Final Report

Research Grant 2021

ATRANS

ASIAN TRANSPORTATION RESEARCH SOCIETY

Assessment of GHG emission reduction potential in Thai aviation sector

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List of Abbreviations and Acronyms

ACI	Airports Council International
AEDP	Alternative Energy Development Plan
APU	Auxiliary Power Unit
ATM	Air Traffic Management
AGERWG	Aviation GHG Emission Reduction Working Group
BAU	Business-As-Usual
CAAT	Civil Aviation Authority of Thailand
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CAAT	Civil Aviation Authority of Thailand
COP	Conference of the Parties
EASA	European Union Aviation Safety Agency
EU	European Union
FAA	Federal Aviation Administration
EV	Electric Vehicle
FCV	Fuel Cell Vehicle
FT	Fischer–Tropsch
GDP	Gross Domestic Product
GHG	Greenhouse gas
GPU	Ground Power Unit
GSE	Ground Support Equipment
HEFA	Hydroprocessed Esters and Fatty Acids
ICAO	International Civil Aviation Organization
LAMP	Landside Access Modernization Program
MRV	Measurement, Reporting and Verification
NAA	Narita International Airport Corporation
NDC	Nationally Determined Contributions
ONEP	Office of Natural Resources and Environmental Policy and Planning
OTP	Office of Transport and Traffic Policy and Planning
PtL	Power-to-Liquid
RPK	Revenue Passenger Kilometer
SAF	Sustainable Aviation Fuel
SDS	Sustainable Development Scenario
UNFCCC	United Nations Framework Convention on Climate Change
VALE	Voluntary Airport Low Emission Program
ZEB	Zero Emission Building

CHAPTER I INTRODUCTION

1.1 Rationale

During 2015 United Nations Climate Change Conference held in Paris in December 2015, where 21st yearly session of the Conference of the Parties (COP) to the 1992 United Nations Framework Convention on Climate Change (UNFCCC) or in short known as "COP 21" was held, a global agreement toward limiting global warming to "well below 2 ºC (compared to pre-industrial level) by representatives of 195 attending parties [1]. Subsequently on 22 April 2016 (Earth Day), 175 countries, including Thailand, signed Paris Agreement in New York followed by a committed statement at 71st United Nations General Assembly on 21 September 2016 from 184 countries accounting for 55% of world greenhouse gas (GHG) emission [2]. As part of committed country, Thailand has formulated Nationally Determined Contributions (NDCs) to itemize committed goal of 20-25% GHG reduction by 2030

As shown in Fig. 1, about three-quarters Thailand GHG emission in 2013 comes from energy related, in which electricity and transport are main contributors. Hence, Thailand NDC has focused on energy and transport sectors toward more environmentally friendly infrastructure. Business-As-Usual (BAU) level of GHG emission is identified at 2005, where none of climate change countermeasure has started, with continuous monitoring and forecasting shown in Fig. 2. With 20% committed target of GHG emission reduction in 2030, or equivalently 111 Mton $CO_{2,eq}$, Thailand has established a NDC Roadmap with 41 Mton $CO_{2,eq}$ target in transportation sectors from Mode Shift (23 Mton $CO_{2,eq}$), Biofuel (10 Mton $CO_{2,eq}$) and Energy Efficiency (8 Mton $CO_{2,eq}$), as shown in Fig. 3 [3].

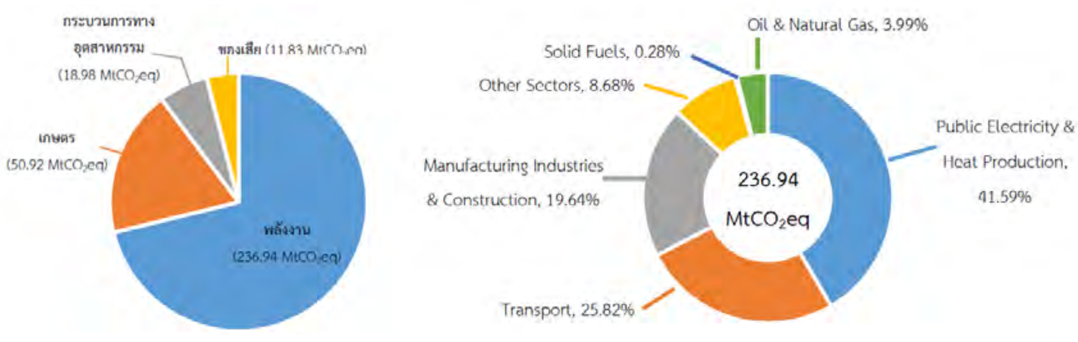


Fig. 1 2013 Thailand GHG emission (left) with breakdown of energy sector (right)

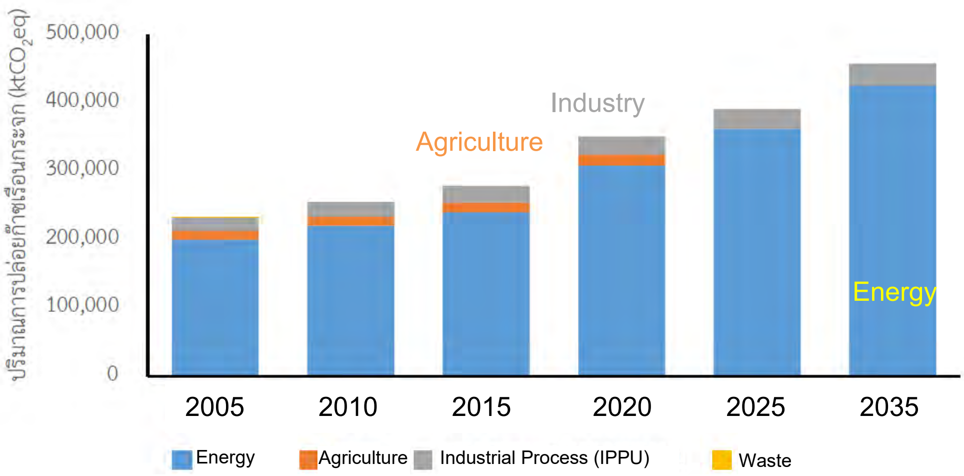


Fig. 2 GHG emission accounting from BAU (2013) with forecasting to 2030

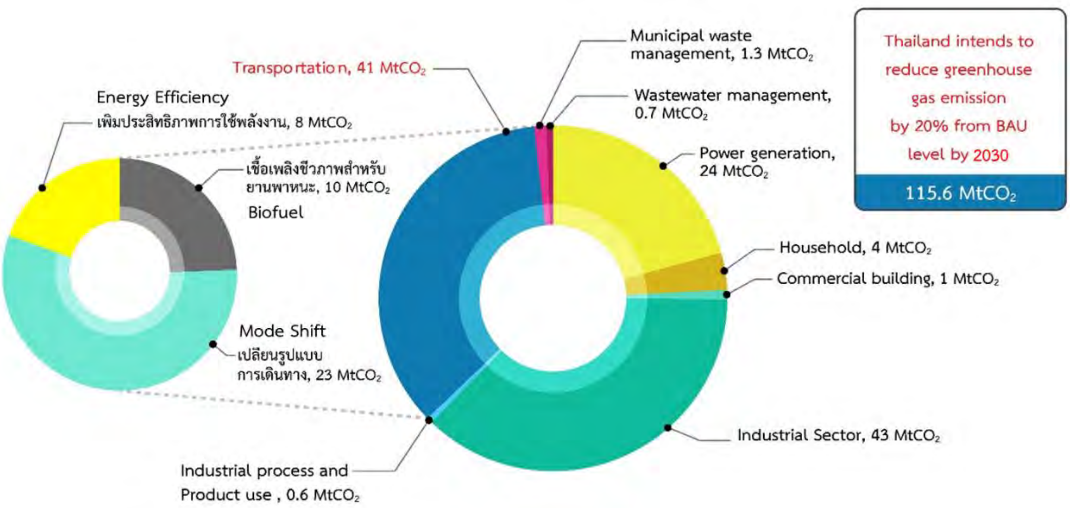


Fig. 3 Thailand NDC roadmap with breakdown of transportation sector

Although all three measures (Mode Shift, Biofuel & Energy Efficiency) of 41 Mton $CO_{2,eq}$ target focus on road, rail and water transport, aviation sector has been growing especially with emerging low-cost airlines accounting for 75% and 32% of domestic and international markets in 2015 [4] On the global scale, 3.6 billion people has travelled by plane resulting one-thirds of passenger-kilometers travelled by car in 2017. Even though CO2 in aviation is currently about 2-3% of global energy-related CO2 emission, historical records show 3-5% growth in aviation energy demand. Fig. 4 shows historical fast growing number of international passengers in Thailand with forecast of BAU CO_2 emission till 2030.

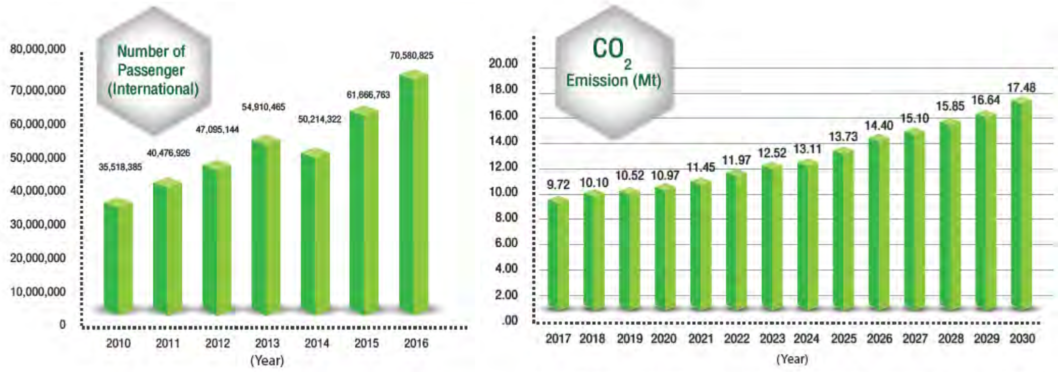


Fig. 4 Historical data of international passengers in Thailand (left) with forecast of CO_2 emission (right)

As part of International Civil Aviation Organization (ICAO), Civil Aviation Authority of Thailand (CAAT) has initiated Thailand's Action Plan to Reduce Aviation Emission in 2013 with recent update in 2018 [4] to join global effort of improving fuel efficiency and stabilizing CO_2 emission at 2020 levels (shown in Fig. 5 [5]) through the following short/medium/long term mitigation measures through Aviation GHG Emission Reduction Working Group (AGERWG) established in 2011 with structure shown in Fig. 6 [4].

1. **Aircraft-related Technology Development such as aircraft minimum fuel efficiency standards**
2. **Alternative Fuels such as bio jet fuel**
3. **Improved Air Traffic Management (ATM) and Infrastructure Use such as efficient ATM planning**
4. **More Efficient Operations such as optimized aircraft maintenance**
5. **Economic / Market-Based Measures such as Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) and**
6. **Regulatory Measures/Other such as transparent carbon reporting**

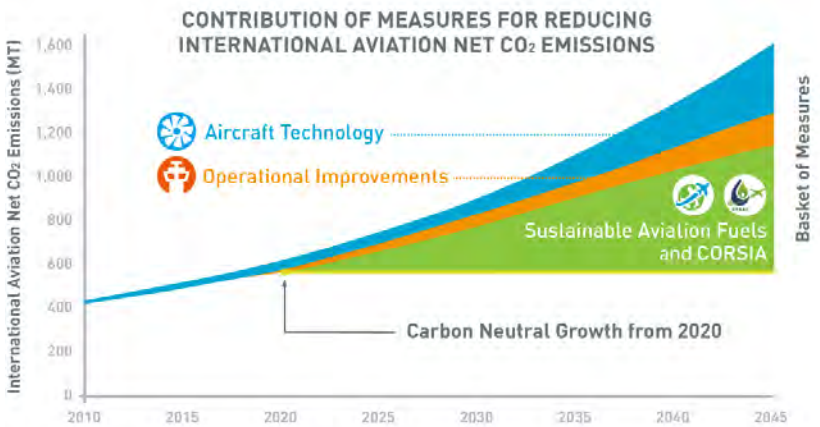


Fig. 5 ICAO's aspirational goals of carbon neutral growth from 2020

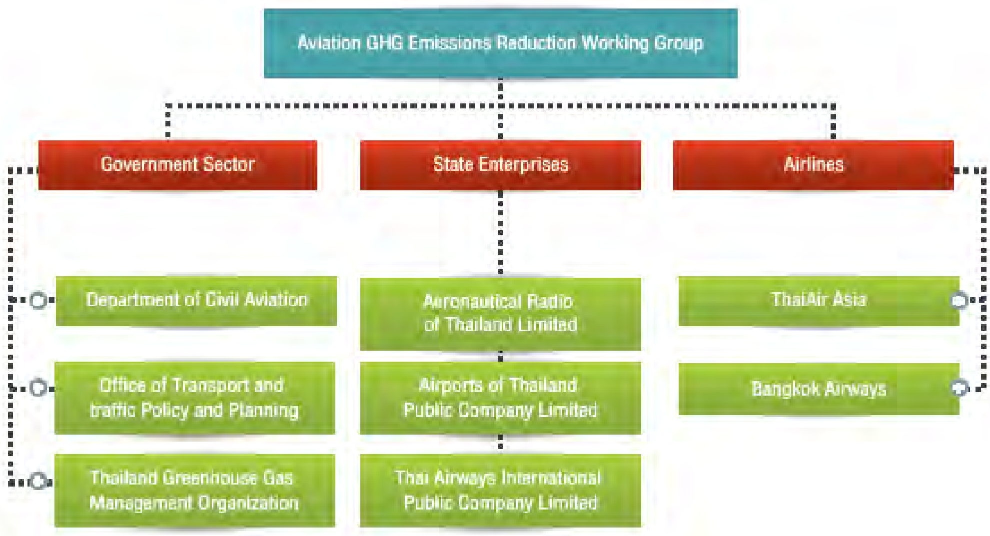


Fig. 6 Aviation GHG Emission Reduction Working Group (AGERWG)

1.2 Objectives

The present study aims to assess potential of GHG emission reduction in Thai aviation sector through selected abovementioned measures with COVID-19 impact, where aviation fuel (Jet A1) consumption in 2020 has decreased 62.3% [6].

1.3 Methodology

In order to systematically assess potential of GHG reduction in Thai aviation sector, the following methodology is proposed.

1. Update global status and trend on aviation GHG emission reduction with COVID-19 impact.
2. Analyze selected measures critical and suitable to Thailand for GHG emission reduction potential.
3. Conduct roundtable discussion with stakeholders to get feedback for final recommendation.

CHAPTER 2 RESEARCH PLAN

2.1 Project Schedule

Table 1 shows the project planning schedule with project expenditure shown in Table 2. All project members are scheduled to meet regularly to discuss the technical results performed by project research assistant, and directions of the project. Occasionally, the progress report will be presented to the advisors to further seek guidelines and comments of the results and future direction.

Table 1: Project planning schedule

Activity	2020									2021		
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Update global status and trend on aviation GHG emission reduction	■	■	■	■								
Analyze selected measures for GHG emission reduction potential				■	■	■	■					
Conduct roundtable discussion with stakeholders							■	■	■	■		
Draft final report with recommendation											■	■
Inception report submission	30-Apr											
Interim report presentation					20-Aug							
Interim report submission						30-Sep						
Final report presentation at board meeting									3-Dec			
Final report presentation to IATSS									14/15 Dec			
Final report submission												31-Mar

2.2 Project Expenditure

Table 2 shows the breakdown of the project expenditure.

Table 2: Project expenditure

No	Item	Unit cost	# of units	Sub total
1	Project leader	3,000	12	36,000
2	2 Researchers (200 THB/hr x 5 hrs/day x 10 days/month) for 12 months)	10,000	24	240,000
3	Expenses for project meeting	3,000	6	18,000
4	Travel expenses to collect data and interview	2,000	6	12,000
5	Office & computer supply	3,000	6	18,000

No	Item	Unit cost	# of units	Sub total
6	Secretariat's participation portion	10,000	1	10,000
7	Publishing proportion of the report book	50,000	1	50,000
			Total	**384,000**

CHAPTER 3 RESULTS & DISCUSSION

3.1 Reviews of International Efforts

As shown in Fig. 7 [7], aviation activity, in term of revenue passenger kilometer or RPK, has been increasing approximately eight fold over the past 40 years during 1980-2020; whereas, COVID-19 pandemic has set back aviation activity due to lock down (shown in a falling dash line). However, COVID-19 pandemic is forecasted to affect aviation activity by 5 years, as shown in prediction in Fig. 7. In details, effect from COVID-19 pandemic is illustrated by numbers of commercial flight and total flight flown during 2019 and 2021 as flight activity in early 2020 significantly decreases due to lock down shown in Fig. 8 [8].

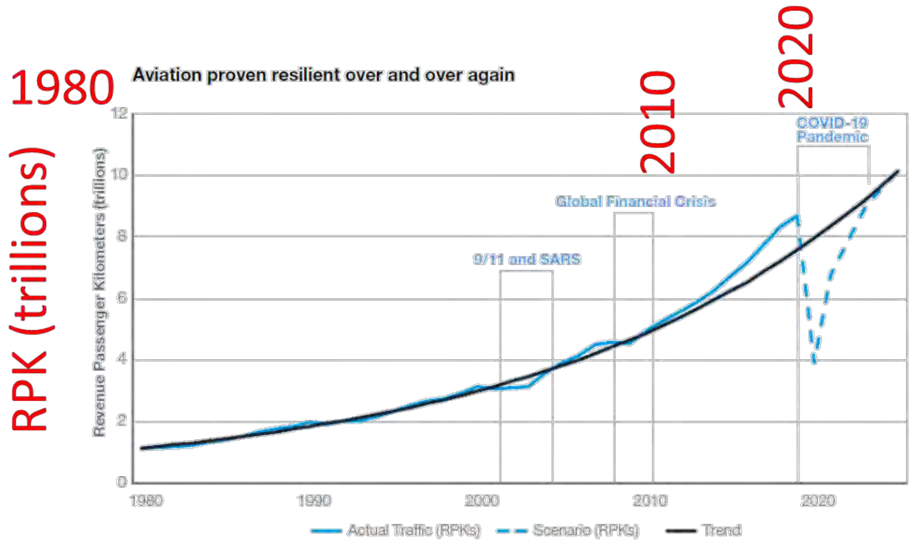


Fig. 7 Aviation traffic trend during 1980-2020 with COVID-19 effect

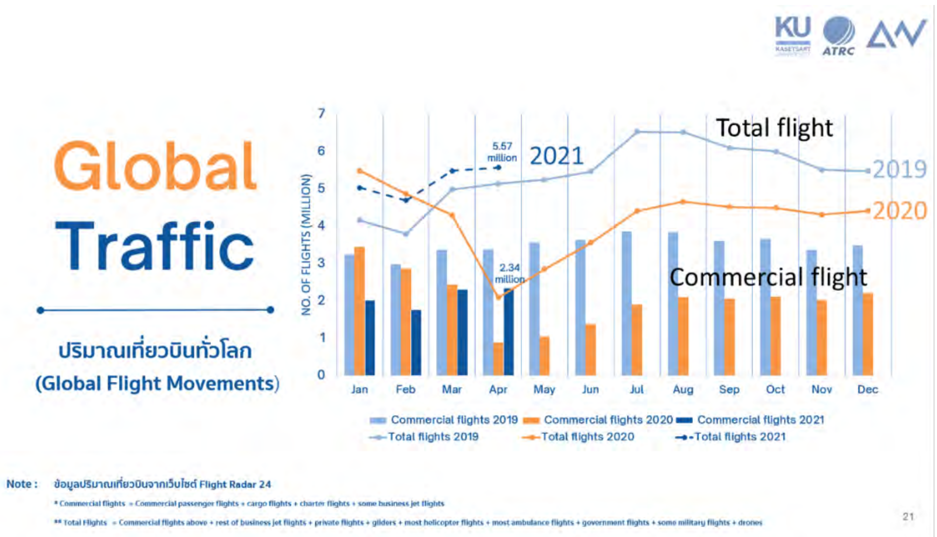


Fig. 8 Global flight movements during 2019 and 2021 by month

As for post COVID-19 recovery, Fig. 9 [7] shows 20 year forecast (2020-2039) for aircraft market demand by region with an average of 4% traffic growth from 3.2% fleet growth contributing to 2.5% GDP growth and 2.1 million new personnel. In particular, Asia-Pacific region is expected to have 17,485 deliveries double the forecast for North America (8,995 deliveries) and Europe (8,810 deliveries). As shown in Fig. 10 [9], current world fleet of aircraft is dominated by Boeing (45%) and Airbus (36%), both of which are in favor of working toward sustainable aviation industry in the future.

Fig. 9 Aviation forecast (2020-2039)

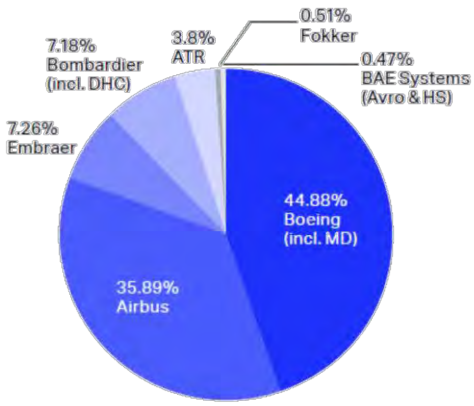


Fig. 10 World fleet by manufacturers

Prior to COVID-19 pandemic, Fig. 11 [9] shows aviation activity, in term of RPK growth, of 7.4% world growth, comprising of high growth region in Asia-Pacific (9.5%) followed by Europe (7.5%) in accordance with forecast in Fig. 9. Zooming into the effect of COVID-19

pandemic, Table 3 [10] clearly shows huge drop of spending on air transport and RPK over 50% during 2019-2020 with rebounding effect during 2020-2021 in line with prediction in Fig. 7.

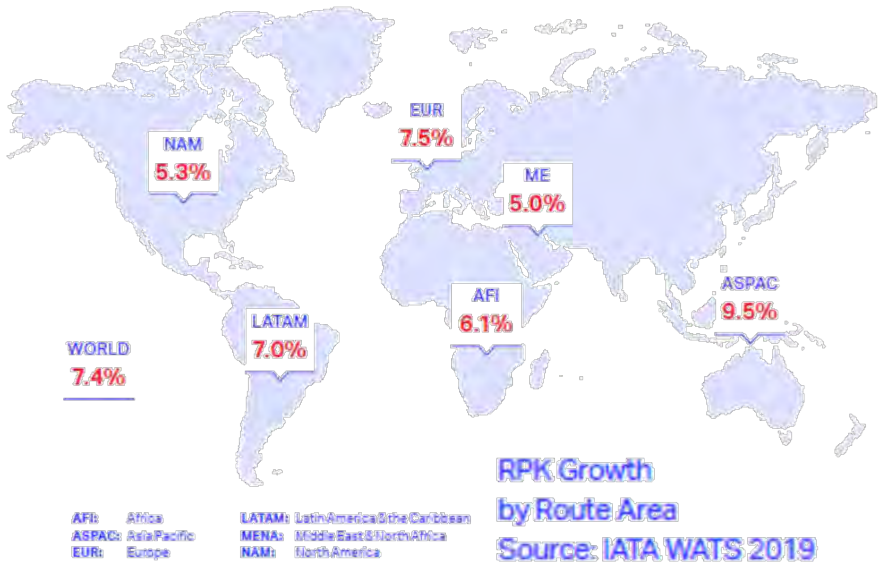


Fig. 11 RPK growth by route area

Table 3: Worldwide airline industry economic

Worldwide airline Industry	2019	2020F	2021F
Spend on air transport*, $billion	876	434	598
% change over year	3.6%	-50.4%	37.7%
% global GDP	1.0%	0.5%	0.6%
RPKs, billion	8680	3929	6099
% change over year	4.2%	-54.7%	55.2%

In term of energy intensity of passenger aviation in MJ/RTK, shows clear trend in Fig. 12 [11] that energy intensity has been continuously decreasing over the past 2 decades (2000-2020), where international route has better (lower) energy intensity than average since longer flight route reduces take-off/landing sections with rather high energy consumption. From 2020 onwards, aviation industry has set challenging goal of 2% improvement after 2020 in Sustainable Development Scenario (SDS). This energy intensity trend is also reflected by amount of fuel used per RTK as shown in Fig. 13 [10], which has been improving (decreasing) regardless of jet fuel price except recent effect by COVID-19.

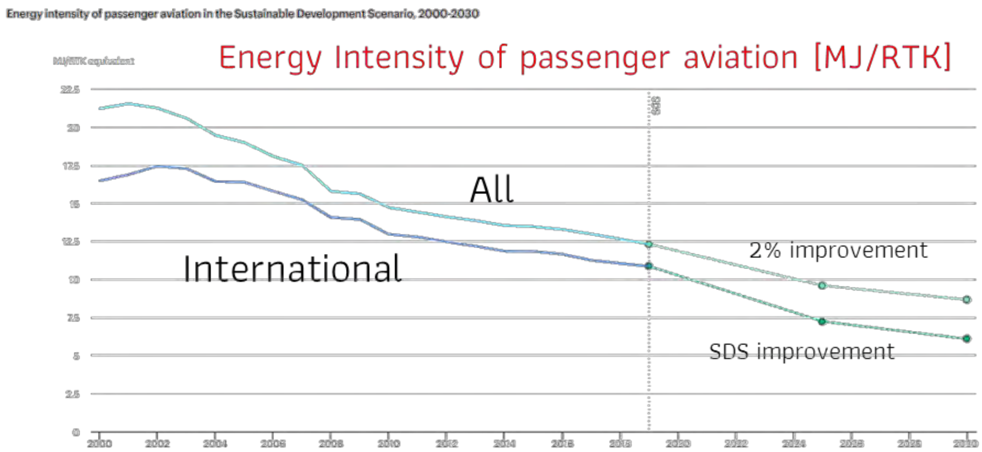


Fig. 12 Energy Intensity of passenger aviation [MJ/RTK]

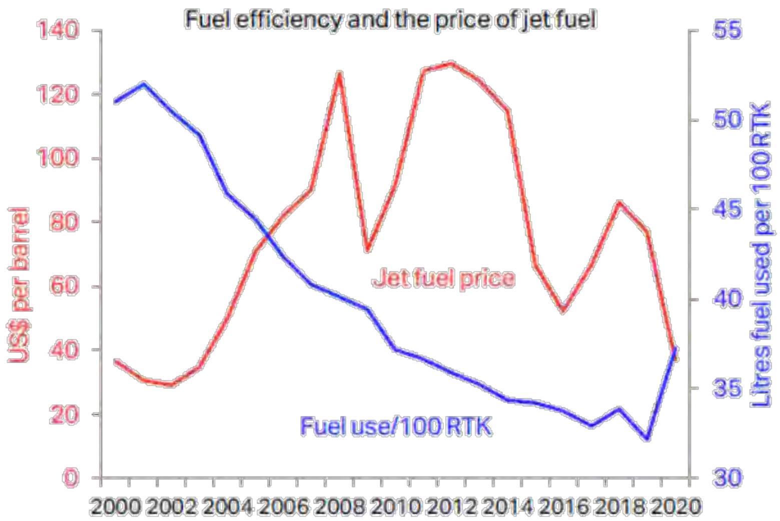


Fig. 13 Aviation fuel efficiency with jet fuel price

International effort in reducing aviation greenhouse gas emission has been formalized in ICAO document on CORSIA methodology for calculating actual life cycle emission values shown in Fig. 14 [12] so that global commercial airline could follow assessment methodology, where technical details is shown in Fig. 15 [13].

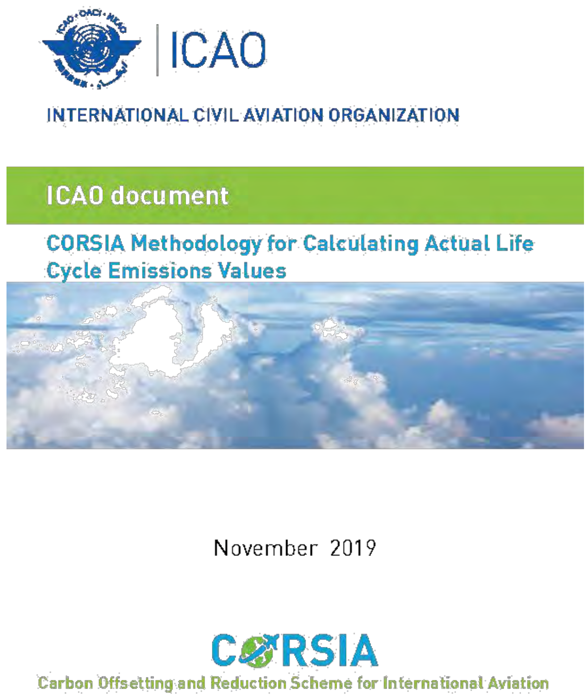


Fig. 14 CORSIA methodology for calculating actual life cycle emission values

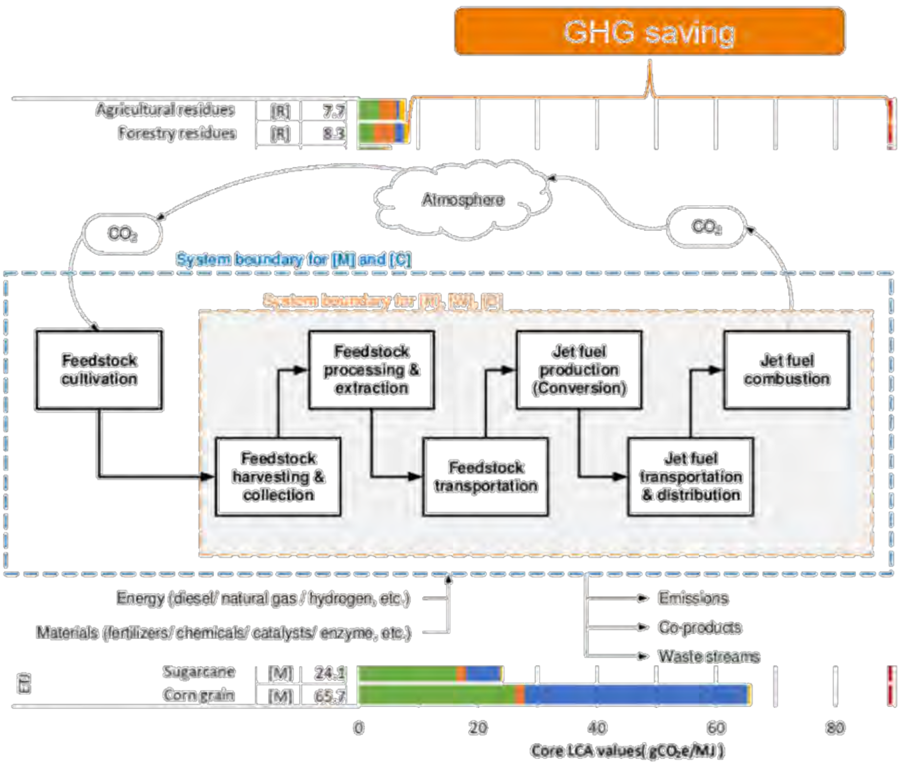


Fig. 15 International approach to calculate life-cycle GHG emission for aviation fuel

As identified in Fig. 5, significant contribution to aviation CO_2 reduction is sustainable aviation fuel (SAF) and CORSIA. Recent study [14] show potential aviation decarbonization

technologies ranking in term of % reduction from battery-electric (100%), hydrogen fuel cell (75-90%), hydrogen turbine (50-75%) to sustainable aviation fuel (30-60%) with varying degree of advantage, as shown in Fig. 16. For example, although battery-electric may be able to complete decarbonize, major challenges are limited ranges of 500-1,000 km from low-battery density and fast-charging/battery exchange system needed. On the other hand, while sustainable aviation fuel may be able to decarbonize 30-60%, only minor change needed with same turnaround time and compatible existing infrastructure. With a focus on sustainable aviation fuel (SAF) technology, Fig. 17 [14] shows various SAF technological status ranging from mature Hydroprocessed Esters and Fatty Acids (HEFA) technology to pilot alcohol-to-jet and gasification/Fischer–Tropsch pathways; whereas, power-to-liquid is still under development stage. Furthermore, Fig. 18 [14] highlights % conversion rate of these four pathways for both SAF co-existing road fuel. Hence, economic viability in term of SAF production cost in the future is forecasted in Fig. 19 [14].

Comparison vs fossil kerosene	1 Battery-electric	2 H_2 fuel cell	H_2 turbine	3 Sustainable aviation fuel
Climate impact[i]	100% reduction[ii]	75%-90% reduction	50%–75% reduction	30%-60% reduction[iii]
Aircraft design	Low-battery density limits ranges to 500km–1,000km	Feasible only for commuter to short-range segments	Feasible for all segments except for flights >10,000km	Only minor changes
Aircraft operations	Same or shorter turnaround times	1-2x longer refuelling times for up to short range	2–3x longer refuelling times for medium and long range	Same turnaround times
Airport infrastructure	Fast-charging or battery exchange system required	LH_2 distribution and storage required		Existing infrastructure can be used

Major advantages   Major challenges

i. Including CO_2, NOx, water vapour and contrails ii. Assuming 100% renewable electricity iii. For e-fuels with fully decarbonized supply chain
Source: Clean Sky 2 JU & FCH 2 JU: Hydrogen-powered aviation report (made possible with funding provided by the EU); expert interviews

Fig. 16 Characteristics of various aviation decarbonization technologies

	HEFA		Alcohol-to-jet[i] / Gasification/FT		Power-to-liquid
Opportunity description	Safe, proven, and scalable technology	—	Potential in the mid-term, however significant techno-economical uncertainty	—	Proof of concept 2025+, primarily where cheap high-volume electricity is available
Technology maturity	Mature	—	Commercial pilot	—	In development
Feedstock	Waste and residue lipids, purposely grown oil energy plants[ii] Transportable and with existing supply chains Potential to cover 5%-10% of total jet fuel demand	—	Agricultural and forestry residues, municipal solid waste[iv], purposely grown cellulosic energy crops[v] High availability of cheap feedstock, but fragmented collection	—	CO_2 and green electricity Unlimited potential via direct air capture Point source capture as bridging technology
% LCA GHG reduction vs. fossil jet	73%–84%[iii]	—	85%-94%[vi]	—	99%[vii]

i. Ethanol route; ii. Oilseed bearing trees on low-ILUC degraded land or as rotational oil cover crops; iii. Excluding all edible oil crops; iv. Mainly used for gas./FT; v. As rotational cover crops; vi. Excluding all edible sugars; vii. Up to 100% with a fully decarbonized supply chain
Source: CORSIA; RED II; De Jong et al. 2017; GLOBIUM 2015; ICCT 2017; ICCT 2019; E4tech 2020; Hayward et al. 2014; ENERGINET renewables catalogue; Van Dyk et al., 2019; NRL 2010; Umweltbundesamt 2016

Fig. 17 Characteristics of various sustainable aviation fuel technologies

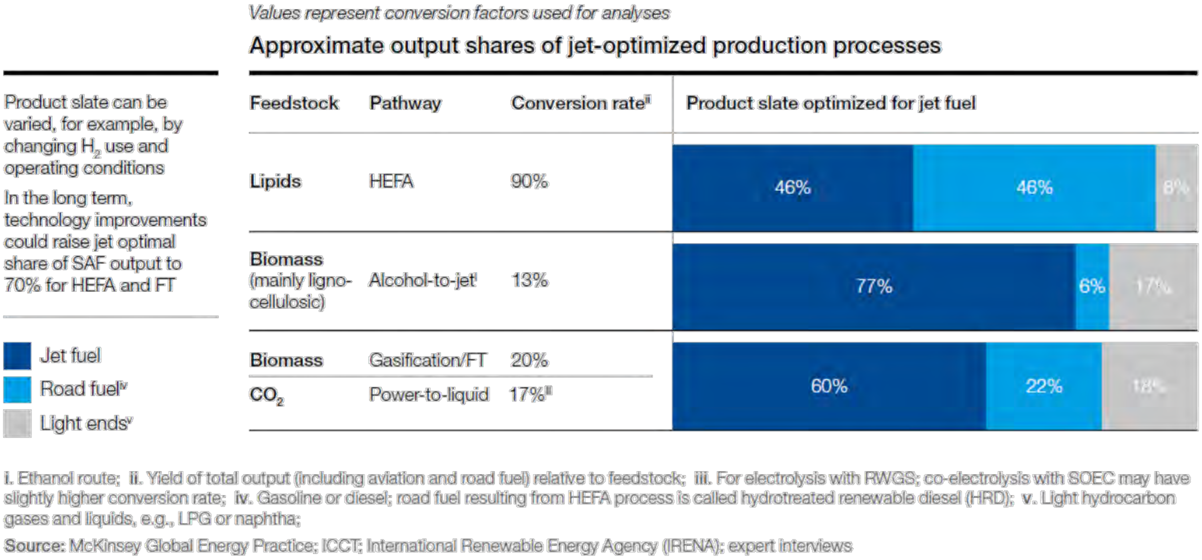


Fig. 18 Four SAF pathways with conversion rate

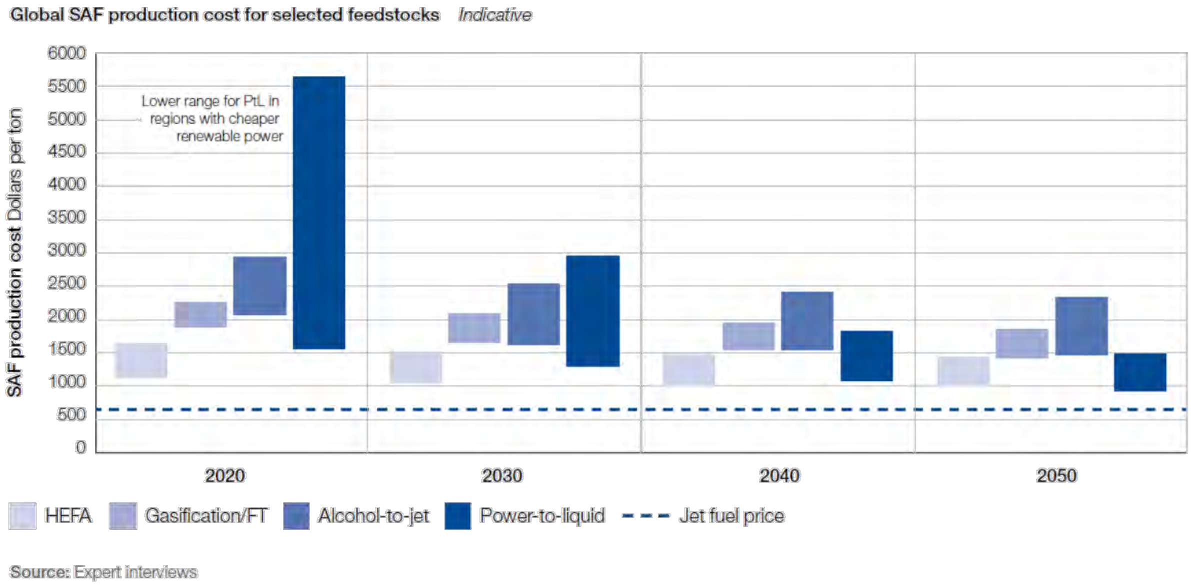


Fig. 19 Economic viability of various SAF technologies till 2050

Over the past 30 years (1990-2020), Fig. 20 [14] clearly illustrated that GHG emission reductions in EU has been on track toward the 95% reduction target for all sectors except transport. Hence, SAF has been widely implemented as a key to decarbonize transport sector, as shown in Fig. 21 [14] with rapid increase of SAF production around the world in the past 5 years since 2016, as shown in Fig. 22 [15]. Fig. 23 [14] shows projection of global SAF demand till 2050 focusing on passenger sector with global SAF mapping in Fig. 24 [15].

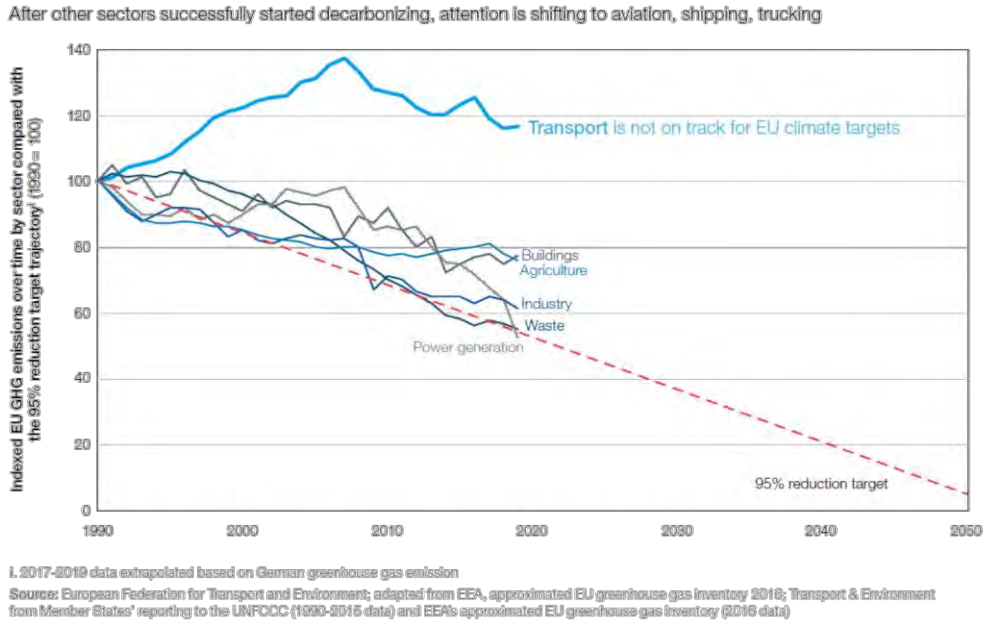


Fig. 20 EU GHG emission by sectors during 1990-2020

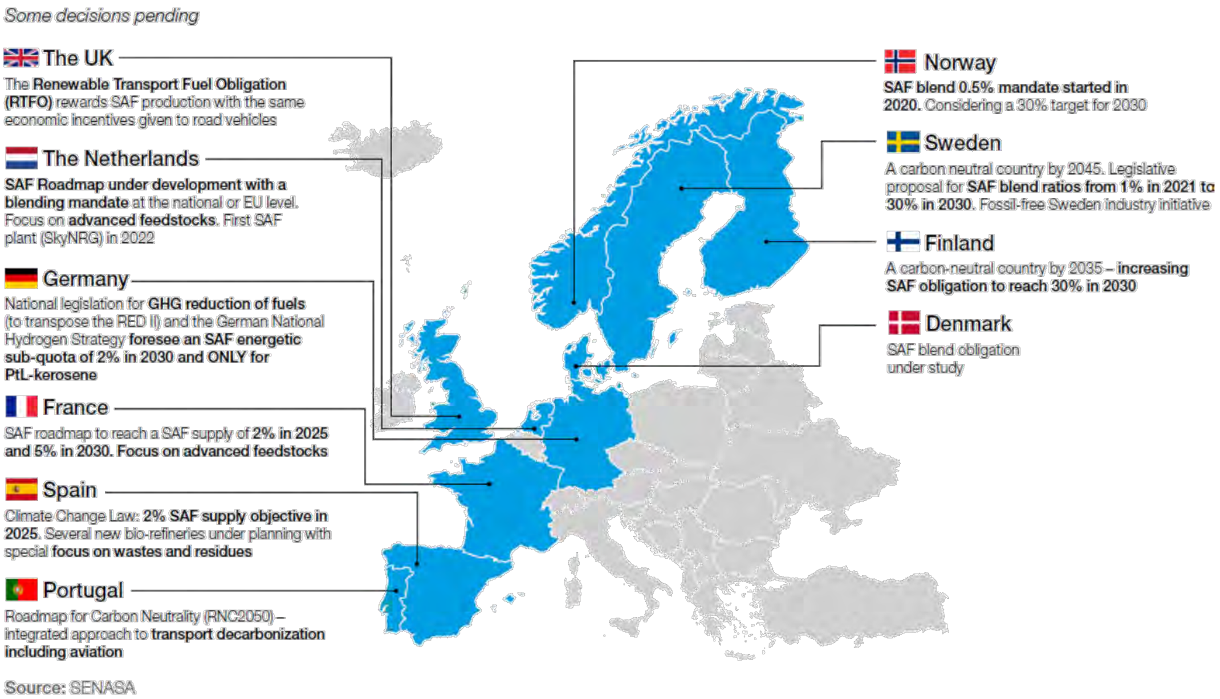


Fig. 21 Status of SAF implementation in EU for transport decarbonization

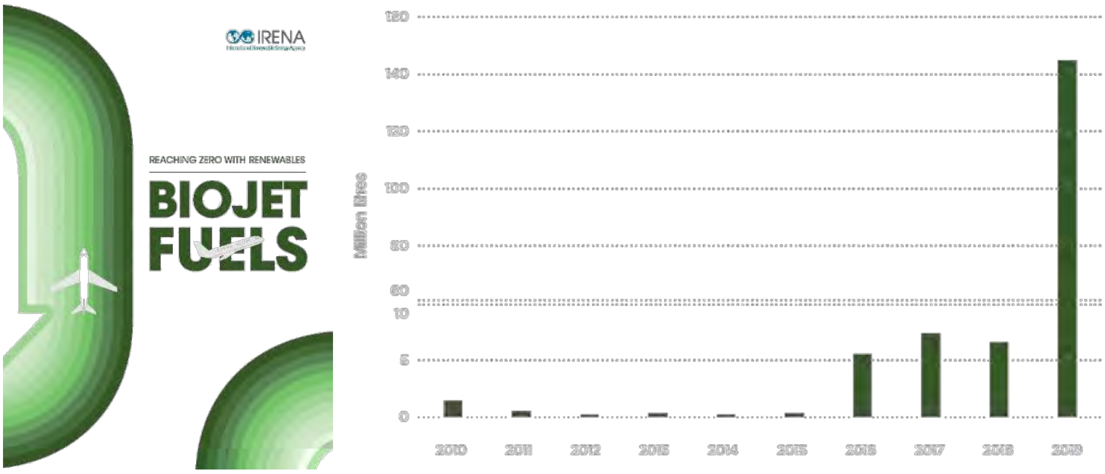


Fig. 22 Aviation decarbonization technologies

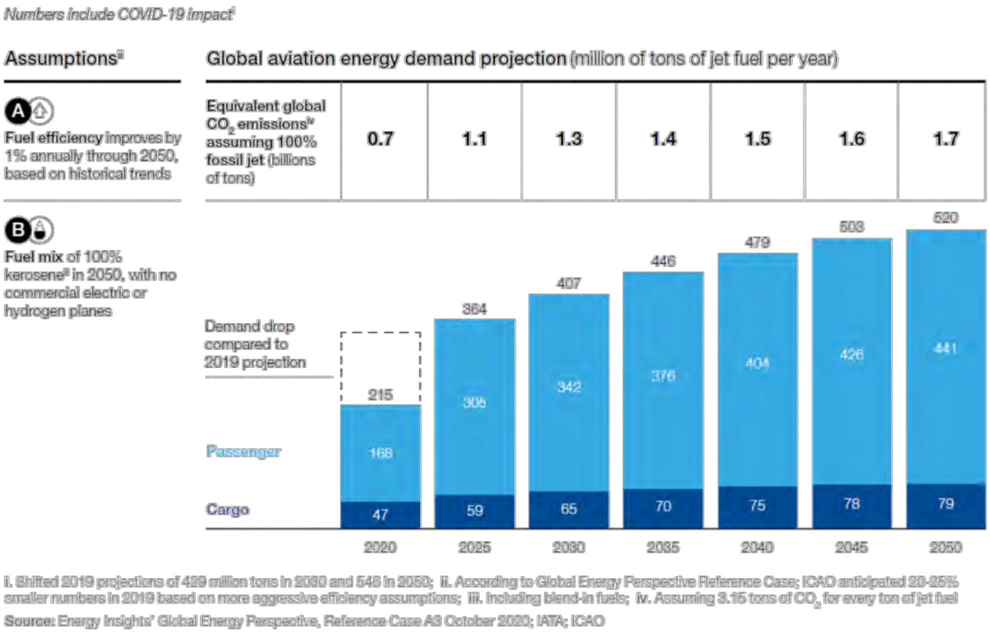


Fig. 23 Aviation decarbonization technologies

Fig. 24 Global SAF mapping

Another promising future SAF technology is power-to-liquid (PtL) with less feedstock constraints to rely vegetable oil, used oil, alcohol and biomass like HEFA, alcohol-to-jet and gasification/FT because PtL concept takes surplus renewable electricity to electrolyze water to obtain hydrogen before reacting with CO_2 to become jet PtL jet fuel, as shown in Fig. 25 [16] and Fig. 26 [17]. PtL roadmap has been recently published for Germany, as shown in Fig. 27 [17].

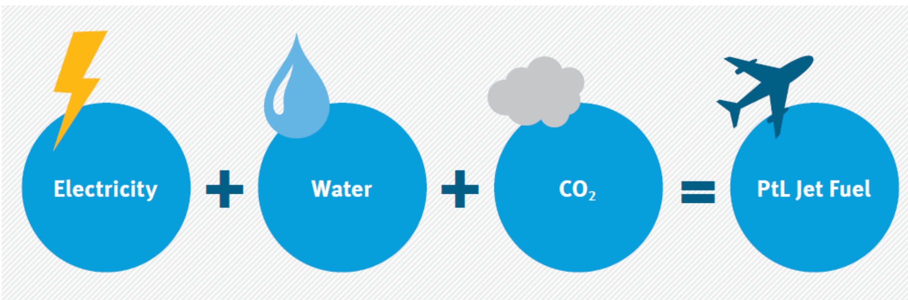


Fig. 25 Concept of power-to-liquid (PtL) for future SAF technology

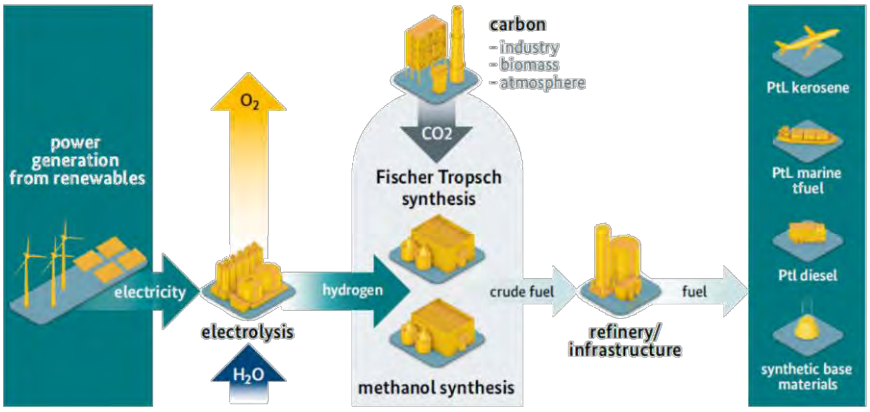


Fig. 26 PtL schematic process

Fig. 27 PtL roadmap

As for Japan, realization of CO_2 emission contribution from aviation sector has dated back since 2005 [18] with various policy initiatives, such as Eco Airport Councils established with published Guideline in July 2005 and SKY Eco Promotion Council established by Civil Aviation Bureau, Ministry of Land, Infrastructure, Transport and Tourism in July 2008. Additional measures included introduction of new planes/equipment, increasing efficiency of the operation and enhancement of airport infrastructure. Changing APU (auxiliary power unit) to GPU (ground power unit) for electricity during parking can reduce CO_2 by 0.8 – 4.2%. Introduction of air carriers with good fuel economy can reduce CO_2 by 4.2 – 8.0%. Reduction of guided running time can reduce CO_2 by 0.8 – 3.1%. Furthermore, CO_2 emission calculation methodologies were established for airport building, vehicles used in airport, air carrier (parking/taxiing/landing-and-taking off).

In 2018 [19], total emission in domestic airport were monitored as follows.

- ✓ Air carriers: landing/taking off 31%; taxiing 20%; auxiliary power 7%
- ✓ Airport (vehicles): GSE (Ground Support Equipment) vehicles 1%

- ✓ Airport: lighting and air conditioning 12%; aviation light 1%
- ✓ Access to airport: 28%

with the following measures

- ✓ Eco airport, e.g. hydrant refueling, switching APU (Auxiliary Power Unit) to GPU (Ground Power Unit) during parking, using LED light
- ✓ New technology, e.g., new air carriers
- ✓ Improvement of aviation management, e.g. optimization of on-land route to reduce taxiing time
- ✓ Usage of sustainable aviation fuel
- ✓ Usage of market mechanism

and additional potential CO_2 reduction as follows

- ✓ Solar farm: 15,000 ha in 97 airports: 13 MW → 8 M ton-CO_2/year
- ✓ APU (Auxiliary Power Unit) to GPU (Ground Power Unit) → 0.39–0.42 M ton-CO_2/year
- ✓ Changing all GSE (Ground Support Equipment) vehicles to EV/FCV → 0.03–0.04 M ton-CO_2/year
- ✓ Changing aviation lighting to LED lighting → 0.03 M ton-CO_2/year

At the present [19], CO_2 reduction target in Japanese aviation is from international flight via CORSIA (fuel efficiency improvement 2% every year and Carbon Neutral Growth after 2020) and domestic flight via Paris Agreement (reducing 1.3977 kgCO_2/ton-km from 2013 to 1.2835 kgCO_2/ton-km in 2030). In respond to Prime Minister's Pledge to make Japan carbon neutral by 2050, additional CO_2 reduction scheme for aviation sector are as follows

- ✓ Promotion of eco airport & increasing sophistication of aviation system
- ✓ Supporting electrification & hydrogen usage for air carrier, promotion of lightweight/high-efficiency engines, technology innovation on alternative fuels
- ✓ Promotion of bio jet fuel
- ✓ Reduction targets for private sector & local govt (26%@2030, 80%@2050) and central govt (40%@2030, 80%@2050)

Additional effort from various airports [20] can be summarized as follows.

- ✓ Narita int'l airport
    - o Sustainable NRT 2050: net zero emission from NAA (Narita International Airport Corporation) group by 2050 (50% CO_2 emission reduction of Narita Int'l Airport comparing to 2015)
    - o Measures: Zero Emission Building (ZEB), changing lighting to LED, zero carbon GSE (Ground Support Equipment) vehicles, carbon zero business trip
- ✓ Kansai int'l airport

- 40% CO_2 reduction by 2030, zero emission by 2050
- Measures: Energy conservation, usage of RE and hydrogen, ZEV, One Eco Airport Plan on KIX, KOBE & ITAMI (promotion of good fuel economy equipment, low-pollution GSE vehicles, promotion of GPU usage, CO2 reduction of electricity

✓ Centrair int'l airport
- Zero Carbon 2050 Pledge
- Measures: introduction of RE, change aviation lighting to LED, introduction of co-generation system, energy conserving equipment, Eco Office

✓ Haneda int'l airport
- CO2 from facilities (59% from terminals, 22% from airlines) & vehicles (40% from ground handling, 33% from airlines)
- Measures: regional air conditioning system, co-generation system, LED lighting, plan for GSE vehicles, CO2 reduction for parking (APU → GPU), Hydrant refueling system

Additional effort around the world [19] is as follows.

✓ ICAO: Doc9988 - Guidance on the Development of States' Action Plans on CO_2 Emissions Reduction Activities

✓ ACI (Airports Council International): Airport Carbon Accreditation

✓ FAA (Federal Aviation Administration)
- VALE (Voluntary Airport Low Emission Program)
- ZEV (Zero Emission Vehicle)
- Automation/electrification of gates

✓ Airports
- Frankfurt airport: zero emission by 2050
- Dallas/Fort Worth International Airport: zero emission by 2030
- Heathrow Airport: public transportation share for airport access 50%@2030/ 55%@2040
- Amsterdam Airport Schiphol: changing taxis into EVs, EV car sharing platform
- Stockholm Arlanda Airport: using biogas/ethanol gas in airport shuttle buses, eco taxis
- Los Angeles Airport: Landside Access Modernization Program (LAMP)

3.2 Reviews of Thailand Efforts

Table 4 [21] shows 16 commercial airlines operating in Thai aviation industry with characteristics of CO2 emission shown in Table 5 [21] and fuel efficiency in Fig. 28 [21].

Similar to Fig. 8 for global flight movement during 2019-2021, Fig. 29 shows similar effect from COVID-19 in Thai flight movement with significant flight activity reduction in 2020 and still low in 2021.

Table 4: Commercial airline in Thailand

AIRLINES COMMERCIAL AIRLINES			
AIRLINE	ICAO	IATA	CALL SIGN
1) Thai Airways International	THA	TG	THAI
2) Thai AirAsia	AIQ	FD	THAI ASIA
3) Nok Air	NOK	DD	NOK AIR
4) Thai Lion Mentari	TLM	SL	MENTARI
5) Orient Thai Airlines	OEA	OX	ORIENT THAI
6) Bangkok airways	BKP	PG	BANGKOK AIR
7) Thai Smile Airways	THD	WE	THAI SMILE
8) Thai AirAsia X	TAX	XJ	EXPRESS WING
9) NewGen Airways	VGO	E3	VIRGO
10) NokScoot	NCT	XW	BIG BIRD
11) Jet Asia Airways	JAA	JF	JET ASIA
12) Siam Air	RBR		SIAM AIR
13) Thai Vietjet Air	TVJ	VZ	THAIVIET JET
14) Asia Atlantic Airlines	AAQ	HB	ASIA ATLANTIC
15) Skyview Airways	RCT	RK	GREEN SKY
16) Sabaidee Airways		VZ	

Table 5: CO_2 emission in Thai aviation sector during 2010-2016

Year	Fuel Burn (FB)		RTK	FB/RTK		CO_2 Emission
	(LITRE)	Tonnes	thousand (Tonnes-km)	LITRE/RTK	kg/RTK	Tonnes
	[A]	[B]	[C]	[D] = [A]/[C]	[E] = [B][1,000]/[C]	[F] = [B] x 3.16
2010	3,440,992,343	2,752,794	7,574,912	0.4543	0.3634	8,671,300
2011	3,582,037,382	2,865,630	8,511,965	0.4208	0.3367	9,026,733
2012	3,575,544,966	2,860,436	8,766,787	0.4079	0.3263	9,010,375
2013	3,456,980,863	2,765,585	9,686,980	0.3569	0.2855	8,711,592
2014	3,251,262,249	2,601,010	9,424,065	0.3450	0.2760	8,193,181
2015	3,792,499,121	3,033,999	10,034,051	0.3780	0.3024	9,557,098
2016	3,636,640,352	2,909,312	10,822,393	0.3360	0.2688	9,164,334

Source: M-Form submitted by airlines and CAAT calculation using no. of flights (B/A) from airport operators, considering AOC's nationalities

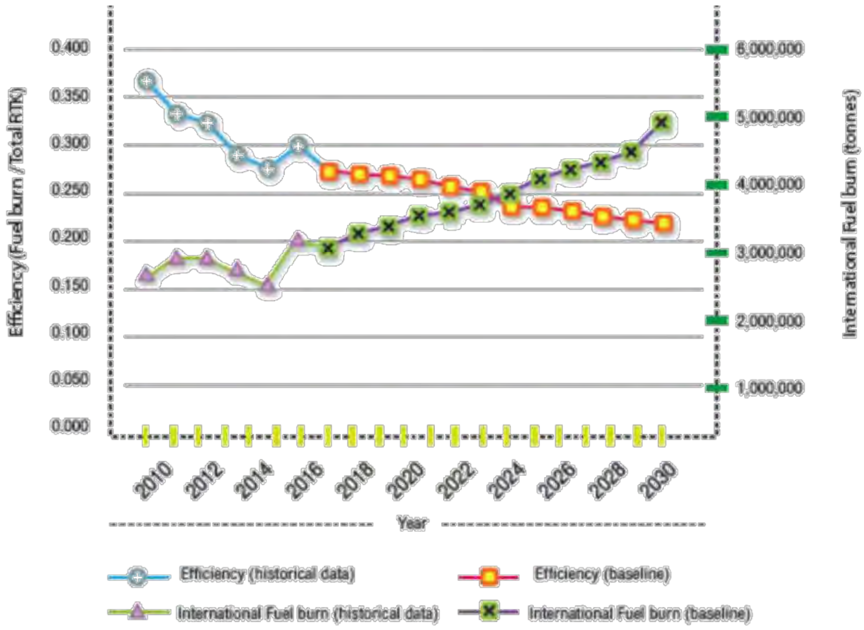


Fig. 28 Aviation decarbonization technologies

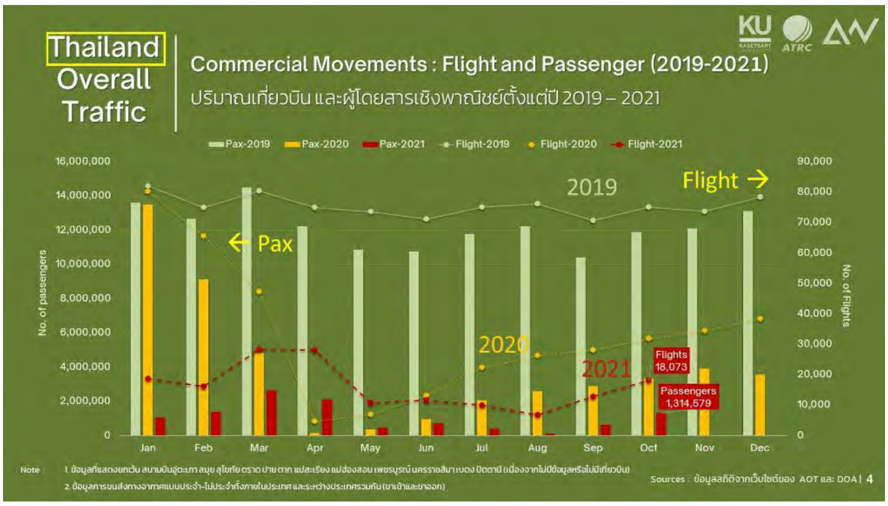


Fig. 29 Thai flight movements during 2019 and 2021 by month

Even though aviation sector is not part of Thailand NDC, Thai government has explored potential through a few recent studies as follows. In 2020, a study [22] on sustainable biojet promotion plan was conducted in response to Alternative Energy Development Plan (AEDP) to position Thailand as strategic hub for biojet fuel production, mainly for refueling in Thailand and some for export, as shown in Fig. 30. In addition, the following outputs were proposed.

- ✓ 2 Phases of commercial biojet fuel development plan: short-medium (2020-2026) and long (2027-2036) terms
- ✓ Detailed action plan categorized by Raw materials/Technology/Policy, with some example as shown in Table 6.

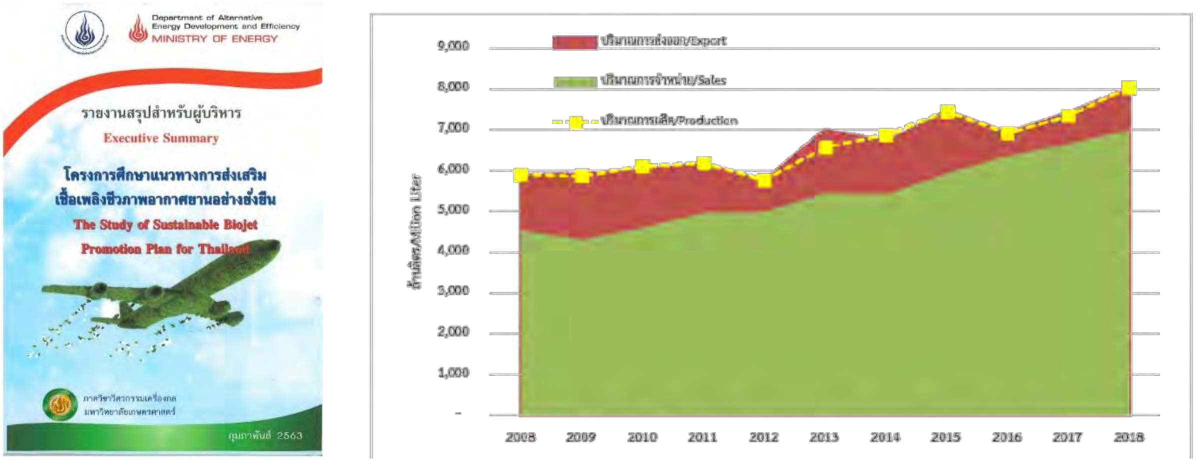


Fig. 30 Projection of Thai biojet fuel production

Table 6: Detailed action plan categorized by Raw materials/Technology/Policy

ลำดับ	กิจกรรม	ระยะสั้น-กลาง Short-medium terms (for year 20..)							ระยะยาว Long term (for year 20..)										ตัวชี้วัด Metric	ผู้รับผิดชอบ Responsible organization
		20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36		
1. ด้านวัตถุดิบ/ Raw Materials																				
1.1	การศึกษาความเป็นไปได้ในการจัดตั้งคณะกรรมการกำกับและจัดการพืชพลังงาน และการจัดตั้งตลาดซื้อขายล่วงหน้าพืชพลังงาน Feasibility Study for Establishment of Control and Management Committee for Energy Crops and for Establishment of Futures Market for Energy Crops								■	■	■	■							องค์ประกอบ บทบาท อำนาจหน้าที่และวิธีการจัดตั้งคณะกรรมการ และตลาดซื้อขายล่วงหน้า Components, roles, authorities, duties and procedures for establishing the committee and the energy crops futures market	พพ. DEDE
1.2	การศึกษาการจัดทำโซนนิ่งพื้นที่เพาะปลูกพืชพลังงาน การบริหารจัดการและการจัดตั้งชุมชนเพื่อการเพาะปลูกพืชพลังงาน A Study on Energy Crop Zoning and Management & Establishment of Energy Crop Cultivation Communities								■	■	■	■							โซนนิ่งพืชพลังงาน สัดส่วนพืชพลังงาน/พืชอาหาร Energy crop zoning, proportion of energy and food crops	พพ., กษ., มท. DEDE, MoA, MoIn
1.3	การศึกษาความเป็นไปได้และความเหมาะสมในการส่งเสริมพืชพลังงานในพื้นที่ความมั่นคง และพื้นที่เสื่อมสภาพ Feasibility study of Energy Crop Cultivation Promotion in Security and Deteriorated Areas										■	■	■	■	■	■			พื้นที่เป้าหมายที่จะกำหนดเป็นพื้นที่เพาะปลูกพืชพลังงาน The target areas that will be designated promotion areas for energy crop cultivation	พพ., กษ., มท., กห., ทส. DEDE, MoA, MoI, MoD, MoN
1.4	การพัฒนาสายพันธุ์ วิธีการเพาะปลูกและการเก็บเกี่ยวพืชพลังงาน เพื่อเพิ่มผลผลิตต่อไร่ ลดต้นทุน เพิ่มรายได้ให้กับเกษตรกร รวมถึงการพัฒนาสายพันธุ์สำหรับพื้นที่เสื่อมสภาพหรือพื้นที่รกร้าง (ปาล์ม อ้อยและมันสำปะหลัง) Varieties development Methods of cultivation and harvesting of energy crops to increase productivity per area, reduce costs, increase income for farmers including varieties development for deteriorated or wasteland areas (palm, sugarcane and cassava)								■	■	■	■	■	■	■	■	■	■	สายพันธุ์ การเพาะปลูกและการเก็บเกี่ยวพืชพลังงานที่มีผลผลิตสูง Varieties, cultivation and harvesting of high-yield energy crops	กวก., กษ. DoA, MoA
1.5	การพัฒนาสายพันธุ์ วิธีการเพาะปลูกและการเก็บเกี่ยวพืชพลังงานทางเลือก (สบู่ดำ สาหร่าย ฯลฯ) Varieties development Methods of cultivation and harvesting of alternative energy crops (jatropha, algae, etc.)											■	■	■	■	■			สายพันธุ์ การเพาะปลูกและการเก็บเกี่ยวพืชพลังงานทางเลือก Varieties, cultivation and harvesting of alternative energy crops	กวก., กษ., อว. DoA, MoA, MHESI
1.6	การวิจัยและพัฒนาเครื่องจักร หุ่นยนต์และระบบอัจฉริยะในการควบคุมดูแลการผลิตพืชพลังงานครบวงจร Machinery research and development of robots and intelligent systems to control the production of integrated energy crops								■	■	■	■	■	■	■	■	■	■	เครื่องจักร หุ่นยนต์และระบบอัจฉริยะ Machinery, robots, and intelligent systems	พพ., สนพ., อว. DEDE, DEP, MHESI
1.7	การศึกษาการบังคับ ส่งเสริมและสนับสนุนการคัดแยกขยะจากต้นทาง เพื่อลดค่าใช้จ่ายและต้นทุนการนำไปผลิตเป็นเชื้อเพลิงชีวภาพ A study of mandatory guidelines, promotion and support for the classification of waste from the source in order to reduce the costs and costs of producing biofuels											■	■	■	■				แนวทางการบังคับ ส่งเสริมและสนับสนุน Mandatory guidelines, promotion and support	พพ., กทม., อปท. มท. DEDE, City of Bangkok, LGO, MoIn

Another recent study [23] focusing on technology roadmap for aviation industry as part of new S-curve industry in Thailand has identified SAF technology with moderate readiness for long term development, as shown in Fig. 31. Furthermore, Fig. 32 has categorized SAF as long term airport services.

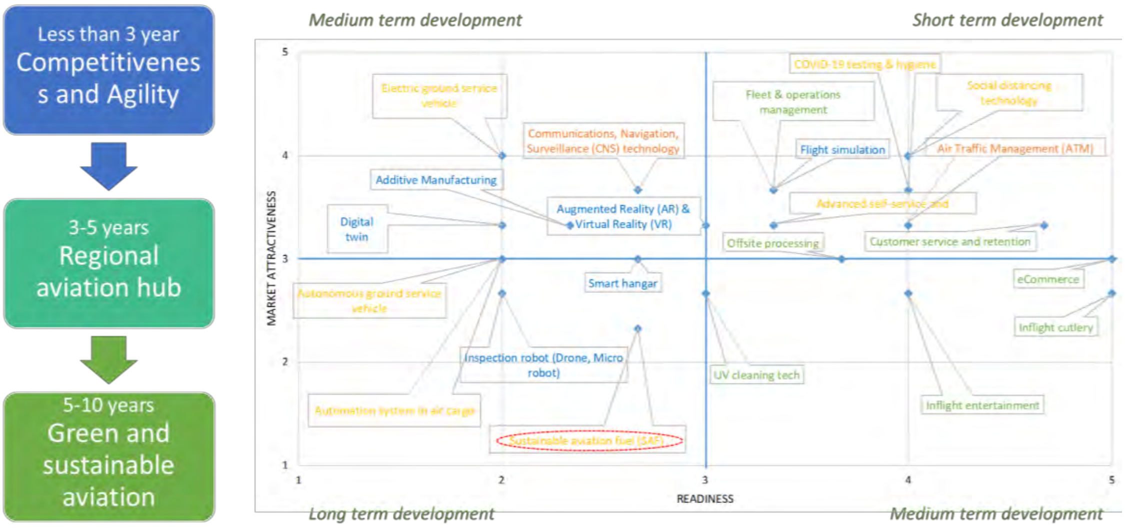


Fig. 31 Technology roadmap for aviation industry by term development

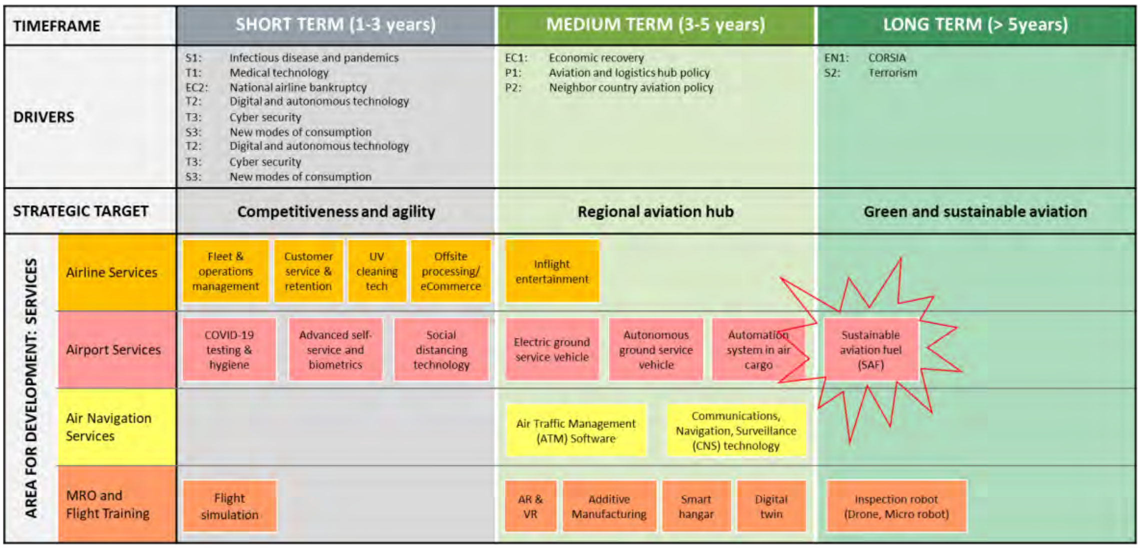


Fig. 32 Technology roadmap for aviation industry by timeframe with strategic targets

Recent online 3-half day workshop on SAF between CAAT and EASA [24], as shown in Fig. 33, still confirmed carbon neutral growth but with 5-year shift from 2020 level in Fig. 5 pre-COVID to start from 2025 level, as shown in Fig. 34, with various SAF technologies scenarios shown in Fig. 35 [25].

Fig. 33 SAF workshop co-organized by CAAT and EASA

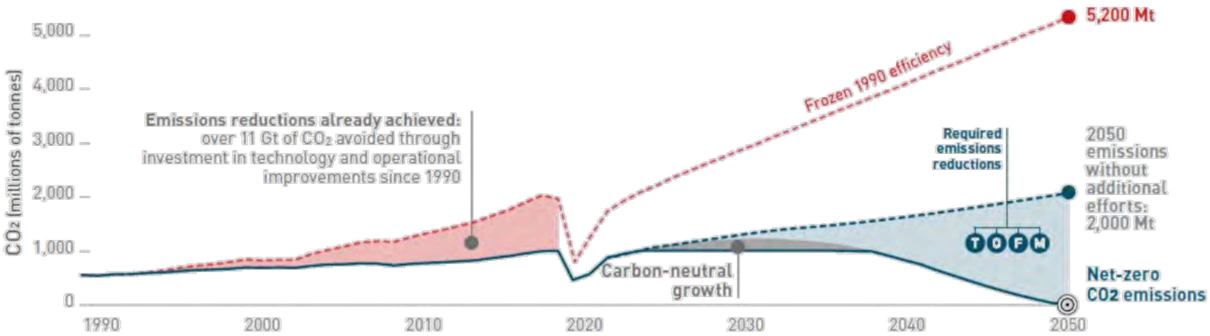


Fig. 34 SAF workshop co-organized by CAAT and EASA

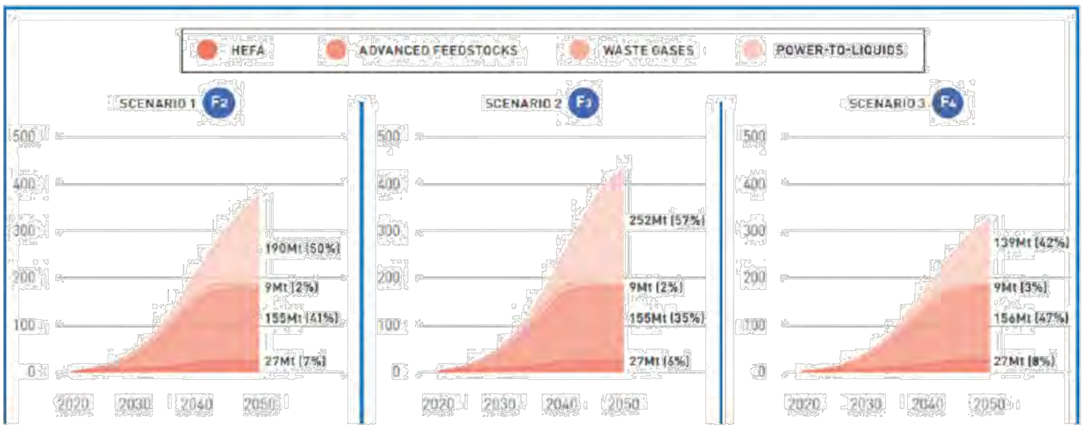


Fig. 35 SAF workshop co-organized by CAAT and EASA

3.3 Draft Master Plan/Action Plan for Thailand

Thailand by CAAT has conducted a study [17] to draft Master/Action Plan on Energy Conservation and Greenhouse Gas Reduction in Aviation Sector (2021-2025), as shown in Fig. 36. Concept for international sector (ICAO) & domestic (UNFCCC) has been followed to establish baseline data on energy consumption and greenhouse gas emissions in the aviation

sector of Thailand during 2021 – 2025 while assessing potential of energy conservation and greenhouse gas emission reduction in the aviation sector of Thailand. In addition, MRV methodology was established, as shown in Fig. 37, with BAU projection (Fig. 38) and prioritized measures (Fig. 39) to achieve target with identified organization in charge. Fuel efficiency baseline and target, as well as potential CO_2 reduction, for domestic and international flights were proposed, as shown in Fig. 40 and Fig. 41, respectively. Finally, both master plan and action plan has been subjected to pubic hearing for roadmap construction, as shown in Fig. 42.

(a) **(b)**

Fig. 36 Draft (a) Master and (b) Action Plan on Energy Conservation and Greenhouse Gas Reduction in Aviation Sector (2021-2025)

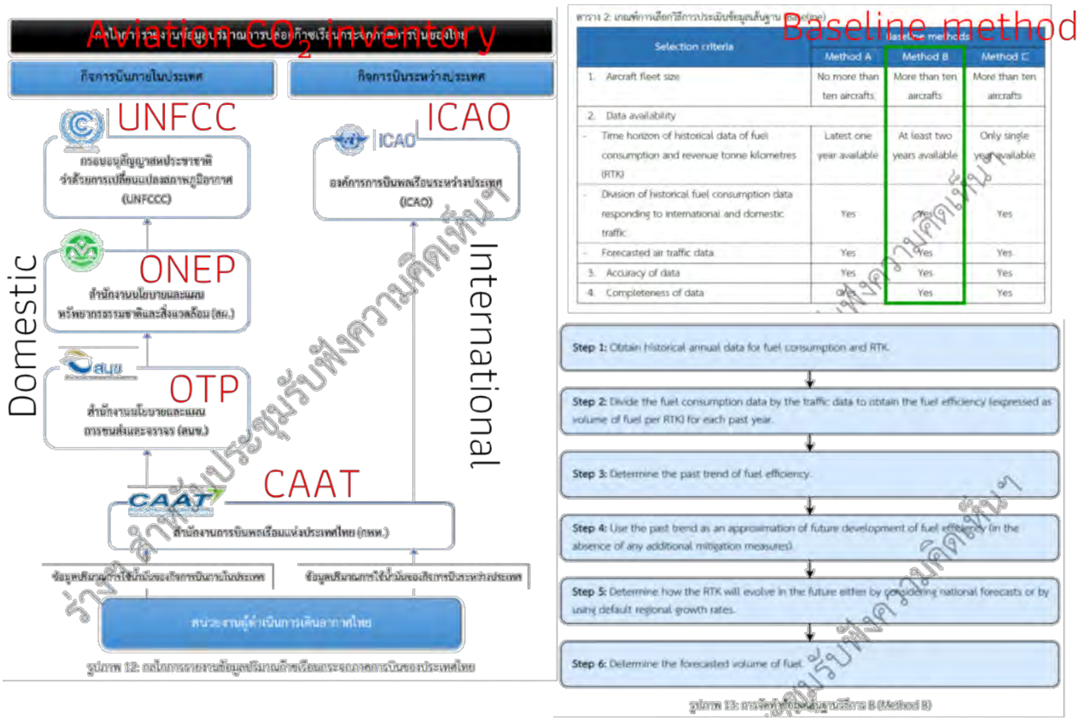


Fig. 37 MRV flow and methodology

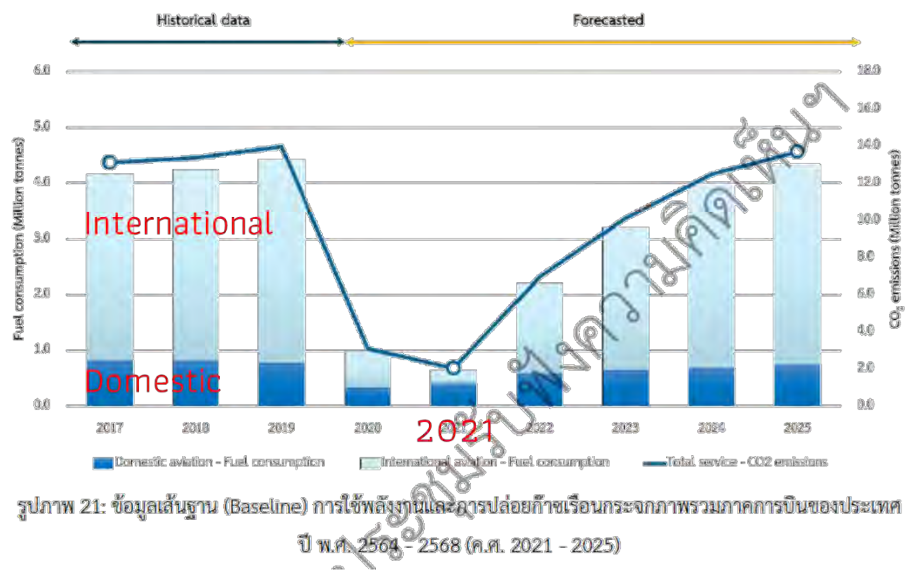


Fig. 38 BAU projection

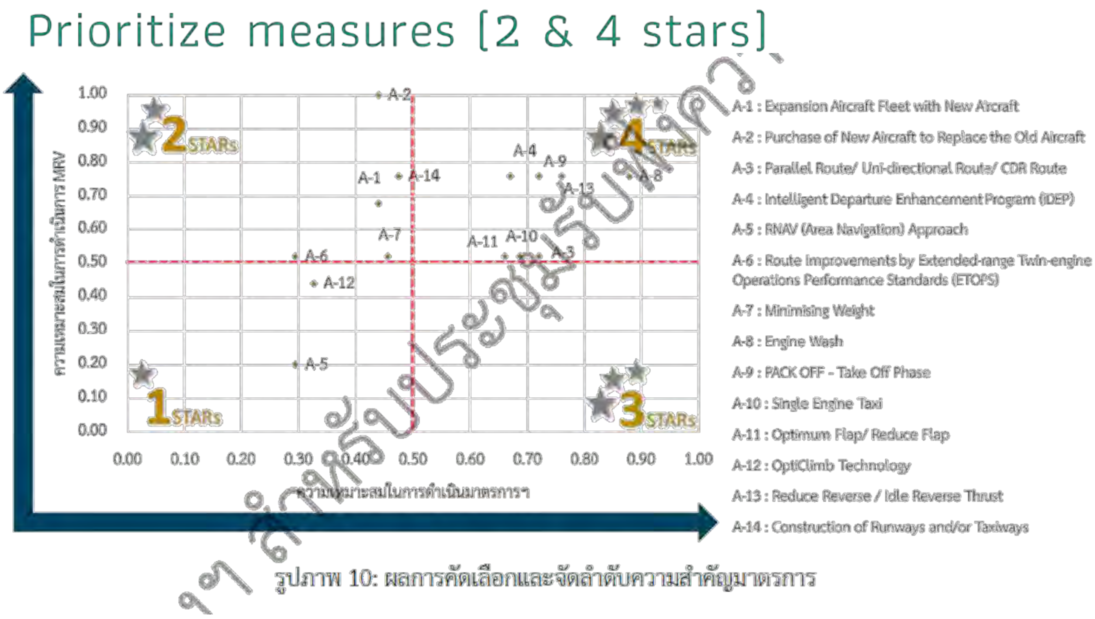
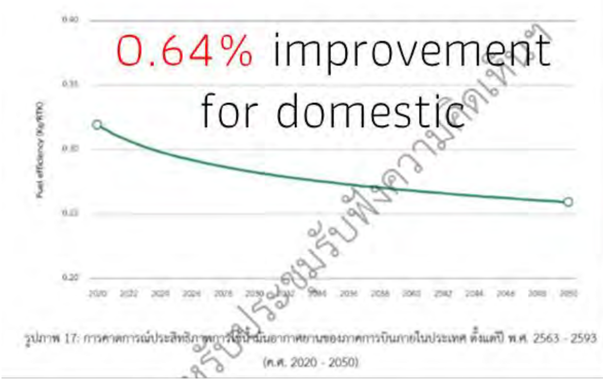


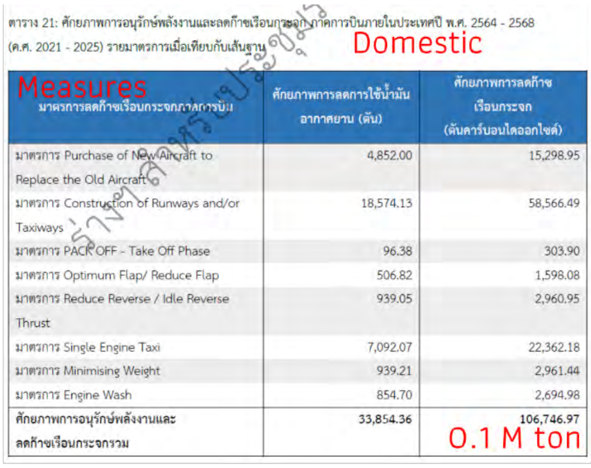
Fig. 39 Prioritized measures from public hearing



(a)

(b)

Fig. 40 Fuel efficiency baseline and target for (a) domestic and (b) international flights



ตาราง 21: ศักยภาพการอนุรักษ์พลังงานและลดก๊าซเรือนกระจก ภาคการบินภายในประเทศปี พ.ศ. 2564 - 2568 (ค.ศ. 2021 - 2025) รายมาตรการเมื่อเทียบกับเส้นฐาน

Domestic

Measures มาตรการลดก๊าซเรือนกระจกภาคการบิน	ศักยภาพการลดการใช้น้ำมันอากาศยาน (ตัน)	ศักยภาพการลดก๊าซเรือนกระจก (ตันคาร์บอนไดออกไซด์)
มาตรการ Purchase of New Aircraft to Replace the Old Aircraft	4,852.00	15,298.95
มาตรการ Construction of Runways and/or Taxiways	18,574.13	58,566.49
มาตรการ PACK OFF - Take Off Phase	96.38	303.90
มาตรการ Optimum Flap/ Reduce Flap	506.82	1,598.08
มาตรการ Reduce Reverse / Idle Reverse Thrust	939.05	2,960.95
มาตรการ Single Engine Taxi	7,092.07	22,362.18
มาตรการ Minimising Weight	939.21	2,961.44
มาตรการ Engine Wash	854.70	2,694.98
ศักยภาพการอนุรักษ์พลังงานและลดก๊าซเรือนกระจกรวม	**33,854.36**	**106,746.97** 0.1 M ton

(a)

ตาราง 23: ศักยภาพการอนุรักษ์พลังงานและลดก๊าซเรือนกระจก ภาคการบินระหว่างประเทศ ปี พ.ศ. 2564 - 2568 (ค.ศ. 2021 - 2025) รายมาตรการเมื่อเทียบกับเส้นฐาน

International

Measures มาตรการลดก๊าซเรือนกระจกภาคการบิน	ศักยภาพการลดการใช้น้ำมันอากาศยาน (ตัน)	ศักยภาพการลดก๊าซเรือนกระจก (ตันคาร์บอนไดออกไซด์)
มาตรการ Expansion Aircraft Fleet with New Aircraft	128.56	406.25
มาตรการ Purchase of New Aircraft to Replace the Old Aircraft	4,806.65	15,189.01
มาตรการ Construction of Runways and/or Taxiways	31,034.46	98,068.88
มาตรการ PACK OFF - Take Off Phase	38.17	120.62
มาตรการ Optimum Flap/ Reduce Flap	176.12	556.54
มาตรการ Reduce Reverse / Idle Reverse Thrust	351.18	1,109.73
มาตรการ Single Engine Taxi	2,226.20	7,034.78
มาตรการ Minimising Weight	775.71	2,451.23
มาตรการ Engine Wash	4,329.57	13,681.45

0.14 M ton

(b)

Fig. 41 CO_2 reduction target for (a) domestic and (b) international flights

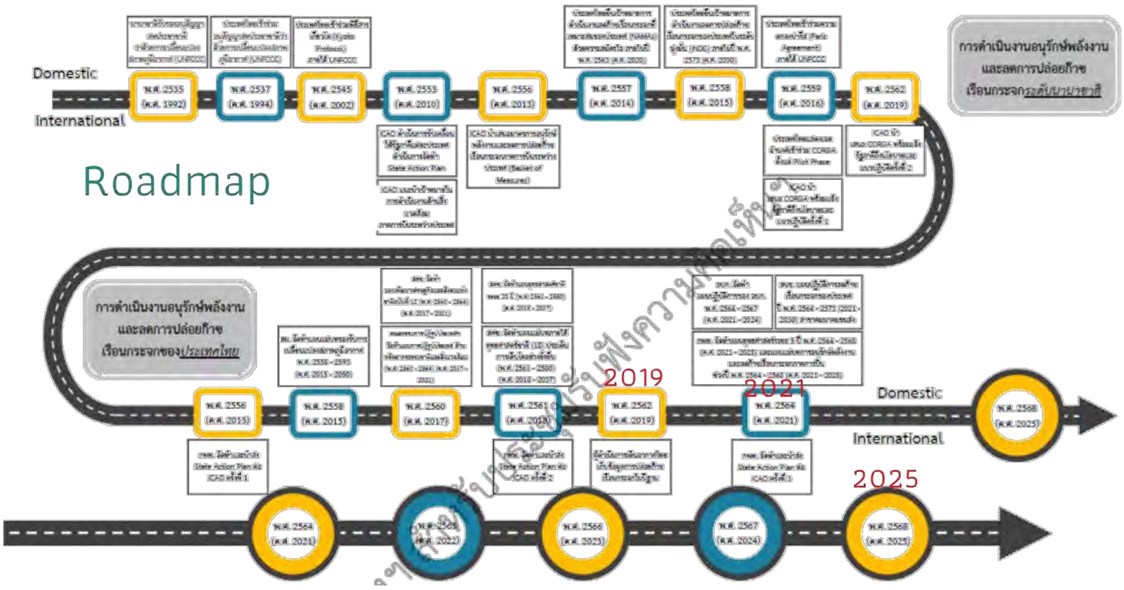


Fig. 42 Roadmap for CO_2 reduction in domestic and international aviation

3.4 Conclusion

Although COVID-19 has set back aviation by 5 years with slowly recovery process, climate change awareness, esp. COP26, has strengthen CORSIA effort by highlighting Sustainable aviation fuel (SAF) as key for decarbonizing aviation sector. Thailand joins worldwide effort in drafting master plan and action plan on Energy Conservation and Greenhouse Gas Reduction in Aviation Sector.

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Final Report

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