



Lifting Off: Analysis of Potential Carbon Offset Supply for CORSIA Phase I (2021-23)

June 2020

Photographer: Steven David Johnson

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Letter from the Authors

Since we began this analysis in December 2019, mandatory travel bans and lockdowns designed to tackle the spread of the COVID-19 virus brought international air travel to a grinding halt. The aviation industry group IATA estimates that 4.5 million flights have been cancelled and airlines will lose an estimated \$314 billion in revenue. While these events continue to unfold, we would like to share some thoughts on what these events mean for the original objectives of this paper.

Last year, uncertainty surrounding the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) could be distilled into two main questions: whether progress would be made in the Article 6 negotiations at COP25 in Madrid, and which programs the International Civil Aviation Organization (ICAO) Council would approve as Emissions Unit Programs in 2020. While the ICAO Council approved the list of Eligible Unit Programs for the first pilot phase in March 2020, a number of new questions have been raised about future supply and demand in CORSIA. These include:

- **Calls for renegotiation of airline baseline calculations:** The airline association IATA has recently pushed for countries to postpone CORSIA emission reporting deadlines for airlines, and to switch the baseline calculation from a 2019-2020 average to a 2019-only baseline. This intervention may or may not be addressed by the next scheduled ICAO Council meeting in June. [April 8, 2020]
- **Extensions of deadlines for airlines to report 2019 emissions data:** Eight countries have announced an intention to extend the May 31st deadline for their airlines.
- **Ability of airlines to report emissions and participate in CORSIA:** Both Avianca and LATAM, two Latin American airlines, recently filed for chapter 11 bankruptcy. More carriers may follow as a result of COVID-19. [May 11 and May 26, 2020]
- **Additional requirements for airlines to meet environmental targets, made conditional by government aid:** The French government has made AirFrance-KLM bailout money conditional on select climate change measures and the Austrian government is requiring a more stringent emissions reductions target for Austrian Airlines. These and other countries may use their COVID-19 response measures as an opportunity to strengthen both the financial and environmental sustainability of airlines. [updated as of June 11, 2020]
- **Uncertainty about finalizing post-2020 trading of offsets within CORSIA:** The United Kingdom government announced its intention to postpone this year's United Nations Framework Convention on Climate Change 26th Conference of the Parties (UNFCCC COP26) until November 2021, when the Article 6 negotiations (and related rules for double counting within CORSIA) will hopefully be finalized. [May 29, 2020]

While the underlying assumptions for demand used in this analysis remain in flux, we strongly believe that these findings bear relevance for decisions which may be made in the coming months. Additional research will be needed to further understand the impact of COVID-19 on the aviation sector and CORSIA in the coming months and years.

We will be following these decisions with interest, and with the hopes of being able to share lessons learned here with the broader carbon market community.

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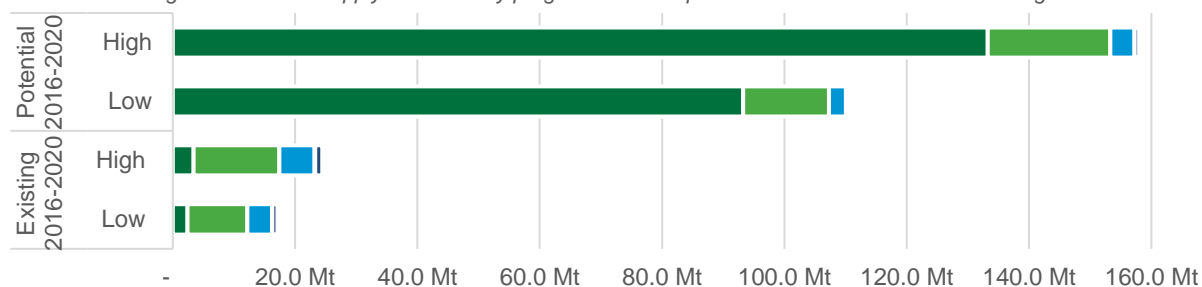
Key Findings

We evaluated the following five programs using publicly available data: The Clean Development Mechanism (CDM), Verra’s Verified Carbon Standard (VCS), the Gold Standard (GS), the Climate Action Reserve (CAR) and the American Carbon Registry (ACR). The China Certified Emission Reduction (CCER) program was not included in this analysis, due to a lack of publicly available data.¹

Using parameters from the recent ICAO Council decision on [CORSlA Eligible Emissions Units](#), we estimate **between 17–24 million tCO₂e (Mt) of CORSlA-eligible credits from the five programs** evaluated in this analysis are immediately available for sale; an additional *potential* supply between **111–158 Mt** from 2016-2020 could be produced; and a *projected* supply of **122–174 Mt** that stem from existing and registered pipeline projects in 2021-2023. An **additional 0-341.3 Mt** could be produced from natural climate solutions (NCS) activities between 2016-2023, contingent on approval from the ICAO Council and strong demand signals. Findings include:

- **CORSlA demand cover:** Based on pre-COVID demand estimates from ICAO², this supply would provide between 91%-131% of required volumes over the same time period. COVID estimates range widely; see section 2 for additional details.
- **Supply shortfall risk:** We anticipate a risk of undersupply of credits for use within CORSlA during the 2021-2023 period, if the potential supply of credits is not realized under the current list of eligible programs. These estimates may change if ICAO accepts [additional programs](#) later this year.
- **Natural Climate Solutions (NCS):** The role of existing NCS activities at this point appears limited in the initial crediting period to 2020. Given strong policy and market signals, NCS credits could contribute from 0-329.3 Mt (see section 3 for insights into the assumptions that result in this wide range of potential supply).
- **Data access, standardization and transparency:** Programs can and should provide better public data for ongoing evaluation, as data are currently difficult to access.

Figure 1 CORSlA supply estimates by program and time period evaluated with a 2016 crediting start



Program	Existing 2016-2020		Potential 2016-2020	
	Low	High	Low	High
CDM	2.4 Mt	3.4 Mt	93.3 Mt	133.2 Mt
VCS	9.8 Mt	14.0 Mt	14.0 Mt	20.1 Mt
GS	4.0 Mt	5.8 Mt	2.8 Mt	4.0 Mt
CAR	0.1 Mt	0.1 Mt	0.0 Mt	0.0 Mt
ACR	0.8 Mt	1.2 Mt	0.5 Mt	0.7 Mt
Total	17.1 Mt	24.5 Mt	110.6 Mt	158.0 Mt

¹ Analysis is based on public data found here: [CDM](#), [Verra](#), [GS](#), [CAR](#), and [ACR](#) (Note: Our analysis used data from Verra’s project database. This was migrated to Verra’s new project registry in April 2020.) While some CCER issuance information can be found in [individual project reports](#), the only database of CCER projects was [last updated in 2017](#) and does not have information needed to determine eligible CORSlA projects.

² [ICAO CAEP Analysis on the estimation of CO₂ emissions reductions and costs expected to result from CORSlA](#)

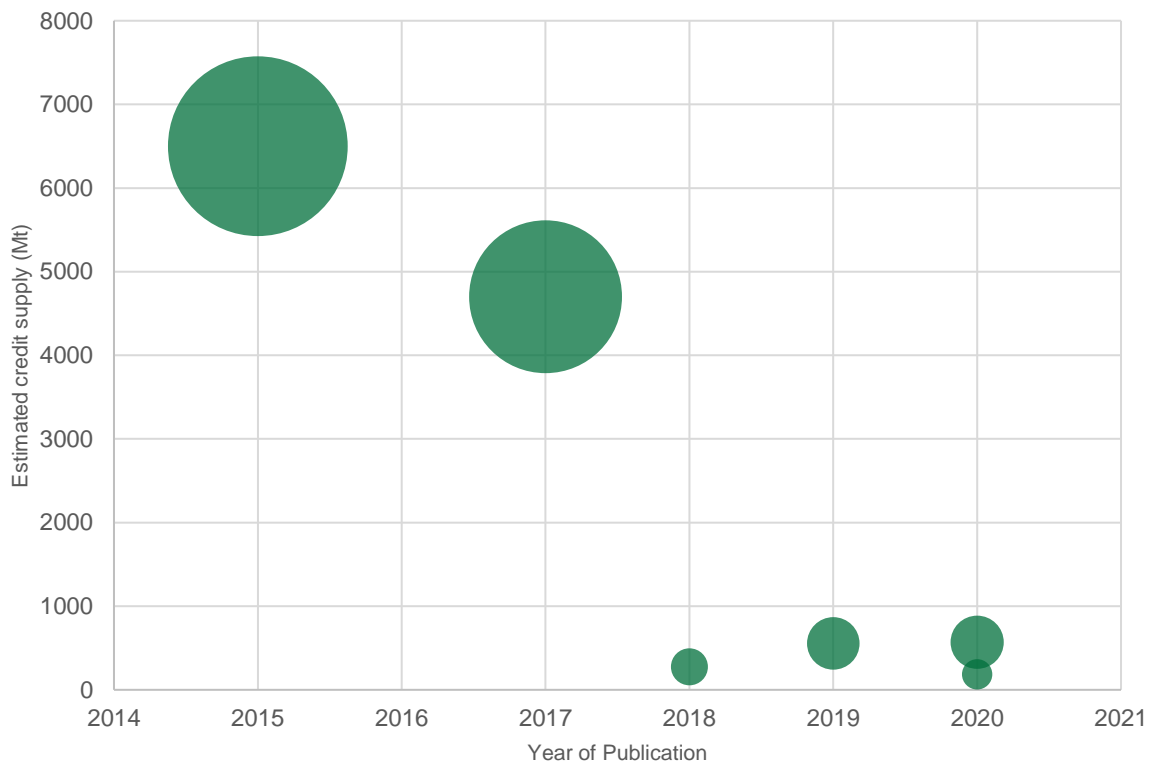
Literature Review

We conducted a literature review before embarking on our own analysis. **Most reported estimates of potential credit supply are out of date** and do not include the latest eligibility restrictions. See **Appendix** for more details.

Findings include:

- **Few estimates share pertinent details** about volumes by program or specifics of methodological choices, which can significantly influence calculations.
- **Few estimates consider alternative demand sources** (outside of CORSIA) and the effect on supply.
- **Estimates of potential supply have fallen drastically over the past five years;** yet older, out-of-date estimates remain regularly cited.

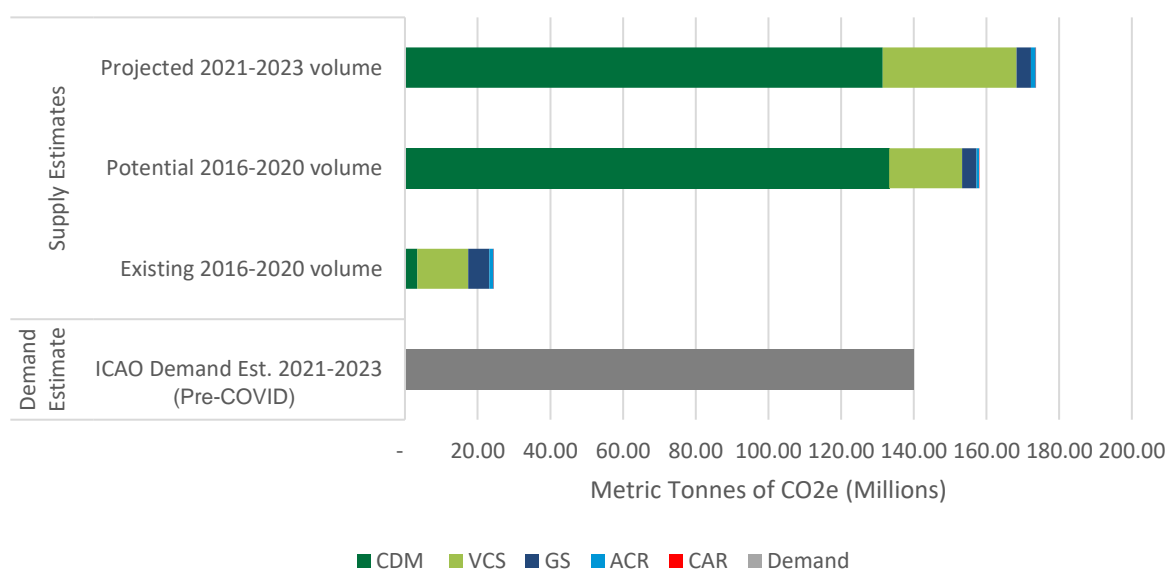
Figure 2 Literature review of CORSIA supply volume estimates, ranging for the pilot phase (2021-2023) across the entire CORSIA program (2021-2037)



1. The majority of eligible 2016-20 credits are not yet issued, presenting a high degree of uncertainty in available supply.

Based on our analysis we estimate that *existing* supply of net³ credits (verified minus retired and/or canceled credits) range between **17–24 Mt**. The same projects which have yet to verify volumes for this period have an estimated *potential* supply between **111–158 Mt**. Additionally, there is a *projected* supply of **121–174 Mt** that could be produced between 2021 to 2023, if the ICAO Council extends the eligible vintage dates past 2020. An **additional 8.7-329 Mt** could be produced from NCS activities between 2016-2023, depending on decisions made by the ICAO Council and by demand signals from CORSIA and other carbon credit buyers. Additional assumptions were made in these NCS-specific calculations: see page 5 for more information.

Figure 3 CORSIA "high" supply estimates by program and time period evaluated with a 2016 crediting start



Key assumptions used include (see Appendix I for more information):

- **For the “low” estimates, we assumed 30%⁴ of all existing, projected, and potential volumes would not be available for sale** to account for (i) time-delay lag between an over-the-counter (OTC) transaction and tracked retirement on a registry; and (ii) potential under-delivery from initial project estimates
- **Program-specific constraints include** assuming 100% of California-eligible credits in the Climate Action Reserve (CAR) and American Carbon Registry (ACR) plan to transfer to the California program and will not be available to meet CORSIA demand.⁵
- **Further constraints identified, but not accounted for here**, include variables such as non-quantified program pipelines, program specific rule-changes, host-country use in domestic programs (such as in Colombia, South Korea, South Africa, and China) and other sources of competing use, in particular from future demand from voluntary buyers.

³ Net supply estimated for all standards except CDM, for which this information was not available.

⁴ The 30% discount rate was chosen based on the authors' experience within the market; however, it is not based on any formal review or study. Should research become available, we would welcome the chance to update our analysis with such data.

⁵ Additional research is needed here. While this assumption is based on historical conversion of California-eligible credits from ACR and CAR, the California program will be limiting the use of carbon credits to 4% this year as opposed to 8% in the past. This may weaken demand from California compliance buyers.

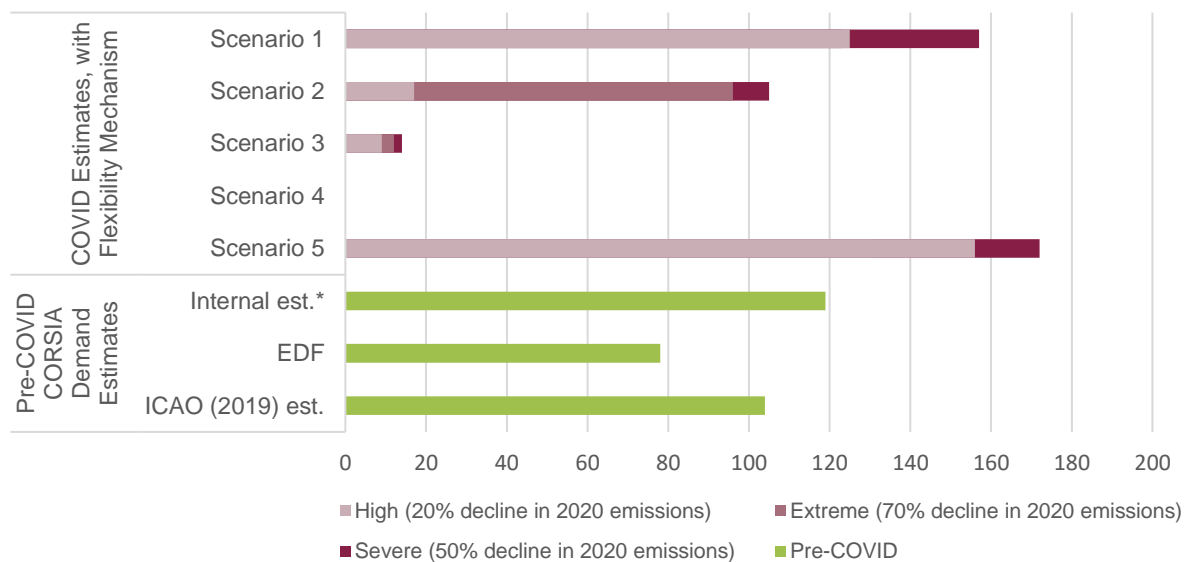
2. Supply shortfall risk within CORSIA’s first voluntary phase.

The first phase (2021-2023) of CORSIA is a voluntary phase, one which, as of April 3rd 2020, 83 countries have signed on to and represent 76.6% coverage.⁶ Here, we summarize a range of demand estimates, including that of ICAO, the Environmental Defense Fund (EDF)⁷, and our own estimates.⁸

However, it is important to note that COVID-19 has thrown these estimates into doubt. Pre-COVID estimates assumed that aviation emissions would increase throughout the first phase; now, analysts are considering various scenarios where flights return to pre-COVID levels or whether demand for flights will remain suppressed in the years following 2020. Figure 4 shows the [latest analysis by EDF](#),⁹ which modeled five scenarios for future flight emissions based on a 20%, 50% and 70% decline in 2020 airline emissions based maintaining the 2019-2020 baseline. If airlines were to use a 2019-only baseline, EDF calculates no credit demand in Scenarios 2-4, a range of 26-72 Mt (Scenario 1), and 37-105 Mt (Scenario 5).

The airline industry group IATA [has proposed dropping 2020 from the baseline calculations](#), and relying only on 2019 emissions data. The group worries that by keeping the 2019-2020 baselines, the precipitously low emissions this year will create an even bigger burden for airlines to comply under CORSIA in a time when airlines are already hurting financially. [Other groups have advocated for a wait-and-see approach](#), arguing it is better to wait and see how demand for future air travel is impacted before making a decision. These groups recommend keeping the rules as they stand until a more informed decision can be made at the next ICAO Council meeting in 2023, while relying on flexibility¹⁰ rules already embedded into the program to address immediate CORSIA compliance concerns.

Figure 4 CORSIA Demand and Supply Estimates in 2021-2023



* Demand estimate calculated by author (Zubair Zakir), are based on pre-Covid19 projected growth in international flights up to 5.7% per year.

⁶ <https://www.icao.int/environmental-protection/CORSIA/Pages/state-pairs.aspx>

⁷ [EDF – ICAO’s market-based measure – interactive tool](#)

⁸ These estimates are based on the assumption that near-term supply of sustainable aviation fuels (SAF) and use of SAF remains low. If there is a shift in the SAF market, that could further lower demand for credits under CORSIA.

⁹ EDF authors indicated to us that Scenarios 2 and 3 are the most likely.

¹⁰ [EDF – CORSIA and Covid-19](#)

3. Natural Climate Solutions (NCS) credits could be ramped up to meet anticipated shortfall

The role of existing NCS activities at this point appears limited in the initial crediting period to 2020 but could address an anticipated supply shortage, *if clear demand signals are given for jurisdictional REDD+*. Such signals could be provided through the full approval of the FCPF, Verra’s Jurisdictional and Nested REDD+ (JNR), the Architecture for REDD+ Transactions’ (ART) The REDD+ Environmental Excellence Standard (TREES), and the BioCarbon Fund’s Initiative for Sustainable Forest Landscapes (ISFL) in subsequent ICAO Council decisions.

NCS in the Climate Action Reserve and American Carbon Registry

Our analysis included one key assumption about the role of demand in the American Carbon Registry and Climate Action Reserve programs: that 100% of California-eligible credits will complete this transition instead of responding to CORSIA demand.¹¹ Based on our calculations, 100% of ACR projects eligible for California have transitioned, while an additional 38.8 Mt in CAR (of which **33.1 Mt** is NCS) could transition to the California market.

It is possible that some California-eligible credits are sold to CORSIA buyers; Table 1 calculates the volume of credits that are eligible for both CORSIA and California’s ETS. Where and whether credits are sold to each of these programs, or to the voluntary markets, will depend on competition for US credits by these various buyers. Further studies of demand estimates for domestic US voluntary action and for the California ETS would be worthwhile, in order to gain a deeper understanding of how these alternative demand sources might impact supply for CORSIA.

Table 1: Projected NCS supply for CORSIA, if sales shift from California’s Emission Trading Scheme to CORSIA

	Potential supply for 2016-2020	Projected supply for 2021-2023
CAR – all credits	46.4 Mt	28.2 Mt
CAR – NCS only credits	39.8 Mt	25.6 Mt
ACR – all credits	93.9 Mt	59.3 Mt
ACR – NCS only credits	85.5 Mt	56.0 Mt

NCS in Verra’s VCS and JNR Standards

Based on the Technical Advisory Body’s recommendations, ICAO approved a handful of NCS methodologies as eligible under Verra’s **VCS Standard** in March 2020. These specific project-based methodologies are: VM0012, VM0022, VM0026, VM0033, VM0036, and VM0040. Based on our analysis, none of these methodologies have projects that began a crediting period after 2016. Therefore, our analysis predicts that there will not be any eligible supply from these approved NCS methodologies for the first pilot phase of CORSIA.¹²

This could change if the ICAO Council approves additional VCS methodologies. When Verra recently submitted [additional documentation](#) for its conditionally eligible JNR Standard, it also included a proposal for its already-approved VCS standard. The proposal would allow for more NCS project-based methodologies, which Verra argues do not need to be nested because the activities present a low risk of leakage. This could change the immediately available supply of NCS credits.¹³

¹¹ This assumption is based on historical conversion of California-eligible credits from ACR and CAR. However, the California program will be limiting the use of carbon credits to 4% this year as opposed to 8% in the past and has introduced a new restriction for buyers to purchase 50% of offsets from projects with a “direct environmental benefit” in the state. These new regulations may change the future rate of conversion.

¹² This is based on our analysis of existing and pipeline projects. However, now that ICAO has clearly defined which methodologies are allowed, there could be new projects that appear in the pipeline in 2020 onwards. Additional analysis in the future could examine whether the ICAO decision has spurred new NCS projects within Verra.

¹³ More research is needed to understand how much supply would be available here.

All other NCS projects will need to transition to Verra’s conditionally eligible **Jurisdictional and Nested REDD+ Standard**; furthermore, only those projects that are able to successfully integrate into either JNR’s Scenario 2 or 3 restrictions will be eligible. This means that stand-alone projects using a jurisdictional baseline will not be recognized (Scenario 1). Instead, all projects will need to be fully integrated (“nested”) within Scenarios 2 and 3. At the moment, no JNR programs exist across Scenarios 1 – 3. It is possible, however, that projects could migrate to Scenario 1, which Verra notes “may be the first phase of jurisdictional program development.”

If projects were to transition into Scenario 2 or 3, it is possible that a number of NCS credits could be eligible for the pilot phase of CORSIA. Currently, there are:

- an estimated **89.8 Mt** credits in Verra’s pipeline that *could* be active from 2021 – 2023,¹⁴
- an estimated **1.2 Mt** credits available from NCS projects with a 2016+ start date,
- an estimated **25.2 Mt** credits available from NCS projects with a 2013+ start date, and
- an estimated **111.3 Mt** credits available from NCS projects with a 2010+ start date.

Why are we including earlier start dates? It is likely that project developers will need to recalculate their baselines and other project elements when transitioning to Verra’s JNR Standard. If these changes are significant, it is possible Verra might recognize those projects as newly started. That said, projects transitioning from a trendline to a jurisdictional historical baseline will likely face significant cuts to their original baselines. **Here, in order to be conservative, we estimate that projects would have to reduce their emissions by half.**¹⁵

Based on these calculations, it is possible that NCS projects could transition into either Scenario 2 or 3 and represent **113.7Mt**, but this relies on the speed at which jurisdictions – many of which may not have considered REDD+ before – can implement the JNR Standard.

NCS in the Forest Carbon Partnership Facility

In March 2020, the ICAO Council recognized the **World Bank’s Forest Carbon Partnership Facility’s (FCPF) Carbon Fund** as conditionally eligible. The Carbon Fund serves as both a fund and a standard for jurisdictional REDD+: the Fund developed its Methodological Framework back in 2013 to provide guidance to tropical forest countries seeking to receive payments for REDD+ emissions reductions. Currently, 11 contributors have committed \$902.7M in this fund for the 19 recipient countries working on REDD+ emissions reductions.

In reality, though, only a fraction of these emissions reductions might be eligible for CORSIA. That’s because there are two tranches within the Carbon Fund: Tranche A and Tranche B. Contributors to Tranche A will receive transferrable emissions reductions, while donors to Tranche B will be paying for results but will not receive any credits. Currently, the majority of contributors have made investments into Tranche B by using Overseas Development Aid. **Of \$902.7M committed to the Carbon Fund, only 5.2% has been committed to Tranche A.**

Assuming that all recipient countries agree to sell emissions reductions at \$5/tCO₂e – which has been the case for the four countries (Democratic Republic of Congo, Chile, Ghana, and Mozambique) that have so far signed Emissions Reductions Purchase Agreements – this means that an **estimated 8.7 Mt** will be available for sale through Tranche A, with call options that could result in a slightly higher volume. **This is out of an estimated 186.5 Mt that could be produced by recipient countries by 2025.**¹⁶

¹⁴ We identified 30 NCS projects in Verra’s pipeline, but it is possible that these projects have been abandoned. These projects comprise nearly all of Verra’s pipeline of projects – non-NCS projects would produce an estimated additional 5.5 Mt.

¹⁵ A 50% reduction is used in an effort to be conservative; more research is needed to determine what an average cut is for projects transitioning to a nested REDD+ program.

¹⁶ <https://www.forestcarbonpartnership.org/carbon-fund-dashboard>

Table 2: List of Tranche A Contributors¹⁷

Tranche A Contributors	Total Funding	% of Total Funding (linked to % of ERs received)
Australia	\$18.4M	2.0%
BP Technology Ventures	\$5.0M	0.6%
The Nature Conservancy	\$5.0M	0.6%
United States	\$18.5M	2.0%

Clearly, Tranche A might not provide an initial substantial volume. However, this underscores the need and opportunity for future FCPF emission reductions in CORSIA. Most countries have included only a single jurisdiction of varying sizes in their REDD+ programs for the Carbon Fund. **With additional demand signals, countries could much more easily scale existing programs to encompass new jurisdictions**, based on the years of work setting up the technical monitoring and capacity building for REDD+ programs in-country.

NCS in ART/TREES and the Carbon Fund’s ISFL

In [ICAO’s second call for applications](#) in April 2020, both ART/TREES and BioCarbon ISFL applied. Additional analysis is needed to determine the projected and potential 2016-2023 volumes from these programs: however, at the very least, ART/TREES will potentially produce up to 12 Mt as noted in the Letter of Intent between Gabon and the Central African Forest Initiative.¹⁸ Many other tropical forest countries have spent years finalizing their REDD+ readiness activities and have capacity to begin monitoring results, so it is also possible that additional volumes could be produced. Additional analysis is needed.

Total Potential NCS Supply for CORSIA

In conclusion, NCS projects and programs could provide an additional **341.3 Mt** not currently anticipated by this analysis, if the right guidance and signals are made. However, this is likely an overestimate of what could realistically be produced, even with strong policy support for NCS and before considering other sources of potential demand for the same units. Should further sources of NCS-credit supply not be approved for use under CORSIA in the voluntary pilot phase, near-term supply options may need to consider activities with a pre-2020 credit start date.

Table 3: Summary of projected NCS supply volumes that could potentially be available for CORSIA

	Actual supply for 2016 – 2020	Projected supply for 2016-2020	Projected supply for 2021-2023
Verra	0 ¹	0	113.7 Mt ²
CAR	33.1 Mt ³	39.8 Mt ⁴	25.6 Mt
ACR	0	85.5 Mt ⁴	56.0 Mt
FCPF	0	0	8.7 Mt (more research needed on ability to scale)
TREES	0	0	12 Mt (more research needed on ability to scale)
ISFL	0	0	(more research needed on ability to scale)
Total	0	125.3 Mt	216.0 Mt

¹This might change if the ICAO Council recognizes additional VCS methodologies, as proposed in Verra’s latest application.

² Assuming all Verra NCS projects excluded by the TAB can successfully transition to Scenario 2 or 3 under Verra’s JNR Standard, and in the process earn a new project start date. It is not likely that all projects would be able to complete this transition, and those that did would likely have much lower baselines than before. Thus, we estimate only 50% of the estimated 227.5 Mt volume might make this transition successfully.

³ We estimate 100% of this supply will transition into the California market. However, future demand may change and warrants further research.

⁴ We also assume earlier in this report that 100% of this supply will transition into the California market. However, there is a better chance that this supply could be used for CORSIA instead, if demand is high.

¹⁷ <https://www.forestcarbonpartnership.org/system/files/documents/FMT+Note+CFM-2019-2+FCPF+CF+Budget+FY20.pdf>

¹⁸ <https://www.cafi.org/content/cafi/en/home/all-news/gabon--first-in-africa-to-receiving-payments-for-preserved-rainf.html>

4. Data access and transparency remains an issue

As ICAO did not offer a public comment period around the decision to limit eligible projects to those beginning a crediting start date in 2016 or later, negotiators often relied on their own analyses or external analyses for insights on how such a decision would affect the supply of credits. There are several issues with this, including:

- 1. Public estimates of Clean Development Mechanism (CDM) credit supply ranges vary widely:** from estimates of 4.3-6.5 GtCO₂e by 2030 to 0.1-2.9 GtCO₂e, depending on restrictions and assumptions applied. These various approaches also make it difficult to compare the analyses side-by-side. Existing literature has broad estimate ranges, with analysis that cannot easily be cross compared; assumptions buried into report details; and static information which does not reflect the rapidly changing/evolving landscape of domestic actions. There is a need for reliable and unbiased analysis, where assumptions are clearly delineated and comparable within current and upcoming UNFCCC and ICAO markets discussions.
- 2. Public data from other programs (American Carbon Registry, Climate Action Reserve, Gold Standard, Verra) varies and often does not contain details relevant to the TAB decision. This includes critical information around a project's first crediting period.** While these programs have this data available upon request, it is not public like that of the CDM and presents a transparency issue to researchers and companies looking to understand the market for CORSIA.
- 3. Finally, we were not able to include any research around existing or potential supply of credits from China's GHG Voluntary Emission Reduction Program, which does not appear to have any public data.**

5. Recommendations:

As CORSIA becomes operationalized and airlines look to purchase carbon credits¹⁹, there is a need for industry-wide data integrity standardization. While these data are available to market participants, stakeholders and policymakers today, it is difficult to access and to compare. Such alignment would make it easier to predict current and future supply and would also benefit policymakers across other negotiating forums such as those in Article 6. We recommend proactively engaging both the approved programs (CAR, ACR, GS, VCS, CDM, CCER) and those seeking approval (FCPF, JNR, ART/TREES) to discuss these findings, including the limitations of analysis possible with data currently provided and the benefits available through standardised data reporting. In particular, the fact that CCER issuance data has not been updated since 2017 is concerning.

Additional research is needed to better understand competing demand for CORSIA-eligible credits. Nearly all of the studies we reviewed prior to this (see Appendix II for more details) did not consider the impact than non-aviation buyers would have in the market. Our analysis did account for offsets already retired on the voluntary markets or transitioned for use within the California ETS; however, additional analysis could be used to better understand future demand within the California market. Also, we did not examine data from other current and upcoming markets, such as those in Korea, Colombia and China. Such data could reduce the amount of available supply of CCER or CDM credits. Furthermore, our analysis did not consider supply constraints that may arise from countries seeking to keep emissions reductions for use towards their own Nationally Determined Contributions (NDCs).

Competing demand considerations are especially relevant for NCS credits: while our analysis of supply and demand revealed that few NCS credits will initially be available under CORSIA, this is due to pre-existing demand in other markets. Most California-eligible credits under CAR and ACR, for example, come from forestry projects. Though Verra does not have any existing NCS projects that meet the ICAO Council criteria, 42% of all Verra-issued credits come from NCS projects. The volume of NCS-issued credits has been rising for the last couple of years, with 72% of Verra's issuances in 2019 coming from NCS projects as opposed to only 38% in 2016.²⁰ More research is needed to determine if and how quickly NCS supply can ramp up to meet additional demand from CORSIA.

¹⁹ <https://ww3.arb.ca.gov/cc/capandtrade/capandtrade.htm>

²⁰ <https://verra.org/datainsights/april-2020/>

Appendix 1: Methodology

Our analysis focused on four main indications of supply:

Verification supply (where possible) or issuance supply, based on a crediting start date or estimated project start date of 2016 or later and with a 2020 cut-off. Programs (also called standards) do not share the same types of data so we used conservative assumptions when making this data comparable:

- **CDM:** Crediting start date used.
- **Verra:** Verification period of projects used – the first year of the first verification period was used to find crediting start date.
- **Gold Standard:** Monitoring periods (i.e., verification period) of projects used: the first year of the first verification period was used to find crediting start date.
- **Climate Action Reserve:** Single vintage years were provided for issuance batches (no verification or monitoring periods were publicly available). The oldest vintage year associated with each project is assumed to be the crediting start date.
- **American Carbon Registry:** Single vintage years were provided for issuance batches (no verification or monitoring periods were publicly available). The oldest vintage year associated with each project is assumed to be the crediting start date.

Retirement or cancellation volume, where available, that represent unavailable supply:

- **CDM:** Trackable retirement volumes not available (these are housed in individual country registries not accessible to the public, or in the voluntary cancellation spreadsheet which provides insufficient data to track against issuances volumes.)
- **Verra:** Trackable retirement and cancellation volumes are available. Cancellation volumes show credits transferred to California’s Air Resources Board (ARB). Since the total number of Verra credits cancelled is minimal, this data was not included in our analysis.
- **GS:** Trackable retirement volumes are available.
- **CAR:** Trackable retirement and cancellation volumes are available. Cancellation volumes show credits transferred to ARB. *We assume 100% of ARB-eligible credits plan to transfer to the California program and will not be available to meet CORSIA demand.*
- **ACR:** Trackable retirement and cancellation volumes are available. Cancellation volumes show credits transferred to ARB. *We assume 100% of ARB-eligible credits plan to transfer to the California program and will not be available to meet CORSIA demand.*

Projected volumes:

- **CDM:** Crediting period used to estimate remaining years that the project can verify activities through 2016-2023.
- **Verra:** Verification period used to estimate whether future verifications from 2016-2023 have not occurred and estimated those volumes.
- **GS:** Monitoring period used to estimate whether future verifications from 2016-2023 have not occurred and estimated those volumes.
- **CAR:** Earliest vintage date used (assumed 7-year crediting period restricted to 2016-20).
- **ACR:** Earliest vintage date used (assumed 7-year crediting period restricted to 2016-20).

Pipeline project volumes:

- **CDM:** Pipeline projects are publicly available; however, projects that intend to seek retroactive CDM credits for existing activities can submit “Prior Consideration” documentation that does not include estimated or anticipated emissions reductions.²¹
- **Verra:** Pipeline projects are publicly available, but no information is given about whether projects have been abandoned. Since pipeline projects are listed in ascending date, we assume any pipeline projects that were first listed in 2015 or earlier have been abandoned.
- **GS, CAR, ACR:** Pipeline projects not available.

²¹ <https://cdm.unfccc.int/Projects/PriorCDM/notifications/index.html>

Appendix II: Literature Review

Publication Name	Publish Date	Authors	Start date	End date	Est. Volume
Analysis of Potential Carbon Offset Supply for CORSIA Phase I (2021-23)	2020	The Nature Conservancy, Anthropocene LLC	2016	2020	185 Mt
Carbon Markets Are Well-Positioned to Meet CORSIA Demand Projections	2020	Ecosystem Marketplace, Environmental Defense Fund	2016	2020	569 Mt
Offset credit supply potential for CORSIA	2019	New Climate Institute, DEHSt, Stockholm Environment Institute	2017	2035	555 Mt
Discussion paper: Marginal cost of CER supply and implications of demand sources	2018	New Climate Institute, DEHSt	2013	2035	275 Mt
Using the Clean Development Mechanism for nationally determined contributions and international aviation Assessment of impacts on global GHG emissions	2017	Stockholm Environment Institute	Any start date, vintage 2013 - 2020	2035	4.7 Bt
Availability of offsets for a global market-based mechanism for international aviation	2015	Öko-Institut	No start date, no vintage restrictions	2035	6.5 Bt

Publication

Analysis

	CDM + Pipeline	Verra + Pipeline	GS + Pipeline	ACR + Pipeline	CAR + Pipeline	CCER	Demand estimated?
Analysis of Potential Carbon Offset Supply for CORSIA Phase I (2021-23)	3Mt + 133Mt	15Mt + 22Mt	6Mt + 4Mt	1Mt + 1Mt	1Mt + 0Mt	Could not find useable information ²²	California-eligible ACR and CAR credits assumed retired; all retired credits from Verra, GS, CAR and ACR assumed to be retired
Carbon Markets Are Well-Positioned to Meet CORSIA Demand Projections	168Mt	Not disclosed by individual standard + 183Mt	Not disclosed by individual standard	Not disclosed by individual standard	Not disclosed by individual standard	Not disclosed by individual standard	All issued Verra, GS, CAR and ACR credits assumed to be retired
Offset credit supply potential for CORSIA							
Discussion paper: Marginal cost of CER supply and implications of demand sources	275Mt (combined current + pipeline)						
Using the Clean Development Mechanism for nationally determined contributions and international aviation Assessment of impacts on global GHG emissions	4700Mt (combined current + pipeline)						
Availability of offsets for a global market-based mechanism for international aviation	6500Mt (combined current + pipeline)						

²² While some CCER issuance information can be found in [individual project reports](#), the only database of CCER projects was [last updated in 2017](#) and does not have information needed to determine eligible CORSIA projects.