International Hydrogen Ramp-Up Programme (H2Uppp)

Stakeholder Mapping and Scoping for Strategic Engagement with the Aviation Sector in Thailand

2023

Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

Published by:
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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Bangkok, 2023

Preface

As the pursuit of environmentally conscious transportation intensifies, the aviation sector faces mounting pressure to diminish its carbon emissions. Additionally, the anticipated resurgence in commercial air traffic accentuates the imperative for emission reductions. The utilisation of alternative fuels is a crucial component in attaining future emission targets and concurrently diminishing reliance on fossil fuels. Sustainable aviation fuels (SAF), encompassing both bio and synthetic variants, currently stand as the most viable option, while hydrogen remains under consideration for long-term application.

This study aims to contribute to the International Hydrogen Ramp-up Programme (H2Uppp)'s initiatives dedicated to advancing the adoption of green hydrogen and PtX (Power-to-X) technologies within Thailand's aviation sphere. This endeavour involves a meticulous analysis focused on identifying pertinent stakeholders, assessing potential opportunities, recognising barriers, and devising policy recommendations pivotal to the successful introduction of these pioneering technologies to the market.

The strategy underscores the significance of SAF and other low-carbon technologies in curbing aviation's carbon footprint, emphasising the promotion of SAF usage. Recognising the necessity for collaborative efforts among industry stakeholders, governments, regulatory bodies, research institutions, and other entities is crucial to collectively strive toward sustainable aviation objectives.

Demonstrating commitment to adhering to existing and forthcoming aviation regulations and striving for certifications that endorse sustainability and environmentally sound practices is also vital.

Through comprehensive study, this project aims to extract invaluable insights from diverse perspectives, encompassing adoption trends, regulatory impacts, economic viability, technological advancements and collaborative endeavours indispensable for amplifying the adoption of SAF.

Relevant regulations on SAF were reviewed on the global landscape with a focus on Thailand's perspective and strategic position in Southeast Asia. The stakeholders' analysis has resulted in stakeholders' mapping and prioritisation to establish an ecosystem for further coordination and implementation. A proactive approach involves monitoring the advancements in Power-to-Liquid (PtL) technology and the promising hydrogen economy within Thailand's aviation landscape. This study concludes with three recommendations as follows:

1. Immediate need for official coordination between the Ministry of Transport and the Ministry of Energy in the form of a National SAF Board comprising relevant government agencies, research institutes and private sector entities to expedite SAF policy development with a mandated target and implementation.
2. Near future need for quantitative research to estimate SAF supply from currently available pathways (HEFA and AtJ) and future economically feasible pathways (Gasification/FT and PtL) to help plan SAF policy and mandate in accordance with aviation industry growth.
3. Consistent watch of other hydrogen activities in Thailand that could help realise hydrogen utilisation in PtL-SAF.

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Abbreviations

ABRETF	Aviation Biofuels and Renewable Energy Task Force
AEDP	Alternative Energy Development Plan
ASAAP	ASEAN Sustainable Aviation Action Plan
ASEAN	Association of Southeast Asian Nations
ASTM	American Society for Testing and Materials
ATJ	Alcohol to Jet
ATM	ASEAN Transport Ministers
BAU	Business as Usual
CAAS	Civil Aviation Authority of Singapore
CAAT	Civil Aviation Authority of Thailand
CO2	Carbon Dioxide
COP	Conference of Parties
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
DGCA	Directorate General of Renewable Energy
EASA	European Union Aviation Safety Agency
EV	Electric Vehicle
FAA	Federal Aviation Administration
FT	Fischer-Trosch Process
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
H2	Hydrogen
H2Uppp	International Hydrogen Ramp-up Programme
HC	Hydrocarbon
HEFA	Hydroprocessed Esters and Fatty Acids
IATA	International Air Transportation Association
ICAO	International Civil Aviation Organisation
IPPU	Industrial Process and Product Use
JAL	Japan Airlines
MOU	Memorandum of Understanding
NDC	Nationally Determined Contribution
OTP	Office of Transport and Traffic Policy and Planning
PFAD	Palm Fatty Acid Distillate
PPP	Public-Private Partnership
PtL	Power to Liquid
PtX	Power to X
SAF	Sustainable Aviation Fuels
SEA	Southeast Asia
SIP	Synthesised Iso-Paraffins
SKA	Synthesised Kerosene with Aromatics
SPK	Synthetic Paraffinic Kerosene
TCO	Total Cost of Ownership
UCO	Used Cooking Oil

1 INTRODUCTION

In the current landscape, amidst a burgeoning global climate agenda and a heightened emphasis on environmental consciousness, the aviation sector faces escalating scrutiny to align with carbon-neutrality imperatives. This scrutiny amplifies as the commercial aviation segment, which experienced a substantial downturn during the pandemic, gears up for an anticipated resurgence, underscoring the urgent necessity to manage emissions within the industry effectively.

Under these circumstances, the exploration of alternative fuels assumes paramount significance for steering the aviation industry towards a more sustainable trajectory. These alternative fuels represent a divergence from conventional fossil fuels, historically a primary contributor to carbon emissions within aviation operations. Notably, Sustainable Aviation Fuels (SAF), encompassing both bio-derived and synthetic variants, have emerged as frontrunners in the quest for immediate and viable replacements.

Moreover, SAF forms an integral part of hydrogen (H_2) derivatives. While this study identifies advancements in SAF development, the ongoing efforts primarily concentrate on the evolution of derivatives developed from the hydrogen side, signifying a concerted focus on innovating, and enhancing this facet of sustainable aviation fuel technologies.

The study's objective is to contribute to the initiatives led by the International Hydrogen Ramp-up Programme (H2Uppp) aimed at fostering the adoption of green hydrogen and PtX (Power-to-X) technologies within Thailand's aviation sector. This undertaking involves a comprehensive analysis focused on identifying prospective key stakeholders, evaluating opportunities, discerning potential barriers, and formulating policy recommendations essential for the successful market introduction of these innovative technologies.

1.1 SAF Processes

SAFs are the most suited to the aviation sector's NDC and Carbon-Neutral Growth targets as SAFs are "drop-in" liquid hydrocarbon fuels with the same performance and safety as conventional jet fuels produced from petroleum, are fully fungible with the existing fuel supply, and can be used in the same infrastructure, engines, and aircraft. SAFs can be created from either renewable or waste materials and, for the purposes of this action plan and U.S. policy, it is considered that SAFs reduce life-cycle GHG emissions by at least 50% relative to conventional jet fuel[1].

This overview serves to introduce the primary feedstocks and conversion processes that have undergone rigorous study and, in certain instances, have already obtained approval for the production of SAF. As of July 2023, the ASTM (American Society for Testing and Materials) has officially certified alternative fuels derived from 10 distinct conversion processes in accordance with the ASTM D7566 and ASTM D1655 standards as shown in Table 1-1. Additionally, ongoing evaluations indicate the progression of more conversion processes through the certification pipeline, further diversifying the range of approved SAF production methods. E-fuel, obtained from the Fischer-Tropsch (FT) process, represents a category of synthetic fuels generated through a complex production method employing water, hydrogen, and carbon dioxide. This sophisticated manufacturing process starts with the extraction of hydrogen via electrolysis of water, followed by its combination with carbon dioxide to yield the desired fuel. Subsequently, the resultant mixture of hydrogen and carbon dioxide undergoes the Fischer-Tropsch process, converting the gaseous constituents into liquid hydrocarbons. This method synthesises the ingredients into a usable fuel form, marking a significant stage in the production of synthetic fuels.

[1] https://www.faa.gov/sites/faa.gov/files/2021-11/Aviation_Climate_Action_Plan.pdf

Table 1-1: Approved Conversion Processes[2]

Conversion process	Abbreviation	Possible Feedstocks	Maximum Blend Ratio[3]	TRL[4]
Fischer-Tropsch hydroprocessed synthesised paraffinic kerosene	FT	Coal, natural gas, biomass	50%	7-8
Synthesised paraffinic kerosene from hydroprocessed esters and fatty acids	HEFA	Bio-oils, animal fat, recycled oils	50%	8-9
Synthesised iso-paraffins from hydroprocessed fermented sugars	SIP	Biomass used for sugar production	10%	7-8
Synthesised kerosene with aromatics derived by alkylation of light aromatics from non-petroleum sources	FT-SKA	Coal, natural gas, biomass	50%	6-7
Alcohol to jet synthetic paraffinic kerosene	ATJ-SPK	Biomass from ethanol, isobutanol or isobuthene	50%	7-8
Catalytic hydrothermolysis jet fuel	CHJ	Triglycerides such as soybean oil, jatropha oil, camelina oil, carinata oil, and tung oil	50%	6
Synthesised paraffinic kerosene from hydrocarbon - hydroprocessed esters and fatty acids	HC-HEFA-SPK	Algae	10%	5
Co-hydroprocessing of esters and fatty acids in a conventional petroleum refinery	co-processed HEFA	Fats, oils, and greases (FOG) co-processed with petroleum	5%	-
Co-hydroprocessing of Fischer-Tropsch hydrocarbons in a conventional petroleum refinery	co-processed FT	Fischer-Tropsch hydrocarbons co-processed with petroleum	5%	-
Co-hydroprocessing of biomass	co-processed biomass		5%	-

1.2 Synthetic Fuels or e-fuels

Synthetic Fuels, often referred to as e-fuels, do not depend on biomass for the generation of liquid hydrocarbons. Consequently, this approach mitigates sustainability concerns associated with scaling up the production of renewable bio-based feedstocks, thereby minimising issues like land utilisation disputes or ethical and economic dilemmas related to food, feed and fuel competition. E-fuels have the potential to emerge as the preferred option for achieving medium- to long-term decarbonization objectives. The production of e-fuels hinges on the process of acquiring syngas by combining "green hydrogen" with CO_2 captured from concentrated sources or directly from the atmosphere.

[2] https://www.icao.int/environmental-protection/GFAAF/Pages/Conversion-processes.aspx
[3] At present, SAF must be blended with conventional jet fuel. It can be blended at different levels within limits of Maximum Blend Ratio, depending on the process.
[4] https://www.easa.europa.eu/eco/eaer/topics/sustainable-aviation-fuels/what-are-sustainable-aviation-fuels#drop-in-saf-production-pathways

1.2.1 Power-to-Liquid

There are two recognised methods for generating PtL (Power-to-Liquid) fuels: the Fischer-Tropsch (FT) pathway and the methanol pathway[5]. They share commonalities, necessitating a provision of captured CO_2 and acquiring H_2, the latter achieved through the electrolysis of water. However, their divergence lies in the process of synthesising hydrocarbons and the subsequent enhancement into fuel. Figure 1-1 illustrates a generalised schematic of the PtL production sequence. The methanol pathway stands as a potential alternative method for jet fuel production within the aviation sector, although it presently lacks certification from ASTM[6]. Despite the current absence of certification, these methodologies are undergoing rigorous evaluation and scrutiny by ASTM[7], signalling a potential avenue of interest and exploration within the aviation industry.

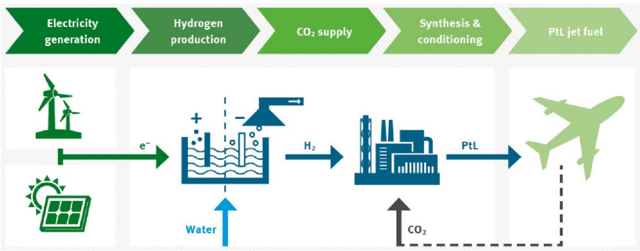

Figure 1-1: Power-to-Liquid production stages[8]

1.2.2 Hydrogen

The production of hydrogen through water electrolysis serves as a critical linchpin in the PtL process, which finds application in both the FT (Fischer-Tropsch) and methanol pathways. Although not currently the prevailing method for industrial-scale hydrogen generation, electrolysis is experiencing a notable surge in interest and recognition as the frontrunner among approaches to procure hydrogen without emitting carbon.

This methodology capitalises on the electrolysis of water, leveraging electricity to split water molecules into hydrogen and oxygen. The allure of this process lies in its potential to yield hydrogen while sidestepping the release of greenhouse gases, positioning it as a compelling solution in the pursuit of sustainable energy practices.

In both the FT and methanol routes, the adoption of electrolysis marks a significant step towards unlocking cleaner and more environmentally friendly methods for producing hydrogen. This shift aligns with the overarching goals of reducing carbon footprints and embracing renewable energy sources, reflecting a pivotal evolution in the realm of energy production and sustainability. As advancements in electrolysis technology continue to unfold, the prospect of large-scale carbon-free hydrogen production becomes increasingly attainable, heralding a promising era for the PtL process and its pivotal role in the transition toward greener energy solutions.

Biofuels, particularly those utilising HEFA, have emerged as closer to achieving widespread commercial viability compared to alternative options. Processes such as Power-to-Liquid (PtL) hinge on forthcoming enhancements in green hydrogen production. Although PtL methods currently lag behind biofuels in terms of cost competitiveness, long-term projections anticipate this pathway becoming an economically viable option. Understanding the regulatory framework, engaging stakeholders, and identifying existing gaps are imperative to adopt the growth of the SAF industry in Thailand.

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[5] Schmidt, P., Batteiger, V., Roth, A., Weindorf, W., & Raksha, T. (2018). Power-to-liquids as renewable fuel option for aviation: a review. Chemie Ingenieur Technik, 90(1-2), 127-140.

[6] Cabrera, E., & de Sousa, J. M. M. (2022). Use of sustainable fuels in aviation—A Review. Energies, 15(7), 2440.

[7] https://www.icao.int/environmental-protection/GFAAF/Pages/Conversion-processes.aspx

[8] P. Schmidt, W. Weindorf, A. Roth, V. Batteiger, F. Riegel, Power-to-Liquids – Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel, UBA, Berlin 2016.

2 REGULATION AND RECOMMENDATIONS

While the strategies outlined by the International Air Transport Association (IATA), the Federal Aviation Administration (FAA), the European Union Aviation Safety Agency (EASA), and Japan Airlines (JAL) etc. have unique elements tailored to their respective organisations and regions, there are common aspects that reflect a shared commitment to achieving sustainability and net-zero carbon goals in the aviation industry. Below is a general overview of the common elements:

Net-Zero Carbon Emissions by 2050:

All strategies emphasise the goal of achieving net-zero carbon emissions from aviation by the year 2050. This overarching objective underscores the commitment to significantly reduce or offset carbon emissions associated with aviation operations. For instance, IATA has constructed Net Zero Roadmaps[9] focusing on 5 aspects, namely aircraft technology, operations, infrastructure, policy, and finance, through 3 pathways: reducing in-flight energy use, changing the fuel, and re-capturing emitted CO_2, as shown in Figure 2-1(a), with estimated large CO_2 reduction targets from SAF in Figure 2-1(b).

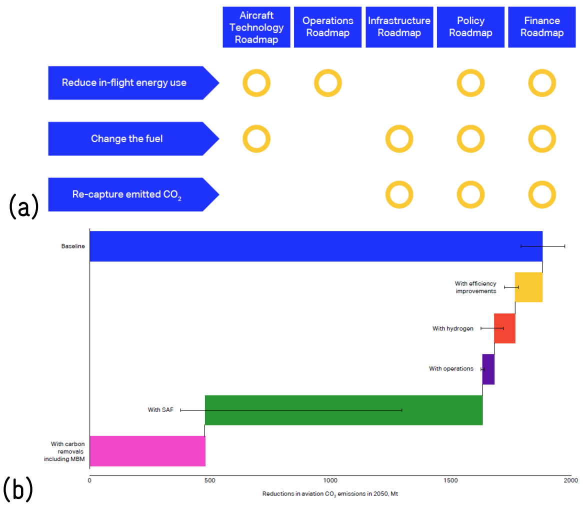

Figure 2-1: (a) IATA roadmaps toward carbon neutrality by 2050 with (b) respective targets of CO_2 reduction

In addition to IATA roadmaps, the following issues have been addressed in other relevant decarbonization plans in aviation sectors.

Sustainable Aviation Fuels (SAF) and Low Carbon Technologies:

Each strategy highlights the importance of sustainable aviation fuels (SAF) or alternative low-carbon technologies to reduce the carbon footprint of aviation. This includes promoting the use of SAF, electric/hybrid aircraft, or other innovative technologies that produce less or zero carbon emissions.

Operational Efficiency and Optimisation:

Strategies emphasise operational improvements and optimisation to enhance fuel efficiency, reduce waste, and lower emissions. This involves optimising flight routes, reducing ground idling time, and improving overall operational practices.

Technological Innovation and Research:

A commitment to investing in research and development to drive technological innovation in the aviation sector. This includes advancements in aircraft design, engines, materials, and other technologies that contribute to reducing emissions and improving sustainability.

Investment in Carbon Offsetting and Environmental Projects:

Acknowledgment of the role of carbon offsetting and investment in environmental projects to compensate for unavoidable emissions and support broader environmental goals such as reforestation, carbon capture and biodiversity conservation.

Collaboration and Partnerships:

Recognition of the need for collaboration among industry stakeholders, governments, regulatory bodies, research institutions, and other organisations to collectively work towards sustainable aviation goals. Partnerships are seen as crucial for sharing knowledge, expertise, and resources to accelerate progress.

[9] https://www.iata.org/contentassets/8d19e716636a47c184e7221c77563c93/executive-summary---net-zero-roadmaps.pdf

Regulatory Compliance and Certification:

Commitment to comply with existing and future aviation regulations and work towards certification standards that promote sustainability and environmentally responsible practices.

It is imperative to contextualize these key elements of SAF development within the landscape of Thailand's aviation sector. Aligning with the national commitment, the SAF regulation framework should be tailored to Thailand's specific challenges and opportunities, while ensuring compatibility within Southeast Asia and worldwide.

2.1 Thailand Perspective

At COP26, Thailand committed to carbon neutrality by 2050 and net zero by 2065, as shown in Figure 2-2 for Thailand's Long-Term Greenhouse Gas Emission Development Strategy[10]. The revised NDC (Nationally Determined Contribution) target was raised to 30-40% from the previous 20-25%, under which the unconditional target of at least 30% reduction in GHG emission is currently proposed to come from energy (22.45%), transport (8.22%), waste (1.17%), agriculture (0.49%) and Industrial Process and Product Use (0.25%) accumulated to 32.58% totally, as shown in Table 2-1 (DCCE, 2023). For the transport sector, 45.61 $MtCO_2e$ target is proposed by the Office of Transport and Traffic Policy and Planning (OTP), Ministry of Transport, through 16 measures under 6 measure groups, as shown in Figure 2-3.

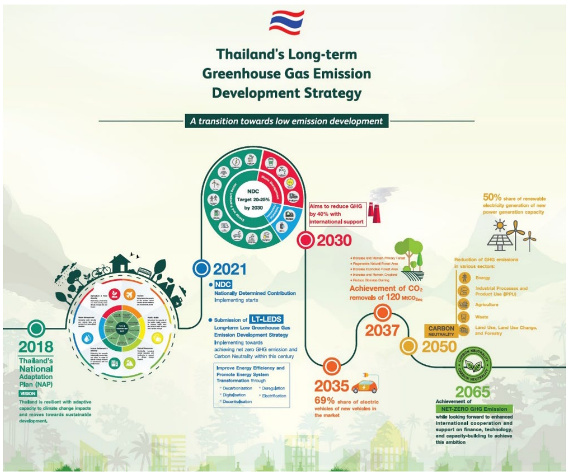

Figure 2-2: Thailand's Long-Term Greenhouse Gas Emission Development Strategy

Table 2-1: 2030 Target of GHG reduction in revised NDC

Sectors	2030 Target GHG reduction by sectors		Total target in 2030 (%)
	$MtCO_2e$	%	
Energy	124.597	22.45	32.58 (from target of 30-40% of BAU)
Transport	45.610	8.22	
Waste	6.495	1.17	
Agriculture	2.740	0.49	
IPPU (Industrial Process and Product Use)	1.400	0.25	
Total	180.842	32.58	

[10] https://unfccc.int/sites/default/files/resource/Thailand%20LT-LEDS%20%28Revised%20Version%29_08Nov2022.pdf

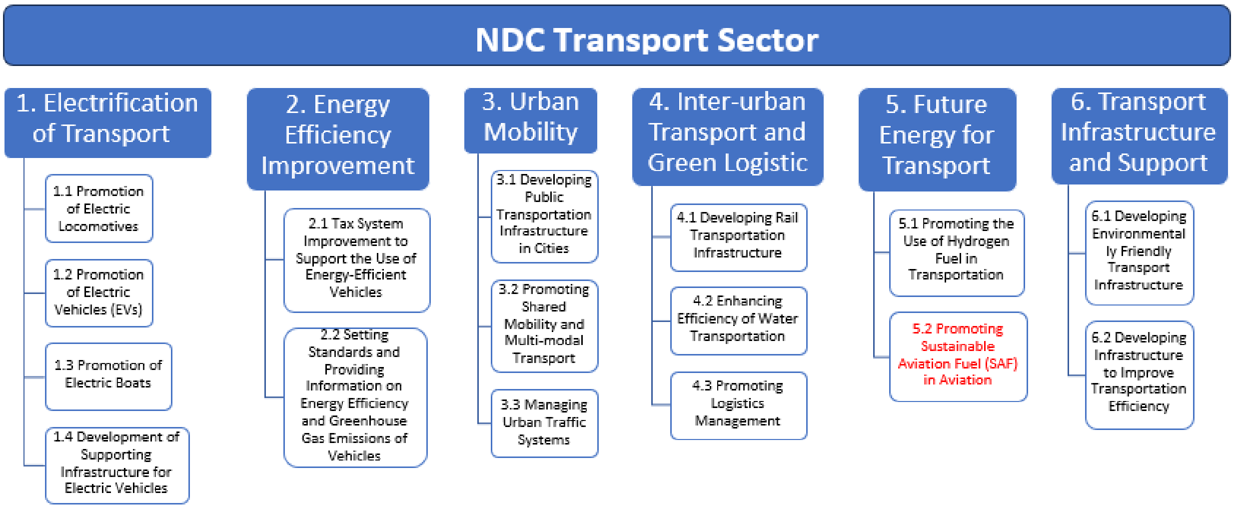

Figure 2-3: Proposed updated NDC (Nationally Determined Contribution) in Transport Sector

Although measure *'5.2 Promoting Sustainable Aviation Fuel (SAF) in Aviation'* does not currently bear a specific GHG emission reduction target in the NDC as SAF is mainly for international flights, this measure provides a driving force for SAF establishment in Thailand. Note that 80% of 2021 jet fuel consumption is from international flights[11].

The current draft of the Alternative Energy Development Plan (AEDP) from the Ministry of Energy proposes to mandate 2% SAF in 2027 via HEFA (Hydroprocessed Esters and Fatty Acids) from UCO (Used Cooking Oil)/PFAD (Palm Fatty Acid Distillate) with a subsequently increasing ratio from AtJ (Alcohol-to-Jet) to 3, 5 and 8% by 2030, 2033 and 2036, respectively, as shown in Figure 2-4.

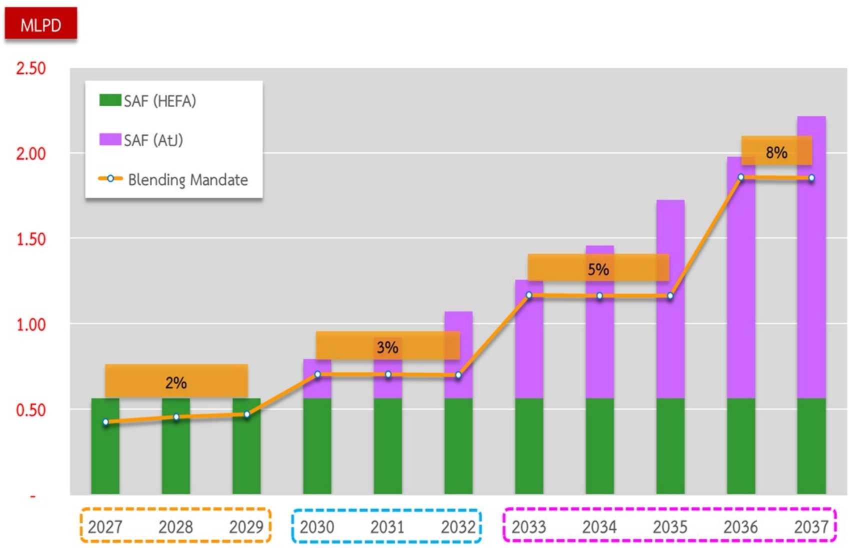

Figure 2-4: SAF blending mandate plan in current draft of Alternative Energy Development Plan (AEDP, 2023)

[11] https://www.dede.go.th/download/state_65/Energy_Balance_of_Thailand_2564_for_web_compressed.pdf

The main factors for choosing HEFA and AtJ pathways over Gasification/Fischer-Tropsch and Power-to-Liquid (PtL) pathways are cost and infrastructure, as well as private sector interest, as shown in Figure 2-5. However, should cost and infrastructure for hydrogen become more practically feasible, the PtL pathway may be considered.

(a) [12]

(b) [13]

(c) [14]

(d) [15]

Figure 2-5: SAF activities from private sectors namely (a) Bangchak, (b) Mitrphol, (c) PTT Groups, (d) Thai Airways

2.2 Southeast Asia (SEA) Perspective

As Thailand has aligned SAF policy with the global trend, it is strategically important for Thailand to position itself regionally within Southeast Asia, especially for countries which already have an SAF policy in place.

2.2.1 Indonesia

Indonesia is the first mover on mandating SAF in the aviation sector with abundant palm oil as feedstock. In December 2013, an MOU was signed between the Ministry of Transportation (The Directorate General of Civil Aviation – DGCA) and the Ministry of Energy and Mineral Resources (Directorate General of Renewable Energy and Energy Conservation – EBTKE) to pursue the use of aviation biofuels and renewable energy at airports under Ministry of Energy and Mineral Resources Decree No. 25/2013 setting mandatory use of bio-jet fuel on a national level of 2% blending in 2016, 3% by 2020, and 5% by 2025[16].

Later, in August 2014, the Aviation Biofuels and Renewable Energy Task Force (ABRETF) was established to execute Indonesia's National Action Plan to reduce GHG emissions from the aviation

[12] https://www.bangchak.co.th/en/newsroom/bangchak-news/1141/bangchak-makes-its-mark-as-future-energy-leader-pioneering-thailand-s-aviation-industry-with-first-construction-agreement-for-sustainable-aviation-fuel-saf-production-unit

[13] https://www.bangkokpost.com/thailand/pr/2330013/two-big-names-foster-collaboration-on-net-zero-mission-for-low-carbon-fuels-towards-aviation-fuelling-excellence

[14] https://www.bangkokpost.com/thailand/pr/2433892/ptt-group-announces-business-expansion-into-sustainable-aviation-fuel-market

[15] https://www.thaiairways.com/sites/en_TH/news/news_announcement/news_detail/SAF-flight.page

[16] https://www.icao.int/environmental-protection/GFAAF/Pages/Project.aspx?ProjectID=40

sector but the mandate was delayed, with a recent goal of 2% by 2025[17]. Recently, on 27 October 2023, Garuda Indonesia successfully flew Boeing 737-800NG aircraft with more than 100 passengers from the capital Jakarta to Surakarta city (about 550 kilometres away) with SAF domestically produced by Indonesian state energy firm PT Pertamina (PERTM.UL) at its Cilacap refinery using hydroprocessed esters and fatty acid (HEFA) technology with refined bleached deodorised palm kernel oil as feedstock[18].

2.2.2 Singapore

In February 2022, the International Advisory Panel (IAP) on Sustainable Air Hub was established to address how international aviation can be made more sustainable and accessible for all, and how Singapore can contribute to this international effort to maintain the competitiveness of the Singapore airport [19] with one of the recommendations on SAF [20]. The Civil Aviation Authority of Singapore (CAAS) has established an SAF Taskforce and introduced incentives to encourage airlines to use sustainable aviation fuels[21].

2.2.3 ASEAN

Regarding regional cooperation in Southeast Asia, the Twenty-Ninth ASEAN Transport Ministers (ATM) Meeting was held on 9 November 2023 in Luang Prabang, Lao PDR [22] with a joint ministerial statement adopting the ASEAN Sustainable Aviation Action Plan (ASAAP) and its Work Plan 2023-2024, which aims to drive sustainable aviation growth in ASEAN, starting from the area of SAF. This demonstrates ASEAN's strong commitment to support the International Civil Aviation Organisation's long-term global aspirational goal for international aviation of net-zero carbon emissions by 2050. The ASEAN Sustainable Aviation Action Plan (ASAAP) will drive sustainable aviation growth in the ASEAN region, through the sharing of best practices, capacity building, information exchange and collaboration, starting with the production and deployment of SAF[23].

In conclusion, as Thailand has been one of the most popular destinations (and transit) for passenger transportation by air (ranked 16th for largest passenger volume on airlines in 2021[24]), Thailand has the potential to become an SAF supplier for airport refuelling with an already initial policy alignment globally and some interest from private sector entities. Thailand should also strategically position herself with larger passenger loads on airlines (ranked 11th in 2021[24]) and the world's largest palm producer like Indonesia, as well as Singapore with world-leading airport competitiveness. Not only can SAF help decarbonize air transport, but SAF could help stimulate industrial investment as post-COVID-19 recovery.

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[17] https://illuminem.com/illuminemvoices/sustainable-aviation-fuel-for-asean-part-2-saf-credit-to-pave-the-way-to-environmental-positive-ambitions

[18] https://www.reuters.com/sustainability/indonesia-conducts-first-commercial-flight-using-palm-oil-blended-jet-fuel-2023-10-27/

[19] https://www.caas.gov.sg/who-we-are/newsroom/Detail/international-advisory-panel-on-sustainable-air-hub-submits-report-with-key-recommendations/

[20] https://asianaviation.com/wp-content/uploads/developing-a-sustainable-air-hub-in-singapore.pdf

[21] https://biofuels-news.com/news/caas-sets-up-new-e35-million-aviation-sustainability-programme/

[22] https://asean.org/joint-ministerial-statement-of-the-twenty-ninth-asean-transport-ministers-meeting-29th-atm/

[23] https://canso.org/asean-member-states-to-adopt-sustainable-aviation-action-plan-to-drive-aviation-growth/

[24] https://www.statista.com/statistics/537002/airline-passengers-worldwide-by-country/

3 STAKEHOLDER MAPPING AND PRIORITISATION

This research focuses on expediting the widespread adoption of SAF within the realm of commercial aviation, serving as a sustainable alternative to conventional fossil-based jet fuel. The deliberate choice of employing the stakeholder mapping approach stems from its capacity to delineate the intricate interconnections among pertinent issues. This strategic method aims not only to elucidate these connections but also to provide a contextual framework for the development of a comprehensive and unified understanding of a collective objective shared among the diverse array of stakeholders involved in advancing the commercial production, implementation, and consumption of SAF.

Through rigorous study, it is anticipated to unravel profound insights into various facets encompassing the adoption, regulatory implications, economic feasibility, technological advancements, and collaborative efforts required to boost the uptake of SAF within the commercial aviation sector. These insights will serve as a pivotal guide in navigating the multifaceted landscape of sustainable aviation, propelling travellers towards a more environmentally conscious and economically viable future for air travel.

3.1 Stakeholder mapping

Stakeholders mapping constitutes a methodical procedure characterised by the identification, categorisation, and thorough analysis of stakeholders. This process hinges upon assessing their interests, level of influence, and extent of engagement within a specific project, initiative, or industry context. The outlined approach adheres to a structured framework designed to facilitate this comprehensive evaluation.

3.1.1 Stakeholder identification

The process of identifying stakeholders for SAF necessitates the identification of individuals, groups, or entities that hold significant interests or wield influence in the development, implementation, or utilisation of SAF within the aviation sector as shown in Figure 3-1. A comprehensive stakeholder identification process involves an assessment of their respective levels of influence, vested interests, areas of concern, and potential impact on the adoption of SAF.

Effectively engaging with these stakeholders through methodologies such as surveys, interviews, forums, or collaborative meetings is instrumental in soliciting a diverse range of perspectives. This engagement fosters a conducive environment for the formulation of strategies aimed at promoting the acceptance and integration of SAF within the aviation industry. Such inclusive approaches to stakeholder engagement contribute to a more holistic understanding of the multifaceted landscape surrounding SAF adoption and utilisation.

Stakeholder classification

- Raw material providers
- Fuel producers
- Distributors
- Airlines
- Government agencies and regulators

3.1.1.1 Raw Material Supply

Entities involved in supplying feedstock (biomass, waste materials, hydrogen, etc.) for SAF production, such as agricultural firms, waste management companies and biofuel producers.

3.1.1.2 Fuel Producer

Fuel producers play a pivotal role within the SAF ecosystem, undertaking several crucial duties that contribute to the development, production, and deployment of SAF. Their primary duty encompasses the development and production of high-quality SAF, ensuring adherence to stringent sustainability standards and aviation specifications. This involves continual innovation and optimisation of production processes to enhance efficiency, reduce carbon emissions and expand the availability of SAF. Fuel producers also engage in collaborations with feedstock suppliers, technology providers, and stakeholders across the aviation industry, fostering partnerships to scale production, drive down costs, and meet increasing demand.

3.1.1.3 Distributor

The distributors play a pivotal role in the logistical and commercial aspects of SAF delivery and utilisation. These entities are responsible for the procurement, storage, transportation, and distribution of SAF to end-users, primarily airlines and aviation fuel providers. Distributors ensure a smooth supply chain by coordinating with SAF producers, handling the logistics of fuel transportation, and managing the storage facilities necessary for SAF. Their duties encompass maintaining the quality and integrity of the fuel throughout the distribution process, complying with aviation standards and regulations, and facilitating the seamless integration of SAF into existing aviation fuel infrastructure.

3.1.1.4 Airline

Figure 3-1: Stakeholders identification[25]

Airlines are significant stakeholders in the SAF ecosystem, playing a crucial role in the adoption, utilisation, and promotion of SAF within the aviation industry. As end-users of aviation fuel, airlines are pivotal in driving the demand for SAF by integrating it into their operations. Their participation and commitment to using sustainable fuel sources are fundamental in advancing the market for SAF. Airlines actively engage in collaborations with SAF producers, governments, and industry associations to facilitate the development, certification, and procurement of SAF.

3.1.1.5 Government Agencies

Government agencies are integral stakeholders in the realm of SAF, playing a pivotal role in shaping policies, regulations and incentives that impact the development, adoption and utilisation of SAF within the aviation industry. These agencies are responsible for overseeing aviation regulations, environmental policies, and energy standards that directly influence the production, certification, distribution and usage of SAF. Their involvement includes setting targets and mandates for the incorporation of sustainable fuels, providing research funding, offering grants or incentives to promote SAF production and adoption, and establishing certification criteria to ensure SAF meets stringent safety and quality standards. Government agencies collaborate with SAF producers, airlines, research institutions and industry associations to facilitate a conducive regulatory environment that supports the growth of SAF, fosters innovation and aligns with broader sustainability objectives. Additionally, these agencies often participate in international forums to harmonise standards and initiatives, contributing to the global development of sustainable aviation practices.

3.1.2 Stakeholder mapping

Following the comprehensive analysis of distinct and shared attributes among stakeholder categories within separate stakeholder maps, the subsequent crucial endeavour revolves around consolidating these diverse perspectives into a singular, overarching representation known as the global stakeholder map. This unified visual construct embodies a synthesis of viewpoints, encompassing the collective insights and considerations of all involved stakeholders. The paramount objective of this amalgamation process lies in meticulously identifying, delineating, and comprehending the entirety of enabling factors across multifaceted constructs. By intricately mapping out the intricate interconnections and relationships between these enabler constructs (as illustrated in Figure 3 2), this holistic

[25] The logo here serves as a representative of the stakeholder's category and does not exclusively denote a singular entity. There are additional companies within this category that are not explicitly depicted by the logo.

approach aims to furnish a comprehensive understanding of the intricate stakeholder ecosystem and the pivotal linkages that drive sustainable progress and collaboration. As shown in Figure 3 2, the primary objective revolves around the development of the SAF industry. This objective's realisation hinges upon adhering to stakeholders mapping strategic pathways. Essential to the development of the SAF industry is the active engagement of stakeholders, meticulous due diligence and the assurance of both business profitability and sustainability. Amidst various influential factors, it is noteworthy that business profitability is discerned as predominantly reliant on the strategic amalgamation of appropriate technology and feedstock, emphasising the criticality of this mix in achieving sustainable and economically viable SAF production.

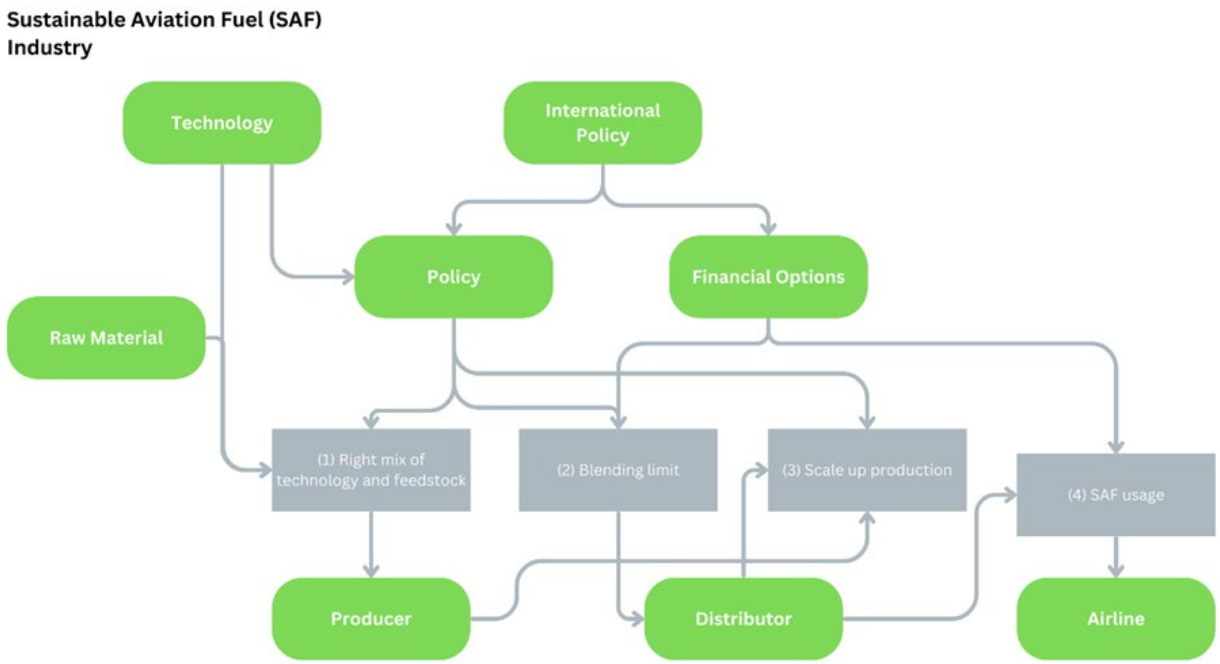

Figure 3-2: Stakeholders Mapping

3.2 Stakeholder interview

In the pursuit of this research objectives, the project deliberately adopted interviews as the primary method for data collection, recognising their intrinsic effectiveness, particularly in exploring areas that are newly emerging or have received limited investigation—such as relevant focal points in the SAF ecosystem.

The selection of interviews as a data collection technique was strategic, aimed at circumventing potential biases often associated with group-based assessments. By engaging individual respondents, we aimed to glean nuanced insights and diverse perspectives while minimising the influence of group dynamics on participants' opinions.

Throughout these interviews, the process emphasised the importance of capturing the professional viewpoints of the participants, distinct from any official positions espoused by their respective organisations. This approach aimed to extract candid and expert opinions on the subject of SAF without the constraints imposed by organisational affiliations.

The formulation of interview questions was guided by a thorough review of academic literature pertaining to innovative and burgeoning technologies, ensuring that project enquiries were grounded in scholarly discourse and aligned with the current discourse on SAF. To further ensure the robustness and relevance of project enquiries, these questions underwent a rigorous validation process conducted by both internal and external experts affiliated with this project. Their insights and feedback were integral to refining and tailoring our questions to effectively elicit comprehensive and meaningful responses from interview participants.

(a) (b)

Figure 3-3: (a) Photo of hybrid SAF's stakeholder interview at OTP, (b) method for developing interview.

3.2.1 Interview Methods

Stakeholders' interviews with the Office of Transport and Traffic Policy and Planning (OTP) and relevant organisations concerning SAF was conducted utilizing a hybrid approach as shown in Figure 3-3 (a). This approach integrates both onsite and online interview methods, strategically designed to enhance flexibility in engaging a wide array of stakeholders situated across different geographic locations. Figure 3-3 (b) is an outline detailing the methodology employed for the hybrid SAF stakeholder interview. Enclosed is an outline delineating the procedural framework for a hybrid stakeholder interview concerning SAF.

Define Objectives and Scope

The primary objectives of the forthcoming interview are to distinctly define the scope and purpose by emphasising key focal points. These encompass technological advancements, regulatory challenges, market trends, and sustainability facets pertinent to SAF.

Furthermore, the project's aim is to engage a diverse spectrum of stakeholders. This will include but is not limited to industry experts, policymakers, researchers, and environmental advocates. The intent is to garner a comprehensive perspective from various vantage points within the domain of aviation fuel sustainability.

Stakeholder Identification and Selection

The critical work task is thoroughly identifying and compiling stakeholders vital to the SAF ecosystem. This includes a thorough cataloguing of participants based on their knowledge, positions, affiliations, and possible contributions to the conversation. The selection process prioritises stakeholders capable of providing distinctive insights or wielding substantial influence in the realms of SAF development and adoption. This meticulous curation aims to encompass a broad spectrum of perspectives, ensuring a robust and holistic representation within the discussion.

Interview Planning and Question Development

The task involves the meticulous creation of a structured interview guide aligned with the predetermined objectives. It is imperative that the questions included within the guide are open-ended and encompass a comprehensive array of facets. These facets should encapsulate technological innovation, regulatory impediments, economic feasibility, environmental ramifications, and prospective trajectories concerning SAF.

Furthermore, the questionnaire is meticulously designed to prompt qualitative responses from the interviewees. These responses are structured to primarily gauge the readiness of each stakeholder in adopting SAF. Subsequently, the questionnaire seeks to assess the perceived impact of SAF on the environment, serving as a pivotal aspect of stakeholder perception evaluation. Prior to finalisation, a pilot testing phase involving a select group of stakeholders is initiated. This testing phase aims to refine and validate the questions, ensuring their efficacy and relevance by eliciting comprehensive and insightful responses from the diverse range of stakeholders involved.

Data Collection and Analysis

It is imperative to meticulously record the responses obtained during the interviews to facilitate reliable data collection and comprehensive documentation. Detailed notetaking will capture essential topics, encompassing the spectrum of ideas, opinions, and suggestions articulated by the stakeholders.

Additionally, systematic organisation and analysis of the collected data are essential. This process entails identifying recurring themes, contrasting viewpoints, and discerning significant findings that emerge from the stakeholder interactions. Afterwards, a comprehensive report or presentation is to be prepared, delineating the key insights, recommendations, and actionable steps derived from the aggregated stakeholder input. This report will serve as a strategic blueprint, encapsulating valuable insights gleaned from the diverse perspectives, facilitating informed decision-making and guiding future actions in the context of SAF development and adoption.

3.2.2 Interview Results

Readiness and Impact of SAF

Upon evaluating the readiness of each stakeholder to adopt SAF, the subsequent assessment aimed to gauge the perceived impact of SAF on the environment. The results, as depicted in Figure 3-4, reveal an average readiness score of 3.80 and an impact score of 3.96. This statistical representation indicates a notable readiness among the stakeholders towards implementing SAF.

Furthermore, the data illustrates a prevailing consensus among stakeholders regarding the prospective environmental benefits of SAF. The majority concur that SAF holds promise in effectively mitigating carbon emissions, aligning with the overarching goal of environmental sustainability.

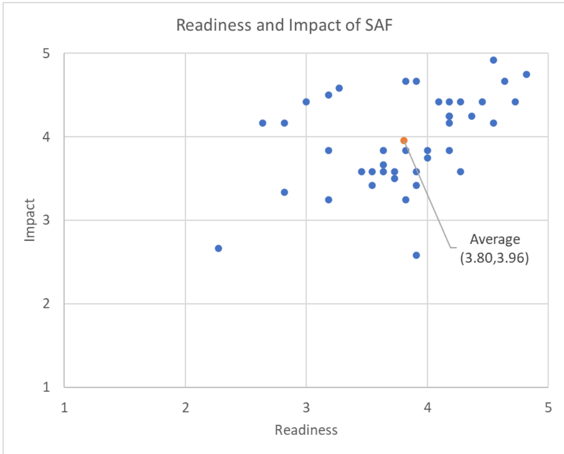

Figure 3-4: Graph showing result of readiness and impact of SAF.

Upon categorisation of stakeholders and subsequent ranking based on the readiness scores obtained, a discernible order emerged. The ranking delineates the degree of preparedness among various stakeholder categories for the adoption of SAF. The categorised ranking, in ascending order of readiness, is as follows:

1. Airline
2. Distributor
3. Fuel producer
4. Raw material providers
5. Government Agencies and Regulators

This ranking structure reflects the differential levels of readiness observed among distinct stakeholder groups, outlining the varying degrees of preparedness for the integration of SAF within their respective domains and operational frameworks.

Following a thorough assessment of the impact scores provided by stakeholders regarding SAF's potential influence on the aviation industry's environmental aspects, a distinct ranking has been derived. This ranking delineates the perceived impact of SAF among various stakeholder categories. The categorised ranking, showcasing the stakeholders' perceptions of SAF's environmental impact within the aviation industry, is as follows:

1. Distributor
2. Government Agencies and Regulators
3. Airlines
4. Fuel producer
5. Raw material providers

This ordered ranking signifies the stakeholders' differing perceptions regarding the potential environmental impact of SAF within their respective spheres of operation and influence within the aviation industry.

When will Thailand be ready for SAF?

During the interview, stakeholders were surveyed regarding the anticipated timeline for Thailand's readiness to adopt SAF. The collected responses indicated a prevailing viewpoint, with the majority (54%) projecting a readiness timeframe within the range of 3-5 years as shown in Figure 3-5. Following closely, the second most common response (29%) predicted the readiness window to fall between 6-10 years.

From these data, a conclusive inference can be drawn: a collective consensus among stakeholders suggests that Thailand's aviation industry will likely be prepared to integrate SAF within a timeframe not exceeding 10 years.

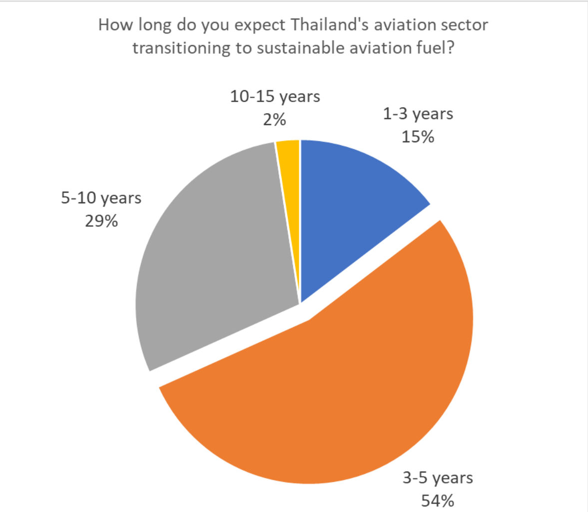

Figure 3-5: Graph showing result of when Thailand will be ready for SAF

Challenges

During the conducted interviews, stakeholders were probed regarding the principal obstacles and challenges associated with the adoption of SAF. An overwhelming majority (83%) cited pricing concerns as the foremost barrier, highlighting its significance in hindering widespread adoption. Following closely, regulatory agencies were identified as a substantial hurdle, with 71% of respondents acknowledging their role as a significant impediment to the adoption of SAF within the aviation industry as shown in Figure 3-6.

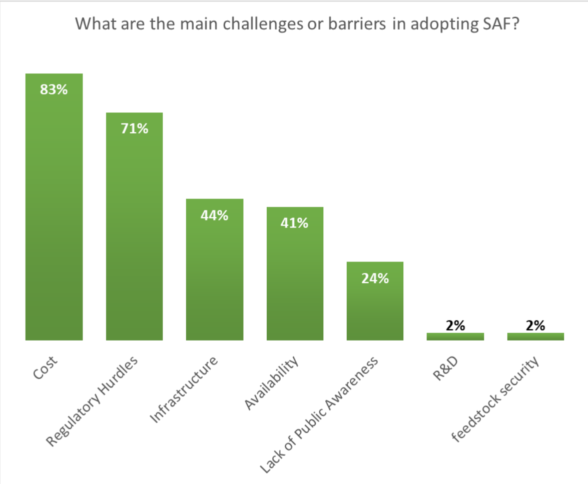

Figure 3-6: Graph showing result of challenges in SAF

Requirements for Assistance

During the comprehensive stakeholder interviews conducted, participants were questioned regarding the paramount areas necessitating government involvement and support for the adoption of SAF. The overwhelming majority (90%) identified regulation and policy as the most crucial aspect requiring government intervention. Following this, 65% of respondents highlighted the importance of incentives and subsidies as significant areas where government support could substantially impact the utilisation of SAF within the aviation industry as shown in Figure 3-7.

Primarily, the resounding consensus among stakeholders emphasising the criticality of regulation and policy signifies an urgent need for the development of robust frameworks. Such frameworks are imperative to effectively negotiate regulatory impediments and establish comprehensive industry standards crucial for the seamless implementation of SAF.

Concurrently, stakeholders' recognition of the significance of incentives and subsidies implies an imperative for the introduction of financial mechanisms. These mechanisms are indispensable in mitigating cost-related barriers, thereby incentivising and facilitating the widespread adoption of SAF among aviation stakeholders.

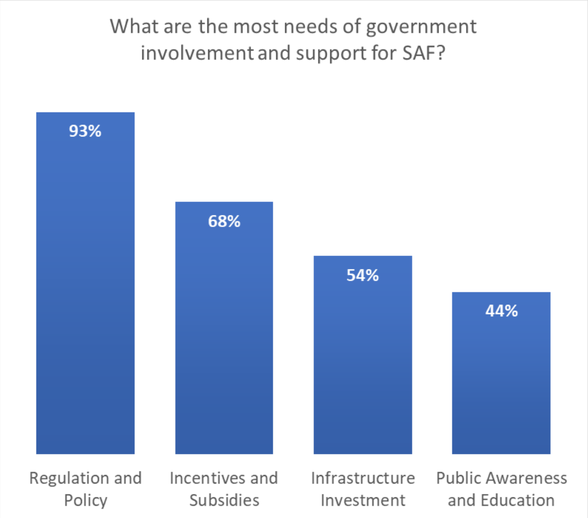

Figure 3-7: Graph showing result of identified needs for support in SAF.

3.2.3 Keys takeaway

From the stakeholders' analysis conducted, key takeaways for SAF can be categorised into several crucial points as follows.

Environmental Impact

The considerable reduction in greenhouse gas emissions attributed to SAF when compared to conventional aviation fuels underscores its pivotal role in the aviation sector's concerted efforts towards environmental sustainability. The adoption and continuous development of SAF stand as cornerstones within the industry's dedicated commitment to diminishing its carbon footprint and actively addressing the global imperative of mitigating climate change.

The ongoing pursuit of SAF adoption not only signifies technological advancement but also serves as a testament to the aviation industry's dedication to innovation and environmental responsibility. It embodies a strategic shift toward sustainable practices, exemplifying the industry's resolute intention to contribute positively to global initiatives aimed at combating climate change and fostering a more sustainable future.

Technological Advancements

Continuous research and innovation in the domain of SAF, particularly concerning advancements in production methodologies, feedstock development, and refining technologies, stand as foundational imperatives. Progress and breakthroughs in these areas hold significant weight, as they play a pivotal role in augmenting the efficiency, scalability, and cost-effectiveness integral to the SAF ecosystem.

The potential of Power-to-Liquid (PtL) technologies to facilitate the scalable production of SAF in the future underscores a promising avenue for the aviation industry. PtL methods offer prospects for increased SAF output, providing a viable pathway towards meeting escalating demand and expanding the availability of sustainable fuel alternatives.

However, concerns pertaining to feedstock sources warrant attention, notably the limitations associated with correcting and procuring adequate quantities of used cooking oil. The challenges surrounding feedstock availability and quality pose notable hurdles, necessitating concerted efforts to identify alternative sustainable sources that can ensure a consistent and sufficient supply for SAF production.

Additionally, assessing the Total Cost of Ownership (TCO) assumes paramount significance in comprehensively understanding the economic viability and feasibility of SAF adoption. An in-depth study analysing the overall costs associated with SAF production, distribution, and utilisation is imperative. Such an analysis not only aids in gauging the financial implications but also assists stakeholders in making informed decisions regarding SAF integration, considering the entire lifecycle of the fuel.

In essence, the continuous pursuit of research and innovation in SAF production methodologies, coupled with a focus on scalable technologies such as PtL, demands strategic attention. Addressing feedstock limitations and comprehensively assessing the Total Cost of Ownership emerge as critical considerations, pivotal in steering the aviation industry towards widespread and sustainable adoption of SAF.

Regulatory Support

Establishing coherent and steadfast policies, coupled with robust regulatory frameworks, stands as a cornerstone in advancing the production and utilization of SAF. The presence of clear guidelines and consistent regulatory structures assumes paramount importance in fostering an environment conducive to promoting and incentivising SAF within the aviation sector. Government support and interventions wield significant influence in expediting the widespread adoption of SAF, further emphasising the pivotal role of policymakers in steering the trajectory of sustainable aviation practices.

It is crucial to recognise that distinct policies governing domestic and international flights play a critical role in shaping the landscape for SAF adoption. Tailoring policies to suit the specificities and requirements of each domain is imperative, ensuring a nuanced and effective approach in promoting SAF integration within both domestic and international flight operations.

In pursuit of expediting the scale-up of SAF adoption, the formulation of a comprehensive SAF white paper emerges as a strategic initiative. This document serves as a blueprint, delineating strategies, recommendations, and frameworks aimed at accelerating the proliferation of SAF within the aviation sector. The SAF white paper stands as a pivotal tool, consolidating insights, best practices, and actionable steps essential for fostering collaboration, stimulating investment, and driving widespread acceptance and utilisation of SAF on a global scale.

Collaboration and Awareness

Collaboration among stakeholders, encompassing governmental entities and the aviation industry, assumes vital importance in the realm of SAF. This collaborative synergy stands as a linchpin in fostering a conducive environment that propels the advancement and uptake of SAF. Furthermore, augmenting awareness and garnering acceptance among consumers and industry stakeholders serves as a catalyst, significantly bolstering the demand for SAF.

The collaborative efforts orchestrated by a diverse array of stakeholders underscore a collective commitment to steering the aviation industry toward sustainability. The amalgamation of perspectives, expertise, and resources from governmental bodies, industry players, and research institutions orchestrates a comprehensive approach to advancing SAF. This concerted endeavour fosters an ecosystem conducive to innovation, knowledge-sharing, and strategic alignment, ultimately driving the progress and integration of SAF within the aviation domain.

Furthermore, incorporating a Public-Private Partnership (PPP) model into the SAF landscape offers a promising avenue to enhance the quality, efficiency and competitiveness of aviation services. Leveraging the strengths of both sectors, a PPP framework could augment SAF initiatives by supplementing public sector capabilities, addressing financial constraints, and capitalising on the private sector's operational efficiencies. This collaborative approach holds the potential to expedite SAF infrastructure development, elevate service standards, and ultimately drive the aviation industry toward a more sustainable future.

In essence, the collaborative synergy among varied stakeholders, coupled with proactive efforts to enhance awareness and foster acceptance, emerges as a pivotal force in amplifying the momentum for SAF within the aviation industry. This collaborative ethos not only accelerates innovation and adoption but also heralds a collective commitment towards a more sustainable aviation landscape.

3.3 Stakeholder Prioritisation

Designing approaches to suit the distinct needs and priorities of individual stakeholder groups is necessary when supporting SAF. Highlighting the multifaceted benefits of SAF—its positive influence on environmental preservation, economic feasibility, and societal welfare—stands as a central strategy in fostering engagement among diverse stakeholders.

It is crucial to recognise that stakeholders exhibit varying levels of readiness and perspectives regarding SAF integration. Acknowledging these differing states of readiness is pivotal in crafting targeted approaches that resonate with each stakeholder group's current standing, concerns, and aspirations regarding SAF adoption. This nuanced understanding allows for the development of bespoke engagement strategies that address the unique contexts and preparedness levels of each stakeholder.

3.3.1 For Raw Material Providers Group

For this stakeholder, it is notable that, as per the Alternative Energy Development Plan (AEDP), biomaterials like Used Cooking Oil (UCO), Palm Oil, and ethanol stand as the primary materials for SAF. However, the potential practical feasibility of hydrogen as a future alternative is considered significant in the SAF landscape.

A critical concern for this group revolves around the reliable supply of feedstock required for SAF production. Ensuring a consistent and sustainable supply of biomaterials remains a critical focal point, given their indispensable role in current SAF production methods. Furthermore, the potential transition to hydrogen as a feasible SAF component underscores the necessity of hydrogen cost and renewable sources for future scalability and feasibility.

In supporting their needs, this stakeholder group emphasises the imperative for policy support. Policies aimed at facilitating a steady and sustainable supply chain for biomaterials and hydrogen feedstock would be instrumental. This group seeks supportive regulatory frameworks that foster a stable and accessible feedstock market, enabling streamlined and resilient production processes for SAF.

3.3.2 For Fuel Producers Group

The emergence of SAF presents a compelling opportunity for innovation and diversification within the industry. Notably, the Ministry of Energy's proposal to mandate a 2% SAF incorporation in 2027, as shown in Figure 2 4, signifies a consistent and substantial demand for SAF production, presenting a favourable market landscape.

However, pertinent concerns arise within this group, primarily centred around crucial aspects hindering efficient SAF production. Foremost among these concerns is the insufficient availability of feedstock, essential for consistent SAF manufacturing. This scarcity poses a significant challenge, impacting the group's ability to meet the escalating demand for SAF. Additionally, the lack of policy clarity and market specifications presents obstacles in charting a clear path for SAF production. Clarity in regulations and market demands is pivotal for strategic planning and investments, ensuring alignment with evolving industry standards and consumer requirements. Furthermore, the absence of standardised testing sites adds to the challenges faced by the fuel producer group. Establishing standardised test sites is crucial for ensuring compliance with quality standards and validating the efficacy of SAF production processes.

They emphasise the necessity for clear and comprehensive policies, transparent market specifications, and the establishment of standardised test sites. These requisites are pivotal in facilitating streamlined and efficient SAF production processes, thereby enabling the group to effectively meet the mandated demands and contribute substantially to the burgeoning SAF market.

Resolving these concerns through policy clarity, market transparency, and the establishment of standardised testing facilities holds the key to unlocking the full potential of the fuel producer group in catering to the escalating demand for SAF and ensuring a sustainable future for aviation fuel alternatives.

3.3.3 For Distributors Group

It is evident that the distributor stakeholder is an excellent illustration of ready-to-use SAF, approved to the technological preparedness, adherence to standards, and successful proofing of SAF efficacy. Primary among these concerns is the cost associated with SAF. While technological advancements and standards compliance facilitate readiness, the current cost of SAF remains a critical constraint. Reducing the cost of SAF production is imperative to align with market competitiveness and facilitate wider adoption.

Furthermore, policy support emerges as another pressing concern. Clear and supportive policies play a pivotal role in fostering a conducive environment for the adoption of SAF. Policies that incentivise SAF production, distribution, and usage are essential to offset initial cost barriers and promote a sustainable market for SAF.

Recognising and mitigating these concerns through concerted policy initiatives and cost-effective production methods would facilitate the seamless integration of SAF among this advanced stakeholder group, propelling the aviation industry towards a sustainable and environmentally conscious future.

3.3.4 For Airlines Group

This stakeholder group stands among the leaders in readiness to use SAF within their operations, aligning with industry advancements and preparedness. However, key concerns continue around the potential impact of SAF costs on ticket prices and the necessity for defining distinct standards between domestic and international flights. While embracing SAF aligns with sustainability objectives, the cost implications pose a significant challenge, potentially affecting ticket prices. Addressing these cost implications without compromising the affordability of air travel is a pressing issue.

Furthermore, the suggestion to establish separate standards for domestic and international flights underscores the need for understanding policies tailored to diverse flight operations. Clear and distinct standards for these flight categories are essential for practical and effective implementation, ensuring compliance while accounting for varying operational requirements.

In advocating for these concerns, this group emphasises the importance of policy support and clarity. Policies that address the cost impact on ticket prices while promoting SAF integration and delineating clear standards for domestic and international flights are crucial. Clarity in regulations and supportive policies are vital for navigating the complexities associated with SAF integration and ensuring a balanced approach that considers both environmental goals and operational feasibility.

Strategic collaboration between aviation stakeholders and policymakers is instrumental to devising policies that strike a balance between environmental objectives and operational realities. Addressing these concerns through supportive policies and cost-effective strategies would empower the airline group to seamlessly integrate SAF while ensuring the sustainability of air travel operations.

3.3.5 For Government Agencies Group

For this stakeholder group, readiness to involve the SAF remains relatively low due to the constraints of the policymaker. However, critical concerns persist, particularly relating to the cost effects of SAF adoption and its impact on consumers utilising airline services.

Foremost among the concerns articulated by this group is the apprehension surrounding the cost dynamics associated with SAF integration. While recognising the potential benefits, the apprehension stems from the financial impact on various stakeholders, especially consumers utilising airline services. Mitigating this impact on consumers becomes crucial in ensuring a balanced transition to SAF without imposing undue financial burdens.

Moreover, the emphasis on supporting the SAF ecosystem to foster the growth of the SAF industry in Thailand underscores the group's commitment to nurturing a sustainable aviation landscape. Policies and initiatives aimed at supporting the entire SAF ecosystem are essential for promoting its growth, bolstering research, development and adoption while ensuring its economic viability.

In advocating for these concerns, this group emphasises the necessity of measures to minimise the impact of SAF adoption on consumers utilising airline services. Additionally, comprehensive support for the SAF ecosystem in Thailand, including incentives and supportive policies, is essential. Collaborative efforts between the government and industry stakeholders are pivotal in formulating policies that balance the economic considerations while promoting a sustainable SAF industry. Addressing these concerns through supportive policies and strategic initiatives would pave the way for a balanced and sustainable integration of SAF, aligning with Thailand's aspirations for a greener and more environmentally conscious aviation sector.

In conclusion, Table 3-1 summarises SAF stakeholders' analysis in terms of readiness and impact with identified concerns and support needed for further consideration on more in-depth investigation.

Table 3-1: Stakeholders' analysis summary

Stakeholder Type	Readiness Rank	Impact Rank	Concerns	Support needed
Raw materials supply	4th	4th	Feedstock, Cost	Policy, Incentive
Fuel producer	3rd	5th	Feedstock, Cost	Incentive, Policy, Infrastructure Investment
Distributor	2nd	1st	Cost, Standard	Policy
Airline	1st	3rd	Cost	Incentive, Policy
Government Agencies and regulators	5th	2nd	Cost, Public Awareness	Policy, Study

4 SUMMARY

The imperative for sustainable aviation is indisputable, especially as the sector assumes an increasingly influential role in global transportation. Despite an unprecedented financial crisis, the entire industry must intensify efforts to hasten the shift toward carbon neutrality.

In this transition, sustainable aviation fuels (SAF) emerge as pivotal contributors. SAF stands out among alternatives, not just for their technological maturity but also for their compatibility with existing aircraft and logistical systems, offering a swift response to the urgency of the issue. Among these, jet fuel sourced from biogenic origins currently presents a more accessible and cost-effective production method, achievable through diverse pathways. Yet, significant hurdles loom for larger-scale implementations, primarily linked to the complexities of feedstock growth that might compromise long-term sustainability objectives. Once technological constraints are overcome, synthetic fuels, particularly those created from Power-to-Liquid (PtL) technologies, are positioned to be significant actors in decarbonization. Nonetheless, biofuel research and promotion are critical, giving critical evidence of scale economies and early significant carbon reductions.

The strategic inclusion of SAF within Thailand's Nationally Determined Contributions (NDC) is yet to outline explicit greenhouse gas (GHG) reduction targets due to the significant implementation timeline for domestic aviation planned beyond 2030. However, an SAF drive from international flights could expedite domestic adaptation given 80% of aviation fuel consumption in Thailand is for international flights. This noticeable gap, however, serves as a catalyst, generating impetus for SAF efforts and advancements in Thailand's aviation sector with an initial formulation of SAF policy and interest shown already by private sector entities.

In advocating for SAF adoption, various stakeholders display differing levels of readiness and concerns. Fuel producers and airlines show eagerness but express apprehensions about SAF costs and the need for policy backing. Meanwhile, government agencies aim to maximise SAF benefits while addressing cost implications for consumers and supporting Thailand's growing SAF industry. The readiness across these sectors varies, underlined by mutual concerns about cost impacts and the necessity for transparent policies and support to facilitate the integration and advancement of SAF.

The subsequent phases in SAF development need further in-depth studies and the formulation of policy recommendations towards establishing an SAF mandate. Additionally, a proactive approach involves monitoring the advancements in Power-to-Liquid (PtL) technology and the promising hydrogen economy within Thailand's aviation landscape. This study concludes with three recommendations as follows:

1. Immediate need for official coordination between the ministries of Transport and Energy in the form of a National SAF Board comprising relevant government agencies, research institutes and private sector entities to expedite SAF policy development with mandated target and implementation.
2. Near future need for quantitative research to estimate SAF supply from currently available pathways (HEFA and AtJ) and future economically feasible pathways (Gasification/FT and PtL) to help plan SAF policy and mandate in accordance with aviation industry growth.
3. Consistent watch of other hydrogen activities in Thailand that could help realise hydrogen utilization in PtL-SAF.

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