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Research article

Greening aviation in era of COVID-19: Towards conceptualizing and operationalizing decarbonization

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ABSTRACT

Although net-zero greenhouse gas emission targets continue to gather burgeoning streams of research, there is a lacuna in current literature on the pathway challenges towards operationalizing decarbonization. The study advanced 2 × 2 matrix of an organizing framework of challenges in accomplishing net-zero emissions targets. Using the global airline industry as an illustrative context, the study provided deep insights on the pivotal industry, institutional, and organizational challenges in the era of COVID-19 such as fleet modernization, over-reliance on fossil fuel, slow progress in the development of hydrogen and electric aircraft, risk of corporate greenwashing, and divergent approaches adopted by airlines. The challenges can be classified into policy-oriented, organization-specific, and external/macro-environment factors. The contributions to theory and practices were identified and examined.

1. Introduction

The last three decades or so have witnessed a quantum shift in scholarly understanding of climate change and its more damaging effects on humanity and lifestyle, thereby precipitating a shift in nations and businesses' policies (c.f. IPCC, 2018; Karlsson et al., 2021; Rogelj et al., 2021; Ahmad et al., 2022). In the aftermath of the 2015 Paris Climate Agreement, there has been invigorated effort around the globe towards reducing greenhouse gas (GHG) emissions by governments and citizens. In this new era, no business is immune from the effects of growing greenhouse emissions. In parallel with governments, the pathways to decarbonize the global economy have also been championed by industries and businesses all around the globe with a flurry of them committing to reaching "net-zero" carbon emissions by 2050 (International Energy Agency, 2021; Kyte, 2021; van der Sman et al., 2021). There are ample opportunities and incentives for organizations to move to net-zero emissions including potential cost savings and resource conservation that can be accrued from embracing renewable sources of energy (International Energy Agency, 2021).

The COVID-19 pandemic – with over 617, 195, 686 coronavirus cases and 6,530,779 fatalities around the world (Worldometers, 2022) – has demonstrated that the fortunes of nations are inextricably linked to one another and thus, require the collective effort of governments and organizations to usher in a green global economy (Amankwah-Amoah, 2020a, 2022; Amankwah-Amoah and Hinson, 2022). Although there is a plethora of scholarly works on global warming and greenhouse emissions (Bergek and Berggren, 2014; Xu et al., 2020; Gustafsson et al., 2021; Kumar et al., 2021), there is a relative paucity of studies offering comprehensive analysis of the industry challenges in the pathways to net-zero emission targets. Much of the current literature tends to focus on policies rather than the pathway challenges in greening an industry. Against this backdrop, the purpose of this paper is to examine the pathway industry challenges of getting to net-zero emission targets. In an attempt to fill this lacuna in current understanding, this study utilizes the global airline industry to examine the range of industry, institutional, and organizational challenges in getting to net-zero emission targets.

The industry is suitable as an illustrative context for a number of reasons. First of all, aviation is an indispensable aspect of the global economy. Indeed, around 54% of international tourists travel by air as well as contribute around $3.5 trillion (4.1%) of the world's gross domestic product (IATA, 2020). Indeed, intra- and inter-regional air connectivity has been found to lead to improved investment and innovation, as well as enhanced business competitiveness (IATA, 2020). The importance is further reinforced by the reality that by 2040, aviation could contribute about 15.5 million jobs and $1.5 trillion of gross

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domestic product to the global economy (Ahlgren, 2021d). Fundamentally, aviation has grown to "become the high-profile poster-child" for global pollution and GHG emissions (Ahlgren, 2021d, p. nd). Thus, examining the pathways towards decarbonization could serve as a useful learning model in other global industries. In 2021, at the International Air Transport Association (IATA) 77th Annual General Meeting, members and the air transport industry adopted a proposal to achieve net-zero carbon emissions by 2050 (IATA, 2021a, 2021c). In the industry, without concrete and concerted efforts to reduce the environmental footprint, CO_2 emissions would triple by 2050 (Timperley, 2021).

The paper makes vital contributions to research on sustainability. First, despite an accumulation of sustainability research over several decades (White and Noble, 2013; de Lima et al., 2021; International Energy Agency, 2021), there is a lack of comprehensive analysis of the different industrial challenges of getting to net-zero emissions. This study deviates from the piecemeal approach to the subject by examining in tandem the institutional and industry (i.e., external), and organizational (i.e., internal) challenges. Moreover, in light of increasing discourse on neutrality and decarbonization within individual organizations (c.f. Liu et al., 2017; Cheng et al., 2021), there is general lacuna pertaining to how researchers can better operationalize the decarbonization processes in industries such as aviation. In this direction, this article adds to previous decarbonization research by developing a conceptual model for operationalizing decarbonization. The paper provides insights on this conceptualization using insights from the global airline industry. In addition, by highlighting the potential environmental impact of net-zero targets and businesses' activities in reducing emissions, our study offers a pathway framework towards greening the industry. In this direction, the study elucidates the concept of sustainability under uncertainty (Baumgärtner and Quaas, 2009; Brink, 2017; de Lima et al., 2021; Diwekar et al., 2021) by highlighting factors that influence net-zero emission targets and how the constraining forces can be neutralized.

The rest of the paper is organized as follows. First, a review of literature on the concept of sustainability under uncertainty and net-zero is presented. Then, the next section briefly sets out the background of the global airline industry and attempts to reach net-zero. After articulating the challenges of net-zero emissions, the implications of net-zero emissions for practitioners and researchers are examined.

2. Literature review: sustainability under uncertainty and net-zero emissions

The analysis is anchored mainly in the concept of sustainability under uncertainty (Baumgärtner and Quaas, 2009; Diwekar et al., 2021) and literature on net-zero (Cheng et al., 2021). The general concept of choice under strict uncertainty is understood to exist when "decision alternatives have several uncertain outcomes whose likelihoods are unknown and cannot" be deduced from prevailing information (Hansen and Helgeson, 1996, p. 153). Uncertainty denotes the inherent difficulties in predicting the future (Beckman et al., 2004). In other words, the inability to assess accurately the organizational and external environmental conditions with greater certainty, which then influences businesses' strategic investment decisions (Sanchez-Peinado and Pla-Barber, 2006; de Lima et al., 2021). Accordingly, the lack of information or knowledge inhibits organizational decision-makers' decisions and strategic implementation (Beckman et al., 2004; Gaba and Terlaak, 2013).

Uncertainty's effect on sustainability policies (Grote, 2009; Griffin and Grote, 2020; Durugbo and Amankwah-Amoah, 2019) may stem from factors such as incomplete information, lack of knowledge and lack of alternatives (Hansen and Helgeson, 1996; Lipshitz and Strauss, 1997; de Lima et al., 2021; Gaba and Terlaak, 2013). Recent research also highlights that uncertainty remains a potent force in the global economy and can stem from ambiguities surrounding current and future government and industrial policies (Diwekar et al., 2021) and political instability (Cavusgil et al., 2020; Jia and Li, 2020). Policy uncertainty includes the nature of governmental future investments and spending, regulations for businesses, carbon neutrality initiatives, environmental emission standards, and industrial certification standards (c.f. Baumgärtner and Quaas, 2009; Diwekar et al., 2021). Such uncertainty may also stem from lack of consensus about the direction of travel among different internal and external stakeholders. Under conditions of uncertainty, there is a lack of clarity/visibility about the future policy direction (Baumgärtner and Quaas, 2009; de Lima et al., 2021). Thus, lowering uncertainty can provide incentives for individuals and organizations to invest in new and potentially promising ventures. Specifically, the unpredictability of governments in relation to setting targets and regulations can impede business development and investment activities (c.f. Diwekar et al., 2021; Ozili, 2021). A higher level of policy uncertainty is likely to diminish confidence in future business investment and new technology adoption (Jiang et al., 2020; Diwekar et al., 2021).

Researchers have indicated that the development of an effective institutional framework via legislative mandate, regulation, and government directives can signal to businesses a legitimate and acceptable standard in the future, thereby necessitating behavioral change (Peng, 2017; Cavusgil et al., 2020). Businesses incorporating environmental sustainability practices such as energy efficiency, eco-friendly raw materials and manufacturing, life cycle assessment, and waste management may be accelerated by an industrial and government policies (c.f. Durugbo and Amankwah-Amoah, 2019; Diwekar et al., 2021). As suggested by prior studies (Erkoyuncu et al., 2013), lack of policy certainty can generate disturbances in business operations as well as stifle the adoption and implementation of new business practices. Online Supplementary Appendix 1 provides an additional overview of the literature on sustainability under uncertainty.

The second theoretical underpinning is the general literature on net-zero carbon dioxide (CO_2) emissions (IPCC, 2018; De La Peña et al., 2022; Su et al., 2022). There is a burgeoning research interest on the topic of net-zero carbon dioxide (CO_2) emissions, which occur when "anthropogenic emissions of GHG to the atmosphere are balanced by anthropogenic removals over a specified period" (IPCC, 2018, p. 24). Thus, net-zero focuses on reducing GHG emissions by ensuring an effective alignment between emissions produced and emissions captured and removed from the atmosphere (IPCC, 2018; De La Peña et al., 2022). Researchers have stressed the importance of business model innovation in meeting future challenges confronting organizations (Foss and Saebi, 2018; Aspara et al., 2013; Ferlito, and Faraci, 2022; Hall et al., 2022). Business model innovation is viewed as a carefully orchestrated set of actions or mechanisms that a business adopts to create value for end users (Yang et al., 2017; Foss and Saebi, 2018; Hall et al., 2022). The adoption of eco-friendly business models and energy transition strategies via adoption of renewable energy sources such as wind turbines and solar photovoltaics can improve the competitiveness of businesses (Li et al., 2017). Managers in modern organizations face a strategic goal of achieving net-zero CO_2 emission targets by renewing and replacing existing resources and capabilities. It has, nevertheless, been demonstrated in the literature that realignment of the business model with the natural environment can improve firm competitiveness (Danso et al., 2019).

3. Historical context of the global airline industry and net-zero emissions

The distinguishing characteristics of the global airline industry in the last three decades have been the rapid internationalization by airlines to all corners of the globe coupled with increased emission of GHG. Historically, unprecedented "Open Skies" changes have paved the way via directive/regulations/agreements such as deregulation reforms

including the passing of the United States' 1978 Airline Deregulation Act, the establishment of a single European Common Aviation Area in 1993, and the adoption of the 1988 Yamoussoukro Declaration in Africa (Doganis, 2006; Amankwah-Amoah and Debrah, 2011; Belobaba et al., 2015). These and other reforms around the globe have been accompanied by an exponential growth in air travel. In contemporary airline businesses, there are now very few barriers to international expansion. In recent times, the turbulent industry environment precipitated by COVID-19 has resulted in a net 2020 loss of around $137.7 billion and $51.8 billion loss for 2021 (IATA, 2021f). The industry's 2020–2022 total losses are expected to exceed $200 billion, partly due to government-imposed constraints on travel (IATA, 2021f). These challenges call for renewal of the airlines' business model and how they engage with different stakeholders towards embracing a robust and wider sustainability agenda (Amankwah-Amoah et al., 2021).

Globally, aviation accounts for around 2–3% of CO_2 emissions and 4% in Europe (van der Sman et al., 2021). The industry faces several substantial challenges in terms of reducing GHG emissions via curtailing fuel consumption, energy use, and overall environmental footprint (Amankwah-Amoah, 2020a, 2020b, 2021; IATA, 2019). Recently, the global industry and airlines have moved sharply towards adopting different ranges of net-zero emission targets in both industrialized and developing nations (Ahlgren, 2021a; IATA, 2021a). One of the outcomes of the 77th IATA Annual General Meeting in 2021 was an adoption of the resolution that IATA member airlines would focus on achieving the noble objective of net-zero carbon emissions by 2050 (IATA, 2021a). The adoption of the Paris Agreement as a binding international treaty by countries on climate change to limit global warming to 1.5 °C around the globe in December 2015 and coming into effect in November 2016 (United Nations Framework Convention on Climate Change, 2021) prompted a sense of urgency on the part of many airlines. The industry's commitment to a net-zero is comprehensive in a sense that it encompasses signatories not only from airlines but also airport operators, engine manufacturers, and aircraft manufacturers rooted in innovations, renewable energy sources, and innovations (IATA, 2021b). This was a departure from the past practices where individual airlines have announced their individual strategies to reach net-zero. This industry-wide approach entails a combination of climate action initiatives such as the adoption of new aircraft technologies including hydrogen and electric, uptake of sustainable aviation fuel (SAF), and carbon removal measures (IATA, 2021b). Specifically, the emissions reduction strategy entails key components such as 65 percent of emission reductions being deduced from wider embrace of SAF, 13% investment in the adoption of new aircraft technologies, as well as 19% from approved carbon offsets (IATA, 2021a).

In a similar vein, in Europe, there is a flagship environmental sustainability initiative, dubbed "Destination 2050", the sector's roadmap to net-zero carbon emissions (Ahlgren, 2021a). This European Green Deal seeks to usher in an era where all flights within and departing from the European Union (EU) achieve net-zero CO_2 emissions by 2050 (van der Sman et al., 2021). This is also expected to be achieved via measures such as the adoption of new and clean technologies and SAFs (van der Sman et al., 2021). In September 2021, the Association of Asia-Pacific Airlines also conveyed its commitment to net-zero emissions by 2050 (Curran, 2021a). Indeed, from its 15 member airlines, some airlines such as Singapore Airlines, Cathay Pacific, All Nippon Airways, and Japan Airlines had already committed to net-zero emissions (Curran, 2021a). Like the global IATA's agreement, this also sought to bring together multiple stakeholders such as governments, fuel suppliers, and aircraft and engine manufacturers (International Energy Agency, 2021).

Although the net-zero CO_2 emission target by 2050 is widely accepted across the global industry, airlines differ in terms of their roadmaps and strategies to decarbonize (Ahlgren, 2021c). Indeed, one world leading airline, Delta Air Lines, has committed around $1 billion to buttress its ambition to become the first carbon-neutral airline around the world (Ahlgren, 2020). Whilst some airlines have focused on enhancing operational efficiency, others focus on enhancement of AI-supported flight plans, coupled with rigorous certification standards, the current noise footprint of new aircraft is at least 15% smaller than the ones they replace (IATA, 2021e).

Online Supplementary Appendix 2 provides a summary of some of the net-zero CO_2 emission initiatives towards decarbonization of the industry. Global aircraft makers such as Boeing and Airbus also had a pivotal role to play in the adoption of new technologies to lower pollution levels (FT, 2021). In the industry, emissions from aircraft engines can impinge on air quality including nitrogen oxides, carbon monoxide, unburned hydrocarbons, and smoke. However, technological development underpinning engine designs has culminated in the reduction of some emissions such as nitrogen oxides and carbon monoxide (IATA, 2021e). In the European Union, in tandem with the desire to achieve climate neutrality, Airbus is also seeking to produce the "world's first zero-emission commercial aircraft" (Singh, 2021a, p. nd). By using energy from renewable sources such as solar, wind, and nuclear as well as carbon-capture technology, businesses would be able to curtail carbon dioxide, thereby making an effort towards achieving zero carbon goals (Rott, 2019).

4. An organizing framework of challenges in accomplishing net-zero emissions targets

In line with prior scholarly works and discussions above, it can be deduced that there are two types of challenges: organization-oriented and external-induced challenges. The organization-oriented challenges relate to firm-specific issues and weakness in organization can serve as obstacles or constraints in getting to net-zero targets. External (environmental) challenges relate to factors outside the organization including industry and institutional conditions such as influence of governments, public policy, environmental pressure groups, industry bodies, etc. Another dimension to these challenges is timing, which can be categorized into short-term and long-term. Traversing the vital pillars produces the 2 × 2 matrix of an organizing framework of challenges in accomplishing net-zero emissions targets. As depicted in Fig. 1, Quadrant I denotes the internal challenges in the short-term (Quadrant I), Quadrant II denotes external challenges in the short-term, Quadrant III refers to the internal challenges in the long-term and Quadrant IV focuses on external challenges in the long-term. Quadrant I denotes the internal challenges in the short-term (Quadrant I), Quadrant II denotes external challenges in the short-term, Quadrant III refers to the internal challenges in the long-term and Quadrant IV focuses on external challenges in the long-term. As demonstrated in Fig. 1, the journey to the adoption of climate and environmental sustainability is typified by several internal and external challenges:

4.1. Quadrant I: Internal challenges in the short-term

Quadrant I focuses on organizational level challenges in the short-term such as internal capacity-building activities, cost of resources and expertise renewal and upgrading, prevalence of short-termism in managerial thinking and net-zero as "vehicle for corporate greenwashing".

4.1.1. Risk of corporate greenwashing

Many businesses are increasingly seeking to develop environmentally friendly brands and reputations via the adoption of net-zero emission targets. A major challenge in meeting net-zero emission targets is the tendency of some businesses to utilize it as some kind of corporate-impression management strategy. Some have contended that net-zero emission targets are viewed as a "vehicle for corporate greenwashing" or license to "pollute as usual" (Bragg et al., 2021, p. 9). Thus, net-zero is an attempt by bid businesses to pretend to be practicing concrete steps towards the green global agenda without necessarily making meaningful and necessary painful changes to help combat

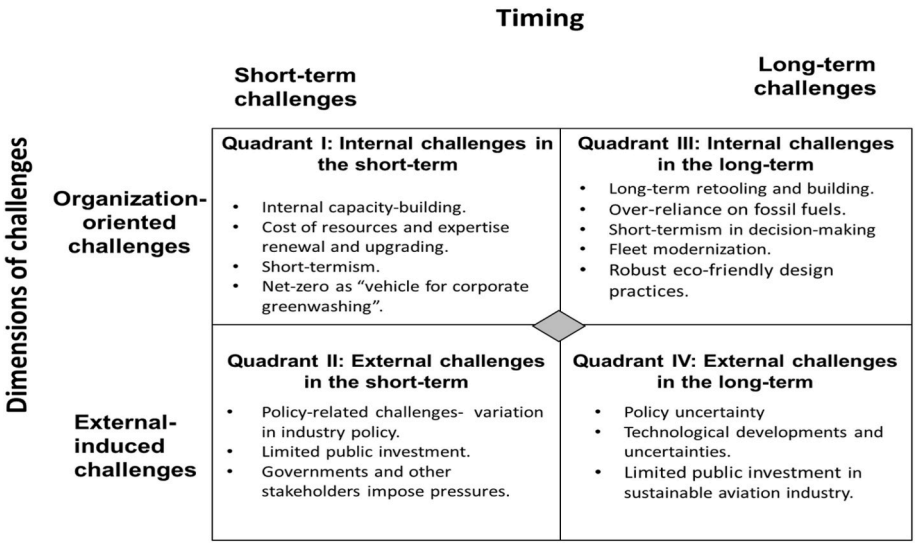

Fig. 1. An organizing framework of challenges in accomplishing net-zero emissions targets.

climate change (Bragg et al., 2021). Given the flurry of companies committing to such targets and displaying their environmental bona fides, there is a real risk that this can become a mechanism for greenwashing, where a business conveys misleading information and makes unwarranted claims of being a green, eco-friendly, or environmentally sustainable business (c.f. Delmas and Burbano, 2011). Globally, over 1500 corporations have committed to net-zero (Bragg et al., 2021). It has been opined that many businesses and big polluters from all corners of the globe have made commitments to different net-zero emission targets as a means of deflecting attention from the needs of regulatory and government-led reforms to shift from old and inefficient sources of energy and resources to renewables (Bragg et al., 2021). Accordingly, "net-zero" emission targets are seen as a carefully orchestrated attempt by big businesses "to delay, deceive, and deny" the need for immediate reforms for a green future (Bragg et al., 2021).

In the industry, some brands, activities, and products have been described as "eco-friendly" with little or no foundation. For instance, in 2019, the UK advertising regulator banned Ryanair's advertising for not offering evidence of its assertion of generating "Europe's lowest emissions" airline (Timmins, 2021). Taken together, the analysis here indicates two vital sources of environmental innovation in the industry: environmental innovation (resource scaling back), and clean and new technology adoption.

4.1.2. *Inflight waste reduction and resource conservation*

Another major challenge surrounds eliminating or reducing inflight waste. As a protracted issue, inflight waste totals around 6.7 million tonnes annually for the industry (Ahlgren, 2020). Besides Portuguese airline, Hi Fly becoming the first carrier to operate a plastic-free flight on Portugal-Brazil connection in December 2018, many airlines have moved beyond mere removal of plastics towards wastes reduction, resources conservations, energy efficiency and mitigating emission associated with inflight products used and activities (Ahlgren, 2020). Since then, Etihad Airways has also become the leading airline to complete a long-haul flight devoid of single-use plastic. Many airlines including Ryanair to become entirely plastic-free by 2023 and British Airways seeking to curtail single-use plastic from its flights (Ahlgren, 2020).

4.2. *Quadrant II: External challenges in the short-term*

Quadrant II displays the challenges that stems from the external environment in the short-term. These include Policy-related challenges or variation in industry policy application, limited public investment and stakeholders' pressures.

4.2.1. *Divergent approaches adopted by airlines*

Apart from changes necessitated by industry regulations and governments, another major challenge in reaching net-zero is the divergent approaches adopted by individual airlines around the globe. For instance, some Chinese airlines have sought to shift the deadline from 2050 to 2060 to provide them with enough time to make the necessary changes (FT, 2021). This demonstrates the difficulties in persuading both developed- and developing-nations airlines to adhere to the same targets (FT, 2021). A study by Gössling and Humpe (2020) demonstrated that just 1% of the global population accounts for 50% of CO_2 from commercial aviation. Thus, in tackling the crisis, attention needs to be directed towards this group to pay for the cost of emissions. In terms of curtailing cabin waste, airlines have focused on "reducing, reusing, and recycling cabin waste" from fleets, including food and plastics, to minimize their environmental footprint (IATA, 2021e, p. nd).

A plethora of research has demonstrated that there are institutional differences between developed and developing nations, which determine firm-level operation and strategic behavior (Autio and Fu, 2015). The global airline industry like many industries is shaped by institutional constraints/malfunctions such as poor regulatory framework, weak and enforcement legal system in the developing nations in the global south. Despite its increasing importance, the variation in firms 'approaches make it difficult to achieve commonalities in the operational processes. There is little deterrent for firms to use net-zero brand and logos for reputational effects whilst making modest or no alterations given that services/products linked to net-zero may have wider appeal with travelers. On the basis of the foregoing analysis, there is a range of pressures and sets of actions leading to the adoption of net-zero emission targets and solutions for the future of sustainable aviation, as depicted in Fig. 2. The figure also demonstrates that a major driver of global zero-emission targets adoption is pressure on governments to regulate from other stakeholders to promote green travel.

4.3. *Quadrant III: Internal challenges in the long-term*

Quadrant III focuses on internal challenges with long-term orientation. This encompasses factors such as over-reliance on fossil fuel, short-termism in decision-making, fleet modernization issues and developing robust eco-friendly design practices.

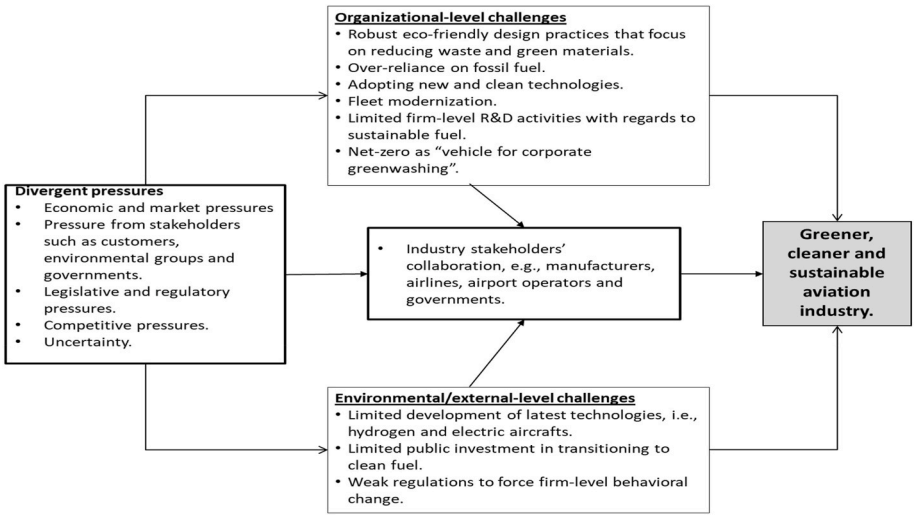

Fig. 2. Activities and challenges in the pathways to decarbonization.

4.3.1. *Over-reliance on fossil fuel and fleet modernization*

A major and interconnected challenge confronting the industry in terms of achieving net-zero flights is the over-reliance on fossil-based jet fuel and the cost of fleet modernization. For decades, "jet kerosene from fossil fuels was the only available option for aeroplanes" (Timperley, 2021, p. nd). Since then, alternative sources of fuel have emerged, and fuel efficiency of aircraft has also improved in line with advancements in new technologies. As demonstrated recently, moving from "an older four-engine jumbo aircraft to a more efficient twin-engine aircraft" can decrease carbon emissions by around 30% per flight (Timperley, 2021, p. nd). SAF, which is centerpiece in meeting the net emissions by 2050, offers a pathway to help curtail emissions given that advanced biofuels produce around "80% less CO_2 than conventional jet fuel" (Ahlgren, 2021c, p. nd).

Despite all the potential to deliver around 80% reduction in GHG emissions, SAF accounts for less than 1% of the fuel used in civil aviation (Singh, 2021b). There has been hesitancy by airlines to move away from traditional fuels (Singh, 2021b). A major barrier in transitioning to SAF is the cost. For instance, it is up to eight times more expensive relative to traditional jet fuel, thereby dis-incentivizing many airlines, especially in the developing world, from making the transition to avoid adding to the operating costs (Shell, 2021). In recent times, Airbus has been collaborating with partners to seek to "transform its aircraft, which all currently are certified to fly with up to a 50% SAF blend, to be 100% compatible by 2030" (Singh, 2021b, p. nd). Although Airbus aircraft are certified to fly with up to a 50% blend of SAF mixed with kerosene, the company with its own net-zero target by 2050 seeks to achieve 100% SAF certification for all planes by 2030 (Singh, 2021c). This would represent a major change given the limited use of such fuel in civil aviation.

A good example of a forward-looking airline is Wizz Air, which is aggressively pursuing a green agenda in Europe. Like most contemporary airlines, Wizz Air is striving to achieve net-zero carbon emissions by 2050 (Curran, 2021b). This strategy is rooted in the utilization of an array of tools including the introduction of fuel-efficient planes, a 20% year-on-year increase in fuel efficiency improvements in tandem with a 25% reduction in carbon emissions by 2030 (Curran, 2021b). Business organizations face monumental challenges in transitioning from current sources of clean energy to alternative-fuel technologies and other renewables.

4.4. *Quadrant IV: External challenges in the long-term*

Quadrant IV focuses on external challenges and their long-term impact. This Quadrant encompasses issues such as policy uncertainties, technological developments and uncertainties and limited public investment in the sustainable aviation industry.

4.4.1. *Slow pace of hydrogen and electric technological breakthroughs*

Anchoring green aviation entails the adoption of more efficient and new aircraft. Although hydrogen remains "the world's most abundant element, to power both electric and combustion engines", hydrogen-powered planes/fleets remain underdeveloped (Furchgott, 2021, p. 4). In addition, hydrogen-powered planes tend to be relatively smaller and experimental aircraft (Furchgott, 2021). For the industry, hydrogen has some vital uses, including as a source of power for batteries such as fuel cells, in hybrid aircraft and as a combustible fuel (Furchgott, 2021). Cementing the foundation for the further development of the technology and larger planes is crucial in meeting net-zero carbon aviation by 2050 (Furchgott, 2021; International Energy Agency, 2021). Indeed, one of the biggest challenges in transitioning to hydrogen relates to how best to store the gas (Ahlgren, 2021b), although: "*liquid hydrogen is easier to store onboard an aircraft than gas … This means heavier tanks and a significant redesign of current aircraft models*" (Ahlgren, 2021c, p. nd).

From the aircraft manufacturers' perspective such as Boeing (the largest of the commercial manufacturers) and Airbus (major manufacturer), net-zero emissions was an effective direction of travel. For instance, in 2021 Airbus announced its decision to fast-track the introduction of its zero-emission hydrogen-powered concept ZEROe – two dedicated Zero-Emission Development Centers in two leading European countries: France and Germany (Ahlgren, 2021b). The goal is to develop and mobilize liquid hydrogen tanks for hydrogen-powered flight, which would become operational around 2023 (Ahlgren, 2021b). To fast-track the development of hydrogen-propulsion technologies towards decarbonizing the aviation industry, Airbus launched the strategy of the complementary project focusing on the design and integration of the hydrogen tanks (Ahlgren, 2021b). In this direction, the European plane maker is seeking to launch a hydrogen-powered aircraft by 2035. Global airlines in tandem with aircraft manufacturers such as Airbus have also invested in R&D activities related to the development of zero-emission aircraft (Hayward, 2021). Boeing flew its first hydrogen-powered fleet in 2008 but more investment is needed to advance the progress (Hayward, 2021).

The adoption of new emerging technologies and zero-emission technology such as Airbus' hydrogen concept planes and electric aircraft seating supplied by Swedish firm, Heart Aerospace, are crucial in achieving the proposed emission objective (Ahlgren, 2021a). Despite the potential synergistic gains from battery-powered electric airliners, the technology still has a long way to go. Indeed, the battery-powered

electric airliners remain in their infancy (Furchgott, 2021). In early 2021, Finnair signed a letter of interest for up to 20 electric 100% electric-powered regional planes from Heart Aerospace with capacity for up to19 passengers to a range of 250 miles with potential certification in 2026 (Bailey, 2021). The focus on electric aircraft as a means of curtailing emissions is a step in the right direction that can then pave the way for achieving carbon-neutral flying. Finnair was not alone in this – eight other airlines have also signed similar deals with the company (Bailey, 2021). EasyJet has also been exploring the challenges in transitioning to electric and hydrogen aircraft (Ahlgren, 2021a).

Some recent developments include a collaboration between Alaska Airlines and ZeroAvia (hydrogen-electric aircraft developer) to launch hydrogen-powered planes on regional routes by 2026 (Ahlgren, 2021c, p. nd). Other recent developments in the industry include Rolls-Royce's investment in the deployment of electric aircraft, which could have a major impact at least on short-haul operations (Singh, 2021c). Accordingly, decarbonization of the transport sector is partly predicated on the shift from fossil-fuel to electric and hydrogen aircraft and new technologies (International Energy Agency, 2021). These developments require investment from the industry and governments to stimulate research and develop the infrastructure. In addition, the European aerospace firm, Airbus, is seeking to launch a hydrogen-powered aircraft by 2035.

4.4.2. Carbon offsetting and reduction scheme

One of the challenges surrounding the industry is the adoption and implementation of carbon offsetting standards. The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), championed by the International Civil Aviation Organization as a carbon offset and reduction scheme, is also a vital tool in reducing emissions and meeting the net-zero targets. Since January 2021, with very few notable exceptions, all international flights have been subjected to offsetting obligations via compensating for their emissions by financing emission-reduction activities (IATA, 2021d). Without CORSIA, the environmental footprint of cross-border aviation could surge from around 600 million tonnes of CO_2 in 2020 to around 900 million tonnes of CO_2 by 2035 (IATA, 2021d). However, the lack of effective and robust legal and regulatory backing for the scheme has limited its ability to cut emissions.

Online Supplementary Appendix 3 summarizes the variety of pathway strategies to net-zero emissions, drivers for change, and obstacles. Appendix 3 details a number of organizational-specific and external challenges that hinder the ability to achieve the zero-emission target including financial resource constraints, limited government financial backing, infrastructural issues related to energy storage and utilization, and embedded culture of short-termism. Based on the above analysis, it can be deduced that the challenges can be classified into policy, organizational, and external/macro-environment. The policy-related challenges relate to the operational and implementation difficulties of achieving net-zero emissions by 2050. The organization-related challenges relate to firm-specific issues, obstacles, and weaknesses such as financial resource constraints and short-termism in organizational decision making that curtail airlines from fully embracing the target. The external/macro-environment focuses on other external factors that impede efforts to achieve the goal.

5. Conclusion and implications

In parallel with the burgeoning policy makers' attention to net-zero emissions is new and growing research on climate change. This paper sought to examine the pathway challenges of getting to net-zero emission targets. Using the global airline industry as an illustrative setting, the study provided insights into organizational and external challenges such as fleet modernization, over-reliance on fossil fuel, slow progress in the development of hydrogen and electric aircraft, risk of corporate greenwashing, and divergent approaches adopted by airlines. The challenges can be classified into policy-oriented, organization-specific, and external/macro-environment factors. The policy-related challenge relates to the implementation of the net-zero emissions by 2050. The organization-related factors include financial resource constraints and short-termism in organizational decision making. The external/macro-environment includes the slow pace of technology development and clean technologies. The analysis sheds light on a host of potential barriers to achieving zero-emission targets and decarbonization approaches. The analysis pertaining to the net-zero target suggests that setting the target has removed some of the cloud of uncertainty surrounding the industry. The current study suggested that going green in global aviation is inextricably linked to investments in renewable sources of energy. The greening of airlines' business models extends beyond just energy sources and aircraft to a range of activities across their value chain including inflight services, waste, and material use. In this new world, net-zero emission targets can serve as catalysts for green innovation, introduction of fuel-efficient technologies, transitioning to electric and hydrogen aircraft, and greater adoption of renewables across the value chain of global airlines.

5.1. Theoretical and practical contributions

From a theoretical standpoint, despite some early studies on net-zero emissions (Pye et al., 2017; Bistline and Blanford, 2021), much of the literature tends to focus on the policy rather than different industrial challenges and constraints. This study addressed the current deficiency in the current literature by developing an organizing framework of challenges in accomplishing net-zero emissions targets and charting the host of challenges that impede transitioning to net-zero emissions efforts. Moreover, in view of its demonstrated "Triple Bottom Line" effects, i.e., the environmental, economic, and social impacts (Elkington, 1998; de Lima et al., 2021), net-zero emission targets continue to attract new streams of research but lack robust insights on the pathway challenges. The present study assimilated various strands of studies to illuminate our understanding of the centrality of the decarbonization process to a sustainable aviation industry.

From a practical standpoint, the present study indicated a need for concrete oversight and robust verification processes to ensure that airlines adhere to their commitments both in the short term (interim targets) and long term (2050 target). This will help to mitigate the risk of the target becoming a "vehicle for corporate green greenwashing". The analysis also reinforced the need for airlines to join forces with governments and other stakeholders to advance technology development (i.e., hydrogen and electric) and scaling up to reduce emissions. The new-zero target has underscored the need for global airlines to recalibrate their functional activities towards developing stronger engagement with stakeholders and address the environmental challenges. Viewing environmental sustainability as a strategic necessity, the analysis indicated a need for "net-zero champions" in organizations. The "champions" also could play a pivotal role in maintaining the urgency and prioritizing of the green agenda, advocating for and helping to elevate net-zero standards, and communicating with relevant stakeholders. The future source of airlines' competitiveness is likely to grow out of their deeper understanding, stakeholder involvement, and carefully orchestrated organizational routines, processes and structure geared towards meeting net-zero emission targets.

5.2. Limitations and recommendations for future research

Besides the practical and theoretical implications, there are some limitations related to the analysis. First, the study was limited in the sense that the focus is purely on the global airline industry. Thus, it would not be intellectually well-grounded to generalize this analysis to other industrial settings. Future research could illuminate our understanding of net-zero and the nature of challenges in multiple industries. Given that the targets are decades away, there is a risk that interest may fade in organizations. In view of this specific limitation, there is a need

for future research to investigate how companies can revitalize and maintain their net-zero commitments over time as changes in top-management teams occur. Moreover, our theoretical framework advanced here captures only a few current organizational, industry, and external challenges. However, many new challenges are likely to emerge in the future, which could present opportunities for new studies. It is hoped this study would serve as a catalyst for new studies on net-zero emissions commitments.

Credit authors statement

Joseph: Conceptualization, Methodology, Data curation, Writing-Original draft preparation, and all sections. **Yaw Debrah**: Data curation, Writing. **Sarah:** Methodology, Data curation

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.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2022.116649.

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