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WORKING PAPER

THIRD CONFERENCE ON AVIATION AND ALTERNATIVE FUELS (CAAF/3)

Dubai, United Arab Emirates, 20 to 24 November 2023

Agenda Item 2: Supporting policies to promote the development and deployment of cleaner energy for aviation

METRICS AND PROJECTIONS FOR POTENTIAL QUANTIFIED GOALS FOR CLEANER ENERGY USE FOR INTERNATIONAL AVIATION

(Presented by the Secretariat)

SUMMARY

This paper presents possible metrics for potential quantified goals for cleaner energy for international aviation, as well as projections on the global levels of cleaner energy use for international aviation, including technical inputs by the ICAO Committee on Aviation Environmental Projection (CAEP) and other relevant information.

Action for the Conference is in paragraph 5.

1. INTRODUCTION

1.1 The Second ICAO Conference on Aviation and Alternative Fuels (CAAF/2), held in October 2017[1], endorsed the "2050 ICAO Vision for Sustainable Aviation Fuels as a living inspirational path and called on States, industry and other stakeholders, for a significant proportion of conventional aviation fuels (CAF) to be substituted with Sustainable Aviation Fuels (SAF) by 2050, for international civil aviation to reduce carbon emissions significantly, and whilst pursuing all opportunities in the basket of mitigation measures to reduce emissions as necessary" (CAAF/2 Declaration, paragraph 1 and Assembly Resolution A41-21, 30th preamble refer).

1.2 The CAAF/2 also noted that "this path is based on the assumptions of a progressively increased use of SAF, and should be periodically reviewed through a stocktaking process to continuously assess progress on the SAF development and deployment, including the necessity to consider policies and actions, and the organization of regular workshops and seminars, leading up to the convening of CAAF/3 no later than 2025, with a view to updating the 2050 ICAO Vision to include a quantified proportion of CAF to be substituted with SAF by 2050, and carbon reductions achieved by SAF" (CAAF/2 Declaration, paragraph 3 refers).

[1] CAAF/2 Declaration: https://www.icao.int/environmental-protection/GFAAF/pages/ICAO-Vision.aspx

1.3 Accordingly, the 41st Session of the ICAO Assembly in October 2022 requested the Council to “continue to assess progress on the development and deployment of SAF, LCAF and other cleaner energy sources for aviation as part of the ICAO stocktaking process, and convene the CAAF/3 in 2023 for reviewing the 2050 ICAO Vision for SAF, including LCAF and other cleaner energy sources for aviation, in order to define a global framework in line with the *No Country Left Behind* (NCLB) initiative and taking into account national circumstances and capabilities” (A41-21, paragraph 28 f) refers).

1.4 In order to support the update and review of the ICAO 2050 Vision, and in line with the implementation of the 2050 net-zero LTAG agreed at the Assembly, this paper provides possible metrics and projections for potential quantified goals for cleaner energy for international aviation, arising from technical inputs from the ICAO Council’s Committee on Aviation Environmental Projection (CAEP).

1.5 In this regard, in March 2023, the ICAO Council requested CAEP to[2]:

a) identify possible metrics for potential quantified goals for cleaner energy for international aviation (e.g. percentages (%) or absolute values (mass/volume), in terms of the uptake levels of SAF, LCAF and other cleaner energies for aviation, or in terms of CO_2 emissions reduction levels), highlighting any advantages and disadvantages of each possible metric;

b) using the possible metrics identified pursuant to a) above, together with the CAEP LTAG report, provide projections on the global levels of cleaner energy use for international aviation, across intermediate milestones, such as 2030, 2040, through to 2050; and

c) in the context of the short-term projections on SAF production, identify geographic distribution and trends of existing and planned SAF production facilities.

2. POSSIBLE METRICS AND THEIR ADVANTAGES AND DISADVANTAGES

2.1 A number of possible metrics for potential quantified goals for cleaner energy[3] for international aviation were identified by CAEP, based on the analysis of different sources: metrics that are used in the CORSIA MRV system (CAAF/3-WPs 5 and 6 refer); metrics that are being used by aviation stakeholders in their net zero commitments; metrics that are included in the LTAG report; and metrics associated with IPCC temperature goals. Ten possible metrics were identified, as presented in Appendix A of this paper[4], and summarized below.

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[2] Council decision C-DEC 229/3, paragraph 2. c) refers.

[3] In the context of this analysis, “cleaner energy” refers to the fuel categories considered in the LTAG projections, that is:

1) LTAG Sustainable Aviation Fuels (LTAG-SAF), which comprise:

a. biomass-based fuels (vegetable oil crops, lignocellulosic energy crops, starchy energy crops, sugary energy crops)

b. waste-based fuels

i. solid wastes – crop residues, Municipal Solid Waste, Forestry Residues.

ii. liquid wastes – Waste and by-product Fats Oils and Greases (FOGs).

iii. gaseous wastes – waste CO_2 from: ethanol production, ammonia production, iron and steel production, and cement production.

c. atmospheric CO_2-based fuels.

2) LTAG Lower Carbon Aviation Fuels (LTAG-LCAF) – petroleum-based fuels that achieve a well-to-wake carbon intensity of < 80.1 gCO_2e/MJ with the use of greenhouse gas (GHG) mitigation technologies and best practices.

3) Non-drop-in fuels, comprising cryogenic Hydrogen (LH_2).

[4] CAEP presentation covering its technical inputs is also available on the pre-CAAF/3 outcomes consultation website: https://www.icao.int/Meetings/pre-CAAF3/Pages/reference-materials.aspx

#	Metric Option	Unit
1	Mass of cleaner energy	KiloTonne (kt)
2	Mass of cleaner energy (*Metric 1*) per Total mass of fuel	%
3	Total CO_{2e} emitted per year	MillionTonne (Mt)
4	Total CO_{2e} emitted per year (*Metric 3*) per total mass of fuel	Tonne CO_2e/Tonne of fuel
5	CO_{2e} reduction from the use of cleaner energy	MillionTonne (Mt)
6	% CO_{2e} emissions reduction from the use of cleaner energy	%
7	Mass average carbon intensity (CI) of fuel (gCO_{2e}/MJ)[5]	Grams of CO_2e/MegaJoule of energy (gCO_{2e}/MJ)
8	Cumulative total CO_2 emissions over the period between 2020 and 2050	GigaTonne (Gt)
9	gCO_2/RTK	gram CO_2 / Revenue Tonne Kilometer
10	gCO_2/ATK	gram CO_2 / Available Tonne Kilometer

2.2 The following set of criteria were applied by CAEP to assess the advantages and disadvantages of each possible metric:

a) metric is reported by aeroplane operators as part of CORSIA requirements;
b) metric is made available by ICAO in the CORSIA Central Registry, or can be calculated/tracked with the use of available CCR information;
c) allows to track progress toward the LTAG, e.g. can be used to assess short, mid, and long-term intermediate goals; and
d) provides a benchmark for comparison; e.g. the metric compares against a reference value instead of being an absolute number.

2.3 A metric allows monitoring of performance on implementation of cleaner energy in civil aviation. Various metric options may impact the development of cleaner energy for the aviation sector differently. Metrics may encourage an increase in cleaner energy volumes, drive a lowering of the emissions of the cleaner energy or influence both volume and emissions.

2.4 The CAEP assessment of the advantages of the ten possible metrics, based on the four criteria above, is presented in Appendix B of this paper. Meeting all of the criteria is not a prerequisite for the suitability of a metric, and indeed, some criteria may be relevant to certain metrics only. A combination of metrics may also be considered. Disadvantages of metrics are also noted in the last column of the table in Appendix B, and summarized below.

Summary of disadvantages of possible metrics

Not reflecting ENV benefits of cleaner energies	Metrics 1 and 2
Lack of available data, such as through CORSIA Central Registry, to track progress	Metrics 9 and 10
Affected by other measures beyond cleaner energies (technology / operation)	Metrics 3, 5 and 8
Is an absolute number and do not compare against a reference value	Metric 1, 3, 4, 5, 8
Metrics 6 and 7 are not affected by these disadvantages	

[5] In calculating the mass average, the mass of each type of fuel (in tonne) is multiplied by the CI (gCO_{2e}/MJ) of the type of fuel. The sum of the weighted values is then divided by the total mass of fuel.

3. PROJECTIONS ON THE GLOBAL LEVELS OF CLEANER ENERGY USE FOR INTERNATIONAL AVIATION

3.1 In order to illustrate the use of the metric options identified, they have been applied to projections on the global levels of cleaner energy use for international aviation from the LTAG report[6]. These projections, provided in Appendix C, were based on information available up to 2021. It includes detailed tables with projections per year using each metric.

3.2 In addition to the projections from the LTAG report in Appendix C, CAEP also provided information on the short-term (up to 2030) geographic distribution and trends of existing and planned SAF production facilities. These are provided in Appendix D. This CAEP initial analysis assessed the level of maturity of SAF facilities announced up to 31 January 2023; therefore the information in Appendix D does not include any of the SAF facility announcements made since then.

3.3 Furthermore, an up-to-date snapshot of SAF production facilities announcements worldwide is provided through the ICAO Tracker on SAF production facilities, which is illustrated in Appendix E. The tracker reflects all announcements without further technical assessments, including on maturity levels.

3.4 An update of the short-term projections and the latest information from the ICAO Tracker on SAF production facilities will be made available to CAAF/3.

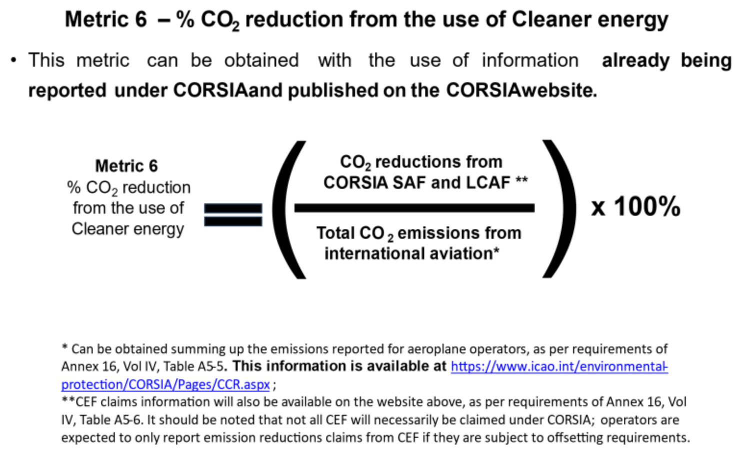
4. ANALYSIS OF POTENTIAL QUANTIFIED METRICS AND GOALS FOR INTERNATIONAL AVIATION

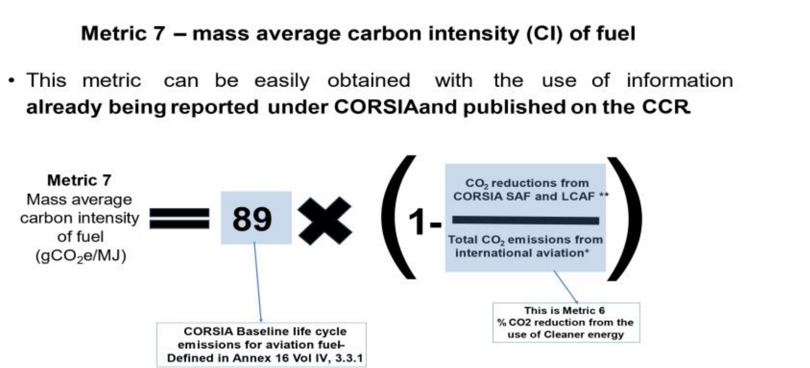
4.1 The LTAG report shows that it is feasible to have 100% use of Sustainable Aviation Fuels in all international aviation flights by the year 2050, which is reflected in Metric Option 1 "mass of cleaner energy". Although being the simplest metric to understand, it does not reflect the climate benefits of such cleaner energies. Since the benefits of cleaner energies are obtained on a life cycle basis, there will be energy options with better environmental benefits on a life cycle basis, which would not be captured by metrics simply associated with mass, as highlighted by CAEP.

4.2 Analysis of possible metrics in Appendix B shows that the Metric Options 6 (% CO2e emissions reduction from the use of cleaner energy) and 7 (Mass average carbon intensity (CI) of fuel) captures these climate benefits associated with cleaner energy use. Both these metrics will also be obtainable with the use of information to be available in the CORSIA Central Registry, and their projections are also available as part of the LTAG report, which allows for the tracking of progress towards any potential goals. These elements show that Metrics 6 and 7 could be good candidates for use in any potential quantified goal for cleaner energy in international aviation.

4.3 The simplicity of understanding is also an important element to be considered, since the metric should allow the signal to be understood easily by the aviation stakeholders and the general public. In that regard, Metric 7 provides a rather scientific unit (gCO2e/MJ), which may require some expertise on life cycle assessment of fuels to be correctly understood. In that regard, Metric 6 (% CO2e emissions reduction from the use of cleaner energy) provides the same level of information in a format that may be easily understood by anyone with basic knowledge on climate change impacts. The Figures below provide more information on how Metrics 6 and 7 can be calculated and how they are inter-related.

[6] A detailed description of the LTAG analysis on fuels, including scenario description and associated costs, is available on the ICAO "LTAG and Fuels" website: https://www.icao.int/environmental-protection/LTAG/Pages/LTAG-and-Fuels.aspx .





4.4 A quantified and collective goal for SAF, LCAF and other cleaner energies in international aviation, in the context of the implementation of the LTAG, could allow for an easier tracking of progress towards the achievement of the LTAG and its periodic review, supporting States in the development of respective clean energy policies. It would also provide more clarity to financing institutions on the investments needs and help drive funds towards SAF, LCAF and other cleaner energy deployment projects.

5. ACTION BY THE CAAF/3

5.1 The CAAF/3 invited to:

a) use information in this paper, including technical inputs from CAEP on possible metrics for potential quantified goals and projections on the global levels of cleaner energy use by international aviation, as well as for monitoring the LTAG process, for consideration of CAAF/3 outcomes; and

b) consider the inclusion of collective goals for cleaner energy use by international aviation, based on the most appropriate metrics and in line with the LTAG report, as part of the review and update of the “2050 ICAO Vision”.

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APPENDIX A: POSSIBLE METRICS FOR POTENTIAL QUANTIFIED GOALS FOR CLEANER ENERGY FOR INTERNATIONAL AVIATION

	Metric Option	**Metric description**	**Unit**	**Examples of Metric use [reference number]**[7]
1	Mass of cleaner energy	Total mass of cleaner energy use	KiloTonne (kt)	CORSIA MRV [1, 7] , ICF (UK industry SAF roadmap) [2] , ATAG Waypoint 2050 [3] EASA Environmental Report [4] , Delta airlines [14] , JetBlue [10]
2	Mass of cleaner energy (*Metric 1*) per Total mass of fuel	Mass proportion of total cleaner energy use to total fuel use	%	CORSIA MRV [1, 7], EASA Environmental Report [4], AirFrance KLM [11]; Japan Airlines [12]; Delta Airlines [14] ; JetBlue [10] ; World Bank [13]; ATAG Waypoint 2050 [3]
3	Total CO_{2e} emitted per year	Total mass of CO_2 equivalent emitted per year	MillionTonne (Mt)	CORSIA MRV [1, 7], ICF (UK industry SAF roadmap) [2], ATAG Waypoint 2050 [3] EASA Environmental Report [4], US Action Plan [5], ICCT [6], IATA Net zero monitoring [10], Japan Airlines [12]; One World carbon roadmap [16]
4	Total CO_{2e} emitted per year (*Metric 3*) per total mass of fuel	Mass proportion of total CO_2 equivalent emitted to total fuel use	Tonne CO_2e/Tonne of fuel	CORSIA MRV [1, 7] ICF (UK industry SAF roadmap) [2] ATAG Waypoint 2050 [3] EASA environmental report [9]
5	CO_{2e} reduction from the use of cleaner energy	Total mass of CO_2 equivalent emissions reductions generated by cleaner energy use	MillionTonne (Mt)	CORSIA MRV [1 ,7] ICF (UK industry SAF roadmap) [2] ATAG Waypoint 2050 [3] US Action Plan [5]
6	% CO_{2e} emissions reduction from the use of cleaner energy	Percentage of CO_2 equivalent emissions reductions resulting from cleaner energy use compared to baseline scenario with zero cleaner energy use	%	CORSIA MRV [1, 7] ICF (UK industry SAF roadmap) [2] ATAG Waypoint 2050 [3] EASA Environmental Report [4]
7	Mass average carbon intensity (CI) of fuel (gCO_{2e}/MJ)[8]	Carbon intensity of total fuel mix based on weighted sum of carbon intensities of cleaner energy and fossil jet fuel	Grams of CO_2e/MegaJoule of energy (gCO_{2e}/MJ)	CORSIA MRV [1, 7]
8	Cumulative total CO_2 emissions over the period between 2020 and 2050	Cumulative total mass of CO_2 emissions from international aviation	GigaTonne (Gt)	CORSIA MRV[9] [1, 7] LTAG report [9] IPCC
9	gCO_2/RTK	CO_2 emissions intensity, whilst accounting for changes in traffic volumes	gram CO_2 / Revenue Tonne Kilometer	IATA Net zero monitoring [15]
10	gCO_2/ATK	CO_2 emissions intensity, whilst accounting for changes in available capacity	gram CO_2 / Available Tonne Kilometer	IATA Net zero monitoring [15]

[7] Note that these are examples of use of the same or similar metrics. They cannot be directly applied to LTAG as is. For example, some may report based on CO2 rather than CO2e

[8] In calculating the mass average, the mass of each type of fuel (in tonne) is multiplied by the CI (gCO_{2e}/MJ) of the type of fuel. The sum of the weighted values is then divided by the total mass of fuel.

[9] CORSIA MRV covers CO_2 emissions up to 2035.

APPENDIX B: ASSESSMENT OF POSSIBLE METRIC OPTIONS FOR CLEANER ENERGY FOR INTERNATIONAL AVIATION

Possible metrics for potential quantified goals associated with using cleaner energy sources for international aviation are identified below, together with the identified criteria, to assess the advantages and disadvantages of each possible metric. Checkmarks indicate advantages of each metric. Disadvantages are highlighted in the last column.

	Metric Option / Criteria	Metric is reported by aeroplane operators as part of CORSIA requirements[10]	Metric is made available by ICAO in the CORSIA Central Registry, or can be calculated/ tracked with the use of available CCR information	Metric Allows tracking progress toward the LTAG, e.g. can be used to assess short, mid, and long-term intermediate goals	Provides a benchmark for comparison;eg. the metric compares against a reference value instead of being an absolute number.	Disadvantages
1	Mass of cleaner energy	✓	✓			Does not capture environmental benefits of cleaner energy or non drop in fuels. Affected by factors beyond cleaner energy (e.g. Tech, Ops, Demand).
2	Mass of cleaner energy *(Metric 1)* / Total mass of fuel)		✓		✓	Does not capture environmental benefits of cleaner energy or non drop in fuels.
3	Total CO_{2e} emitted per year	✓	✓	✓		Affected by factors beyond cleaner energy (e.g. Tech, Ops, Demand).
4	Total CO_{2e} emitted per year (*metric 3*) / per total mass of fuel		✓	✓		
5	CO_{2e} reduction from the use of cleaner energy	✓	✓	✓		Affected by factors beyond cleaner energy (e.g. Tech, Ops, Demand).
6	% CO_{2e} emissions reduction from the use of cleaner energy		✓	✓	✓	
7	Mass average carbon intensity (CI) of fuel (gCO_{2e}/MJ)		✓	✓	✓	

[10] Information provided by CORSIA is not fully comprehensive due to the scope of CORSIA

8	Cumulative CO2 emissions over the period between 2020 and 2050		✓[11]	✓		Affected by factors beyond cleaner energy (e.g. Tech, Ops, Demand).
9	gCO2/RTK			✓	✓	Affected by factors beyond cleaner energy (e.g. Tech, Ops, Demand). Restricted to commercial aviation.
10	gCO2/ATK			✓	✓	Affected by factors beyond cleaner energy (e.g. Tech, Ops, Demand).

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[11] CCR information covers up to 2035.

APPENDIX C: DETAILED PROJECTIONS ON THE GLOBAL LEVELS OF CLEANER ENERGY USE FOR INTERNATIONAL AVIATION

The projections below on the global levels of cleaner energy use for international aviation, using the identified possible metrics in Appendix A, are based on the fuels data using the medium traffic scenario in the LTAG Report (data spreadsheet available at https://www.icao.int/environmental-protection/LTAG/Pages/LTAG-data-spreadsheet.aspx).

Projections for cumulative CO2 emissions (metric 8) are provided in the LTAG report, Appendix R3, Table 1.

The projections used 43 MJ/kg as fuel energy content (heating value), and values are given for milestones for 2030, 2040 and 2050 and for three fuel-related scenarios (F1, F2 and F3).

It is important to highlight that volume results from the LTAG report for 2030 were based on announcements made up to 2021.

	Metric Option	**Unit**	**Scenario F1**			**Scenario F2**			**Scenario F3**		
			2030	**2040**	**2050**	**2030**	**2040**	**2050**	**2030**	**2040**	**2050**
1	Mass of Cleaner energy	**kt**	8292	51732	129354	36971	188802	357319	78493	275912	335619
2	Mass of cleaner energy/Total mass of fuel	**%**	3.81	17.73	34.45	17.13	65.94	100.00	36.97	100.00	100.00
3	Total CO_{2e} emitted	**Mt**	816.61	1024.25	1155.97	742.62	756.18	599.62	672.94	465.14	242.65
4	Total CO_{2e} emitted per year/Total mass of fuel	**t CO2/t of fuel**	3.75	3.51	3.08	3.44	2.64	1.68	3.17	1.69	0.72
5	CO_{2e} reduction from the use of cleaner energy	**Mt**	15.95	92.68	280.91	83.24	339.66	767.84	139.53	590.77	1041.77
6	% CO_{2e} emissions reduction from the use of cleaner energy	**%**	1.92	8.30	19.55	10.08	31.00	56.15	17.17	55.95	81.11
7	Mass average carbon intensity (CI) of fuel (gCO_{2e}/MJ)	**gCO_{2e}/MJ**	87.30	81.62	71.60	80.03	61.41	39.03	73.72	39.21	16.81
8	Cumulative CO2 emissions over the period between 2020 and 2050	**$GtCO_2$**	23			17			12		
9	gCO2/RTK		Can't be obtained from LTAG fuels data								
10	gCO2/ATK		Can't be obtained from LTAG fuels data								

Assumptions used in the constrained scenarios of the LTAG report for fuels:

- Under Scenario F1, the scenario prioritization emphasized low cost GHG reduction, and fuels were ordered by minimum selling price (MSP).
- Under Scenario F2, selection prioritized cost effective GHG reduction, using marginal abatement cost as the ordering criterion given in units of $/kg CO2reduced.
- Under Scenario F3, the emphasis was on maximizing GHG reductions, and the fuel LCA value was used as the ordering criterion with lowest LCA value fuels prioritized.

DETAILED TABLE FOR THE SCENARIO F1

	Scenario F1						
	Mass of Cleaner energy	Mass of cleaner energy/Total mass of fuel	Total CO_{2e} emitted	Total CO_{2e} emitted per year/Total mass of fuel	CO_{2e} reduction from the use of cleaner energy	% CO_{2e} emissions reduction from the use of cleaner energy	Mass average CI of fuels (gCO2e/MJ)[b]
Unit	**kt**	**%**	**Mt**	**t CO2/t of fuel**	**Mt**	**%**	**gCO_{2e}/MJ**
2030	8292	3.8%	816.61	3.75	15.95	1.92%	87.30
2031	12319	5.5%	833.61	3.74	19.96	2.34%	86.92
2032	16521	7.2%	850.07	3.72	24.51	2.80%	86.51
2033	20934	8.9%	865.90	3.70	29.69	3.32%	86.05
2034	25612	10.7%	880.94	3.68	35.66	3.89%	85.54
2035	30589	12.5%	895.10	3.65	42.52	4.53%	84.96
2036	33747	13.3%	923.23	3.63	49.60	5.10%	84.46
2037	37350	14.2%	950.14	3.61	57.91	5.74%	83.89
2038	41499	15.2%	975.54	3.58	67.73	6.49%	83.22
2039	46248	16.4%	999.28	3.55	79.20	7.34%	82.46
2040	51732	17.7%	1024.25	3.51	92.68	8.30%	81.62
2041	57955	19.3%	1040.64	3.47	108.28	9.42%	80.61
2042	65126	21.1%	1054.41	3.42	126.50	10.71%	79.47
2043	73316	23.1%	1065.39	3.36	147.52	12.16%	78.18
2044	82658	25.4%	1073.20	3.30	171.70	13.79%	76.72
2045	91413	27.4%	1083.19	3.25	193.71	15.17%	75.50
2046	97509	28.5%	1101.35	3.22	207.55	15.86%	74.89
2047	104367	29.8%	1117.66	3.19	223.24	16.65%	74.18
2048	111951	31.2%	1132.21	3.16	240.68	17.53%	73.40
2049	120288	32.8%	1144.96	3.12	259.93	18.50%	72.53
2050	129354	34.5%	1155.97	3.08	280.91	19.55%	71.60

DETAILED TABLE FOR THE SCENARIO F2

	Scenario F2						
	Mass of Cleaner energy	Mass of cleaner energy/Total mass of fuel	Total CO_{2e} emitted	Total CO_{2e} emitted per year/Total mass of fuel	CO_{2e} reduction from the use of cleaner energy	% CO_{2e} emissions reduction from the use of cleaner energy	Mass average CI of fuels (gCO2e/MJ)[b]
Unit	**kt**	**%**	**Mt**	**t CO2/t of fuel**	**Mt**	**%**	**gCO_{2e}/MJ**
2030	36971	17.1%	742.62	3.44	83.24	10.08%	80.03
2031	48440	21.9%	745.97	3.38	99.81	11.80%	78.50
2032	60348	26.7%	747.96	3.31	117.74	13.60%	76.90
2033	72795	31.5%	748.29	3.23	137.32	15.51%	75.20
2034	85837	36.3%	746.80	3.16	158.73	17.53%	73.40
2035	99568	41.2%	743.20	3.07	182.24	19.69%	71.47
2036	115473	46.1%	749.91	2.99	208.46	21.75%	69.64
2037	132317	51.1%	754.06	2.91	237.24	23.93%	67.70
2038	150115	56.1%	755.61	2.82	268.61	26.23%	65.66
2039	168910	61.1%	754.45	2.73	302.69	28.63%	63.52
2040	188802	65.9%	756.18	2.64	339.66	31.00%	61.41
2041	204402	69.7%	744.17	2.54	378.83	33.73%	58.98
2042	220824	73.5%	729.89	2.43	420.27	36.54%	56.48
2043	237918	77.3%	713.76	2.32	463.57	39.37%	53.96
2044	255480	81.2%	696.31	2.21	508.18	42.19%	51.45
2045	273300	84.9%	678.11	2.11	553.54	44.94%	49.00
2046	291103	88.5%	659.84	2.01	598.97	47.58%	46.65
2047	308576	91.8%	642.39	1.91	643.58	50.05%	44.46
2048	325566	94.9%	626.20	1.82	686.94	52.31%	42.44
2049	341863	97.6%	611.81	1.75	728.49	54.35%	40.63
2050	357319	100.0%	599.62	1.68	767.84	56.15%	39.03

DETAILED TABLE FOR THE SCENARIO F3

	Scenario F3						
	Mass of Cleaner energy	Mass of cleaner energy/Total mass of fuel	Total CO_{2e} emitted	Total CO_{2e} emitted per year/Total mass of fuel	CO_{2e} reduction from the use of cleaner energy	% CO_{2e} emissions reduction from the use of cleaner energy	Mass average CI of fuels (gCO2e/MJ)[b]
Unit	**kt**	**%**	**Mt**	**t CO2/t of fuel**	**Mt**	**%**	**gCO_{2e}/MJ**
2030	78493	36.97%	672.94	3.17	139.53	17.17%	73.72
2031	98093	45.22%	658.90	3.04	171.30	20.63%	70.64
2032	118606	53.53%	641.90	2.90	206.02	24.30%	67.38
2033	140136	61.95%	621.60	2.75	244.05	28.19%	63.91
2034	162844	70.55%	597.47	2.59	285.91	32.37%	60.19
2035	186690	79.29%	569.52	2.42	331.58	36.80%	56.25
2036	202486	83.26%	553.00	2.27	377.72	40.58%	52.88
2037	219487	87.47%	533.10	2.12	427.22	44.49%	49.41
2038	237536	91.83%	510.28	1.97	479.65	48.45%	45.88
2039	256385	96.24%	485.23	1.82	534.32	52.41%	42.36
2040	275912	100.00%	465.14	1.69	590.77	55.95%	39.21
2041	281882	100.00%	412.02	1.46	666.75	61.81%	33.99
2042	287853	100.00%	359.47	1.25	742.15	67.37%	29.04
2043	293824	100.00%	308.19	1.05	816.28	72.59%	24.39
2044	299795	100.00%	258.87	0.86	888.45	77.44%	20.08
2045	305765	100.00%	254.51	0.83	915.65	78.25%	19.36
2046	311736	100.00%	252.72	0.81	940.29	78.82%	18.85
2047	317707	100.00%	250.64	0.79	965.23	79.39%	18.35
2048	323678	100.00%	248.27	0.77	990.45	79.96%	17.84
2049	329648	100.00%	245.60	0.75	1015.96	80.53%	17.33
2050	335619	100.00%	242.65	0.72	1041.77	81.11%	16.81

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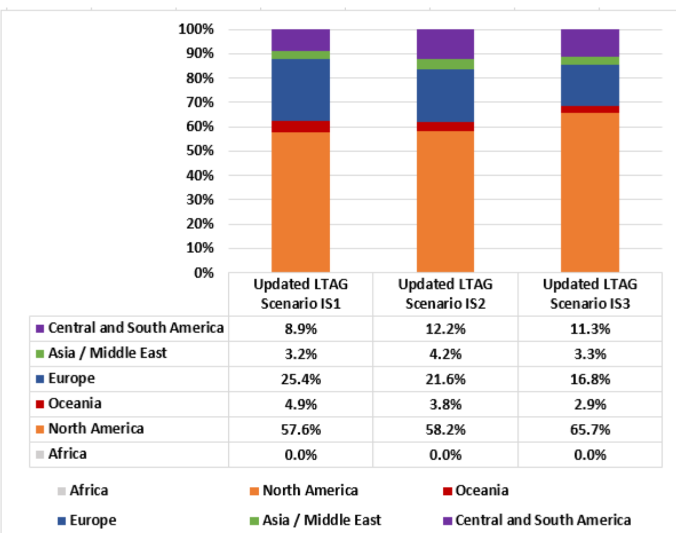
APPENDIX D

GEOGRAPHIC DISTRIBUTION AND TRENDS OF EXISTING AND PLANNED SAF PRODUCTION FACILITIES IN 2030

The short-term scenarios for 2030 were originally developed by CAEP in 2021, and included 5 short-term scenarios based on publically-available announcements of SAF production: “low”, “moderate”, “high”, ”high+”, and “max”. Such information **in 2021** was incorporated in the LTAG report in 2022, in which the three short-term scenarios “moderate”, “high” and “high+” were associated with the LTAG scenarios IS1, IS2 and IS3, respectively.

The results shown in this Appendix reflect a further update of the short-term projections for 2030, as compared to the LTAG scenarios IS1, IS2 and IS3. The updates to the short term projections include further announcements of SAF production facilities **by 31 January 2023**. Therefore, fuel volumes from the short-term projections out to 2030 outlined in this Appendix are not the same volumes reported in the LTAG-report, given the different points in time in which the different analyses have been prepared.

Based on the updated SAF short-term projection in 2030, the geographical distribution by world-region (in %) in 2030 is provided in the Figure below.



	Updated LTAG Scenario IS1	Updated LTAG Scenario IS2	Updated LTAG Scenario IS3
Central and South America	8.9%	12.2%	11.3%
Asia / Middle East	3.2%	4.2%	3.3%
Europe	25.4%	21.6%	16.8%
Oceania	4.9%	3.8%	2.9%
North America	57.6%	58.2%	65.7%
Africa	0.0%	0.0%	0.0%

Notes – There are efforts ongoing in other world regions that could lead to SAF production by 2030 but have not reached the maturity level yet for inclusion in these projections at the time the database was frozen as of 31 January 2023. This analysis was developed by CAEP in a short period of time and should be reviewed in the future to ensure its accuracy and to use the definition of ICAO regions.

The database used by the CAEP analysis was frozen on 31 January 2023 and information above does not include any SAF facility announcements made since then.

Details on the methodology

Diffusion modelling was used to more accurately project later years' production beyond the 4-5 years typical for project announcements. However, the diffusion approach does not yield world-region-specific projections but rather global projections. Therefore, the analysis rely on scenario-adjusted announcements from the database for reporting world-region-specific SAF volumes in 2030.

The database used in the analysis includes 108 facilities, including 25 with a maturity level of A, 20 with a maturity level of B, and 27 with a maturity level of C, while other 36 facilities received a maturity level of D and were, therefore, not used in the analysis.

Although SAF activities are in its early stages and are evolving very rapidly in different parts of the world, when analyzing the current results by region of production, it is found that across all scenarios, the majority of SAF production is forecasted to be in the US, followed by the EU (see Figure above). The following essential aspects are highlighted:

a) The analysis used the SAF database that was frozen on 31 January 2023, and announcements made since then are not included in the data;

b) Facility announcements made later, as well as policy developments that could support the SAF production scale-up, are not included in the regional breakdown;

c) Updating the database is a continuous task with additional announcements being captured, and therefore the output from database analyses in the future will change;

d) Given the relatively small global SAF volumes, small volume changes in one world region can have a significant impact on the share of this world region in total production;

e) Many facility announcements have incomplete data, and assumptions had to be made with regard to product slate; and

f) The regional breakdown is based on scenario-adjusted announcements and does not include any diffusion-modelling. The assessment results and methodology can be found in the ICAO public website (https://www.icao.int/environmental-protection/Pages/SAF-Projections.aspx).

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APPENDIX E

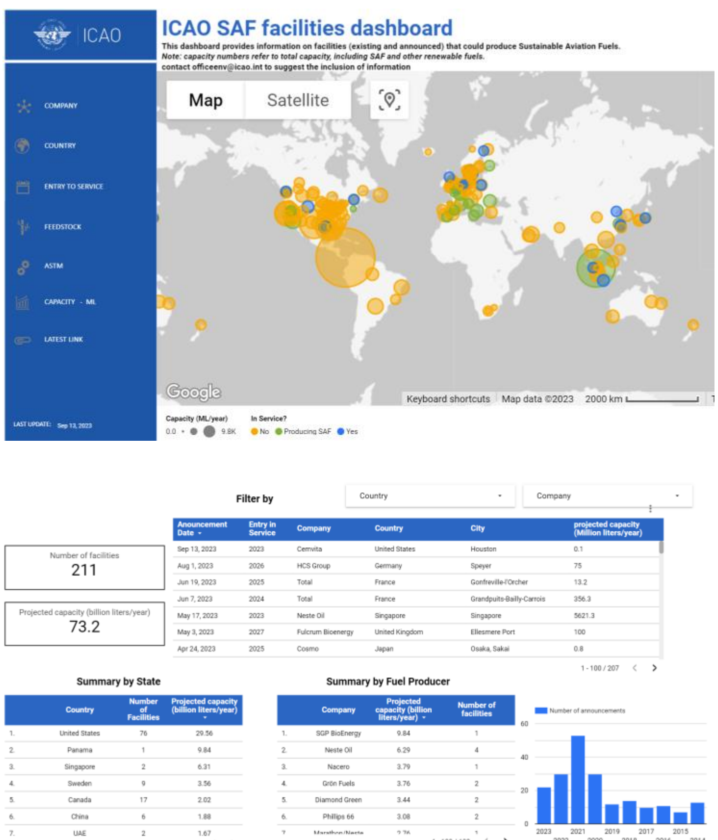
ICAO TRACKER ON SAF PRODUCTION FACILITIES

An up-to-date snapshot of SAF production facilities announcements worldwide is provided through the ICAO Tracker on SAF production facilities, which is illustrated below and available for consultation at https://www.icao.int/environmental-protection/GFAAF/Pages/Production-Facilities.aspx.

The tracker reflects all announcements without further technical assessments, including on maturity levels.

The capacity numbers refer to the total capacity of the facilities (including ground transportation fuels). There is significant uncertainty on the share of this capacity that will be directed to SAF compared to other fuels.

Information is based on publically-available announcements. ICAO does not actively verify the situation of announcements made in the past.



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