

Certifying Geologically Balanced Fuels

Pathways, requirements and the case for reforming Lower Carbon Aviation Fuels

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A note on the frameworks reviewed

This policy brief draws on provisions from: CORSIA SAFs and LCAF guidelines (ICAO, 2023); Article 6.4 of the Paris Agreement and associated Supervisory Body decisions; the EU Carbon Removal Certification Framework (CRCF) Regulation; California's Low Carbon Fuel Standard (LCFS); the EU CCS Directive; the Integrity Council for Voluntary Carbon Markets (ICVCM) Core Carbon Principles; and the EU Renewable Energy Directive (RED) delegated acts on Renewable Fuels of Non-Biological Origin.

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Summary

Geologically Balanced Fuels (GBFs) represent a novel approach to aligning fossil aviation fuel use with net-zero objectives as a complementary strategy to sustainable aviation fuels. By pairing conventional kerosene with geologically stored CO₂ units that match its life-cycle emissions, GBFs operationalise a 'like-for-like' offsetting principle consistent with Geological Net Zero. For this pairing to be credible, and for GBFs to become a scalable product eventually recognised under compliance schemes, robust certification frameworks are essential.

This brief identifies key certification requirements for GBFs and assesses how the CORSIA Lower Carbon Aviation Fuels (LCAFs) framework could evolve into a GBF-aligned product following best practices from certification standards in and beyond the aviation sector. Annex I provides a list of workable point-by-point recommendations on how to amend LCAFs and make them GBF-ready.

Key recommendations:

1. GBFs could be operationalised as credits purchased by fuel suppliers and transferred to airlines, or as a novel fuel category alongside sustainable aviation fuels and LCAFs.
2. There are significant quality concerns if GBFs are operationalised via credits eligible under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA); the adoption of higher-integrity credits such as Paris Agreement Article 6.4 credits would be necessary, but the supply of these credits remains uncertain.
3. As a novel fuel category, GBFs would require dedicated certification rules. Given their technological similarities, GBF certification frameworks could be built from existing CORSIA LCAF frameworks.
4. While LCAFs already handle several certification aspects well (e.g. permanence, monitoring, reporting and verification), to integrate GBFs they would need to be amended to ensure net-zero aligned climate benefits, emission reduction claims going beyond the boundaries of fuel production, and high-integrity rules on counterfactual scenarios, additionality, leakage and accounting.
5. We identify best practices that could inspire a GBF-ready certification framework and make precise amendment suggestions to the current LCAF framework.

Because GBF integration in frameworks such as CORSIA could substantially enhance their integrity and credibility, this brief identifies amendments to the LCAFs to integrate GBFs.

1. Introduction: Geologically Balanced Fuels and the need for high-integrity certification

To stop fossil aviation fuels from causing further warming before the full transition to clean fuels is completed, **like-for-like offsetting**¹ based on geological CO₂ storage can provide a net-zero aligned solution. This principle requires counterbalancing long-lived CO₂ emissions with equally durable carbon removals, in a way that is compatible with the goal of **geological net zero**.¹ While durable carbon removals fit this offsetting standard, their higher price and the absence of incentives rewarding greater climate integrity limit uptake.² This issue is visible in aviation, too, where durable removals are absent from major aviation climate policy frameworks.^{3,4} Currently, the only carbon removal initiatives in aviation also concentrate offsetting responsibility at the tail end of the value chain^{3,5} – with airlines and passengers paying. Meanwhile, they miss critical opportunities to leverage the fossil extractive sector's expertise in geological storage,⁶ which would extend responsibility to key value-chain actors^{7,8} and level the playing field for sustainable aviation fuels by internalising the climate cost of fossil kerosene at the point of supply.

This policy brief discusses which guardrails are needed to ensure that **Geologically Balanced Fuels (GBFs)** result in credible emission reductions. GBFs are a potential product category defined as kerosene supplied together with geological CO₂ storage units – where CO₂ captured from industrial point sources or the atmosphere is stored in underground geological formations, matched unit-for-unit with the emissions from each tonne of kerosene supplied.⁹ A GBF comprises two components: (i) *physical fuel delivery*, following the conventional supply chain; and (ii) *climate attributes* in the form of geological CO₂ storage or geological CO₂ removal units, unbundled from physical delivery and tracked separately but sold jointly by the fuel supplier. As set out in Jiang *et al.*,¹⁰ we define GBFs as initially allowing point-source carbon capture and

1. Allen, M. R. et al. "Geological Net Zero and the need for disaggregated accounting for carbon sinks". Nature 638, 343–350 (2025). <https://doi.org/10.1038/s41586-024-08326-8>

2. Smith, S. M. et al. The State of Carbon Dioxide Removal - 2nd Edition. <https://www.stateofcdr.org/report/2nd-edition> (2024).

3. ICAO. Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). <https://www.icao.int/CORSIA> (2021).

4. European Commission. ReFuelEU Aviation - European Commission. https://transport.ec.europa.eu/transport-modes/air/environment/refuelev-aviation_en (2024).

5. Climeworks. "Runway to net zero: Climeworks partners with SWISS and Lufthansa Group". Press release. <https://climeworks.com/press-release/swiss-and-lufthansa-group-first-airline-customers> (7 March 2024).

6. Hastings, A. and Smith, P. "Achieving Net Zero Emissions Requires the Knowledge and Skills of the Oil and Gas Industry". Front. Clim. 2, (2020). <https://doi.org/10.3389/fclim.2020.601778>

7. Jenkins, S., Kuijper, M., Helferty, H., Girardin, C. and Allen, M. "Extended producer responsibility for fossil fuels*". Environ. Res. Lett. 18, 011005 (2023). <https://doi.org/10.1088/1748-9326/aca4e8>

8. Jenkins, S., Mitchell-Larson, E., Ives, M. C., Haszeldine, S. and Allen, M. "Upstream decarbonization through a carbon takeback obligation: An affordable backstop climate policy". Joule 5, 2777–2796 (2021). <https://doi.org/10.1016/j.joule.2021.10.012>

9. Jenkins, S., Mehnaz, R., Kettlety, T., Cox, E. and Allen, M. Geologically Balanced Fuels: A net zero goal for Low-Carbon Aviation Fuels? Oxford Net Zero and IATA (2024). <https://netzeroclimate.org/publications/geologically-balanced-fuels-a-net-zero-goal-for-low-carbon-aviation-fuels/>

storage (CCS) and gradually evolving to include only bioenergy and direct air capture with CCS (BECCS and DACCS).

If GBFs are to ensure broad societal buy-in and market integration, robust Measurement, Reporting and Verification (MRV) and certification systems need to guarantee that the climate impacts of fossil kerosene are truly counterbalanced by the climate claims that are bundled with it. MRV and certification systems must also be recognised by schemes under which GBFs could become eligible, and thus need to align with their overall logic. This brief discusses the most appropriate pathways for the certification of GBFs and assesses the improvements required in order to establish a high-integrity GBF framework, focusing on the necessary amendment of a certification framework, that of CORSIA Lower Carbon Aviation Fuels (LCAFs).

2. Are existing certification frameworks GBF-ready?

Key finding: no single framework is GBF-ready

No existing policy or certification framework can be adopted 'as-is' to certify geological CO₂ offsets for aviation. GBF certification must draw selectively on best practices across multiple frameworks.

- Credit pathway: Paris Agreement Article 6.4 offers the highest integrity ceiling, pending carbon dioxide removal (CDR)/CCS-specific methodologies.
- Fuel pathway: LCAF certification provides the closest fit and can serve as a strong foundation for GBF certification, with targeted amendments.

Based on our review of certification policies and standards¹¹ for alternative aviation fuels and carbon credits that could be used towards aviation's climate mitigation, we find that there is no single existing policy or certification framework that can be adopted 'as is' to certify GBFs. Instead, aviation-relevant certification needs to draw selectively on best practices across multiple frameworks to ensure like-for-like offsetting and tailor the specific technological characteristics of geological CO₂ storage pathways.

If GBFs were to be operationalised through a carbon crediting mechanism, fuel suppliers would either generate or procure geological CO₂ offset credits and bundle them with fuel sales, requiring airlines to purchase the credit alongside the physical fuel. This approach is conceptually compatible with existing mechanisms such as offsetting under CORSIA, whereby units can be retired on behalf of the airline by third parties. While CORSIA eligible emission units currently allow different carbon credits, most of which would not adhere to the like-for-like criteria demanded by GBFs, kerosene could be selectively bundled with CORSIA credits generated from point-source capture or BECCS and DACCS. However, this integration could bear risks for the integrity of GBFs due to the vague quality requirements imposed on CORSIA eligible emissions units, which are purposefully generic so as to allow a case-by-case evaluation of crediting programmes. By contrast, if these credits were to comply with Article 6.4 requirements, a significantly higher all-round integrity could be warranted. Indeed, following a

10. Jiang, K., S. Jenkins, N. Brazzola, T. Kettlety and M. Allen (in review). "Geologically Balanced Fuels: Design choices and their implications".

11. Brazzola, N., T. Kettlety, M. Thoppil, E. Muchos, N. Martirosian, K. Jiang, S. Jenkins, J. House, M. Allen (in preparation). "Credibility of Aviation Decarbonisation: A Review of Certification Frameworks". Preprint available at <https://cdrixiv.org/preprint/515>.

recent resolution,¹² Article 6.4 credits may become eligible for use under CORSIA, provided that they align with its eligibility criteria. However, thus far no methodologies have been developed to allow CCS-based activities under Article 6.4 credits. Furthermore, the supply of Article 6.4 credits to CORSIA remains uncertain, as countries are likely to deploy higher-quality credits under Article 6.4 to reach their own nationally determined contributions (NDCs).

Alternatively, fuel producers could directly store a sufficient amount of CO₂ to compensate for an increasing share of the emissions embedded in the jet fuel that they deliver to airlines and claim a lower life-cycle carbon intensity of the fuel they sell. To incentivise this approach, GBFs would need to be recognised as an additional fuel category within existing fuel policies – either alongside sustainable aviation fuels (SAFs) and LCAFs, or as a higher-ambition evolution of LCAFs. This integration would, critically, rely on revised accounting and certification rules, as currently eligibility as SAF or LCAF presupposes that emission reductions are inherent to the fuel feedstock. New GBF certification methodologies for fuels would thus have to combine the quantification of life-cycle emissions due to jet A1 fuel production with the CO₂ reductions, certification and MRV of removals into a single protocol. This exercise could draw from existing greenhouse gas accounting rules for jet A1 emissions and tie these to established certification and MRV practices for CCS, DACCS and BECCS, e.g. looking at CCS-specific elements of the California Low Carbon Fuel Standard (LCFS), and the EU Carbon Removal and Carbon Farming Certification Framework (CRCF).

Another potential avenue is to amend the CORSIA LCAFs to progressively evolve into a GBF-aligned product. LCAFs are traditional jet fuels with reduced carbon intensity due to the implementation of mitigation measures during their production chain, including CCS, low-carbon electricity, and the use of newly developed crudes. Based on this technological similarity, LCAFs represent the most tractable entry point for GBF integration – either through direct amendment of existing LCAF provisions or by using them as the basis for a novel certification framework, an avenue explored in the chapters that follow. In the next chapter, we describe how existing LCAF provisions could be amended to align with GBFs.

3. Amending LCAFs for GBF inclusion

CORSIA Lower Carbon Aviation Fuels (LCAFs) are traditional jet fuels whose carbon intensity is reduced through production-chain mitigation measures, including CCS. Two fundamental amendments to the LCAF framework are necessary before it can serve as a basis for GBF certification:

- **Boundary expansion:** Currently, only CCS-based reductions directly contributing to fuel production are counted within boundaries of CORSIA eligible fuels. In practice, this ties CCS to the capture of fuel production-related emissions or to enhanced oil recovery activities. GBF alignment requires allowing CCS activities that are operationally independent from or merely co-located with fuel production to contribute to reducing the carbon intensity of LCAFs, independently of the source and purpose of the stored CO₂.

12. “Decides that emissions units generated from mechanisms established under the UNFCCC and the Paris Agreement are eligible for use in CORSIA, provided that they align with decisions by the Council, with the technical contribution of CAEP, including on avoiding double counting and on eligible vintage and timeframe;” Resolution A39-3: Consolidated statement of continuing ICAO policies and practices related to environmental protection – Global Market-based Measure (MBM) scheme, ICAO (2025).

- **Emissions reduction threshold:** To be considered CORSIA eligible fuels, LCAFs need to meet a minimum 10% reduction in their life-cycle emissions relative to a fixed benchmark derived from the global average carbon intensity of fossil jet fuel production, as well as additional sustainability criteria. Full GBF alignment would require progressively increasing this threshold up to 100% emissions reductions, enabling net-zero aligned, like-for-like geological balancing of fossil kerosene emissions.

Subject to these amendments, the LCAF certification framework could provide a potential template or entry point for GBF certification. Below we review those rules and identify key amendment needs.

Key LCAF amendments

1. Amend LCAF boundary rules to allow CCS/DACCS/BECCS activities financially linked to or co-located with fossil fuel production to count toward emissions reduction, regardless of direct process linkage.
2. Replace the minimum 10% carbon intensity reduction threshold with a net greenhouse gas (GHG) reduction requirement scalable to 100%.
3. Introduce regionally resolved baselines for the carbon intensity of fossil jet fuel to prevent strategic tankering.
4. Strengthen permanence provisions: where unspecified by the national CCS regulation applying, mandate transfer of liability to the competent authority after a low risk of reversals has been assessed and specify Reserve Account replenishment rules.
5. Require separate quantification and reporting of emissions reductions versus carbon removals.
6. Introduce comprehensive uncertainty quantification and restrict look-up table use to cases where they yield more conservative estimates.
7. Apply CORSIA SAF-equivalent sustainability and land-use change provisions to all bio-based GBF pathways.
8. Adopt Article 6.4-aligned social and governance safeguards across all GBF pathways.
9. Formalise inter-scheme recognition of GBF certification under CORSIA, ReFuelEU and EU ETS to avoid administrative and regulatory duplication for multi-jurisdictional fuel suppliers and develop interoperable registry linkages to prevent double claiming.
10. Establish a structured GBF methodology development and periodic review process.

3.1 Counterfactuals and additionality

General context: Baselines are needed to estimate the extent of emissions reductions against a counterfactual scenario. Additionality tests ensure that credited emissions reductions would not have occurred without the crediting mechanism.

What LCAFs do: LCAF baselines are anchored to a global fossil fuel carbon intensity (CI) ceiling of 89 gCO₂e/MJ, with facility-specific baselines calculated as the gap between this cap and actual pre-LCAF emissions. The global nature of the baseline means that, in regions with low fossil fuel CI, minimal interventions are sufficient to consider an LCAF as CORSIA-eligible. LCAFs lack formal additionality tests, which implies that all LCAF-aligned interventions are additional. The sole additionality requirement is for renewable electricity sourcing.

What GBF alignment requires: Regional baselines should reflect the fact that the CI of fossil fuel production is different even before LCAF interventions. Due to the different technologies involved in GBFs, baseline and additionality rules should be differentiated by pathway. For fossil fuel CI, baselines should follow Article 6.4 best practices – performance-based, anchored to the best available technology, or historically adjusted downward and with periodic three-year reviews.

For DACCS, a zero-emissions baseline (as in the EU CRCF) may be acceptable, given high capital costs and the absence of independent demand signals. For BECCS, baselines must account for cascading biomass uses, ensuring that redirecting biomass to credited activities does not increase net biomass-related emissions upstream, following Article 6.4 prohibition of diverting biomass from existing uses to newly credited activities. For point source CCS, ambitious benchmarks reflecting the counterfactual deployment of captured CO₂ streams should apply, alongside measurement of baseline reservoir CO₂ releases (as in the California LCFS). Across all pathways, deployment must exceed any legally mandated mitigation unless the regulation formally integrates GBFs as an implementation instrument, and electricity additionality requirements must prevent diversion of renewable capacity from other decarbonisation uses, especially where DACCS is deployed.

Amendment recommendations

- ✓ **Baseline fossil jet fuel carbon intensity:** Baseline fossil fuel carbon intensity should be regionally resolved and should account for evolving best available technologies (such as in the Article 6.4 and Integrity Council for the Voluntary Carbon Market (ICVCM) Core Carbon Principles (CCPs)).
- ✓ **DACCS baseline:** A zero baseline (such as in the EU CRCF) may be acceptable due to high capital costs, a lack of demand-generating schemes for DACCS, and system-wide benefits due to the deployment of DACCS in the niche market of aviation.
- ✓ **BECCS-specific biomass baseline:** Baseline-setting must account for cascading biomass uses. As under Article 6.4, redirecting biomass away from existing uses towards newly-credited BECCS should be prohibited or at least should not increase net biomass-related emissions.
- ✓ **CCS baseline:** In cases where GBFs initially allow point-source CCS to balance fossil jet fuel emissions, CCS baselines should be based on ambitious benchmarks taking into account counterfactual deployment of CO₂ streams (following Article 6.4 rules). Adopting LCFS-style measurement of baseline CO₂ releases from the reservoir prior to injection would enable accurate monitoring of net storage benefits.
- ✓ **Downward trajectory:** Baselines should be periodically reviewed and iteratively adjusted downward to maintain conservativeness in line with sector-wide decarbonisation progress (Article 6.4).
- ✓ **Regulatory additionality test:** CCS/DACCS/BECCS deployment must exceed any mitigation required by law or regulation, unless the regulation formally integrates GBFs as an implementation instrument (following Article 6.4 rules).
- ✓ **Financial additionality:** Given the capital intensity of DACCS and BECCS, regulatory analysis is typically sufficient. For CCS projects sequestering already-captured industrial CO₂, it is important to ensure that the credited net GHG reduction derives from a marginal and newly installed CO₂ source (following the California LCFS).

3.2 Quantification, system boundaries and life-cycle assessment

General context: Quantification rules determine how the GHG benefits of a certified activity are calculated. Leakage describes the displacement of emissions to activities outside the accounting boundary. For GBFs, quantification must accurately and conservatively capture the full life-cycle emissions of fuel production alongside CO₂ reductions and removals attributable to CCS, DACCS and BECCS within appropriate system boundaries, taking into account leakage, and explicitly handling uncertainties.

What LCAFs do: LCAFs provide strong quantification foundations: full supply chain system boundaries from feedstock to combustion, explicit inclusion of the CCS process chain, and quantification of all major life-cycle GHG emissions based on International Civil Aviation Organization (ICAO) tools or look-up tables. However, the 10% minimum CI reduction threshold is incompatible with the like-for-like offsetting logic of GBFs. Moreover, LCAFs' CCS accounting

is restricted to process emissions within fuel production, implicitly tying CO₂ capture to fuel production emissions and geological storage to Enhanced Oil Recovery. Emissions reductions and carbon removals are bundled into a single reported CI value, obscuring quantification of demand for carbon removals from the aviation sector. Finally, leakage provisions are almost entirely absent.

What GBF alignment requires: To align with GBFs, the CI threshold of 10% must be replaced by a net GHG reduction requirement scalable to 100%, and GBF certification should allow CCS-based emissions reductions and removals to be credited wherever the storage activity is co-located with or financially linked to fuel supply. Removals via BECCS and DACCS should be separately quantified and reported. On quantification, look-up tables should be restricted to cases where they yield more conservative estimates than site-specific reporting values, following ICVCM practices. Higher-tier IPCC methods, uncertainty quantifications and sensitivity analysis should be mandated across all quantification areas. For BECCS, biomass leakage treatment should match the more rigorous CORSIA SAF standard, including consequential assessment of indirect land-use change, rather than the weaker CRCF BECCS methodology.

Amendment recommendations

- ✓ **Emissions reduction threshold:** Replace the current minimum 10% CI reduction with a net GHG reduction requirement scalable to 100% – consistent with CRCF (net carbon removal benefit), or ReFuelEU (70% life-cycle GHG reduction as minimum).
- ✓ **Decoupled CCS accounting:** Allow geological CCS benefits to be credited independently of whether they arise from direct life-cycle stages of CORSIA eligible fuel production, following the logic of the California LCFS. This removes the implicit link to process emissions and Enhanced Oil Recovery.
- ✓ **Separate reductions and removals:** Require separate quantification and reporting of emissions reductions versus carbon removals. This prevents mitigation deterrence and enables tracking of CDR deployment against global carbon budgetary needs.
- ✓ **Uncertainty quantification:** Introduce Monte Carlo sensitivity analyses and annual uncertainty assessment per ISO JCGM 100:2008, with mandatory discount factors where uncertainty is material (following ReFuelEU and ICVCM best practices). Restrict look-up tables to cases where they produce more conservative estimates than site-specific reporting values (following ICVCM best practices).
- ✓ **Tiering uplift:** Mandate higher-tier IPCC methods across all quantification areas, even absent high uncertainty, to improve overall accuracy.
- ✓ **Boundary expansion:** Allow geological CO₂ reductions and removals that are financially linked to or merely co-located with fuel production to be credited, where the CO₂ stored arises from activities outside the direct production process.
- ✓ **Biomass leakage (BECCS):** Adopt CORSIA SAF-equivalent treatment of land-use change and biomass leakage, including consequential assessment of indirect impacts. Avoid adopting BECCS rules from the EU CRCF, which has poor treatment of land-use change and biomass emissions.
- ✓ **Energy leakage:** Maintain and strengthen existing renewable energy additionality requirements, ensuring electricity used in GBF production does not displace capacity serving other decarbonisation needs.

3.3 Monitoring, reporting and verification (MRV), and permanence

General context: MRV requirements govern how emissions, removals and permanence are tracked, reported, and independently verified. Like-for-like offsetting for aviation requires geological CO₂ storage maintained on timescales commensurate with the atmospheric lifetime of the fossil CO₂ it counterbalances – that is, effectively millennia. Permanence provisions must cover not just the avoidance of near-term reversals, but also long-term storage integrity backed by monitoring, liability assignment and remediation obligations.

What LCAFs do: LCAFs cover MRV fundamentals well, with clear monitoring plans, annual reporting, record-keeping and data quality standards. Verification is required by independent, accredited bodies compliant with ISO 17065, with annual recertification audits, including on-site visits. The approach to ensure permanence from CCS requires computing the expected leakage over a 100-year period and deducting it from the fuel's CI. Moreover, storage sites must demonstrate sufficient capacity and trapping mechanisms and operators must establish a Reserve Inventory Account to cover potential leakage scenarios. The framework is silent on post-closure monitoring obligations and Reserve Account replenishment rules in States without a recognised CCS regulatory scheme.

What GBF alignment requires: Verification must be explicitly ex-post, and sampling-based validation for CCS activities should be supplemented with continuous or high-frequency monitoring where material leakage risk exists. On permanence, operators must remain responsible for monitoring, corrective measures and site sealing after closure for a period sufficient to ensure minimal CO₂ release risk, after which responsibility transfers to the competent authorities, following EU CCS Directive logic. Reserve Inventory Account contributions should be determined by project-specific risk ratings, with a clear distinction between avoidable and unavoidable reversals: operators must be fully liable for replenishing the account for avoidable reversals, consistent with Article 6.4 rules.

Amendment recommendations

- ✓ **Verification timing:** Explicitly require ex-post verification of actual outcomes rather than projected performance. The current framework leaves verification timing unspecified.
- ✓ **Monitoring methodology:** Review the use of sampling-based validation for CCS activities and supplement with prescriptive monitoring plans, continuous or high-frequency monitoring requirements, and stringent data controls where relevant, consistent with regulated CCS MRV standards.
- ✓ **Monitoring duration:** After site closure, operators must remain responsible for monitoring, corrective measures and site sealing for a period sufficient to ensure minimal risks of CO₂ releases. Thereafter, responsibility is transferred to the competent authorities (following EU CCS Directive logic).
- ✓ **Reserve Account replenishment:** Specify clear rules for Reserve Inventory Account contributions and replenishment, determined by project-specific risk ratings. Distinguish avoidable from unavoidable reversals, making storage operators and fuel producers liable for replenishing the account for avoidable reversals (following Article 6.4).
- ✓ **Liability transfer:** Define conditions under which long-term liability for storage site integrity transfers from operators to the competent authorities, consistent with EU CCS Directive practice, to be applied also in the case of legislation that lacks explicit CCS regulations.

3.4 Accounting integrity

General context: Accounting rules must ensure that emissions reductions credits are generated, transferred and claimed only once, and that the entity paying for GBF attributes is the entity that benefits from the associated emissions reduction claim. This requires preventing the same geological CO₂ storage unit from being credited simultaneously under different schemes – for example, both as an ETS compliance unit for a point source and as a GBF attribute under CORSIA.

What LCAFs do: The CORSIA Central Registry tracks CORSIA-related reporting. A mass-balance chain of custody applies up to the blending point, with book-and-claim thereafter. Double-claiming of Scope 1 emissions reductions under multiple mitigation obligations is explicitly

prohibited and there are provisions ensuring that waste gas-based LCAF production is reflected in national GHG inventories. However, missing links to registries of other mechanisms pose the risk of double counting.

What GBF alignment requires: To avoid double counting, fuel reporting entities must demonstrate retirement of GBF credits equal to their compliance obligations for each period, modelled on LCFS compliance mechanics, and state the purpose of retirement. This ensures the linkage between the geological offset and the fuel unit. ICVCM-inspired provisions should further require the identification and resolution of overlapping GHG accounting boundaries between mitigation activities. GBF registries and other relevant compliance registries (EU ETS, CORSIA, national inventories) should also be interlinked to ensure that no geological CO₂ unit is claimed under more than one scheme.

Amendment recommendations

- ✓ **Report and retire GBF credits:** Require fuel reporting entities to demonstrate retirement of GBF credits equal to their compliance obligations for each period, modelled on California LCFS compliance.
- ✓ **Anti-double issuance:** Implement ICVCM-inspired provisions requiring identification and resolution of overlapping GHG accounting boundaries between mitigation activities.
- ✓ **Transparent retirement statements:** Require retirement statements to explicitly identify the purpose of retirement (e.g. CORSIA compliance, EU ETS exemption, voluntary claim), enabling cross-registry reconciliation (following ICVCM best practices).
- ✓ **Interlinked registries:** Work toward interoperability between GBF registries and other relevant compliance registries (EU ETS, CORSIA, national inventories) to verify that no geological CO₂ unit is claimed under more than one scheme.
- ✓ **Erroneous issuance mechanism:** Introduce an executive review and invalidation procedure for erroneously issued credits, modelled on LCFS's Executive Officer review process.

3.5 Sustainability and social safeguards

General context: Sustainability and social safeguards address environmental and social impacts of certified activities, including effects on land use, biodiversity, food security, water resources and host communities.

What LCAFs do: Each certified entity provides evidence that the fuel satisfies the CORSIA Sustainability Criteria for CORSIA eligible fuels, e.g. via a Proof of Sustainability (PoS) document. PoSs are based on environmental impact assessments addressing multiple CORSIA LCAF Sustainability Themes, such as avoiding emissions, material releases and pollution generated by fuel production. Sustainability Criteria also include measures to minimise seismic and vibrational impacts and acoustic energy related to surface, subsurface and underwater activities. While LCAFs do not currently involve biomass, CORSIA Sustainability Themes assess different dimensions of biomass and land-use sustainability targeted at SAFs, such as strict eligibility criteria on biomass sourcing, biodiversity protection and respect for Indigenous and customary rights in land conversion decisions.

What GBF alignment requires: Amendments are needed for GBF pathways including biomass, whereby CORSIA SAF rules on biomass sourcing should be adopted. These prohibit conversion from land with high carbon stock and high biodiversity and avoid the introduction of alien species, modified microorganisms and monocultures. Article 6.4 best practices should be adopted to avoid conversion of culturally and environmentally relevant land and to survey the impacts on the

livelihoods of affected communities. Finally, Article 6.4 should inspire provisions to protect labour, gender and human rights, Indigenous people and local communities, to robustly share benefits with local communities, and to assess impacts on the Sustainable Development Goals.

Amendment recommendations

- ✓ **Biomass sustainability:** Adopt rules on biomass sourcing prohibiting conversion from land with high carbon stock and high biodiversity and avoiding the introduction of alien species, modified microorganisms and monocultures (CORSIA SAFs).
- ✓ **Land-use safeguards:** Follow Article 6.4 best practices to avoid conversion of culturally and environmentally relevant land and to assess the impacts on the livelihoods of affected communities.
- ✓ **Social safeguards:** Adopt Article 6.4-inspired provisions to protect labour, gender and human rights, as well as Indigenous people and local communities, to robustly share benefits with local communities, and to assess impacts on the Sustainable Development Goals.

3.6 Governance and scalability

General context: Governance provisions determine whether a certification framework is institutionally credible, publicly accountable and responsive to stakeholders. Scalability provisions determine whether a certification framework can be deployed rapidly across diverse contexts, integrated with other regulatory schemes and adapted to emerging technologies without becoming a bottleneck.

What LCAFs currently do: Governance oversight is provided by ICAO, with approved sustainability certification schemes acting as independent certification bodies. These schemes are required to have documented procedures for handling stakeholder input, complaints and non-conformities and non-compliance. Data for life-cycle emissions calculations and information about certification bodies must be publicly accessible. On scalability, the use of default values and look-up tables in life-cycle emissions calculations reduces the administrative burden, although it increases uncertainty. Pathway flexibility exists through a defined process for introducing additional fuel pathways, requiring Advanced Standards Transforming Markets (ASTM) certification and sufficient life-cycle emissions data.

What GBF alignment requires: GBF project developers should demonstrate financial security sufficient to cover long-term storage obligations, consistent with the EU CCS Directive. Certification fees should be transparently disclosed, following ICVCM standards. GBF certification should be formally recognised for compliance under ReFuelEU and EU ETS, reducing duplication for multi-jurisdictional suppliers. A structured methodology development and review process should be established, including scientific advisory input, public comment periods, and mechanisms to revise or withdraw methodologies generating overestimates. Finally, the LCAF acceptance mechanism for new fuel pathways should be extended to novel CCS configurations and emerging permanent CDR approaches.

Amendment recommendations

- ✓ Financial security and project credibility: Require GBF project developers to demonstrate financial security sufficient to cover long-term storage site obligations (closure, post-closure and remediation), consistent with the EU CCS Directive. For new pathways, require proof that the production process is validated at sufficient scale to reach commercialisation, following CORSIA's existing logic.
- ✓ Cost and revenue transparency: Require transparent disclosure of certification fees and, in future iterations, the price and volume of GBF credits, following the ICVCM's lead on cost transparency.
- ✓ Interoperability: Formalise inter-scheme recognition provisions. GBF certification aligned with CORSIA should be recognised for compliance purposes under EU policies (ReFuelEU, EU ETS) and vice versa, reducing duplication for multi-jurisdictional fuel suppliers.
- ✓ Structured methodology development: Establish a formal GBF methodology development and review process with expert and scientific advisory input, structured public comment periods, and mechanisms to revise, suspend or withdraw methodologies found to generate overestimates (see ICVCM).
- ✓ Periodic review cadence: Commit to regular framework reviews to keep GBF certification aligned with scientific developments, regulatory evolution and deployment experience, while limiting the frequency of changes to methodologies to preserve investment certainty for project developers, following Article 6.4.
- ✓ Flexibility for emerging pathways: Maintain and formalise the LCAF mechanism for adding new pathways, extending it explicitly to novel CCS configurations, new geological storage formations and emerging permanent CDR approaches.

