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ORIGINAL PAPER

Public perception of transitioning to a low-carbon nation: a Malaysian scenario

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Abstract

Efforts such as the Glasgow United Nations Climate Change Conference of the Parties 26, the Paris Agreement (Paris agreement, United Nations, Paris, 2015) and the United Nations Sustainable Development Goals are supporting the drive to protect the planet from global warming by ensuring sustainable development. The oil and gas industry, as key contributor to greenhouse gas emissions, must transition to more sustainable energy solutions and play their part in reducing these emissions. Currently, oil and gas companies are implementing technical solutions to achieve net zero carbon emissions. The energy transition from fossil fuel reliance has also happened by exploiting alternative renewable energy sources to meet global energy demand such as wind, solar, biogas and bioderived feedstocks. This net zero energy transition will require a fair and just transition for all in society, and to implement this, it is crucial for those working in the oil and gas industry to understand the technologies needed, the importance of carbon policies and their roles. This research presents a modified Delphi study of employees in Malaysia's national oil and gas company to understand their perceptions towards a net-zero carbon future. The paper briefly reviews Malaysia's low-carbon policy plans, its current carbon dioxide accounting balance, and identifies potential technologies for decarbonisation to set the scene for the modified Delphi study. The results indicated that the national oil and gas company has both the capabilities and the financial resources to significantly contribute towards Malaysia transitioning to a carbon neutral nation. This can be achieved by implementing advanced technologies complementing with nature-based solutions to realise net zero carbon emissions. This study also portrays the confidence that the portfolio of solutions should be executed through a coordinated effort to maximise the outcome and minimise the financial impact in terms of economical sustainability. Implementation of activities towards this energy transition will require significant social commitment, and hence, gauging their perception towards this journey is key objective of this paper.

Graphical abstract

Keywords Low-carbon nation · Nature-based solution · Climate change · National oil companies · Public perception · Comparative survey study

Extended author information available on the last page of the article

Introduction

Over the last decades, we have started to fully realise the impact from greenhouse gasses (GHG) on climate change and the catastrophic consequences have urged global leaders to come together to resolve this challenge (World Economic Forum Report 2019). This led to the Paris Agreement adopting the United Nations (UN) Sustainable Development Goals (SGDs) at the 21st Conference of Parties (COP21) in Paris on 12 December 2015 (United Nations Paris Agreement 2015). Governments from many countries have passed new legislations to accelerate the reduction in carbon dioxide (CO_2) emissions globally. As CO_2 emissions are largely contributed by oil and gas companies of the energy sector, they are pivoting from their reliance on fossils towards alternate energy sources and implementing carbon reduction technologies on existing production, (Hartmann et al. 2021). Oil and gas companies now make genuine efforts to address climate change issues directed by corporate strategies and inspired by social responsibilities. These efforts can be seen through their investment in renewables (Pickl 2019) (*e.g.* wind, solar, hydro, biomass and etc.) as well as in decarbonisation technologies (*e.g.* energy storage technology, carbon capture, utilisation, and storage (CCUS) and direct carbon capture from the air) and carbon offsetting as part of their low-carbon transition vision.

Carbon emission reduction has become a key goal to many oil and gas companies which includes National Oil Companies (NOCs) that produce approximately 55% of the world's oil and gas and control up to 90% of global reserves (Silvana et al. 2011). Research indicates that clear decarbonisation strategies coupled with different industrial approaches are emerging at regional and national levels, for example, Europe being more active than the USA (The-White-House 2021). Likewise, oil and gas producing countries in the Middle East and North Africa (MENA) and the Association of Southeast Asian Nations (ASEAN) had pledged to transition to cleaner energy sources in the coming decades (IEA 2019). This transition and the choice of approaches will be politically, economically and socially motivated, especially in countries with NOCs since their economies rely heavily on oil and gas production for income and employment. For example, about 40% of Malaysia's revenue and 87% of Saudi budget revenues are linked to oil and gas (Forbes Feature 2018). In the recent COP26, it was also acknowledged that nature-based solutions (NBS) are equally important to complement existing industrial and renewable solutions in combating climate change through GHG emissions reduction. COP26 also recognised that conservation, protection, sustainable management and restoration of forests, and other terrestrial ecosystems (Smith 2021) are vital to achieve net-zero carbon emissions. The novelty of our study lies in assessing Malaysia's public perception regarding the use and adoption of low-carbon technologies and natural resources to support NBS technologies and comply with Malaysia's emissions targets. However, NBS heavily relies on geographical location of countries that are rich in biodiversity to create and develop technology solutions combining nature and the environment, which in this case is prefect for Malaysia. These strategic directions from governments and industries on decarbonisation efforts are unilateral and could be implemented successfully if society accepts this together. Hence, it is critical that we do transition thoughtfully, combining policies, industrial and nature-based solutions with societal acceptance to avoid adverse social and economic impacts that deflect from combating global warming. The oil and gas industry must undergo an energy transition to reduce carbon emissions. This may be achieved holistically by implementing carbon reduction technologies coupled with nature-based solutions. Therefore, we argue that it is important that we understand the perceptions of those working in the oil and gas sector to begin with, as they will be the key actors in facilitating a national and global low-carbon transition. To address this gap, we conducted a modified Delphi study of employees in a NOC in Malaysia to explore those perceptions and inform corporate decision-making. This is a study of a country such as Malaysia, rich in natural resources that can contribute to the global energy transition scenario, and the outcome from such a community would be able to translate to other parts of the world. We also believe that getting Malaysia policies and energy transformation towards zero carbon is highly important as Malaysia contributes towards 0.74% of world emissions and has an average of 6.54% increment yearly for the past 20 years. We trust that this study will help the government to develop and enforce new carbon policies that will benefit Malaysians and impact global climate change.

Malaysian initiatives towards a low-carbon society

Malaysia has recently reaffirmed its commitment to support and implement the 2030 Agenda for Sustainable Development and its 17 SDGs. In 2015, Malaysia has pledged to manage natural resources and conserve the environment while mitigating the effects of climate change by implementing a Green Growth strategy under the 11th Malaysia Plan (Fig. 1).

Since 2011, Malaysia has implemented strategies through its 10th Malaysia Plan by recognising the importance of environmental sustainability as part of a comprehensive social-economic development plan to address the issues of climate change, environmental degradation and sustainable utilisation of Malaysia's natural endowment (The Economic Planning Unit 2010). Notable initiatives include implementing the 2011 Renewable Energy (RE)

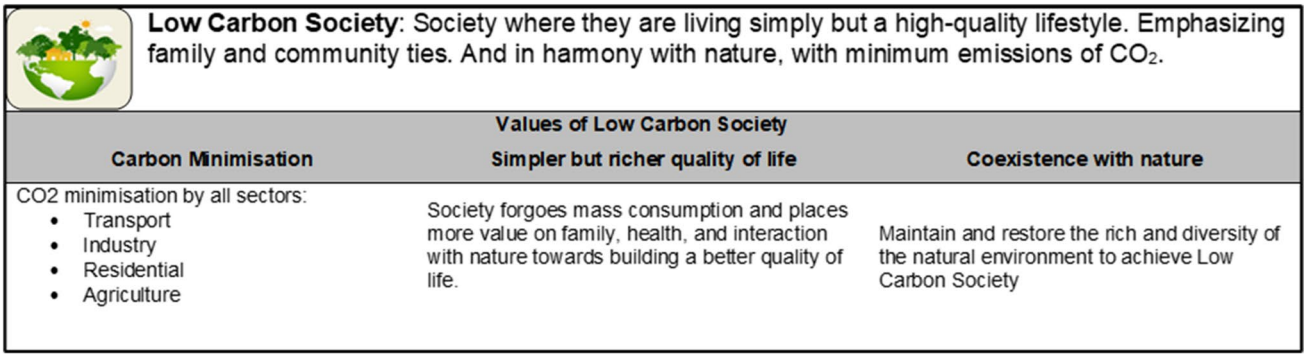

Fig. 1 Summary of focus areas—adapted from (The Economic Planning Unit 2015)

Act, to accelerate RE growth (i.e. biogas, biomass, hydro and solar), implementing flood mitigation projects and finally the declaration of 23,264 hectares of forested areas as Permanent Reserved Forest under the Central Forest Spine initiatives. The RE Act 2011 has also established the Feed-in Tariff (FiT) scheme to catalyse electricity generation from RE sources. It offers long-term agreements (up to 21 years) to RE producers to sell electricity to the grid at premium prices. Hence, RE has grown from being an energy supplier of 2,864,469 MWh in 2012 to 8,403,838 MWh in 2018 (Energy Commission 2021). These efforts are accelerated through the 11th Malaysia Plan 2016–2020, with the introduction of green growth and economy that will be the fundamental shift in how Malaysia sees the role of natural resources and the environment in its socio-economic development, protecting both development gains and biodiversity simultaneously. Malaysia is also committed to fostering the development of green economy. This means encouraging the development of green businesses, green products and services, which in turn will create green jobs. Malaysia's vision of a green economy means moving beyond its status as a manufacturing hub, to establish low-carbon emissions, highly efficient use of resources and a healthy, well-educated population.

The Malaysian government is supporting new regulations, and policy makers are leaning towards the pursue and addressing issues in environment protection, climate change and biodiversity. The Malaysian Plan continues to strengthen the nation's resilience to natural disasters and more fundamentally charts a paradigm shift towards green growth. With the incentives of the green economic model, green development is coming to cities of Malaysia. Figure 2 shows the context in which Malaysia adopted the green growth definition.

Malaysia has adopted a green pilot city "Iskandar Malaysia (IM)" study that follows the philosophy of green growth. Since its launch, it has seen tremendous success in attracting investment support from international communities. IM is pursuing green growth in the planning (Zikri Zahari et al. 2016), development and management of this rapidly growing economic region in southern Johor, a state at the south end peak of Peninsular Malaysia bordering Singapore. Iskandar Regional Development Authority (IRDA) was created to drive and manage this growth and has put in place the

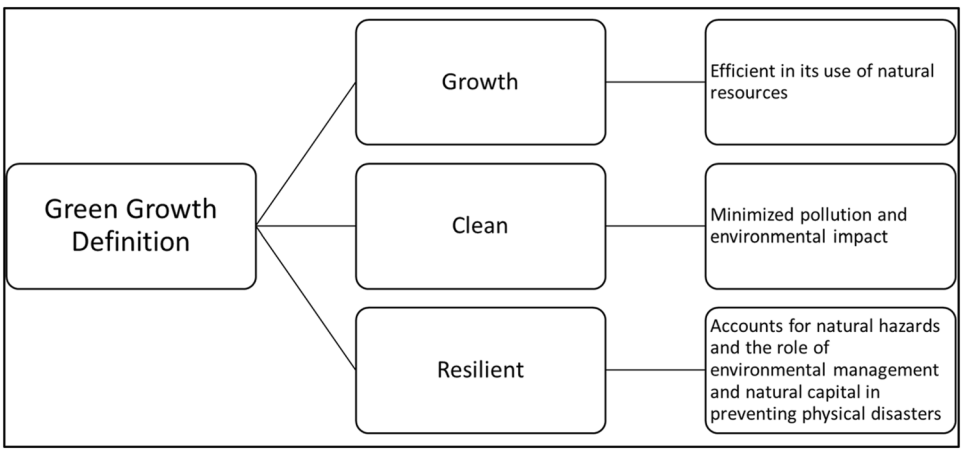

Fig. 2 Malaysia's adaptation of Green Growth Definition (The Economic Planning Unit 2017)

Green Economy Guidelines (GEG), covering the nine sectors being promoted to effectively develop IM into a global hub for green industries. The preparation of the GEG is one of the 281 programmes outlined in the Adopted Low Carbon Society Blueprint 2025, which IRDA launched in November 2012 at COP18 in Doha, Qatar (Chin et al. 2015).

The GEG provides investors with a clear guide to IM's strategic environmental and economic policy direction. It covers policy framework, incentives, institutional requirements, approval processes and procedures, planning compliance, monitoring and reporting mechanisms regarding investing in the green industry in IM. Figure 3 summarises a low-carbon society aspiration for Malaysia.

Until 2019, Malaysia's energy mix, comprised by petroleum – 29.5%, natural gas – 63.1%, coal – 1.7%, hydroelectric power 3.4% and others – 0.9%, has proved to be reliable in meeting energy needs thus far (Chin Hao et al. 2019). The situation is expected to change as Malaysia is projected to become a net energy importer by the end of the 2030s, unless new energy sources of indigenous origin are found and successfully developed. Strategies for the use of renewable energy improving energy efficiency and conservation practices and enhancing the supply security of coal for electricity generation options to the year 2030 and beyond are available; successful implementation of the proposed strategies will require reducing the government's subsidies on gas prices and electricity tariffs in tandem with a common regulatory framework overseeing efforts by all relevant entities involved.

Malaysia's total greenhouse gas (GHG) emission in 2016 was 334,635 Gg CO_2 equivalent (CO_2-eq), and the total removal was 259,146 Gg CO_2-eq. The net emissions after accounting for removal were about 75,488 Gg CO_2-eq., which is the highest since 1994 as shown in Table 1. The

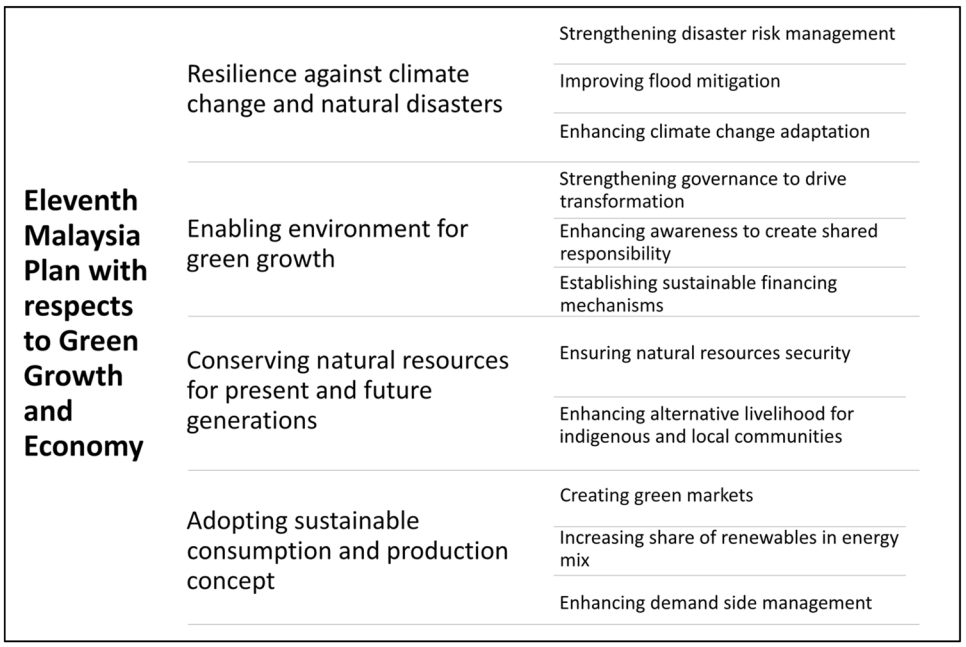

Fig. 3 Low-carbon society in Malaysia—adapted from *(*The Economic Planning Unit 2017*)*

Table 1 Malaysian GHG emissions 1994–2016 by sectors—adapted from (Ministry of Environment and Water 2020)

Sector	Emissions/removals (Gg CO_2 eq)					
	1994	2000	2005	2011	2014	2016
Energy	92,050	143,141	198,514	225,061	253,517	251,695
Industrial processes and product use	5678	11,532	15,102	17,058	20,258	27,348
Agriculture	7867	8547	10,028	9688	10,851	10,627
LULUCF (emissions)	137,523	54,299	35,985	3560	3317	17,801
LULUCF (removals)	211,843	235,244	233,918	242,586	267,148	259,146
Waste	12,605	16,671	21,928	26,957	28,216	27,162
Total emissions (without LULUCF)	118,517	180,096	245,797	278,982	313,073	316,833
Total emission (including LULUCF emissions part only)	256,040	234,395	281,782	282,543	316,390	334,635
Net total (after subtracting sink)	44,197	– 849	47,864	39,956	49,242	75,488

energy sector that comprises of fuel combustion activities for the energy industries, transportations, manufacturing industries and construction, fugitive emissions from solid fuels with oil and natural gas contributed to 79.4% of GHG of which 70% were CO_2 (Ministry of Environment and Water 2020). Table 1 summarises the Malaysian GHG emissions by sectors.

It was also reported that in 2016, a total of 49.4Gt CO_2eq was emitted globally of which the energy industries contributions were estimated at 34.58 Gt CO_2eq (73%), which includes emissions from transport of 7.85Gt CO_2eq (15.9%). The emissions from energy industries were mainly due to the fuel consumption by the power and auto producers resulting from producing electricity, petroleum refining and natural gas utilisation (World Resources Institute 2020). Figure 4 shows the GHG emissions plot against population trends from a recent review (Wan Mansor et al. 2020). It can be observed that the dependence on coal increased beyond 2008. This happened after the oil crisis in 1973 and 1979. The Malaysian government has adopted the Four Fuel Policy in 1981 that aimed to increase fuel diversity (i.e. natural gas, coal and hydro). The share of gas in primary energy consumption of Malaysia increased from 1% in 1971 to around 40% in 2008. However, since 2009, Malaysia started facing gas shortages due to declining domestic gas supply and high demand due to fast economic growth. This has resulted in an increase in share of coal and oil, from 18 and 28% in 2008 to 23% and 31% in 2013, respectively (Global Energy and CO2 Data 2015).

Technologies for decarbonisation

As governments and firms embark on a strategy to curve emissions, they should be prepared for the long haul. Through the energy sector, which includes power generation, transport and industries, national policies have been developed to address the challenges of climate change effectively and holistically (MOSTI Malaysia 2018). Mitigation actions include renewable energy initiatives, energy efficiency, advanced technologies in coal and gas power plants, efficient public transportation, energy efficient vehicles, electric vehicles and biofuel initiatives (Qazi et al. 2019).

Carbon capture, utilisation and storage (CCUS)

CCUS is a solution that reduces GHG emissions that encompasses methods and technologies to remove CO_2 from the flue gas and the atmosphere, followed by recycling of the CO_2 for utilisation and permanent storage options (Ofélia and de Medeiros 2021). This relies on separation of the CO_2 using sorbent or membrane technology. CO2 can also be injected into the reservoirs for geological storage (i.e. deep saline aquifers, depleted oil, and gas fields and/or unmineable coal seams) or into ageing oil fields for improved oil recovery (IOR). Another mitigation strategy is the use of renewable energy technologies. Thanks to the decrease in the cost of wind and solar power equipment and mature hydroelectric power industry, renewable energy already accounts for over one-quarter of global electricity production. In the last 10 years, we have observed more of the oil and gas companies investing heavily in renewable energy technologies,.

Natural gas as cleaner alternative

The use of natural gas represents a cleaner energy option when compared to oil and coal. The global population is expected to increase by a billion by 2030, and abundant natural gas is a fossil fuel energy sources that can meet growing demand for the medium-term future. Hence, natural gas will be serving as an intermediary during the energy transition, since it reduces CO_2 emissions and improve air quality, wherever it has been replaced for coal, gasoline and diesel. This has been achieved for electricity generation in UK, USA and China, whereby increased use of natural gas is enabling to reduce air pollution caused by power and industry (SHELL 2018). However, natural gas can have a negative effect on climate change the same as coal due to

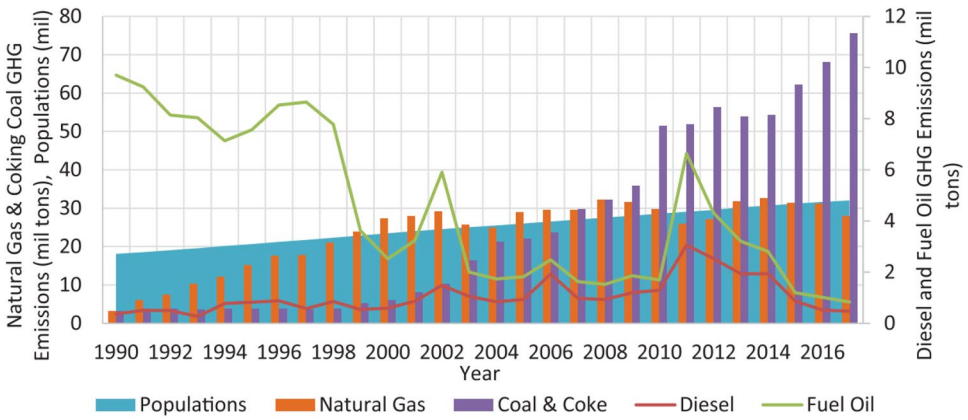

Fig. 4 Time-series plot for GHG emissions and population trends (Wan Mansor et al. 2020)

the associated methane emissions during production and distribution. Natural gas is approximately 90% methane which is a potent greenhouse gas and major contributor to climate change.

Nature-based solutions

Nature-based solutions (NBS) are basically to utilise the resources already present in nature to address climate change or societal challenges (Bayulken et al. 2021). They can be either nature-based, nature-derived or nature-inspired solutions. In a publication by International Union for Conservative of Nature (IUCN): French Committee, NBS are further defined as actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits. Examples of NBS projects across the continents adapted from 2021 IHS Market Survey and examples of Malaysia's initiatives are presented in Fig. 5.

In Malaysia's CO_2 balance, it was reported that nature-based solutions on CO_2 removals by sinks occurred in the Land Use, Land-Use Change and Forestry (LULUCF) and Agriculture Forestry and Other Land Use (AFOLU) sectors (MOSTI Malaysia 2018). Net removal from the AFOLU-LULUCF sector amounted to 263,831 Gg CO_2eq. Emissions considered in *Forest Land Remaining Forest Land* were carbon loss from commercial harvest, forest fires and emissions from drained peat swamp forests. As for *Crop Land Remaining Crop Land*, emissions considered were from total harvest and cultivation in drained peatlands. The categorised natural sinks in Malaysia were reported as not enough to trade off the carbon amount of the nation's utilisation and production. Hence, the energy sector has been heavily scrutinised to provide actions by mitigation scenarios through technology.

Public perception on energy transition in global context

Public perception studies on carbon dioxide removal (CDR) technologies in the USA and UK show that public perceives CDR as offering too slow a response to the climate crisis (Cox et al. 2020). In China, the survey reported some issues on public understanding of the climate sciences, society's knowledge and acceptance of low emission technologies, especially on Carbon Capture and Storage (CCS) technology (Zheng-Ao et al. 2015). It also examines the public interests and concerns about the positive and negative impacts of CCS technology, and public attitudes towards CCS policies supported by the government. In Singapore, (Sonny et al. 2013) argue that the government plays a central role in policymaking, communications and influencing on issues

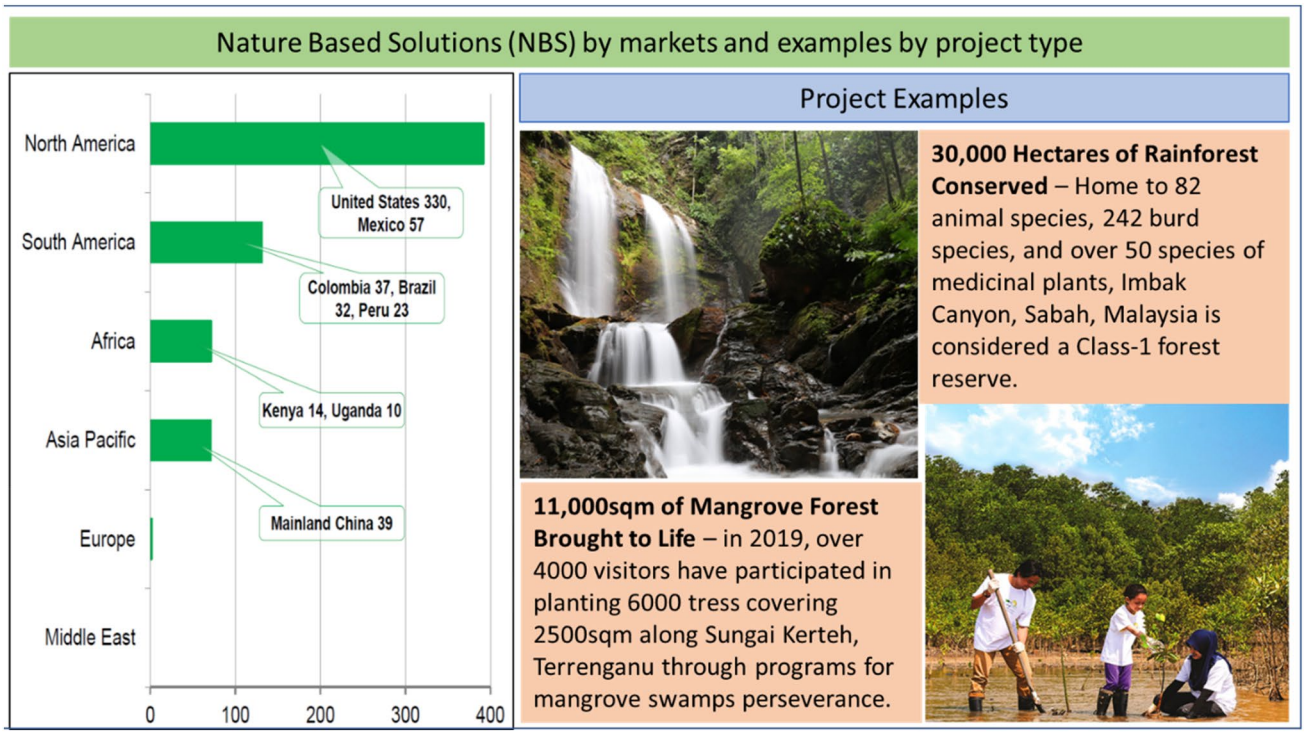

Fig. 5 NBS projects across the continents adapted from 2021 IHS Market Survey and Malaysia's NBS project examples (https://www.petronas.com/sustainability/safeguard-environment)

of climate change and sustainability where the public generally do not openly criticise its decisions. A study by (Dowd et al. 2014) comparing Australia, the Netherlands and Japan, focussing mainly on CCS shows that the public had a general understanding of CO2 but poor knowledge of its scientific dimensions and technological impact towards implementation. Ostfeld and Reiner (Ostfeld and Reiner 2020) explored how the public in Scotland perceive their country's path to decarbonisation. To understand public awareness, they used focus groups and citizens' juries to assess public perception of climate policy, renewable energy and low-carbon energy technologies. Citizens' juries were calling for a more diversified energy portfolio involving RE and believe that CCS technologies should undergo further R&D to address better environmental and safety concerns. In France, Minh et al. published a survey on the public perception of CCS using sample of French residents aged 15 years and above (Minh et al. 2009). They explored respondents' awareness about CCS by comparing the variability of the results relative to semantics used such as storage and sequestration describing CCS. Their survey showed that the French public largely recognises climate change as a serious problem and the idea of CCS could potentially fit positively depends critically on both risks and political use of this technology. Marjelain et al. conducted two research methods in Netherlands to analyse public opinions of Dutch on CCS using informed and uninformed questionnaires (Marjolein et al. 2009). Their studies suggested that the public were more supportive of CCS technologies when they were well informed about global warming than being uninformed.

A review conducted by Selma et al. on public awareness of CCS technologies globally concluded that the practicality of such technologies, their acceptance and implementation success were highly dependent on their local social, economic and political context (Selma et al. 2014). In the UK, a comprehensive research study was conducted as part of the country's Social Intelligence Report regarding public attitudes on clean growth (Prior 2019). The primary focus was to gauge public response to climate change and energy in the UK. Public awareness was reported to be low, the level of agreement on the existence of climate change was broad, and society is not considering it seriously.

In Malaysia, there are a few studies conducted on carbon tax and studies regarding awareness of carbon reduction technology (CRT) towards climate change impact, but those studies are mainly focusing on CCS technology. For instance, (Zulkipli et al. 2016) concluded that while Malaysians are aware of the impacts of CO_2 emissions and climate change, they do not have a good understanding on mitigation plans and technology deployment (i.e. CCS). Hence, more efforts are needed to increase public awareness and knowledge on these areas.

Our study has examined the public perception and awareness of other CRT in both energy and transportation sectors coupled with nature-based solutions considering social, political and economic presence.

Survey methodology

In this survey, a modified Delphi study approach (Dalkey and Helmer 1963) was utilised to know the perception of respondents with different levels of expertise opinions gathered via a questionnaire. The questions for the survey took a similar approach as reported by Curry et al. (2004). We conducted the survey to explore the attitudes, knowledge and perceptions of the NOC employees to emulate a focused public group reaction and response to Malaysia moving towards a low-carbon society. We examined the respondents' perception and understanding of various CRT, its affordability and their view on additional nature-based solutions through two focus groups in the modified Delphi study. We utilised various response formats (*i.e.* dichotomous, nominal, ordinal, interval level and continuous) while designing the questionnaires (Xibei et al. 2020). The survey was designed to take no more than 10 min to complete. It contained five demographic questions and fifteen survey questions across five sections. The design and development of the survey questionnaire was based on the current social, political, economics and technology context in Malaysia.

The first section of the survey explored respondent's understanding on climate sciences. The second section investigated actual and perceived knowledge of CRT and nature-based solutions offered by energy companies and/or government policies for the usage as energy in utilities and transportations. The third section measured the respondent's understanding and acceptance of carbon tax while the fourth section examined the willingness of respondent to pay the cost trade-off for renewable energy. The final section explored respondents' perception on initiatives of Malaysia's oil and gas companies towards decarbonising the company and nation. Most questions used priority ranking that prompted the respondents to display responses from most promising to least promising, most influential to least influential or simply ranking based on level of importance. Online Resource 1 presents the full survey questionnaire.

Survey representation

Data from total of $n = 94$ survey participants were collected from two focus groups. Group 1 (G1) was collected from a more informed participants since they come from

the research and technology division of a national oil and gas company that deals with decarbonisation technologies while Group 2 (G2) was from the same company but were not in the research and technology division. The objective was to compare the perception of both groups given one is providing the solution for decarbonisation while the other group were from the less informed category. G1 had $n = 65$ respondents comprising of 63% male, 34% female and 3% undisclosed. Figure 6 shows that the survey included a split between different age groups, with the least representation from the younger age group (21–29) of only 2% and majority represented by the middle age group (30–39 years old) of 66%. Almost 94% of all respondents in G1 were Malaysians with 5% from other nationalities and 1% from

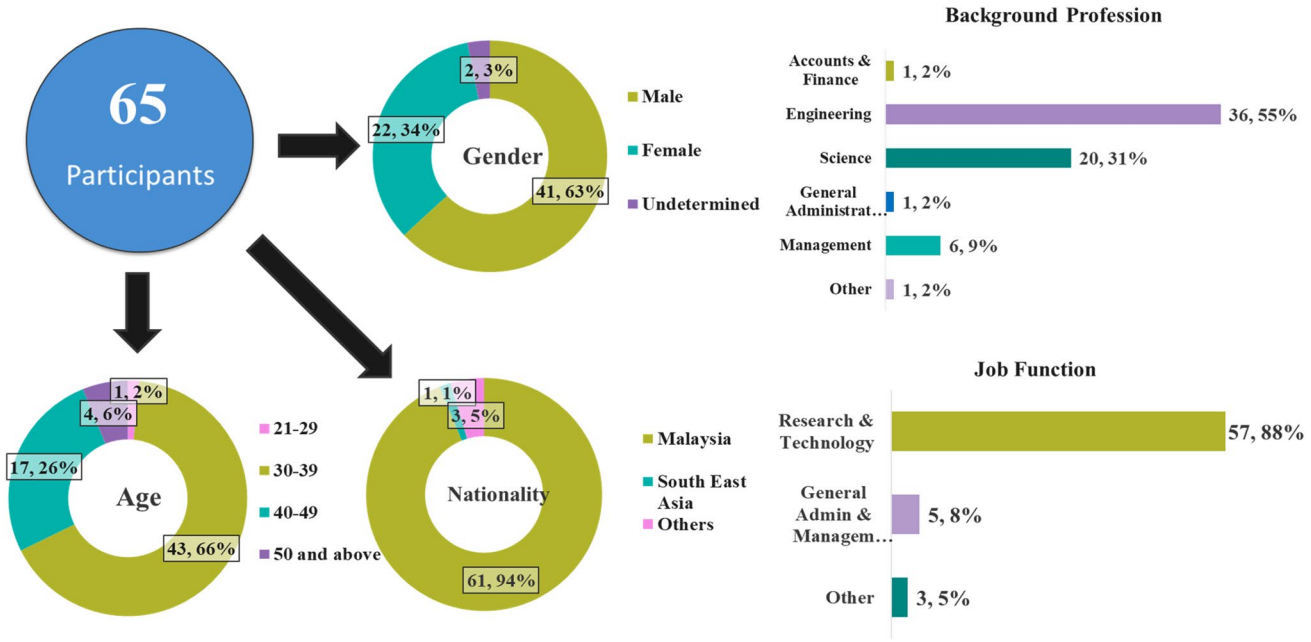

Fig. 6 Demographic details of Group 1

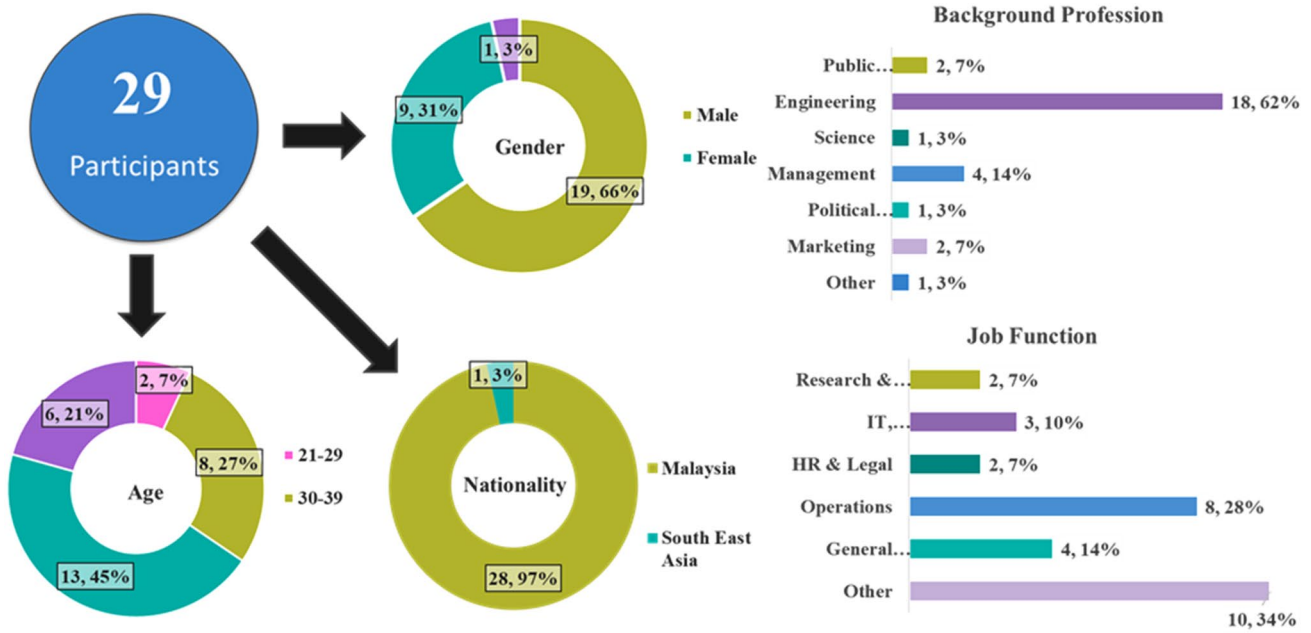

Fig. 7 Demographic details of Group 2

Southeast Asia. G1 showed a majority of 55% with engineering backgrounds followed by 31% in sciences and 2% each from accounts, administrations and other backgrounds. In general, 88% of the respondents stated their job functions as being from research and technology while the rest were from administrations, management and others. Figure 7 shows that G2 had n = 29 respondents with 66% male, 31% female and 3% undisclosed. This group also had a split between different ages, with the least representation again in the younger age group (21–29 years old) of 7% but with majority represented by the high middle age group (40–49 years old) of 45%. 97% of all respondents in G2 were Malaysians with a 3% from Southeast Asia. G2 showed a majority of 62% with engineering as background profession followed by 14% in management with the least of 3% each from science, political science and others. Out of all the respondents, the majority of 34% have depicted their job functions in 'other areas' followed by 28% in operations with the least of 7% each in research and technology, human resources (HR) and legal.

Results and analysis

The first section of the survey explored the respondent understanding of climate sciences, gauging the importance of Malaysia transitioning towards a low-carbon society. A total of 86% of respondents from both groups were aware and applauded the fact that Malaysia is now taking steps to make changes to our normal way of doing things to be on par with nations that aspire to be low-carbon emitters. 79% called for lower GHG emissions from energy and transportation sector and movements towards the use of renewable energies, cleaner transportation through EV or hybrids and calling for less fossil production. Many agreed that a sustainable lifestyle will promote a cleaner (less CO_2), healthier and greener (less pollution) society and agreed that Malaysia should adopt SDGs from the Paris Agreement. The results from the first section were in line with another nation in the same region. Our neighbour Singapore, for example, has commissioned a survey by the National Climate Change Secretariat (NCCS) from May to July 2019 to gauge public perception and views on climate change. Public awareness for Singapore was high at about 94.9% where most are aware of the impact of climate change and 95.4% of Singaporean responded strong support for Singapore in making a shift to a low-carbon economy (National Climate Change Secretariat Singapore 2019).

The second section of the survey investigated actual and perceived knowledge of carbon reduction technologies and nature-based solutions offered by energy companies and/or government policies for utilities and transportations. Both groups perceived that using solar photo voltaic is the most promising approach to reduce CO_2 emissions for electricity generation, which is currently sourced through a combination of natural gas, hydroelectric, and coal in Malaysia. Figure 8 shows that both groups favour more the use of CCU than CCS, suggesting that participants prefer converting waste to useful materials. These results corroborate with other studies done on CCS, which showed that the public

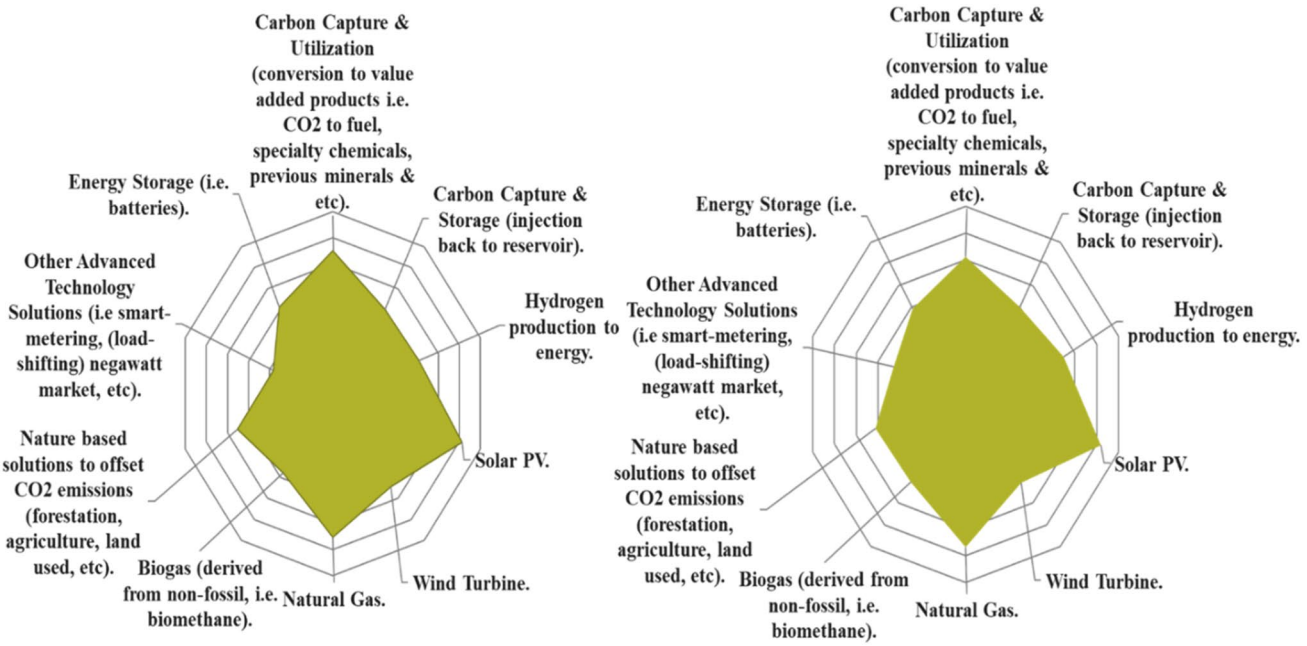

Fig. 8 G1 (left) and G2 (right) relative most promising factors in electricity sector

is generally less accepting of CCS due to safety and risks reasons (Ostfeld and Reiner 2020). All respondents agreed that for energy efficiency technologies, biogas and wind are the least promising. Unexpectedly, nature-based solutions for both groups were equally divided. Perhaps the public required more awareness and/or evidence on how nature-based solutions can help to compliment other solutions in reducing carbon emissions. We found similar trends comparing these results from our respondents to another region in Scotland covering public perceptions of Aberdeen and Edinburgh. Public opinion there has also placed the highest acceptance to renewables (*i.e.* first solar followed by wind), seconded by natural gas and lastly on CCS. It was also reported that the majority (53%) of the British public do not trust energy providers; Scottish respondents were 48% not trusting their energy providers and only 4% of respondents expressed a lot of trust. The primary reservations are reported to be related to costs associated with CCS and concerns about safety.

Figure 9 shows that both groups agreed that using hybrid electrical vehicles (EV) will be the best to reduce emissions, followed by plug-in EVs. The trends are consistent for both groups having the perception that changing the type of fuel to bio-based or synthetic may not contribute much to lowering carbon emissions. The worst-case scenario might be doing nothing and maintaining status quo. It was observed with regard to public awareness and education on what constitutes to carbon emission; contributions from passenger vehicles gained popularity with EV being the solution to it, casting dominance from public's perception.

People believe that changing the engine from internal combustion to electric will prevent fossil fuel consumption. However, studies show that changing to synthetic fuel or biofuel can also reduce CO_2 emissions in the range of 50–80% (Navas-Anguita et al. 2020). While using EV is perceived to generate almost zero carbon footprint, we need to be careful on this understanding. This is because electricity used to charge the EV may have produced the same or even more emissions as an internal combustion engine vehicle. A similar study in Spain on technologies to produce alternative fuels (biofuels, electricity and hydrogen) for road transport has also reported strong regards that it should be produced based on renewable energy and the retirement of fossil fuels would involve high reduction in GHG emissions (Navas-Anguita et al. 2020).

The third section of the survey measured the understanding and acceptance of respondents towards carbon tax as shown in Fig. 10. As the figure shows, both groups showed the same trend with regards to Carbon Tax questions. The majority (G1-80%, G2-66%) agree that implementing a carbon tax is a key mechanism to achieve climate goals and both groups also agreed that Malaysia should implement a carbon tax (G1-86%, G2-79%). However, the majority of both groups (G1-63%, G2-62%) also agreed that they have no idea where the revenue from a carbon tax should be distributed, similar to a study by (Wong et al. 2019). A survey conducted for 321 people from Delhi, Mumbai and Bangalore (India) has reported major findings of the study which suggested that socio-economic factors, especially income, education and age, have significant role in determining willingness to pay for carbon tax. In short, people are willing to to pay despite being a developing nation because they care and want to protect the environment for future generation but

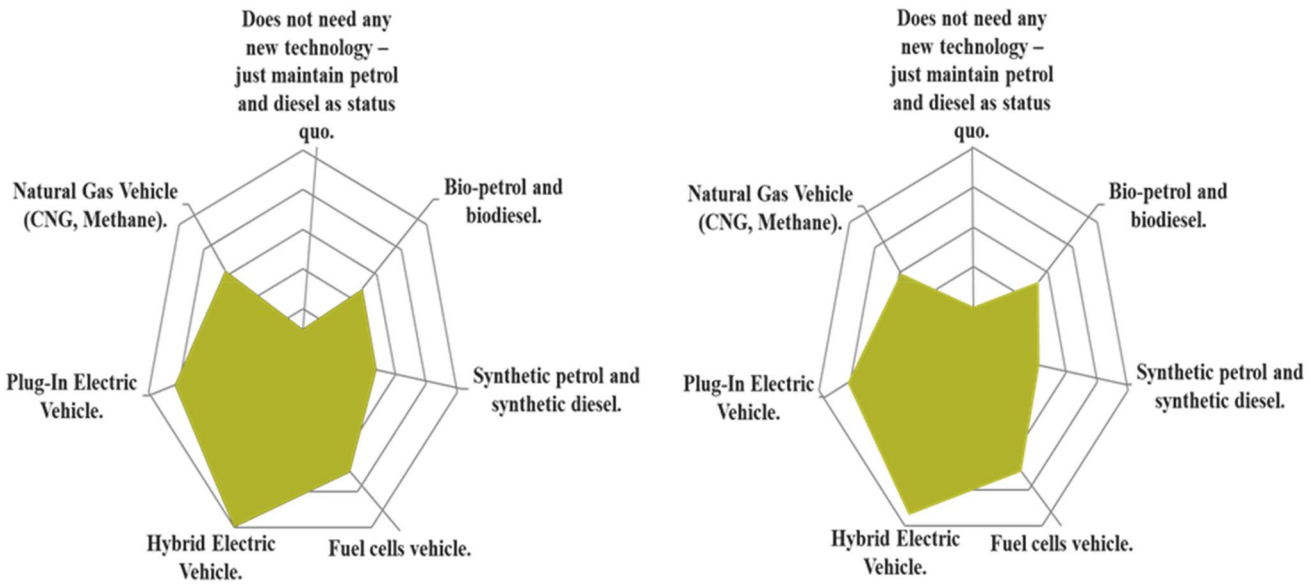

Fig. 9 G1(left) and G2(right) relative most promising factors in transportation sector

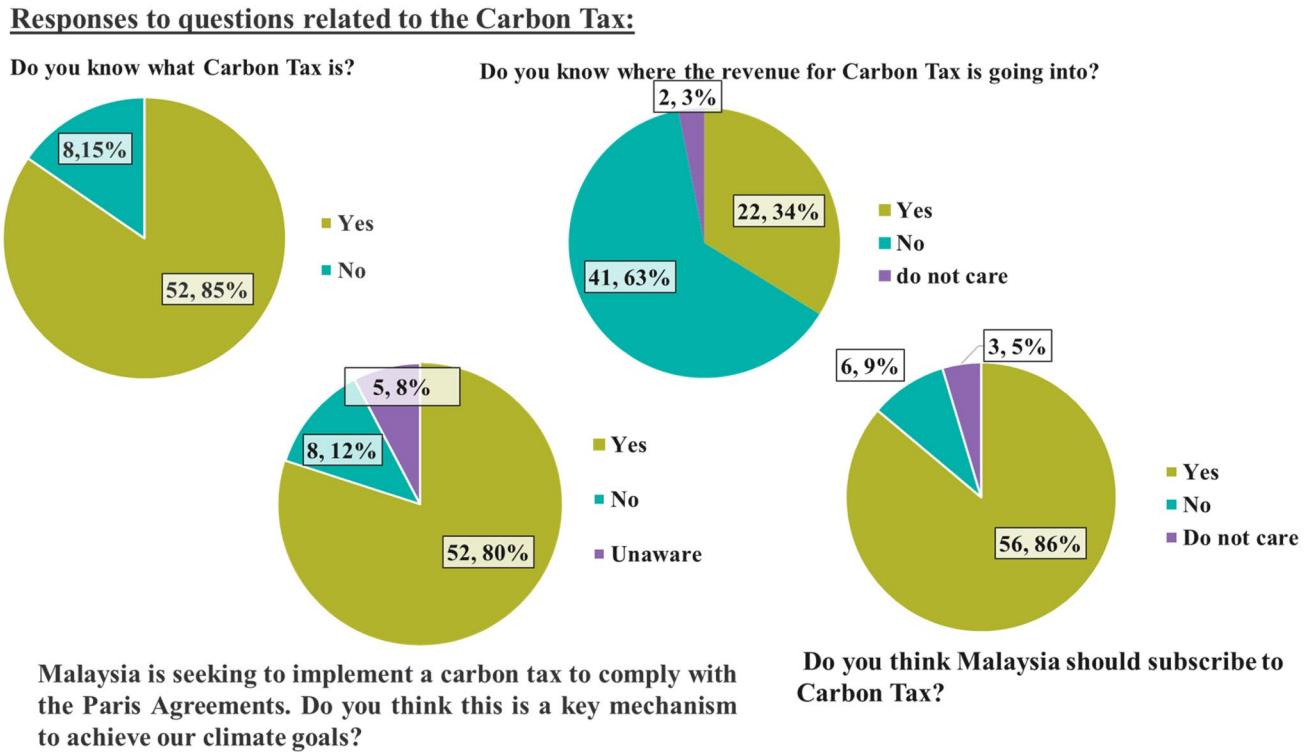

Fig. 10 G1 response on carbon tax questions

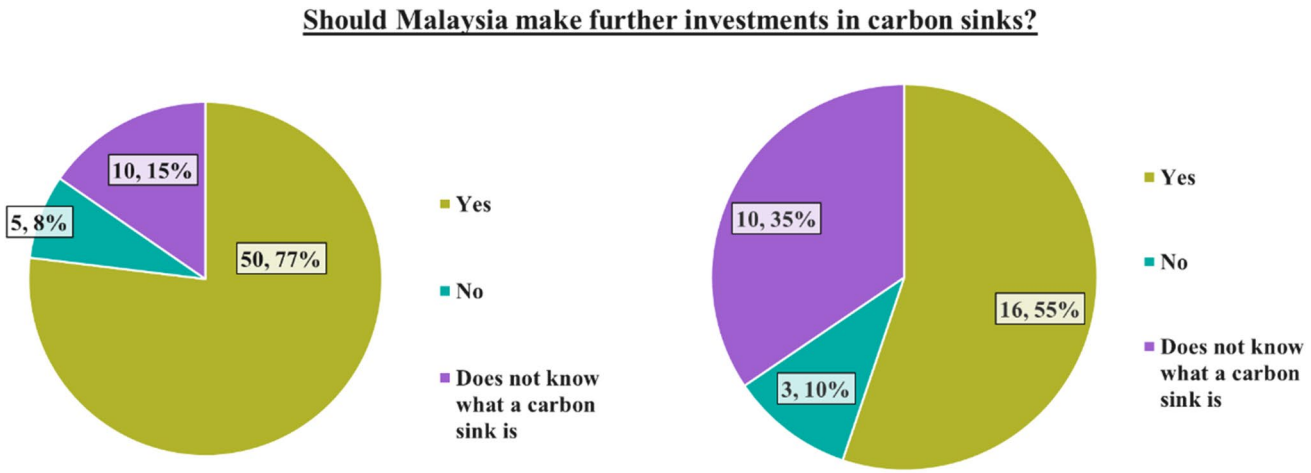

Fig. 11 G2 response on carbon tax questions

are wary of the government abusing tax proceeds collected from carbon tax (Gupta 2016).

The survey question on the importance of carbon sink was important for three reasons. First, because it gauged the participants' understanding about carbon sinks. Second, it provided an understanding of how it has been perceived on the importance of having more carbon sinks. And third, it showed the inclination of the groups perceived that investing into carbon sinks is important. Figure 11 depicts that G1 from the research and technology group had higher awareness of carbon sinks than G2 (77%, 55%). Those who replied yes mainly belonged to the profession group of science and engineering with job functions in operations and research compared to other background profession and job functions. This indicated that perhaps those not in these categories have the lack of awareness on carbon sinks and its importance to climate perseverance.

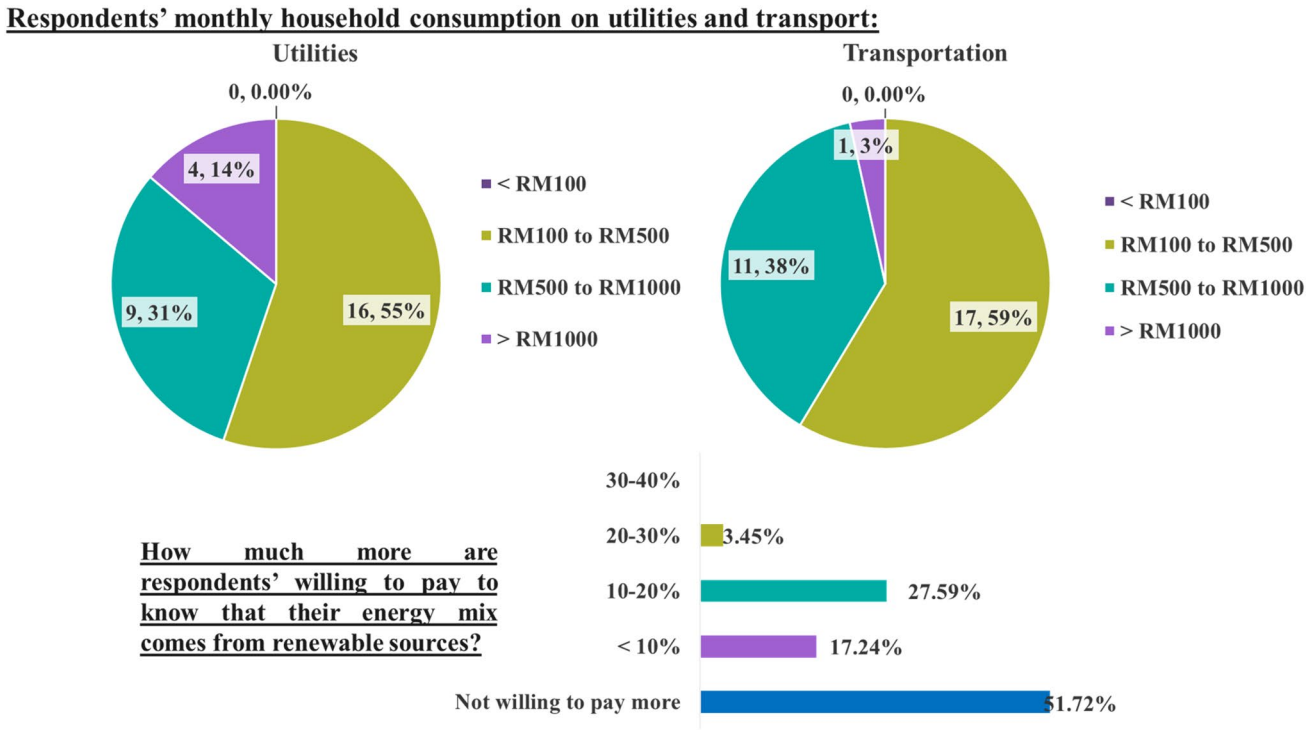

Fig. 12 G1 responses on affordability and willingness to switch from fossil to renewables

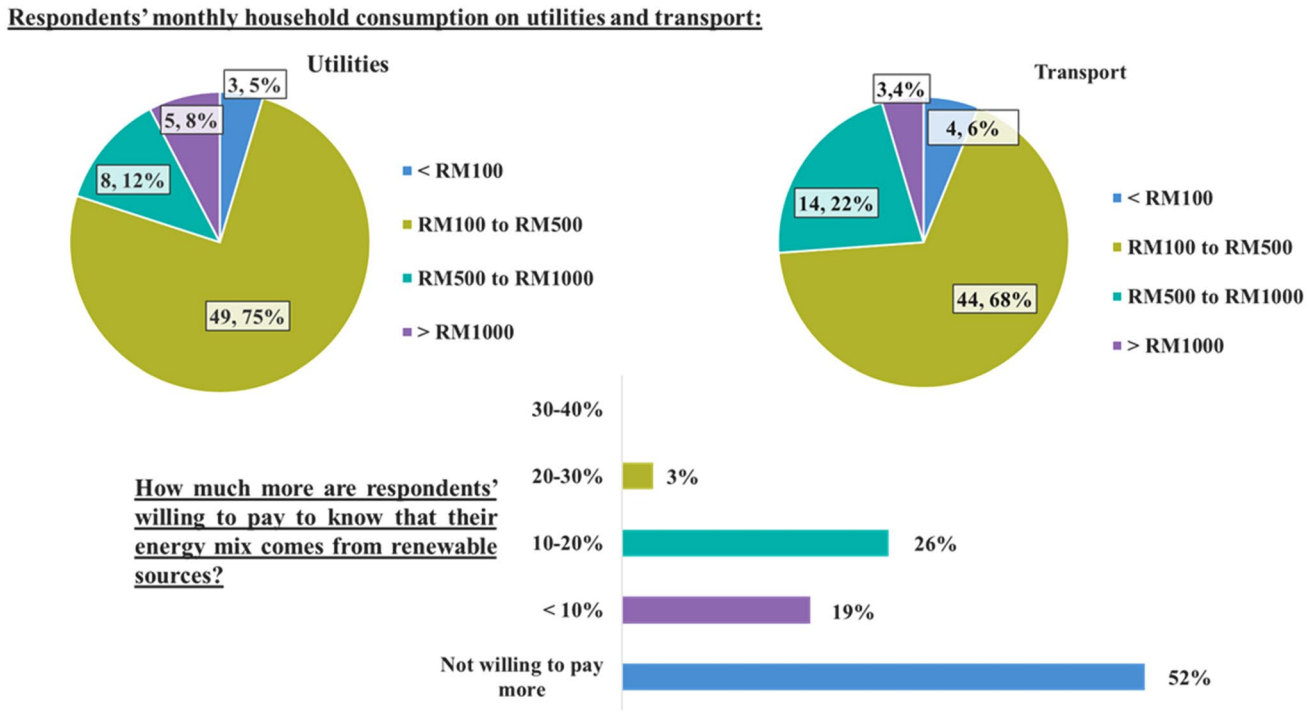

Fig. 13 G2 responses on affordability and willingness to switch from fossil to renewables

The fourth section of the survey examined the willingness to pay the cost trade-off for renewables. Both groups showed most participants spending between RM100 and RM500 for utilities and transportation per month, with G1 having a larger majority in this category (utilities: G1-75% G2-55%; transport: G1-68% G2-59%) as shown in Figs. 12 and 13. Half of both groups would not be willing to pay more for cleaner energy sources for both utilities and transportation. This may not be surprising as Malaysians have been living off subsidies for both and the utilities rates and fuel are heavily subsidised by the government for more than 50 years (Husaini et al. 2019). The survey further showed that those who were willing to pay were not willing to recompense anything more than 20% increment (G1-26%, G2-28%). Compared to our neighbour Singapore, 78.2% of respondents in the 2019 survey are prepared to play their part, even if they are expected to be additional costs and inconvenience as consumers (National Climate Change Secretariat Singapore 2019).

Further analysis revealed that women are willing to pay more for cleaner energy than men (women G1-64%, G2-56%; men G1-37%, G2-47%; total women: men 61%:40%) as shown in Fig. 14. Figure 15 shows that most of the women who are willing to pay more were under the age bracket of (30–39) from both groups while men who are willing to pay more come from age bracket (G1:40–49) and (G2: above 50). Traditionally, Malaysian men are expected to be the bread winner of the family. At the age group between 30 and 39, men seem to be spending most of their incomes on family expenses and hence are decision makers who would not be willing to pay more for cleaner energy and fuel. The data suggest that older men have higher income and are willing to pay extra expenses for cleaner energy and fuel. In contrast, women of the same age bracket of (30–39) may have more disposable income since household expenses would have been borne mostly by men already (Sabri et al. 2020).

Our findings support the idea that women have higher levels of environmental awareness. Indeed, in earlier research, gender-based disparity has been shown regarding attitudes to and the perception of climate change (Viscusi and Richard 2005) and sustainability (Furszyfer Del Rio et al. 2021). Women, for example, have expressed to be "more fearful of the risks of climate change" and that "traditional divisions of labour" account for higher levels of environmental concern among women (Kellstedt et al. 2008). Research conducted in Finland has found that men were more sceptical about climate change-induced impacts (Upham et al. 2015) while (Denton 2002) has argued that women place greater importance on mitigating climate change as they would also be disproportionately affected by it. Women have also been shown to be more likely than men to be aware of environmental concerns such as in healthy food and sorting out waste (Kawgan-Kagan 2015).

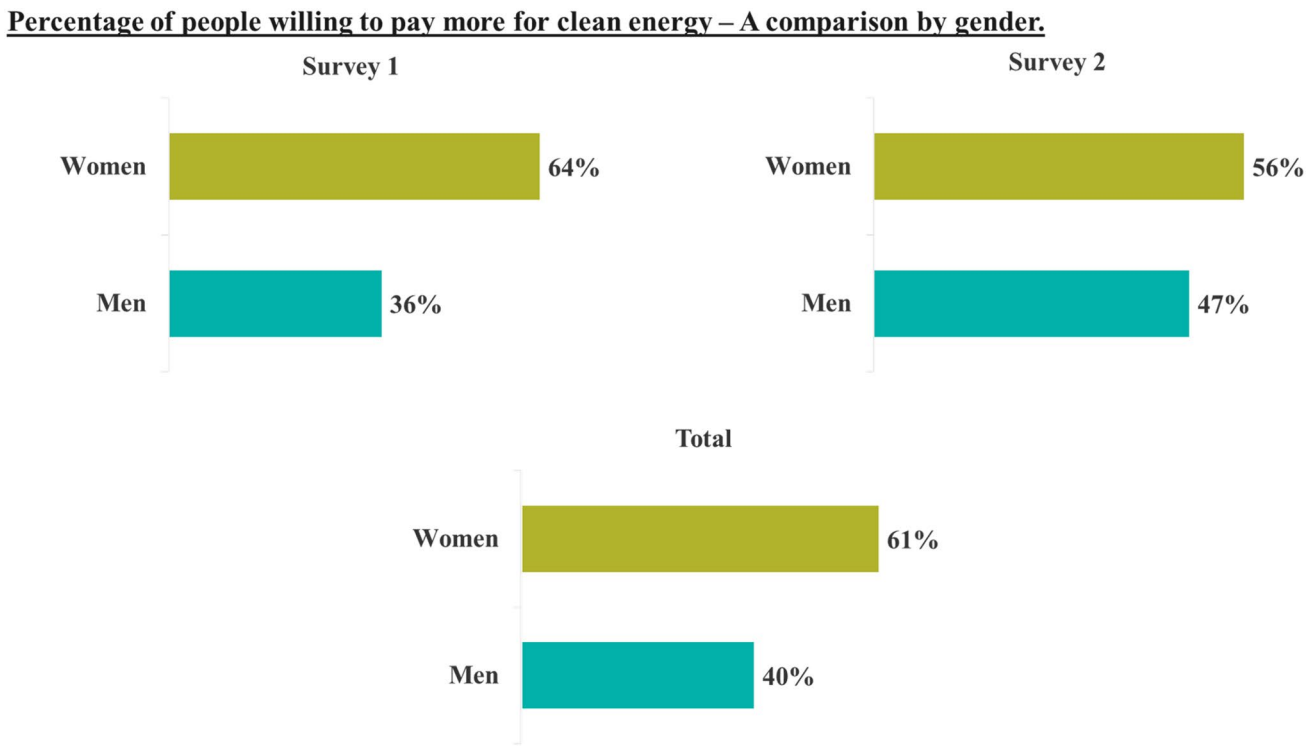

Fig. 14 Women are willing to spend more

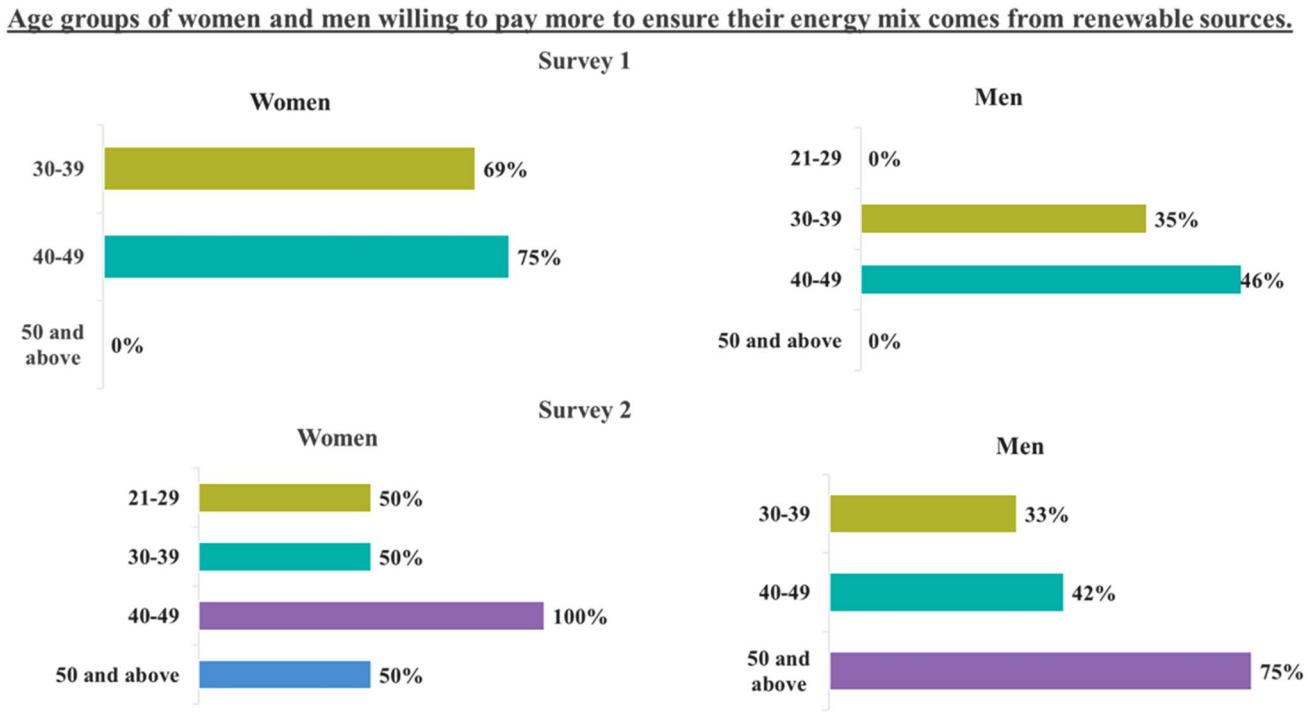

Fig. 15 Age groups of men and women that are willing to spend more

In general, women are more supportive of implementing carbon tax, investing in carbon sinks, and believing that the national oil and gas company can provide energy without harming nature. All women who participated in the survey believe in this irrespective of their professional background and are not limited to engineering and science (67%). Coincidently, men who are not in engineering and science (100%) also seem to support these initiatives compared to about (72%) of engineers and scientists.

The final section of the survey explores respondent perception to initiatives by the Malaysia NOC to decarbonising the company and nation. The data showed that both groups agreed with current sustainable plan and carbon vision of the Malaysia NOC; however, in their opinion, more can be done to achieve this. Some of the feedbacks received included calling on the company to implement the sustainable plans in their current operating sites, developing new energy businesses from renewables while maintaining fossil production with CDR technologies. With regard to challenges, both groups also agreed that political willingness is the main hurdle that needs to be overcome.

The majority of (G1-71%, G2-83%) also believe that the NOC can provide greener energy without harming nature whilst contributing to its well-being. Some believe that if the NOC implements a circular economy strategy, it will reduce waste production by ensuring waste materials to be reused. Venturing into new renewable energy businesses marks the transition to cleaner energy. The company is deploying CCUS via fossil fuel production technologies that will ensure less carbon emissions driving down GHG. NOC involvement in the country's green sustainable initiatives also demonstrates the commitment for ensuring a global sustainable future.

A total of 78% of the respondent felt and agreed that the NOC is on the right path through the new sustainable plan which includes renewable and clean energy businesses (*i.e.* wind, solar, hydrogen). However, implementation requires clear strategy and practice. "It is only the first step to have a plan", as quoted by one of the respondents, "Need a lot of 'walk the talk', be bold on CCUS effort, and green energy growth".

Conclusion

The energy sector is undergoing a transition towards net zero carbon to address climate change. Although climate change is a global challenge, tackling it is a collective approach collating efforts from policies, technologies and socioeconomic commitments. Additionally, there is a big possibility of carbon management using nature-based solutions which subsequently relies on geographical location and recourses available. Implementation of activities towards this energy transition will require significant social commitment, and hence, gauging their perception towards this journey is key. In this research, we have reviewed the Malaysian landscape focussing low-carbon society and conducted a modified

Delphi study from employees in a NOC based in Malaysia to explore their perspectives on the low-carbon transition to support corporate decision-making as part of sustainable governance in supporting Malaysia's Green Agenda.

There are three key findings from this work, which are as follows:

1. Nature-based carbon offset contributions represent around 83.1% of the total and must be considered when addressing Malaysia's carbon emissions since they represent a competitive advantage the nation possesses. Although nature-based solutions need to be preserved and increased, this study portrays that they cannot represent the only solution to the problem. Moreover, current data analysis shows that the Malaysian energy sector is the biggest contributor in term of carbon emissions, accounting to around 54%.
2. Within the energy sector, Malaysia's NOC is the biggest player and has both the calibre and the financial resources to significantly contribute to transferring Malaysia to carbon neutrality by researching and implementing technology-based solutions complemented by nature-based solutions. Hence, the survey that was conducted among the NOC's employees highlighted the whole portfolio of solutions needs to be pondered together in a coordinated effort to maximise the outcome and minimise the financial impact in terms of economical sustainability.
3. Communication and awareness campaign from government in NOC countries along with its holistic coordination between technology-based and nature-based solutions are key for this transition to happen.

The next phase of this work is to take these results and examine literature and case study work of nature-based solutions that complement technological solutions.

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Data availability Enquiries about data availability should be directed to the authors.

Declarations

Competing interests The authors have not disclosed any competing interests.

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