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Exploring socioeconomic and political feasibility of aviation biofuel production and usage in Malaysia: A thematic analysis approach using expert opinion from aviation industry

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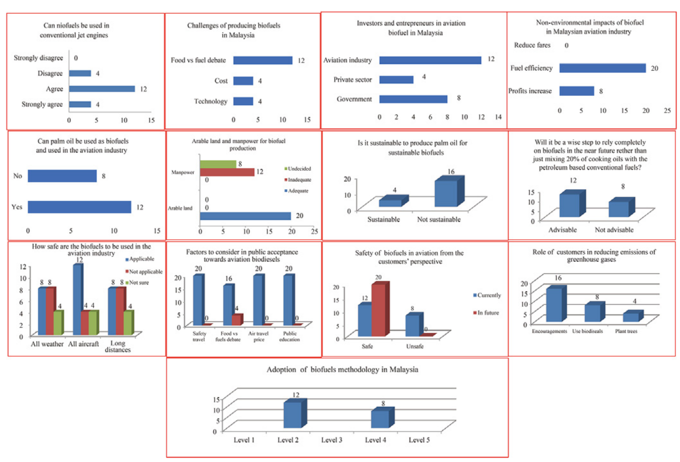
HIGHLIGHTS

- Biofuel technology can reduce the carbon footprint of aviation.
- Expert opinion on a new technology can determine the social economic and political effects of possible usage.
- Experts had mixed reactions on the adoption level of biofuels in the aviation industry in Malaysia.
- Study indicated that the level of adoption of biofuels in Malaysian aviation industry is high.

GRAPHICAL ABSTRACT



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ABSTRACT

Aviation biofuel, which is derived from renewable feedstocks, is typically seen as being fundamentally sustainable. However, a variety of industries are involved in its creation, and several societal actors are involved as well. Therefore, it is crucial to comprehend and assess not just the process's consequences on the environment but also its economic and political ones. Studies examining the social and political implications of aviation biofuel are now uncommon in scholarly literature. The aim of this study, therefore, is to assess key effects of economic, social and politics in aviation biofuel production and usage in aviation industry in Malaysia. This paper addresses this gap by investigating the issues with pertaining to economic, social, and political effects of using biofuels in aviation,

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usage, adoption, and challenges in aviation industries. A grounded theory approach in qualitative data analysis was used to examine 20 interviews with experts of varying roles and experiences in aviation. Semi-structured were used to interview experts to answer, respond to or comment on them in a way that they think best. Discourse analysis method was used for data collection and analysed using thematic analysis. A total of 21 themes were identified with the first dataset (socioeconomic feasibility) had 16 themes and second dataset (political feasibility) had a total of 5 themes. The study revealed that experts had mixed reactions on the adoption level of biofuels in the aviation industry with most of them indicating that the level of adoption of biofuels in Malaysian aviation industry is high.

1. Introduction

"Global warming is caused by a build-up of carbon dioxide (CO_2) acting like a planetary duvet and trapping heat in the atmosphere. Climate Change refers to the increase in the average temperature of the Earth's near-surface air and oceans since the mid-twentieth century and its projected continuation. The main cause of climate change is attributed to the build-up of carbon dioxide (CO_2) in the atmosphere. While every living thing produces CO_2 naturally, human activities such as the combustion of fossil fuels and deforestation have caused the concentration of atmospheric carbon dioxide to increase by about 35% since the early 1900's. Despite the impacts of the pandemic, aviation activity is expected to grow over the long term. Unless aviation activity can be decoupled from CO_2 emissions, this growth will lead to increasing impacts on climate change [1]. Experts believe that the increasing global temperature may cause sea levels to rise, exacerbate the intensity of extreme weather events, and affect the amount and pattern of global precipitation. Other effects of global warming will include changes in agricultural yields, trade routes, glacier retreat, species extinctions and extension in the ranges of disease vectors [2]". "Worldwide, flights produced 705 million tonnes of CO_2 in 2013 [3]". In addition to CO_2 from fuel combustion, airplanes can also emit methane (CH_4), nitrous oxide (N_2O), hydrocarbons (HC), particulate matter (PM), sulphur oxides (SO_2), and nitrogen oxides (NO_2). GHG by-products from phases incorporated in the fuel life cycle consist of CO_2, N_2O, and CH_4, are indicated with regards to of CO_{2e} making use of their 100-year global warming possibilities, in accordance to the Fifth Assessment Report (AR5) of Intergovernmental Panel on Climate Change (IPCC) [4,5]. Moreover, certain high-altitude aviation emissions can spur heat-trapping cloud formation [6]. The aviation industry alone consumes 1.5 billion barrels (250 billion litres or 70 billion gallons) of Jet A-1 fuel annually and spends an average of $50 billion [7].

Hypothetically, biofuels are often manufactured from any sort of sustainable biological carbon product, though frequent resources are vegetations which digest carbon dioxide (CO_2) and utilize sun rays to cultivate. Worldwide, biofuels are utilized for transportation, home warming system, energy production and culinary. The two most frequently used feedstock resources for producing biofuels are vegetations abundant in sugars and bio-derived natural oils. Plants which are high in starch (such as corn) or sugars (such as sugar cane) is often manufactured to discharge sugar composition and is fermented to produce ethyl alcohol (ethanol), that is often applied as a crude oil alternative or preservative. Acknowledged as first-generation biofuels, these fuels are likely not appropriate for usage in airplane, due to lack of required efficiency and safety characteristics for advanced aircraft engine usage. The United Nation's (UN) International Civil Aviation Organization (ICAO) utilizes systematic, information-influenced judgement to formulate steps to deal with the ecological effects of aviation [1]. As an illustration, a worldwide CO_2 requirement that controls fuel effectiveness for new aircraft plummeted into effect in 2020 [8] and International Civil Aviation Organization (ICAO) participants come with an aspirational target of 2% yearly fuel efficiency upgrade. Considering such significant assessment of the aviation industry, in 2016, the International Civil Aviation Organization (ICAO) consented the acceptance of an international market dependent strategy to restrict global aviation CO_2 equivalent (CO_{2e}) GHG the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) [8]. CORSIA demands air carriers to reduce CO_{2e}. Discharges that surpass 2019 levels. Considering impact evaluations, CORSIA remains a scheme that offsets either with credits or with the application of CORSIA Eligible Fuels (CEFs), in a way that world aviation accomplishes carbon neutral maturity from 2020 [9]. Nevertheless, bio-based crude oil, frequently found in vegetations such as soybeans, jatropha, algae, corn, camelina and halophytes [10] is refined and can be transformed by chemical procedures to create top-notch aircraft and diesel gasoline. These are generally identified as second-generation biofuels and are applicable for aviation.

Regardless of constant improvements in gas effectiveness, primarily accomplished by new aircraft going into the fleet (from fuel usage of 4.4 l/100 passenger-km in 2005 to 3.4 in 2017 (−24%) in European countries, and yearly enhancement of 2.3% between 1991 and 2009 in America together with proceeded down trend through 2018) [6–8], decarbonizing modern aviation continues to be a complicated process, as a result of fast development of the aviation sector [9]. This is especially valid for worldwide aviation where growth that is pre-pandemic had been above 4% per year [10]. Renewable propulsion choices (hybrid systems and electric driven) and options to aircraft fuel have now been proposed but have just been tested on the pilot-scale to date. There are several unsettled technical dilemmas connected with these possibilities [11]; consequently, providing a strong foundation for worldwide aviation CO_2 discharges at 2019 grade will probably need the utilization of drop-in sustainable aviation fuels (SAFs). Drop-in SAFs tend not to require existing engine or system customizations, but they might need devoted infrastructure for refuelling [11,12].

Yujie et al. (2015) [11] reviewed the national biofuel policies and strategy plans of the world's leading states. They found that the biofuel sector is within growing phase. Within past 10 years, biofuels advancement is influenced by the governmental strategies, and the authorities has offered continued financial assistance for the entire procedure starting from feedstock, research to commercialization of biofuel trade to minimize financial investment risk. Within last 3 years, the authorities concentrated on the factory and commercialisation initiatives. There are political arguments on the influence of biofuels on environment, GHG discharge grew to become a powered influence of biofuels evolution. America specified a restriction on the GHG discharge during the biofuels manufacturing stage and targeted on the evolution of the enhanced biofuels. Various biofuel corporations have effectively developed marketable biofuels, nevertheless, the initiatives had been impacted by governmental policy changes. It will be an obstacle for the policy developers to maintain general trends of biofuels manufacture whilst obliging to sustainable manufacturing specifications.

Thushara et al. (2015) [12] overviewed the potential and obstacles in the evolution of renewable gasoline for aviation. The manufacturing procedures, feedstock utilized, and the most appealing worldwide initiatives were additionally discussed in this study. They concluded that the manufacture of substitute aviation fuels from sustainable biofuels are extremely appealing engineering which is anticipated to replace the crude oil formulated fuels. Among the renewable fuels, hydro manufactured sustainable jet fuel (HRJ) and Fisher Tropsch fuels (FT fuels) possess the prospective to substitute the traditional gas turbine fuels. The foremost issues with biofuels as aviation fuels are their weak fuel characteristics. The usage of liquid methane and liquid hydrogen fuels are preferred, but high manufacturing price and reduced relevance to traditional gas turbine engines put them as considerably less favoured option. Numerous difficulties develop such as supply of feedstock, rapport of renewable fuels with traditional fuels, ecological issue and manufacturing and dispersion concerns. The growing attention of authorities and global companies can assist the transformation, commercialisation, and distribution chain facilities to huge level. The consumption of used components from various resources that are commonly obtainable as the feedstock can play a role to the problems associated with feedstock expenses.

Cremonez et al. (2015) [13] identified the major environmental, economic and social impacts arising from the production of aviation biofuels in Brazil. They found that aviation biofuels offer very good prospective to enhance the existing array in aviation and can offer energy resources that could strive to prevent the high prices of crude oil. Nevertheless, the necessity for enhancement and optimisation of manufacturing channels is essential to minimize manufacturing expenses of such materials. Raw products for acquiring biofuels possess ecological threat, such as NO_x pollutants, massive usage of arable farmland, deprivation of wild animals and rigorous water system usage, and additionally socioeconomic and political effects, particularly when considering the monoculture agriculture for substantial manufacturing and exportation.

Noh et al. (2016) [14] studied the need of introducing biofuels for the use of the civil aviation sector, and the different possibilities of application of incentive mechanisms if the existing market conditions do not allow their direct commercialisation. The authors found stated that, keeping in mind the present financial circumstances, it is impossible to attain Carbon Neutral Growth within the commercial aviation industry without developing alternate aviation fuels with a scaled-down carbon impact. Although the application of low carbon aviation fuels such as liquid hydrogen tends to be viable and potentially future fuels, only drop-in aviation biofuels are suggested as temporary solutions. Since the drop-in aviation biofuels have exclusively been formulated in research and development scale, the prospective expenses of manufacturing aviation biofuels in commercial scale cannot be determined currently with a perfect degree of precision, but it appears to be more expensive than the existing aviation turbine fuel which is kerosene-based fuel. It indicates the necessity of various industry formulated rewards to motivate the usage of such aviation biofuels and permit the financial circumstances to be developed at big level. There are different encounters in numerous nations of compensation strategies used in different industries, primarily in the automobile industry, however none of these aviation biofuels were evaluated in the worldwide industry under standard guidelines, something crucial in the commercial aviation industry. This needs legal agreements on feedstock, blending and targets, prior to choosing the relevant financial resources. It is essential to establish a generally recognized Monitoring, Verification and Reporting (MRV) method and an evident LCA evaluation computation for both kerosene-based aviation turbine fuel and alternative aviation biofuels to measure the attainable CO_2 emission standards.

Kousoulidou and Lonza (2016) [15] presented the outcomes of a research performed at the European Commission's Joint Research Centre directed at examining the potential development of aviation biofuel, the consequent fuel need and the implementation of aviation biofuels in Europe. Data for aviation biofuel development and consequently the fuel need are planned every year till the year 2030, making use of the year 2010 as the standard baseline year. Information resources are Eurostat reports and actual airline flight data provided by EUROCONTROL. Appropriate factors particularly the number of air travel, the type of airplanes, travellers and production indicators (RPKs) are utilized collectively with fuel usage and carbon dioxide pollutants data. The aim of the European Advanced Aviation Biofuels Flightpath is to make sure the commercialisation and usage of two million tons of ecologically safely manufactured paraffinic aviation biofuels by 2030. Outcomes pertaining to carbon dioxide emission predictions to 2030, exposed a consistent yearly boost in the sequence of 3%, 1% and 4% on the average, offering an effective relationship in comparison to the yearly targeted air traffic development costs. In absolute values, these ratios corresponded to the central, the pessimistic and the positive scenarios correspondingly, corresponding to 360 million tonnes carbon dioxide pollutants in 2030, varying from 271 million tonnes to 401 million tonnes for the pessimistic and positive scenarios, correspondingly.

Mousavi and Bossink (2017) [16] investigated organisational and managing skills whereby organizations can introduce sustainability, mentioned as energetic skills for renewable invention via a back dated longitudinal report of the initiatives of the KLM Royal Dutch Airlines (KLM), which applied its authoritative situation to encourage manufacturing of aviation biofuel. The research recognized vital organisational and managing skills that are building the foundation of the prosperous realignment of an organisation's energetic skills with its renewable invention techniques and revealed the way these skills are developed and enhanced for long lasting invention and how these skills work during the formation strategy of sustainable innovation. The study showed that by developing sensing, seizing and reconfiguring capabilities, a firm can develop a sustainable innovation demonstration project that has an effect on the firm's sustainability strategy and organization, as well as the sustainability strategy and organization of the value chain the firm is part of.

Filimonau and Hogstrom (2017) [17] explored the attitudes of UK tourists to the use of biofuels in aviation. They found that while the public are generally aware of biofuel technology, public knowledge of its specific application in aviation alongside the carbon benefits this brings is limited. The study recommended future policy-making and managerial measures aimed at enhancing public understanding of biofuel technology use in aviation in the UK.

Lu (2018) [18] evaluated the monetary and environmental expenditures of using kerosene based aviation turbine fuels and aviation biofuels on chosen airline flight paths. Price-advantage evaluation and the dose–response technique were employed for assessing the monetary and environmental expenditures of using kerosene-based aviation turbine fuels and aviation biofuels. Chosen airline flight paths commencing at Taipei were applied for scientific evaluation, for the objective of evaluating the usage of various fuels in financial conditions. The usage of aviation biofuel causes significant rise in fuel sales price; nevertheless, it creates in less unfavourable ecological impacts in comparison to the usage of the kerosene-based aviation turbine fuel. The scientific outcomes and susceptibility evaluation revealed that the decrease in ecological expenses can merely surpass the extra sales price of aviation biofuel if the unit ecological social expenses of air-borne emissions are viewed to be very high. The expected rewards for the usage of aviation biofuel in business-oriented routes could appear from some kind of governmental steps that internalize externalities, or through a decrease in aviation biofuel cost (e.g. via subsidy) or by raising the cost of kerosene based aviation turbine fuels (e.g. via taxation). The ecological advantage of utilizing aviation biofuel in commercial airline travel, approximated in financial conditions and contrasted with its additional monetary expenses, offer effective resource for policy creators when employing strategies and rewards for the formation of aviation biofuels.

Deane and Pye (2018) [19] reviewed the challenges and opportunities for a nascent bio jet fuel sector in Europe and presented options to stimulate the sector in Europe. This study found that bio jet fuel has not profited from this rise with just one Member State (The Netherlands) recognizing the alternative of bio jet fuel as an approach of participation to the sustainable transportation goal. Greater expenses, trader hesitation and weak policy awareness at Member State level have provided to the nascent state of bio jet fuel in European countries. An evident and consistent policy situation for bio jet fuel can assist alleviate a few of these concerns. Nevertheless, various other non-policy steps are also necessary to tackle these obstacles.

Filimonau et al. (2018) [20] researched general public viewpoint pertaining to aviation biofuel usage in Poland. Study revealed, people knowledge concerning the viewpoints regarding aviation biofuel development, such as its safety, is certainly constrained and ought to be strengthened. It was noticed, the plausibility of aviation biofuels as an effective common carbon abatement tool had been thoroughly acknowledged but public understanding of its usage in aviation sector had been minimal. Similarly, there had been constrained knowledge on the obstacles linked towards the acceptance of aviation biofuel technology. The research demonstrated, because of restricted public understanding about the use of aviation biofuels, Polish tourists were some-what concerned about this technological innovation as being a safe alternative to existing kerosene-based aviation turbine fuels. This recommends aviation biofuel safety which must emerge as an essential aspect among all public understanding development initiatives as established through the Polish context. Right after public acceptance of biofuel applications in aviation, especially when safety issues are strengthened and acknowledged to public, there is greater opportunities for such an innovation to obtain consumer assurance in Poland.

Neuling and Kaltschmitt (2018) [21] presented a comprehensive evaluation of various manufacturing routes for bio-kerosene in view of technical, economic and ecological elements. Four various procedures with two types of biomass feedstocks were recognized, established on comparable presumptions, and simulated with an industrial procedure modelling application. Outcomes revealed that in words of energy efficiency, the HEFA procedures appeared to possess the ideal efficiency attributes (90% in total and 60% kerosene efficiency), relatively minimal manufacturing expenses (890 €/t) and reasonably lower GHG by-products. All the steps structured on lignocellulosic biomass displayed very good outcomes from a GHG-reduction aspect. From financial point of view, AtJ utilizing wheat grain as feedstock (AtJ-WG) appeared as an ideal choice, ensuing in biokerosene manufacturing expenses of 827 €/t.

Dodd et al. (2018) [22] identified a crucial variation in business outlooks as well as affiliated important understandings on the aviation biofuels sector in Australia, Germany, and the USA. Authors examined the ideas of creators to assist this type of renewable energy, along with end consumers, for instance airlines. In their reports, a motive of business optimism and cynicism appeared. Candidates having encouraging industry perspective seemed to plan distinctly than those with a cynical industry outlook. On the other hand, the contrary mindsets were found to delay development caused by variations in accomplishments and opinions. The difference in beliefs that has been found using interview information, that varied with document information, revealed, policymakers, entrepreneurs, intrapreneurs, and academicians should bring into consideration personal communications whenever assessing the upcoming prospective of a sector. The research even revealed geographic distinctions within sector outlooks between aviation biofuel business owners as well as several investors in Australia, Germany, and the USA. Of these three countries, the institutional conditions are most favourable for aviation biofuels in Germany. However, numerousness of outlooks appeared around the three major nations, recommending possibility for professionals and policymakers to reveal the causes for regional inactivity more than the documented technical, economic, and social boundaries.

Wang et al. (2019) [23] to assessed the socioeconomic consequences of aviation biofuel progress on job opportunities, GDP and investment stability. This was accomplished by implementing a situation-oriented IO evaluation, choosing Brazil as sample. All the situations displayed important socioeconomic consequences on job opportunities and GDP. Aviation biofuel manufacturing demonstrated huge favourable total socioeconomic consequence on job opportunities and GDP, while some of the fossil industries were badly impacted. Besides the reasonably small scales of these unfavourable consequence, initiatives like expert exercises for newer opportunities or achieving agreements to re-determine labour to aviation biofuel associated industries are significant, in order to rebalance the out of place socioeconomic advantages. In general, the macauba-HEFA chain appeared the favourable alternative contemplating the situations examined, irrespective of the uncertainty corresponding with its establishment. In connection with this, regional strategies to encourage economic strategies associated to the “biojet” industry, particularly the manufacturing of macauba feedstock, could be advantageous to reduce the concerns and fundamentally to accomplish the ideal degree of socioeconomic advantages.

Mousavi and Bossink (2020) [24] studied the beginning of the collaboration among corporations along with non-governmental organisations (NGO) for eco-friendly renewable development, on top of its advancement in the long haul. Continuing through a powerful capabilities way, it offered an ex post facto, longitudinal evaluation of a 10-year partnership among KLM Royal Dutch Airlines (KLM) along with World Wildlife Fund for Nature Netherlands (WNF), that marketed for aviation biofuels. The case study recommended that the progression on the collaboration is motivated by three certain dynamic abilities of KLM and WNF, specifically, learning, coordination, and reconfiguration. The outcomes exposed two small foundations for every single of such dynamic features. For learning, such small foundations would sense proper associates to specialise resources. For coordination, these comprise of discovering a suit among associates and achieving a built-in quest. Subsequently, the small foundations of reconfiguration are considered the cultivating of an institutional discussion and the establishing of emerging industry specifications. This research is advantageous to researches since it exposes a research opportunity regarding the compelling functionality and small foundations that assist corporate NGOs integrating for eco-friendly renewable development. Professionals can make use of these compelling potential and small foundations as recommendations for establishing corporate NGO collaborations.

Shahabuddin et al. (2020) [25] reviewed the combustion of biomass and residual wastes, followed by syngas conditioning and Fischer–Tropsch catalytic synthesis, to produce sustainable aviation fuels. A description of both established and cutting-edge gasification technology is reviewed along with the difficulties associated with gasifying wastes. It is described about how to condition syngas by removing particles, tars, sulphur, carbon dioxide, nitrogen-compound chemicals, chlorine, and alkali metals. Reactor methods for the production of renewable aviation fuels are detailed with recent advancements in Fischer–Tropsch synthesis, such as improved catalyst compositions. Major obstacles to wider adoption are the energy effectiveness and capital expense of turning biomass and residual wastes into aviation fuels. Therefore, further advancement of cutting-edge technology will be essential for the aviation sector to meet its stated goal of reducing greenhouse gas emissions by 2050.

Chong et al. (2021) [26] said decarbonization of the aviation industry is crucial for reducing the effects of climate change. Biofuels will be essential in reaching zero carbon growth by 2050, according to the aviation industry. In order to guarantee that the environment and resources are not impacted, a comprehensive examination of the sustainability of using biojet fuel is required. Alternative jet fuels made from biomass have been found in studies to dramatically lower carbon footprint. The fundamental LCA values of CORSIA qualified fuels that have received ASTM D7566 approval have just been made public by the International Civil Aviation Organization (ICAO). The energy-water-food (EWF) nexus method is used to account for the influence of biojet fuel on resource management. It is determined which resources are scarce enough to produce biojet fuel sustainably. Alternative jet fuel production has risks and possibilities connected to carbon emissions, and they are assessed for different feedstock options and production methods [26].

Abrantes et al. (2021) [27] raised questions regarding increasing emissions and climate change which have elevated the concerns of decarbonization. Abrantes et al. (2021) [27] provided quantitative figures to assist decision-making towards the very first principle of International Air Transport Association (IATA) plan of action to minimize modern aviation environmental impact. This approach consists of enhancing aircraft technologies and implementing environmentally friendly low-carbon fuels. Essentially the most encouraging technologies for an impending application are new engine architecture and natural laminar flow [27–29]. Conversely, initiatives currently placed to develop Sustainable Aviation Fuel (SAF) attaining the stage in which a few techniques for the generation of renewable jet fuel are undoubtedly certified by ASTM. Abrantes et al. (2021) [27] quantified the prospective decrease of CO_2 pollution levels by 2050 in the aviation a mathematical modelling to estimate fuel usage and CO_2 discharges from the worldwide air transportation. Relating to the SAF evaluation, it is formulated a method that takes into account, aside from the SAF development, the feedstocks, together with the development path. The mixed impact of systems with SAF is regarded verifying if the objectives suggested by IATA, carbon-neutral development from 2020, and a decrease of 50% in total emissions by 2050 compared to 2005 levels are attained. The evaluation outcomes unveiled that the objectives cannot be achieved merely with the merged action of brewing aircraft technological advances and the utilization of alternate fuels. Carbon-neutral development is simply achieved when it is deemed the mutual effect of technological innovations with the circumstance where the quantity of SAF delivered is greater (an enhancement of 15% yearly between 2030 and 2050) [1,27,30,31]. Nevertheless, this carbon-neutral development is entirely potential to begin in 2040 and upcoming aircraft technological advances can decrease up to 15% in CO_2 pollutants [27,30,32].

Prussi et al. (2021) [1] identified biofuels as a notable way to minimize Greenhouse gas (GHG) emissions of the worldwide aviation industry. The Life cycle assessment (LCA) method established for Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) displayed allows the computation of (GHG) pollutants decrease by Sustainable aviation fuels (SAF) for the worldwide aviation industry. Induced land-use change (ILUC) GHG emissions are regarded collectively with primary LCA standards to accomplish all-natural GHG decreases by SAFs. Authors presented earliest globally embraced strategy for the computation of life cycle GHG emissions of aviation fuels, subsequently making an essential measure in direction of the objective of a less polluting aviation industry. The prospective GHG discharge reductions, in the structure of the executed attribution LCA, produced up to 94% when evaluated to petroleum-originated baseline jet fuel. As a result, Prussi et al. (2021) recommended that SAFs is able to perform a big part to decreasing aviation industry's GHG gas emissions. Attempting for intercontinental arrangements is a complicated process, and additional hard work will have to be invested to improve harmonization with various other local and/or federal systems. The CORSIA technique can work as a structure for remaining transport industries that are internationally associated like maritime transportation, and for other non-transport sectors.

Sustainability requirements and substantiation thru federal regulations and accreditation programmes are crucial resources to guarantee long lasting resource and bioenergy progress. The Renewable Energy Directive Recast (RED II) establishes the platform for renewable energy for the duration of 2021–2030 with up-to-date and emerging sustainability requirements [31]. Mai-Moulin et al. (2021) [31] reviewed the sustainability standards in the RED II and in current nationwide regulations and programmes. The goal was to recognize potentials and recommend a set of sustainability standards that are reliable and that are essentially relevant to the entire bioenergy market. The recommended set of reliable sustainability standards was authenticated using investor interviews. Moulin et al. (2021) [31] proved that the RED II is a significant action ahead in securing sustainable bioenergy sources; nevertheless, it still involves sustainability threats in environment control and is missing explanation and requirements for foreign biomass. The recommended reliable sustainability standards in this research are considerably comprehensive than RED II and assist to ensure sustainable soil usage, to preserve biodiversity, and to preserve ecosystems, while also answering protection under the law for employees and regional villages, and the effective consumption of resources. Mai-Moulin et al. (2021) strongly suggested that policy and law developers, system directors and sustainability professionals organize conversations and legal agreements on the different sustainability elements. A transparent classification of waste material and deposits, dimension of unintended land utilization modification, and acknowledgment of proficient voluntary tactics to illustrate sustainability compliance at EU level.

Parada et al. (2022) [33] mentioned that aviation biofuels are appealing to decrease carbon by-products in the aviation industry. Nevertheless, rising questions over biofuels reveal a necessity for sustainability studies that consider the perspective surrounding biofuel generation. Parada et al. (2022) presented a creative sustainability research of industry possibilities for aviation biofuel in Southeast of Brazil. They considered regional investors' considerations, the research is aimed on environment (climate), industrial acceptability, performance, energy reliability, stakeholder security, revenues, social improvement, and land longevity. They identified concerns involving manufacturing other possibilities and sustainability elements, authors outlined potential for additional improvements, particularly sugarcane ethanol-to-jet generation for the foreseeable future, and internal manufacturing of hydrogen and power with sustainable energy. In addition, manufacturer-company collaborations and launching the decision-making to investors are recommended to encourage social growth and accommodate diverging concerns with bio-based manufacturing. They also analysed longevity with attention to the regional perspective could play a role to discover possibilities for more renewable decarbonization solutions.

Villarreal et al. (2022) [32] said that recently, governing bodies throughout the globe have actually decided moving in direction of carbon-neutral establishments for restraining the consequences of weather variations. A significant barrier restricting this accomplishment is carbon dioxide emissions, which is why the aviation industry is a crucial factor due to its reliance on fossil fuels. As a replacement, biofuels with comparable attributes to existing fossil-fuels and completely suitable for the existing petroleum facilities (drop-in biofuels) are now being produced. In this respect, microalgae really are a likely feedstock for their prospect of lipid deposits. Villarreal et al. (2022) [32] explained the programming condition, possibilities, and problems of various technologies which are ideal for or appropriate to transform microalgae into aviation fuels. They further mentioned that additional improvements are essential to lessen the expenses of growing and cropping of microalgae, as well as a biorefinery strategy to enhance the production. Whilst every associated transformation path explained has its own advantages and disadvantages, they converge upon the necessity of improving the deoxygenation strategies therefore the percentage associated with the ideal form of hydrocarbons that fit gasoline demands [32].

Initiatives related to biofuels are at the heart of the worldwide shift to a low-carbon transportation industry. After various nations ratified the Paris Climate Change Agreement in 2015, biofuels have emerged as a viable choice for transportation fuel in the case of global warming of less than 2 °C [34]. A decade ago, encouraging policies including mix requirements, subsidies, and fossil fuel taxes gave the global biofuel industry a boost [35]. The initial stage of the biofuel boom was dominated by crop-based biofuels in the US, EU, and Brazil. In the late 2000s, a number of additional established and emerging nations, including Canada, New Zealand, the Philippines, Argentina, Indonesia, Malaysia, Thailand, India, China, a few African nations, and other Southeast Asian nations, gradually entered the global biofuel industry.

Promoters of biofuels frequently link the benefits for developing nations to improved income and job prospects, technological and scientific spill overs, and new business potential from markets for biobased goods [36]. Early scientists and academics saw biofuels as an environmentally friendly alternative to fossil fuels. However, the marketplaces were far away at the time. A new pragmatic movement in biofuel science and economics was inspired by the global documentation of the unintended consequences of biofuels, including the “food vs. fuel” argument and land-use change (LUC) issues. This shift attracted criticism from the media, legislators, and scholars. The 2008 global food crisis [37] and the indirect land use change (iLUC) apprehensions changed the global judgement on first-generation biofuels from sustainable to unfair and distortionary [38]. Other adverse effects like land conflicts [39], loss of biodiversity, and ecological disturbances [40,41] have further subdued interest in biofuels.

Food security issues have led to considerable discontent and jeopardised the pro-poor vision of biofuels for developing nations, even if the effects of biofuels are yet unknown. The national biofuel promotion policies of emerging nations need to be re-evaluated considering these challenges. For instance, China and India deliberately selected non-arable, non-grain, and non-edible land as the source of their biofuel feedstocks [42,43]. A few African nations, including South Africa, Zambia, and Mozambique, saw a slowdown in the development of biofuels due to issues with food security, socio-ecological concerns from extensive land acquisition, and financial crises. Over time, national aims and misleading objectives have resulted from governmental expectations for biofuels.

With a few significant investment plans and governmental efforts still to be put into action, developing nations—aside from Brazil—are still in the early stages of the biofuels market's growth. The market dynamics of these nations are still developing and are significantly impacted by the biofuel policies of the US and the EU. Research reveals that US and EU biofuel policies have both favourable and unfavourable effects on emerging nations [44,45]. Due to the production of maize ethanol in the US and EU, as well as the expansion of rapeseed farming in India, modelling-based studies predict that over 2.8 million hectares of land will be converted in Brazil, as well as 2.3 million ha in China and India [46].

Although existing literature does not support crop use for biofuels [47], first-generation biofuels will likely dominate the biofuels complex in the coming decade. Their effects will unavoidably continue in emerging nations' food-energy nexus. Furthermore, because second-generation biofuel development depends on emerging nations like China, India, South Africa, Tanzania, Thailand, and Brazil, these nations will probably be crucial to the future growth of biofuels.

In several areas, international cooperation will be necessary to develop a viable global biofuel industry. Better land-use data will be produced because of collaborative worldwide field mapping initiatives, which will also aid in improving the understanding of the world's potential biomass. Efforts at crop breeding and extensive field tests should be conducted together, fusing local knowledge of indigenous crop species with already-existing technological knowledge. Regions with a lack of resources in this area need to be introduced to the best practises for cultivating sustainable feedstock. This is crucial to assisting small feedstock producers in adhering to sustainability certification programmes and gaining access to global markets. To assure capacity growth and knowledge transfer, joint research and development activities to create biofuel conversion methods need to be strengthened.

For the large-scale deployment of biofuels, especially advanced biofuels, to be effective, developing nations must be involved in the technological development process. Between industrialised and emerging nations as well as among developing nations, cooperation will be required. Publicly supported initiatives should disseminate knowledge in a way that encourages vertical and horizontal access to technology and expertise for sustainable biofuel production. It is important to foster international cooperation in creating strong sustainability standards and coordinating certification programmes for biofuels and other biomass products. This is essential to guarantee not only the marketability of biofuels with various certification schemes in various markets, but also their sustainable production, which will increase global commerce in biofuels. The ability to trade in biofuels and feedstocks will be improved, and infrastructure compatibility and consumer acceptance non-economic hurdles will be helped by the global convergence of technical standards, including fuel and vehicle standards. The seamless introduction of biofuels into new markets will be made possible by the exchange of experiences between developing markets and major biofuel-producing nations and areas (such as Brazil, the US, and the EU). The development of sustainable bioenergy and biofuels is the focus of several worldwide bodies and efforts. For instance, the IEA Bioenergy Implementing Agreement 28 focuses on both large-scale worldwide bioenergy deployment and research and development. The 12 tasks that make up the IEA Bioenergy Implementing Agreement concentrate on various technologies and supply-side components of bioenergy development. Increased cooperation between OECD and non-OECD nations on the commercialization of biofuels is possible thanks to Task 39.

It will be essential to consider the unique policy environment and demands of developing nations to achieve the biofuel deployment envisioned in this roadmap. Commercial biofuel production is already taking place in several non-OECD nations, with Brazil, Argentina, China, and Thailand showing the most activity. The development of biofuels has just recently begun in other developing nations, and there is currently no large-scale commercial biofuel production in most African nations. The applicability of various biofuels must be compared to other renewable energy choices that could be of more relevance in the short term given these nations' low financial resources and lack of access to basic energy demands (such as lighting and cooking).

Many developing nations are beginning to recognise the potential economic and social benefits of generating and consuming biofuels, as seen by the rising biofuel output and the growing number of nations implementing biofuel support programmes. In many areas, developing new revenue streams for rural communities is important, along with the chance to reduce spending on petroleum imports. The possibility of exporting biofuels to markets with high demand, such as the United States and the European Union, also exists. Doing so would help boost foreign exchange reserves.

Growing biofuel production and the rise in nations implementing biofuel support programmes indicate that many developing nations are becoming aware of the potential economic and social advantages of generating and utilising biofuels. A major motivator in many areas is the opportunity to reduce spending on importing petroleum products as well as the development of new revenue streams for rural communities. Additionally, there is potential to export biofuels to markets with high demand, such as the United States and the European Union, which would assist in boosting foreign exchange reserves.

To align corporate models with thorough agricultural education and training ideas for farmers, international engagement and funding through public-private partnerships are required. To minimise negative effects on rural development and prevent residents from being displaced, supporting smallholder involvement in biofuel value chains will be essential. Enhancing research and development cooperation between industrialised and developing nations, as well as between developing nations, is necessary to enable technological access and transfer. Based on lessons learned from other nations, technologies and biofuel supply models tailored to a country's unique needs should be created. Feedstock exchange may be an alternative in the near term for nations without biofuel production facilities or with surplus feedstock.

Focus should be placed on biofuel technologies that are economically feasible and technically simple in order to produce biofuels. Longer term, poor nations can benefit from lessons learned in the production of sustainable conventional biofuels and can embrace advanced biofuel technologies once they have achieved economic viability. Developing nations may require international investment in addition to domestic money to build a sustainable biofuel industry. Large-scale foreign investment may be negatively impacted by administrative and governance issues in developing nations. However, even if these problems are not as serious, the small size of local markets may still limit foreign investment in biofuel initiatives.

Investor confidence is expected to rise if exports of biofuels can reach global markets, but doing so would necessitate meeting sustainability norms in the importing nations. The proliferation of sustainability initiatives in important consuming nations is currently a major concern. Thus, the need for globally accepted sustainability standards and certification programmes to produce biofuels and the necessity for poor nations to actively participate in their creation The fact that certification prices are frequently greater than in industrialised nations and can account for up to 20% of smallholder producers' total production expenses is a difficulty for developing nations. To enable developing nations to learn and use certification systems, enhance the legitimacy of national assessment bodies, and lower certification fees for biofuel production, certification criteria must be coupled with funding and technical support.

This plan is a response to the G8 and other government leaders' calls for a more thorough examination of the sustainable development trajectory for biofuels, a crucial carbon mitigation technology. The biofuel

Table 1
Advantages and disadvantages (gaps) of the literature reviews considered in this study.

Source	Authors/Year	Advantages of the study	Identified knowledge gap of the study
[11]	Yujie et al. (2015)	Biofuels advancement is influenced by the governmental strategies, and the authorities has offered continued financial assistance for the entire procedure starting from feedstock, research to commercialization of biofuel trade in an effort to minimize financial investment risk.	Complying with sustainable production requirements for the policy makers to continue trends of biofuels production
[12]	Thushara et al. (2015)	Potential and obstacles in the evolution of renewable gasoline for aviation	✓ Food–fuel competition ✓ Environmental issues ✓ Sustainability with tolerable cost
[13,48]	Cremonez et al. (2015)	Identified the significant negative effects on the environment, the economy, and society caused by Brazil's manufacture of aviation biofuels	✓ Need for improvement and optimization of production routes is crucial to reduce production costs of these materials. ✓ Considering the monoculture farming for extensive production and exports.
[14]	Noh et al. (2016)	Carbon Neutral Growth within the commercial aviation industry without developing alternate aviation fuels with a scaled-down carbon impact	The prospective cost of manufacturing biofuels in industrial settings cannot yet be estimated with great precision, and none of them have undergone worldwide testing in accordance with common standards, which is crucial for the civil aviation industry.
[15]	Kousoulidou and Lonza (2016)	Commercialisation and usage of two million tons of ecologically safely manufactured paraffinic aviation biofuels by 2030	Year 2010 as the standard baseline year
[16]	Mousavi and Bossink (2017)	Firm may create a sustainable innovation demonstration project that affects its sustainability strategy and organisation as well as the sustainability strategy and structure of the value chain by building sensing, seizing, and reconfiguring skills.	Back dated longitudinal report of the initiatives of the KLM Royal Dutch Airlines (KLM)
[17]	Filimonau and Hogstrom (2017)	UK publics are generally aware of biofuel technology	✓ Focused on UK community. ✓ Public knowledge on biofuel is very limited
[18]	Lu (2018)	Centred on the comparison of biofuels' buying costs and environmental advantages to those of conventional fossil fuels and assessed the environmental advantages of emission reduction, one of the most important sustainable factors when selecting biofuels.	Depending on the feedstock utilised, the actual biofuel combustion emission index may change
[19]	Deane and Pye (2018)	Specific policy challenges and opportunities for the European biofuel sector.	Non-policy measures are required to overcome these challenges.
[20]	Filimonau et al. (2018)	Public opinion on the use of biofuels in aircraft in the context of an expanding East-Central European tourism industry; promise of biofuels as a general tool for reducing carbon emissions was well acknowledged.	Focused on the community of East-Central Europe (Poland); poor public knowledge of its specialised usage in the aviation sector; insufficient comprehension of the difficulties associated with the adoption of biofuel technology in aviation
[21]	Neuling and Kaltschmitt (2018)	Extensive assessment of different production pathways for biokerosene in terms of technical, economic and environmental aspects.	Production costs of the biomass feedstock must be reduced and/or regulatory measures have to be implemented in an international level to support such options.
[22]	Dodd et al. (2018)	Perceptions of innovators working to support this form of renewable energy, as well as end users, such as airlines.	Discrepancy in mindsets found in interview data, which differed from document data
[23]	Wang et al. (2019)	The impacts of the development of aviation biofuel on GDP, employment, and trade balance.	Focusing on Brazil makes it undesirable to make initiatives like professionalising training for new positions or signing agreements to reallocate labour to industries relevant to aviation biofuels.
[24]	Mousavi and Bossink (2020)	Detailed, long-term case study of a corporate-NGO cooperation for ESI in which the parties, KLM and WNF, collaborated to create and commercialise sustainable aviation biofuels in order to lower CO_2 emissions.	✓ There are no all-encompassing success criteria, clear action instructions, or golden standards in this study. ✓ Research design, which was based on a single case study rooted in the relatively modest ambitions of the partnership being investigated
[25]	Shahabuddin et al. (2020)	Examined the gasification, syngas conditioning, and Fischer–Tropsch catalytic synthesis processes used to produce renewable aviation fuels from biomass and residual wastes.	The capital expense and energy efficiency of turning biomass and leftover wastes into aviation fuels are the main obstacles to their broad use.
[26]	Chong et al. (2021)	Significant research on energy balances for biojet fuels, greenhouse gas emissions, and life cycle assessment (LCA). Alternative jet fuels made from biomass have been found in studies to dramatically lower carbon footprint.	Major obstacles to wider adoption are the energy effectiveness and capital expense of turning biomass and residual wastes into aviation fuels.
[27]	Abrantes et al. (2021)	Gives quantifiable information to support the first pillar of the International Air Transport Association's (IATA) policy to reduce the impact of aviation on the environment.	The targets cannot be achieved alone by the combined employment of impending aeroplane technology and alternative fuels, according to evaluation results. The varied feedstocks utilised in each step to create SAF do not significantly affect CO_2 emissions.
[1]	Prussi et al. (2021)	193 ICAO member nations provide a technique for evaluating the life-cycle greenhouse gas emissions of sustainable aviation fuels (SAFs) in the CORSIA system. Show that a variety of SAFs may produce substantial life-cycle emission savings in comparison to jet fuel sourced from petroleum.	✓ Finding international agreements is a difficult process. ✓ Additional work will be required to improve alignment with other regional and/or national systems.
[31]	Mai-Moulin et al. (2021)	RED II is a significant action ahead in securing sustainable bioenergy sources.	sustainability threats in environment control and is missing explanation and requirements for foreign biomass
[33]	Parada et al. (2022)	Creative sustainability research of industry possibilities for aviation biofuel in Southeast of Brazil. They considered regional investors' considerations, the research is aimed on environment (climate), industrial acceptability, performance, energy	✓ Focuses on southeast of Brazil only. ✓ Discover possibilities for more renewable decarbonization solutions.

(continued on next page)

Table 1 (*continued*)

Source	Authors/Year	Advantages of the study	Identified knowledge gap of the study
		reliability, stakeholder security, revenues, social improvement, and land longevity.	
[32]	Villarreal et al. (2022)	Outlines programming condition, possibilities, and problems of various technologies which are ideal for or appropriate to transform microalgae into aviation fuels.	✓ Additional improvements are essential to lessen the expenses of growing and cropping of microalgae, as well as a biorefinery strategy to enhance the production. ✓ Necessity of improving the deoxygenation strategies therefore the percentage associated with the ideal form of hydrocarbons that fit gasoline demands

roadmap is meant to be an evolving process that considers new technological advancements, laws, and efforts at international cooperation. The international community may use the milestones in the roadmap to check that biofuel development initiatives are moving towards the reductions in GHG emissions needed by 2050 in a sustainable way. The IEA will frequently update stakeholders in government, business, and non-governmental organisations on the advancement made towards the goals of this roadmap.

The objective of this study is to assess socioeconomic and political effects related to aviation biofuel production and usage in Malaysia. Malaysia was selected as case study in this analysis as Malaysia has the potential of growing feedstock needed to manufacture and produce biofuels at a commercial scale. Producing 85% of the world's palm oil along with Indonesia, Malaysia has the tendency of supplying a blend of palm oil mixed with the conventional jet fuel to power the commercial aircraft engines. The availability of land and benign climatic conditions can also potentially contribute to the establishment of aviation biofuel production. Malaysia has a large arable land to produce palm oil which can be processed to aviation biofuels but still faces the challenge of inadequate manpower and technology. Locally produced aviation biofuel offers Malaysia the opportunity to facilitate its fast-growing aviation sector in a more sustainable way. The thorough and in-depth socioeconomic and political impacts of aviation biofuel production, considering Malaysia, feedstocks, technology, and future scenarios, are the study's main contributions. Overall, this study adds to the existing assessments of the sustainability of aviation biofuel (which are dominated by GHG emission and techno-economic feasibility analysis) and helps producers of aviation biofuel make informed decisions.

Table 1 shows the advantages and gaps of the studies discussed in this manuscript in the introduction section. Closely assessing all these review articles suggest that none of the studies have attempted to review the possible socioeconomic and political feasibility of aviation biofuel production and usage specific to developing countries from southeast Asia region, such as Malaysia. This study addresses this research gap. By reviewing the socioeconomic and political feasibility of aviation biofuel production and usage impacts, the paper aims to answer critical questions surrounding biofuel endorsement in developing countries specifically in southeast Asia region. Firstly, to address the socioeconomic feasibility, the study provides a broader overview of the recent development of biofuels in developing countries addressing fossil fuel sustainability, biofuels in conventional jet engine adaptation, challenges in producing Biofuel, investor commitment, cost reduction possibilities, role of palm oil in aviation biofuel, modifications needed in the agricultural sector, arable land issues, effects of food production, reliability of aviation biofuel, safety, public acceptance, price fluctuations and customer responsibility. Secondly, by reviewing the political feasibility, the study synthesizes adaptation of Malaysia for aviation biofuel, preservation of the environment, role of the government and the reactions from palm oil importers from southeast Asia region.

The remaining paper is organized as follows. Section 2 sets the methodology used for the study that includes participants, data collection, procedure for interview sessions, layout of the semi-structured interview, socioeconomic questions, political questions, data analysis, data reporting, familiarisation with the data, coding, search of themes, review of themes, defining themes, naming themes and validity and reliability of the data. Section 3 discusses all the 21 themes identified in the methodology of the study, critically. Section 4 concludes the study.

2. Research design

This is a non-experimental research because no intervention (no treatment), variables are not deliberately manipulated, nor is the setting, data collected without making any changes or introducing any treatment and tend to be closest to the real-life situation [49]. It is also a descriptive survey as interview with experts in aviation industry is conducted via semi-structured interview because it is believed that they will help to provide best and accurate answers to the questions of who, what, when, where, and how associated with biofuel in aviation in Malaysia [50]. It is also descriptive because it helps to make specific predictions – Feasible or not feasible? And determines relationships between variables. This study is categorised as a cross-sectional research because there are no experimental procedure involved, takes place at a single point in time, variables are not manipulated by researchers, it provides information only; do not answer why, groups are selected based on existing differences rather than random allocation and there is no time dimension [51,52]. This study shows a non-probability sampling because it's concerned with holistic understanding of the phenomena of interest (use of biofuel in aviation industry – a feasibility study in Malaysia) and sampling decision are based on informational and theoretical needs (expert views). Through this non-probability sampling prove can be shown on how social, political, and economical changes occur and how the approach being flexible and able to change [53]. This study is a purposive sampling because 'knowledgeable people', i.e., those who have in-depth knowledge about issues, maybe by virtue of their professional role, power, access to networks, expertise or experience are required to answer the questions imposed.

2.1. Participants

Twenty (20) participants (aviation experts) were interviewed as per Table 2. The participants were from Malaysia Airlines, AirAsia (Malaysia), Malindo Air (Malaysia), Royal Malaysia Police Air Operations Force, Royal Malaysia Army, Civil Aviation Authority of Malaysia (CAAM) and Malaysian University Senior Lecturers/Associate Professors/Professors working on biofuel usage in aviation. The years of experience in the industry ranged from 1.5 years to 35 years. The sites were mainly based in Malaysia.

2.2. Data collection

This method involves a person to carry out field study which can be done by conducting face to face interviews with experts in aviation industry based in Malaysia and overseas and any other interactive method that one can devise to obtain personal views and opinions of an expert in this field [54]. I have resolved to use the method of face-to-face interview sessions with experts from the aviation industry directly and indirectly. Semi-structured questions will be the strategy to interview experts as the experts are asked to answer, respond to or comment on them in a way that they think best. This strategy provides a clear structure, sequence and focus, but the format is open-ended, enabling experts to reply in their

Table 2
Details of the experts and their area of expertise in Aviation Biofuel research and development.

Expert	Designation	Expertise
Expert (1)	Senior Lecturer, Faculty of Engineering, Computing and Science, Sarawak, Malaysia	Biofuel processing; Catalysis and reaction engineering; Process development and sustainability.
Expert (2)	Professor, School of Chemical & Energy Engineering, Faculty of Engineering, Johor, Malaysia	Research into renewable resources and energy. The aviation industry's compatibility with sustainable and affordable fuel is the expertise of ongoing research.
Expert (3)	Commander, Air Operations Force, Local Law Enforcement Agency, Malaysia	35 years of experience as a Pilot (Captain) of King Air Beechcraft 350, CE-208, C172SP, Pilatus Porter-6, CE-206. Actively involved in government policies for biofuel implementations in government fleets.
Expert (4)	Pilot (Captain), Kuala Lumpur, Malaysia	30 years of experience as a Pilot (Captain) of Airbus & Boeing Fleets. Actively involved in company policies for biofuel implementations in company fleets.
Expert (5)	Engineer, ExxonMobil, Malaysia	Ph.D. candidate in sustainable aviation fuel in one of the renowned universities in Malaysia, has published 19 research papers on Sustainable Aviation Fuels in reputable journals such as Applied Energy (Elsevier), Fuel (Elsevier), Alexandria Engineering Journal (Elsevier), Chemical Engineering Transactions (Italy), SAE International.
Expert (6)	Global Senior Aerospace Engineer/Aviation Biofuel/ Consultant, Malaysia	Airline operators, OEMs, and service centres (MRO) on-site offer specialised training, technical support, and maintenance assistance in accordance with client need. Areas of actuation include manpower for aircraft repairs, service bulletin application, installation of new systems/features, training, aircraft and engine predictive health monitoring, assistance with aircraft re-delivery, help interacting with OEMs, aircraft inspections, schedule preparation and management activities, expertise in aviation biofuels, conducting research and development, building plants and updating infrastructure, agriculture growing and harvesting feedstocks.
Expert (7)	Originator of Sustainable Aviation Fuel (SAF), Marine Biofuel @ Oil & Gas Company, Malaysia	Business development for Marine Biofuel on Low Carbon Fuels and Sustainable Aviation Fuel (SAF) (LCF). A mix of offtakes, investments, and technology development through public/private partnership, including the DoE national lab system, was used to establish and implement the company's short- and long-term SAF strategy.
Expert (8)	Associate Professor, School of Chemical & Energy Engineering, Faculty of Engineering, Johor, Malaysia	Research related to energy and sustainable resources. Current research involves with the compatibility study of sustainable and cost-effective fuel for aviation industry.
Expert (9)	Plant Manager at Biofuel Company based in Malaysia	Strategy, coordinate, supervise, and take responsibility for all elements of the biodiesel plant's operations. Safely, effectively, and legally implement the business plan. Oversee the engineering, building, and commissioning of a new biofuel's refinery.
Expert (10)	PhD, Fellow at renowned university in Kuala Lumpur, Malaysia.	Climate objectives for 2030 and 2050, effort sharing rules, renewable energy, sustainability standards for biofuels, biofuel feedstock, transportation greenhouse gas emission reductions, and biodiversity are among the themes of expertise.
Expert (11)	Global Strategy head, Oil & Gas company, Kuala Lumpur, Malaysia.	Concentrating on inorganic growth in integrated solutions, new energy, biofuels, low carbon fuels, hydrogen, and aviation.
Expert (12)	Air Operations Force, Royal Malaysia Police, Malaysia	35 years of experienced Pilot (Captain) of King Air Beechcraft 350, CE-208, C172SP, Pilatus Porter-6, CE-206. Actively involved in government policies for biofuel implementations in government fleets.
Expert (13)	Independent Researcher and Biofuel Consultant, Kuala Lumpur, Malaysia	Focuses on biofuels, sustainable aviation fuels, and renewable energy with the aim of creating a more wholesome and sustainable environment for the coming generation of inhabitants.
Expert (14)	Expert in Sustainable Aviation Alternative Fuels, Alternative & Renewable Fuels Consulting, Kuala Lumpur, Malaysia	Lead consultant and member of advisory board for sustainable waste management, sustainable biomaterials certification, and sustainable alternative fuels for aviation.
Expert (15)	Nominated Expert - Fuel Task Group, Civil Aviation Authority, Malaysia	Representative chosen by the industry to work on the development and implementation of the Carbon Offsetting and Reduction Scheme for International Aviation's core components.
Expert (16)	Pilot (Captain), Kuala Lumpur, Malaysia	15 years of experience as a Pilot (Captain) of Airbus & Boeing Fleets. Actively involved in company policies for biofuel implementations in company fleets.
Expert (17)	Manager, Advanced Biofuel Business, Kuala Lumpur, Malaysia	Planning for strategic sales and marketing in the biofuel sector with a focus on the Malaysian, the Sustainable Aviation Fuel (SAF) project, the trade and commercialization of hydrotreated vegetable oil (HVO), and sustainability certificate experiences.
Expert (18)	Air Operations Force, Royal Malaysia Police, Malaysia	Police Pilot cum Ph.D. holder in sustainable aviation fuel from one of the renowned universities in Malaysia, has published 21 research papers on Sustainable Aviation Fuels in reputable journals such as Applied Energy (Elsevier), Fuel (Elsevier), Alexandria Engineering Journal (Elsevier), Chemical Engineering Transactions (Italy), SAE International. Actively involved in post-doctoral studies on Sustainable Aviation Fuel.
Expert (19)	Senior biofuels specialist, Intl trader Global Biojet fuel developer, Aviation pilot	Aircraft enthusiast, expert in biofuels, and worldwide trader. Comprehensive understanding of the biodiesel, renewable diesel for aviation industries, and the trade of agricultural tools and biofuels. The logistics of the cotton trade are the main points.
Expert (20)	Independent contractor with leadership experience in aviation and chemical industry fields	Environmental health and safety (EHS) management and programme development experience spanning over 35 years. For the past 18 years, including alternative fuels and EHS in aviation.

own terms. Face-to-face interview has high response rates as experts more readily answer live questions about the subject when interviewed [55]. Tolerable Longer Interviews and open-ended questions are more tolerated through interviews since the experts would be more convenient at expressing their long answers orally than in writing.

2.3. Procedure for interview sessions

The procedure for interviewing the experts depends on the amount of cooperation by each interviewee. Appointments were made in advance either via email, social media chats or via phone calls. Once the suitable, day, date, time, and venue was arranged, and we had the interviewees consent to record the interview session and proceeded to meet with them and conducted the interview session. The questions for the interview were semi-structured. This means that what we wish to ask them were pre-planned and jotted down in point form, but the questions were flexible and may deviate from their original course depending on the response of the interviewee. Questions were added during the session whenever we felt that the interviewee needed to elaborate a certain point in greater details, or the questions were omitted if the interviewee had answered the next question and it will be a repetition. Throughout the interview session, notes were taken, and a recorder was used to record the whole conversation. Emphasis was given on the interviewees' body language as it assured us of his/her comfort level. The questions were arranged in three categories studying the socioeconomic and political aspects. Twenty (20) experts in aviation industry and fields related to aviation biofuel who had full knowledge on the subject matter and will be able to answer our questions based on their past experiences and understanding of their work were identified to be interviewed. Questions were posed to the experts in the form of semi-structured questionnaire that sets the agenda but does not presuppose the nature of the response.

2.4. Layout of the semi-structured questions

The questions are divided into two main categories.

A Socioeconomic feasibility
B Political feasibility

Since this is an interview with the experts, categorisation of the questions helped the purposes of the study and helped experts to focus on the sections of the question when answering. The questions were arranged in an ascending level of difficulty starting from the easiest ones like introduction and gradually moving to the most difficult ones. The questions were made based on CORSIA sustainability criteria applicable for batches of CORSIA eligible fuel produced by a certified fuel producer before 1 January 2024 as per Table 3.

2.4.1. Socioeconomic feasibility questions

✓ For how many decades or centuries will the fossil fuels reserve last?
✓ Can biofuels be successfully used in the conventional jet engines, or it needs structural adaptation?
✓ Challenges in producing Biofuel in Malaysia: Under-produced/Over-produced?
✓ How is the commitment & interest of investors & entrepreneurs in Aviation Biofuel in Malaysia? Example?
✓ Will aviation biofuel profit the aviation industry and still reduce the air fares and how is the aviation industry in Malaysia becoming cost effective and fuel efficient as per their claims?
✓ Malaysia as an abundance of palm oil (77% of its cultivable land is used for farming palm trees and it produces 85% of the world's total palm oil), so can we process palm oil into a biofuel and use it as aviation fuel?
✓ What modifications will be needed in the agricultural sector as well as the aviation industry for its practical implementation?
✓ Does Malaysia have enough arable land and manpower to cultivate palm trees and other biofuel crops like rapeseed, soybeans and sugar cane, on a commercial scale?

Table 3
CORSIA sustainability criteria applicable for batches of CORSIA sustainable aviation fuel produced by a certified fuel producer on or after 1 January 2024 [56].

No.	Theme	Principle	Criterion
1	Greenhouse Gases (GHG) Principle	CORSIA SAF should generate lower carbon emissions on a life cycle basis	In comparison to the baseline life cycle emissions values for aviation fuel, CORSIA SAF will achieve net greenhouse gas emissions reductions of at least 10%.
2	Carbon stock Principle	CORSIA SAF should not be made from biomass obtained from land with high carbon stock	Since primary forests, wetlands, and peat lands all have high carbon stocks, CORSIA SAF will not be made from biomass obtained from land converted after 1 January 2008 that was primary forests, wetlands, or peat lands and/or contributes to the degradation of the carbon stock in primary forests, wetlands, or peat lands. Direct land use change (DLUC) emissions will be determined in the case of land use conversion after 1 January 2008, as defined based on the Intergovernmental Panel on Climate Change (IPCC) land categories. The DLUC value will take the place of the default induced land-use change (ILUC) value if DLUC greenhouse gas emissions are greater.
3	Water Principle	Production of CORSIA SAF should maintain or enhance water quality and availability.	To preserve or improve the quality of the water, operational procedures will be put into place. Operational procedures will be put into place to make the best use of water while preventing the depletion of surface or groundwater resources beyond their replenishment potential.
4	Soil Principle	Production of CORSIA SAFs should maintain or enhance soil health.	To maintain or improve soil health, including physical, chemical, and biological conditions, best management techniques for agriculture and forestry will be put into place for feedstock production or residue collection.
5	Air Principle	Production of CORSIA SAF should minimize negative effects on air quality	Emissions of air pollution will be restricted. CORSIA Sustainability Criteria for CORSIA Eligible Fuels, ICAO document
6	Conservation Principle	Production of CORSIA SAF should maintain biodiversity, conservation value and ecosystem services.	Unless there is proof that the activity does not conflict with the aims of protection, CORSIA SAF will not be created from biomass collected from places that are protected by the State having authority over such areas because to its biodiversity, conservation value, or ecosystem services. To avoid the uncontrolled spread of grown foreign species and altered microorganisms, low invasive-risk feedstock will be used for production and suitable controls will be implemented. Operational procedures shall be used to prevent negative effects on sites that are protected by the State with authority over that area because of its biodiversity, conservation value, or ecosystem services.
7	Waste and Chemicals Principle	Production of CORSIA SAF should promote responsible management of waste and use of chemicals.	Operational procedures will be put in place to guarantee that chemicals utilised in the production process waste is kept, handled, and disposed of safely. The usage of pesticides shall be restricted or decreased using ethical and scientific operating procedures.
8	Human and labour rights Principle	Production of CORSIA SAF should respect human and labour rights.	Human and labour rights shall be upheld in CORSIA SAF manufacturing.
9	Land use rights and land use Principle	Production of CORSIA SAF should respect land rights and land use rights including indigenous and/or customary rights.	Existing land rights and land use rights, especially the official and informal rights of indigenous peoples, shall be respected in CORSIA SAF production.
10	Water use rights Principle	Production of CORSIA SAF should respect prior formal or customary water use rights.	The CORSIA SAF production will respect the local and indigenous populations' current water use rights.
11	Local and social development Principle	Production of CORSIA SAF should contribute to social and economic development in regions of poverty.	In areas of poverty, CORSIA SAF manufacturing will work to better the socioeconomic circumstances of the impacted populations.
12	Food security Principle	Production of CORSIA SAF should promote food security in food insecure regions.	In food-insecure areas, CORSIA SAF production will work to improve the local food security of the stakeholders who are directly impacted.

- ✓ Is it possible to grow them as sustainable biofuels so that it doesn't compete with our consumption of it as food produce?
- ✓ Will it be a wise step to rely completely on biofuels in the near future rather than just mixing 20% of cooking oils with the petroleum based conventional fuels?
- ✓ Are these fuels safe enough to be used in all weather conditions, all kinds of aircrafts (commercial and air force) and for long distance journeys?
- ✓ What are the conditions to bear in mind when it comes to public acceptance of Aviation Biofuels?
- ✓ How will the price fluctuate if aviation biofuel is introduced in the market?
- ✓ In the perspective of a customer, how safe is an aviation biofuel when used for flying?
- ✓ How will customers play part in reducing emissions of greenhouse gases?

2.4.2. Political feasibility questions

- ✓ Other countries like US, Japan, UK, New Zealand and Qatar have carried out flight tests and are already using biofuels in commercial jets. So how far is Malaysia from adopting the same methodology?
- ✓ Would biofuels help in preserving the environment and in making Malaysia independent in energy production?
- ✓ Does the Malaysian government have any plans to invest in the research for this project? Is any organization (private or government owned) already working in this field in Malaysia?
- ✓ How will be the reaction from other countries on the usage of palm oil in Malaysia as biofuel for aviation industry, especially from the countries Malaysia export palm oil to?
- ✓ How is the Malaysian government's will in promoting or implementing the usage of biofuel in aviation industry in Malaysia? (Facilities given, funding, subsidies, and etc)

2.5. Data analysis and reporting

Qualitative data were collected in this study and hence qualitative data analysis methods were applied. In this case, semi-structured questions used in the interview were analysed by discourse analysis method where tapes used in data collection were played and replayed [57]. Discourse analysis method is very useful since when a tape is played and replayed it becomes very easy for the researcher to understand what was said by the participants/expert [58]. Data collected through qualitative interview were analysed through the Thematic Analysis (TA) method [59]. The purpose of TA is to identify patterns of meaning across a dataset that provide an answer to the research question being addressed [60]. Patterns were identified through a rigorous process of data familiarisation, data coding, and theme development and revision. One of the advantages of (our version of) TA is that it is theoretically flexible. This means it can be used within different frameworks, to answer quite different types of research question. It suits questions related to people's experiences, or people's views and perceptions. The approach to TA that was used for the analysis of the data involved a six-phase processes as below.

2.5.1. Familiarisation with the data

This phase involved reading and re-reading the data, to become immersed and intimately familiar with its content. After the interview sessions with all the experts, the recordings were played and the whole interview session was scripted down. Once the transcription was completed, the text was read and re-read to comprehend the statements made by each experts and the important facts, figures and key words were highlighted which were the essential information needed for the analysis and presentation of the findings.

2.5.2. Coding

This phase involved generating codes that were identified as important features of the data. It involved coding of the entire dataset, and after that, collating all the codes and all relevant data extracts, together for later stages of analysis. And therefore, the three dataset that were most obvious from our study were.

a) The socioeconomic feasibility: aimed at highlighting the profitability of aviation industry after the usage of biofuels, the pricing of biofuels, the technical adaptation needed in the aircraft engines, the technology needed to produce biofuels, acceptability of biofuels from the perspective of the customers/passengers and the debated issues like is it safe enough to be substituted with conventional biofuels and will it compete with the food crops etc;
b) Political feasibility; aimed at highlighting role and efforts of the Malaysian government in the promotion and funding for biofuel.

2.5.3. Searching for themes

This phase involved examining the codes and the collated data to identify significant broader patterns of meaning (potential themes). It then involved collating data relevant to each candidate theme, so that the data can be reviewed for the viability of each candidate theme. From our interview sessions and independent research, a total of 21 themes were identified. Attention was given to the over lapping facts and details and as a result there was a quite a lot of repeating information that was omitted from the Results and Discussion chapter.

2.5.4. Reviewing themes

This phase involved checking the candidate themes against the dataset, to determine that the experts told convincing story of the data, and one that answers the research questions. In this phase, themes were refined, which involved the step of the themes being split, combined, or discarded. All the 21 themes were then segmented into the three data sets mentioned above and as a result, the first dataset (socioeconomic feasibility) had 16 themes. The second dataset (political feasibility) had a total of 5 themes.

2.5.5. Defining and naming themes

This phase involved developing a detailed analysis of each theme, working out the scope and focus of each theme, determining the ‘story’ of each. It also involved deciding on an informative name for each theme. The 21 themes are as follows.

A. Socioeconomic feasibility
   1. How long fossil fuels will last
   2. Use of biofuels in conventional jet Engines
   3. Challenges in producing biofuels (Technical, costly, food vs. fuel)
   4. Commitments and interest of investors and entrepreneurs in aviation biofuel
   5. Impacts of aviation biofuels on the Aviation Industry
   6. Environmental impacts of biofuels
   7. Processing Palm Oil to be used at jet fuel
   8. Modifications needed in the Aviation and Agricultural sector for the production and usage of biofuels
   9. Arable land and manpower for biofuel production
   10. Production of palm Oil as a sustainable biofuel in Malaysia
   11. Relying completely on biofuels in the future
   12. How safe are the biofuels to be used in the aviation industry?
   13. Conditions to consider in public acceptance of aviation biofuels
   14. Price fluctuations when Aviation biofuels are introduced in the market
   15. Safety of Biofuels in Aviation from the Customers' Perspective
   16. Role Played by Consumers in Reducing Emissions of Greenhouse Gases

B. Political Feasibility
   17. Adoption of Biofuels Methodology in Malaysia

18. Role of biofuels in preserving the Environment and in making Malaysia independent in Energy Production.
19. The efforts of Malaysian Government and Private Organisations in the production of biofuels.
20. Reaction from other countries on the usage of palm oil in Malaysia as biofuel for aviation industry, especially from the countries Malaysia export palm oil to.
21. Political Will in terms of facilities given, funding, subsidies etc.

2.5.6. Validity and reliability

Accounts were supplemented with case notes and information discussed in multi-disciplinary team meetings; credibility and authenticity were regarded throughout analysis [60]. Integrity of the analytic process was a constant consideration, and regular meetings were held among the researchers to discuss clarity within data. To ensure a true account could be given, a degree of flexibility within interviews was practised outside of set questioning [60]. Moreover, specific considerations such as design, sampling adequacy, bracketing, and acknowledgement of researcher perspective were employed through regular grounded discussions between researchers [60].

3. Results and Discussion

The results chapter analyses and presents the findings of the study. The results are presented in graphs, charts and tables for easy comprehension. This results chapter is divided into two parts: socioeconomic and political feasibility of using aviation biofuel.

3.1. Socioeconomic feasibility

3.1.1. Theme 1: How long fossil fuels will last?

The study results indicated that fossil fuels are categorized into petroleum, natural gas, and coal. The experts indicated that the fossil fuels will last differently. Experts gave diverse reasons as to why petroleum has the least number of years while the coal has the highest number of years. All this estimation is based on the current consumption. If the consumption increases at a rate higher than the years mentioned by the experts, then the reserve of fossil fuel will replenish earlier than the estimation. As for Malaysia, the fossil fuel (petroleum) is estimated to last for another 20 more years only. If we carry on at this rate without any increase for our growing population or aspirations, our known oil deposits will be exhausted by 2052. Experts noted that; if we take an initiative to adopt renewable sources of energy from now on and make it a low to conserve power and fossil fuels then there is hope that our future generation can make use of it. It is not abundant; and we are taking no measures for its sustenance. Coal is relatively easier to extract and can be obtained just by quarrying and mining. Whereas it is much more difficult to retrieve oil and natural gas from the ground. It has been estimated that there are over 861 billion tonnes of proven coal reserves worldwide. This means that there is enough coal to last us around 112 years at current rates of production. In contrast, proven oil and gas reserves are equivalent to around 46 and 54 years at current production levels. Papiez et al. (2022) [61] presented the decoupling indicator, which is determined by dividing the percentage changes in GDP by the percentage changes in resource usage. This metric assesses the relationship between resource usage and economic expansion. When a drop in the use of fossil fuels coincides with positive economic growth, the decoupling is said to be absolute [23,62,63]. Relative decoupling occurs when the pace of economic growth exceeds the rate of increase of material (resource) usage. Regression analysis was performed on individual nations by Lenzen et al. (2022) [64] and it was discovered that the coupling coefficient, which is a country's income elasticity of consumption, reflects the degree and intensity of the relationship between economic development and resource usage. When the regression coefficient is not statistically different from zero, decoupling happens. From the responses of the experts, it is evident that they all unanimously agree that coal reserves are in a much greater amount as compared to the natural gas and oil and therefore will last much longer.

3.1.2. Theme 2: Use of biofuels in conventional jet engines

The study found that biofuels can be a viable option for sustainable energy needs in the aviation sector. As indicated in Fig. 1 below, majority of the experts indicated that biofuels can be effectively and efficiently used in the conventional jet engines hence making it easy for the aviation industry to achieve sustainability. The responses were indicated in a scale of five elements (1 strongly agree and 5 strongly disagree). As the figure indicates, none of the expert strongly disagreed that biofuels cannot be used in the conventional jet engines. However, eight experts who agreed indicated that biofuels should be used 50%. One expert indicated that biofuels can be used directly without being blended with fossil fuels in the conventional jet engines. Whereas the rest encouraged the use of biofuels mixed with Type A Jet fuels, kerosene, on commercial flights until test flights prove that using biofuels 100% in the jet engines is safe and reliable. The experts who disagreed indicated that, biofuels can be mixed with conventional jet fuel, can use the same supply infrastructure, and do not require adaptation of aircraft or engines (drop-in fuel). But it must also meet the same specifications as conventional jet fuel, resistance to cold (Jet A: −40°C, Jet A-1: −47°C), and high energy content (min 42.8 MJ/kg). Next it must meet the sustainability criteria such as life-cycle carbon reductions, limited freshwater requirements, no competition with food production and no need for cutting down the remaining 64% of forest area in Malaysia and leading to deforestation. These include limited land for deforestation and usage, food versus fuel prioritization, feedstock issues, sustainability, and tough global competition [65]. They also mentioned that there are no recent reviews on the engine performance and exhaust emission characteristics of a fuelled diesel engine with various biodiesel blends and recent development of technologies to reduce emissions. One expert said that turbojet engine's energy efficiency increases from 17.058% to 17.103% by using biofuel instead of jet fuel [66]. Aircraft engine's environmental effect factor rises

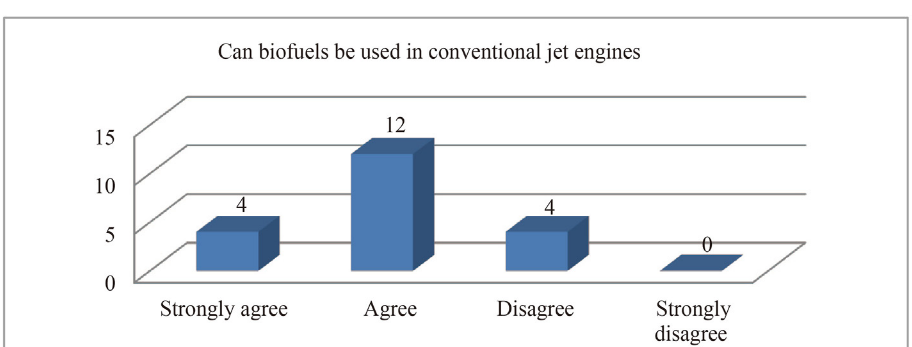

Fig. 1. Use of biofuels in conventional jet engines.

from 5.261 to 5.299 by the utilization of biofuel. Sustainability index reduces 1.463% for the combustion chamber component, 1.201% for the gas turbine component and 0.735% for the overall engine by using biofuel instead of jet fuel [66]. Thus, he strongly clarified that biofuel can be considered as a sustainable aviation fuel.

One of the experts, said that the sustainability criteria, which are currently outlined as having life cycle GHG emissions that are at least 10% lower than those of the petroleum jet fuel baseline and not being made from biomass obtained from land with high carbon stock, must be met by a CORSIA eligible fuel (CEF) in order to be eligible for ICAO CORSIA [1]. Within ICAO, more sustainability standards are being developed. SAFs are fuels made from waste or renewable feedstocks that adhere to certain CORSIA sustainability standards. The average life cycle GHG intensity baseline has been set at 89 gCO_{2e}/MJ [1] from well to wake (WTW), including crude oil recovery, transportation, and refining, jet fuel transportation, and jet fuel combustion. This baseline was determined after a thorough analysis of the global petroleum jet fuel production. Therefore, fuels that do not endanger the conversion of high-carbon stock land and have life cycle GHG emissions below 80.1 g CO_{2e}/MJ are eligible under CORSIA. The expert also mentioned that SAFs and lower carbon aviation fuels are two fuel types that fall under CEF (LCAFs). While SAFs may be made from waste or renewable sources, LCAFs are fuels that come from fossil sources but have life cycle GHG emissions that are at least 10% lower than the baseline petroleum jet fuel. The ICAO is still developing the method for calculating life cycle GHG emissions for LCAFs. Compliance with ASTM standards is a key feature of SAFs. The requirements for mixing non-petroleum components with typical petroleum-based jet fuel, which is accredited under ASTM D1655, are tightly governed by ASTM D7566. These requirements guarantee the safety of these fuels for use in aviation. ASTM has certified the following conversion procedures and renewable feedstock varieties to manufacture SAFs and has included them in the ASTM D1655 and D7566 (Table 4). Additionally, there are other new SAF avenues for ASTM certification in the horizon.

Table 4
Types of SAFs approved by ASTM [1,26].

ASTM D7566	Synthetic paraffinic kerosene (SPK), mostly made from woody residual biomass and municipal solid waste (MSW), was hydroprocessed by Fischer–Tropsch (FT). 50% *v/v* is the maximum blending rate permitted.
ASTM D7566	Hydroprocessed esters and fatty acids (HEFA) from lipid feedstocks such vegetable oils, leftover cooking oils, tallow, etc. are used to create synthetic paraffinic kerosene. 50% v/v is the maximum blending rate permitted.
ASTM D7566	Synthetic iso-paraffins (SIP) made from fermented sugars after hydroprocessing. 10% v/v is the maximum blend rate permitted.
ASTM D7566 Annex A4	By alkylating light aromatics from non-petroleum sources, FT created paraffinic kerosene containing aromatics (SPK/A). 50% v/v is the maximum blending rate permitted.
ASTM D7566	Using ethanol or isobutanol as an intermediary molecule, alcohol-to-jet (ATJ) SPK. 50% v/v is the maximum blending rate permitted.
ASTM D7566	Kerosene was created by catalytic hydrothermolysis from fatty acids and fatty acid esters. 50% v/v is the maximum blending rate permitted.
ASTM D7566	Fatty acids, esters, and hydrocarbons that have been hydroprocessed by the algal species Botryococcus braunii. 10% v/v is the maximum blend rate permitted.
ASTM D1655	FOG or Fischer Tropsch biocrude, which is unrefined hydrocarbon content that comes from an FT reactor, may only be co-processed in a standard petroleum refinery up to 5% of the volume of the refinery's input.

3.1.3. *Theme 3: Challenges in producing biofuels in Malaysia*

As indicated in Fig. 2 below, according to the experts, there are three major challenges in the production of biofuels in Malaysia that lead to underproduction of this type of fuel: cost, technology, and food vs. fuels debate. Majority of the experts (12 experts) indicated that biofuels are under-produced in Malaysia because of the food versus fuels debates as most of the sources of the biofuels are grown on arable land which is mostly used for cultivating food crops. In a nutshell, the results revealed that Malaysia has a huge potential to produce biofuels, but the available chances are not exploited fully.

All the experts investigated in this study indicated that biofuels are under-produced in Malaysia despite their importance in the aviation as well as other industries. All the experts agreed that globally, Malaysia is the major producer of palm oil along with Indonesia where both the countries produce 80% of the world's palm oil [5,67]. Palm oil is also used in the production of biofuels. Palm oil is grown on arable farms which are used to grow food and cash crops. But at the same time experts agreed that now Malaysia's progress in turning palm oil into a biodiesel or biofuel is quite slow and we are relying heavily on the foreign technology and expertise for venturing into this sector. Even though local Malaysian palm oil producers are setting up their own research and development centres for producing biofuel from palm oil, the rate of acceptability and investment is quite low. Then the 3rd challenge which was identified is the cost of biofuels in the market. It is also posing as an obstacle for its wide scale adoption. Because of its low production rate, biofuels are 2–3 times more expensive as compared to the conventional fossil fuels. According to one of the experts, “The price of biofuels will be expensive during the introduction due to its intensive research and production. As the year passes by, the obstacles that were faced in producing biofuels is reduced”. And due to this we may see a drop in its prices as we are seeing in the current situation where the prices of fossil fuels are dropping all around the world due to the exploration of shale oil [68,69].

One expert mentioned that the recent surge in the numbers of manufactured/traded vehicles across the globe and automation of motor vehicle industries has led to a steady rise in the vehicular carbon footprint, making the transportation sector one of the major polluting sectors

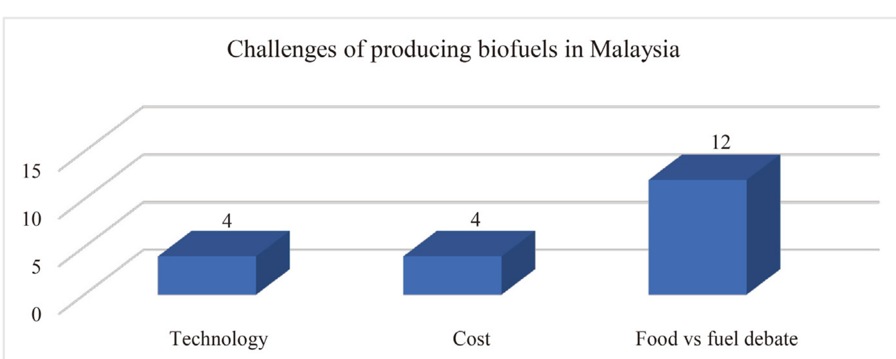

Fig. 2. Challenges of producing biofuels in Malaysia.

as well [70]. By 2020, the total CO_2 emission is close to 34.8 billion tonnes, of which, the transport sector contributes 23% (it also consumes 28% of the total energy of the system) as per the Intergovernmental Panel on Climate Change report. The contribution of aviation industry (11%) in the transport sector is also indicated [12].

One expert added that recently, US-EPA and the California Air Resources Board (CARB) found that biofuel use is enough in decreasing tailpipe GHG emissions by 50% equivalents to fossil fuel [71]. Blending of 20% biodiesel and 80% Low-Sulfur Diesel fuel (ULSD) can reduce GHGs by 50–85% without any investments [71]. According to the latest data obtained, CARB indicated that blends of ULSD in biodiesel could significantly decrease transport related GHG emissions [71]. Fig. 3 shows the cumulative CO_2 reductions in million tons (Mt).

Another expert voiced his worries about the definition of high-ILUC-risk feedstocks in the Delegated Regulation on ILUC risks. Only those biofuels, bioliquids, and biomass fuels that meet the requirements for reducing GHG emissions and were created using extra feedstock procured through additionality methods are eligible for certification as low ILUC-risk fuels [31]. These measures include (1) raising productivity on already-used land; (2) planting crops in previously uncultivated areas (unused land), provided that a financial barrier has been removed, the land has been abandoned or has undergone multiple forms of degradation, or the crop has been grown by a small farmer; and (3) strong proof that measures (1) and (2) have been met. Three schemes have minimal ILUC risk requirements that are, in some ways, comparable to those outlined in the ILUC delegated rule. The Low Indirect Impact Biofuels (LIIB) technique or an equivalent approach must be used to evaluate the low ILUC risks for biomass obtained from bioenergy plantation systems (equal to or bigger than 500 ha) that were planted after January 1, 2008. Increasing crop yields and/or extending agriculture on formerly non-agricultural land with low carbon stores and low biodiversity values are two ways to produce biofuels with minimal ILUC risk, according to the ILLB technique. Three indicators are listed by the RSB as being evaluated for low ILUC feedstocks: In order to produce more biomass, three things must happen. They are; yields must increase; land that was not previously cultivated or not thought of as arable land must be used; and the existing supply chains must be used; otherwise, arable land must be cultivated specifically for the purpose of producing biomass. The low ILUC criterion are deemed optional by the RSB. Three distinct options are provided to biomass producers by Better Biomass to lower the danger of ILUC: (1) Producing biomass on previously unproductive land; (2) Raising productivity through measures including reducing the amount of time that arable land is kept fallow; enhancing the use of grassland; (3) Combining current agriculture or forestry with extra biomass production.

3.1.4. *Theme 4: Commitment and Interest of Investors and Entrepreneurs in aviation biofuel in Malaysia*

The study indicated that investors and entrepreneurs are highly committed and have high interests in the aviation biofuel in Malaysia. Experts mentioned that both the government and the aviation industry are interested and committed in the aviation biofuel. As per Fig. 4 out of 20 experts indicated that the government is highly committed and attracted to aviation biofuels; 4 out of 20 experts indicated that private companies highly committed and attracted to aviation biofuels; and 12 out of 20 experts mentioned that aviation industry by itself is highly committed and attracted to aviation biofuels. Some of the companies which were mentioned to be interested in the renewable energies in Malaysia include Airbus [72] and Brookfield Renewables [73]. Conducting research in the aviation biofuels was indicated as the major commitment on the side of the government, private sector, and the aviation industry.

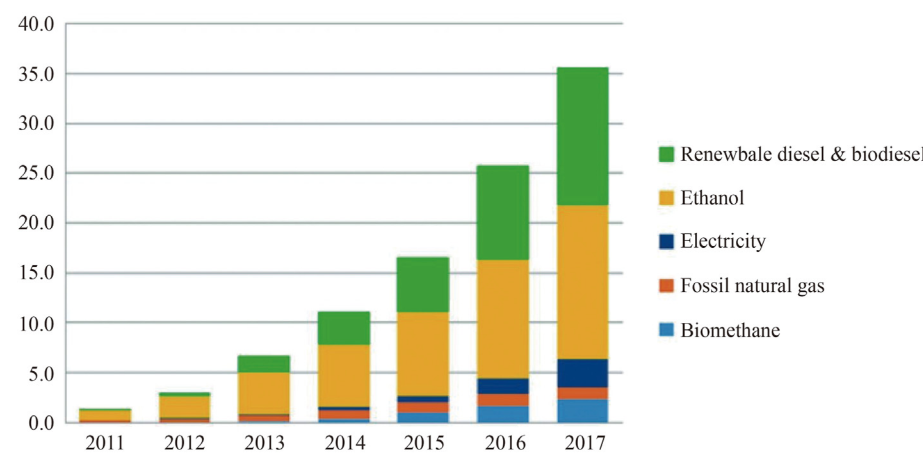

Fig. 3. Cumulative CO_2 reductions in million tons (Mt) [71].

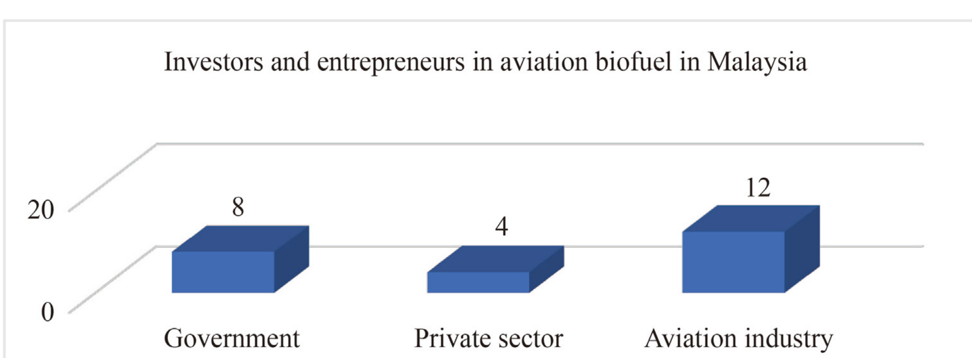

Fig. 4. Commitment and interest of investors and entrepreneurs in aviation biofuel in Malaysia.

Aviation industry is the main player in the aviation biofuels with Airbus taking a lead. However, the government supports and finances numerous research in the aviation biofuels. Expert 1 indicated that, with the current research and development, Malaysia will attract more investors on aviation bio-fuel industry. Investor Brooke Renewables has planned to provide up to $1 billion (RM 3.38 billion) over a five-year period to build a facility that converts inedible crops into green fuel [73]. Similarly, as an initiative by the Malaysian government, Forest Research Institute Malaysia (FRIM) successfully produced biodiesel from non-food-based alternative resources such as *Jatropha curcas*, bintangor laut (Collyphylum innophylum L.), perah (*Elateriospermum tapos*) and industrial effluents [74]. Funding for this centre comes completely from the government (Ministry of Environment)", said expert 5. Other experts also mentioned of MoU's (e.g. between University Technology Petronas and Japan's Mitsubishi Corp.) that have been signed between the private investors and Malaysian government to share knowledge and expertise and train the staff for manufacturing aviation fuel using biofuels [75]. These cumulatively proves the interest shown by the government, private and aviation sector in the cultivation, boosting and promotion of aviation biofuel in Malaysia.

3.1.5. Theme 5: Impacts of Aviation Biofuels on the aviation industry

In the short run, the use of biofuels will not increase the profit level of biofuels or reduce air travel fares because once the biofuels are introduced in the market or the aviation industry to be used for all commercial flights, due to the increased and sudden demand, they will be priced much higher than the conventional jet fuels. However, with time, we expect the prices to become stable when its production is in surplus and different types of biofuels are attested to be used as aviation fuel. The study indicated that use of biofuels is more efficient both to the environment and cost. Fig. 5 below indicates the responses given on the profits, efficiency, and fare reduction due to application of biofuels in the aviation industry.

As per Fig. 5, all the experts agreed that biofuels are more fuel efficient as compared to the fossil fuels. Their view is also in-line with the report by Continental Airlines, the blend of biofuel, which they used in their test flight, increased the efficiency by 1.1% [76]. However, the experts indicated that in the short run, the aviation industry will not make higher profits from the use of biofuels. Only 8 out of 20 experts mentioned profit increase using biofuels of the aviation sector but in contrast none of the experts mentioned that aviation biofuel usage will reduce fares. Presently, biofuels cost four times that of fossil fuels, but if production is speeded up, within 5–6 years, both will cost the same [77]. Its advantages are huge in the longer term. But expensive biofuels will force airlines to raise ticket prices to compensate and will eventually put airlines implementing aviation biofuel initiatives go out of the market and incur huge losses. This indicates that the present use of biofuels cannot guarantee reduction of air fares because of the increased costs incurred in producing the biofuels. However, the experts indicated that the benefits of biofuels in the aviation would be realized in the long run due to its fuel efficiency, little amounts of it will be required all around the world and gradually, the overall or worldwide fuel consumption will decrease creating sustainable and eco-friendly future for aviation industry.

3.1.6. Theme 6: Environmental impacts of biofuels

All the experts agreed that the use of biofuels in the aviation industry will help in reducing the carbon footprint that is said to rise to 3% of the total global carbon emission by the year 2050 [78]. Biofuels are environmentally friendly unlike the conventional fossil fuels and have the capacity to reduce the carbon dioxide (CO_2) emissions up to 84% on every flight [79]. The aviation sector is now playing a major role in the depletion of ozone layer and speeding up the process of global warming because all the carbon dioxide and other nitrates and sulphates released during the combustion of fuel are emitted at the highest levels of troposphere (very close to the ozone layer). Therefore, it is mandatory that aviation industry should be the key player in the reducing the carbon footprint set-off by its activities as suggested by the experts in this study.

One expert said that the core LCA values show that, in comparison to petroleum jet fuel, SAF routes offer potentially considerable GHG emission reductions in attributional life cycle GHG emissions. The effect of each step in a specific SAF's supply chain on the fundamental LCA values is shown in Fig. 6. It is crucial to emphasise that the midpoint values of independent LCA results across various organisations of the Core LCA Working Group define the emissions per LCA stage listed below (as described above). Because the feedstock contains 40% non-biogenic carbon, the FT MSW route in Fig. 6 exhibits non-zero fuel combustion emissions (red bar). The carbon absorbed by feedstock growth would completely offset combustion CO_2 emissions in the event of employing just 100% biogenic MSW. In comparison to other kinds of feedstocks [R, W, B], SAFs made from primary [M]- or co-products [C] biomass feedstocks often have greater emissions related to cultivation and collection. This is because it was decided not to allocate agricultural emissions to [R, W, B] feedstocks. Energy utilisation and fertiliser emissions have a considerable influence on the total life cycle GHG emissions for crops ([M, C]). The variations in the length of the green bars demonstrate that a crucial factor in achieving low-GHG aviation fuels is the utilisation of waste and residual feedstocks or low-input feedstocks (such as specialised energy crops).

Another expert remarked that all voluntary programmes recognised by the EC had definitions of high biodiversity values [31]. Some plans additionally demand a greater level of biodiversity conservation, including the maintenance, preservation, and strengthening of high biodiversity value, in consideration with the effective sustainability requirements. The ILUC Directive has set rules to assess low ILUC risks addressing GHG emissions from ILUC. The RED II introduces national limits for high ILUC-risk biofuels, bioliquids, and biomass fuels (produced from food or feed crops for which a notable expansion of the production area into land with high carbon stock is observed): they should be maintained at MSs' 2019 levels for the period of 2021–2023, and then gradually decrease to zero by 2030.

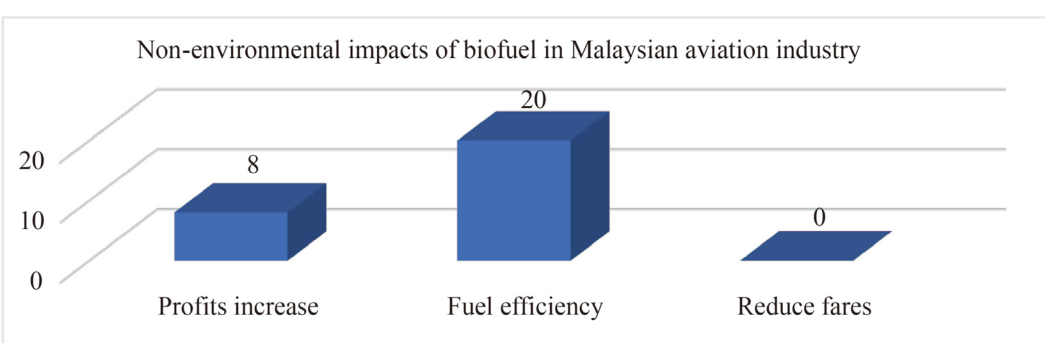

Fig. 5. Impacts of aviation biofuels on the aviation industry.

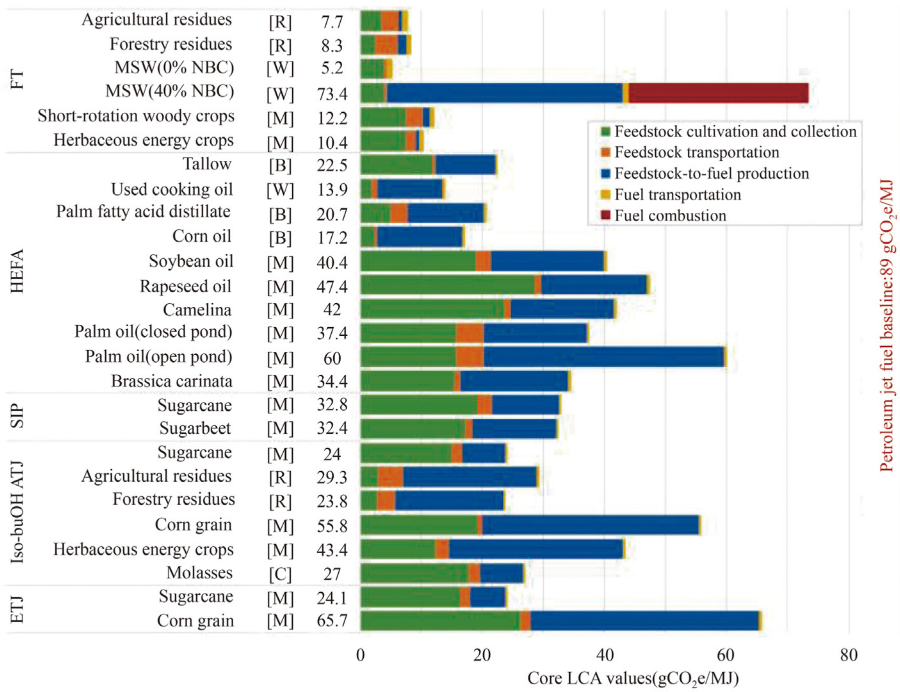

Fig. 6. Default core LCA values for SAF production routes that have so far been authorised by ICAO. Non-biogenic carbon content, or NBC.

3.1.7. Theme 7: Processing Palm oil to be used as aviation fuel

The study found that Malaysia has an abundance of palm oil whereby about 77% of the country's cultivable land is used to produce about 85% of the global total palm oil. The experts had mixed reactions but the majority, 12 experts, indicated that this oil can be processed into biofuels and used in the aviation industry. It is a known fact that the very first test flight with 20% biofuel by Virgin Atlantic did use a mixture of palm oil, coconut oil and babassu nut oil [80]. Oil palm is the most productive oil-bearing plant species known. The yield of palm oil per unit area is 5–10 times higher than rapeseed and soybean oil, respectively. Considering the comparative yields of various oil-bearing crops, oil palm is clearly the most efficiently produced oil in the world today.

Fig. 7 above indicates that experts have mixed reactions towards the applicability of palm oil as aviation biofuels. 12 out of 20 experts indicated that the palm oil can be processed as biofuels and used in the aviation industry. They mentioned that palm oil can be processed into biofuel and be used as an aviation fuel. Three experts validated that in 2016, Garuda (Indonesian airline) started to mix palm oil-based biofuel with its jet fuel to use it as the fuel for their planes." Contradictorily, 8 out of 20 experts indicated that now, processing palm oil to biofuels and using it in the aviation industry is not possible due to the involved costs and technologies. They claimed that "environmental and social effects need to be considered when converting palm oil into biofuel. Clearing land for oil palm plantations will cause rainforest destruction and loss of biodiversity."

Fig. 8 presents a summary of the ILUC emission intensity estimates for the 17 SAF paths from two of the experts who said "no." The findings show that the studied routes had ILUC emission intensities ranging from 58.5 (USA miscanthus ATJ) to 34.6 (Malaysia & Indonesia palm oil HEFA) g CO_{2e} MJ1. Comparatively to area and technology, feedstock appears to be the most significant driver of the variances between routes. The paths are divided into three groups by feedstocks; starch & sugar crops; vegetable oil crops; and (3) cellulosic crops. This classification helps with results interpretation and comparison. On the one hand, it is estimated that vegetable oil pathways produce the highest average amount of ILUC emissions (24.4 g CO_{2e} MJ1), primarily because of their direct or indirect connections to Southeast Asia's high rates of deforestation and peat oxidation brought on by the expansion of the palm

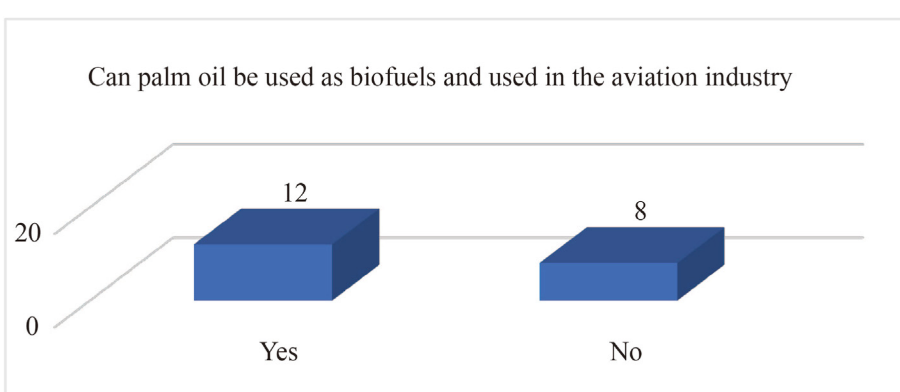

Fig. 7. Use of palm oil in the aviation industry.

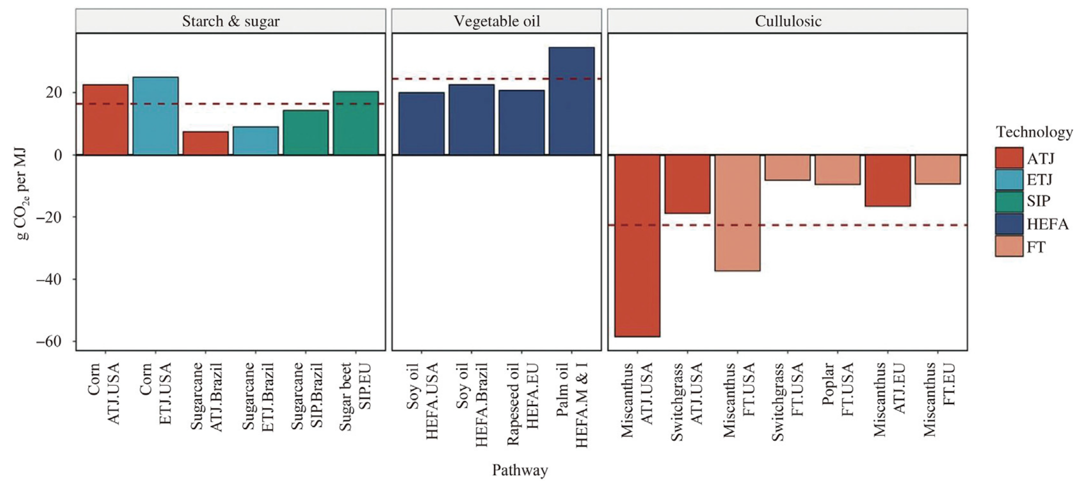

Fig. 8. Emission intensity for sustainable aviation fuel routes due to induced land-use change (ILUC). AEZ-EF and GTAP-BIO were used to estimate the 25-year ILUC emission intensity (in g CO_{2e}/MJ) for each of the 17 paths. The technologies are indicated by a different hue. The letters "M & I″" stand for Malaysia and Indonesia [30].

industry. As a result, it is not unexpected that Malaysian and Indonesian palm oil HEFA has the highest ILUC emission score. On the other hand, due to the significant soil carbon sequestration and biomass carbon from growing cellulosic crops, all the cellulose routes exhibit negative ILUC emission intensities, with an average of 22.6 g CO_{2e} MJ1. In other words, SAF generated through these routes may potentially offer carbon credits through changes in land use. Additionally, 16.4 g CO_{2e} MJ1 of average emission intensity comes from the six starch and sugar pathways.

3.1.8. Theme 8: Modifications needed in the agricultural and aviation sector for the production and usage of biofuels

The study results indicated that the aviation industry is rushing to beat the 2020 deadline for carbon neutral growth. The responses given indicate that modifications are needed both in the agricultural and aviation sectors. All experts agreed that, in aviation industry, participation of all stakeholders including the government, investors, customers, and entrepreneurs and among other is needed to conduct better research to ascertain how biofuels can be used to reduce costs and increase fuel efficiency as this involves modifications in the engines of the aircrafts and safety of passengers and aircrew. As for the agricultural sector, all the experts agreed that production of biofuels in Malaysia should be improved by using other products rather than relying solely on palm oil alone. Crop sustainability should be increased by using methods like crop rotation and allotting quotas for the plantation of feedstock while utilizing the remaining 90% of cultivable land for the systematic farming of biofuel crops. However, it was a common understanding among experts that the agricultural sector requires major modifications to ensure that production of biofuels is increased and does not compromise the production of foods in the country.

3.1.9. Theme 9: Arable land and manpower for biofuel production

For biofuels to be used in the aviation industry and revolutionize the industry, it must be sustainable in terms of production. All the experts indicated that Malaysia has a large arable land that could be used for the large-scale production of biofuels. However, 12 out of 20 experts indicated that Malaysia does not have adequate manpower for the large-scale production of biofuels from palm oil. 8 experts, however, were indecisive on the issue of manpower. This information is presented graphically in Fig. 9.

The above figure indicates that though Malaysia has a large arable land to produce palm oil which can be processed to aviation biofuels; it still faces the challenge of inadequate manpower and technology. None of the experts indicated that the country has adequate manpower to produce biofuels. One of the experts notified that, "as for now, Malaysia has sufficient arable land for cultivating more palm trees and other biofuel crops. There is huge arable land available at Sabah and Sarawak, as we can see the economic growth at east Malaysia is quite low." Another expert mentioned "now Malaysia is using 1.97% of the cultivable land for the plantation of palm oil seeds. So, there is still a large portion of arable land available if we plan on systematically planting the crops for its commercial use as biofuel." However, as for the manpower, Malaysia still do not have sufficient manpower as our population, including the migrant workers is only 32 million, which is 0.43% of the total world population [81]. At the same time, Malaysia lacks technical expertise and rely heavily on foreign technology to help extract, refine, produce and use biofuel in aircraft engines. An expert elaborated about the Induced land-use change (ILUC) emissions. He said CORSIA Eligible Fuel production may require some additional land to be used, and generate land use change GHG emissions [30]. These could occur where

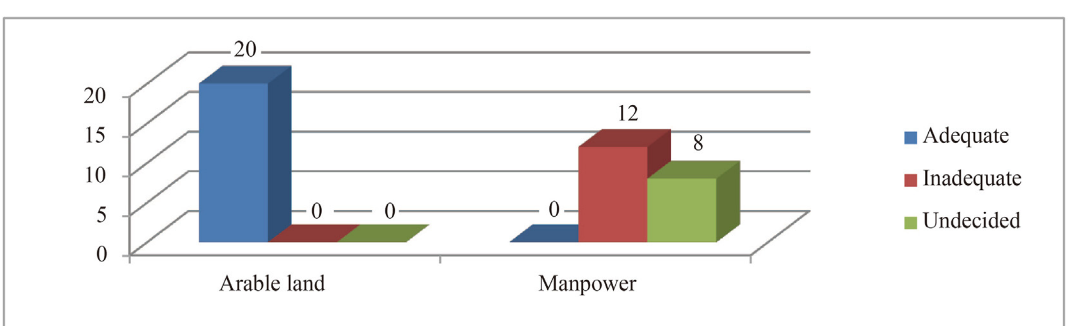

Fig. 9. Arable land and manpower for biofuel production in Malaysia.

the new CORSIA Eligible Fuel production is taking place (direct land use change) but also in other locations due to the displacement of crops (or animals) for which the land was previously used (indirect land use change). ILUC emissions assessment accounts for these different effects, by evaluating greenhouse gas released from conversion of natural vegetation (forest, other natural land), soil organic carbon, oxidation of peatlands, and sequestered biomass.

3.1.10. Theme 10: Production of palm oil as sustainable biofuels in Malaysia

16 out of 20 experts indicated that there is high demand for palm oil not only in Malaysia but also globally (mainly in China and India) and satisfying this demand with producing palm oil as an aviation fuel and also as a food product is not sustainable. This study results indicated that relying on palm oil for the sustainable production of biofuels in Malaysia is not possible.

Fig. 10 above indicates that Malaysia has not achieved sustainability in the production of biofuels from palm oil due to the increased competition posed on the production of palm oil from food products. Majority of the experts indicated that, the problem with depending on crops is that it is never sustainable. Malaysia cannot avoid the changes in climatic and weather conditions. Rain, floods, pests and varying levels of soil fertility, salinity and water table all affect the harvest drastically. Even with high class, technically adaptable facilities like huge greenhouses to monitor the factors needed for a good harvest, it is not possible, especially in Malaysia at the moment, to invest such high capital on the building and maintenance of such large facilities for planting palm oil trees in them. 4 experts who claimed the sustainability of palm oil production for aviation biofuel purpose revealed that, the sustainability comes with huge amount of investment. Based on the CORSIA objective for 2035, the magnitude of growth in each drop-in SAF route, or "shock," is chosen. The production goals of the paths under investigation align with the predictions made by the World Energy Outlook (WEO) 450 Scenario by the International Energy Agency (IEA) [30]. This scenario, which predicts worldwide SAF production in 2025 and 2040, is the most extreme one created by the IEA. Based on those assumptions, the 2035 total SAF output target of 2,596 Petajoules (PJ) or 21.2 billion gallons of gasoline equivalent (BGGE) is interpolated linearly [30,82]. Based on the WEO and Southeast Asia energy forecast, the worldwide projection is further distributed to the regional level and across routes, taking into account feedstock availability, economic viability, and coproduct proportions of road biofuels. Table 5 displays the produced shocks [10,83,84].

Table 5
Shock size for sustainable aviation fuel pathways [30].

Region	Feedstock	Technology	SAF (PJ)	Fuel coproduct (PJ)	Total (PJ)
USA	Soy oil	HEFA	57	171	228
	Corn	ATJ	104	0	104
	Corn	ETJ	104	32	136
	Miscanthus	FT	69	208	277
	Miscanthus	ATJ	69	0	69
	Switchgrass	FT	69	208	277
	Switchgrass	ATJ	69	0	69
	Poplar	FT	69	208	277
Brazil	Soy oil	HEFA	44	132	177
	Sugarcane	SIP	104	0	104
	Sugarcane	ATJ	104	14	118
	Sugarcane	ETJ	104	65	169
EU	Rapeseed oil	HEFA	65	195	260
	Miscanthus	FT	52	156	208
	Miscanthus	ATJ	52	0	52
	Sugar beet	SIP	78	0	78
Malaysia & Indonesia	Palm oil	HEFA	52	156	208

3.1.11. Theme 11: Relying Completely on Biofuels in Future

Experts had mixed reactions on whether it is advisable to rely completely on biofuels soon rather than just mixing 20% of cooking oil with petroleum based conventional fuels. Fig. 11 below gives a graphical representation of this information. From the figure biofuels can be used alone in the aviation industry to reduce carbon emission from petroleum-based engine fuels. However, relying completely on biofuels requires large production of palm oil which is processed into biofuels and used in the jet engines. Relying completely on biofuels is a good bet because it does not release locked carbon into the free carbon cycle. In addition to that, biofuel is sustainable and renewable unlike the fossil fuel reserves mainly because of the argument that it can even be produced from waste products like algae, used cooking oil, organic waste etc. But at the same time 8 of the 20 experts seemed doubtful about its possibility due to growing safety concerns especially when the whole project is still in its research phase and due to sustainability issues.

3.1.12. Theme 12: How safe are the biofuels to be used in the aviation industry?

The social feasibility of biofuels in the aviation sector involves the safety of the fuels in all weather conditions, the safety of the fuels in all kinds of aircrafts and for long distance journeys. Experts had mixed reactions on whether biofuels are safe to be used in all weather conditions, all aircraft engines and for long distance journeys. As indicated in Fig. 12 below, 4 experts were not sure whether biofuels are safe to be used in all-weather conditions; 8 experts claimed biofuels can be used in all weather conditions while 8 experts said biofuels cannot be applied in all weather conditions. In terms of all aircraft operation capability factor, 4 experts were not sure whether biofuels are safe to be used in all aircrafts; 12 experts claimed biofuels can be used in all aircrafts while 4 experts said biofuels cannot be applied in all aircrafts. When looking at the aspect of long-distance applicability of biofuels, 4 experts were not sure whether biofuels can be used for long distance flights; 8 experts claimed biofuels can be used for long distance flights while 8 experts said biofuels cannot be for long distance flights.

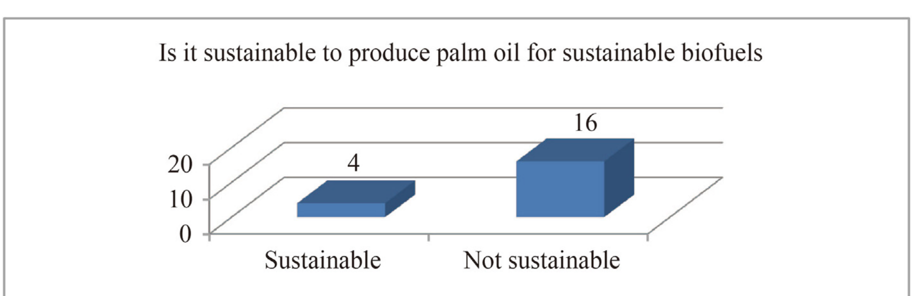

Fig. 10. Possibilities to produce palm oil as sustainable biofuels in Malaysia.

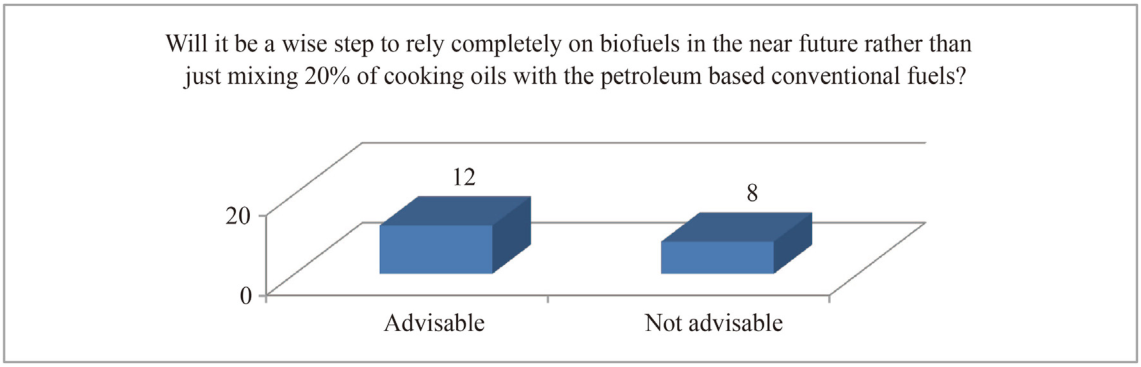

Fig. 11. Relying completely on biofuels in future.

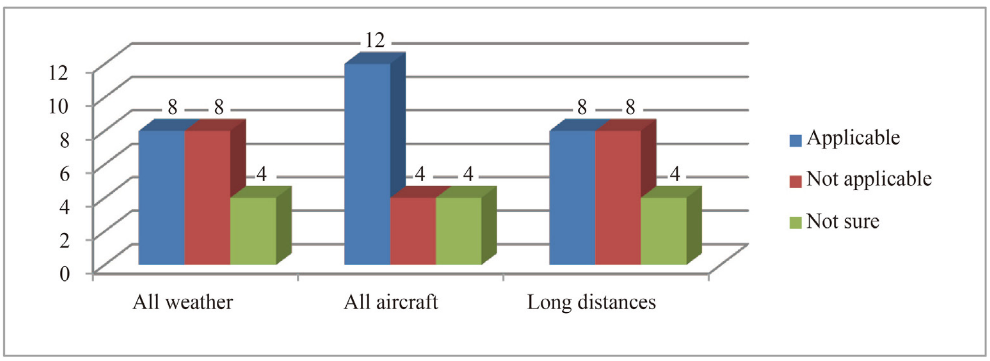

Fig. 12. Safety of biofuels in the aviation industry.

It can be observed that majority of the experts indicated that biofuels can be used in all aircraft engines and can be used in all weather conditions and in long distances. One of the expert claimed that "several commercial airlines like Lufthansa, Finnair, Air Mexico and LKM (a Dutch based airlines) are using as far as a blend of 50% cooking oil to power their aircrafts and flying as far as 1.500 km successfully without refuelling [85]. Another experts said that both Airbus and Boeing are flying test flights with commercial aircrafts and with passengers on board to prove the usability of biofuels [86]. Since a very long-time biodiesel has been used to power helicopters, trucks and lorries as an environmentally friendly measure.

3.1.13. Theme 13: Conditions to consider in public acceptance of aviation biofuels

Experts had mixed reactions on the factors to consider when it comes to public acceptance of aviation biofuels. The conditions raised were grouped into four main areas: safety of travelling, food versus fuel debate, air travel fare, and public education. All experts indicated that there is a great need to ensure that the use of biofuels will not compromise the safety of travelling otherwise public acceptance of biofuel usage in aviation cannot be implemented. 16 out of 20 experts indicated that the food versus fuel debate is a factor to consider when accepting aviation biofuels. All experts agreed that the issue of changes in air travel prices as an important factor to consider for public acceptance of biofuel usage in aviation. All experts gave correlative remarks about the importance of public education on the factors and conditions to consider when deciding on the public acceptance of aviation fuels. This information is presented in Fig. 13.

Safety of travel, food security, reduced air travel costs and public education are some of the factors that determine whether the public will accept the use of biofuels in the aviation industry or not. Once all the conditions are met and the public are clear on the point that the switch

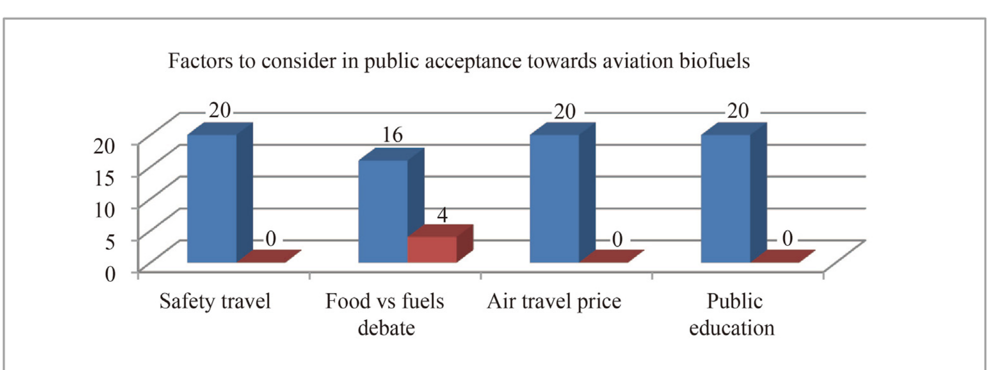

Fig. 13. Conditions and factors to consider in public acceptance of aviation **biodiesels.**

from conventional jet fuels to biofuels will not only benefit the industry but will also ensure safe and cheaper air travels along with the protection of the environment, there will be a nationwide acceptability.

3.1.14. Theme 14: Price fluctuations when aviation biofuels are introduced in the market

All experts agreed that the price of biofuels will increase if aviation biofuels are introduced in the market. This increase will be because of increased demand for biofuels and high cost of production. One expert indicated that the price of food products will increase because of high demand for food and less production of food crops due to competition from palm oils and other plants which are used in the production of biofuels. Additionally, the price of land will increase as the demand for biofuels and food increases. However, replacement of crude oils by biofuels will result in a decreased demand for crude oils resulting to low prices. However, all Experts agreed that if effectively produced the price of biofuels in the aviation industry will decrease with time due to decreasing costs of production and increase in the volume of output. This will positively impact the industry by reducing the expenditure on aviation fuel and hence the air travel prices will reduce with time. One expert reported that, “the price may drop in the future. Besides that, relying solely, on biofuel might increase the demand of biofuel thus will cause the price to increase drastically.” While one of the experts noted that, “It depends on the production volume. If it can be constantly produced to meet the demands, then it is possible to maintain the price.”

3.1.15. Theme 15: Safety of Biofuels in Aviation from the customers' perspective

One of the conditions for the public acceptance of biofuels raised in this study was safety of aviation biofuels used for flying. The experts indicated that the customers must be assured that the application of biofuels in flying is highly safe and would not cause accidents as a result of engine failures. Experts had mixed reactions on whether customers feel that biofuels are safe to be used for flying. Twelve experts indicated that customers would not have any problem with the use of biofuels for flying while eight experts indicated that customers would initially fear and ask several questions. The reason for fear of customers given was lack of adequate education and information on the side of customers on the safety and importance of biofuels in the aviation sector. However, all experts agreed that in future all customers would not have problems with biofuels being used for flying because adequate information will be disseminated, and various tests will be made. As indicated in Fig. 14 below, biofuels are considered as safe fuels for flying both by the aviation management and customers hence there would be no problem in accepting the application of these fuels especially in the future.

3.1.16. Theme 16: Role played by consumers in reducing emissions of greenhouse gases

Aviation industry is the fastest growing emitter of greenhouse gases in the world. The experts indicated that both customers and aviation management have a role to play in reducing emissions of greenhouse gases. Their responses given were categorized into three factors; encouragements (giving businesses to companies using biofuels though they are required to pay extra money), use biodiesels, and plant trees. Four experts did not respond to this question. Sixteen experts agreed that customers should offer encouragements to the aviation companies using biofuels. Eight experts indicated that customers should use biodiesels as a way of reducing greenhouse gases, and four experts indicated that customers should engage in activities that promote clean environment such as tree planting. The responses given indicate that customers have a huge role to play to achieve reduced greenhouse gas emissions. As illustrated in Fig. 15 below, customers should encourage companies using biofuels in order to promote campaign for reduction of greenhouse gases in the aviation industry. Using biodiesels and planting trees were identified as associated factors that are not directly related to the aviation industry, but which play a great role in promotion of environmental protection.

3.2. Political feasibility

3.2.1. Theme 17: Adoption of biofuels methodology in Malaysia

Experts gave mixed reactions on the level of biofuels methodology adoption in Malaysia. Based on Fig. 16, in a scale of 5 with 1 indicating highest level and 5 the lowest level, 12 experts rated the adoption of biofuels in Malaysia at level 2 and 8 experts rated it at level 4. This indicated that 12 experts who gave level 2 remarks believed that Malaysia though it has not reached the highest level of adoption of biofuels, it is on the edge of achieving the highest levels. However, 8 experts indicated that Malaysia is lagging in the adoption of biofuels in the aviation industry. Experts who supported the adoption of biofuels gave an example of Airbus with Malaysian partners which signed a Memorandum of Understanding (MoU) to assess local solutions for sustainable bio-mass production in Malaysia [87]. Although Malaysia has not reached the highest level of biofuels adoption but is in the process due to increased campaigns in the market. The aim is to determine the most suitable feed stocks to ensure that any future jet fuel production in the region is based only on sustainable solutions.” Experts who gave level 2 score for the adoption of biofuel in aviation in Malaysia mentioned that Malaysia is still far from the compliance of the European Union's Renewable Energy Directive (EU-RED) where it is mandatory to give evidence of compliance with the national member state system & where the biofuel is used, to meet the terms of a bilateral or multilateral agreement approved by the European commission (EC), and to refer to a voluntary certification scheme approved by the EC [88].

Since the introduction of the Renewable Energy Directive (2009/28/EC) in 2009, the deployment of renewables has kept growing yearly, reaching 21.8% in 2021 [88]. Sweden had the highest share of renewables in consumption (62.6%) in 2021, ahead of Finland (43.1%) and Latvia (42.1%), as reported to Eurostat. The 2022 study ‘EU's global leadership in renewables' confirms that the EU is already in a leading position for renewables technology development and deployment, but suggests that its competitive position on global renewable energy markets could be further strengthened [31]. The existing directive sets the

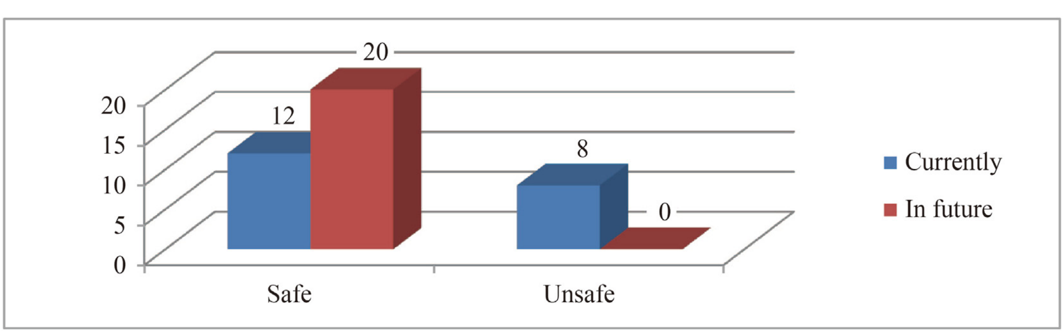

Fig. 14. Safety of biofuels in aviation from the customers' perspective.

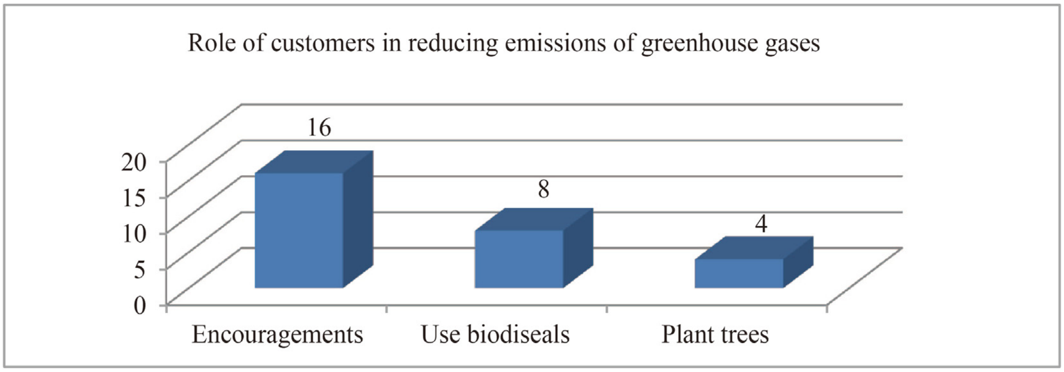

Fig. 15. Role played by consumers in reducing emissions of greenhouse gases.

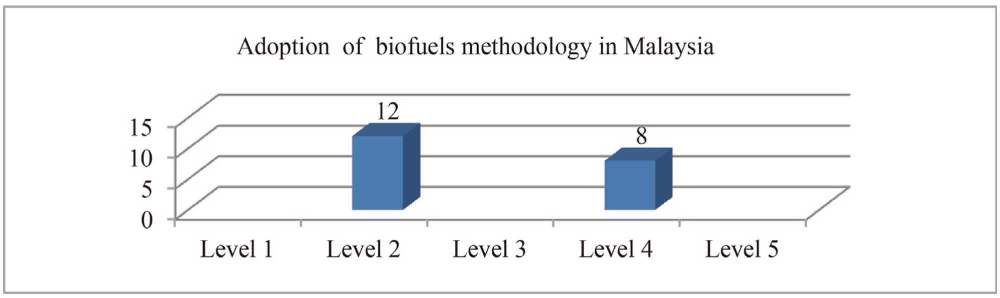

Fig. 16. Adoption of biofuels methodology in Malaysia.

overarching European target for renewable energy and includes rules to ensure the uptake of renewables in the transport sector and in heating and cooling, as well as common principles and rules for renewables support schemes, the rights to produce and consume renewable energy and to establish renewable energy communities, and sustainability criteria for biomass. The directive also establishes rules to remove barriers, stimulate investments and drive cost reductions in renewable energy technologies, and empowers citizens, consumers and businesses to participate in the clean energy transformation [88].

In July 2021, the Commission proposed another revision to accelerate the take-up of renewables in the EU and to help reaching the 2030 energy and climate objectives. The directive sets a common target – currently 32% – for renewable energy in the EU's energy consumption by 2030 [88]. The proposed revision and the REPowerEU plan, presented in May 2022, suggest further evolution of the target to accelerate the take-up of renewables in the EU, including by speeding up the permitting processes for the deployment of renewables.

The ambition and measures in the directive have been reviewed several times in order to deliver the urgent emission cuts (at least 55% by 2030) that are required to achieve the EU's increased climate ambitions. In July 2021, the Commission proposed a revision of the directive (COM/2021/557 final) with an increased 40% target as part of the package to deliver on the European Green Deal. In May 2022, the Commission proposed in its Communication on the REPowerEU plan (COM/2022/230 final) to further increase this target to 45% by 2030 [88].

The revision of the directive also introduces new measures to complement the already existing building blocks established by the 2009 and 2018 directives to ensure that all potentials for the development of renewable energy are optimally exploited, which is a necessary condition to achieve the EU's objective of climate neutrality by 2050 [88]. These include notably strengthened measures to support renewables uptake in transport, heating and cooling, seeking to convert into EU law some of the concepts outlined in the energy system integration and hydrogen strategies, published in 2020. These concepts aim at creating an energy efficient and circular energy system based on renewable energy that facilitates renewables-based electrification and promotes the use of renewable and low-carbon fuels, including hydrogen, in sectors where electrification is not yet a feasible option, such as transport [88].

3.2.2. *Theme 18: Role of biofuels in preserving the environment and in making Malaysia independent in energy production*

All the experts agreed that use of biofuels would help in preserving the environment and in making Malaysia independent in energy production. However, the experts expressed that achieving independence in energy production required over production of biofuels and this may result in increased costs and low food production in the short run. All experts agreed that Malaysia would achieve independence in energy production in the long run but in the short run it must supplement biofuels with crude oils. One of the aims of using biofuels in the aviation industry is to conserve the environment by reducing emissions of greenhouse gases. Experts stated that currently, many institutions in Malaysia are working on biofuel production in order to make the country independent and improve environmental purification. One of the experts noted that, "One day the world will run out of fossil fuels, and with it, our main sources of energy will go up in smoke. But biofuels are different. Some "energy crops" produce more energy than others for example palm oil, which is the main source of biofuel in Malaysia and yields 5 to 10 times more energy as compared to other oil seeds."

3.2.3. *Theme 19: The efforts of Malaysian Government and private organizations in the production of biofuels*

The political aspect of adoption of biofuels in the aviation industry is explained by the role played by the government such as investing in research projects. All the experts agreed that the Malaysian government has plans to invest in the research of biofuels and there are some projects that are ongoing. Additionally, experts agreed that organizations both privately and government owned are already working in the field of biofuels in Malaysia. This indicated the commitment of the Malaysian government as well as organizations in improving the nature of biofuel applications in the aviation industry. One expert noted that, there are several organizations that are working together with Malaysian government's support such as such as Ghent Bio-Economy Valley (GBEV) and Malaysian Biotechnology (BiotechCorp) [89]. The aim of this collaboration agreement is to build an international network and knowledge platform which allows to share information, tools, and resources on the development of bio-based technology and products and thus create new collaborations between Malaysian and Belgian companies and research institutes in the bio-based economic business. This will be done by organising business partner meetings, business matching and by participation in congresses, workshops and seminars in Belgium and Malaysia. But the state of biofuel development in Malaysia is still very slow, almost stagnant. As aviation fuel or bio ethanol is currently not produced in Malaysia for use as a fuel and currently Malaysia solely focuses specifically on biodiesel, with palm oil as the feedstock of choice.

One expert mentioned that several national laws and business efforts have created sustainability standards and reporting guidelines for the use of aviation biofuel in the generation of heat and power. In similar assistance programmes like the UK Renewable Obligation Order for Solid Biomass (RO), the Netherlands Stimulation of Sustainable Energy Production (SDE+), and Belgian Green Certificates (GCs), the sustainability standards are legally enforceable [31]. The criteria may also be optional, similar to the Danish Industry Agreement voluntary initiative. These systems, which are related to both voluntary and specified national sustainability standards, are created to promote the generation of renewable energy from sustainable aviation biofuels. The systems in the Netherlands and the UK were evaluated and compared with the RED II sustainability standards and verification requirements because they offer public and complete guidelines for bioenergy sustainability [31]. There are other popular voluntary programmes including the Sustainable Biomass Program (SBP), Programme for the Endorsement of Forest Certification (PEFC), and Forest Stewardship Council (FSC) [31]. Different certifications are established by the FSC and PEFC. As they certify sustainable forest feedstocks, the SBP, FSC, and PEFC were evaluated. Belgium, Denmark, the Netherlands, and the United Kingdom recognise three programmes where sustainability standards for aviation biofuels have already been put in place. These plans can be used to show that the environmental and socioeconomic requirements for forest biomass are being met. Implementation of such similar schemes in Malaysia is vital in showing the commitment of the Malaysian government as well as organizations in improving the nature of biofuel applications in the aviation industry.

3.2.4. Theme 20: Reaction from other countries on the usage of palm oil in Malaysia as biofuel for aviation industry, especially from the countries Malaysia export palm oil to

All experts indicated that the demand for palm oil would increase when Malaysia starts using the oil in the aviation industry. They indicated that there would be a positive reaction because other countries where Malaysia exports palm oil would view the move as innovative and directed to improve environmental protection and achieve sustainability in fuel production. However, these countries would look for alternatives such as corn oil and soya oil among others. The experts indicated that there will be no problem in the international market with the use of palm oil in the Malaysian aviation industry.

3.2.5. Theme 21: Political will in terms of facilities given, funding, subsidies etc.

All experts asserted that the government is determined to promote and implement the usage of biofuels in the aviation industry through funding and subsidiaries. The Malaysian government have recruited the Malaysia Innovation Centre (AMIC), Malaysian Industry-Government Group for High Technology (MIGHT), Universiti Putra Malaysia (UPM) and the Malaysian Biotechnology Corporation (BioTech Corp) for this 3rd generation of biofuel [90]. The Ministry of Plantation Industries and Commodities (MPIC) is obliged for implementation and policy development. However, one expert stated that there is still a lack political will where fuel prices and funding for research and development is concerned. “Political will is almost minimal as we speak. But we are hoping that with time we will see an increase as more and more public pressure amounts up. There is already a hike in fuel prices and government plans on cancelling the subsidies on RON 95 petrol and diesel by 20 cents per litre.”

4. Conclusion

4.1. Socioeconomic feasibility

Globally, Malaysia can be said as the major producer of palm oil. High resource of oil palm at Malaysia leads to extensive R&D with MPOB on the production of biodiesel. Production of biodiesel was established since 1980's. MPOB has now become one of the successful technology providers to produce biodiesel with the building of its first commercial plant in 2006. Recent research shows that, Malaysian palm oil has ability to replace a moderate (12%) percentage of world aviation biofuel demand. There are various social, economic, environmental, and technical issues with biofuel production and use, which have been discussed in the popular media and scientific journals. These include: the effect of moderating oil prices, the “food vs fuel” debate, poverty reduction potential, carbon emissions levels, sustainable biofuel production, deforestation and soil erosion, loss of biodiversity, impact on water resources, the possible modifications necessary to run the engine on biofuel, as well as energy balance and efficiency.

Biofuel would be a profiting industry in Malaysia id the continuous improvement and innovation is being introduced along the biofuel for aviation production. For many years, the aviation industry has been criticized for its high greenhouse gas (GHG) emissions. A recent Ramboll report claims that it is both technically and economically feasible to facilitate a sustainable and renewable Jet A-1 biofuel production by 2020–25. However, it all depends on where the biofuel is being made and its availability. Presently, biofuels cost four times that of fossil fuels, but if production is speeded up, within 5–6 years, both will cost the same. Biofuels can be used in the conventional jet engines without any modifications. However, the study found that Malaysia does not have the adequate manpower and technology to effectively exploit enough biofuels and use them in the aviation industry. Nevertheless, both the government and the aviation industry are playing a great role in improving R&D and encouraging stakeholders to support use of biofuels.

The study results indicated that biofuels can be used in all aircrafts without any modifications, all weather conditions, and in long distances. Biodiesel that is stored for long periods of time is more likely to oxidize, especially at low temperatures, causing it to gel. Some additives improve the cold weather tolerance of biodiesel, but only by a few degrees. Sustainable aviation biofuel has been rigorously tested to ensure that it’s completely safe and has been fully certified and signed off for use in aircraft. During a test flight, pilots perform several ordinary and not-so-ordinary tests to ensure the fuel can withstand use under any operating conditions.

The study indicated that there are three major factors to consider when using biofuels in the aviation industry: safety travel, food versus fuel debate, and air travel price. The public may reject use of biofuels in the aviation if they feel that their travel would not be safe due to incompatibility with the conventional engines. Mostly, public will be always sceptical toward introduction of new technology. Furthermore, usage of biofuel in one of the riskiest modes of transportation might even further boost the fear level. But as much as the sceptical the public is, they are also can be easily convinced with proper method.

Understanding price fluctuations in the aviation with the introduction of biofuels in the industry is very important. The extant study found that introduction of biofuels would lead to a decrease in the use and demand for crude oils, but the price of foods would increase due to competition for arable lands in Malaysia. However, the price of biofuels would be expensive during the introduction due to its intensive research and production but as the year passes by, the obstacles that were faced in producing biofuels is reduced thus, reducing the price in the future. Besides that, relying solely on, in biofuel might increase the demand of biofuel thus will cause the price to increase drastically.

Initiatives related to biofuels are at the heart of the worldwide shift to a low-carbon transportation industry. After various nations ratified the Paris Climate Change Agreement in 2015, biofuels have emerged as a viable choice for transportation fuel in the case of global warming of less than 2 °C. A decade ago, encouraging policies including mix requirements, subsidies, and fossil fuel taxes gave the global biofuel industry a boost. The initial stage of the biofuel boom was dominated by crop-based biofuels in the US, EU, and Brazil. In the late 2000s, several additional established and emerging nations, including Canada, New Zealand, the Philippines, Argentina, Indonesia, Malaysia, Thailand, India, China, a few African nations, and other Southeast Asian nations, gradually entered the global biofuel industry.

Promoters of biofuels frequently link the benefits for developing nations to improved income and job prospects, technological and scientific spill overs, and new business potential from markets for biobased goods. Early scientists and academics saw biofuels as an environmentally friendly alternative to fossil fuels. However, the marketplaces were far away at the time. A new pragmatic movement in biofuel science and economics was inspired by the global documentation of the unintended consequences of biofuels, including the “food vs. fuel” argument and land-use change (LUC) issues. This shift attracted criticism from the media, legislators, and scholars. The 2008 global food crisis and the indirect land use change (iLUC) apprehensions changed the global judgement on first-generation biofuels from sustainable to unfair and distortionary. Other adverse effects like land conflicts, loss of biodiversity, and ecological disturbances have further subdued interest in biofuels.

Food security issues have led to considerable discontent and jeopardised the pro-poor vision of biofuels for developing nations, even if the effects of biofuels are yet unknown. The national biofuel promotion policies of emerging nations need to be re-evaluated considering these challenges. For instance, China and India deliberately selected non-arable, non-grain, and non-edible land as the source of their biofuel feedstocks. A few African nations, including South Africa, Zambia, and Mozambique, saw a slowdown in the development of biofuels due to issues with food security, socio-ecological concerns from extensive land acquisition, and financial crises. Over time, national aims and misleading objectives have resulted from governmental expectations for biofuels.

Although existing literature does not support crop use for biofuels, first-generation biofuels will likely dominate the biofuels complex in the coming decade. Their effects will unavoidably continue in emerging nations' food-energy nexus. Furthermore, because second-generation biofuel development depends on emerging nations like China, India, South Africa, Tanzania, Thailand, and Brazil, these nations will probably be crucial to the future growth of biofuels.

For the large-scale deployment of biofuels, especially advanced biofuels, to be effective, developing nations must be involved in the technological development process. Between industrialised and emerging nations as well as among developing nations, cooperation will be required. Publicly supported initiatives should disseminate knowledge in a way that encourages vertical and horizontal access to technology and expertise for sustainable biofuel production. It is important to foster international cooperation in creating strong sustainability standards and coordinating certification programmes for biofuels and other biomass products. This is essential to guarantee not only the marketability of biofuels with various certification schemes in various markets, but also their sustainable production, which will increase global commerce in biofuels. The ability to trade in biofuels and feedstocks will be improved, and infrastructure compatibility and consumer acceptance non-economic hurdles will be helped by the global convergence of technical standards, including fuel and vehicle standards. The seamless introduction of biofuels into new markets will be made possible by the exchange of experiences between developing markets and major biofuel-producing nations and areas (such as Brazil, the US, and the EU). The development of sustainable bioenergy and biofuels is the focus of several worldwide bodies and efforts. For instance, the IEA Bioenergy Implementing Agreement 28 focuses on both large-scale worldwide bioenergy deployment and research and development. The 12 tasks that make up the IEA Bioenergy Implementing Agreement concentrate on various technologies and supply-side components of bioenergy development. Increased cooperation between OECD and non-OECD nations on the commercialization of biofuels is possible thanks to Task 39.

It will be essential to consider the unique policy environment and demands of developing nations to achieve the biofuel deployment envisioned in this roadmap. Commercial biofuel production is already taking place in several non-OECD nations, with Brazil, Argentina, China, and Thailand showing the most activity. The development of biofuels has just recently begun in other developing nations, and there is currently no large-scale commercial biofuel production in most African nations. The applicability of various biofuels must be compared to other renewable energy choices that could be of more relevance in the short term given these nations' low financial resources and lack of access to basic energy demands (such as lighting and cooking).

Many developing nations are beginning to recognise the potential economic and social benefits of generating and consuming biofuels, as seen by the rising biofuel output and the growing number of nations implementing biofuel support programmes. In many areas, developing new revenue streams for rural communities is important, along with the chance to reduce spending on petroleum imports. The possibility of exporting biofuels to markets with high demand, such as the United States and the European Union, also exists. Doing so would help boost foreign exchange reserves.

Growing biofuel production and the rise in nations implementing biofuel support programmes indicate that many developing nations are becoming aware of the potential economic and social advantages of generating and utilising biofuels. A major motivator in many areas is the opportunity to reduce spending on importing petroleum products as well as the development of new revenue streams for rural communities. Additionally, there is potential to export biofuels to markets with high demand, such as the United States and the European Union, which would assist in boosting foreign exchange reserves.

To align corporate models with thorough agricultural education and training ideas for farmers, international engagement and funding through public-private partnerships are required. To minimise negative effects on rural development and prevent residents from being displaced, supporting smallholder involvement in biofuel value chains will be essential. Enhancing research and development cooperation between industrialised and developing nations, as well as between developing nations, is necessary to enable technological access and transfer. Based on lessons learned from other nations, technologies and biofuel supply models tailored to a country's unique needs should be created. Feedstock exchange may be an alternative in the near term for nations without biofuel production facilities or with surplus feedstock.

Focus should be placed on biofuel technologies that are economically feasible and technically simple to produce biofuels. Longer term, poor nations can benefit from lessons learned in the production of sustainable conventional biofuels and can embrace advanced biofuel technologies once they have achieved economic viability. Developing nations may require international investment in addition to domestic money to build a sustainable biofuel industry. Large-scale foreign investment may be negatively impacted by administrative and governance issues in developing nations. However, even if these problems are not as serious, the small size of local markets may still limit foreign investment in biofuel initiatives.

Closely assessing all these review articles suggest that none of the studies have attempted to review the possible socioeconomic and political feasibility of aviation biofuel production and usage specific to developing countries from southeast Asia region, such as Malaysia. This study addresses this research gap. By reviewing the socioeconomic and political feasibility of aviation biofuel production and usage impacts, the paper aims to answer critical questions surrounding biofuel endorsement in developing countries specifically in southeast Asia region. Firstly, to address the socioeconomic feasibility, the study provides a broader overview of the recent development of biofuels in developing countries addressing fossil fuel sustainability, biofuels in conventional jet engine adaptation, challenges in producing Biofuel, investor commitment, cost reduction possibilities, role of palm oil in aviation biofuel, modifications needed in the agricultural sector, arable land issues, effects of food production, reliability of aviation biofuel, safety, public acceptance, price fluctuations and customer responsibility.

4.2. Political feasibility

The study revealed that experts had mixed reactions on the adoption level of biofuels in the aviation industry. Most of the experts indicated that the level of adoption of biofuels in Malaysian aviation industry is high. Companies such as Airbus have showed initiatives of assessing the local solutions for sustainable bio-mass production in the country. Malaysian participants in the new study span industry, government, and academia. In a nutshell, Malaysia still under the process of research study and will implement the biofuel in our commercial jet in near future. However, Malaysia is not that far honestly speaking say about maybe 5 more years until we as the national carrier fly our first commercial flight on biofuel.

The study showed that biofuels play a critical role in preserving the environment and in making Malaysia independent in energy production. Assessment of the results of the project in progress developed in cooperation with AIRBUS and the Research Centre for Aviation and the Environment based in Manchester (Great Britain) shows that usage of biofuel reduces the carbon dioxide emissions up to 350 kg per flight. Malaysia has 4 billion barrels of oil as of 2014 according to the oil and gas journal which is almost 4% of the worlds' combined oil reserves. We produce 40% of our power from oil, 36% from natural gas, 17% from coal, 3% from hydro power and the remaining 4% from biomass and waste.

The extant study indicated that the Malaysian government has initiated plans to invest in the research for the use of biofuels in the aviation industry in order to reduce emissions. The Aerospace Malaysia Innovation Centre (AMIC), Malaysian Industry-Government Group for High Technology (MIGHT), Universiti Putra Malaysia (UPM) and the Malaysian Biotechnology Corporation (Bio Tech Corp) were conducting study on GTL (gas-to-liquid) and algae where oil can be extracted. There are several organizations has been working together with Malaysia government supported company such as biotech Corp. But the state of biofuel development in Malaysia is still bad. On 25 October 2011 – Forest Research Institute Malaysia (FRIM) successfully produced biodiesel from non-food-based alternative resources such as Jatrophacurcas, bintangorlaut (Collyphyluminnophylum L.), perah (Elateriospermumtapos) and industrial effluents. Funding for this centre comes completely from the government/Ministry of Environment.

With a few significant investment plans and governmental efforts still to be put into action, developing nations—aside from Brazil—are still in the early stages of the biofuels market's growth. The market dynamics of these nations are still developing and are significantly impacted by the biofuel policies of the US and the EU. Research reveals that US and EU biofuel policies have both favourable and unfavourable effects on emerging nations. Due to the production of maize ethanol in the US and EU, as well as the expansion of rapeseed farming in India, modelling-based studies predict that over 2.8 million hectares of land will be converted in Brazil, as well as 2.3 million ha in China and India.

In several areas, international cooperation will be necessary to develop a viable global biofuel industry. Better land-use data will be produced because of collaborative worldwide field mapping initiatives, which will also aid in improving the understanding of the world's potential biomass. Efforts at crop breeding and extensive field tests should be conducted together, fusing local knowledge of indigenous crop species with already-existing technological knowledge. Regions with a lack of resources in this area need to be introduced to the best practises for cultivating sustainable feedstock. This is crucial to assisting small feedstock producers in adhering to sustainability certification programmes and gaining access to global markets. To assure capacity growth and knowledge transfer, joint research and development activities to create biofuel conversion methods need to be strengthened.

Investor confidence is expected to rise if exports of biofuels can reach global markets, but doing so would necessitate meeting sustainability norms in the importing nations. The proliferation of sustainability initiatives in important consuming nations is currently a major concern. Thus, the need for globally accepted sustainability standards and certification programmes to produce biofuels and the necessity for poor nations to actively participate in their creation The fact that certification prices are frequently greater than in industrialised nations and can account for up to 20% of smallholder producers' total production expenses is a difficulty for developing nations. To enable developing nations to learn and use certification systems, enhance the legitimacy of national assessment bodies, and lower certification fees for biofuel production, certification criteria must be coupled with funding and technical support.

This plan is a response to the G8 and other government leaders' calls for a more thorough examination of the sustainable development trajectory for biofuels, a crucial carbon mitigation technology. The biofuel roadmap is meant to be an evolving process that considers new technological advancements, laws, and efforts at international cooperation. The international community may use the milestones in the roadmap to check that biofuel development initiatives are moving towards the reductions in GHG emissions needed by 2050 in a sustainable way. The IEA will frequently update stakeholders in government, business, and non-governmental organisations on the advancement made towards the goals of this roadmap.

Closely assessing all these review articles suggest that none of the studies have attempted to review the possible socioeconomic and political feasibility of aviation biofuel production and usage specific to developing countries from southeast Asia region, such as Malaysia. This study addresses this research gap. By reviewing the political feasibility, the study synthesizes adaptation of Malaysia for aviation biofuel, preservation of the environment, role of the government and the reactions from palm oil importers from southeast Asia region.

The extant study revealed that if Malaysia started to use biofuel for aviation industry, the demand for the palm oil will increase and eventually the price of the palm oil increase as well. As the palm oil price increases, those countries which Malaysia exports will find substituent for palm oil such as corn oil, soya oil and so on. There will be a positive reaction, because of the multiple income can produced from just a single type of agricultural process. This will also encourage the other countries which has agricultural dependent economics to invest in biofuel production. According to Malaysian Palm Oil Council (MPOC), Malaysia currently accounts for 39% of world palm oil production and 44% of world exports. If considered of other oils & fats produced in the country, Malaysia accounts for 12% and 27% of the world's total production and exports of oils and fats. So far Malaysian government has encouraged the biofuel usage by implementing the memorandum of understanding. Besides that, they have supported the studies on the 3rd generation of biofuel which is GTL (gas-to-liquid) and algae.

CRediT authorship contribution statement

Thanikasalam Kumar: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Project administration. **B Gevansri K Basakran:** Investigation, Writing - review & editing. **Ananth Manickam Wash:** Investigation, Writing - review & editing. **Mohd Zuhdi Bin Marsuki:** Supervision, Funding acquisition. **Rahmat Mohsin:** Supervision, Funding acquisition. **Zulkifli Abd.**

Majid: Supervision. Mohammad Fahmi Abdul Ghafir: Software, Supervision.

Data availability

The data and materials used to support the findings of this study are available from the corresponding author upon reasonable request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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