, such as seaweed, where 80% reduction in methane emissions from cattle has been observed when incorporated as 3% of the total diet. Other studies have also shown that feeding palm oil kernel cake to cattle, sheep, and goats can reduce microorganisms in the rumen, contributing to methane emission reduction. Through a combination of diet optimisation levers, total emissions from enteric fermentation can be reduced by 20%, amounting to 0.4 MtCO_2e of emission reductions in 2050.

Other levers with indirect implications on agriculture sector emissions

Besides these emission levers which directly address agriculture emissions, levers covered in other sections can also indirectly reduce emissions through agriculture demand-side or supply-side shifts. This include structural changes to reduce agriculture demand (e.g., shift to plant-based diets, reduced food waste), measures to increase agriculture land yield productivity (e.g., reducing land required per unit agriculture input), or shift to alternate sources of supply (e.g., hydroponic agriculture, vertical farming). A subset of these levers are covered under other sections such as the waste and LULUCF sectors.

Collective impact of levers on GHG emissions pathway

Based on the agriculture abatement levers explored, approximately 1 $MtCO_2e$ of emissions can be reduced from the current trajectory pathway in the low carbon pathway. These levers include the use of controlled release fertilisers, alternate wetting & drying on rice field (30%) and improving feed and nutrition for cattle.

In the Net Zero 2050 pathway, both fertiliser reduction by precision agriculture & further alternate wetting & drying on rice field (60%) has been identified to achieve a total of 2 $MtCO_2e$ reduction when combined with the levers in the low carbon pathway, which equates to a 15% increase in GHG emissions removed from the agriculture sector.

Figure 81: Low carbon pathway evolution of GHG emissions for the agriculture sector

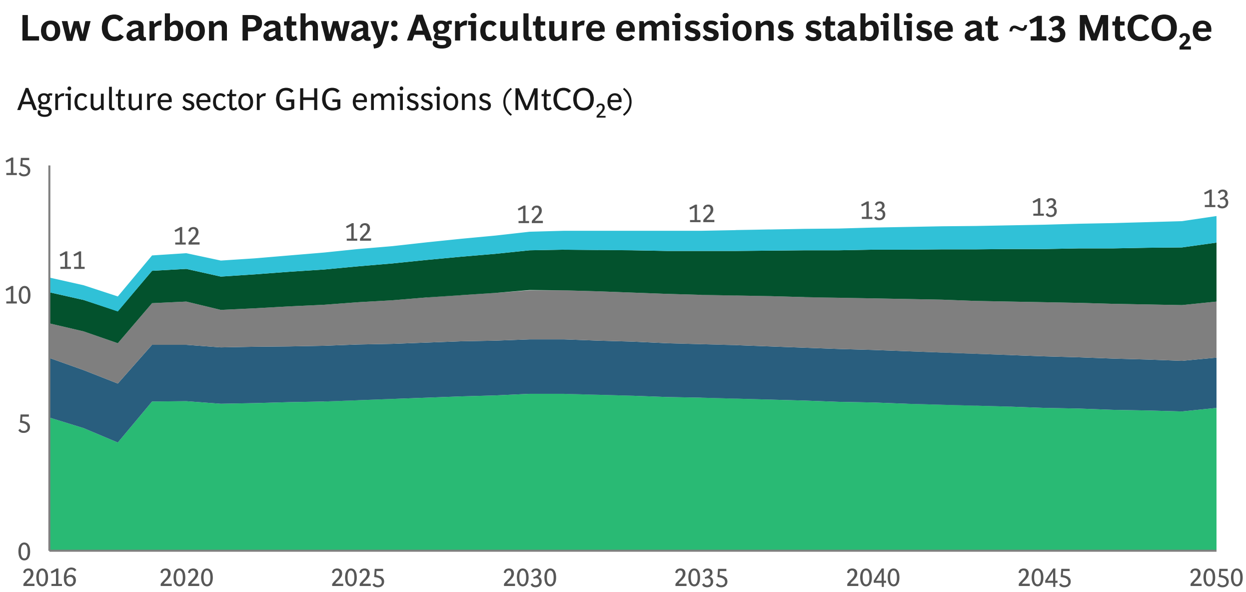


Figure 82: Net Zero 2050 pathway evolution of GHG emissions for the agriculture sector

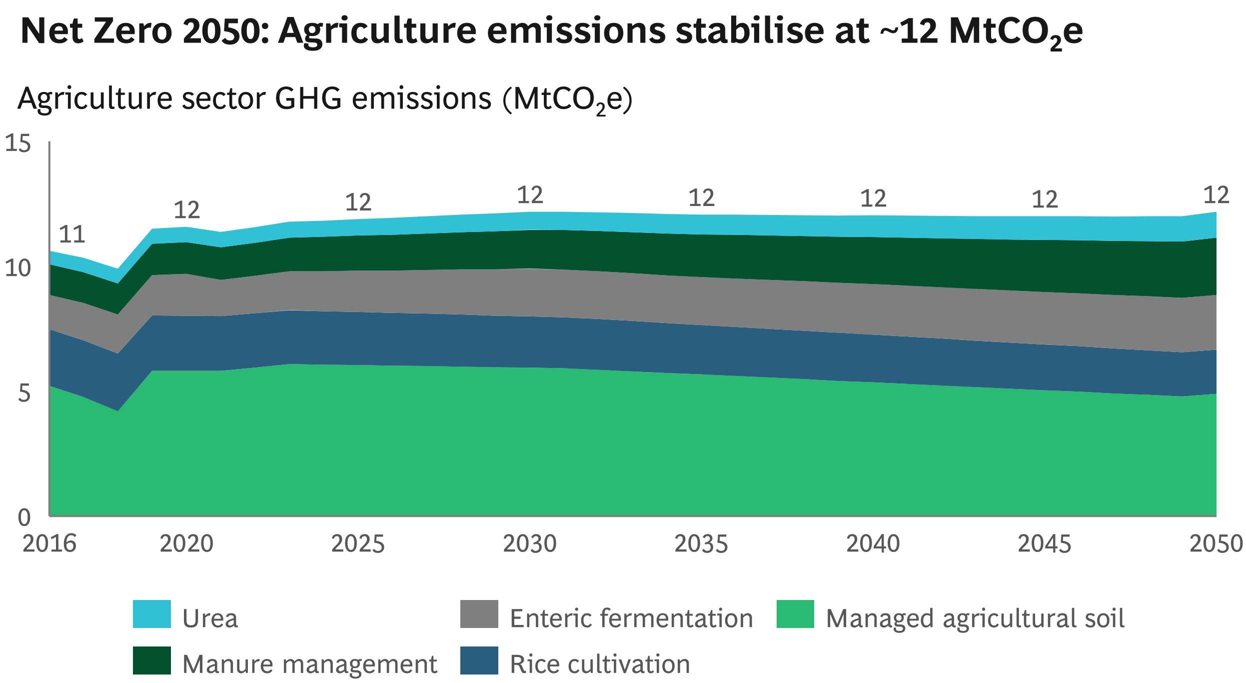
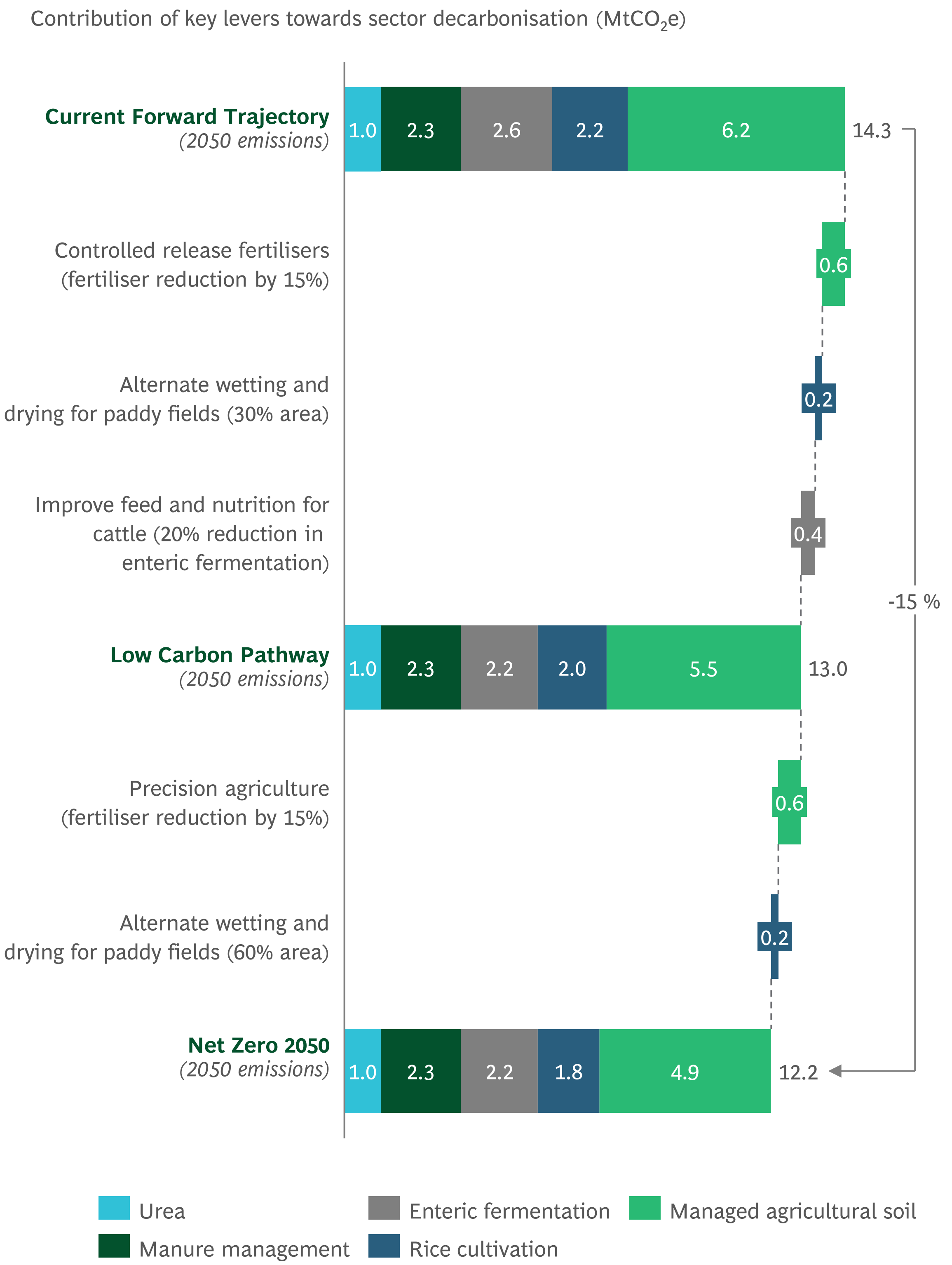


Figure 83: Breakdown of lever contribution towards sectoral decarbonisation in the agriculture sector

~15% increased reduction in GHG emissions from current forward trajectory in Net Zero by 2050 scenario for the agriculture sector



Priority #4:

Price carbon

Overview

Carbon pricing is a key technology-agnostic lever to support the reduction of GHG emissions through the use of market mechanisms to pass the cost of emissions onto emitters. Implemented effectively, carbon pricing discourages the net emissions of GHG into the atmosphere, addressing the causes of climate change and supporting countries to meet climate agreements.

The release of GHG emissions into the atmosphere has large costs for society, from the impact on air pollution, warming temperatures, and various adverse impacts related to global warming such as extreme weather events, risks to food and water suppliers, and others. As these costs are borne by society at large and not the emitter, this represents a form of negative externality. Moreover, without any mechanism for emitters to be liable for the adverse societal impact they incur, there is no direct economic disincentive for emitters to reduce harmful emissions. This phenomenon is known as market failure – where current economic incentives fail to factor in the current and future social costs of a decision, leading to sub-optimal decisions by individual players to the detriment of society.

By putting a price on carbon, society can hold emitters responsible for the costs of adding GHG emissions to the atmosphere. Carbon prices are highly scalable and have the potential to decarbonise across various sectors of the economy by changing the behaviour of consumers, businesses, and investors whilst incentivising technological innovation and generating revenues which can be rechannelled for productive use. Well-designed carbon prices offer three-pronged benefits by protecting the environment, driving investments in clean technologies, and raising revenues.

Carbon prices can be adopted through various applications and channels, each with its own unique considerations and design choices:

- Domestic carbon tax or an emission trading system (ETS)
- International carbon border adjustment mechanisms (CBAM)
- Voluntary carbon markets
- Internal carbon pricing or shadow pricing by corporates

Domestic carbon pricing mechanisms

Domestic carbon price options

There are two dominant mechanisms for domestic carbon prices, which are carbon tax and emission trading systems (ETS) which is otherwise known as compliance carbon markets.

- **Carbon tax** puts a direct price on GHG emissions and requires emitters to pay for every tonne of carbon pollution emitted. The added costs of emissions represents a deterrent and encourages emissions reduction as lower emissions equates to lower taxes. This approach fixes the price of emissions and allows the market to determine the volume of emission reductions, influenced by the price signal (i.e., fixed price, variable quantity).

- **An emission trading system (ETS)** or a cap-and-trade system sets a limit on the total direct GHG emissions from a specific sector and establishes a market where the rights to emit, known as carbon permits or allowances, are traded amongst market participants. This enables for market efficiency as players who can reduce their emissions are able to purchase less credits or even sell surplus credits to other producers at the prevailing market price. In contrast to carbon tax, ETS schemes provides certainty on emissions reduction (based on the established cap) and allows the market to determine the price required to clear market demand and supply for allowances (i.e., fixed quantity, variable price).

Figure 84: Penetration and country coverage of various carbon pricing schemes

Over 7,500 $MtCO_2e$ covered under carbon pricing schemes

1 Market cap & trade (ETS[2])

Set Quantity: Issue limited number of allowances per year (e.g., via auctions) that can be traded on a secondary market, creating a carbon price

EU ETS	Shenzhen pilot ETS
Korea ETS	Shanghai pilot ETS
Switzerland ETS	Beijing ETS
Tokyo CaT	Guangdong pilot ETS
Saitama ETS	Hubei pilot ETS
Kazakhstan ETS	Chongqing pilot ETS
UK carbon price floor[1]	Fujian pilot ETS
Alberta CCIR	China national ETS
BC GGIRCA	New Zealand ETS
Ontario CaT	Australia CPM
Canada federal OBPS	Australia ERF Safeguard Mechanism
Nova Scotia CaT	RGGI (Eastern US States)
Saskatchewan OBPS	California CaT
Canada federal fuel charge	Washington CAR
Quebec CaT	Massachusetts ETS

Covers ~5,300 $MtCO_2e$

2 Carbon tax

Set Price: Set a direct price on GHG (i.e., dollar per every ton of emissions produced)

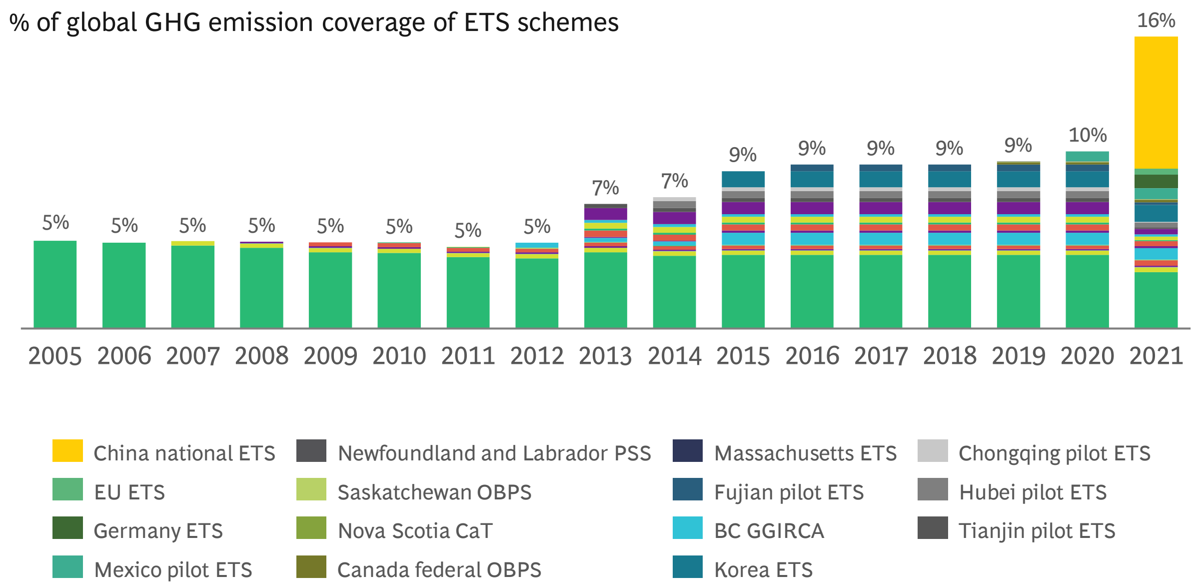
Finland carbon tax	France carbon tax
Poland carbon tax	Mexico carbon tax
Norway carbon tax	Spain carbon tax
Sweden carbon tax	Portugal carbon tax
Denmark carbon tax	Chile carbon tax
Slovenia carbon tax	Colombia carbon tax
Estonia carbon tax	Argentina carbon tax
Latvia carbon tax	Singapore carbon tax
Switzerland carbon tax	South Africa carbon tax
Liechtenstein carbon tax	
BC carbon tax	
Alberta carbon tax	
Iceland carbon tax	
Ukraine carbon tax	
Japan carbon tax	

Covers ~2,350 $MtCO_2e$

1. UK Carbon Floor Price is currently a fixed fee, rather working like a tax 2. ETS = Emission Trading Scheme
Source: WRI; C2E2

Figure 85: Growing coverage of ETS schemes of total global emissions

ETS growing quickly, with EU and China ETS the largest share



Source: World Bank

Perspectives on key design parameters

In the adoption of domestic carbon pricing policies, learnings from international applications can be adopted to ensure strong policy design:

- **Perspectives on carbon tax compared to ETS**

  Carbon tax and ETS are highly established carbon pricing policy mechanisms. Currently, ETS schemes and carbon tax covers around 5,300 $MtCO_2e$ and 2,350 $MtCO_2e$ of global emissions, respectively. Both have advantages and drawbacks relative to each other. However, many of the relative drawbacks of each scheme can be mitigated by effective market design and supplementary mechanisms. Both schemes, if well designed, can support the country to achieve its climate ambitions.

  On the surface, the typical associated disadvantages for carbon tax include the lack of certainty of emission reduction, exacerbated in boom periods where carbon prices may not be a sufficient deterrent to drive demand reduction due to high demand[103] . Whilst it is true that the carbon tax by design does not offer the same degree of emissions certainty as cap-and-trade, design elements such as a "ratcheting mechanism" that will adjust the tax upward if the initial emissions reductions are too low can be considered.

  Moreover, it should be considered that cap-and-trade mechanisms limit the maximum possible emissions savings, whereas carbon taxes do not. This can encourage emissions reduction beyond targets (compared to a cap which fixes the emission levels) and can be particularly effective to drive emissions reduction when the cost of alternative low carbon technologies are rapidly declining.

  In contrast, ETS schemes are typically associated with disadvantages of high price volatility which increases complexity of long-term investment planning given the challenges of determining the net present value of low carbon investments. Moreover, in periods of low economic activity, prices of allowances can drop to zero as seen in multiple instances in the EU ETS, effectively not providing a price signal for a shift towards low carbon alternatives. However, effective market design such as the setting of carbon price floors and ceilings or the more stringent setting of emission caps can address this challenge. Other mechanisms include the establishment of a market stability reserve which automatically adjusts the volume of demand and supply of allowances to avoid large surpluses (causing zero carbon prices) or large shortages (causing rapid price inflation).

  Another key downside associated with ETS schemes is the relative higher sophistication of the scheme relative to carbon prices, such as the need to establish a secondary market and the capabilities to manage the demand-supply balances of allowances, which increases time to market. Without strong regulator capabilities, the risks of large fluctuation or zero carbon price scenarios from an excess supply of allowances may also emerge. There is also sophistication required in determining the level of free allocations to be provided to players, known as free allocation through grandparenting.

Background

Following the 12th Malaysia Plan, a domestic emissions trading scheme (DETS) will serve as a catalyst for the country's carbon trading sector. The development of the DETS will be carried out jointly with the Finance Ministry, Bursa Malaysia, and other stakeholders. The DETS is planned for implementation in phases and a single platform will be developed. Establishment of the DETS will enable state government authorities and the private sector to execute carbon credit transactions domestically instead of internationally which potentially has higher transaction costs.

103. World Resource Institute (2016) Carbon Tax vs. Cap-and-Trade: What's a Better Policy to Cut Emissions?

Firstly, these downsides can be mitigated by effective capability transfer from experienced regulators of other ETS schemes. In addition, Malaysia has the benefit of observing the track record and impact from ETS schemes such as the EU and is in a better starting position to avoid pitfalls observed in the past. Some of these complexities can be mitigated by adopting mechanisms such as the market stability reserves that reduces the burden on regulators to get the volume of allowances right in the first instance, due to the ability to adjust based on market demand-supply interventions.

Whilst secondary markets may take a longer duration of time to establish, this creates a higher amount of economic flexibility for players. For example, a tax requires a firm each year to decide how much to reduce its emissions and how much tax to pay. Under a cap-and-trade system, borrowing, banking and extended compliance periods allow firms the flexibility to make compliance planning decisions on a multi-year basis, increasing flexibility and the benefits associated with it.

Common characteristics of successful domestic carbon price scheme

There are some key common characteristics which make both carbon taxes and emission trading systems (ETS) effective. Developed by the World Bank and the OECD, the FASTER Principles for Successful Carbon Pricing outline some of these common characteristics:

- **Fairness**

    - ***Ensure level playing field*** – carbon prices policies must serve to level the playing field between emission-intensive and low-carbon economic activities, and anchor on the "polluter pays" principle. This includes ensuring that carbon is priced sufficiently to capture the negative externality impact of carbon. This relates to the concept of the social cost of carbon, which attempts to value the damage created by one extra tonne of carbon dioxide emissions in order to internalise this negative externality. This is a key input into environmental policies such as in the United States where the social cost of carbon is estimated to be between USD 43 – 51 per tonne of CO2e[104] (range of social carbon costs for the Obama and Biden administration).

    - ***Avoid carbon leakage*** – other key characteristics of fairness include avoiding risk of adverse competitiveness impacts or carbon leakage. Where risks of carbon leakage exists, various mechanisms can be implemented, including the adoption of a carbon border adjustment mechanism and other countervailing mechanisms.

    - ***Ensure equitable redistributive effects*** – where carbon pricing disproportionally burdens lower income households, targeted complementary measures such as fiscal measures can provide protection without undermining incentives to reduce emission-intensive activities. This can inform one of the uses of carbon tax or ETS proceeds.

- **Alignment of policies and objectives**

    - ***Support with facilitative emission reduction policies*** – carbon pricing policies need to be supported by other enablers such as innovation policies, removal of institutional behaviours, and public spending reallocations, which create coherent direction and provide paths for corporates to decarbonise and move towards a low carbon economy.

    - ***Eliminate conflicting price signals*** – carbon pricing and other mechanisms need to provide consistent signals to consumers, and counterproductive policies such as fossil fuel subsidies should be reformed to ensure clarity of country direction.

104. Stanford (2021) Stanford explainer: Social cost of carbon.

- **Stability and predictability**

    - ***Provides forward-looking direction*** – carbon taxes or ETS system should provide forward-looking direction on carbon price levels or expected reductions in allowance levels in ETS markets over time. For example, the price for a carbon tax can be scheduled to increase gradually over time, providing that future certainty. Alternatively, for an ETS initiative, this could take the form of transparency into future allowance retirements, which would drive pricing dynamics in the market. Such transparency encourages investors to incorporate these considerations into their long-term investment decisions, which accelerates decarbonisation faster than the price alone would.

- **Transparency**

    - ***Awareness*** – where early and regular communication with the stakeholders support clear understanding of requirements and impact of carbon prices, as well as the desired outcome and shared benefits to generate buy-in for carbon prices.

    - ***Accurate monitoring*** – systems that effectively monitor and verify emissions and mitigation efforts are fundamental for public and market trust. This includes clear standards of emissions accounting, which are verifiable and enforced to avoid manipulation.

- **Efficiency and cost effectiveness**

    - ***Promote economic efficiency*** – by encouraging least-cost emissions reduction, players are able to decide on the optimal mechanism to adopt in order to reduce emissions. The technology-agnostic nature of carbon pricing also serves to promote economic efficiency and optimise resource allocation.

    - ***Minimise administrative costs*** – Reduced costs of administration to avoid burden on both producers (i.e., carbon prices should penalise producers based on emissions produced and not with large fixed administrative costs associated with non-value adding reporting or bureaucracy) and government (i.e., reducing total proceeds for redeployment due to high overhead costs). Tracking of emissions in select use cases may be highly administratively burdensome, and this will need to weigh into the prioritisation of sector coverage of carbon prices.

- **Reliability and environmental integrity**

    - ***Sufficient and material coverage*** – ensuring a sufficient coverage of emissions to drive material emission reduction, but also accounting for where transaction and monitoring costs need to be managed.

    - ***Availability of low emission substitutes*** – carbon price policies are more effective when substitutes for emission intensive activities are available at competitive costs. Where options to decarbonise are not available and demand is inelastic, there is a risk that carbon prices will be purely inflationary, with costs passed down to consumers.

    - ***Safeguard from creation of other negative externalities*** – mechanisms need to be in place to avoid solutions which are effective in reducing measured carbon emissions but create large adverse externalities on other dimensions (e.g., emissions in other portions of the value chain, non-emissions environmental impact, social impact). These safeguards will need to support the filtering out of the climate false solutions which may be inadvertently promoted by carbon pricing.

- **Deep dive perspectives on the right price of carbon**

  There are several aspects to consider in determining the required carbon price needed to have a material impact on emissions reduction especially with a carbon tax scheme. This includes perspectives on the social cost of carbon, the bottom-up or goal-seek price required to achieve carbon emissions reduction to the quantum necessary to align to the country's climate targets, or reference carbon prices globally required for 1.5^{0}C compatible pathways.

  The social cost of carbon is based on the principle of ensuring distributive efficiency by fully internalising the negative externalities of carbon emissions. The cost of carbon is the net present value or costs of climate change impacts over a long horizon as a result of the emission of one tonne of carbon today. Many variables influence the social cost of carbon, such as coverage (e.g., should the impact to society only in-country or globally be considered), assessment of the cost of future climate change impact, and discount rates. Limited countries have a view on the social cost of carbon, with the social cost of carbon in the United States of USD 43 – 51 per tonne of CO_2e as a useful reference.

  Another alternative input into carbon pricing is assessing what would be the cost of carbon required to drive abatement to the level required to meet climate targets (e.g., Net Zero 2050) based on the view of current available technologies. Through bottom-up sectoral analysis and abatement curves developed in the study, it is estimated that a carbon price of RM 200 per tonne of CO_2e can economically incentivise 87% of emissions required to achieve Net Zero 2050. Increasing the carbon price to RM 300 per tonne of CO_2e increases that to 95%. This equates to a range of USD 48 – 72 per tonne of CO_2e.

  As a third angle, global reference points on carbon pricing aligned to 1.5^{0}C or 2^{0}C pathways can also be used as inputs into the carbon price setting. The IMF has stated that limiting global warming to 2°C or lower demands an immediate global carbon price that reaches USD 75 / $MtCO_2e$ by 2030. Similarly, the High-Level Commission on Carbon Prices has reported a carbon price range of at least USD 40–80 / $MtCO_2e$ in 2020 rising to USD 50–100 / $MtCO_2e$ by 2030 to meet a 2°C target. The International Energy Agency's (IEA) Net Zero 2050 scenario estimates a USD 75 / $MtCO_2e$ price for advanced economies by 2025 increasing to over USD 130 / $MtCO_2e$ by 2030, in addition to strict climate policies such as renewable energy mandates and elimination of fossil fuel subsidies.

  Given a consideration of factors above, a potential range of carbon prices to consider towards the 2030 period could range between USD 50 – 80 / $MtCO_2e$ by 2030 along the path towards Net Zero 2050.

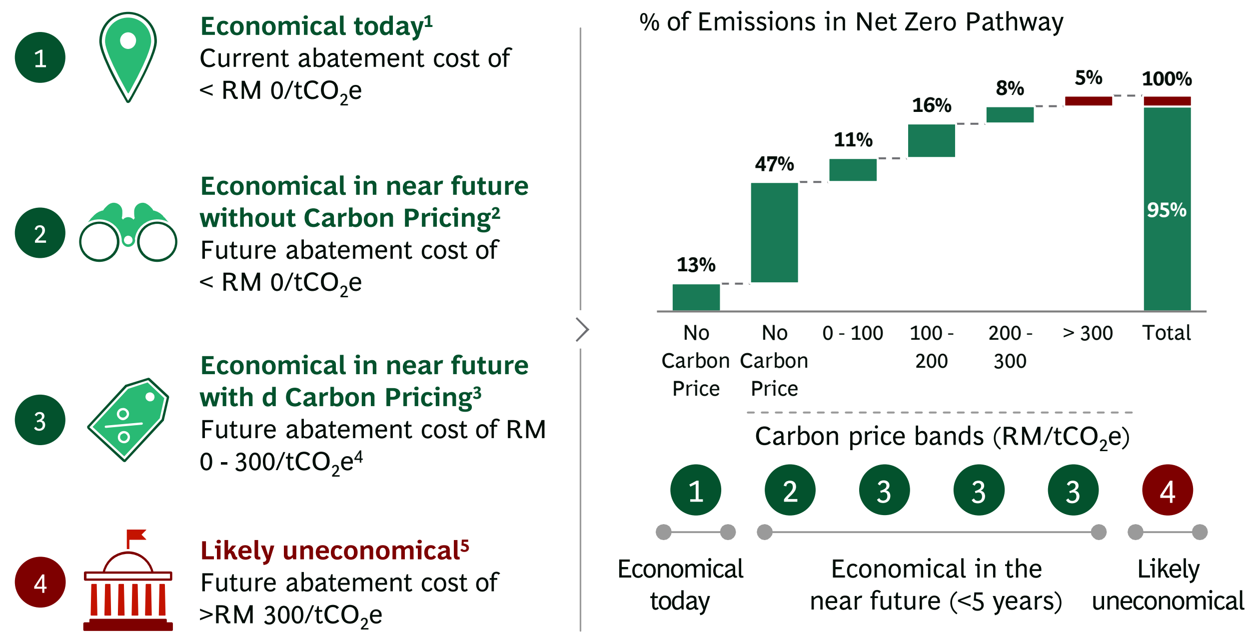
- **Deep dive perspectives on coverage of carbon pricing**

  ETS schemes globally are observed to cover under 40% of emissions on average, with the highest total emissions coverage around 80%. There are several sectors which are almost universally covered by carbon pricing. This includes the industry sector and electricity sector, which are also the largest sources of emissions in the country. Despite a large transport share of total emissions, the coverage is not as high compared to other industries and electricity due to challenges and cost of enforcement.

  Selecting priority sectors for carbon pricing adoption in Malaysia will be critical to ensure material coverage and sufficient impact in driving reduction of emission in key areas. Adoption of carbon tax especially where there are a smaller number of producers with high emission footprint may be considered as implementation is likely to be more manageable compared to large-scale roll-out across sectors with fragmented market supply. Relevant adjustment periods will need to be provided to the sector, to allow for enablers such as carbon accounting and reporting to be built, catalysed by mechanisms such as a zero-carbon price pilot stage to increase market familiarity with the carbon price policy mechanism.

Figure 86: Carbon pricing required to make majority of Net Zero investments economic

Carbon price needed to make 35% of emissions reduction required for Net Zero 2050 pathway commercial



1. Economically net positive (NPV > 0) with current technology maturity 2. Economically net positive (NPV > 0) based on projected technology evolution in next few years 3. Carbon pricing could make these levers economically feasible 4. Based on median carbon pricing ($50-$80) from Report of the High-Level Commission on Carbon Prices (Carbon Pricing Leadership Coalition) and conversion of RM: USD rate of 4:1. 5. Most uneconomic levers; will likely require government funding. Lever justified for broader spillover effects (multiplier impact on GDP, jobs, and positive externalities beyond carbon reduction
Source: Carbon Pricing Leadership Coalition, Project Team Analysis

Figure 87: Country coverage of total emissions via ETS

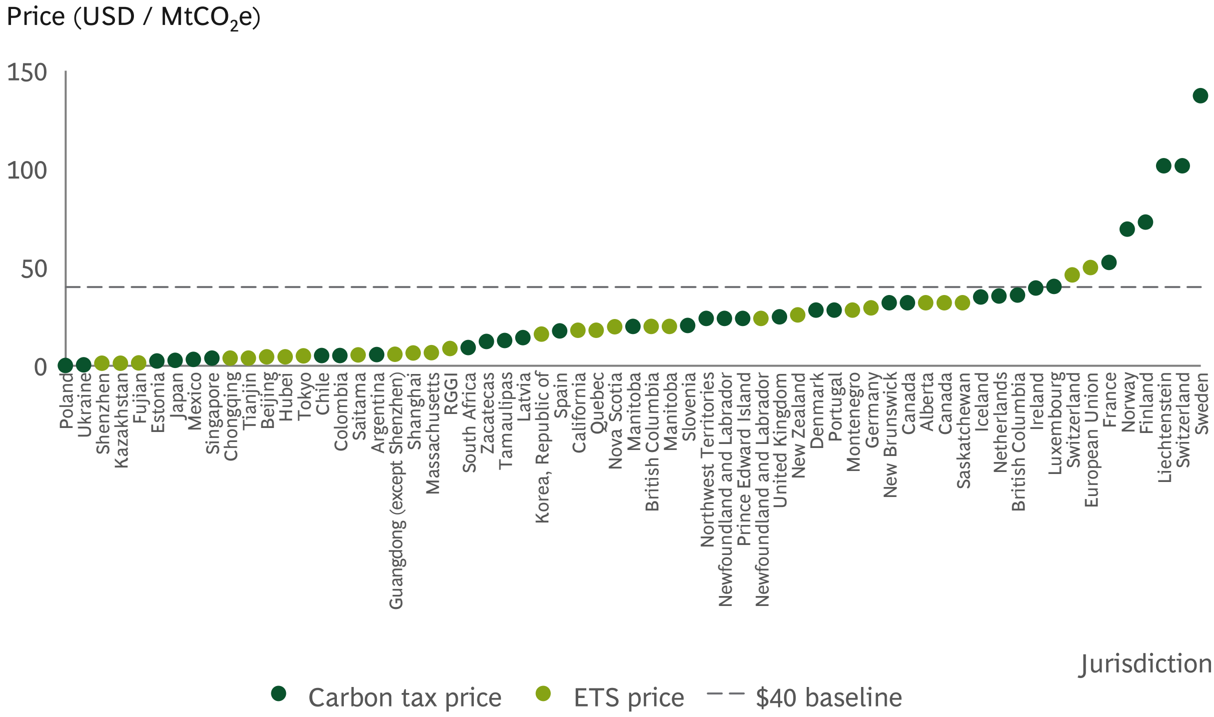
Sector and emission coverage of various ETS schemes

Country	Industry	Aviation	Waste	Agriculture	Electricity	Transport	Buildings	Fossil Fuels	% of Total Emission Covered
South Korea	✓	✓	✓		✓		✓		77%
Kazakhstan	✓			✓	✓				55%
Switzerland	✓				✓		✓		10%
EU	✓	✓			✓			✓	39%
Canada	✓		✓		✓			✓	78%
California	✓				✓	✓			75%
New Zealand	✓		✓	✓	✓	✓		✓	51%
Australia	✓				✓				60%
China[1]	✓	✓			✓	✓	✓	✓	40%
Japan	✓				✓		✓	✓	20%
UK	✓	✓			✓				31%

1. The coverage includes the China national ETS and eight ETS pilots. The coverage represents early unofficial estimates based on the announcement of China's NDRC on the launch of the national ETS of December 2017 and takes into account the GHG emissions that will be covered under the national ETS and are already covered under the ETS pilots. The sector symbol refers to the covered sectors in the national ETS or (one of the) ETS pilots. The national ETS will initially cover the power sector only. The covered sectors vary per ETS pilot.
Source: State and Trends of Carbon Pricing 2019, World Bank; BCG

Figure 88: Global distribution of carbon prices

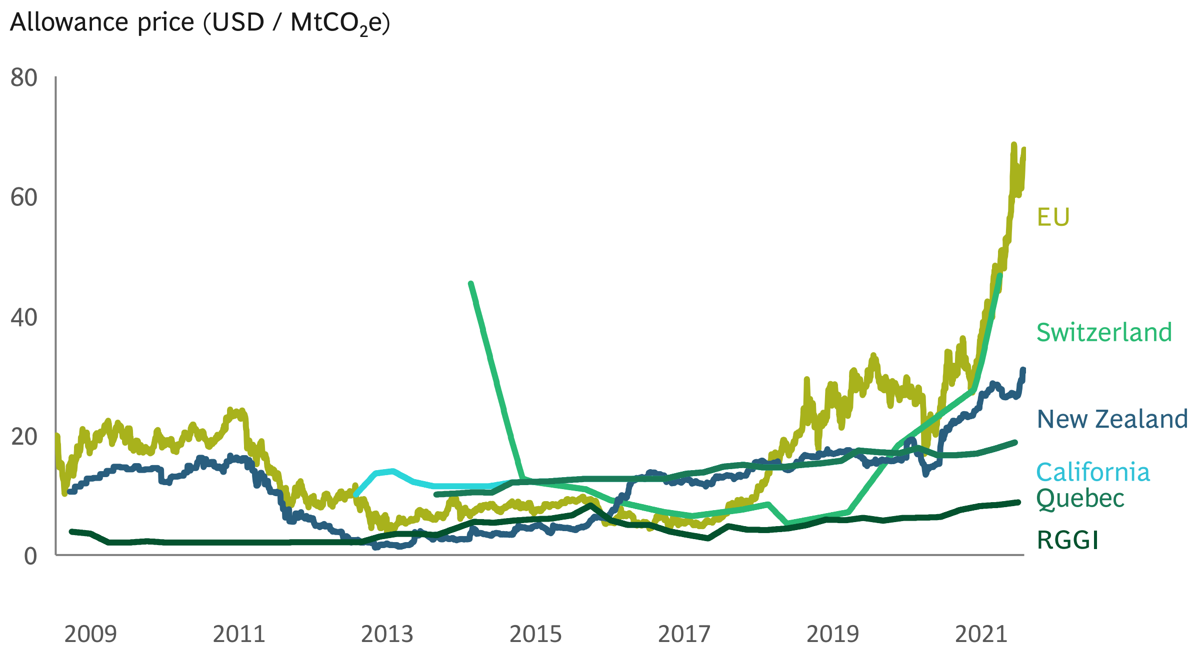
Carbon price needed to make 35% of emissions reduction required for Net Zero 2050 pathway commercial



Source: World Bank (August 2021)

Figure 89: Historic price movement on ETS schemes

Significant fluctuation of compliance ETS allowance prices over time



1. RGGI is the first mandatory market-based program in the United States to reduce greenhouse gas emissions. RGGI is a cooperative effort among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, and Virginia to cap and reduce carbon dioxide (CO2) emissions from the power sector

Source: World Bank; Ember Climate

International carbon border adjustment mechanisms (CBAM)

Overview

Carbon border adjustment mechanism (CBAM) refers to a carbon pricing imposed on imports into a country or a region. One example is the CBAM which is being planned for imports into the European Union (EU) bloc.

The main motivation to introduce the CBAM is to counter the risk of carbon leakage, which diminishes the effectiveness of carbon pricing schemes from reducing emissions. Carbon leakage can happen in two ways. First, consumers shift from local producers with higher prices for goods due to carbon prices towards imported goods which are subject to lower or no carbon prices. Second, producers may also transfer their production to other countries with lower carbon prices, whilst continuing to supply demand in areas where carbon prices are adopted with the same level of emissions. As a result of carbon leakage, there is the potential that the same volume of emissions are being incurred but at locations outside the EU, diminishing and undermining the effectiveness of the EU ETS as well as wider global climate efforts[106] .

Therefore, the CBAM is intended to prevent carbon leakage by imposing the difference between the ETS price and the carbon price in the country of origin for the imported product. To comply with CBAM, importers into the EU will need to purchase carbon certificates that correspond with the carbon price based on weekly ETS allowances. The importer will have to declare emissions embedded in its imports at the border and surrender the corresponding number of certificates yearly.

The EU plans to roll out its CBAM gradually in waves with the first wave planned for 2023 to include a select number of industries that have a high risk of carbon leakage, namely – cement, iron and steel, aluminium, fertilisers and electricity generation. In this wave, a mandatory reporting system will be imposed on importers with a zero-carbon price as a pilot until 2026.

From 2026 onwards, there are plans for the full implementation of CBAM in line with EU ETS prices, where importers will be required to purchase import carbon certificates. Based on the implementation success of Wave 1 products, CBAM is scheduled to expand to include Wave 2 products such as glass, pulp and paper, organic chemicals, consumer appliances, chemical products, engineered products, construction, and automotive products. In the long term, CBAM will likely include the full range of products and services in order for CBAM coverage to be identical with domestic carbon tax coverage under the EU ETS.

For CBAM to be rolled out, the EU will need to ensure that the CBAM is compliant with World Trade Organisation (WTO) commitments and address concerns raised by countries such as China[106] and Australia[107] which have argued against the CBAM on the grounds of protectionism and violation of WTO principles. Ongoing developments in the area will need to be monitored, but countries can embark on some no regret initiatives to ensure readiness to high likelihood of future CBAM adoption.

Potential implications for Malaysia

Initial impact of CBAM on Malaysia's exports to the EU will be small in the short term as only 3% of Malaysia’s exports value to the EU will be affected in Wave 1. However, in Wave 2 of the CBAM roll-out, up to 66% of Malaysia's EU exports can be affected. Without timely actions to position for the CBAM, Malaysian firms may decline in relative trade competitiveness or experience lower margins if emissions incurred in the supply chain are higher compared to other exporting countries.

Therefore, Malaysian companies will need to start building capabilities on emissions tracking, accounting, and reporting as a foundation to be compliant with potential future CBAM regulations. Moreover, companies should also focus on decarbonisation of the supply chain in order to reduce emissions embedded in their own products. This includes optimising emissions along the supply chain by procuring raw materials and goods with a lower emission footprint.

As Malaysia adopts its domestic carbon price mechanism, it will also need to mitigate the risk of carbon leakage. This can be done by adopting a CBAM mechanism for Malaysia for sectors with a high risk of carbon leakage.

105. Carbon border adjustment mechanism, European Commission
106. EU's planned carbon border levy violates trade principles, Euractiv (2021)
107. Australia attacks EU carbon border levy plans, Politico (2021); Australia labels possible EU carbon border tax discriminatory, IHS Markit

As Malaysia moves towards a lower carbon economy, the introduction of the CBAM could potentially become a source of advantage for Malaysian companies. If local firms begin to reduce their carbon footprint across operations at levels much lower compared to competitors, they will be able to develop a potential trade advantage as they will face lower taxation at the EU border. Hence, the impetus for local firms to decarbonise their operations and to optimise emissions along the supply chain will be crucial to reduce emission intensity of their goods and services.

With the potential for a rise in CBAM mechanisms going forward, the design of the domestic carbon price policies will need to ensure global compatibility. Countries such as Canada are also proactively reviewing compatibility and addressing disparities which may arise from the proposed EU CBAM, including extensive consultations with exporters to Europe. Early engagement, involvement, and building a deep understanding of implications of CBAM is critical for countries such as Malaysia with significant exposure to trends in global trade.

Figure 90: Schedule of the European Union CBAM roll-out

EU Carbon Border Adjustment Mechanism to be launched in wave; Malaysia's exports most affected in Wave 2

Wave 1 Products

Emission intensive sectors where risk of carbon leakage is highest (focus on primary imports)

- Cement
- Iron, steel, and aluminum
- Fertilisers and select chemicals
- Electricity

3% Of Malaysia’s exports value to the EU

Timeline of adoption

- **2023:** Mandatory carbon reporting and “zero price” CBAM[1]
- **2026:** Full implementation of CBAM in line with domestic carbon tax[2]

Wave 2 Products

Next wave of emission intensive sectors (expanded to semi-finished products, services, etc.)

- Glass, pulp and paper
- Organic chemicals
- Consumer appliances
- Chemical products
- Engineered products
- Construction
- Automotive

63% Of Malaysia’s exports value to the EU

Timeline of adoption

- **2026:** Based on implementation success of Wave 1, CBAM extended to Wave 2 products

Long-Term Plans[3]

Full range of products and services, CBAM coverage identical with domestic carbon tax coverage

- Secondary products
- Agriculture / Agri-food[4]
- …

12% Of Malaysia’s exports value to the EU

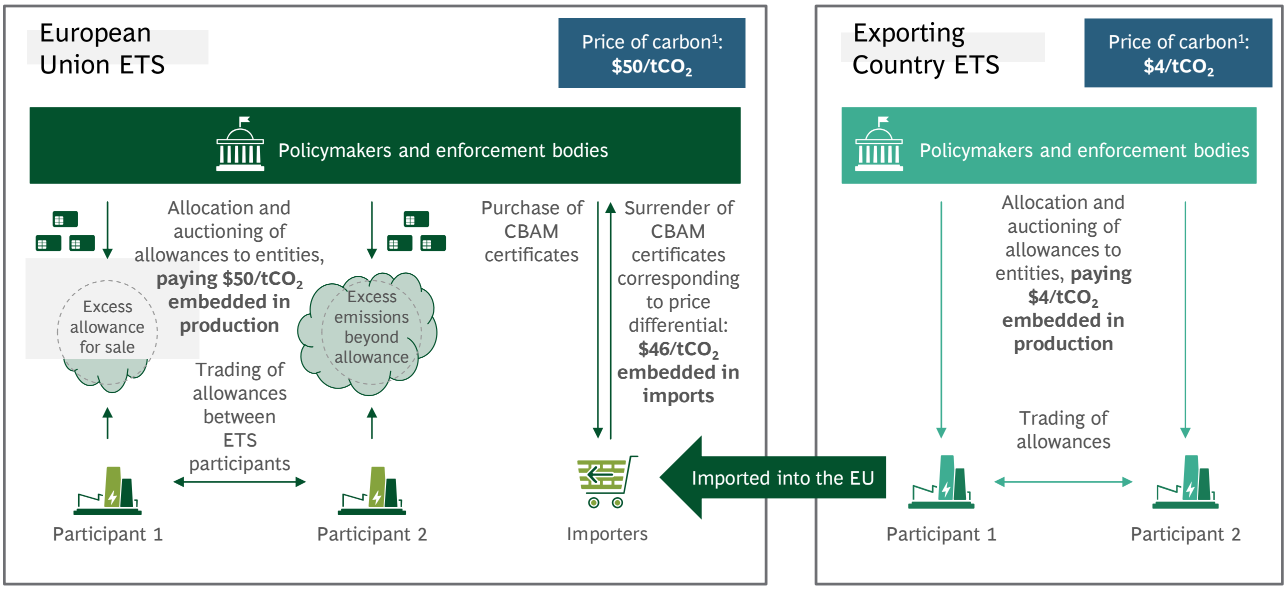
Timeline of adoption

- **TBD**

1. Importers must calculate and report emissions but will not have to buy import permits 2. Purchase of import permits required 3. Based on scope of existing EU ETS market 4. Food products based on potential plans from EU to introduce carbon pricing in agriculture/LULUCF 5. CBAM = Carbon Border Adjustment Mechanism (EU) 6. 2023 – 2026 period to focus on Scope 1 and 2 emissions; 2026 period and beyond to focus on Scope 1,2, and 3 emissions
Source: Expert Discussion, Press Searches

Figure 91: Mechanism for EU CBAM implementation with other ETS systems

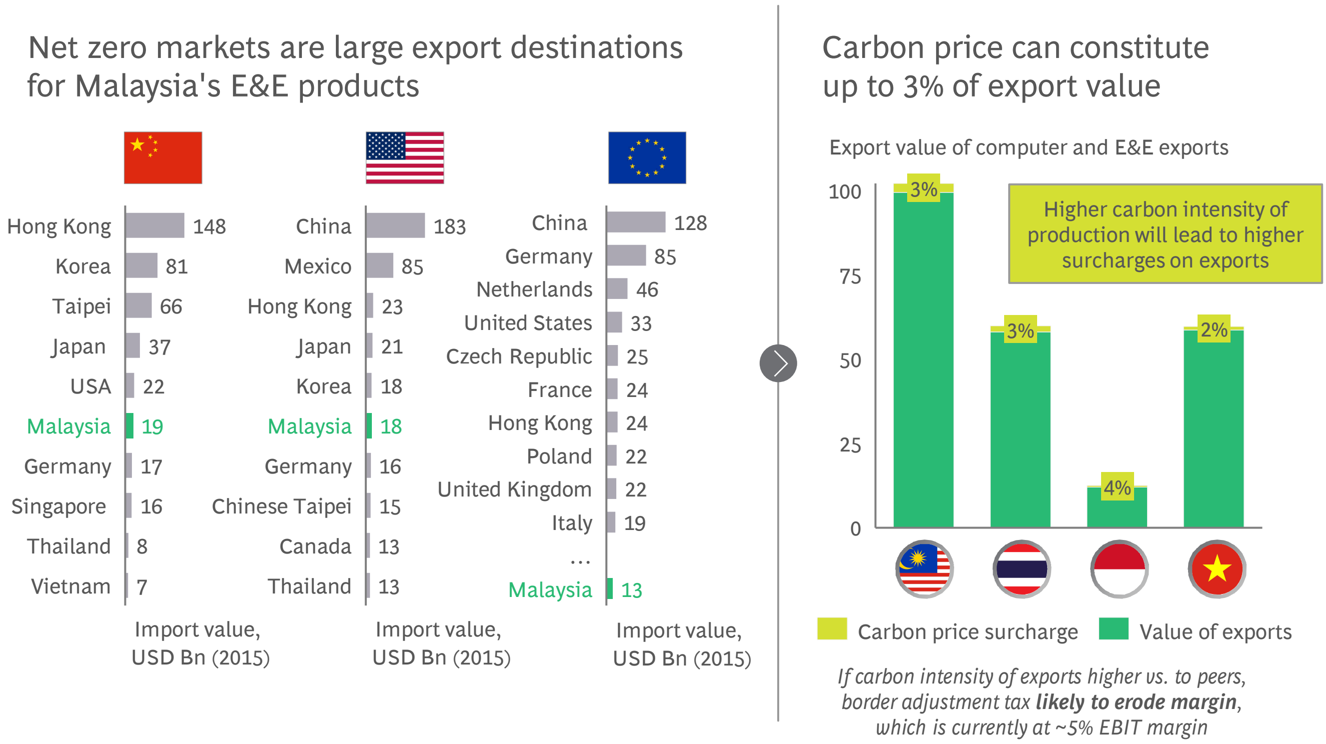
Overview of EU CBAM mechanism relative to another ETS market



Source: Project Team Analysis

Figure 92: Potential impact of CBAM on relative trade competitiveness

Electrical and electronics exports constitute ~25% of Malaysia's total carbon exports, and highly susceptible to border carbon tax



1. Carbon price assumed to be USD 80 to reflect 2020 upper bound recommendation High-Level Commission on Carbon Prices estimates to limit the increase in global warming to 2°C.; Source: OECD Stat, Project Team Analysis

Voluntary Carbon Markets (VCM)

Background

During the Budget 2022 speech, plans to establish a domestic voluntary carbon market (VCM) was announced in support of the country's climate ambitions.

Subsequently, KASA announced plans for the development of a VCM guide as a reference for all stakeholders, including state governments and the private sector that are interested in carbon credit transactions at the international level. The goal of the VCM guide was to ensure the country's interest in climate change reporting and commitment to reduce greenhouse gas (GHG) emission is not compromised in these transactions. Through this VCM guide, state governments or the private sector that are involved in international carbon credit transactions will need to report information on their carbon projects to KASA.

In the following section we highlight potential considerations for the domestic voluntary carbon markets before separately addressing cross-border VCM transactions.

Overview

Voluntary carbon markets (VCMs) channel funding for voluntary projects that avoid, reduce or remove GHG emissions. The carbon credits these projects generate can be traded in the VCM as credits or in some specific instances sold as “compliance offsets” to regulated entities for use toward their compliance obligations, where approved by compliance offset programs.

VCMs comprise a range of project types which either remove carbon from the atmosphere (carbon removals) or prevent more carbon from going into the atmosphere (avoidance or reduction). AFOLU (Agriculture, Forestry, and Other Land Use) projects generate the largest portion of VCM credits, which, together with renewable-energy-related credits, make up about 90 percent of all VCM issuances. Within AFOLU, REDD (Reducing Emissions from Deforestation and Forest Degradation) projects account for more than 90 percent of issuances. Wind and solar are the primary drivers of renewable energy growth.

Since the 1990s, VCMs have been growing rapidly, scaling from around 6 $MtCO_2e$ to around 300 $MtCO_2e$ between 2007 and 2021 globally. Despite this growth, VCM credits remain miniscule as a fraction of global emissions. Moreover, average VCM credit prices have remained low for several years at around USD 3 per $MtCO_2e$, but with notable variations by project type ranging from over USD 8 per $MtCO_2e$ for afforestation and reforestation, compared to USD 1-2 per $MtCO_2e$ for renewable energy projects as an example.

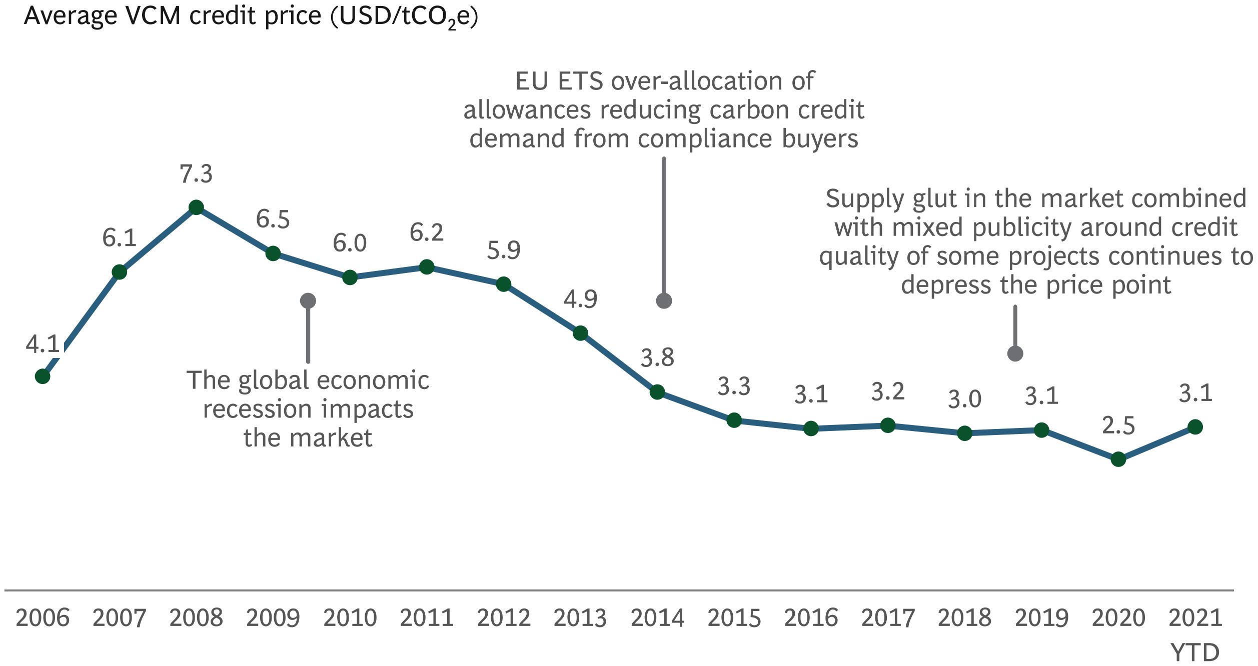
The challenges faced by Voluntary Carbon Markets

There are four thematic challenges which have faced various VCMs to different extents globally which will need to be addressed to ensure an effective VCM:

- **Credibility** – VCMs have increasingly faced challenges to the credibility of credits, including skepticism of their impact and alignment to the core principles of additionality, prevention of leakage and double counting, and permanence. This is exacerbated by inconsistent measurement and verification standards.
- **Eligibility** – a core underlying challenge is also the lack of market consensus on the eligibility of these credits in contributing towards the climate commitments or targets by corporates or financial institutions. For example, the validity of a corporate using carbon credits to achieve its net zero ambitions is also questioned, as it provides a way out from decarbonisation of the core business. These questions are further compounded by the uncertainty of additionality, permanence, and double counting from carbon credits.

Figure 93: Historic evolution of VCM carbon credit costs

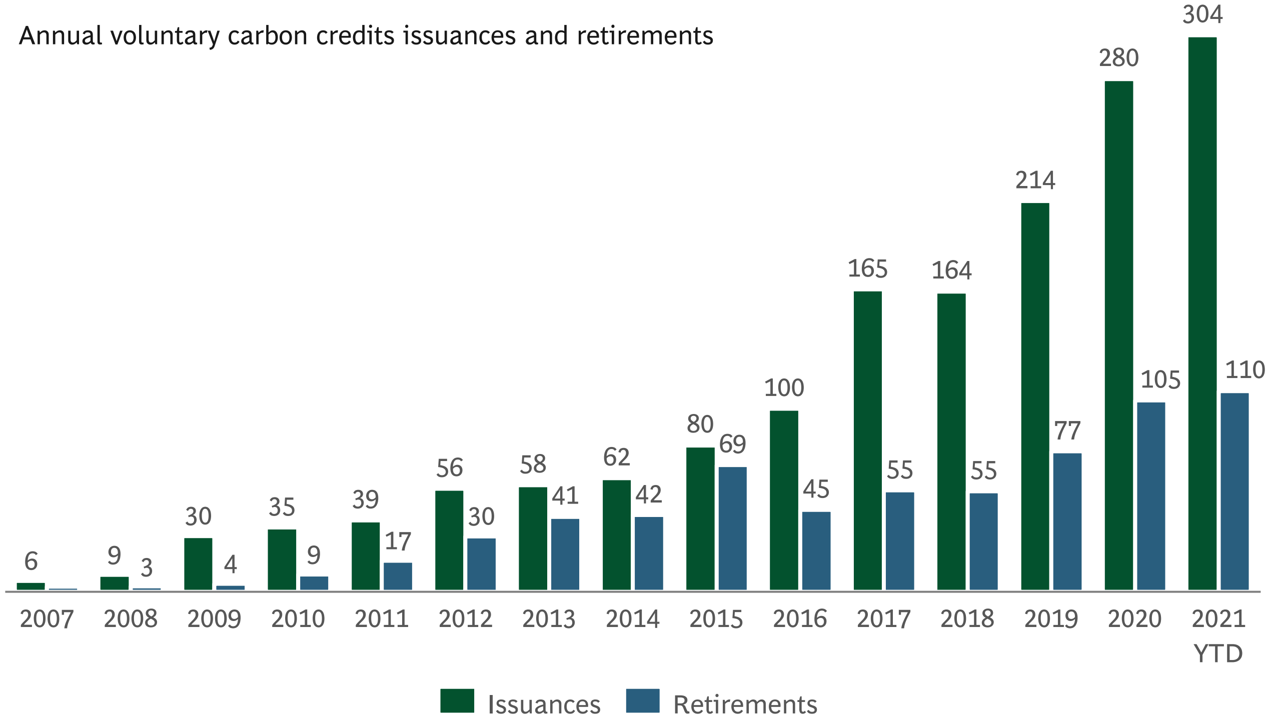
Average carbon credit prices in voluntary carbon markets have been hovering around USD 3 per $MtCO_2e$ since 2016



Source: Forest Trends State of the Voluntary Carbon Markets 2017; Forest Trends Ecosystem Marketplace: Voluntary Carbon Markets Insights: 2018 Outlook and First-Quarter Trends, Financing Emissions Reductions for the Future, State of the Voluntary Carbon Market 2019; Forest Trends Ecosystem Marketplace: State of the Voluntary Carbon Market 2021; Press Searches; Project Team Analysis

Figure 94: Total volume of VCM issuances and retirements

Size of VCM markets has grown steadily over past 10 years



Source: Ecosystem marketplace as of October 12, 2021; data reported by VCS, Plan Vivo, ProClima, Gold Standard, ACR, CARB, CAR, and Climate Forward

- **Comparability** – Thirdly, VCM credits have high degrees of variation due to their wide variety of attributes. These include varying project types, credit types (removals vs. avoidance), and co-benefits to other Sustainable Development Goals (SDGs). The lack of a clear taxonomy to define the additional attributes leads to low transparency in the market regarding credits bought. The lack of a reference index that would support comparability and trading also limits liquidity and velocity in the market.

- **Interoperability** – Finally, VCM markets are also fragmented with divergent standards and the lack of a single taxonomy with a comprehensive coverage of all relevant attributes. This has also contributed to limited interoperability between voluntary and compliance markets, although there is a small cadre of ETS that allows for a portion of compliance obligations to be met through compliance offsets. This limited interoperability between compliance markets and the VCM often stems from the potential risks of diluting ETS ambitions, since it is difficult to ensure VCM credits are of "high quality".

The combination of these challenges has led to generally low demand and several sub-par credits that sell at low prices. The average price level in VCMs have remained below USD 5 / MtCO_2e per credit for several years. Low prices, in turn, have led to challenges in terms of both supply of high quality credits that require stronger price levels and long-term demand for development of projects that deliver robust emissions and removals.

Mitigating key challenges and designing an effective voluntary carbon market for Malaysia

Building on lessons globally, several key factors can be incorporated into the design of voluntary carbon markets in Malaysia:

Enhancing credibility and integrity of carbon credits

The credibility of carbon credits in driving real emissions reduction impact can be enhanced by embedding four key safeguards, supported by strong measurement and verification protocols:

- **Additionality –** carbon credits issued only for projects that generate emissions reduction or removals that would not have occurred in the absence of a market to trade carbon credits.

- **Permanence** – carbon credits should represent emissions reductions or removals that will not be reversed (in the long term) after the issuance of that unit.

- **Absence of leakage –** the generation of carbon credits should not lead to an increase in emissions elsewhere, or safeguards must be in place to monitor and mitigate any increases that occur.

- **Avoidance of double counting** – the underlying emissions reductions of carbon credits should be monitored and reported and must be verified by an accredited third-party auditor with appropriate measures to prevent double counting.

Sharpening the clarity on the role of VCM in Malaysia's context

VCMs can play three key roles for the country. Firstly, VCMs can play the role of a transitory mechanism in sectors or regions that are not fully covered by regulated mechanisms such as carbon taxes or ETS. Secondly, as a long-term marketplace for carbon removals for entities to neutralise hard-to-abate residual emissions and to pursue negative emissions. Thirdly, as a complementary mechanism for corporates and financial services sectors to compensate for their emissions while they pursue sectoral decarbonisation to reduce emissions in their value chain.

Developing common taxonomy for carbon credits

A common taxonomy will support the enhancement in transparency of the credits being purchased. With better understanding and transparency, more players may be attracted to participate in VCM, enhancing liquidity and velocity of the market. Comparability through a taxonomy or a reference index across credits can consequently be traded with spreads. The taxonomy will also need to deliberate the applicability of certain types of credits for the VCM such as for carbon removals from geo-engineering, filtering out potential climate false solutions by ascertaining whether these solutions deliver total societal and environmental impact.

Exploring interoperability between VCM and ETS scheme

Enhanced interoperability across ETS and VCM schemes through tightly controlled mechanisms would serve to grow carbon markets whilst driving additional co-benefits. One of the major barriers to interoperability is the potential concerns of diluting ETS ambitions with VCM credits. However, enhancements in ensuring additionality, quality of carbon credits, and a common taxonomy can allay these concerns. Finally, limits on the eligibility and the quantity of fungible VCM credits, in terms of sector or geographic eligibility, will be required to prevent encroachment on ETS markets.

Perspectives on international carbon markets

International carbon markets can take various forms, including international VCMs or interoperability across various ETS schemes. One of the unique aspects of international carbon markets which is not relevant for domestic carbon markets are the implications of transactions on the overall national GHG inventory accounting. Article 6 of the Paris Agreement on climate change contains two operative paragraphs which encapsulate the accounting for cross-border carbon market transactions, which support to ensure that there is no "double counting" of emissions reduction.

- *Article 6.2* provides an accounting framework for international cooperation, such as linking the emissions-trading schemes of two or more countries (for example, linking the European Union cap-and-trade program with emissions-reduction transfers from Switzerland). It also allows for the international transfer of carbon credits between countries.

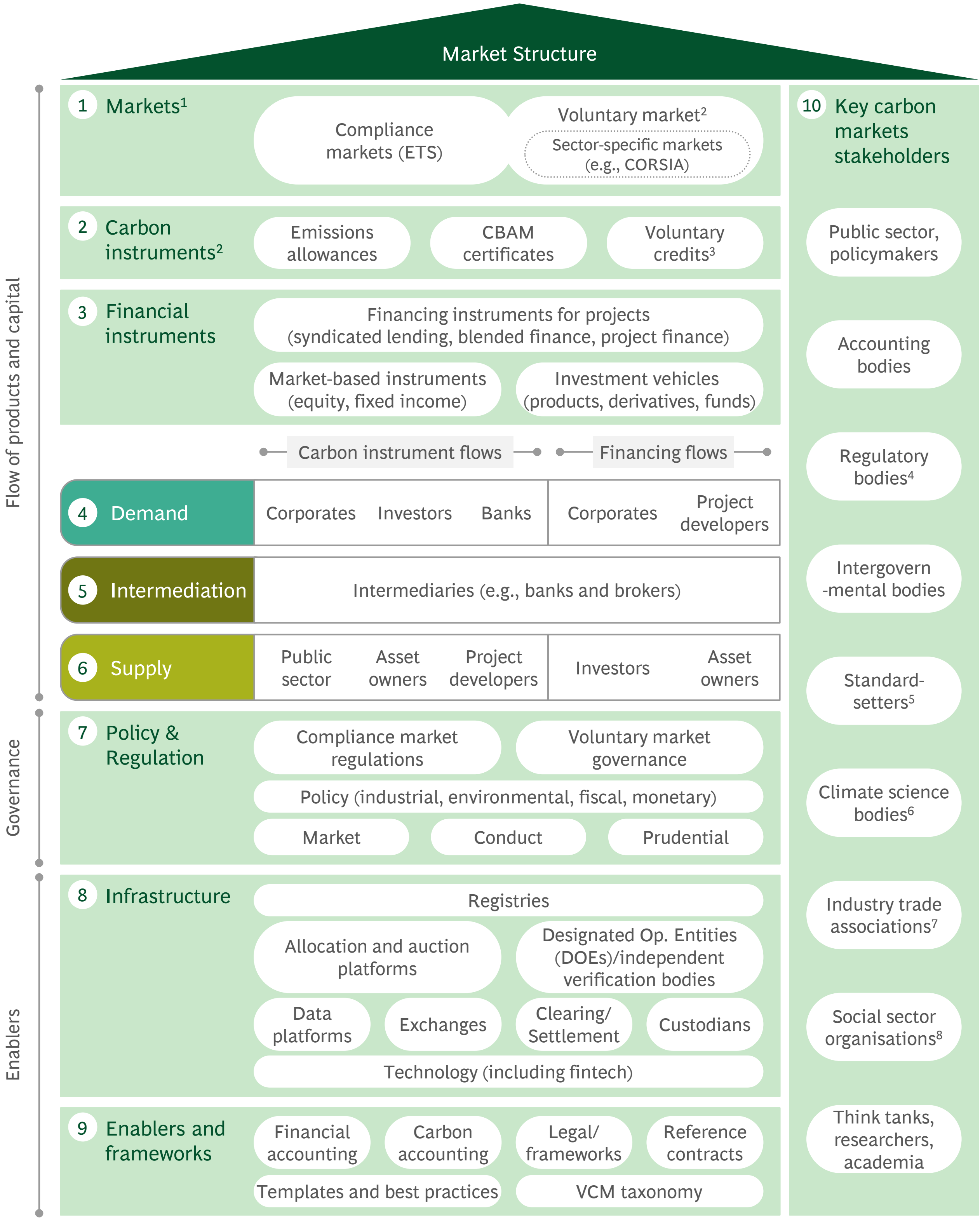
- *Article 6.4* establishes a central UN mechanism to trade credits from emissions reductions generated through specific projects. For example, country A could pay for country B to build a wind farm instead of a coal plant. Emissions are reduced, country B benefits from the clean energy and country A gets carbon credits for the reductions.

Based on these principles, cross-border sale of carbon market credit does not only have implications on the individuals involved in the transaction (buyer and seller of the carbon credit) but also the national GHG inventory. Strong safeguards or even restrictions may be required as the potential sale of carbon credits internationally motivated by economic profit, risks the diminishing of national GHG removals inventory, which adversely impacts the ability of the country to get towards net zero. As such, it is vital that strong oversight and clear regulations are established with relation to international carbon markets transactions.

Moreover, several prevailing mechanisms to secure international multilateral climate financing for forest restoration and protection already exist beyond international voluntary carbon markets. Results-based climate finance (RBCF) frameworks such as with REDD+ results-based payments scheme enables country to receive funds when they meet pre-defined climate-related goals. The measurement and verification for REDD+ activities is a two-step process: first, there is a technical assessment of the proposed forest reference emission level or forest reference level (FREL). Second, the actual results compared to the assessed FREL are submitted in a technical annex to the biennial update report of a developing country party seeking to obtain and receive payments for results-based actions, and these results undergo a separate technical analysis. Upon verification that the goals have been met, funds are credited.

Figure 95: Overview of a holistic carbon market structure

Overview of a mature carbon market structure setup and enablers



1. Some linkages between compliance markets and the voluntary market exist today; 2. In some ETS markets such as the EU, carbon allowances are treated as financial instruments; 3. Includes both credits issued by designated operational entities (DOEs) and independent verification bodies; 4. Such as ISDA and the Basel Committee; 5. Such as Verra and the Gold Standard; 6. Such as SBTi and the GHG Protocol; 7. Such as the international Civil Aviation Organisation (ICAO); 8. Such as NGOs and foundations

Internal carbon pricing mechanisms

An internal or shadow price on carbon creates a theoretical or assumed cost per ton of carbon emissions. It is used to better understand the potential impact of external carbon pricing on the profitability of a project, a new business model, or an investment in order to reveal hidden risks. When emissions incur a cost in the company's profit and loss statements, it helps to uncover inefficiencies and incentivise low carbon innovation within departments, supporting the decarbonisation of a company. Overall, internal carbon prices help companies in a few ways:

- **Support the reduction in emissions** by incentivising a change in internal behaviours such as energy efficiency adoption, in contribution to the company's emission reduction targets.
- **Spur low-carbon investments**, by identifying and seizing low carbon opportunities and by stress testing investments.
- **Support to de-risk the business and investments** against future carbon pricing legislation in advance. By measuring, modelling, and managing financial and regulatory risk, the company can better meet the expectations of investors and stakeholders.

Internal carbon prices can be used to inform a wide range of key decisions within a company. These include:

- **Capital expenditure** (**CAPEX**) decisions where climate risks are priced-in for investment decisions and the internal carbon price is included in return of investment calculations.
- **Operational expenditure** (**OPEX**) decisions when evaluating climate risks when making operational decisions, where the internal carbon price is a key factor in decisions.
- **Corporate transaction decisions** where merger and acquisition (M&A) prospects are screened factoring in internal carbon prices.
- **Procurement and supply chain supplier criteria** decisions where climate-related costs in purchasing is evaluated, and shifts economics towards low carbon suppliers.
- **Research and development** decisions in evaluating the climate component of R&D costs and to channel allocations into low-carbon innovations.
- **Product pricing** where the carbon footprint is included into the sales price, primarily for business-to-consumer (B2C) sales.

There are four approaches to adopt internal carbon pricing policies at varying degrees of complexity. As a starting point a shadow price is typically adopted and may be enhanced over time into an implicit price, internal carbon fee, or even an internal cap-and-trade market:

Informative:
Shadow Price

Simulation of potential carbon taxation scenarios to inform business planning and investment decisions

Decision criteria:
Implicit Price

Price based on spending on emission reductions to comply with government regulations, used as benchmark before fee is introduced

Direct taxation:
Internal Carbon Fee

Establishment of internal taxation on area's emissions, to encourage reductions and fund emission reduction efforts

Internal market:
Cap and Trade

Establishment of emission quotas by business area, in the cap-and-trade model, provides greater flexibility to diverse businesses

Developing an internal carbon price

In order to develop a well-informed internal carbon price, a company will need to go through a four-step iterative process.

- First, direct and indirect GHG emissions will need to be mapped across the operations. This includes Scope 1 direct emissions which are incurred in the process of production; Scope 2 indirect emissions from purchased energy such as in the form of electricity or heat; and Scope 3 indirect emissions along the company's supply chain.

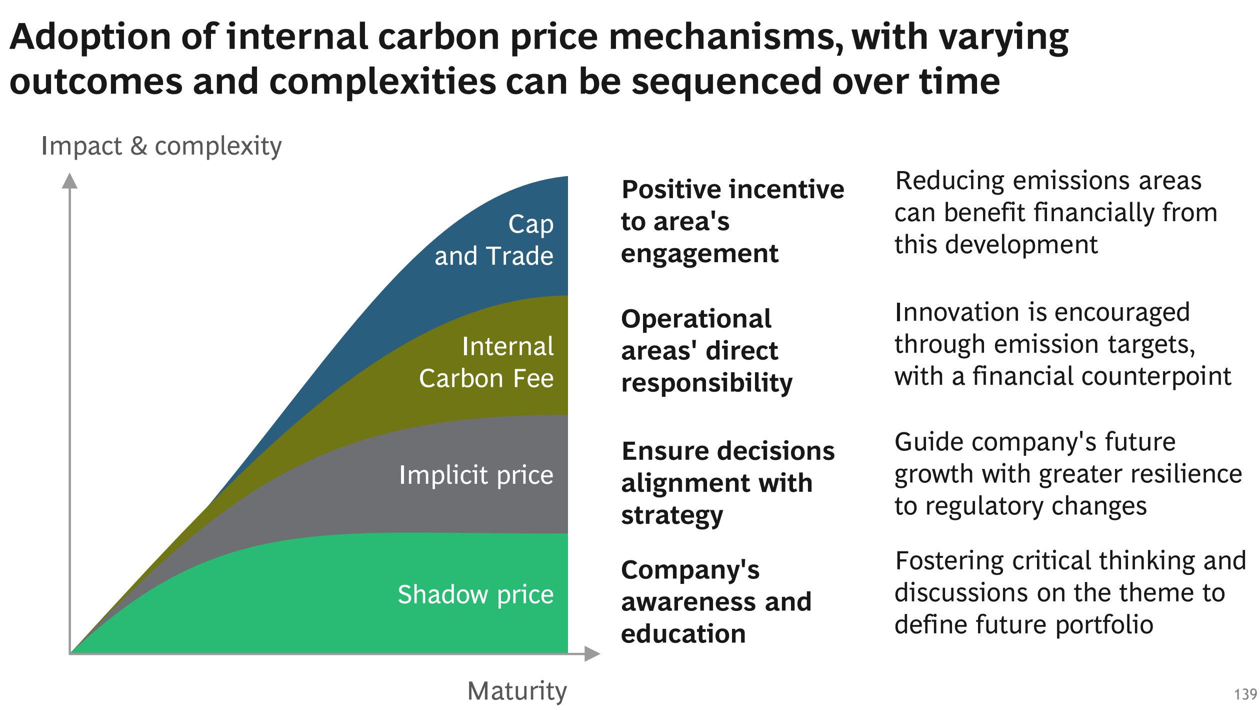
- Second, a forecast of future carbon prices will need to be developed. This entails examining the exposure to current and estimated future carbon prices based on an assessment on climate policies in the various countries of operation. Forward-looking carbon prices will need to be forecasted based on price scenarios and simulations to inform a right level of internal carbon price.

- Third, an internal carbon price is set and applied by deciding between a range of available mechanisms – including a shadow or implicit price, internal carbon fee, or cap and trade mechanism. These measures can be applied both individually or in combination and will need to be informed by the maturity of carbon price adoption within the company. Another key step is to determine if and how different prices should be adopted for decisions with different time horizons, where the internal carbon price needs to be sufficiently material to achieve the desired change.

- Finally, the internal carbon price will need to be integrated into day-to-day processes. Regular reassessment of integration and processes should be conducted with clear feedback loops to inform future adjustments. The internal carbon price should be ratcheted up if feedback loops indicate that emission reduction behaviours are not being observed by business units or if a jurisdiction is operating at a carbon price higher than the firm's internal carbon price.

The roll out of internal carbon price will need to be phased and supported by various enablers. For example, pilots will be needed to test the designed approach, tools to reduce the administrative burden of internal carbon price adoption, a carefully planned roll-out strategy including securing buy-in from employees, and robust monitoring will need to be established.

Figure 96: Comparison between internal carbon price mechanisms



Priority #5:

Mobilise climate finance

Overview

Climate financing will be required to facilitate large-scale economic transformation and deep decarbonisation across all sectors of the economy needed to achieve the country's Net Zero ambitions. To achieve Net Zero 2050 in Malaysia, around RM 350 to 450 billion of climate investments will be required between 2020 to 2050. Climate finance will need to be mobilised across the public sector, private sector, as well as international multilateral sources to fund the investments required.

In the early stages of green transition, there are three thematic hurdles which need to be addressed to effectively scale climate finance, unlocking the full potential of private sector finance, and to meet climate transition needs:

- **Resolving market failure and lack of climate finance demand**

  A lack of demand for green products and services is a major inhibitor for the scale up of climate financing. Market failure is one of the root causes of the lack of demand, where carbon is not sufficiently priced into the real economy and markets as a negative externality and where economics are not providing significant motivation for green transition. Moreover, legacy policies such as fossil fuel subsidies or incoherent and contradictory policy signals work against the mobilisation of private capital towards climate-aligned instruments.

  Enhancements will be required to ensure that GHG emissions are fully priced into the real economy and markets, leading to climate action that is economically motivated, and a level playing field that fully factors in the cost of emissions. In addition, coherent public policy and incentives that work efficiently and effectively to mobilise private sector capital towards climate-aligned instruments are critical.

- **Addressing ambiguity and lack of clarity in climate finance markets**

  Without established climate data foundations from the real economy, the finance industry will be faced with challenges of information clarity. For example, climate-related data are mostly limited to large corporates, and even where available, face challenges of incomparability and inconsistency. Transition pathways by sectors and regions which reflect overarching climate ambitions also lack definition. Moreover, the high perceived risks and limited understanding of sustainable finance products and solutions further increase market hesitancies.

  High-quality and comparable climate data which is universally available and integrated across all financial asset classes and platforms will be required to enable investors and market participants to make informed and climate-integrated decisions on both primary and secondary markets. Globally-aligned definitions and clear sectoral and region taxonomies will need to be established. Finally, supporting market mechanisms such as credit ratings, data availability, taxonomies, and labels will need to be developed to the same level for climate-related factors as for other financial instruments.

- **Addressing sub-scale products and mismatches between capital demand-supply**

  On the supply-side, climate financing solutions remain niche with limited integration into core financing activity and high transaction costs exist for climate finance products. Mismatches in risk profile of capital supply and demand also limit product attractiveness and private sector take-up. Finally, a lack of widespread capabilities to integrate climate factors into financial products and risk frameworks which are short-term and do not holistically account for climate risks also inhibit the scaling of climate finance.

Initiatives which aggregate and build a pipeline of high quality and bankable climate projects for funding can increase the economies of scale and reduce the transaction costs of climate financing. Innovations in climate financing instruments oriented to specific market needs can improve the matching of the demand and supply of climate finance. Other efforts include mainstreaming the consideration of material, decision-relevant climate factors in risk assessment, pricing, and investment decision making across all financial products and services. The secondary market for activities and instruments associated with climate finance (e.g., derivatives, structured products, securities lending, and others) that enhances market liquidity, price discovery, and risk allocation will also need to be strengthened. Finally, a large healthy ecosystem of issuers, investors, and intermediaries will need to be developed to ensure efficient, liquid, and at-scale green capital flows.

Current ongoing efforts

Established in 2019, the Joint Committee on Climate Change (JC3) platform co-chaired by the Securities Commission (SC) and Bank Negara Malaysia (BNM) and represented by Bursa Malaysia and 19 industry participants, was established to pursue collaborative actions for building climate change resilience within the Malaysian financial sector. The JC3 platform is guided by three key mandates:

- Building capacity through the sharing of knowledge, expertise and best practices in assessing and managing climate-related risks

- Identifying issues, challenges and priorities facing the financial sector in managing the transition towards a low carbon economy

- Facilitating collaboration between stakeholders in advancing coordinated solutions to address arising challenges and issues

The JC3 comprises of five sub-committees which reflect priority areas that are foundational to the scale-up of climate financing. This includes risk management, governance and disclosure, product and innovation, engagement and capacity building as well as bridging data gaps. The key results and ongoing initiatives across the priority areas are summarised below:

- **Risk management:** The development of climate-related prudential standards and risk management policy is a key foundational element for the scale-up of climate finance. The Climate Change and Principles-Based Taxonomy (CCPT) has been established to provide a common framework for the classification of climate risk related exposures for financial institutions. The taxonomy aims to encourage financial flows to activities that support the transition to a low-carbon and climate resilience economy. With the taxonomy in place and due for enforcement from July 2022, the focus of the JC3 will evolve to support its consistent and credible implementation within the financial sector. In complementary efforts, the Sustainable and Responsible Investment Taxonomy is being developed to enhance clarity and guidance in identifying sustainable investment assets or activities.

  Other related outcomes include the issuance of sectoral guides under the Value-based Intermediation Assessment Framework (VBIAF) to help financial institutions conduct ESG risk assessments at a more granular level. The first wave of sectors under the VBIAF includes palm oil, renewable energy, and energy efficiency, and the second wave of sectors due for release in 2022 includes oil and gas, manufacturing, and construction and infrastructure. The VBI Takaful Framework (VBITF) which outlines the implementation approach for activities in the takaful industry that is aligned with sustainability considerations has also been launched.

- **Governance and disclosures:** Several key initiatives are underway to support financial institutions with the integration of climate risks in their business strategy, risk management framework and practices. This includes guidance documents on climate risk management and scenario analysis as well as an application guide to enhance TCFD-aligned disclosures by financial intermediaries. Plans for mandatory climate-related financial disclosures by financial institutions are also being evaluated. Collectively, these will ensure that best practice governance disclosures are adopted, and that risks of greenwashing are mitigated in Malaysia.

- **Product and innovation:** To foster an environment which encourages the development of green financing and investments, efforts to first understand key current impediments and gaps in demand and supply of green financing, investment, and protection solutions to facilitate a transition to a low carbon economy are being conducted. In response to these identified gaps, potential intermediation structures that embed consideration for climate risks and financial solutions are being explored as well as measures to increase the supply of financing and protection solutions that support climate risks mitigation and adaptation.

- **Engagement and capacity building:** Engagement and capacity building efforts with the goals of supporting climate action and risk management in the financial sector are also being spearheaded by the JC3 platform. This includes interfacing with non-financial service sectors, their key institutions, and agencies to increase climate risk awareness. Capacity building strategies and initiatives to upskill financial institutions in managing climate and transition-related risks and opportunities are also underway. Finally, engagement to promote alignment with key stakeholders on climate and transition initiatives are being conducted, including active contribution to the formulation of national climate policies.

- **Bridging data gaps:** Adequate and good quality data on climate and environmental risks are critical to make informed assessment and judgments especially for climate risk management, disclosure, and scenario analysis. This includes data to support investment and lending decisions, macroeconomic modelling, stress testing, scenario analysis, and product development. Focused efforts to identify and address data gaps for climate risks analysis and scaling up of green finance is also underway in collaboration with industry players and experts.

In addition to the efforts through the JC3, various efforts from the government have contributed to key enablers to climate finance. Selected highlights of government initiatives to promote or to provide climate financing include:

- **Green technology financing:** Government guarantees for green loans have reduced the risks of lending for green technology investments. Over time, over RM 10 billion has been allocated to Green Technology Financing Schemes (GTFS) over time with the first GTFS 1.0 in 2010 and the latest GTFS 3.0 in 2020 as part of Budget 2021.

- **Green tax exemptions:** This includes programs such as the Green Investment Technology Allowance (2013) targeted at encouraging green technology capital expenditures as well as the Green Income Tax Exemption (2013) to encourage green certifications of companies.

- **Catalytic green investing and grants**: A range of initiatives to catalyse the transition to the green economy including budgetary allocations for the build-out of electric vehicle charging infrastructure; incentives for energy efficient appliances, energy efficient vehicles, and electric vehicles; provision of energy audit conditional grants, and policies to support renewable penetration such as feed-in-tariffs (FiT) and net energy metering (NEM).

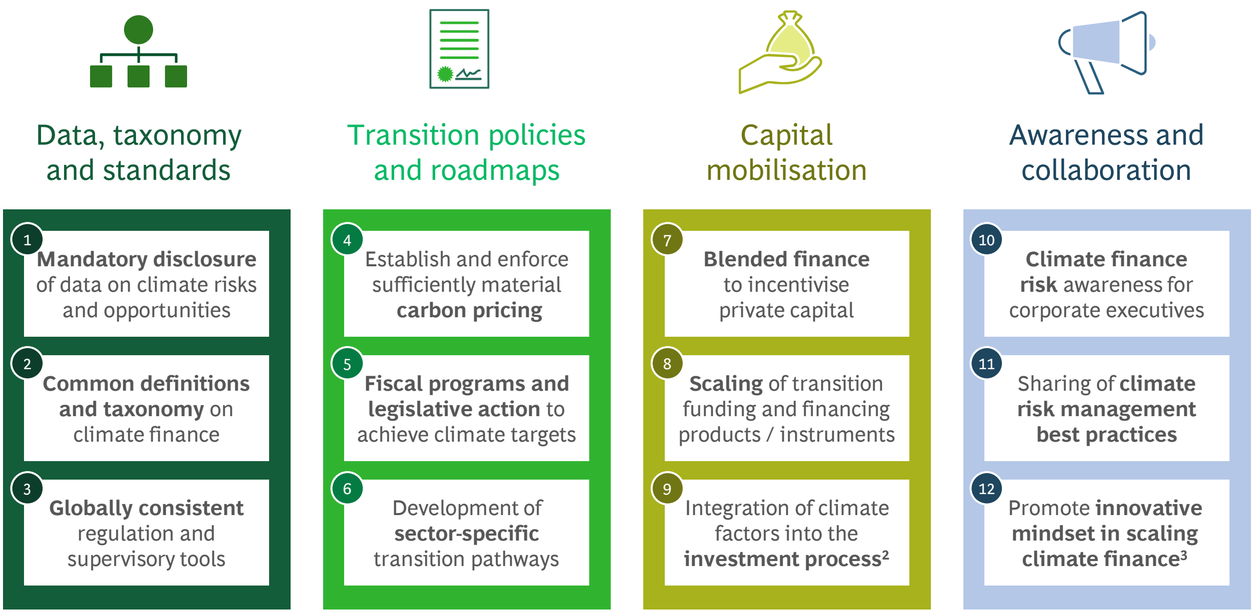
- **Access to green financing through government-funded vehicles:** To enhance access to debt financing, Malaysia Debt Ventures to enhance access to affordable capital for projects with green sustainability elements.

- **Government green bonds:** This includes the launch of the world's first green sukuk launched in 2017 to expand financing channels for green projects, and the sustainability bond which was launched in 2020 under Sukuk Prihatin to support funding for green economy growth.

- **Sustainable and green budgeting:** Budget 2022 formulation in alignment to the Sustainable Development Goals (SDG), Environmental Social Governance (ESG) factors, and green budgeting principles. Other complementary efforts include the upcoming launch of Voluntary Carbon Markets (VCM) for carbon credit trading by BURSA Malaysia.

Figure 97: Key enablers to scale private sector climate finance

Twelve foundational enablers to scale private sector climate finance



1. **Mandatory disclosures** of corporate-specific financially material, decision-relevant data relating to climate risks and opportunities; supported by consistent global disclosure frameworks
2. **Common definition and principles** for climate finance, translated into region and sector-specific taxonomies that are 1.5^{0}C pathway aligned, comparable, and flexible to technological evolutions
3. **Globally consistent regulation and supervisory tools** to mitigate market fragmentation and support the development of consistent regulatory drivers aligned with pace of developments
4. **Carbon pricing** such as a carbon tax or ETS which is enforced, comprehensive, and at sufficiently high price points, with forward-looking price direction and supportive of a "just transition"
5. **Effective and coherent government policies, fiscal programs, and legislative actions** that are aligned to the country's climate targets and implemented in a timely manner
6. **Sector- and region-specific transition or decarbonisation pathways** to achieve the country's climate targets, involving government, industry players, scientific community
7. **Enhance blended or public-private financing** to motivate mobilisation of private sector capital funded by government and multilateral international climate funding
8. **Develop broad range of development of financial products and instruments** to meet financing, investing, hedging, market liquidity, and funding needs of players in transition
9. **Integration of climate factors by investors and asset managers** into the investment process, risk and valuation models and frameworks, and portfolio company engagement and stewardship
10. **Climate finance risk awareness** and financial education building at the Board and executive level in corporates to actively prioritise and accelerate preparations for a low carbon future
11. **Sharing of best practices** of climate risk management capabilities and the transparency of the integration of climate risk within the firm's governance, strategy planning, and operations
12. **Promote an innovation mindset** in scaling climate finance, with the use of financial product innovation, advanced data and analytics for climate risk modelling, scenario analysis, and others

1. From either government or national / multilateral development banks 2. And portfolio company stewardship 3. Including data, use of tech, etc.
Source: Global Financial Market Association

Other forward-looking actions to scale climate finance

Through the JC3 platform and other government efforts, various foundational enablers for the scaling of climate finance are being established. This includes mandatory climate-related data disclosures, standardised climate taxonomies, promoting data availability to accelerate integration of climate-related risk factors, engagement and capacity building on topics such as climate finance risk awareness and financial education, and others. Complementing on existing efforts, several other key actions can support the strengthening of the foundations required to scale climate finance, based on both key gaps and forward-looking opportunities observed in the current set up:

- **Finance requirement sizing based on sector-specific decarbonisation pathways**

  The development of clear sectoral decarbonisation pathways, aligned to overall national GHG emission reduction targets, are critical to bring enhanced clarity on the areas of priority needed for climate finance. Understanding and sizing the contribution of various solutions will provide more granular estimates of the amount of different types of capital that are needed, by sector and asset class to facilitate the country's decarbonisation pathways. In doing so, these estimates can enable policy markets, regulators, and other market actors to prioritise their strategies to grow specific market segments in which the opportunities for both climate impact and commercial opportunity are greatest.

  Three additional levels of sector-specific insights are required to enhance the clarity of potential areas of allocation of climate finance. Firstly, a strong articulation of investment needs by sector and levers such as specific decarbonisation technologies or activities by sector is needed. Secondly, estimation of the investment need is required, ideally with clarity of investment needs both at the domestic and regional level. Thirdly, this has to be translated into implications for the banking and capital market sectors, such as an estimation of the types of capital needed (e.g., bonds versus loans versus equity).

  Developing mechanisms to review and optimise climate mitigation pathways will also be needed as technology matures. Similar clarity can also be developed for climate adaptation and resilience solutions in order to better inform the design of instruments to fit specific demand needs, in alignment with long-term adaptation and resilience roadmaps.

- **Reducing financing risks by strengthening the local industry's capability to deliver**

  Credit risks in emerging green economy sectors can be a key barrier to green financing. In emerging green economy sectors, local players have shallow track records, low capitalisation, limited collateral, and high uncertainty on delivery certainty which collectively add to credit risks. Besides government-guaranteed financing, several government-supported measures can support increased confidence of lending institutions in green economy sectors.

  Firstly, ensuring tight technical due diligence in tender and award processes to build lending institution confidence that approved suppliers have high certainty of delivery. For example, in large-scale solar build-outs, this entails ensuring that players awarded with contracts are verified to be in a strong position to deliver, with low risks of land rights issues, adequate internal technical capacity and experience to execute, financial stability, and others. Secondly, strategic decisions on the volume and size of projects should be made in order to facilitate local players to build up successful track record of delivery and to prevent overstretching of local players which increases the risks of delivery failure. Thirdly, efforts to strengthen the creditworthiness of players in the industry such as building at-scale players with strong balance sheets through consolidation, without compromising competition, should be encouraged.

  In addition, capability building to enhance financial institutions' ability to assess risks and understand return profiles of various green technology projects will be critical in order to reduce the risk premia associated with financing green projects. Collectively, with improved in project risk-return assessments, strengthened safeguards to ensure awarded contracts are made to players with high confidence of delivery, and maturation of industry players will serve to reduce risks and enable the scale-up of capital for emerging green economy sectors.

- **Scaling climate finance across various asset classes to improve capital intermediation**

  There are three areas where focus on enhancing capital intermediation is needed to facilitate greater investments. This includes early-stage technologies that are still high risk and require patient long-term capital as well as smaller-scale projects which are too small in scale for investors seeking larger ticket sizes to reduce transaction costs:

  Mobilise new sources of patient, higher-risk capital

  There are a growing number of clients, particularly among family offices, wealth management clients, venture capital, and private equity, who seek to invest their capital in ways that are aligned with their values and a multigenerational time frame. Banks, especially those with wealth management business lines, have a significant role to play in developing the structures and products that would enable these investors to do so. In addition, patient capital from institutional investors with long-term investing horizons such as Government Linked Investment Companies (GLICs) can be leveraged.

  Enhancing blended finance instruments and increased catalytic capital

  Blended finance structures are playing an increasingly important role in mobilising new, additional private capital for climate mitigation and adaption. However, the scale of this market pales in comparison with the total investment need. Further, the public and social sectors should provide more, and better-structured, forms of catalytic capital. Catalytic capital is particularly needed to offset the technology risks associated with early-stage technologies that are required in several sectors to achieve a Paris-aligned pathway. It is also needed to address the sovereign, currency, and political risks involved with financing climate action in emerging markets.

  Facilitating pooling and securitisation

  A key structural constraint is a lack of intermediation between numerous smaller-scale projects on the one hand, and the desire for large deals with lower risk levels on the other. Financial institutions, in their role as issuers, underwriters, and providers of additional support (e.g., credit enhancement, liquidity support) can play a key role in scaling the pooling and securitisation of smaller financing transactions. Establishing platforms which screen and facilitate aggregation to produce a pipeline of high-quality bankable climate funding projects, can be a key step in increasing scale required to reduce transaction costs.

  Catalyse derivative markets for climate finance

  Derivatives markets provide risk management tools for businesses and investors. They also enhance transparency and price discovery through mechanisms such as the provision of forward information. Similar to how derivatives can be used to hedge traditional risks (e.g., currency risks), they can also be used to hedge ESG or climate risks. One example is credit derivatives (single name or basket) employed to manage the credit risk of sectors or counterparties whose financial results may suffer as a result of physical or transition risk. This type of instrument can be used by banks or institutional investors as a potential alternative to direct investment in underlying assets.

  Critically, derivatives can help provide transparency around market pricing and risk because they help convert information into market-established pricing of risks. This is highly beneficial in enabling better assessment of climate risk and stronger management of portfolios. This also enables new hedging opportunities (e.g., commodity derivatives to manage changing risk appetite in the mining industry) that increase allocational efficiency and decrease price volatility. Additionally, derivatives can offer firms tools to manage their business risks for the long term by smoothing volatility. This can also address potential scarcity and mispricing in bond markets (e.g., through accessing more liquid derivative markets).

- **Securing international climate funding and financing**

  Multilateral and bilateral international climate funding and financing play a critical role in stimulating climate action that can accelerate the transition to a green and climate resilient economy anchored on the principles of global climate equity. Anchored on the principle of common but differentiated responsibilities and respective capabilities, climate financing and funding from developed countries to developing countries will be critical as another source to support the investments required to achieve the country's Net Zero objectives. Climate finance can derive from multiple sources, through loans, guarantees, bilateral funding, and funding from donor governments via multilateral bodies such as the Green Climate Fund, Asian Development Fund, or the World Bank.

  At the COP-15 in 2009, Annex 1 countries (developed countries) committed to provide a total of USD 100 billion per year by 2020 of climate financing by 2020[109] to non-Annex 1 countries (developing countries). This was reiterated at the COP-16, and subsequently at the COP-21 where the commitment was extended to provide USD 100 billion per year to 2025. Current figures are expected to fall short. A step up is required from developed countries to deliver on their climate funding commitments to support both global mitigation and adaptation and resilience efforts.

  Besides strongly advocating on a global stage for developed countries to fulfil their global climate funding pledges, optimising the positioning of the country to secure equitable climate funds is also critical, especially to alleviate the public financing costs associated with the Net Zero pathway. One such example is positioning to leverage the Green Climate Fund (GCF) which is currently endowed with USD 10 billion of funding. The GCF was established to limit and reduce GHG emissions in developing countries and to help vulnerable societies adapt to unavoidable impacts of climate change. There are four key areas that the GCF is focused on:

  - **Transformational planning and programming** by promoting integrated strategies, planning and policymaking to maximise the co-benefits between mitigation, adaptation and sustainable development.

  - **Catalysing climate innovation** by investing in new technologies, business models, and practices to establish a proof of concept.

  - **De-risking investment to mobilise finance at scale:** by using scarce public resources to improve the risk-reward profile of low emission climate resilient investment and crowd-in private finance

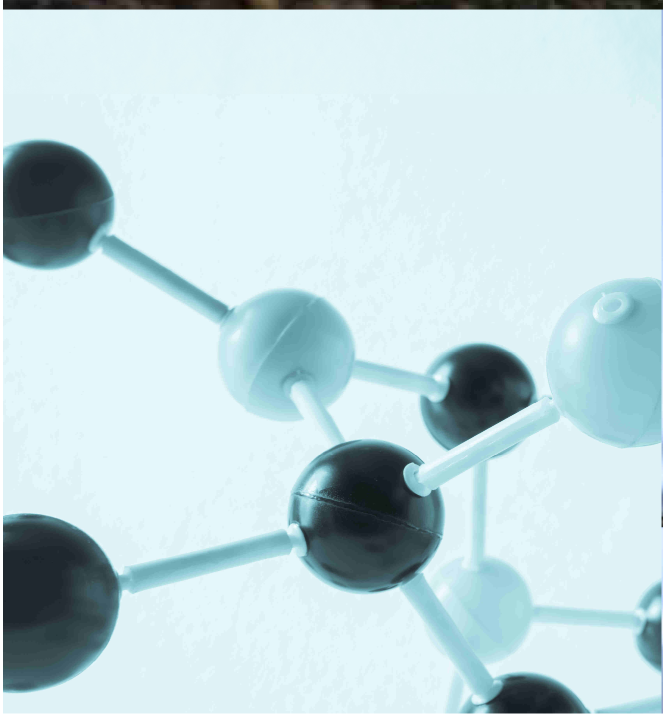
  - **Mainstreaming climate risks and opportunities** across investment decision-making by promoting methodologies, standards, and practices that align finance with sustainable development.

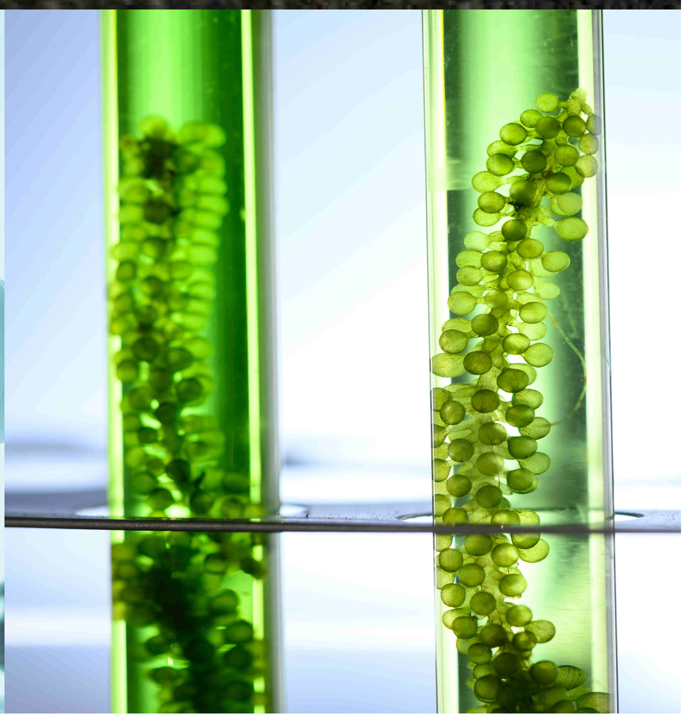
  Leveraging these funds to promote increased blended financing[110] for green projects will be important, where private capital is invested alongside international climate funds into priority areas for climate mitigation and adaptation and resilience which otherwise would not have been taken up by the private sector.

109. COP26: Delivering on $100 billion climate finance, House of Commons, UK Parliament
110. Why blended finance is our best bet in successfully adapting to climate change, WEF 2021

Priority #6:

Spur innovation and scale high potential technologies





Overview

Technology will need to play a key role if we are to be successful in delivering the scale of change needed at the pace required in the fight against climate change. Rapid developments in technology, such as the accelerating competitiveness of renewable energy, electric mobility, battery storage and many others are making climate decarbonisation pathways more accessible and affordable for countries to embark on.

Despite the rapid improvements in climate technology, a technology gap still exists for the world to achieve Net Zero by 2050. Based on conservative estimates, approximately 20% to 30% of climate technologies required to achieve Net Zero are not yet available. Moreover, for the 70% to 80% of technologies which are available, just over half of them are technologies in early adoption where an increase in pace of delivery is required.

The large climate technology gap should not be seen solely as a challenge but a large opportunity. Climate innovation, the process of maturing climate ideas into reality, represents a critical engine for the development of climate technologies. Given the large demand and global nature of the challenge of climate change, innovative breakthroughs made by individuals, corporates, or countries on climate technologies can result in large financial and competitive advantage upsides.

To strengthen the climate innovation ecosystem to meet Malaysia's overall objectives of achieving net zero emission targets and to strengthen national competitive advantage, seven key priorities actions are proposed:

1. Localise key technologies which are fundamental to Malaysia's climate transition pathway
2. Adopt a mission-based approach to anchor climate innovation
3. Address gaps along climate funding lifecycle
4. Establish dedicated climate innovation funding
5. Foster collaboration, open data access, and knowledge agglomeration
6. Ensure time-to-market with test beds for pilots and deployment
7. Scale-up highest potential technologies where Malaysia has competitive advantage

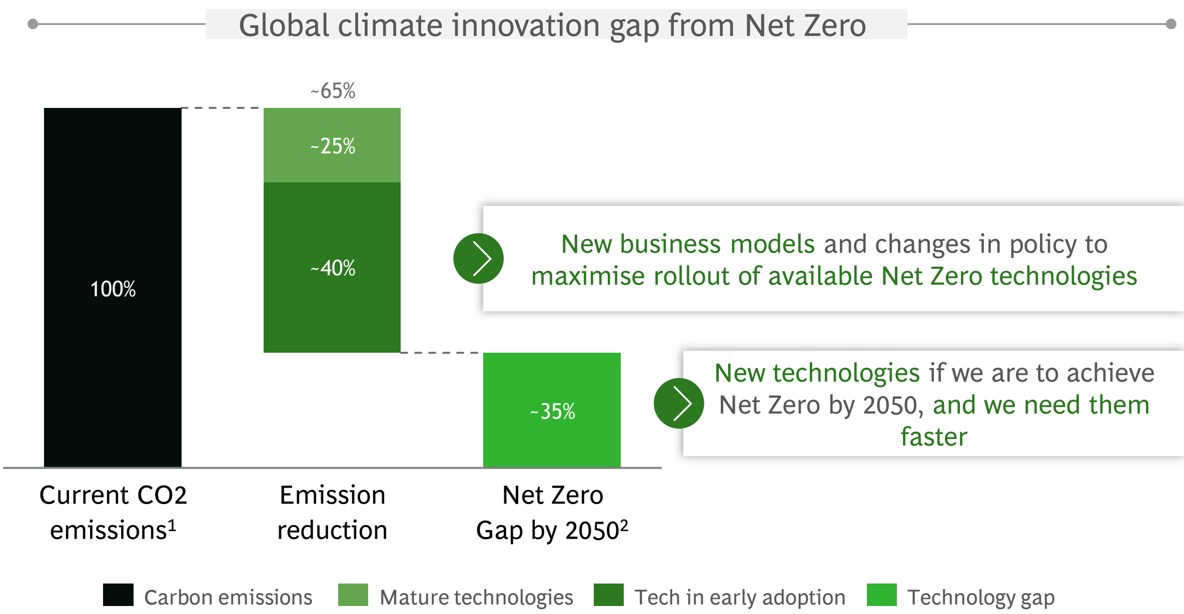
Localise key technologies which are fundamental to Malaysia's climate transition pathway

Based on the outlook of the highest potential technically feasible and commercially attractive decarbonisation levers, a series of key supporting technologies can be identified which are key to the country's climate transition pathway. Ensuring the appropriate localisation of these technologies are critical in order to reduce costs, protect trade balances, and internalise GDP and job spillover impacts in the country.

For example, some of the largest scale levers to decarbonise are in the transport sector. One such example is the take-up of electric vehicles. Given the size of the lever, ensuring that key technologies are localised will be critical to enable local production and to bring down costs for the consumers. These technologies can be either developed domestically where the country has a strong starting position (e.g., technology adjacencies with the electrical and electronics cluster) or prioritised for technology transfer. Other examples include the high potential take-up of biofuels. Driving local innovation and technologies to produce sustainable biofuels with process innovation to produce biofuels from various bio-based feedstock and key technologies at bioenergy processing plants will be required.

Figure 98: Global climate innovation gap to achieve Net Zero

Around 35% of technology is not yet available to solve climate challenges globally – creating need for climate innovation



1. Current CO2 emissions 35Gt per year (2020); total GHG emissions 51Gt with similar ratio of new to existing technology assumed 2. Estimated Net Zero gap in 2050 from tech in demonstration (17%) and large prototyping (19%),
Source: IEA Sep 2020: Global energy sector CO2 emissions reductions by current technology maturity category in the Sustainable Development Scenario relative to the Stated Policies Scenario, 2019-2070, Project Team Analysis

With enhanced clarity on the sectoral decarbonisation pathways, a comprehensive technology localisation strategy can be developed based on prioritisation of technologies required for the country's Net Zero pathway. In addition, understanding of the starting position of local innovation and technologies in these areas will be key in order to inform strategies to "locally develop" and / or to "transfer technologies" through international partnerships.

Adopt a mission-based approach to anchor climate innovation

Mission-oriented policies can be defined as systemic public policies that draw on frontier knowledge to attain specific goals, or *big science deployed to meet big problems*. Missions such as tackling climate change are grand challenges and are "wicked" problems as they are complex, systemic, interconnected, and urgent, requiring insights from many perspectives.

Given the scale of these challenges and importance to orientate climate investments in a focused manner, governments will need to adopt a mission-driven approach to climate investments:

- Missions should be well defined. Investments should be based on detailed definitions of technological challenges, goals and deliverables, including processes for monitoring and accountability.
- Missions should comprise a portfolio of R&D or innovation projects for each technology challenge. R&D (especially early-stage) is highly uncertain and requires policymakers to accept failures and use them as learning experiences without punishing stakeholders for defeats derived from good-faith efforts.
- Missions should result in investment across sectors and involve different types of actors. The highest impact can be achieved only if funds focus on actors across an entire economy and ecosystem, not just one sector or ventures limited to the private or public realm.

- Missions require integrated policymaking. Priorities need to be translated into concrete policy instruments and actions carried out at all levels of the public institutions involved, with a clear and strategic division of labour among them.

Using a mission-driven approach, governments should assess their domestic climate innovation needs. Governments can then select investment areas by analysing available opportunities based on their impact (financial and climate), policy or regulatory direction, and market attractiveness (technology maturity, funding gaps, and general barriers). The level of need is guided by three main criteria.

The first is the current state of the country's climate innovation ecosystem – the human and technological capabilities of its research institutions and start-up ventures. This serves as an indicator for the quantity and quality of climate innovation investment opportunities. Next comes access to capital, an indicator for potential climate innovation funding gaps and co-investment opportunities. Third is the level of domestic carbon emissions produced by current economic activities, which points to the most pressing areas of focus.

Using these lenses, priority missions can be identified for the country for stakeholders to unite around. This will reduce fragmentation of focus, ensure at-scale funding for innovation in these key areas, and ensure that research and innovation efforts have a clear target outcome which is being addressed.

Address gaps along climate funding lifecycle

Another key priority will need to be addressing key gaps along the climate funding lifecycle which inhibits the development and scale-up of innovation and technologies. There are three key stages of the climate innovation cycle, possessing various pain points

- **Research and development** – *basic science R&D and translational science R&D*

  Whilst increasing budgets are being dedicated to climate, this is still insufficient in relation to estimated funding requirements. With the lack of mission-driven focus, R&D efforts are typically fragmented which further exacerbates the scale of funding. Given the pace needed for climate solutions, there is an urgent need to rethink how to deploy budgets in a much faster and more targeted way.

  A key priority in this area will be to enhance R&D grant programs as mission-driven programs with a clear climate innovation focused strategy and lean processes to nurture the ecosystem. Given the high-risk capital needed in this area, the public sector is well placed to plug the funding gap. However, to ensure long-term sustainability, focused programs with clear time horizon goals can be considered.

  For example, in Norway, to foster focused and outcome-driven R&D, the Energi21 program which is the national research and innovation strategy for new climate-friendly energy technology was developed with mission-driven focus on 6 areas. Research centres were established to support each of these areas but with the unique characteristic that these research centres were to be shut down after a period of 8 years (5-years as based, and 3-year extension option based on review). The 8-year time horizons creates focus to ensure speed to outcomes and output, which also enhances the long-term sustainability of R&D grant programs.

- **Validation and early deployment stage** – *pre-seed and seed*

  One of the largest challenges in the validation and deployment stage is the "valley of death" which refers to the significant underfunding in this area. Innovation in this area is too developed or mature for government-funded grants, yet too undeveloped for private sector entry due to risk-return appetite of investors. Hence, many high potential technologies fail to scale at this stage.

Enhancing funding levels and activating support of the greater innovation system to validate and deploy technologies are critical. Other forms of financing at this stage to overcome the "valley of death" include public-private partnerships to co-fund investments into high potential innovations at the validation stage. This includes public-private partnership general partner (GP) models or co-funding models with a general partner (GP) and limited partner (LP) investments to increase into high-impact, high-risk companies.

- **Growth funding** – *series A/B and growth*

  Several unique challenges are also faced in growth funding. Although private equity and venture investments into the space has been increasing, this is still limited compared to funding levels required. The level of risk-return appetite remains prohibitive for a majority of private capital. High asset intensity required to scale climate solutions requires abnormally high investments, which may be a deterrent to private sector investments. Moreover, the large ticket-size of climate scale up does not fit into existing PE and VC fund structures.

  Growth funding in this area with the activation of catalytic investing by development-oriented sovereign wealth funds, or matching facilities to incentivise patient capital institutional investor to invest into climate innovation funds can be considered.

Establish dedicated climate innovation funding

Recognising the gaps in existing climate innovation financing, governments have established climate innovation and technology funds focused on R&D, basic research, innovative technology star-ups, and growth financing. This includes Japan's METI Green Fund, Germany's KfW Future Fund, and the climate innovation funding allocation under the American Jobs plan. Focusing on various areas of the climate innovation lifecycles, these funds serve to plug market gaps in funding and are focused on high potential mission-driven technologies which are important to realise net zero goals for the country.

Figure 99: Government-funded climate innovation funds

Leading economies with recent declarations to establish climate innovation and technology funds

12/2020
METI[1] Green Fund
$19 Bn to support companies that develop and deploy key technologies (e.g., hydrogen, electric vehicles) required to realise Japan's net zero targets by 2050 and fuel sustainable "green growth"

03/2021
KfW Future Fund
$12 Bn to support innovative technology start-ups with a focus on growth financing, that is set to mobilise more than $30bn in public and private capital for start-ups in Germany until 2030

04/2021
American Jobs Plan
$35 Bn for climate R&D, including $5bn for basic research and $15bn for demonstration programs in utility scale storage, CCUS, hydrogen, floating offshore wind, advanced nuclear, biofuels, and rare earth supply chains

1. Ministry of Economy, Trade and Industry, 2. German state-owned promotional bank
Source: Press Searches, Project Team Analysis

Figure 100: Addressing pain points across the innovation funding lifecycle

Three funding mechanisms proposed to nurture the ecosystem and close investment cycle funding gaps

Climate innovation investment cycle

	Research and development	Validation and early deployment	Large scale deployment
	Basic science R&D / Translational science R&D	Pre-Seed / Seed	Series A-B / Growth
Current pain points	• Increasing budget dedicated to climate, yet still insufficient in relation to estimated funding requirements • Urgent need to rethink how to deploy budgets faster and targeted	• Overall funding levels across climate innovation space from private and public sector still limited • Companies moving into (pre-) seed typically face "valley of death" and require support of greater innovation ecosystem to validate and deploy	• Funding levels limited despite deep PE pockets moving into growth • High asset intensity of climate innovation investments can require abnormal (i.e., large) ticket sizes during scale-up, which don't fit into existing VC or PE fund structures
Potential Solutions	**R&D grant programs** **Mission driven** programs with a clear **climate innovation focused strategy** (e.g., address largest domestic needs)	**Early-stage funding** **Public-private partnership and co-funding (blended finance)**[1] to increase investments into high-impact, early-stage companies	**Growth funding** Investment matching facility to **incentivise institutional investors and corporations** to invest into climate innovation
Investment Approach	• **Direct funding via grants**, following established R&D funding mechanisms • **No ownership** assumed	• **Matching** of **direct GP** and **fund-of-fund** investments • Focused on **minority equity investments** (no direct ownership)	• **Matching** of **direct GP** and **fund-of-fund** investments • Focused on **minority equity investments** (no direct ownership)
Ticket Size (USD)	• R&D stage funding with varying **ticket sizes of < USD 1 Mn to > USD 10 Mn** depending on the tech	• Pre-seed to seed funding with varying **ticket sizes of < USD 1 Mn to > USD 10 Mn** depending on the tech	• Series A to growth funding with varying **ticket sizes of < USD 10 Mn to > USD 100 Mn** depending on the tech

Source: Expert interviews, Project Team Analysis

Foster collaboration, open data access, and knowledge agglomeration

Ecosystems are the collective sum of public, private and governmental stakeholders who compete and cooperate, working towards one or more common goals. The presence of ecosystems suggests that much of a stakeholder's success is defined by their environment, not just by individual organisational capacities. Thus, healthier and more vibrant ecosystems are more beneficial for all stakeholders. Besides funding and financing, various other enablers are needed to foster a healthy climate innovation ecosystem. This includes enhancing collaboration, open data access, and knowledge agglomeration[111] .

- **Collaboration:** The scale and complexity of climate challenges means that no one individual or party can solve it alone. Findings through engagements with climate innovators across the globe indicate that it is not the idea that makes an innovative solution become a reality, but rather the ability to collaborate with a variety of stakeholders. To catalyse swarm intelligence, organisation must establish effective interfaces between themselves and relevant ecosystems. This includes having lean structures with numerous ecosystem touchpoints which are agile and can respond quickly to changes which facilitate large-scale cross boundary innovation.

- **Open data access:** Open and shared climate data access is fundamental to democratising and mainstreaming climate action, harnessing the problem-solving and innovation over a larger audience. Open data, which is the publication of datasets that can be freely used and redistributed by anyone, anywhere offers opportunities to ensure climate innovations can be formed by relevant data. Data access supports the identification of pain points or market gaps which require solutions, accurate sizing of innovation impact, and identification of potential areas to test and deploy innovation solutions. To enhance data required for innovation, improved data collection and quality is required, along with common data repositories, greater coordination and novel partnerships on data, and democratising model approaches which are transparent and accessible all examples of steps where public and private sector can collectively take to enhance innovation ecosystem foundations.

- **Knowledge agglomeration:** With increased focus on mission-based innovation priority areas, and with stronger ecosystem, knowledge agglomeration benefits can be unlocked. This includes the sharing of knowledge in between various innovative use cases in order to develop integrated solutions which holistically meet the specific requirements of climate change challenges. By fostering both physical and virtual ecosystems which enable collaborative knowledge sharing and development amongst academicians, researchers, venture builders, climate data experts and many others, the pace of innovation can be accelerated. Both formal and informal networks are important to support knowledge agglomeration and the creation of hubs for climate innovation facilitates interactions required to agglomerate knowledge to support the identification and development of potential breakthrough technologies.

Ensure time-to-market with test beds for pilots and deployment

Another key challenge typically faced is the ability to find strong test beds for innovation or technology pilots and deployments in real life settings. Reasons which inhibit the availability of test beds for innovation including the inconvenience and disruption to daily routines with pilots and the limited incentives of end users or asset owners to support technology pilots, others may include potential risks to operations or plants with the adoption of new technologies.

However, given the importance of finding climate solutions, corporates will need to be compelled to support innovators by providing real-life test beds and to facilitate pilots to prove technical feasibility and commercial viability of projects. Bilateral and multilateral partnerships between academia and innovators with sector players can be encouraged to reduce time required to convince and identify suitable test beds for technology. Industry associations can also be the key points of contacts which encourage members to support innovation with the provision of test beds.

Moreover, incentive schemes or recognition to corporate players which strongly support the progress of innovation by supporting pilots can be rewarded, increasing the incentives for market players to support or even invest in innovation pilots[112] .

111. Implementing Open Data Strategies For Climate Action, World Resources Institute
112. Collaborative Innovation for Urban Climate Futures, Better Together Award, Impact Hub Berlin

Scale-up highest potential emerging technologies where Malaysia has competitive advantage

Malaysia's endowments have provided it with large opportunities to capture green growth from high potential emerging technologies where it has potential differentiated competitive advantage. Catalytic investments into these technologies are critical to support the scale-up required to adopt these technologies at scale and emerge as key technology hubs in these areas.

Some high potential technology areas for Malaysia to consider include, but are by no means exhaustive of potential new innovation-led growth opportunities:

- **Green hydrogen technologies**

  Endowed with cost-competitive renewable energy sources such as sustainable hydropower, Malaysia is positioned strongly to become a regional hub for the export of green hydrogen which has high potential to scale in demand.

  This includes serving key export markets such as Japan, South Korea, and potentially China in the future. Malaysia's strong advantages are in its ability to have region-leading cost competitive renewable electricity inputs to produce hydrogen, geographical proximity to key export markets, and early mover advantages such as the construction of green hydrogen production facilities in Sarawak. From the cost advantage provided by cost competitive electricity inputs alone, Malaysia has the ability to produce green hydrogen at approximately 20% lower production cost by 2030 compared to the rest of Southeast Asia, as electrolysers become increasingly cost competitive.

  Furthering this advantage, innovations can be unlocked and localised across the full value chain. This includes innovations to further optimise the cost of electricity production with latest technologies, reducing the costs of electrolysers by enhancing technology localisation, and identifying potential breakthrough technologies in long-range hydrogen export through various mediums, including through metal hydrides where the country has innovation foundations in.

- **Solar and energy efficiency value chain technologies**

  Building on the strong starting position as a top three solar photovoltaic manufacturer globally, the country has the potential to move up the value chain into high value areas associated with solar technologies. Innovation can support enhanced efficiency of solar energy from various aspects – from leveraging advanced materials in solar panel production to innovations in the setup and operations of solar farms. Other areas include unlocking innovations to decrease the land use impact of solar such as through innovative dual use solar farms with optimised crops and solar panel layouts, or by scaling emerging technology applications such as floating solar.

  Besides in solar panel production, the innovations in the area of energy efficiency can be spurred by the country's strong electrical and electronic sectors. This includes innovation in smart devices which can support demand side management and energy efficiency, optimise industry processes through Industry 4.0 technologies, and others which can support to reduce overall energy demand and emissions.

- **Second and third generation bioenergy**

  Given its strong agriculture sector and various endowments such as year-round access to sunlight, the country has facilitative conditions to produce bioenergy. This includes supply-side innovation on bioenergy feedstocks, such scaling-up second and third generation biofuels produced from both agricultural waste and algae. In addition, innovations in bioenergy production combined with reforestation efforts through agroforestry can be explored, to realise circular economy benefits.

  Besides innovation on the supply-side, large new opportunities also exist on the demand-side such as adoption particularly in transport to decarbonise the marine and aviation sector. This includes advancements and innovation in chemical conversion pathways from feedstock to end-user fuels for various types of feedstock.

- **Carbon capture and storage (CCS):**

  Other technologies include carbon capture and storage where due to the availability of depleted oil reservoirs and saline aquifers, Malaysia has potential technology advantages in CCS technologies. However, the environmental sustainability of CCS as a solution will need to first be verified, through holistic environmental impact assessments to ensure that these solutions do not impact marine life, risk leakage, or other damages to the oceans.

  Given the adjacencies with the Oil and Gas sector, leveraging on existing technological strengths and know-how can also support the positioning of Malaysia as a regional leader in the space. Other innovations to further enhance safeguards to any form of environmental damage from CCS represents an opportunity to greater increase public confidence in the viability and environmental friendliness of the option. Other areas of innovation include identifying high potential industrial cluster sites for carbon capture at low cost across Malaysia.

Case Study 6 | Scaling up clean hydrogen production and deployment

Hydrogen is a highly versatile energy vector which has a wide variety of potential use cases and sources of generation. An overview of the key supply-side sources and demand-side uses and are outlined.

On the supply side, there are three types of hydrogen, namely grey hydrogen, blue hydrogen, and green hydrogen:

- Grey hydrogen is predominantly produced by steam methane reforming or autothermal reforming of fossil fuels such as gas or crude oil, which causes the release of carbon dioxide. Grey hydrogen production currently stands as the most economically viable form of hydrogen, with economic applications primarily in the chemical industry for ammonia, fertiliser, and oil refining.

- Blue hydrogen is generated from grey hydrogen with the additional step of carbon capture and storage, which enable up to 90% of carbon dioxide typically released in the production of grey hydrogen to be captured. Blue hydrogen may also be produced as a petrochemical by-product, provided the production pathway has low carbon emissions. As the prominence of hydrogen economy grows, official internationally accepted definition on the carbon content allowable under blue hydrogen will likely be defined.

- Green hydrogen is generated from the use of electricity produced from renewable sources, such as hydroelectric or solar or bioenergy, with water to enable the production of hydrogen and oxygen through electrolysis.

On the demand side, hydrogen has multiple potential end uses, each with different levels of technical and commercial viability today, as illustrated, including:

- Use in industry, such as hydrogen for refineries and in factories to produce ammonia, steel, and other chemicals.

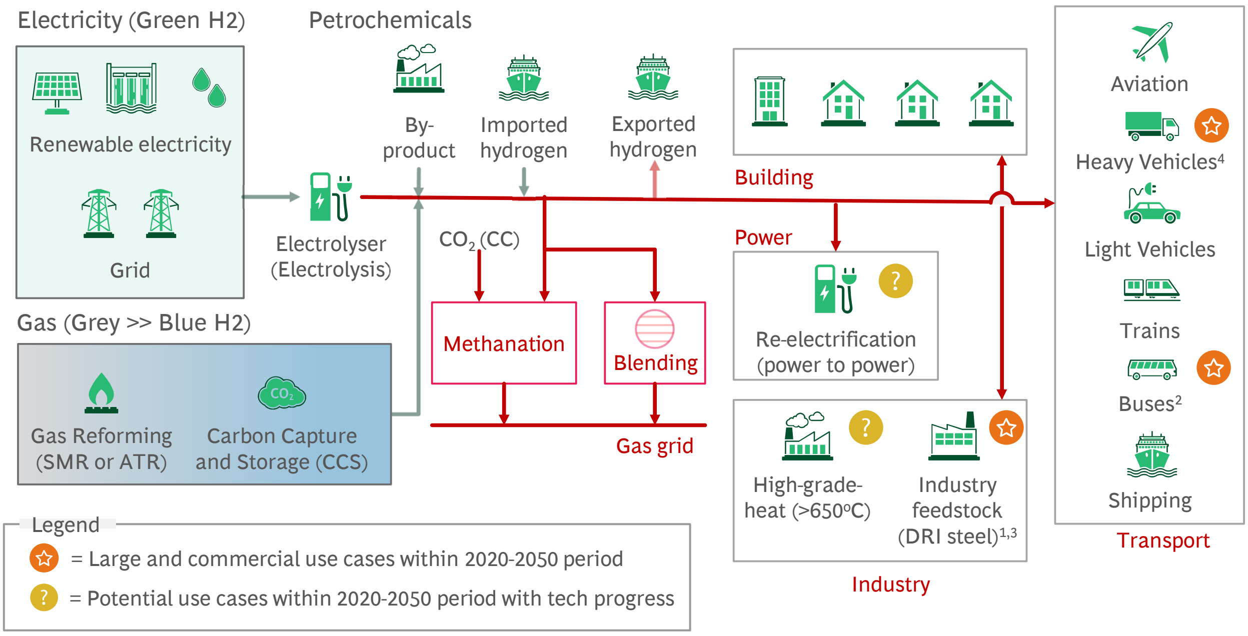
- Use in transport as a fuel supplied through refuelling stations and converted into electricity through fuel cells to power trains, ships, heavy transport, and light transport.

- Use in power generation, as a form of energy storage by converting excess power into hydrogen, and for power generation through blending and use at gas power plants or by converting back into electricity with fuel cells, known as power-to-power hydrogen application.

- Use through direct injection of hydrogen into the gas grid, for use in households and commercial cooking, heating, and cooling, known as power-to-gas hydrogen application.

Figure 101: Potential sources and uses of hydrogen across sectors

Near-term use cases for hydrogen in heavy transport and industry



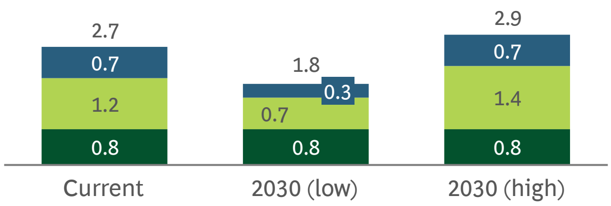
1. Substitution of natural gas for hydrogen in direct-reduced iron production process 2. Within 2020-2030 pilots, scale post 2030 3. Within 2030-2040 period 4. Within 2040-2050 period
Source: Project Team Analysis

Figure 102: Evolution of hydrogen production economics, based on Malaysia's regional advantages

Malaysia has regional-leading cost advantage in green hydrogen production due to cost competitive LCOE of hydropower

Blue Hydrogen

Production cost ($/kg)

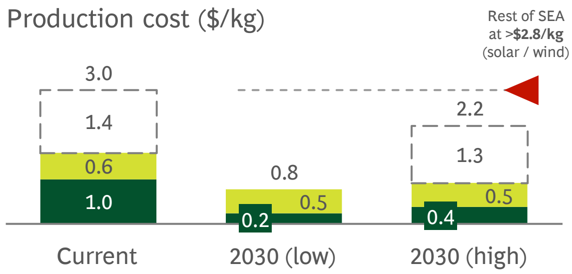


	Current	2030 (low)	2030 (high)
LNG price[1] ($/MMBtu)	8	5	10
CCUS cost ($/ton)	57	23	57
CCUS efficiency	90%	99.9%	90%

CAPEX Natural gas CCUS

Green Hydrogen

Production cost ($/kg)



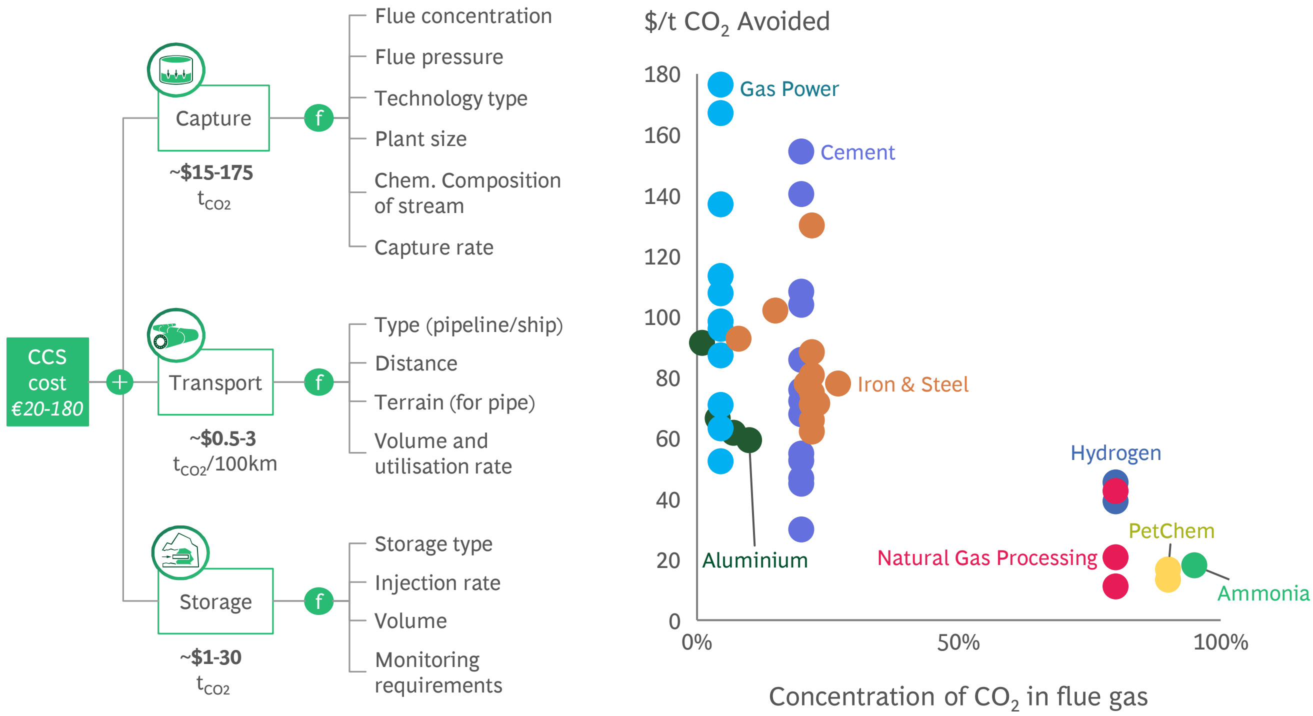
	Current	2030 (low)	2030 (high)
RE LCOE[2] ($/kWh)	0.01 +0.03 grid fee[6]	0.01	0.01 +0.03 grid fee[6]
Electrolyser efficiency	59%	65%	65%
Electrolyser CAPEX[3] ($/kW)	1200	390	640
Lifetime (hr)	60,000	77,000	77,000

CAPEX Electricity Grid fee

1. Current price based on Malaysia Industrial user piped gas tariff Dec 2019; 2030 figures based on Rystad projection price range between today-2030 2. LCOE based on estimated current Malaysia hydropower LCOE 3. Estimates based on Proton Exchange Membrane 20MW capacity–expected winning technology; 2030 (high) estimates based on expected 2025 prices–assumes slower experience curve 4. Current EU carbon trading price/ton 5. Based on IEA Sustainable Development scenario for developing economies 6. Based on difference between Malaysia current overall LCOE and retail tariff to Industry customers; may be omitted if RE plant was built adjacent to H2 production facility and power is supplied directly to electrolysers
Source: Expert Interviews, Project Team Analysis

Figure 103: Key drivers for carbon capture and storage (CCS) lifecycle cost

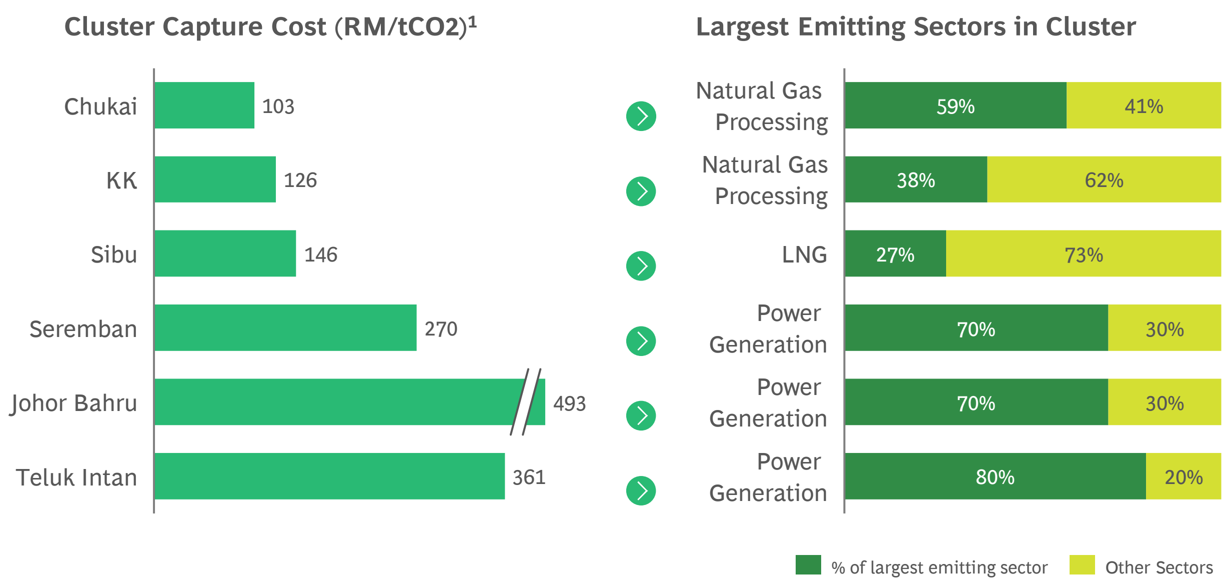
Cost of CCS – across capture, transport, and storage – varies by range of factors, affecting relative CCS economics



Source: IEA Energy Technology Perspectives 2017; Piotr Kosowski et al (2016); Jo Husebye et al. / Energy Procedia 23 381 – 390; Navigant Gas for Climate (2019); European Zero-Emissions Platform (2011); US Department of Energy – Saline CO2 storage (2014); Rubin et al – Cost of CCS (2015); Project Team Analysis

Figure 104: Assessment of CCUS capture costs across various clusters in Malaysia

CCS for highest potential clusters around RM 100-150 / tCO_2e



1. Capture cost is discounted at a rate of ~8% (Malaysia's Bond Yields),
Source: Project Team Analysis, BCG OGCI CCUS Potential Study

Priority #7:

Strengthen environmental and social safeguards

Overview

Safeguards in the context of this study refers to measures put in place to ensure holistic and climate initiatives which deliver total societal impact aligned with overall sustainable development goals. These safeguards will need to factor in total environmental impact, social impact, and be anchored on principles of equitability both at the local level (i.e., across people groups and communities) as well as at the international level (i.e., across countries). Safeguards should be designed as preventive rather than reactive measures, as effective screens before potentially damaging actions are taken. In addition, during the onset of implementation, safeguards should also be backward applied to previous actions taken, and interventions defined to mitigate effects or reverse actions which are assessed to be damaging.

These safeguard measures are key to build credibility on climate solutions, enhancing stakeholder confidence and gaining broad acceptance that climate mitigation pathways will deliver real impact. Safeguards will protect against "greenwashing" by corporates or governments, and to plug loopholes which are detrimental to overall climate action. Overall, safeguards are key foundational enablers to a just and equitable climate transition.

Whilst it is important that safeguards are widely applied across all aspects of climate transition, there are several hotspots which are highly susceptible to green washing or broader total societal impact damage, where safeguards are needed as a priority. These include:

- Screening for holistic impact of emerging climate technologies
- Safeguarding against unintended impact of nature-based solutions and carbon markets
- Ensuring equitability in international climate arrangements
- Distributive justice of green taxes and financial transfers
- Strengthening taxonomy and disclosures standards to avoid corporate greenwashing
- Enhancing stock of climate knowledge and climate data foundations

Screening for holistic impact of emerging climate technologies

Given the limited window of time to address global warming, technology will need to play a key part in driving decarbonisation globally. This includes the rapid scale-up of existing technology solutions and introduction of nascent and emerging technology solutions, which are gaining in momentum with a global push towards Net Zero. Ensuring that these technologies are holistically screened for total societal impact will be key, along with several key dimensions:

- **Assessment of end-to-end GHG footprint impact (cradle-to-grave)**

  Safeguards to ensure that end-to-end lifecycle emissions are factored into account for climate solutions are critical. This may be underestimated by countries especially if the GHG emissions are being incurred in the global supply chain and do not directly impact national GHG inventory. For example, for low carbon mobility solutions, such as Electric Vehicles, this includes assessing the full supply chain impact, such as the emissions in extractive industries and manufacturing of batteries and various components. Safeguards to ensure that automakers account for these emissions, and work with the supply chain either unilaterally or through alliance to drive decarbonisation of the full supply chain, will be important as a pre-requisite for the at-scale technology adoption. Opportunity costs at an overall system level also needs to be evaluated, such as the impact of climate solutions on land use, which create opportunity costs relative to other land uses such as for forests or agriculture.

- **Assessment of broader environmental impact (i.e., beyond GHG emissions)**

  Moreover, safeguards will need to be made to ensure that the broader environmental impact beyond GHG emissions is factored into account during climate action decisions. This includes holistic assessments on impact on wildlife, marine life, natural landscapes, and ecosystems. For example, safeguard standards will need to be established to require holistic location-specific environmental impact assessments for renewable energy sources.

  Deep focus will be needed to also assess the impact of geo-engineering solutions given the nascency and potential large-scale impact of these solutions. This includes carbon removal solutions which may have relevance to Malaysia's context such as carbon capture and storage (CCS) in depleted hydrocarbon reservoirs and subsurface saline aquifers. Adequate safeguards which ensure that the adoption of CCS in the country meets strong science-based evidence that broader environmental factors are not adversely affected will be required, to avoid both potential near-term or long-term environmental liabilities for the country.

- **Assessment of social impact and equitability**

  Beyond environmental considerations, strong social safeguards will also be needed. This includes safeguards to ensure protection of rights, ensuring that costs of climate action are not disproportionately incurred on low-income households, equitable distribution of costs and benefits across regions, people groups, and others will be key. For example, with the increased penetration of decentralised renewable energy, it is critical that the tariff structure is reviewed to avoid disproportionate effects on lower income households, which have less propensity to be prosumers of decentralised energy production. Others include the impact on local communities, such as people displacements or livelihood impacts from renewable energy development. Mandatory local community impact assessments and consultation processes will be critical to mitigate these social risks on topics such as human and land rights violation, water and natural resource access, social tension amongst communities due to inequitable distributions of cost and benefits, and impact to other local industries.

Safeguarding against the unintended impact of nature-based solutions and carbon markets

Nature-based solutions and carbon credits, through both voluntary and compliance carbon markets, will need to be designed with the relevant safeguards to ensure target outcomes are achieved. If effectively designed with the right safeguards, these solutions can accelerate solutions to climate change and strongly improve the protection and enhancement of nature. On the other hand, without the right safeguards, these solutions can undermine the momentum towards real climate action, harm nature, and result in adverse social spillovers to local populations. There are four key demand-side and supply-side safeguards required to ensure positive total environmental and social impact from nature-based solutions and carbon credits:

- **Ensuring no substitution for in-house action**

  Safeguards will need to ensure that nature-based solutions (NBS) and carbon credits do not provide entities with an incentive to excuse or delay emission reductions within its own operations and value chain[113]. For example, land-based credits should not be used to offset continued fossil fuel use or the lack of decarbonisation in high emission sectors. Parties buying carbon credits must demonstrate that they are doing everything they should to reduce their own emissions before carbon offsets and credits are considered. In essence, NBS or carbon offsets must serve to enhance, not dilute, the pace of emission reductions[114].

- **Holistic environmental impact, beyond carbon sequestration**

  Solutions will need to reinforce the importance of holistic environmental impact including ecological integrity and conservation of biological diversity. Approaches solely based on carbon sequestration without consideration of ecosystem values will need to be avoided, and climate and biodiversity challenges must be addressed in an integrative fashion instead. Safeguards will need to exclude climate false solutions, with strong attention on the feasibility to geo-engineering related carbon offsets to ensure end-to-end emission reduction and total environmental benefits.

113. Climate Land Ambition Rights Alliance (CLARA) (2020). CLARA Submission to the Standing Committee on Finance
114. World Resources Institute (2021). Corporate Financing of Nature Based Solutions: What Next?

- **Social safeguards such as the protection of land and people rights**

  Safeguards to protect social outcomes and against any violation of the land rights of indigenous peoples and local communities are required. Of particular concern is NBS related to reforestation using exotic or single-specific planting approaches which compromise of ecological intensity and potentially exacerbate adverse social impact. Ensuring a rights-based solution is especially pertinent for NBS which often has direct and indirect implications to highly vulnerable indigenous communities which rely of forests for livelihoods.

- **Permanence and additionality of measures**

  The principle of permanence is critical to ensure that emissions reduction and removals are not reversed, and if reversed are compensated with risk mitigation measures, long-term monitoring and reporting, and mechanisms to compensate for reversals. For additionality, safeguards will need to ensure that emissions reductions and removals are "real" and would not have happened without this measure. This includes establishing a clear baseline and reference period using robust methodologies which avoid inflated baselines. In addition, other measures to ensure data accuracy are critical such as the accurate IPCC compliant measurement of emission removals impact, mitigation steps to reduce measurement error risks, and clear accounting mechanisms to avoid double counting are equally critical.

Ensuring equitability in international climate arrangements

Strong safeguards will be required to uphold climate justice and equitability in international climate arrangements, such as cross-border emissions trading referenced under Article 6 of the Paris Agreement. This includes protecting for the interest of the Global South in these arrangements to ensure climate justice and equitability. The Global South broadly refers to developing countries, with lower per capita incomes than the Global North. Over time, countries in the Global South have had significantly lower cumulative contributions to GHG emissions, but face larger impacts from climate change, with lower capacities to adapt to the effects of climate change compared to the Global North.

Safeguards are required against low-cost and low-quality carbon offset credits which enabled the continued emissions and delayed decarbonisation of the Global North at the expense of the Global South. International offsetting mechanisms will fail to reduce overall emissions if plagued with inadequate safeguards to ensure additionality and permanence. In fact, a 2016 Oeko Institute report for the European Commission found that nearly three quarters of all credits which can be supplied before 2020 are not likely to be additional[115]. Equally important are safeguards to avoid carbon offset projects with adverse social impact on vulnerable communities, such as human rights and land rights abuses, especially for indigenous communities.

For example, large hydroelectric projects through the Clean Development Mechanism (CDM) program have been criticised for non-conformance to additionality and sustainability objectives, originally set out in the Kyoto Protocol. These projects have been shown to exacerbate local social issues such as local community displacement, diversion of water access from indigenous communities, and others which point towards the need for strong safeguards standards to ensure total societal impact of climate solutions brought about through international climate arrangements[116.]

Distributive justice of green taxes and financial transfers

With the imposition of carbon pricing schemes, safeguards will need to be established to ensure that these mechanisms or other green-related taxes are equitable across the population. Well-designed mechanisms will be required to ensure distributive justice of these schemes, especially for low income and vulnerable households. These mechanisms are explored further in the *carbon pricing* section of this report.

115. Oeko Institute (2016). How additional is the Clean Development Mechanism? Analysis of the application of current tools and proposed alternatives..
116. Koo (2017). Preparing hydropower projects for the post-Paris regime: An econometric analysis of the main drivers for registration in the Clean Development Mechanism

Safeguards will also be needed to ensure the equitable allocation of resources and benefits from green financial transfers, such as international climate funding within a country. Ensuring the benefits and costs of green transition are equitably shared among various segments of the population are key for a just transition. These mechanisms are explored further under the *climate finance* section of this report.

Strengthening taxonomy and disclosures standards to avoid corporate greenwashing

With the lack of standards or common definitions on environmental sustainability, there is a high risk of corporate greenwashing. Corporate greenwashing occurs when corporates or products are marketed as environmentally sustainable without sufficient factual basis for their claims. Subjectivity in what is deemed as "green" is a key enabler to corporate greenwashing, and this can be addressed with strengthened clarity of taxonomy (i.e., establishing a common language or definition for what is green) and environmental disclosures (i.e., what needs to be reported) required for corporates.

For example, to ensure appropriate safeguards against greenwashing, the European Parliament in 2020 formally adopted the EU's Sustainability Taxonomy Regulation. The aim of the Regulation is to provide an EU-wide framework for classifying economic activity as environmentally sustainable[117]. The taxonomy represents a key safeguard as it necessitates corporates to adhere to a holistic definition of environmental sustainability for a corporate or product to be deemed as green, including six objectives of climate change mitigation; climate change adaptation, sustainable use of water and marine resources, transition to a circular economy, pollution prevention and control, and the protection and restoration of biodiversity and ecosystems. Technical screening criteria is established for each objective for avoidance of doubt to ensure common definition and standards across all corporates.

It is critical that both holistic green taxonomies and disclosure standards at the international level are cascaded to the national level, based on country-specific nuances. In addition, ensuring widespread adherence or enforcement of a common taxonomy, supplemented with transparent disclosures which are independently verifiable and auditable will be key to mitigate against corporate greenwashing, informing more fact-driven green choices by consumers, corporates, investors, and governments.

Enhancing stock of climate knowledge and climate data foundations

Strong data foundations is a key pre-requisite for effective climate action. Climate mitigation decisions are strongly informed by GHG inventory baselines, such as the national GHG inventory to determine the country's GHG emission path. Improving both the inventory accuracy (e.g., improving data collection and measurement for existing inventory data collected for sectors) and inventory coverage (e.g., including new sectors or GHGs for a more comprehensive inventory) will be critical. For GHG removals as an example, increasing the granularity or area resolution of forest conditions can improve the accuracy of forest land GHG removals accounting, whilst better efforts to understand the GHG emissions and removal contribution of oceans and coastal areas can increase the comprehensiveness of GHG inventory coverage.

In addition, building knowledge on climate mitigation levers, informed by detailed environmental impact assessments over the lifecycle of projects, can strengthen data-driven decision making in the adoption of these levers in the future. This is particularly important for emerging climate solutions which will likely be deployed on a large scale to meet GHG emission reduction objectives. Strengthening climate data foundations will also be needed to inform climate adaptation and resilience measures, such as a better understanding of how material physical risks which will affect different areas across the country over time.

Finally, ensuring strong data transparency and open access will be critical to ensure verifiability of climate data and knowledge, as well as open platforms to voice alternative views will be critical to sharpen climate discourse and climate data foundations in the country. Together, these measures will set important enablers and foundations for enhanced safeguards for both climate mitigation pathways as well as climate adaptation and resilience efforts.

117. The National Law Review (2020).EU Parliament Adopts Sustainability Taxonomy Regulation to Fight Greenwashing

Priority #8:

Human capital and just workforce transition

Overview

Pursuing an ambitious climate agenda such as the Net Zero 2050 pathway has the potential to unlock large socioeconomic impact for Malaysia. The degree of socioeconomic impact the country can realise relative to this potential is influenced significantly by Malaysia's ability to orchestrate a smooth workforce transition. This transition is achieved when three key criteria are met.

First, that Malaysia's workforce builds skills-of-the-future in a timely manner to provide the country with competitive advantage and to capture job opportunities created from the emergence of new green sectors. Second, that the transition between declining sectors in the brown economy to emerging sectors in the green economy is minimised, to avoid a prolonged interim period of unemployment which would impact the livelihoods of Malaysians. Third, that the costs and benefits of job creation and job transition are equitable, where the economic benefits of climate transition are enjoyed by all Malaysians, and not exclusively by certain groups of people.

Given the rapid pace of climate transition, workforce transition cannot be left to the markets and to chance but instead will need to be proactively orchestrated, coordinated, and managed over time. Market forces typically underprovide for workforce reskilling, redeployment, and others and hence government oversight for this enabler will be required. Aside from the jobs impact from various climate mitigation pathways, the country also needs to address the transition for the oil and gas sector, which is expected to face decline due to gradual resource depletion over time.

Key areas of job transition required

Job demand losses from declining sectors of the economy are expected to have the highest impact in the following sectors as a result of climate transition driven economic shifts:

- **Internal Combustion Engine (ICE) vehicle manufacturing and supply chain:** Decline in job demand associated with the shift of the light transport sector from ICE to EV at-scale driven by technology and policy trends. The largest decline is expected around the 2030 period as economic inflection points between ICE and EV are reached. The decline in job demand is expected in ICE auto manufacturing and ICE powertrain specific supply chain components which is not shared by EVs. The workforce from ICE can be largely redeployed effectively for EV manufacturing with timely policy measures and reskilling.

- **Transport fuels value chain – refineries and fuel retail:** Reduction in transport fuel demand at both the domestic and regional level with a shift towards EV will reduce demand for selected petroleum products such as gasoline and diesel. The reduced demand for these refined petroleum products may result in an optimisation of refinery capacity in the country.

- **Coal power plants:** Marginal losses in local job demand from the phase out of coal power plants. A large portion of employment along the coal power plant value chain is not captured within the country, such as the import of coal as well as the international expertise required for coal plant engineering, procurement, and construction. Job demand losses will primarily derive from operations and maintenance-related roles for these power plants. The workforce from coal power plants are likely to be absorbed by job demand at new gas power plants in the country.

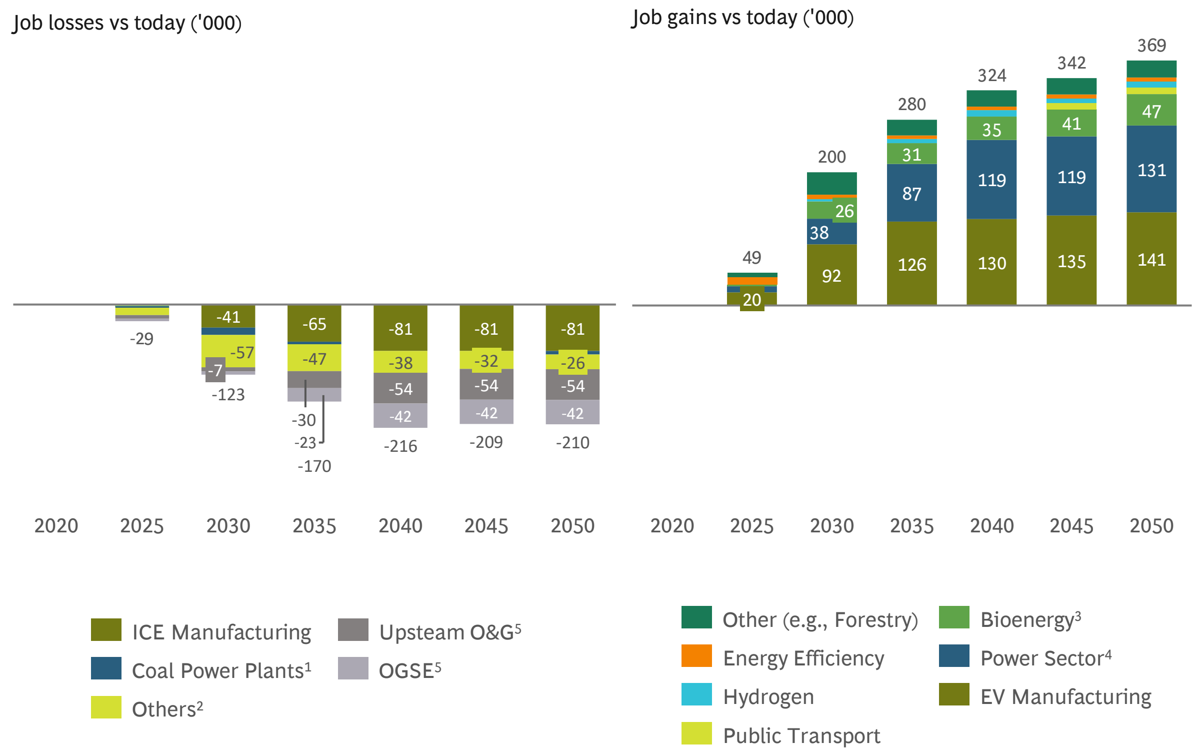
Aside from job demand losses as a direct result of the economic impact of climate transition, natural resource depletion is also expected to result in a reduction in job demand over time:

- **Oil and Gas:** Gradual decline in production based on the natural depletion of economic oil and gas resources will have an impact on job demand. The extent of job demand losses will be dependent on a range of factors including the forward-looking oil and gas prices and breakeven economics, technology development, potential discoveries, and national policies for the sector. Potential adjacencies include high value emerging industries such as hydrogen and for other emerging technologies such as carbon capture and storage (CCS) where relevant for the country.

- **Oil and Gas Service and Equipment (OGSE) sector:** Aligned to the oil and gas industry, job demand losses in the OGSE sector will depend on the level of oil and gas activity. The OGSE sector has adjacency potential in areas such as hydrogen production, renewable energy, next generation bioenergy, and others which is expected to gain strong traction over time.

Figure 105: Breakdown of job losses and job gains across key economic sectors

Job transitions required between declining sectors, due to green transition and resource depletion, to new green growth sectors



1. Excludes impact to any industry from border adjustment mechanisms 2. Job losses from coal power plants are minimal due to low labour-intensity and low portion of local content across fuels and EPC value chain 3. Includes both agriculture sector and bioenergy from refineries required for biodiesel 4. Includes jobs related to grid upgrades as well as power plants; but excludes solar manufacturing for export 5. Losses in Upstream O&G and OGSE (Oil & Gas Service and Equipment) driven by production decreases from natural resource decline
Source: DOSM, UNEP, ILO, Project Team Analysis

Emerging growth sectors

Large job opportunities are expected to emerge with the green economy with timely economic transition as well as supportive policies and enablers:

- **Low carbon mobility clusters:** The rise in EV demand will result in significant job creation contingent on the timely transition of the automotive sector. Through a build up of local supply chains, building on adjacencies with the strong electrical and electronics sector in the industry, large domestic value capture can be obtained. Besides jobs in EV auto-manufacturing and supply chain, job creation in the build-up and maintenance of charging infrastructure will also be created. Besides EV-related jobs, the build out of public transport infrastructure will also contribute to job creation as the country such as with mass transit projects will be required to support an increase in public transport modal share.

- **Power sector development:** With growing electrification penetration and demand in the country, an increased amount of jobs will be demanded by the power sector. This will be realised particularly in renewable energy development, with significantly higher domestic value capture across the value chain compared to fossil fuels. The demand for renewable energy jobs will derive from both large-scale projects and also decentralised energy production such as rooftop solar which has the potential to create a large number of jobs in installation, operations and maintenance. The increase in absolute capacity of gas power plants is also expected to create new jobs, fully absorbing job demand losses from the phase out of coal. In addition, jobs will be required for grid infrastructure upgrades to accommodate increased renewable energy production.

- **Energy efficiency:** Supported by measures such as mandatory energy audits and other activities which follow such as energy retrofits, job demand related to energy efficiency is expected to increase. The mainstreaming of energy efficiency across the economy will spur the development of the domestic energy service company (ESCO) sector, contributing to new job creation. Spillover effects to smart energy efficiency device manufacturing can also contribute towards additional jobs in the country.

- **Hydrogen:** Given the natural resource endowment advantages of the country, Malaysia has high potential to emerge as a key green hydrogen export hub for the region. This will result in strong job creation particularly in regions with strong natural advantages, such as Sarawak. Jobs will be created along the value chain, such as in hydrogen production facilities but potentially also in the supply chain as key technologies such as electrolysers are localised.

- **Bioenergy:** Growth in demand for bioenergy as a key decarbonisation solution, particularly in the transport sector, will result in strong job creation. This includes demand driven by increasing bioenergy penetration in emerging applications such as in the aviation and shipping industry. This demand will be derived from bioenergy from palm oil feedstocks as well as emerging next generation feedstocks such as algae. Harvesting of agroforestry produce to produce biofuels are also expected to result in job creation as these initiatives gain traction.

- **Forestry and Nature-Related Growth:** With the growing recognition of the value of forests and its biodiversity in Malaysia, new jobs are expected in the sector related to both the preservation, protection, and restoration of forests as well as eco-tourism sectors which leverage the competitive advantage of Malaysia's mega-biodiverse forests and ocean natural habitats.

Steps to ensure human capital and just workforce transition

To successfully develop the human capital required to build competitive advantage in the future green economy and to ensure a equitable and just workforce transition, four thematic actions are required:

- **Long-term national strategic workforce planning**

  National-level strategic workforce planning involves the holistic assessment of the evolution of workforce demand and supply needs at a granular job family level, in order to identify interventions required to ensure optimal demand-supply side matching of talent and human capital. On the demand side, this includes forecasting how workforce demand and skill requirements will shift based on the forward-looking view on the nature of work. On the supply side, this includes accounting for the total workforce supply, factoring in workforce retirement and the pipeline of workforce entrants, and the profile of skills of the workforce. Through a mapping of forward-looking workforce demand and supply, key gaps can be identified, both where demand significantly exceeds supply or vice versa.

  There are five key fundamental steps to effective strategic workforce planning which will be required for the country in order to effectively plan for workforce transition:

  - Projecting the evolution in the number and type of jobs demanded by sector and job family based on the pace of emergence or decline of various sectors of the economy due to economic shifts as a result of climate transition trends.

- Evolution in current and future skill requirements, which include both functional (across all sectors) and sector-specific skills in across the economy. This includes understanding the types of roles needed at different stages of the lifecycle for the sector from the build phase to the operations and maintenance stage.

- Profile of the country's sector workforce in terms of demographics, job roles and skills, including new entrants into the workforce from educational institutions to determine workforce supply profile over time.

- Identification of key current and future workforce demand-supply gaps and workforce skill gaps to be addressed. This includes identifying where there are the largest risks of workforce oversupply (primarily in declining sectors) and workforce undersupply (primarily in fast emerging new sectors with highly specific skill requirements).

- Prioritising key interventions to address workforce demand-supply gaps. This includes developing workforce reskilling and redeployment strategies to transition individuals from areas of workforce oversupply to areas of workforce undersupply, optimised based on skill adjacencies of the individual to reduce the reskilling period. Other levers include shaping higher education or TVET enrolments or slots to better match workforce demand requirements of the future in the country.

- **Optimised, timely, and structured reskilling and redeployment**

  Based on strategic workforce planning assessment inputs, structured programs for optimised and timely reskilling and redeployment of the workforce from declining to emerging sectors:

  - Optimised reskilling entails strategically defining adjacent job roles that individuals can be retrained into, which leverages precedent skills and knowledge that an individual has built up in his previous role, guided by job family or job function adjacencies. Besides supporting better skill and knowledge retention, this is also critical to reduce the reskilling time period and increasing the speed for individual readiness for redeployment. Optimised redeployment ensures that the redeployed individual has the sufficient training and pre-requisites to adequately perform in the new role.

  - Timely reskilling and redeployment entails a planned sequencing out of training and reallocation over time in view of the pace of demand evolution, to avoid workforce demand-supply imbalances at each time period. Long-term strategic workforce transition plans should be refined and reviewed into short-term and medium-term reskilling and redeployment plans factoring in enhanced information on the pace of sectoral shifts being experienced.

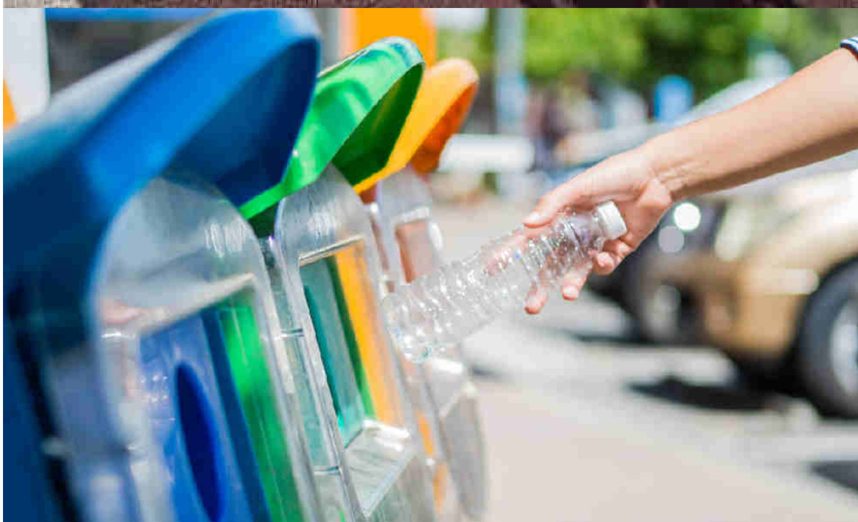
  - Structured reskilling entails clarity on the responsible stakeholders for the reskilling and redeployment activities. For example, for selected within-sector transition such as the transition from ICE to EV manufacturing can be led by corporates. Within-sector supply chain workforce transitions can be jointly managed by leading corporates or industry associations with government support. In contrast, cross-sector workforce transitions can be facilitated with greater public sector orchestration. Corporate-academia partnerships can also be established to support this transition, as demonstrated in the United Kingdom with the partnership of oil and gas companies with local universities to develop structured mid-career reskilling curriculum for oil and gas sector employees for growing green and renewable energy sectors.

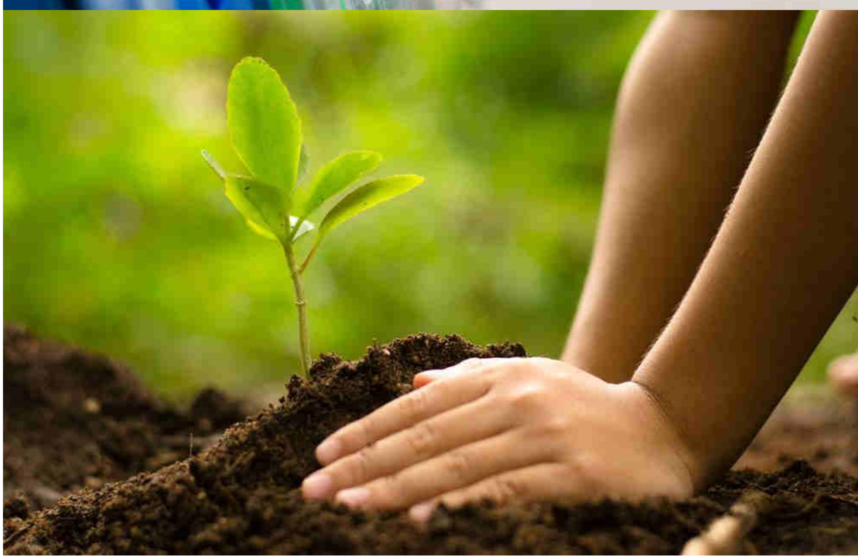
- **Clarity of skill-of-the-future requirements for future green sectors**

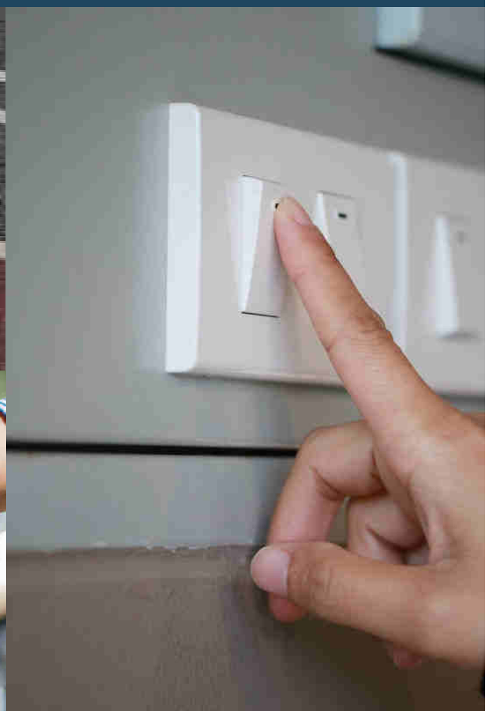
  A key enabler to achieving competitive advantage in new green growth sectors will be strong human capital foundations with the right skills, aligned to the demand of green sectors. Increasing the clarity of these skill requirements will be critical, and ensuring alignment of education curriculums against these skill requirements will be critical.

Priority #9:

Behavioural change and consumer action







Overview

Climate change represents one of the defining global challenges of our time, with far reaching threats on people and communities across the globe. If mankind is to stand a chance in lessening the worst impacts of climate change, rapid and sustained GHG emission reductions are required over the coming decades.

Individual behaviour change, when taken up by billions of people, makes a decisive difference[118]. Nearly two-thirds of global emissions are linked to both direct and indirect forms of human consumption. The landmark IPCC 1.5^{0}C Special Report points towards the need for substantial demand-side mitigation, behavioural and lifestyle changes in all mitigation pathways where global warming is limited to 1.5^{0}C. The ability to change and alter the trajectory of global warming does not reside only at the scale of government and industry, but also at the level of individuals, households, and communities making a difference in their everyday choices to optimise their climate footprints.

The impact of behavioural change on emissions reduction – the "why"

Through behaviour change and environmentally conscious decisions in transport, energy, waste, diet, and product purchase decisions, consumers can significantly reduce their individual climate footprint.

Transport

Transport emissions is one of the largest sources of individual climate footprint emission contributors. Malaysia also has one of the highest penetration of car ownership in the region adjusted for GDP per capita, presenting a large opportunity where emissions reduction can be realised[119,120]. Compared to a single occupancy journey using an average car in Malaysia, by adopting various levers, consumers can reduce their climate footprint for that exact same journey by the following degrees:

Figure 106: Key levers which can be adopted to reduce individual transport emissions

Potential emission reduction levers and impact compared to a single passenger occupancy trip by an individual

68-76%	40-60%	5-15%
Used rail or road public transport	Carpooled with a ride-sharing app	Adopted eco-driving
33%	16%	70%
Used an Energy Efficient Vehicle (2025 ASEAN standard)	Used a Battery Electric Vehicle (2020 power mix)	Used a Battery Electric Vehicle (2050 power mix)
74%	100%	100%
Used a motorcycle	Walked or cycled instead	Not travelled

118. Centre For Behaviour and the Environment (2018). Climate Change Needs Behavior Change Making the Case for Behavioral Solutions to Reduce Global Warming
119. IOP Publishing (2019). Addressing GHG emissions from land transport in a developing country
120. Briggs (2016). Malaysia Stocktaking Report on Sustainable Transport and Climate Change Data, Policy, and Monitoring

Energy in Households

Final energy consumption in households has been growing at a steady pace of approximately 3% per annum. Three quarters of household energy demand is for electricity, with the majority of demand for LPG or natural gas used as cooking fuel. Close to 98% of total household energy demand is estimated to derive from four key sources – electrical appliances (55%), cooking (23%), space cooling or air-conditioning (11%), and lighting (8%)[121] . Consumers and households can significantly reduce their individual climate footprint by adopting demand-side management or energy conservation practices and energy efficiency.

Figure 107: Key levers which can be adopted to reduce individual electricity consumption

Electrical savings from switching from the lowest 2-star energy efficiency product to a 5-star energy efficiency product

45%	43%	75%
Air-conditioning unit (1.5 HP)	Refrigerator (489 litres)	Washing machine (7.5 kg)
57%	30%	72%
Ceiling fan (54 watt)	Standing fan (50 watt)	Television (32-inch)

Other energy efficiency or use of renewable energy measures include:

- Switching from incandescent lamps to LED lights which can add up to 85% of savings[122]
- Enhancing water heater efficiency and using solar water heaters
- Installation of rooftop solar for own use and sale of excess power via Net Energy Metering (NEM) to the grid

From a demand-side management perspective, key levers include:

- Temperature controls, such as setting air-conditioning temperatures between the optimal range of 23 ^{0}C to 26 ^{0}C [123]
- Habit formation in energy conservation, such as switching off electrical appliances or light when not in use, using washing machine with full loads, or line drying
- Increased penetration of smart devices and adoption of energy efficiency optimisation automation technologies (smart homes)

Choosing energy efficient building design can also contribute to energy savings over the lifetime:

- Architectural design elements such as effective daylighting and natural ventilation[124]
- Use of optimal materials and insulation to avoid heat capture in roofs, windows, facades
- Use of sustainable building materials, including recycled materials

121. National Energy Balance (2016), Suruhanjaya Tenaga
122. Tenaga National Berhad (2021). Energy Savings At Home
123. Live Mint (2018). Running your AC at 27°C vs 18°C can cut your electricity by over 30%
124. Department of Standards Malaysia (2017). Energy efficiency and use of renewable energy for residential buildings - code of practice

Consumer or household waste

Household waste is estimated to contribute around two thirds of total solid waste, which are primarily channelled to landfills . Reduction in waste will reduce the emissions from landfills but will also serve to reduce demand and emissions incurred through the value chain in the production of the product[125]. Within household waste, food waste is the largest contributor, amounting to 45% of total household waste[126] .

Responsible waste practices can be practiced throughout the lifecycle to reduce the overall emission impact of waste, along the themes of Reduce, Reuse, and Recycle. In addition, households can also take steps to effectively manage their waste such as with composting:

- **Reduce:** Adopting sustainable and responsible consumption behaviour, by only buying what is needed, avoiding over-packaged products, and selecting products which can be reused (e.g., avoiding single use plastics) or effectively recycled. For food products, this includes planning to enhance demand-supply matching to avoid food expiry and excess portion food wastage.

- **Reuse:** Extending useful life of products through care and maintenance, using reusable over disposable packaging products such as water bottles and grocery bags, selling or donating underused products in good condition, and others.

- **Recycle:** Understanding which products can be recycled, disciplined separation of products which can be recycled, emptying and drying packaged products to enhance ease of recycling, transfer recycle products to recyclers either at drop-off points or with pick-ups.

- **Compost:** Segregation of suitable kitchen scraps and food waste for home composting. By adding suitable food waste and other organic material to soil, a source of nutrients can be provided to plants, promoting circular economy principles. Composting directly reduces a household's emission footprint, as It is estimated that emissions from composting are just 14% of the same food if dumped into a landfill[127] .

Consumer Diets and Food Choices

Optimising consumer diets can have a significant impact on demand for agricultural and livestock products, which will affect emissions in the agriculture sector and the land use sector.

- **Reducing high emission meat sources.** Emission intensities of meat production vary significantly by the type of livestock. In general, emission intensity is highest for beef at 300 kg CO_2e per kilogram of protein, compared to other livestock such as chickens with emission intensity of less than 100 kg CO_2e per kilogram of protein[128]. Shifting away from high emission meat sources will have an influence on upstream agricultural emissions.

- **Substitute towards increased plant-based diets.** Globally, meat and dairy provide just 18% of calories consumed but use 83% of global farmland and are responsible for around 60% of agriculture GHG[129]. Strong consumer shifts to plant-based diets will significantly reduce agricultural emissions and create economies of scale to lower cost of production in plant-based alternatives.

- **Choose between food product brands based on emissions in production.** Agriculture emissions can be reduced such as optimising livestock nutrition and feed. Expressing consumer preferences that reward brands which take active steps to reduce production emissions and penalise those which don't can send strong consumer demand signals. Food emission labelling is nascent but slowly gaining traction, hence proactive research or label scanning may be required by consumers to decide between brands.

125. BBC (2020). How cutting your food waste can help the climate
126. Ministry of Housing and Local Government
127. Using LCA to evaluate impacts and resources conservation potential of composting – Gian Andrea Blengini (2008)
128. Food and Agriculture Organisation of the United Nations (n.d). Key facts and findings
129. Reducing food's environmental impacts through producers and consumers, Poore and Nemecek (2019)

- **Buying local seasonal food.** Purchasing local seasonal food reduces supply chain emissions associated with food logistics and distribution[130]. Moreover, imported food with short shelf lives such as fruits and vegetables are typically imported by air, resulting in a large carbon footprint. By signalling demand shifts from imported to seasonal, locally produced food, this can reduce the climate footprint of the consumer and create support for local farmers that benefits the local economy. Whilst emissions in international transportation does not count towards the country's national inventory, these measures are nevertheless important to support broader climate action causes.

- **Purchasing fruits and vegetables with aesthetic flaws.** It is estimated that around 25-30% of fruits and vegetables do not make it to grocery stores as aesthetic standards of the produce are not met, even though the products are fully fit for consumption. With signals of increased consumer receptiveness to aesthetically flawed produce, groceries are likely to increase acceptance of these fruits, avoiding food waste in the supply chain.

The actions above summarise a range of consumer actions which can support individuals to reduce their climate footprint along key emission sectors. Beyond these areas, consumers can orientate towards universally purchasing green products and services, supporting brands which show strong commitments to climate action, and also ensuring environmental sustainability in financial products or investments made. Decisions where an individual's investments are made can also have a large impact, such as choosing certified green financial products, avoiding stocks of companies which harm the environment, and opting into green options for pension savings, as some examples.

Civil society involvement to champion the green agenda

Aside from their capacity as consumers, citizens play a key role in championing the green agenda as members of the civil society.

- **A voice for change.** Through participation in various aspects of community, the voices of citizens are key to advocate for change and the adoption of environmentally friendly policies at the local, regional, and federal level. Mainstreaming environmental sustainability in the public debate and dialogue will be key, with bipartisanship given the criticality of the topic in securing Malaysia's future. Citizens also have a key role to play in holding both corporates and leaders in Malaysia to account in delivering against climate promises and promoting environmental sustainability, for the betterment of Malaysia.

- **Green volunteerism.** Participating directly in green activities and green volunteerism can increase awareness of the environment and provide first-hand experiences for people to connect with nature. For example, this may include tree planting campaigns or environmental clean-up projects or championing specific socio-environmental topics of passion and interest.

- **Community influence.** Large gaps still exist amongst the general public on the real threat of climate change, and the urgent actions required within a limited window of time to alter the current unsustainable trajectory of global warming. Through influence of peers and the communities we live in, greater awareness and social pressures to act can be a key catalyst for large-scale behavioural change needed to achieve Net Zero in the country.

130. The Do Nation Enterprise (n.d). Eat seasonal

Enabling shifts in consumer behaviour – the "how"

Given the large potential of behavioural change in shifting the climate trajectory, establishing the right enablers to influence and nudge the decision making of consumers towards environmentally friendly options are crucial. New insights across the science of human of behaviour have transformed the understanding of what motivates people. The decision-making process of consumers is strongly influenced by the contextual environment and the way choices are presented. To drive change, innovative solutions are required to meet consumers where they are, using the power of emotional appeals, social incentives, choice architecture, and others are required.

Shifting consumer behaviours at scale will not be trivial, with the need to reverse ingrained patterns of natural resource consumption that are pervasive across modern, consumption-driven economies. The adoption of a full range of enablers informed by the latest behavioural science will be required, along with six key dimensions[131] :

- **Information provision:** Providing information to improve knowledge-based decision making of consumers, where information and education leads to awareness and attitude change, which translates to behaviour change.
- **Economic incentives:** Introducing economic incentives (e.g., subsidies, payments, rewards) or disincentives (e.g., taxes, fines), aligned to extrinsic motivation models where behaviours are optimised in response to external motivations such as financial "carrots and sticks".
- **Rules and regulations:** Setting boundary conditions which limits the range of choices available to the consumer, through the enforcement of law.
- **Emotional appeals:** Messaging or other interventions which appeal to specific positive or negative emotions and feelings (e.g., joy, pride, guilt, compassion, empathy, etc.) which influence consumer decision-making.
- **Social incentives:** Leveraging social pressures to provide cues to consumers based on influence of social groups onto individual members within the group, to nudge conformity when behaviour deviates from expected norms.
- **Choice architecture:** Optimising how choices are framed and presented to consumers with the goal of guiding consumers towards desired behaviours.

Information provision

Information provision can be enhanced to provide consumers with a better understanding of the case for change (why), their importance as part of this change (what), and decision-making support to enable consumers to make choices aligned to the change they want to bring (how). This includes:

- **Increased awareness on climate change and the role consumers play in the solution**

  Enhancing informational awareness of all Malaysians on the importance and urgency of climate action in response to climate change and the major causes of climate change will be critical. Information provided through education, media, and other channels will need to highlight the size of the climate challenge and how consumers can play a part in contributing to the solution in everyday choices and decisions they make. The increased awareness will also enable greater understanding, buy-in, and support of Malaysians for climate-related policies established by government.

118. Centre For Behaviour and the Environment (2018). Climate Change Needs Behavior Change Making the Case for Behavioral Solutions to Reduce Global Warming

- **Decision-making support with eco-labelling**

  Eco-labelling provides consumers with information at the point of purchase to enable informed environmentally friendly decision-making. Scaling up existing eco-labelling schemes such as SIRIM's eco-labelling scheme will be critical both from the number of products covered (around 100 products at end of 2020) and the number of applying and green certified companies (around 150 companies at end of 2020). In addition, the MyHIJAU mark which is the official green recognition scheme by the government that ensures compliance against various green product certifications, can also be scaled more broadly and mainstreamed with widespread consumer awareness.

  Besides green product labelling, energy efficiency labelling has been adopted in Malaysia for key electrical appliances, such as with the 5-star energy rating. Building on these efforts by increasing product coverage, reviewing rating scales, and enhancing information provision which resonates with consumers (e.g., translating energy savings to cost savings) are potential priorities which can be pursued. Other information provided during purchase, such as the optimal air-conditioner temperature to maximise energy saving, can also be provided at point of purchase of product.

- **Corporate disclosures and green taxonomies**

  Besides enhancing information provision at a product level, consumers can be provided with better information on companies in order to inform their green choices. Consumers face challenges in differentiating between the environmental sustainability of company operations due to two main reasons. Each company reports on environmental metrics in a non standardised way by providing different extent of information (i.e., no common disclosures) and based on different definitions of what is green or environmentally sustainable (i.e., no common taxonomy) with a high degree of subjectivity.

  Consumers can be supported to make decisions between companies and brands with standardised disclosure requirements, where companies are mandated to report the same level of key information for comparability, and based on clear definitions or a common taxonomy. These steps will be critical to reduce corporate "greenwashing" where the perception of environmental sustainability is marketed by corporates without the corresponding underlying supporting evidence. Misleading information from "greenwashing" leads to suboptimal decision-making from well-intentioned consumers, and hence will need to be addressed by well-defined and verifiable corporate disclosures and green taxonomies.

- **Real time technology-driven feedback loops**

  The rise of technology solutions is enabling consumers to obtain higher frequency or even real-time feedback loops of information which can be used to shape behaviour more effectively as consumers instantaneously see the impact of their decisions. Examples include home energy monitors which provide real time information on the energy usage of individual appliances and suggested personalised recommendations on immediate actions which can be taken to enhance energy efficiency.

  Other examples include real-time feedback on eco-driving behaviour. Innovative applications, such as Toyota's "A Glass of Water" application mimics a glass of water placed on a car's dashboard and challenges users to not spill a drop. This provides drivers with real-time feedback loops on non eco-driving behaviour, such as from accelerating too fast or braking too suddenly which results in the spilling of water. This is estimated to support driver to lower their fuel consumption by 10 percent, saving costs and reducing emissions per trip.

Rules and regulations

Rules and regulations, supported by credible enforcement, are key measures which can ensure certainty of key environmentally friendly consumer behaviour. This mechanism can be used to strictly prevent consumer decisions which can create large negative externalities on the environment, when there are clear superior options available. These include phasing out the most emission-intensive choices along key decision points, especially when superior alternative options which are affordable and accessible by consumers already exist.

- **Energy and transport consumption related rules and regulation for consumers**

  To reduce household energy intensity, mandatory minimum efficiency performance standards (MEPS) have been established for key household electrical appliances. Building on this strong starting foundation, the product coverage of MEPS can be extended and ratchet up of MEPS over time to phase out the highest energy intensity appliances, when equally affordable and more sustainable options become mainstream in the market.

  Beyond electrical equipment, MEPS can also be adopted in the transport sector, setting minimum standards for fuel economy for vehicles sold in the country as practiced in many countries globally. Other rules and regulations in the long-term which have been committed to include city or country bans on ICE sales, which would be adopted once alternatives such as electric vehicles become both a cleaner and more affordable option for consumers.

  Long-term roadmaps for MEPS are also important to enhance the readiness of market participants for tightening of rules and regulations over time. In addition to ensuring new product sales have lowered emissions, potential regulations to phase out units in operations which are of high emissions intensity, can also be considered.

- **Waste management related rules and regulations for consumers**

  Rules and regulations to reduce waste and to reduce costs of effective waste management have been established and can be enhanced over time. This includes enhancements in the separation biowaste, which is the largest cause of emissions in landfills.

  Other rules and regulations can support the 3R process such as bans on single use plastics for certain applications, such as with the banning of plastic straws in Selangor and all three Federal Territories states and the "No Plastic Bag" campaign across all Malaysia states[132 133]. Other rules include for groceries to provide specific sections which sell non-aesthetically conforming fruits and vegetables can reduce food waste. Scaling these efforts across geographies and applications, as well as ensuring strong environmentally sustainable alternatives are in place for consumers will be key to the further success of these efforts.

Economic incentives

Motivated by financial objectives, economic incentives can be used to tilt consumer decision-making towards green economy choices. A key role of economic incentives is to price in the long-term the externality value of consumer choices, which include both positive and negative externalities, to ensure product or service pricing reflects the "true cost" of the product.

- **Encouraging early adoption of green technology prior to inflection points**

  Incentives to encourage consumer adoption of green technology is key to improve the affordability gap of these technologies, to generate scale required to attract green technology producers, and to overcome inherent risk hurdles which may be associated with consumer adoption. Early adoption incentives, which reduce over time as green technologies become more competitive, include the areas of low carbon mobility, household renewable energy production, and other emerging technologies such as smart devices and smart homes.

132. Chen, H.L., Nath, T.K., Chong, S. et al. (2021). The plastic waste problem in Malaysia: management, recycling and disposal of local and global plastic waste
133. The Malay Mail (2020). All state govts back implementation of 'No Plastic Bag' campaign, says Environment and Water Ministry

- **Incentives to overcome the inertia of replacement for emission-intensive products**

  Incentives can also support loss aversion barriers or inertia for individuals to switch out from high emission products for higher efficiency and lower emission products even though they are financially positive for the consumer. Examples include financial incentives such as rebates to trade-in old electrical equipment or low fuel economy vehicles, or to subsidise the cost of replacement.

- **Internalising negative externalities of emissions with taxes or levies**

  Another key economic incentive to shift towards green products and services will be to price in the cost of negative externalities of carbon across products and services. Carbon taxes applied at a national level for certain key categories can support this in the medium term, but individual levies in the short term can also support this outcome. This includes levies on luxury vehicles with high emission footprints, products which have high waste management costs such as non bio-degradable products, and disposable products which contribute to waste by design.

- **Reducing opportunity cost of green activities and behaviours**

  Reducing costs of green activities also represents a key economic incentive to nudge consumer behaviour. Based on rational choice theory, the amount of effort spent by an individual on a particular environmentally sustainable act is the sum of the perceived benefit and perceived value of the incentive minus the perceived effort. Hence, reducing the perceived effort by reducing the cost of green activities also represents a key economic incentive. This includes reducing the costs of recycling[134] by providing more collection points to reduce travelling distance or to have recycling collection from homes as an example. Other activities include reducing the opportunity costs of green volunteerism, such as with corporates allowing employees to participate in green volunteerism for a certain number of days in a year as part of the company's corporate social responsibility efforts.

Emotional appeals

In studies of psychology and neuroscience, it has been shown that when people evaluate products or brands, their limbic systems and parts of the brain responsible for feelings, memory, and value judgments are highly active, while much of the brain's centres for analysis are not. Appealing strongly to specific emotions and feelings can engage the powerful centres of the brain that are often responsible for decisions[135] [136] [137] [138].

- **Visual and immersive experiences on the impact of climate change**

  The concept of climate change can be so overwhelming and abstract that people struggle to comprehend the direct impact it has on their daily lives. Rising sea levels, glacier erosion, forest diebacks, and others may seem like highly conceptual ideas that happen slowly, in distant parts of the globe. People often struggle to see how climate change will affect their lives in negative ways or the direct impact it has on their daily lives. Moreover, people often fail to build emotional connections or empathise with complex data on the science, data, facts, and figures of climate change.

  Visual and immersive experiences, aided by technology, can support this change. Experiments with immersive climate change experiences with virtual reality and augmented reality translate climate change into a real experience for consumers, enabling the messages to resonate strongly[139]. This also enhances the reach of climate messages, with people of all technical skill levels understanding why climate changes matters and how it will directly impact their lives.

134. Edie Newsroom (2002). Financial incentives to encourage recycling within the community
135. Matthes, Wonneberger, Schmuck (2013). Consumers' green involvement and the persuasive effects of emotional versus functional ads
136. Warwick Business School (2019). How do you persuade people to buy sustainable goods?
137. Harvard Business Review (2019). The Elusive Green Consumer
138. Camp, J., 2012. Decisions are emotional, not logical
139. Medium (2020). How can Immersive Technology Help in the Fight Against Global Climate Change?

- **Optimising emotional appeals based on the latest behavioural science**

  To enhance effectiveness of messaging to drive climate change, findings from the latest behavioural sciences can be used to enhance the effectiveness of climate action messaging:

  Resonating with feelings of pride during green purchases

  Recent behavioural research shows that reminding consumers of the pride they felt after a previous sustainable purchase was significantly more likely to drive positive behaviour compared to if consumers were made to feel guilty over a past environmentally-damaging choice. This is because consumers want to replicate the same positive feelings of pride[140] . Messages of encouragement that show people can contribute positively to climate change can build on the emotion of pride, nudging consumer behaviour towards green choices.

  Leveraging mixed appeals and emotions to resonate with consumers

  Based on behavioural studies, green product advertisements point towards the effectiveness of combined emotional and functional messaging in affecting brand attitudes of a wider audience, compared to functional advertisements which only impacts brand perception when existing green product attitudes are already high[141] . Other research shows that green advertisements featuring mixed emotions of happiness and sadness enhances intentions of consumers to purchase pro-environmental luxury products, over single emotional appeals such as happiness alone[142].

  Balancing the level of negative emotion appeals to optimise consumer responses

  Negative emotions such as guilt is also a powerful emotion which can shape consumer behaviour, but must be used selectively in order to nudge the right consumer behaviour. In one experiment[143] , when accountability was subtly highlighted, twice the number of participants made green choices compared to when explicit guilt appeal was adopted, calling out the negative behaviour of the individual. With explicit guilt appeals, individuals resort to becoming angry, upset, or irritable, reducing their propensity to select green options. This is in line with an abundance of other research confirming that activating moderate amounts of guilt, sadness, or fear, is more effective than trying to elicit a strong reaction.

Social incentives

Social incentives and norms can thus be powerful motivators for behaviour. They can provide cues for members of a group on how to behave, and they also add considerable pressure to change behaviour and conform when behaviour deviates from expected norms. Moreover, as individuals care about their reputation and how it compares to the status of others within a group, positive social pressure on environmental sustainability can be a large driver of large-scale change.

- **Leveraging personalised normative feedback (PNF) techniques**

  Personalised normative feedback is an approach that is used to provide individuals with information about themselves as well as their peers in an attempt to highlight how an individual or group's behaviour deviates from the norm. For example, making homeowners with significantly higher energy consumption compared to neighbours aware of the fact pressures users to reduce their consumption and emissions. Creating norms also encourages consumer adoption, by pointing to the environmentally friendly actions that the majority is taking in order to pressure the minority of laggards into conforming.

140. Feelings of guilt and pride: Consumer intention to buy LED lights Moghavvemi S, Jaafar NI, Sulaiman A, Parveen Tajudeen F (2020)
141. Consumers' green involvement and the persuasive effects of emotional versus functional ads – Matthes J, Wonneberger A, Schmuck D (2013)
142. Nallaperuma, Kaushalya & Septianto, Felix & Bandyopadhyay, Argho. (2021). Mixed emotional appeal enhances advertising effectiveness of pro-environmental luxury brands: the mediating role of cognitive flexibility.
143. The Elusive Green Consumer – White K, Hardisty D, Habib R (2019)

- **Mainstreaming environmental sustainability into social conversation**

  Platforms to discuss matters on environmental sustainability for various population segments such as youths on channels which resonate with various types of audience can be useful in building up social momentum in mainstreaming environmental sustainability into social conversation. The mainstreaming of these conversations is critical to propagate information about the importance of behavioural change, and to build positive peer pressure to conform to environmental practices being practiced by peers. Leveraging platforms such as social media to reach a broader audience on environmental sustainability topics are critical to change behaviours but also to solicit feedback on potential barriers which could be inhibiting green behaviours.

Choice architecture

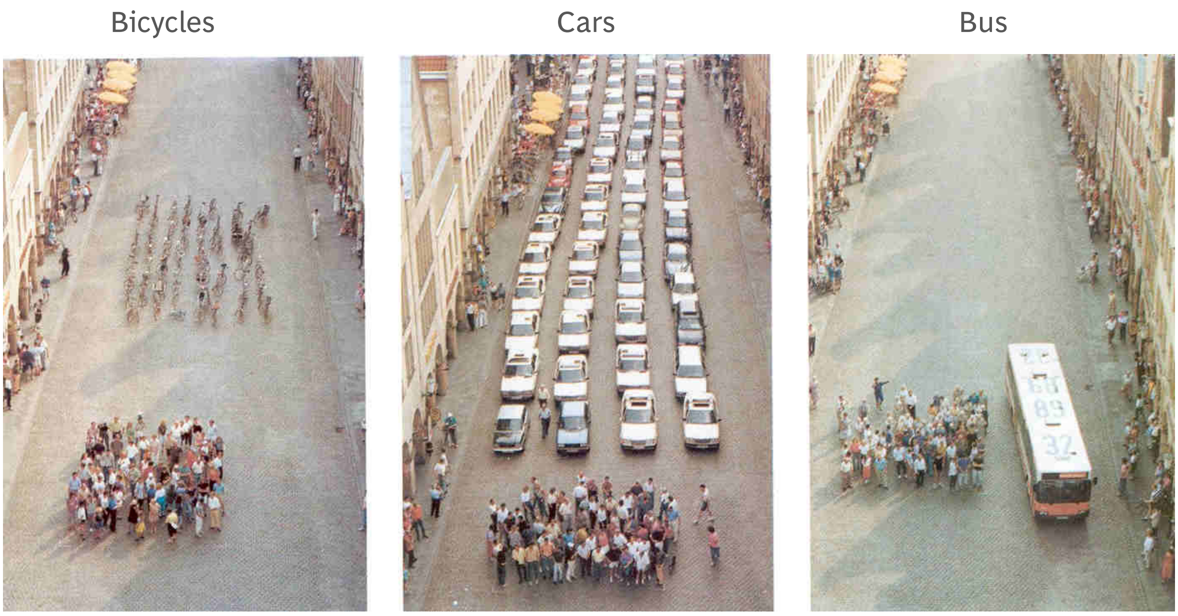
Choice architecture refers to the shaping of the context or environment in which choices are being made in order to increase the probability of making socially optimal choices. Solutions that employ thoughtful choice architecture will simplify what we are asked to do, reduce the apparent number of choices we have, and frame decisions in a way that guide us towards desired behaviour. Some examples of choice architecture used to promote environmentally sustainable behaviour include:

- **Simplification and framing of information**

  The simplification and framing of information denotes a deliberate change in how information conveyed to decision-makers is presented. Simplification is targeted at conveying information to decision-makers in the most intelligible way and in an amount which makes its processing possible. Framing is the conscious phrasing of information that activates certain values and attitudes of individuals. One such example is designing eco-labels based on consumer behavioural science, where information is distilled and simplified to what is truly important for the consumer and to nudge behaviour in the right direction. Visual cues can also help to frame environmentally sustainable messages strongly which are simple and resonate with consumers, such as the visual impact of private mobility compared to public and alternative transport.

Figure 108: Driving behavioural change with simplification and framing of information

Visual representation on space required for 60 commuters – to encourage public and alternative transportation options



Source: Muenster Planning Office, August 2001

- **The role of defaults in promoting environmental sustainability**

  The setting of defaults is one of the most powerful nudging tools to shift consumer behaviour. This rests on the behavioural science of default effects, which refers to the human tendency to choose an option that is automatically selected rather than choosing an alternate option, even if the effort to make that change is negligible. Setting the more environmentally friendly option as the default significantly increases adoption of that behaviour.

  There are numerous examples of defaults which are relevant to Malaysia and can be scaled to enhance the size of impact. Examples of defaults include using digital documents over physical documents, optimising printer settings for double-sided printing, restaurants not providing plastic straws unless explicitly asked for, setting electronics defaults to be on battery-saving mode, and others. Setting these default choices to promote environmental friendliness across key consumer touchpoints such as retail, restaurants, hotels, and others can support strong positive behaviour shifts.

- **Changes to the physical environment context**

  Other choice architecture behavioural nudges include changes in physical environments, which sets the context for consumer decisions to be made. For example, experiments of reducing the size of the plate at buffets can have an impact of up to 20% in food waste reduction[126] . Others include the increasing of visibility to environmentally sustainable foods such as placing them at prime locations in supermarkets and in canteens to nudge purchases. Other examples include slightly increasing the effort to access less sustainable options compared to green options. In toilet designs across airports, certain countries have required hand dryers to be located close to the exit as a more convenient option compared to paper towels[145] , significantly reducing the consumption of paper towels as the less environmentally friendly option compared to when they were placed side-by-side.

The measures outlined above are non-exhaustive and a large range of options exist for communities, corporates, and governments to set the right enabler foundations to nudge consumer choices towards environmentally friendly options. Enablers should also be enhanced over time based on the latest consumer behavioural science to increase the effectiveness of efforts and likelihood of target outcomes of environmental sustainability being achieved.

In addition, consumer engagement on specific topics are also critical to understand potential barriers to the take-up of green options. For example, detailed engagement of consumers pointed towards charging infrastructure access as well as health and safety risks as some non-price barriers prohibiting electric vehicle take-up. Pinpointing barriers to consumer adoption can increase the targeting of measures to enable green behaviours.

Overall, the potential impact of a change in consumer behaviours in materially reducing GHG emissions should not be underestimated. Moreover, levers to shift consumer behaviours, such as the changing of defaults or creating social norms are some of the lowest abatement cost measures available to achieve GHG emission reduction. Awareness of these solutions and rapid scale-up of these solutions at the local, regional, and national level will be required to support the country on its Net Zero journey.

144. 'Nudging' hotel guests to reduce food waste as a win-win environmental measure – Kallbekken S, Sælen Håkon (2013)
145. Sustainable Brands (2018) Sustainability by Default: Making Doing Good the Easiest Choice

Priority #10:

Public and private sector climate leadership

Overview

Climate transition and the accelerated move towards the green economy will have tremendous economic implications for corporates and countries. Much like the digital revolution, green economy megatrends will have widespread and far-reaching impact across all sectors and aspects of the economy. Corporates and countries will be faced with both challenges and opportunities, and the timeliness and decisiveness of response will separate the leaders from the laggards in transition.

Laggards in climate transition are likely to face significant financial pressures, especially for those concentrated in sectors with high physical or transition risks. Challenges are likely to emerge in the form of constraints in capital access, decline in valuations, loss of demand, and restricted export market access due to environmental factors. Country laggards will face decline in sectoral growth, reduced FDI flows, and loss of trade competitiveness which can affect jobs and household incomes in the country.

Leaders on the other hand have an opportunity to leapfrog as new sectors grow and new sources of competitive advantage emerge in green transition. Early mover advantage into green economy sectors can position both corporates and countries to capture benefits from rapidly increasing demand for green products and services. Corporates with progressive green agendas are increasingly being rewarded with valuation premiums in markets. Similarly, countries which take active steps on climate transition are expected to benefit from enhanced resilience associated with green future-proof sectors of the economy.

Public sector climate leadership

The widespread and large-scale impact of climate transition demands timely and orchestrated actions across public sector stakeholders at both the federal and state level. Building on existing efforts, the government can *safeguard*, *catalyse*, and *lead* the country through climate transition to realise large socioeconomic benefits for the country.

Safeguard

Safeguard represents a set of actions which the government can take to protect against key environmental and socioeconomic risks the country will face related to climate transition and climate change. Under this theme, the government has a key role to do no harm to the environment through its policies and public spending, strengthen environmental legislation and enforcement, mitigate material transition risks in key sectors, and ensure timely adaptation and resilience in response to growing physical climate risks.

- **Ensure policies or public expenditure do no harm to the environment**

  To support a progressive climate agenda, the government will need to strengthen safeguards to ensure that policies and public expenditure are anchored on bringing no harm to the environment. Unintended adverse environmental side effects of policies or public expenditure risk the reversal of years of good work in environmental protection and climate action in the country.

  Without strong environmental safeguards, large infrastructure projects have high risks of causing environmental damage. Ensuring these projects avoid, or at the minimum strongly mitigate impact to forest lands, ecological corridors, biodiversity, water and soil quality, and other environmental factors will be critical. Damages to natural assets, such as the clearing of mangrove forests for infrastructure development, risk the loss to rich biodiverse habitats and key natural adaptation and resilience barriers for flood prevention.

  Safeguards will also be needed for trade or industrial policies with large potential environmental impact, which may regress Malaysia on its climate agenda. This includes policies on mining and mineral development, high-emission manufacturing sectors, waste imports and processing.

Well intentioned fiscal incentives may also lead to hidden environmental costs without the right safeguards. Incentives to reduce costs of personal vehicle ownership may counteract efforts to promote emission-reducing shared mobility or public transport modal share increases. Agriculture policies to subsidise synthetic fertilisers may increase nitrous oxide emissions, and disincentivise other more environmentally-friendly mechanisms of crop nutrient provision. Blanket transport fuel subsidies may also have the unintended effect of delaying transitions to low carbon mobility, especially where low carbon alternatives are already competitive relative to incumbent vehicles reliant on fossil fuels. Enhancing these policy measures to ensure they do no harm will be important to jointly achieve socioeconomic objectives of these measures without adversely impacting environmental outcomes.

These efforts will build and complement the current government efforts on SDG-aligned and green budgeting which was launched in the Budget 2022 and contribute to national aspirations of environmental sustainability.

- **Strengthening legislation and enforcement of key environmental safeguards**

Besides ensuring policies do no harm, reviewing and enacting strengthened environmental legislation represents key safeguards for the climate and environment. Examples include tightening environmental laws for waste, including industrial pollution which has a large impact on the environment and functioning of water purification systems. The strengthening of foundational legislation, such as the Environmental Quality Act of 1974 to enhance waste and pollution reduction, holistic impact assessment protocols, and strengthened deterrents and penalties against offenders will be critical. Legislation for extended producer responsibilities for the recycling and end-of-life waste management for key products can also be considered to promote enhanced sustainability and progressive climate action.

Efforts to conserve and protect the country's unique natural assets including both forests and oceans will also be critical. This includes strengthening federal and state cooperation to protect against degazetting of forest reserves, enhancing forest restoration, eradicating illegal logging as well as protecting wildlife habitat and forest continuity. These and other natural assets along coastlines and in oceans play significant roles not only in climate mitigation but climate resilience and adaptation for the country.

Damages to natural assets, once incurred, may be difficult to reverse and extra focus will need to be placed on preventive safeguards in these areas. Preventing climate and environmental damage will also lower the future costs of rehabilitation and restoration, increasing the economic incentives for strong safeguards.

- **Mitigate material transition risks in key sectors**

Malaysia is expected to face key transition risks over the coming years with an accelerated shift towards the green economy. Currently, around 20% of Malaysia's GDP is concentrated in sectors which are expected to face strong environmental scrutiny and high transition risks. Moreover, as a key exporting nation, Malaysia will also face a test of its trade competitiveness with the growing likelihood of carbon border adjustment (CBAM) implementation, beginning with the European Union in 2023.

Given these risks, it is important that the government takes early measures to facilitate the timely transition of these sectors to safeguard the future resilience of the economy. This includes enhancing awareness of transition risks among corporates in the sector, issuing directives which require decarbonisation and green transition of players in the sector, and providing financing and other support for transition. In addition, mandates for domestic players to adopt widely accepted carbon accounting will be critical to ensure continued market access to key export partners.

- **Ensure timely adaptation and resilience actions in response to physical climate risks**

  Even with the best global efforts on climate mitigation, physical climate risks are expected to increase, driven by global warming effects already set in motion. Malaysia will need to ensure adaptation and resilience against the impacts of climate change, such as the rise in sea levels, increased frequency and intensity of weather extremes, and a rise in mean temperatures. The threat of climate disasters such as floods, droughts, heatwaves, and others will also grow over time.

  A comprehensive mapping out of key physical risk hotspots across the country will be critical to inform prioritisation of climate adaptation and resilience efforts. Long-term planning and budgetary allocations to implement these prioritised climate adaptation and resilience projects or initiatives will be critical. Early investments into these areas represent prudent steps to prevent costly future damages, and to safeguard both lives and livelihoods of populations most exposed to adverse climate-related effects.

- **Social protection safeguards in transition**

  Without the right social protection safeguards, the economic transition towards the green economy can be highly disruptive to the workforce in declining industries. The role of the government to ensure equitable workforce transition is critical. This includes understanding of key structural workforce shifts due to climate transition, planning and early action on reskilling and redeployment in the workforce from declining brown industries to growing green industries, and providing social protection in the interim to households during periods of job transition.

  Social safeguards will also be needed to protect vulnerable people groups in the country. For example, the government will need to uphold the rights of indigenous communities and eradicate exploitative practices conducted under the disguise of climate action. Besides indigenous communities, low income households may be disproportionately affected by climate transition, and will also require social protection safeguards in transition.

Catalyse

Catalyse represents a set of actions where the government establishes the required foundations and spurs private sector action to realise socioeconomic opportunities of climate transition, strengthening the domestic economy in the process. The government has various levers at its disposal to catalyse positive climate action including establishing national policies and plans, enacting legislation and regulations, as well as channelling government spending or financing.

The role of government in this area will need to be strategic and selective to deliver maximum impact, to ensure sustainable public finances and to avoid crowding-out of the private sector.

- **Set progressive Net Zero 2050 ambition with clear roadmap and milestones**

  Efforts will be needed to follow-up on progressive Net Zero 2050 ambitions with clear roadmaps and milestones for carbon emissions reduction. This includes updating Nationally Determined Contributions (NDCs) for 2030 to reflect the required path needed to achieve the ambition of Net Zero by 2050. Moreover, 5-year emission reduction targets should be established to ensure transparency on how Malaysia is tracking towards its long-term climate ambitions against its planned pathway. This will inform timely interventions to course correct, bringing confidence to the public, investors, and the international community on the delivery credibility and strong commitment to the Net Zero 2050 target.

- **Cascade level of ambition into clear sectoral decarbonisation roadmaps**

  Strengthen clarity on the pathway by cascading overall Net Zero 2050 ambitions into clear sectoral decarbonisation roadmaps across key GHG emissions and removal sectors. These roadmaps will need to focus on priority decarbonisation levers for sector stakeholders to pursue, informed by technical feasibility and commercial viability as well as suitability to the Malaysia-specific context. The combination of levers identified should support GHG emission reduction required to deliver on sectoral decarbonisation targets, which reflect the ambition of national decarbonisation targets. Enablers to sectoral decarbonisation will also need to be comprehensively identified, from policies and regulations to key infrastructure and enablers required on funding, financing, and human capital.

- **Establish coherent and progressive policies and regulations**

  The cross-cutting nature of climate transition will require multiple sectoral policies and regulations, under the jurisdiction of various ministries, to coherently support the delivery of key levers required for decarbonisation. For example, to ensure strong EV take-up, various sectoral policies will need to be deeply coordinated for coherence. This includes industrial policies (e.g., build-up of local EV manufacturing and supply chains), transport policies (e.g., charging infrastructure network planning, EV attribute standards), power sector policies (e.g., EV tariffs, local grid upgrades to accommodate charging infrastructure), and waste policies (e.g., second-life use, recycling and responsible waste management) which will be collectively needed to enable EV take-up at scale. Moreover, various fiscal demand-side and supply-side incentives, investment accelerators, and human capital enablers will need to support and align with these policies.

  The lack of coherence across policies and regulations will result in the full value capture of the lever not being realised. For example, without timely development of domestic EV manufacturing and supply chain capabilities, adopting EV uptake will have lower value capture and spillover effects to domestic GDP and job benefits. Sustained fuel subsidies as another example has the potential to be counterproductive to low carbon mobility efforts, highlighting the importance of coherent policies aligned to priority national ambitions.

- **Invest to build-up catalytic green infrastructure and enablers**

  Bridging permanent market gaps of green public goods and broad-based enablers provision

  The government has a key role to play in bridging permanent market gaps that inhibit large socioeconomic benefits from being realised. One such example is public or social goods, which deliver large socioeconomic benefits but may be structurally under-provided due to the low attractiveness of financial returns. The government has a key long-term role to play in providing green public goods, such as the build-up of public transport infrastructure to reduce emissions and achieve benefits of reduced congestion, affordable mobility, and others.

  In addition, the public sector has a key role in supporting under-provided enablers by the private sector required to catalyse green growth. This includes investments for workforce reskilling and human capital development, early-stage research and development as well as innovation funding and ecosystem development.

  For example, governments are in the unique position of coordinating at-scale reskilling and human capital development programs oriented to future-proof green economy sectors. Embedding skills of the future into education and training vocational education and training (TVET) programs will enhance graduate employability and increase the competitive advantage of the country in attracting green investments into the country. Public education can be shaped to inculcate environmental consciousness and environmentally-friendly habits to reduce the climate footprint of citizens over their lifetime. Government funded climate innovation funds can fill market gaps required to scale-up of promising technology and innovations, aligned to the needs of the country. This can be further supported by enablers such as the democratisation of climate data and knowledge to facilitate widespread problem solving and entrepreneurship on the country's most pertinent climate challenges.

Bridging interim market gaps to catalyse future private sector involvement

In other areas, the government has a key role to play in bridging interim market gaps where private sector infrastructure or actions are disincentivised by the lack of economies of scale. For example, this includes government-led development of initial EV charging infrastructure build-out required to overcome range anxiety of consumers and to spur early waves of EV adoption. However, as economies of scale are reached, the improved financial attractiveness will reduce the role of government investments through private-public partnerships and eventually fully private sector-led infrastructure growth.

The reservations of financial institutions for lending support to green projects using emerging technologies due to lending risks or lack of technology familiarity, can lead to low availability of capital or high premiums which do not encourage the adoption of these technologies. The government also plays a key role to bridge this interim market gap, through government-guaranteed finance or government-funded green revolving funds to reduce barriers to lending by private sector institutions. This will complement the strong existing government enablers established through the Green Technology Financing Schemes (GTFS) 1.0 – 3.0.

The government also has a key interim role to play in green infrastructure megaprojects where the government has the ability to raise financing at a lower cost of capital compared to the private sector due to sovereign credit ratings and the lowered regulatory risk. In this area, government-led green infrastructure development, followed by ownership transfers to the private sector during the more stable operation and maintenance stages, can reduce the costs of green infrastructure.

- **Adopt carbon pricing to price-in negative externalities of carbon**

  Through fiscal levers, the government can support the pricing-in of negative externalities to better align economic interests with overall societal impact. One key example is the establishment of carbon pricing, either through carbon taxes or emission trading schemes. Carbon pricing schemes will need to be designed for sufficient coverage and to encourage carbon price points which will make a material difference in the reduction of the country's emissions. These schemes will also need to be equitable, with clarity on how carbon pricing proceeds may be used, distributional effects of carbon prices, and the implications on country competitiveness.

  The government also has a key role to ensure sufficient safeguards are in place for both voluntary and compliance carbon markets by meeting standards which ensure total societal impact from carbon market transactions. Given the interdependency with other carbon pricing regimes through border adjustment mechanism linkages, it is also critical that the government ensures compatibility with international carbon pricing schemes. The topic of carbon pricing is covered in depth under the *price carbon section* of this report.

- **Secure equitable international climate funding and finance and multilateral support**

  The principle of the "common but differentiated responsibilities and respective capabilities" is critical to ensure the global equitability of climate transition paths. As a developing country, it is critical that Malaysia secures multilateral climate funding and financing support to enable its ambitious climate transition towards Net Zero 2050. The government plays a key role in demanding support not only from climate funding and financing, but also capacity and capability building as well as knowledge and technology transfers in multilateral climate negotiations.

  The secured climate finance and funding will need to be channelled effectively to high impact areas to support the country's decarbonisation path, with international cooperation established for timely technology and knowledge transfer to localise the development of key climate technologies. Discussions on equitable multilateral climate support should be anchored on Malaysia's fair share, where taking a higher level of climate ambition will need to be equitably supported by developed nations in fulfilment of their international climate obligations and responsibilities.

Case Study 7 | Malaysia's fair share of emission reduction – a perspective

The concept of fair share is based on Article 4.3 of the Paris Agreement which states that individual countries (parties) should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof.

Estimating the fair share for a country is an attempt to quantify what would be an equitable contribution of a country towards the global effort in reducing greenhouse gases. There are no agreed guidelines on what would constitute a fair share, given the subjectivity of interpretation of climate equitability.

As one reference point to frame the discussion on fair share, the Climate Equity Reference Calculator by the Stockholm Environment Institute estimates a range of potential values for a country's fair share, based on various input dimensions capturing the sensitivity to subjective interpretations of "common but differentiated responsibilities" along various dimensions. There are four major input variables which serve as inputs in the calculator:

1. **Global mitigation pathway** refers to a global emissions trajectory that is designed to, over time, keep the climate system within a given carbon budget, or to keep temperature increases below a certain limit. The more stringent the budgetary or temperature limit, the higher the level of global ambition. There are three scenarios in the calculator – a 1.5^{0}C scenario with a precautionary approach to negative emission technologies such as bioenergy with carbon capture and storage (BECCS), a standard 1.5^{0}C pathway scenario without restrictions on emission technologies, and a standard 2^{0}C scenario. The second scenario was adopted for the estimations, in line with the goal to limit global warming to 1.5^{0}C to avoid irreversible climate change effects.

2. **Historical responsibility** is related to the principle that a country's contribution to the global mobilisation should be proportional to its responsibility for the emergency. The dimension aims to capture the measure of contribution of countries towards the climate problem, as defined by the sum of all cumulative emissions from a certain start date of responsibility. Three start dates are simulated – 1850 (pre-industrial), 1950 (pre-economic boom), 1990 (year of the drafting the UN Framework Convention on Climate Change).

3. **Capacity** is related to the principle that a country’s contribution to the global emergency mobilisation should be proportional to its capacity to act. Three definitions are simulated – one where a development threshold is not considered, one with a USD 7,500 PPP per person per year development threshold aligned to a reasonable global poverty line estimates, and one with the identical development threshold estimate and with progressivity factors (higher income countries contribute more, scaling proportionally based on income once the development threshold is exceeded).

4. **Weighting between the dimensions of historical responsibility and capacity** is another key dimension in the calculation of the fair share. For example, whether both measures should count in equal contribution, or whether there should be a skew towards one of the dimensions as the primary factor to guide the division of fair share responsibilities. A 50:50 weightage is used between historical responsibility and capacity in the absence of other reference parameter guidance pointing towards other than a non-equal split.

Note: Refer to source for full technical notes
Source: Kemp-Benedict, Eric, Christian Holz, Paul Baer, Tom Athanaisou, and Sivan Kartha (2019) *The Climate Equity Reference Calculator*. Berkeley and Somerville: Climate Equity Reference Project (EcoEquity and Stockholm Environment Institute)

Figure 109: Overview of fair share calculation methodology for Malaysia

Estimates for Malaysia's fair share of GHG reductions range between 0.49% - 0.77% of total global emission reductions

Historical Responsibility

- a Based on cumulative emissions since 1850
- b Based on cumulative emissions since 1950
- c Based on cumulative emissions since 1990

Capability to Act

- 1 No development threshold
- 2 $7,500 PPP[5] per person development threshold[1]
- 3 $7,500 PPP[5] per person[1] per development threshold and greater contributions from high income countries

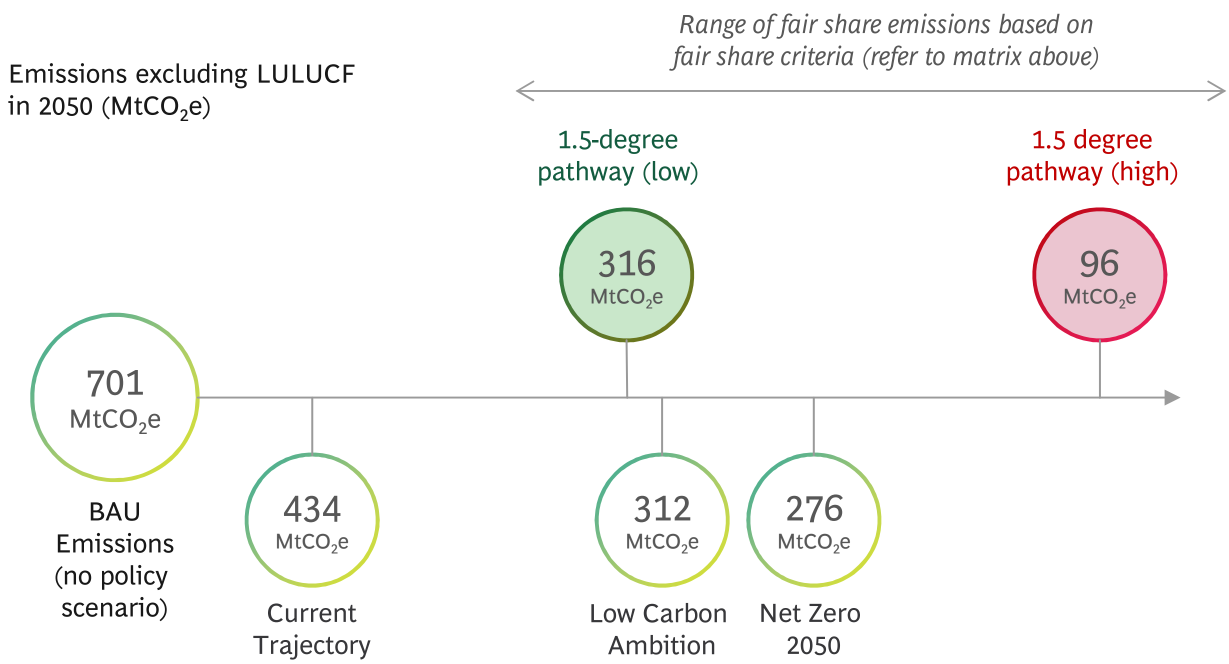
Malaysia's fair share of global GHG reductions for 1.5⁰C pathway for 2050 *(under various scenarios of responsibility and capability to act)*

Historical Responsibility \ Capability to Act	1 Less Progressive[2]	2	3 More Progressive[2]
a Early Responsibility Start Date (1850)	(0.56%)	(0.66%)	(0.49%) *low*
b	(0.59%)	(0.67%)	(0.51%)
c Later Responsibility Start Date (1990)	(0.69%)	(0.77%) *high*	(0.58%)

1. Low-income individual threshold cut-off defined by the Climate Equity Reference calculator 2. Distributing emissions reductions between countries based on level of income – 'more progressive' includes $7,500 development threshold and other progress factors while 'less progressive' does not consider a development threshold 3. 2-degree pathway used, 50% weighting between capability and historical responsibility used 4. PPP = Power Purchasing Parity
Source: Climate Equity Reference (Stockholm Environment Institute), Project Team Analysis

Figure 110: Malaysia's fair share contextualised against GHG emission pathways

Factoring in historical emissions from 1850 and adjusting for capability to act, Net Zero 2050 is above Malaysia's fair share



Source: Climate Equity Reference (Stockholm Environment Institute), Project Team Analysis

Lead

Lead represents a set of actions where the government shows exemplary leadership by example on key climate action, for both stakeholders within the country and on the international stage. These actions will signal the deep commitment of the Malaysian government towards sustainability, strengthen the confidence of the public in green solutions based on successful demonstrations in the public sector, and position Malaysia strongly on the international stage as a key informed voice on climate and sustainability.

- **Green public procurement**

  Green public procurement or green government procurement (GGP)[146] has been growing over time in Malaysia. In the 11th Malaysia Plan the target of 20% GGP by 2020 was established, and this was enhanced in the 12th Malaysia Plan to a target of 25% GGP by 2025. Public procurement constitutes around 15% of total GDP and can spur large supply-side shifts towards the green economy in response to demand. Malaysia has the opportunity raise its targets of GGP over time to converge with leading regional peers and enhance enablers to support GGP such as clear guidelines for green procurement cascaded at the national, state, and local levels and green product directory databases which increase ease of identification of green certified products and suppliers. These supporting enablers have supported countries such as Thailand to achieve central government GGP levels of over 90%.

- **Institutionalising green practices across the public sector**

  The government also has the opportunity to demonstrate leadership by adopting green technologies at-scale across the public sector. This includes the scale-up of energy efficiency adoption and retrofits in public sector buildings, leveraging suitable public sector buildings for rooftop solar production, adopting electric vehicles, ensuring fuel economy of the government vehicle fleet, and others. Enablers such as scaling up the adoption of Energy Performance Contracts (EPC) can support this ambition, contributing to the development of domestic Energy Service Companies (ESCO) ecosystem in the country. Moreover, demand-side behavioural changes such as energy conservation, recycling and waste management, building temperature controls, shared mobility, and optimised travel can contribute to the reduction in the government's GHG footprint and set leading examples for the private sector.

- **Orchestrating focused efforts to grow high potential nascent green growth sectors**

  Beyond playing a role as a catalyst, the government can take a direct proactive lead in orchestrating cross-stakeholder coordination across the public and private sector to move at pace on priority nascent green growth sectors. This includes investing ahead of the curve to build early mover advantage in areas where there is large global demand potential and where Malaysia has the potential for differentiated competitive advantages.

- **Champion key regional and global topics to further climate agenda**

  Malaysia also has the opportunity to demonstrate leadership on the international stage on specific climate agenda topics critical for Malaysia's interests or where international decisions have large implications on Malaysia. This could include championing strong safeguards for nature-based solutions given our large forest cover, or topics such as the positioning of sustainable palm oil biofuels in export markets. In ASEAN, this could include leadership on multilateral topics such as the ASEAN interconnected grid and bilateral efforts such as the Heart of Borneo initiative.

146. Green Public Procurement and Eco-Labelling Programmes, UNEP

Corporate climate leadership and governance

The corporate sector also has a significant role to play in climate transition as key engines of the national economy. With rapidly accelerating green megatrends, corporates are increasingly compelled and economically incentivised to demonstrate strong climate leadership and governance.

Safeguard

Safeguard represents a set of actions which corporates will need to take to meet the demands and expectations of customers, shareholders, and stakeholders. These actions are critical to ensure corporates build strong public reputations, not only as profit-maximising entities but as contributors to overall societal impact in the communities that they operate in.

- **Ensure operations or corporate actions do no harm to the environment**

  In line with the objective of ensuring a strong public reputation, corporates will need to ensure their practices do no harm to the environment. This includes strengthening environmental sustainability of practices across the business with sustainable and responsible production practices, effective waste reduction and management practices, and a conscious effort to protect the environment in development projects. With increasing environmental consciousness of consumers, strong environmental safeguards will reduce potential downside reputational risks and demand impact for corporates.

- **Mitigate key transition risks from ESG megatrends**

  Transition risks are business-related risks that follow societal and economic shifts toward a low-carbon and more climate-friendly future. These include reputation, technology, market, policy, and legal risks which emerge due to shifts towards the green economy. Examples include the impact of domestic and border adjustment carbon pricing on business, or regulatory bans on high emission products, green technology disruption risks, capital exclusions of high emission sectors from financial institutions and others. Investor exits from assets which have high transition risks creates a key imperative for rapid response in order to protect shareholder value.

- **Understand and adapt to key climate-related physical risks**

  Physical risks, which can cause significant damages to infrastructure, facilities, and products from climate change will need to be prevented with climate adaptation and resilience safeguards. This includes protecting or relocating assets along coastal areas prone to increased flooding, upgrades of equipment to withstand higher mean heat temperature from global warming, and climate-proofing key infrastructure against increased extreme climate events.

- **Measure and disclose on key ESG and climate metrics**

  Measurement and disclosures of key climate metrics and climate risk reporting is increasingly being required to meet the expectation of regulators and shareholders, and to prevent capital exclusions. Legislation to mandate disclosures and accompanying standard taxonomies are expected to grow over time. Building out internal capabilities for climate-related data collection, processing, and reporting will be critical to meet stakeholder requirements. Even prior to the establishment of national standards, corporates with global shareholders are being compelled to report in accordance with Carbon Disclosure Project (CDP) guidelines.

Catalyse

Climate transition has the potential to unlock new sources of competitive advantage for corporates that move in a timely and decisive manner to set clear climate ambitions, cascade climate ambitions into day-to-day operations, and capture green growth opportunities. In addition, corporates can catalyse climate transition by leveraging their influence over the supply chain, business partners, employees, and customers to promote environmentally sustainable practices, contributing to the virtuous cycle of green economy growth.

- **Setting a clear climate ambition and science-based emission reduction target**

  Setting corporate climate ambition and targets is becoming increasingly mainstream, in alignment to globally recognised standards such as the Science Based Target Initiative (SBTi). SBTi aims to enable companies to set ambitious and meaningful corporate GHG reduction targets. Targets adopted by companies to reduce GHG emissions are considered science-based if they are in line with what the latest climate science says is necessary to meet the goals of the Paris Agreement – to limit global warming to well below 2^{0}C above pre-industrial levels and to pursue efforts to limit warming to 1.5^{0}C.

  Several key steps are required to set a clear climate target, such as the SBTi. As a starting point, a clear baseline will be required, covering Scope 1 and Scope 2 emissions, as well as Scope 3 emissions if selected criteria of materiality are met. Following the baseline, a clear climate ambition will need to be set for emissions, aligned to science-based targets such as the 1.5^{0}C, well below 2^{0}C, or 2^{0}C pathways. A target timeframe of emission reductions will also need to be established. For the SBTi, timeframe for targets will be within the window of 5 to 10 years, as opposed to the currently permissible 15 year target setting timeframe. The shorter-term timeframe of SBTi is designed to promote greater accountability and to stimulate immediate action, whilst enabling a sufficient time frame for material emission reduction targets to be achieved. Finally, target setting methods will need to be determined for Scope 1 and 2 emissions and where relevant for Scope 3 emissions.

- **Cascading climate ambition with a clear roadmap and changes to everyday processes**

  Setting an ambitious climate or emission reductions target alone is not enough. Corporates which have set bold long term climate ambition targets, but without support of a clear and detailed plan, have been subject to scrutiny and criticisms of "greenwashing".

  Hence, a credible and concrete decarbonisation roadmap, with clear interim milestones and well defined initiatives, aligned to the overall climate ambition is key. Moreover, climate considerations will also need to be embedded in a structured and deliberate manner into day-to-day corporate decisions. Corporates will also need to cascade climate ambitions to their investment strategies, such as screening new projects and deals with a shadow internal carbon price or embedding climate risk assessment into the end-to-end investment process. Finally, a clear plan on supply chain engagement will be required to ensure collaboration with suppliers to ensure emissions traceability and to embark on joint initiatives to reduce emissions through the supply chain in support of Scope 3 emissions reductions.

- **Awareness and action on green economy opportunities**

  Rapid demand shifts are opening up large green economy opportunities and early movers into high potential green economy areas can create new sources of diversified income and competitive advantage for companies. Building up internal capabilities and ensuring sufficient bandwidth to scan, assess, and act on green economy opportunities can realise various benefits for businesses, whilst contributing towards the green economy. Moreover, competitive advantage in the green economy typically requires more than the actions of one company alone. Advocacy to ensure the right supportive policies and enablers, coordinated actions to build complementary products and services, and others represent key catalytic actions which can be conducted by corporates to enhance competitive advantages in green growth sectors.

- **Mainstream conversations on climate in organisation**

  Another key step to catalyse climate action will be to mainstream conversations on climate across the organisation. Corporates have a strong sphere of influence over their supply chain, business partners, employees, and even customers. Leveraging this influence to inculcate climate awareness and consciousness represents a large opportunity. This starts from the top of the organisation in the Boardroom, where members are tuned to key climate risks and opportunities the business is facing and active discussions on the company's environmental sustainability with the company's management are held. Supplier engagements on topics of green and sustainable supply chains and mainstreaming environmental considerations in day-to-day procurement and supply chain decisions will also be key. Employee engagement to increase the level of climate and environmental awareness, and to ensure that employees are environmentally conscious in everyday activities in the workplace also represent an important step.

  The mainstreaming of climate conversations is a key catalytic step to ensure that large-scale behavioural change needed to catalyse progressive climate transition is possible. Corporates can support this by fostering a green company culture through effective messaging, with leaders leading by example on green practices and establishing platforms for engagement on environmental sustainability.

Lead

Corporates also have the opportunity to show green leadership in key areas and position themselves at the forefront as a champion for environmental sustainability.

- **Participation in global alliances to tackle most complex green challenges in sectors**

  Despite the rapid progress over recent years, the green agenda in sectors is largely still an emerging topic and an evolving body of knowledge. Global alliances are forming between progressive corporates within a sector to influence and shape this agenda, with leading companies forming alliance to tackle some of the most complex topics related to environmental sustainability for the sector. Take for example the automotive sector, where one of the largest concerns is the social and environmental impact of battery demand on rare earth production. Given the complexity of this global supply chain challenge and the intricacies with geopolitics, around 10 leading global manufacturers established the Drive Sustainability alliance to increase sustainability throughout the global automotive supply chain, including the focus on sustainable rare earth production.

  There is an opportunity for Malaysian companies to selectively demonstrate leadership on the regional or global stage on key topics, in collaboration with players globally on some of the most complex climate-related challenges faced by each sector.

- **Spearheading green sectoral transformation in Malaysia**

  Corporates can also step up as leaders to spearhead green sectoral transformation in Malaysia as a leading reference example for the rest of the sector in the country. As the green agenda is relatively nascent in many sectors across the country, this may include leadership to provide inputs into the shaping of policy in collaboration with the public sector in order to establish strong catalytic foundations for green transition in the country.

  This can include leading the development of green standards by industry and for industry which are suited to the Malaysia context and can act as the reference points for all players in the sector. Alternatively, leadership can include fostering coordination across Malaysian stakeholders to develop synergistic green ecosystems in the country. To decide on potential areas to demonstrate green leadership, corporates can map out key green topics which are most pertinent but nascent for the sector in Malaysia, and align this against where strong topic contributions can be made based on existing capabilities or experiences possessed within the corporate organisation.

Case Study 8 | Actions by Sarawak government towards Net Zero Carbon Economy

Sarawak is endowed with large tracts of forests that have remained intact, covering 63% of the total land mass. The state is strengthened by policies which mandate sustainable forest management and the conservation as totally protected, which need to constitute a minimum of 56% of the total land mass. The Strategic Plan (2021-2025) of the Forest Department of Sarawak outlines plans to increase permanent forest cover by an additional 600,000 hectares from the current 3,964,880 hectares. In addition, the state government also targets to increase a further 0.13 million hectares as totally protected terrestrial areas, in alignment with the long-term goal of achieving 1 million hectares of totally protected terrestrial areas.

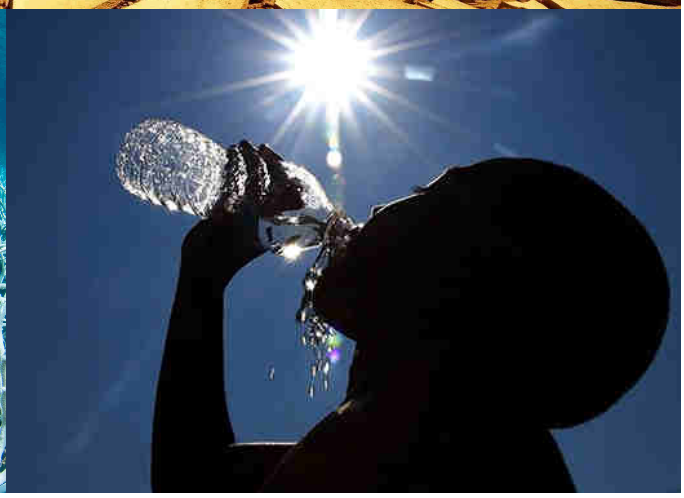
Blessed with abundant water resources, Sarawak has also embarked into sustainable renewable energy production such as with sustainable hydropower. The state aims to become the powerhouse of the hydrogen economy not only in Malaysia but in Southeast Asia by 2030. Hydrogen enables deep decarbonisation across the energy, transportation and industrial sectors, enabling Sarawak to propel towards a greener economy.

Sarawak is at the forefront to significantly reduce its GHG emissions and is a major contributor to Malaysia's Nationally Determined Contributions (NDCs). The aspirations and commitment to maintain forest cover and conserve watersheds for the provision of ecosystem services, have become even more significant and relevant with rising climate change impact. It is critical that Sarawak sustains its current efforts to protect and conserve more forests whilst ensuring sustainable development, including efforts such as carbon avoidance and energy efficiency, are carried out for the greater benefit of the people and its economy.

Photo credit: Tan Hao Jin / WWF-Malaysia

Special Chapter

The importance of adaptation and resilience



Overview

The importance of climate adaptation and mitigation

The pace of climate change is accelerating and changes in the Earth's climate in every region and across the whole climate system are already being observed. From rises in average temperatures to increasing frequency and intensity of extreme weather events, the impact of climate change is intensifying. Many of the changes already set in motion, such as the continued sea level rise, will be irreversible over hundreds to thousands of years.

Even with the best efforts on climate mitigation, climate change will have significant impacts on communities and populations before the impact of sustained global climate mitigation efforts take effect. Hence, steps for climate adaptation and resilience are critical. Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change.

Holistic climate solutions place strong and equal emphasis on both climate mitigation as well as climate adaptation and resilience. With accelerating climate changes, the longer adaptation efforts are put off, the more difficult and costly they will become. Urgent and large-scale action is needed to implement adaptation solutions to address impacts of climate change that are already occurring, as well as to prepare for future impacts.

Adaptation solutions will need to be highly specific on the unique context being faced by a country. Each country will face different types and magnitude of risks and each country also possesses unique natural solutions which can be used to ensure adaptation to these risks. There is no "one size fits all" solution for climate adaptation and resilience, and each country will need to take strong efforts to pursue these measures to secure their futures. Successful adaptation does not only depend on governments, but the support of all stakeholders including corporates, civil society, and individuals which each have a common interest in ensuring effective climate adaptation and resilience measures are taken.

Climate adaptation and mitigation in the context of this study

Whilst the current report focuses primarily on climate mitigation measures, the equal importance of climate adaptation and resilience is recognised. This sentiment is shared by various stakeholders engaged throughout the course of the study. Gaps related to adaptation and resilience efforts are recognised, and many stakeholders see the importance to accelerating the understanding on the climate-related physical risks that will impact various regions across Malaysia.

The study does not attempt to cover either the starting position or the solutions required for climate adaptation and resilience in Malaysia. However, given the criticality of this issue, the study aims to highlight the case for change for climate adaptation and resilience and some of the priority next steps required on the topic, for stakeholders to take forward.

Case for change

As a region, Southeast Asia has been identified as vulnerable to key climate risks which will need adaptation and resilience efforts. An increase in intensity and frequency of heavy precipitation as well as rising global sea levels will increase the risk of inland and coastal floods without adaptation measures. These floods are expected to incur damage and result in people displacements, affecting both lives and livelihoods. In addition, increase in the intensity and frequency of hot weather extremes and mean temperature is expected, affecting agriculture yields, productivity of outdoor work, and increase the prevalence of heat-related sickness.

Without climate adaptation, climate disasters will create large damage and destruction to property, infrastructure, natural landscapes, and others. Besides increasing strain on federal and state government finances for recovery and damage repair, products and services required such as building materials, construction services, replacement household products, and others will increase demand and emissions, slowing down the country's climate mitigation path.

As climate adaptation measures are implemented to protect vulnerable economic sectors and natural ecosystems, these assets gain resilience and optimise their contribution towards climate change mitigation efforts. For example, it is critical that efforts are made to conserve peatlands and wetland forests through maintenance and restoration of these ecosystems, in the form of nature-based solutions. These provide significant carbon removal potential whilst supporting climate adaptation and disaster risk reduction. However, if degraded these assets will be exposed to future climate risks such as increased temperatures, precipitation, humidity, sea level rises, and others which will reduce the capacity of these assets to sequester carbon.

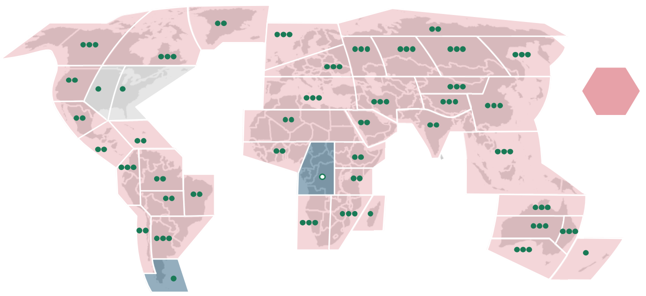
Photo credits: Wetlands International Malaysia

Photo credits: New Straits Times

Figure 111: Historic evolution of key climate impact measures on Southeast Asia

Southeast Asia has experienced strong increase in extreme heat and heavy precipitation since the 1950s based on IPCC findings

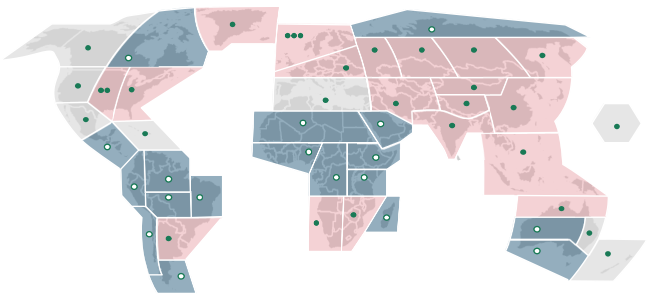
Change in extreme heat (observed since 1950s)[1]



Confidence level

- ●●● High evidence and agreement
- ●● Medium evidence and agreement
- ● Low due to limited agreement
- ○ Low due to limited evidence

Change in heavy precipitation (observed since 1950s)[2]



Direction of change

- Increase
- Low agreement in type of change
- Decrease
- Limited data

1. Based on daily maximum temperatures; regional studies using other indices (heatwave duration, frequency and intensity) are used in addition
2. Changes in indices based on one-day or 5-eday precipitation amounts using global and regional studies.

Source: IPCC AR6 Physical Science Report

Figure 112: Projected evolution of climate risks in Southeast Asia in 2°C pathway vs. 1.5°C pathway

Large future expected climate risks in Southeast Asia

Physical climate impact	Range of impact between 2-4°C pathway by 2100		Socioeconomic impact
Increase in intensity and frequency of heavy precipitation	4% to 10% vs. 1.5°C pathway	In continuous precipitation level (1-day & 5-day precipitation)	Higher instances of flooding
Increase in intensity and frequency of hot weather extremes	0.5°C to 2.5°C vs. 1.5°C pathway	Increase in maximum daily temperature (max value of max daily temperature)	Exceed critical thresholds for health, agriculture yields, and productivity of other sectors
Increase in mean temperature	<60 to >150 days vs. current no. of days	Increase in number of days exceeding 35°C	
Increase in global mean sea levels	0.3m to 1.0m[1] vs. current levels	Increase in sea levels due to ocean warming	Displacement of coastal populations

1. Rounded to nearest decimal place

Source IPCC AR6 Table 11.7 and 11.8 and Figure TS.24, IPCC AR5 WG1 Chapter13 (sea levels), IPCC Climate Change Report: Impacts, Adaptation, and Vulnerability (2014), Project Team Analysis

Climate adaptation and resilience responses

A structured approach will be required to holistically develop climate adaptation and resilience solutions to rising climate risks. There are several key stages in the development and implementation of climate adaptation and resilience plans:

- **Quantify impact of physical risk and adaptation and resilience levers**

  Holistic mapping and quantification of material physical risks will be required to understand the extent of climate change to be faced by various geographies. These material climate risks include, but are not limited to, the impact of rising sea levels on low-lying coastal population, the impact of increased heavy precipitation on flood risks, the impact of hot extremes and mean temperature rises on various activities and agriculture yields, and others. In addition to a geographic lens, the impact of climate risks on various population groups should also be assessed in order to inform targeted measures.

  Besides comprehensive mapping of the physical risks, assessing the relevance and availability of various adaptation and resilience measures with location-specific nuances will be critical. Adaptation levers will need to be location-specific, with varying natural resources and local endowments which will inform the optimal adaptation and resilience response. The socioeconomic impact of adaptation and resilience measures on local populations will also need to be assessed. Collectively, a strong fact-driven view of the potential levers at disposal against relevant physical risks, with a geographic-specific nuances will be required.

- **Assess impact on systems**

  The impact of physical risks and the corresponding adaptation and resilience measures on key systems will also need to be assessed. This includes the impact on agriculture and food security, cities and infrastructure, nature and biodiversity, water access, health and well-being, and natural disasters. The impact to vulnerable populations and livelihoods will also need to be assessed across these systems. Based on the impact to each of these systems, adaptation and resilience measures will need to be identified. This includes measures to strengthen the resilience of food systems, enhance climate-proof infrastructure, secure continued access to drinking water, and strengthen systems for health and disaster response.

- **Prioritise measures**

  Given limited resources which can be set aside for adaptation and resilience activities, a clear view on priorities over time horizons will be required, oriented to where physical risks are the most urgent to address. Clear ambition and priorities by time horizon will need to be established for adaptation and resilience, aligned to long-term budget allocations and resource deployment. For example, responding to the threat of sea level rise, Singapore is allocating SGD 100 billion over a period of 50-100 years for coastal adaptation plan efforts, with a sequencing of priorities over time. Long term target setting and prioritisation will ensure that sufficient discipline is created to ensure adequate funding allocations to key adaptation and resilience needed, where if not deployed in a timely manner will risks even more costly damage as a result of climate disasters.

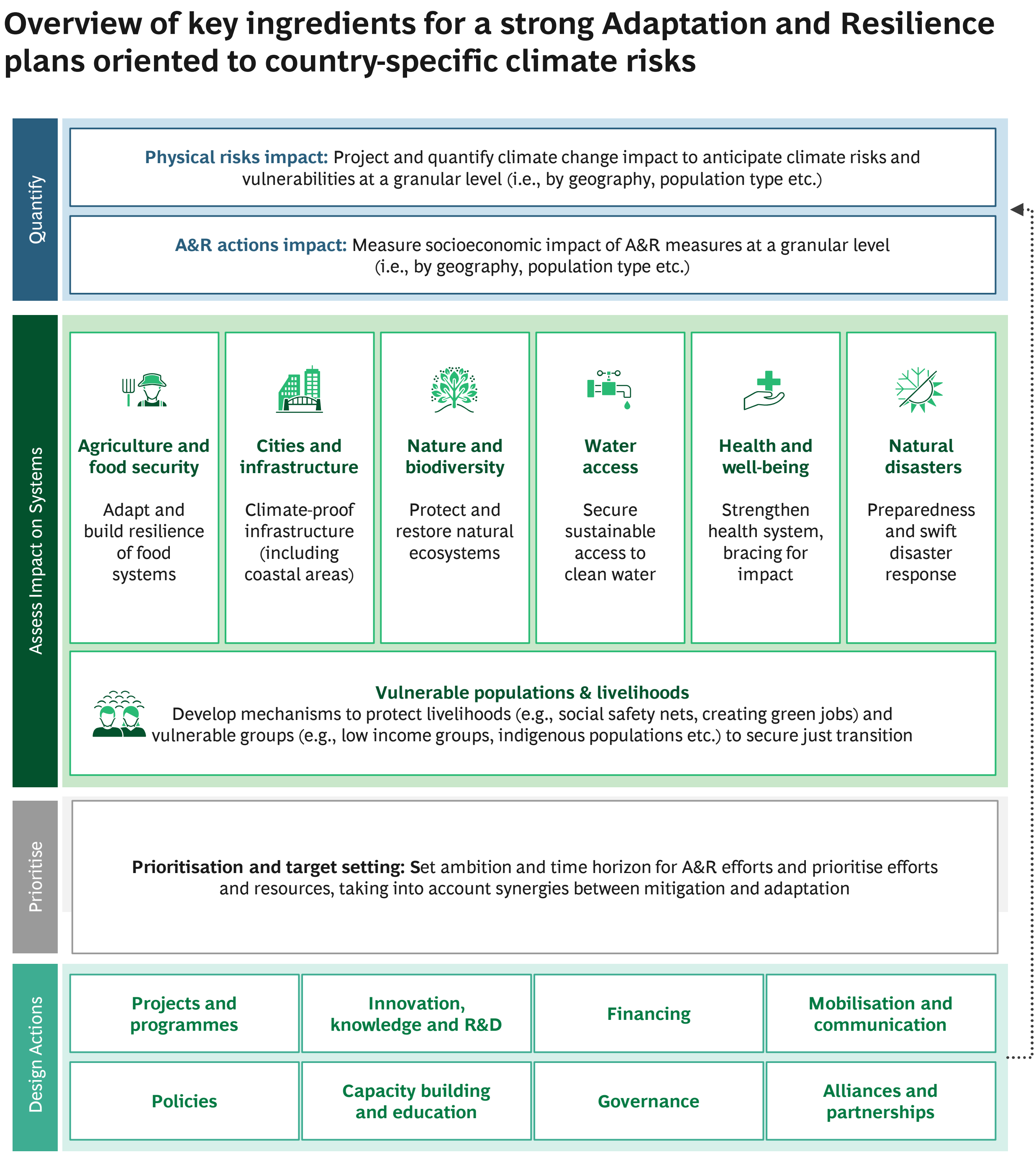
- **Design actions and enablers**

  With clear long-term targets and sequenced priorities over time, various enablers can be designed and established. Examples include orienting innovation, knowledge, and research to identify solutions for key adaptation and resilience needs, developing structured projects and programs to ensure structured delivery, and unlocking supporting finance from both the public and private sector. Other enablers include entering into alliances and partnerships with other countries facing similar physical risks, to share knowledge and co-develop scalable solutions where relevant to ensure adaptation and resilience.

The combination of measures can be culminated into a long-term national adaptation plan which creates clarity across stakeholders on the way forward. Timely implementation of identified measures will be required to prevent costly damages and adverse impact on lives and livelihoods. During implementation, the effectiveness of various adaptation and resilience measures will need to be assessed, in order to inform learnings and feedback loops into future measure design.

Moreover, synergies between both climate mitigation and climate adaptation can be unlocked with effective advanced planning. For example, efforts to restore mangrove swamps or degraded forests may serve dual benefits of reducing emissions and enhancing resilience against climate change.

Figure 113: Framework of key steps towards a holistic, long-term climate adaptation plan



Source: Project Team Analysis

Study methodology and data sources

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Overview of data sources and methodology leveraged in the study

This study is developed based on best publicly available information and stakeholder inputs from various engagement sessions conducted with subject matter experts on various topics.

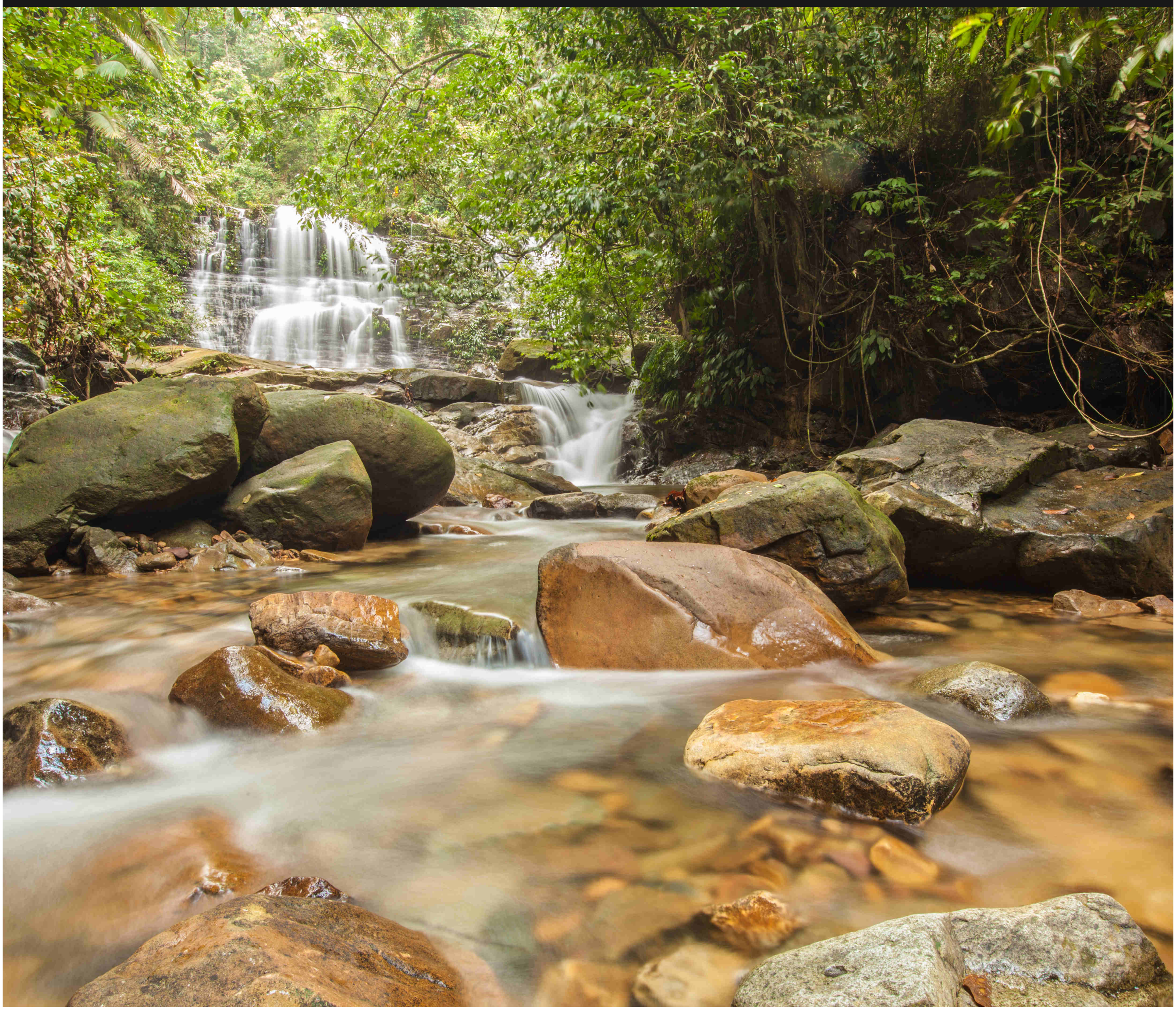
- The findings of the study are based on best available GHG inventory data available for Malaysia, as presented in Malaysia's Third Biennial Update Report to the UNFCCC (2020). The study recognises that the GHG inventory starting position may not be fully exhaustive of all sources of GHG emissions and removals in the country which we as a nation are either unaware of, or have yet to document and record, or are presently reporting using proxies. It is critical that the findings and pathways outlined within the study are contextualised and updated based on future developments in the country's GHG inventory estimations. Moreover, efforts to enhance both the accuracy and exhaustiveness of the country's GHG inventory estimations will need to continue, as a key foundation to accurate climate mitigation pathway development.

- Forward-looking projections under various scenarios were developed from this starting position in coherence with national inventory accounting guidelines and methodologies by the IPCC. Where relevant, the forward-looking projections of sectoral emissions was estimated using specific modelling tools. For example, the TIMES (The Integrated MARKAL-EFOM System) model generator tool was leveraged for holistic energy system modelling, supplemented with the use of PLEXOS for electricity system modelling for the country.

- To develop the *current trajectory pathway* of GHG emissions and removals, Malaysia's forward-looking plans outlined in official policies, plans, and announcements were also incorporated. Importantly, a key assumption made is the pre-supposition of successful implementation of these policies and the resultant benefits of emission reduction. The study notes the varying degrees of success of policy implementation and that outlined plans do not necessarily translate to results. Assessments on the likelihood of implementation success of an outlined policy were not conducted in the development of this pathways, and hence no discretion was applied to discount for potential official policies which may not result in implementation success in the future. In addition, a range of assumptions and proxies have been used where publicly available data is not available based on the research and consultation of the project team. The study also recognises specific data gaps and limitations which are outlined in the technical reports.

- Finally, estimations on the size of GHG impact and abatement costs have been made based on a series of assumptions, triangulated to the best degree possible with global benchmarks, subject matter expert inputs, and others. The sizing of these levers are core to the development of alternative GHG emission pathway scenarios for the country in addition to the current trajectory pathway. To the best extent possible, local customisations have been applied to ensure that country-specific context and conditions are fully incorporated into the pathway. Where critical, the methodology adopted for sectoral abatement lever assessment is detailed under the individual chapters of the report.

Acknowledgments



Acknowledgements

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We would like to acknowledge the support and contribution of the Steering Committee in providing steer and guidance for the WWF-BCG Net Zero Pathway study

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We also would like to express our deep gratitude towards the following individuals for their technical inputs and views which have supported the development of this report:

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This study is a joint initiative of WWF-Malaysia and Boston Consulting Group, whose team members have contributed tirelessly to writing and reviewing the report. As part of the study process, stakeholder engagement meetings involving over 50 organisations in the private sector, 18 government agencies, 25 actors within civil society (including organisations and individuals), and 8 parliamentarians.

A series of engagement events to share findings of the study were were held in collaboration with the CEO Action Network and the secretariat of the All-Party Parliamentary Group Malaysia - Sustainable Development Goals (APPGM-SDG). The British High Commission also held two events where the study was presented, involving embassies and foreign missions in Malaysia.

We would like to acknowledge the contribution of all who have contributed their time and effort in making this study possible.

Acknowledgements

Special appreciation to:

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Extending our deepest gratitude to our lead contributors who contributed greatly to make this study a success

Lead Contributor | Amundi

Consistent with our ambition to be a leader in responsible investing and forerunner in climate finance, Amundi proudly joined the Net Zero Asset Manager initiative July 2021, to support the goal of global carbon neutrality by 2050.

Climate Change is arguably the greatest challenge of our times. Exacerbated by human activities, it presents itself as one of the greatest systemic risks for society with long-lasting impact for investors and financial actors. Since the Paris Agreement in 2015, we have strengthened our ambition to support climate action across geographies and asset classes. Our success and continued progress on this front has been possible through the strategic partnerships forged with the World Bank Group's International Finance Corporation, the European Investment Bank, the Asian Infrastructure Investment Bank, and through the support of our clients across the world.

Acknowledging that there is an urgent need to accelerate the transition towards global net zero emissions, Amundi is proud to join the Net Zero Asset Managers Initiative this year, committing to supporting the goal of net zero emissions by 2050. The 5 convictions that will drive our Climate Action Plan:

- The financial sector is a key catalyst for action: While maintaining a stringent sector policy to phase out coal, we will focus on supporting net-zero aligned investment across sectors and regions, and on ensuring investors are equipped with efficient and ambitious climate investment strategies supporting global neutrality.
- Change must be embraced at every layer of the organisation: Amundi will not only align its own operations with global carbon neutrality objectives but will ensure that this mission is shared throughout the organisation, empowering staff to be actors of change.
- Transition will need to be socially just and respectful of our environment: COP26 is held in a context marked by the social and economic fallout from the sanitary crisis. We are convinced of the need to achieve a low-carbon transition that is socially acceptable and have co-founded "Investors for a Just Transition", the first investor coalition on the just transition, to support collaborative efforts addressing this complex challenge.
- Knowledge, data and analytics are significant drivers of change: Aligning financial flows with carbon neutrality objectives requires significant improvement in our ability to integrate climate change risk, transition opportunities, and adverse impact on sustainability factors, when allocating capital.
- Engaging companies on a climate-neutral path will remain a key pillar of our climate strategy: We fully integrate the emissions' trajectory of the companies we invest in in our ESG analysis. Amundi also encourages companies to have increased transparency on their strategy to reduce emissions, and deeper public commitments on carbon emissions reduction plans, by notably declaring an alignment objective with the Paris agreements under the Science-Based Targets framework.

> *Climate Change is arguably the greatest challenge of our times. Governments and companies have a collective responsibility to transition to decarbonised economies by adopting ambitious emission reduction targets. Amundi is a pioneer in responsible investing with strong climate convictions and a deep awareness of our responsibility. Therefore, we are proud to embrace global carbon neutrality objectives, gearing towards social cohesion and sustainable capital market development.*
>
> ***Jean-Jacques Barbéris, Executive Committee Member and Head of ESG, Amundi***

Extending our deepest gratitude to our lead contributors who contributed greatly to make this study a success

Lead Contributor | Bursa Malaysia

Bursa Malaysia or the Exchange, incorporated in 1976, is an exchange holding company that has been publicly listed on the Malaysian bourse since 2005. Today, the Exchange is one of the most vibrant and diverse marketplaces in ASEAN, facilitating trade in both conventional and Islamic securities and derivatives. Bursa Malaysia has grown from strength to strength since its listing and is currently home to the largest number of public listed companies (PLCs) in ASEAN.

The Exchange is also renowned for its pioneering innovations in niche markets, especially in palm oil-based derivative products and the Islamic capital market. Its Crude Palm Oil Futures serves as a global price benchmark for the commodity, while innovations such as our Bursa Suq Al-Sila' commodity Murabahah trading platform and Bursa Malaysia-i Shariah-compliant securities trading platform are world's firsts in the Islamic capital market. The globally benchmarked FTSE4Good Bursa Malaysia (F4GBM) Index, which was introduced in 2014 continues to play an important role in recognising companies that demonstrate strong environmental, social and governance practices and disclosures.

In 2020, Bursa Malaysia developed a new Sustainability Roadmap 2021-2023 that outlines its sustainability priorities over the next three years, holistically covering aspects of the development of the capital market, workplace and communities. Importantly, a key focus of the roadmap includes driving the transition to a green economy through continuous expansion in our scope of offerings supported by product innovation, with a stronger focus on Shariah, ESG and Sustainability.

Bursa Malaysia is also driving the sustainability agenda by encouraging the adoption and integration of sustainable and responsible principles in our marketplace. PLCs are required to make sustainability-related disclosures in their annual reports as required by the Exchange's Main Market and ACE Market Listing Requirements. We also aim to grow the sustainability ecosystem through our various sustainability education and awareness creation efforts.

In September 2021, Bursa Malaysia had pledged to become carbon-neutral by 2022 having identified eight initiatives to support this aim, as well as to achieve net zero emissions by 2050 across its entire operations. The Exchange also joined the CEO Action Network which represents a coalition of sustainability-focused companies that are dedicated to driving the transformation towards a sustainable future. In addition, Bursa Malaysia is collaborating with the Environment and Water Ministry and the Finance Ministry to develop a voluntary carbon market and domestic emission trading scheme. This is a significant nation-building project that will assist Malaysia in meeting its climate ambitions while creating an ecosystem that is transparent, rules-based, and meets the needs of intended market participants.

> *Businesses sit at the intersection of societal demands and material resources. This unique position presents an important opportunity for businesses to be a driving force against climate change by influencing consumer behaviour and actively decarbonising supply chains. Bursa Malaysia aims to play an active role to support and facilitate a healthy investing ecosystem that enables the transition towards net zero emission for the capital market.*
>
> ***Datuk Muhamad Umar Swift, Chief Executive Officer, Bursa Malaysia***

Extending our deepest gratitude to our lead contributors who contributed greatly to make this study a success

Lead Contributor | Tenaga Nasional Berhad

TNB is pursuing an ambitious growth agenda through our Reimagining TNB (RT) Strategy to be a leading provider of sustainable energy solutions in Malaysia and internationally and achieve a Net-Zero Emissions target by 2050.

This pursuit driven by its Sustainability Pathway initiatives include efforts to reduce 35% of the company's emissions intensity and decrease 50% of its coal portfolio by the year 2035. In addition, TNB has pledged to ensure its revenue from coal generation plants does not exceed 25% of its total revenue. It will no longer invest in greenfield coal plants after Jimah East Power, which was commissioned in 2019, while existing plants will be phased out on expiry of their power purchase agreement (PPA).

Leading up to this commitment, TNB will continue to improve efficiency at its existing thermal plants and build up scale in its renewable generation portfolio. Additionally, its international investment will increasingly focus on RE and emerging green technologies. All of this will be done in order to achieve 8,300MW of Renewable Energy (RE) by 2025.

TNB believes that an inflection point between 2035 and 2040 will determine the speed at which its Net-Zero Emissions ambition can be achieved. The organisation is also committed to the development of energy storage solutions to enable RE growth, as well as green technology including hydrogen as an energy generation source, and Carbon Capture and Utilisation (CCU) through investments in Research and Development and strategic partnerships.

Recently, the Government of Malaysia has announced its commitment to become a carbon neutral country by 2050, at the earliest. Hence, TNB's Sustainability Pathway also supports the nation's sustainability journey towards a greener, healthier, more sustainable future for the next generation. Sustainability is a long-term journey. Today's commitment is an initial step towards decarbonisation and will be strengthened as TNB charts the path over the next 30 years.

> *The clarion call for Sustainability is shaping business decision-making and redefining corporate aspirations. Through this study we hope to be part of charting Malaysia's journey towards a better world and brighter lives anchored on TNB's aspiration towards net zero emissions by 2050.*
>
> ***Datuk Ir. Baharin Din, President and Chief Executive Officer, Tenaga Nasional Berhad***

Extending our deepest gratitude to our co-lead contributors who contributed greatly to make this study a success

Co-Lead Contributor | CIMB

CIMB Group Holdings Bhd ("CIMB") is a leading focused ASEAN universal bank, one of the region's foremost corporate advisors, and a world leader in Islamic finance. Under the Forward23+ Strategic Plan, CIMB's strategic themes include to embrace sustainable practices and to actively shape the role in society.

As a founding signatory of the United Nations Environment Programme Finance Initiative Principles for Responsible Banking, signatory of the Collective Commitment on Climate Action and the Net-Zero Banking Alliance, and an official supporter of the Task Force on Climate-related Financial Disclosures, CIMB has made great strides since embarking on its sustainable agenda. With the recently announced sustainability commitment to mobilise RM30 billion towards sustainable finance by 2024 and to achieve net zero emissions by 2050, CIMB plans to put the regional banking group on track towards becoming an ASEAN sustainability leader.

The group has also set its sights on achieving the top quartile ranking for banks based on the S&P Global Corporate Sustainability Assessment in support of the aspiration to be an industry leader on the Dow Jones Sustainability Index (DJSI) by 2024. CIMB has made admirable progress — moving from the 19th percentile in 2017 to the 79th percentile in 2020.

Co-Lead Contributor | Digi

LET'S INSPIRE

Digi is committed towards achieving a low carbon pathway in our operations and supply chain. We believe the mobile industry is strategically positioned to deliver technologies with the potential to cut carbon emissions, stimulate economic growth, and deliver substantial social benefits. We demonstrate industry leadership by actively managing our exposure to natural capital risks through our environmental management system, investments in renewable energy and energy efficient solutions, green buildings and digitalising our operations to dematerialise physical products and reduce waste.

In the next decade, we foresee unprecedented growth in internet data leading to incremental energy demand. Digi's Yellow Heart commitment aspires to tackle these challenges by systematically transiting into a low carbon business model, drive holistic and systemic emission reductions while addressing our physical and transition risks. We shall continue to improve the standards of our climate reporting for greater transparency and accountability towards developing decision-useful, climate-related metrics.

As Malaysia commits to advancing green growth, we shall also steer ourselves to incorporate more ambitious climate mitigation strategies across our value chain, aligning ourselves to clearly defined science-based pathways, empower our customers to reduce their carbon footprint and to contribute to a stronger whole-of-society approach towards shaping a more sustainable planet.

Extending our deepest gratitude to our co-lead contributors who contributed greatly to make this study a success

Co-Lead Contributor | UMW

UMW

Sustainability is what drives UMW to contribute to our evolving business landscape and society. We are committed to lead by placing innovation and technology at the forefront of creating long-term value. As we grow together with our people, business affiliates, customers and local communities, we continue to identify the risks and opportunities that will enable us to build on our strengths and achieve more. As a responsible conglomerate, sustainability is integral to our journey of value creation. We have adopted a holistic approach to business management; taking into consideration the economic, environmental and social ("EES") risks and opportunities alongside financial implications.

Our commitment towards protecting the environment begins with ensuring full compliance to environmental regulations in our manufacturing processes and commercial activities. We further aspire to reduce our carbon footprint through various measures including but not limited to continuing to promote green labels for our products, enhancing our green energy consumption; as well as carrying out tree-planting initiative in the communities where we operate.

The Group aspires to contribute to the climate change targets as outlined in the Paris Agreement as we seek to support the transition to a low-carbon economy through increased renewable energy consumption and improved energy efficiency.