第三次航空与代用燃料会议
（CAAF/3）

2023 年 11 月 20 日至 24 日，阿拉伯联合酋长国，迪拜

议程项目 2：促进航空更清洁能源开发和部署的支持性政策

关于国际航空使用更清洁能源的潜在量化目标的衡量指标和预测

（由秘书提交）

摘要

本文介绍了国际航空更清洁能源潜在量化目标的可能衡量指标，以及对国际航空更清洁能源全球使用水平的预测，包括国际民航组织航空环境预测委员会（CAEP）的技术投入意见和其他相关信息。

会议的行动在第 5 段。

1. 引言

1.1 2017 年 10 月举行的第二次国际民航组织航空与代用燃料会议（CAAF/2）[1]核准“国际民航组织可持续航空燃料 2050 年愿景作为一个动态的激励之路，并号召各国、航空业和各利益相关方，在 2050 年之前将传统航空燃料（CAF）中的很大一部分用可持续航空燃料（SAF）所替代，以使得国际民用航空大幅度减少碳排放量，同时，如果有必要，也不放弃可促使减排的一揽子缓解措施中的任何机会”（见《CAAF/2 宣言》第 1 段和大会第 A41-21 号决议序言部分第 30 段）。

1.2 CAAF/2 还注意到，“这条道路的假设前提是逐渐增加可持续航空燃料的使用比重，并应通过盘点流程进行定期审查，以持续评估在可持续航空燃料开发和部署方面的进展，包括有必要审议各项政策和行动，并定期举办讲习班和研讨会，为不晚于 2025 年召开 CAAF/3 会议做准备，以便在该会议上更新国际民航组织 2050 年愿景，以涵盖到 2050 年时可持续航空燃料替代传统航空燃料的量化比重以及通过可持续航空燃料实现的碳减排量”（见《CAAF/2 宣言》第 3 段）。

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

1.3 因此，2022 年 10 月举行的国际民航组织大会第 41 届会议请理事会“继续评估在开发和部署可持续航空燃料、低碳航空燃料和其他更清洁航空能源来源方面取得的进展，以此作为国际民航组织盘点流程的一部分，并于 2023 年召开第三次航空与代用燃料会议，以审查 2050 年国际民航组织可持续航空燃料愿景，其中包括低碳航空燃料和其他更清洁航空能源来源，以按照“不让任何国家掉队”（NCLB）举措并虑及国情和能力，确定一个全球框架”（见 A41-21 号决议第 28 f) 段）。

1.4 为了支持国际民航组织 2050 年愿景的更新和审查，并配合实施大会商定的 2050 年净零的全球长期理想目标（LTAG），本文件根据国际民航组织理事会航空环境保护委员会（CAEP）的技术投入意见，为国际航空更清洁能源的潜在量化目标提供了可能的衡量指标和预测。

1.5 在这方面，2023 年 3 月，国际民航组织理事会要求 CAEP[2]：

a) 确定国际航空更清洁能源潜在量化目标的可能衡量指标（如以百分比（%）或绝对值（质量/体积）表示的可持续航空燃料（SAF）、低碳航空燃料（LCAF）和其他更清洁能源的采纳水平或二氧化碳减排水平），突出说明每种可能衡量指标的优势和劣势；

b) 使用上述 a) 确定的可能衡量指标，结合 CAEP 的《LTAG 报告》，预测中途各节点上如 2030 年、2040 年至 2050 年的国际航空更清洁能源的全球使用水平；和

c) 在可持续航空燃料的短期生产预测的范畴内，查明现有的和计划中的可持续航空燃料生产设施的地理分布和趋势。

2. 可能的衡量指标及其优劣

2.1 CAEP 根据对不同来源的分析，查明了国际航空更清洁能源[3]潜在量化目标的若干可能衡量指标：国际航空碳抵消和减排计划（CORSIA）监测、报告和核查（MRV）系统中使用的衡量指标（见 CAAF/3-WP/5 和 CAAF/3-WP/6）；航空利害攸关方在其净零承诺中使用的衡量指标；LTAG 报告中包含的衡量指标；和与政府间气候变化专门委员会（IPCC）温度目标相关的衡量指标。CAEP 确定了十个可能的衡量指标，载于本文件附录 A[4]并概述如下。

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[2] 参见理事会 C-DEC 229/3 号决定第 2.c) 段。

[3] 在本分析中，“更清洁能源”是指 LTAG 预测中考虑的燃料类别，即：

1) **LTAG 可持续航空燃料（LTAG-SAF）**，包括：
   a. 基于生物质的燃料（植物油作物、木质纤维素能源作物、淀粉能源作物、含糖能源作物）
   b. 基于废物的燃料
      i. 固体废物 — 农作物残渣、城市固体废物、林业残渣。
      ii. 液体废物 — 废物和副产品脂肪油和油脂（FOGs）。
      iii. 气体废物 — 来自乙醇生产、氨生产、钢铁生产和水泥生产的废弃二氧化碳
   c. 基于大气二氧化碳的燃料。
2) **LTAG 低碳航空燃料（LTAG-LCAF）** — 使用温室气体（GHG）缓解技术和最佳实践，实现油井到尾流碳强度 $< 80.1\ gCO_{2e}/MJ$ 的石油基燃料。
3) **非直接掺混燃料**，包括低温氢（LH_2）。

[4] CAEP 关于其技术投入意见的介绍也可在 CAAF/3 会前成果磋商网站上查阅，网址为：https://www.icao.int/Meetings/pre-CAAF3/Pages/reference-materials.aspx

#	衡量指标选项	单位
1	更清洁能源的质量	千吨（kt）
2	更清洁能源（衡量指标 1）在燃料总质量中的百分比	%
3	每年的二氧化碳排放总量	百万吨（Mt）
4	每年的二氧化碳排放总量（衡量指标 3）与燃料总质量之比	二氧化碳吨数/燃料吨数
5	使用更清洁能源带来的二氧化碳减排量	百万吨（Mt）

#	衡量指标选项	单位
6	使用更清洁能源带来的二氧化碳减排量所占的百分比（%）	%
7	燃料的平均碳强度（CI）质量（gCO_{2e}/MJ）[5]	二氧化碳克数/能量的兆焦耳（gCO_{2e}/MJ）
8	2020 年至 2050 年期间二氧化碳累计排放总量	千兆吨（Gt）
9	gCO_2/RTK	二氧化碳克数/收入吨公里
10	gCO_2/ATK	二氧化碳克数/可用吨公里

2.2 航空环保委员会在评估每个可能衡量指标的优势和劣势时采用了以下评估标准：

a) 飞机运营人报告衡量指标情况，作为 CORSIA 要求的一部分；

b) 衡量指标由 ICAO 在 CORSIA 中央登记册（CCR）中提供，或者可以使用可用的 CCR 信息进行计算/跟踪；

c) 可以跟踪 LTAG 的进展，例如，可用于在中间过程中评估短期、中期和长期目标；和

d) 提供比较基准；例如，衡量指标与一个参考值进行比较，而不是一个绝对数值。

2.3 通过衡量指标，可以监测民用航空中实施更清洁能源的绩效。各种衡量指标选项可能会对航空部门更清洁能源的发展产生不同的影响。衡量指标可以鼓励增加更清洁能源的数量，推动降低更清洁能源的排放或者对数量和排放量均产生影响。

2.4 航空环保委员会根据上述四个标准对十个可能衡量指标的优势进行的评估，载于本文件附录 B。满足所有标准并不是衡量指标适用性的先决条件，事实上，一些标准可能只与某些衡量指标相关。也可以考虑衡量指标的组合使用。附录 B 表格的最后一栏也指出了衡量指标的劣势，概述如下。

可能衡量指标的劣势概述

未反映出更清洁能源的环境益处	衡量指标 1 和 2
缺乏可用的数据，如通过 CORSIA 中央登记处跟踪进展情况的数据	衡量指标 9 和 10
受到更清洁能源以外的其他措施（技术/运行措施）的影响	衡量指标 3、5 和 8
是绝对值，不与参考值比较	衡量指标 1、3、4、5、8
衡量指标 6 和 7 不受这些劣势影响	

[5] 在计算质量平均值时，每种燃料的质量（以吨为单位）乘以该种燃料的二氧化碳当量（gCO_{2e}/MJ）。然后将加权值的总和除以燃料的总质量。

3. 国际航空更清洁能源全球使用水平的预测

3.1 为了说明如何使用所确定的衡量指标选项，在 LTAG 报告所载的国际航空更清洁能源全球使用水平预测中应用了这些指标[6]。附录 C 提供的这些预测是基于截至 2021 年的可用信息。附录 C 包括详细表格，其中包含使用每种衡量指标作出的每年预测结果。

3.2 除了附录 C 所载的 LTAG 报告的预测外，CAEP 还提供了有关现有和计划中的可持续航空燃料生产设施的短期（至 2030 年）地理分布和趋势的信息。这些信息载于附录 D。CAEP 的这一初步分析评估了截至 2023 年 1 月 31 日宣布的可持续航空燃料设施的成熟度水平；因此附录 D 中的信息不包括此后宣布的任何可持续航空燃料设施。

3.3 此外，国际民航组织“可持续航空燃料生产设施跟踪器”提供了全球宣布的可持续航空燃料生产设施的最新概览，载于附录 E。跟踪器反映了所有未进行进一步技术评估的生产设施公告，包括成熟度水平。

3.4 将向 CAAF/3 提供短期预测的最新情况和国际民航组织跟踪器生成的关于可持续航空燃料生产设施的最新信息。

4. 对国际航空潜在量化衡量指标和目标的分析

4.1 《LTAG 报告》显示，到 2050 年所有国际航空飞行 100%使用可持续航空燃料是可行的，这反映在衡量指标选项 1“更清洁能源的质量”中。尽管这是最容易理解的衡量指标，但它并没有反映这种更清洁能源的气候效益。由于更清洁能源的效益是通过整个生命周期获得的，因此会有在整个生命周期中带来更大环境益处的能源选项，无法通过这个简单与质量关联的衡量指标予以反映（如航空环保委所突出说明的那样）。

4.2 附录 B 中对可能衡量指标的分析表明，衡量指标选项 6（使用更清洁能源带来的 CO_{2e} 减排量所占的百分比）和选项 7（燃料的平均碳密度（CI）质量）反映了与使用更清洁能源相关的这些气候效益。这两个衡量指标也可以通过使用 CORSIA 中央登记册提供的信息获得，它们的预测作为 LTAG 报告的一部分，从而可以跟踪任何潜在目标的进展情况。这些因素表明，衡量指标 6 和 7 可以是国际航空更清洁能源任何潜在量化目标的好选项。

4.3 易于理解也是一个需要考虑的重要因素，因为衡量指标应能使航空利害攸关方和公众容易理解这一信息。在这方面，衡量指标 7 提供了一个相当科学的单位（gCO_{2e}/MJ），可能需要一些燃料生命周期评估方面的专门知识才能正确理解。而衡量指标 6（使用更清洁能源带来的 CO_{2e} 减排量所占的百分比）提供了同样水平的信息，但从表达形式上来看，任何对气候变化影响有基本知识的人都可能容易理解。下图提供了更多信息，说明如何计算衡量指标 6 和 7 以及它们之间的相互关系。

[6] 关于 LTAG 燃料分析的详细说明，包括设想方案说明和相关费用，可在国际民航组织“LTAG 和燃料”网站上查阅：https://www.icao.int/environmental-protection/LTAG/Pages/LTAG-and-Fuels.aspx。

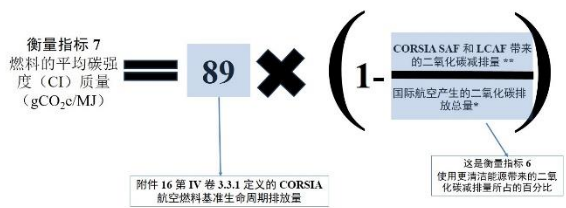
衡量指标 6 – 使用更清洁能源带来的二氧化碳减排量所占的百分比（%）

- 利用 **CORSIA 已经报告并在 CORSIA 网站上公布的**信息，可以获得这一指标。

* 可根据附件 16 第 IV 卷表 A5-5 的要求，将飞机运营人报告的排放量相加得出这一数字。**该信息可在 https://www.icao.int/environmental-protection/CORSIA/Pages/CCR.aspx 上查阅；**
** 根据附件 16 第 IV 卷表 A5-6 的要求，也将在上述网站上提供 CEF 申报信息。应注意的是，并非所有 CEF 都必定在 CORSIA 下提出申报；运营人只有在需满足抵消要求的情况下，才报告 CEF 产生的减排申报。

衡量指标 7 – 燃料的平均碳强度（CI）质量

- 利用**已按照 CORSIA 报告并在 CCR 上公布的**信息，可以很容易地获得这一指标。



4.4 在实施 LTAG 的背景下，为国际航空中的 SAF、LCAF 和其他更清洁能源制定一个量化的集体目标，将易于跟踪在实现 LTAG 和开展定期审评方面取得的进展，并支持各国制定各自的更清洁能源政策。它还将向金融机构提供更清晰的投资需求，并有助于推动资金流向 SAF、LCAF 和其他更清洁能源的部署项目。

5. 第三次航空与代用燃料会议的行动

5.1 请第三次航空与代用燃料会议：

a) 采用本文件中的信息，包括 CAEP 提供的关于潜在量化目标的可能衡量指标、国际航空更清洁能源的全球使用水平预测，以及用于监测 LTAG 进程的技术投入意见，以审议 CAAF/3 成果；和

b) 考虑基于最适当的衡量指标和根据 LTAG 报告纳入使用国际航空更清洁能源的集体目标，作为审查和更新“国际民航组织 2050 年愿景”工作的一部分。

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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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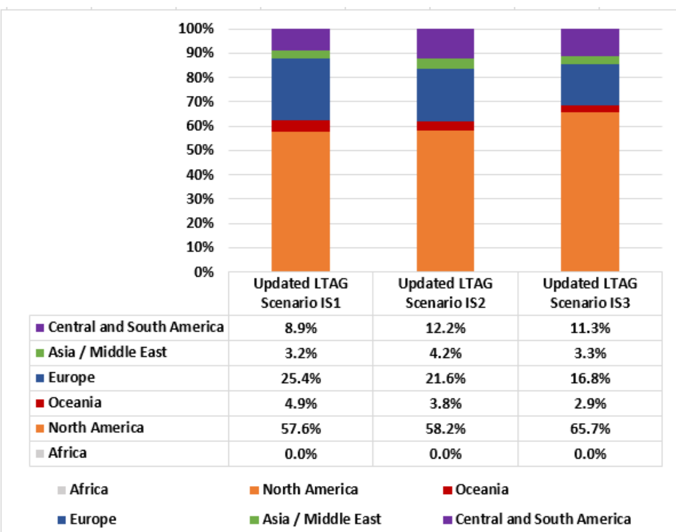
APPENDIX D

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

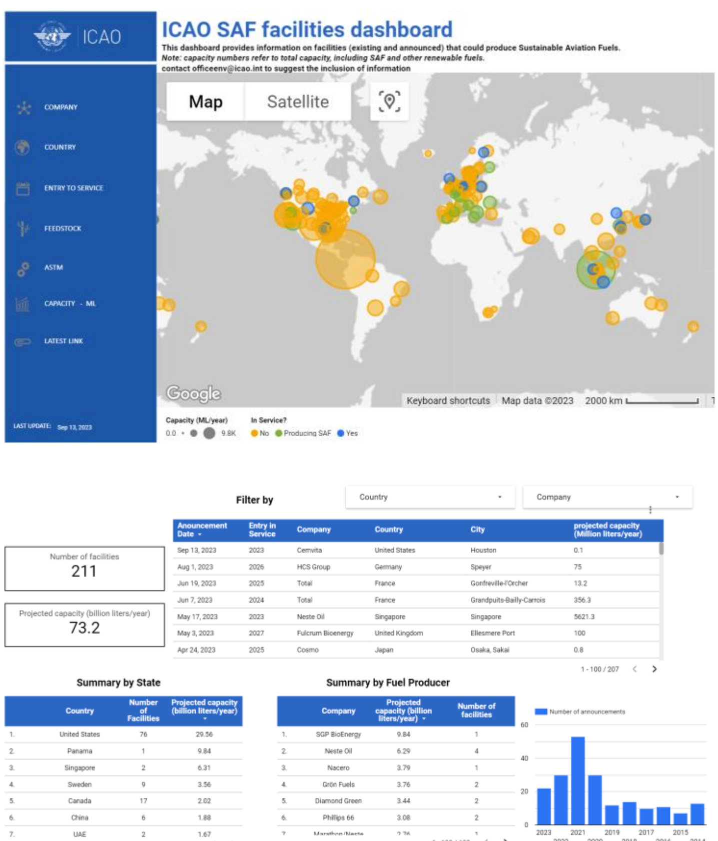
ICAO TRACKER ON SAF PRODUCTION FACILITIES

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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