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Superpollutants: Tackling a Major Climate Threat

Prepared by The Carbon Containment Lab and Calyx Global

REPORT

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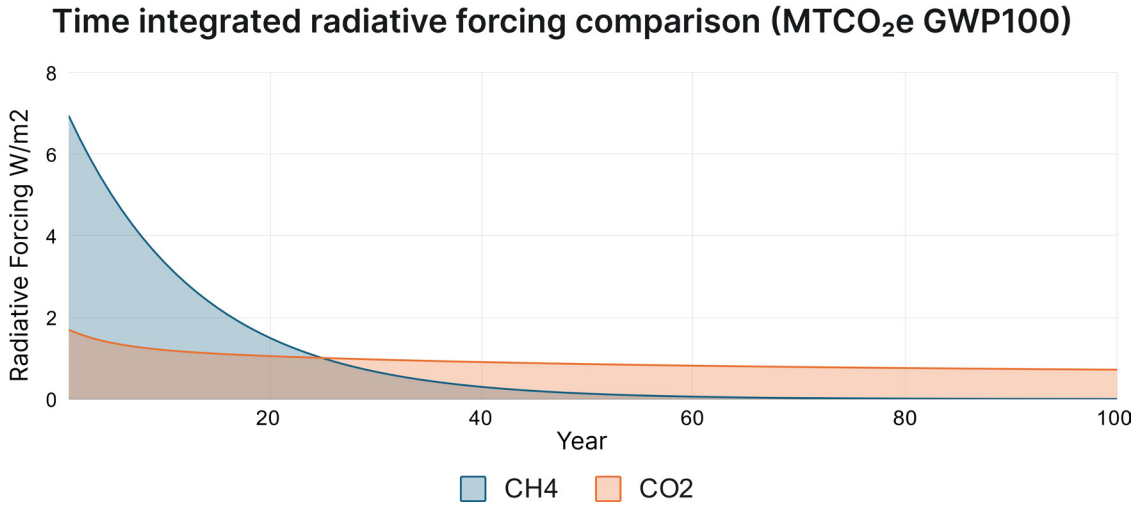
Superpollutants are a major planetary threat

Accessible, affordable action that will immediately and drastically slow near-term climate warming is at our fingertips. As we exceed 1.5°C, damages in the near term are large and growing exponentially due to a subset of greenhouse gases—superpollutants—that create high near-term global warming. Climate leaders Google, Netflix, Workday, and others are adding these gases into the core of their climate action playbooks, scaling their investments up quickly to address the climate crisis.[1] [2] [3]

Superpollutant emissions are key contributors to near-term warming. Gases such as methane, nitrous oxide, and fluorocarbons are responsible for approximately half of the warming observed today.[4] Each of them has properties that accelerate warming in the near term, with warming effects of 100s or 1000s of times that of carbon dioxide. Superpollutant emissions have an outsized effect on the current rate of warming, whereas carbon dioxide (CO_2) emissions are more deterministic of the ultimate extent of warming over longer time periods. By reducing emissions of superpollutants, we can achieve an immediate reduction in the rate of warming, buying our planet critical time by bending the climate curve when it matters most.

To put the challenge into context, studies suggest that mitigating the entire stock of superpollutants could avoid more than half a degree Celsius of warming by midcentury and over one degree by the end of the century.[5] Investing in superpollutant mitigation may be among the best uses of climate capital today.



Source: Takahashi & Crotty, 2025, in prep.

***Figure 1. The impact of superpollutants on global warming is more potent in the near term**, which is why they are also sometimes referred to as "short-lived climate forcers." Historically, gases have been quantified in terms of their equivalence to the avoided or removed emission of one metric ton of CO_2 in units of aggregate radiative forcing over 100 years. To illustrate, Figure 1 shows that one ton of CO_2 emitted in the first year will persist in the atmosphere and contribute to radiative forcing over centuries, whereas one $MTCO_2e$ of CH_4 over 100 years behaves differently. It initially contributes much more to radiative forcing, with an outsized impact in the near term, and a lesser impact in the long term.[6] With annual superpollutant emissions from anthropogenic sources estimated to be around 15 billion metric tons of CO_2 equivalent ($MTCO_2e$)[7], there is potential for a wide variety of policy and market measures to mitigate near-term warming.*

We have the tools to mitigate superpollutants today

We know many of the key actions that are needed to reduce superpollutants and their potential impact. Methane, nitrous oxide, fluorinated gases, and black carbon are emitted from well-understood sources. For many of these sources, policy measures are in place, or emerging and mitigation activity is underway. These elements provide the groundwork to scale now, with significant impact.[8]

	Methane	Nitrous oxide	Fluorocarbon	Black carbon
Key considerations	Methane has caused half of the total observed warming since the Industrial Revolution.[9]	Nitrous oxide has the same global warming potential over both 20-year and 100-year timescales.[10]	Fluorocarbons comprise a wide variety of compounds, each with distinct GWP values from the tens to over 10,000. Vast banks of fluorocarbons (HFCs, ODS) still exist even with the phaseout and phasedown of the highest GWP gases under the Montreal Protocol.	Black carbon is a particle rather than a gas. It contributes to warming when it absorbs sunlight and releases it as heat.[11] Black carbon is released by incomplete combustion processes.
Examples of mitigatable sources	Manure, livestock, rice cultivation, mines, wastewater, landfills.	Adipic acid in nylon production, manure, fertilizer use, tilling soils, burning crop residues.	Venting and leaks of high-GWP refrigerants from refrigeration and air conditioning equipment.	Fossil fuel combustion, municipal solid waste, diesel engines, kerosene lamps, fuelwood or charcoal cookstoves, steel and brick kilns, agricultural residue.
Impact opportunity	**0.2°C of warming** can be avoided by 2050 by mitigating just 30 percent of the 11 billion $MTCO_2e$ GWP100 of methane emitted annually.[12]	**0.1°C of warming** can be avoided by 2050[13] by cutting anthropogenic emissions, currently at annual levels of 2.79 billion $MTCO_2e$[14] [15], by 50-75 percent.	**0.5°C of warming** can be avoided by 2100 by achieving complete international compliance with the Kigali Amendment to the Montreal Protocol.[16] Potential for further reducing emissions of ~2 $GtCO_2e$ / yr by 2050 and ~3-4 $GtCO_2e$ / yr by 2100.	**0.2°C of warming** can be avoided by 2050[17] with aggressive reduction of current emissions of approximately 5.2 billion $MTCO_2e$ annually[18] [19]. Reductions also achieve substantial improvements in local air quality, public health, and food security.[20]

Many of these activities are possible today. This is evidenced by international and national policies, industry commitments, and the voluntary carbon market (VCM). Considering the last, Figure 2 illustrates the mitigation activities within the VCM that delivered emission reductions in 2024. The VCM, in part, is serving as a proving ground for financing, implementing, and verifying the abatement of these emissions. It also hosts a pipeline of up-and-coming activities that reduce superpollutant emissions. These currently include mitigating methane from manure, followed by landfill gas capture/flaring, rice methane management, biodigesters, and wastewater methane management.[21] While there is ongoing and necessary improvement in impact measurement based on the latest scientific knowledge (see discussion on integrity below), the mitigation activities that are underway (credit issuances) and planned already provide a blueprint for activity that can be accelerated.

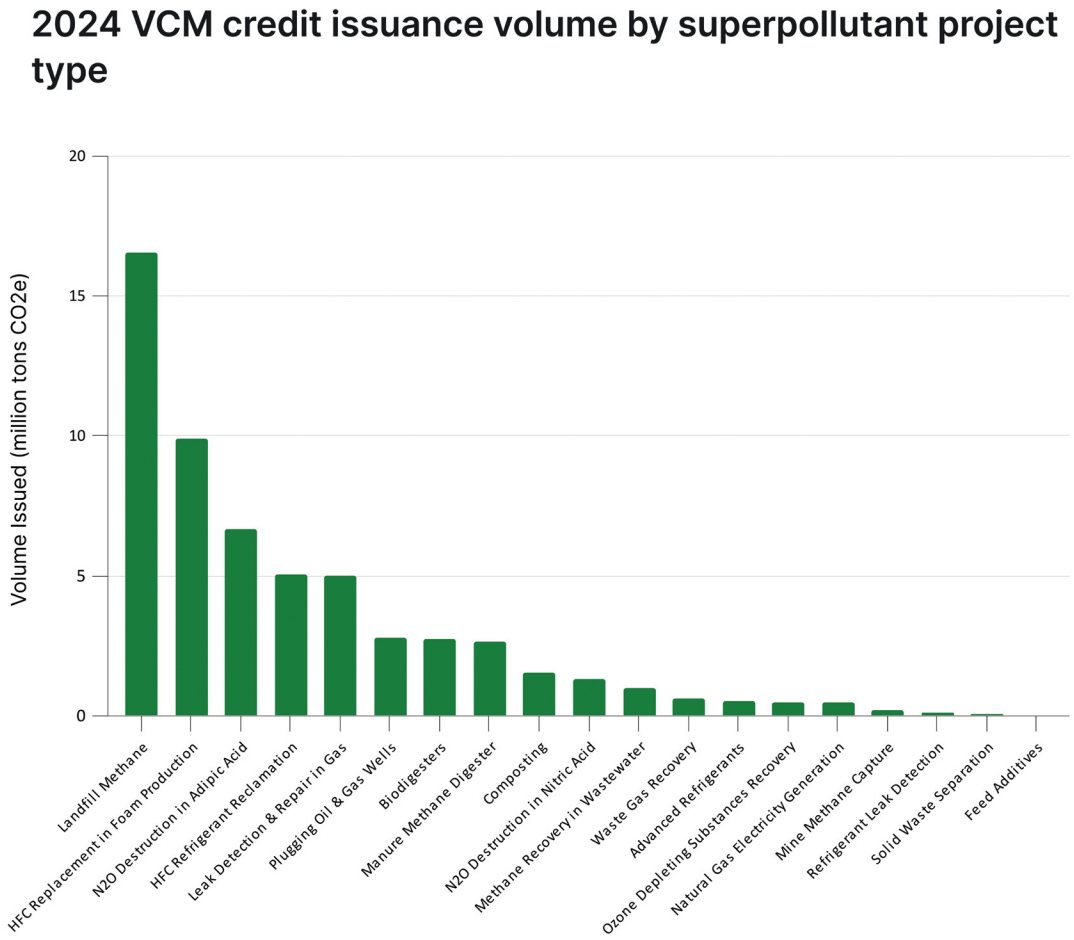


Figure 2. Superpollutant mitigation activity (illustrated by credits issued in the VCM in 2024) provides a view into what is both feasible and affordable in the very near term for climate action*. Methane mitigation represents the largest share of activity to date compared to nitrous oxide and fluorocarbons. Methane abatement—through flaring or capturing landfill gas and, more recently, addressing leaks in transmission lines or orphaned wells and capturing gas from mines, manure, or wastewater—comprises over 50 percent of the superpollutant credits issued. In terms of available carbon credits (i.e., those issued but not yet retired or used) from these types of activities, landfill gas (41 million credits), HFC replacement (36 million credits), leak detection and repair (25 million credits from less than 10 projects), and biodigesters (14 million credits) offer the highest volumes. Expanding the view to include California's Air Resources Board-eligible credits brings mine methane and manure methane digesters into the picture, each with just over 10 million credits available. Issuance figures do not include credits issued via the Clean Development Mechanism.*

Governments play an important role through regulation of these substances, but the voluntary carbon market can also play a role where regulation is not possible, to support innovation or build political will for future regulation. Projections from the Carbon Containment Lab indicate one billion $MTCO_2e$ of mitigation via the existing VCM is likely in a business-as-usual scenario (BAU) by 2023 (see Figure 3), and, in a more aggressive scenario, 3.5 billion $MTCO_2e$ is within reach by 2035.

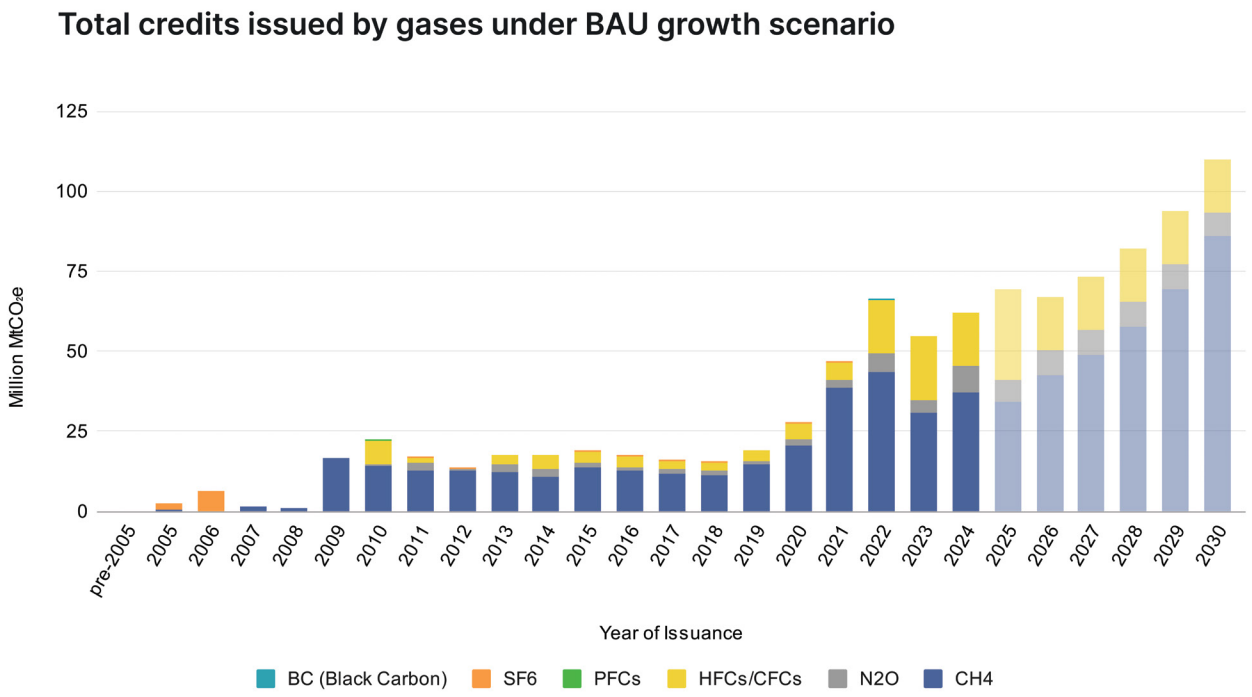


Figure 3. Projections show business-as-usual growth, and there is significant potential to accelerate with investment beyond these rates. *By applying a growth rate to existing data on voluntary carbon credits from the four largest registries (ACR, Climate Action Reserve, Gold Standard, and Verra) for superpollutants, three scenarios were modeled: business-as-usual (BAU), medium, and aggressive growth rates. The BAU pathway was generated by applying the compounded annual growth rate observed from 2014 to 2024. This reflects a cumulative total of 0.467 billion $MTCO_2e$ for 2025–2030. In the aggressive-growth pathway (applying the BAU plus a 20 percent growth per year), credit issued volumes are projected at roughly 0.705 billion $MTCO_2e$ for 2025–2030. Figures for 2025 include actuals through June, and projections through December. Of course, different types of projects face different drivers and constraints than in the past, and project activity will vary based on region and demand.*

Scale is achievable but activities in the VCM will require improvement. Calyx Global has generated over 1000 greenhouse gas integrity ratings and found that 40 percent of superpollutant ratings fall into the Tier 1 range—the top tier for greenhouse gas integrity (AAA, AA, or A)—compared to only one percent of non-superpollutant credits (see Figure 4). While superpollutant credits tend to make stronger climate benefit claims compared to non-superpollutant credits, over half remain in the lower tiers, suggesting considerable room for improvement. Fortunately, addressing these issues is possible and the market is seeing steady improvement in carbon credit quality. The stakes are high and getting it right matters to earn the confidence of buyers and the broader public that is needed to scale the market and accelerate mitigation activities more broadly.

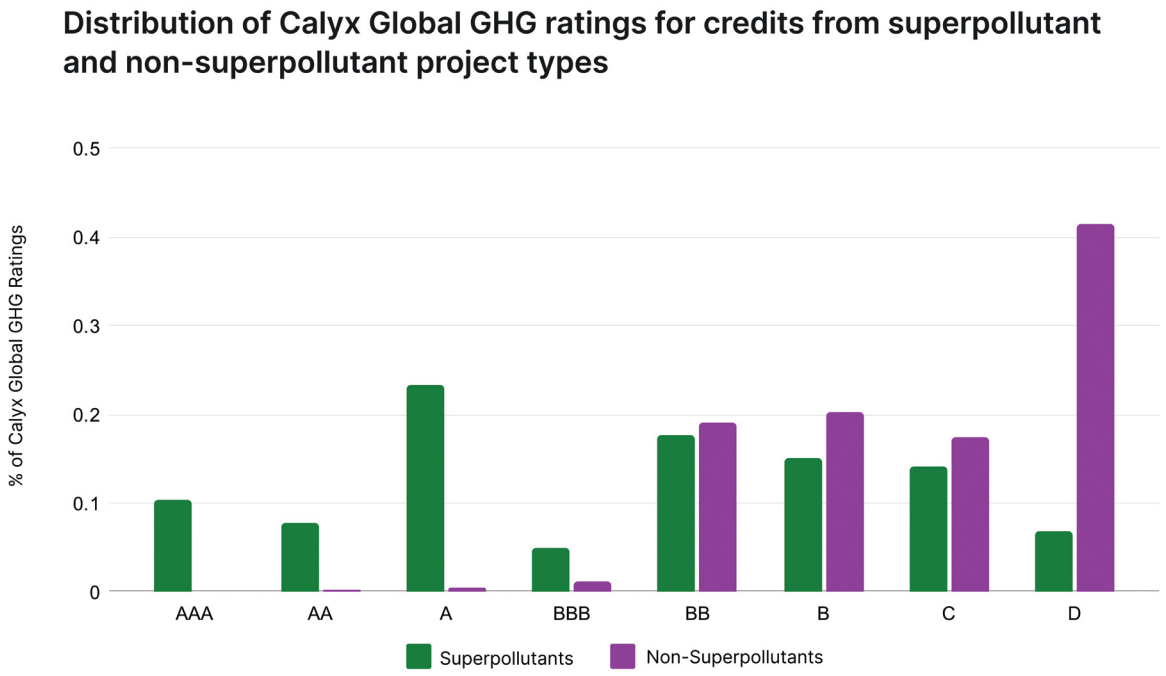


Figure 4. Ratings of superpollutant credits versus other credit types. *Among Calyx Global's 1000+ ratings, superpollutant credits tend to have higher GHG integrity, on average, than all other project types (e.g., forestry, renewable energy, etc.). This is not to suggest that other projects cannot achieve higher integrity. We note that many other project types—in particular, nature- and household-based (e.g., cookstove) projects–are undergoing methodology revisions that we believe will change the distribution of these ratings over time.*

Finally, there is still space to innovate, scaling new mitigation technologies and new approaches to support early-stage projects. While policy and carbon market activity is underway for some of the major sources of superpollutant emissions, there are still many superpollutant emissions that need attention. For example, the Carbon Containment Lab has identified natural and agricultural sources of methane emissions for which mitigation pathways are being tested.[22] In addition, novel approaches to gathering and mitigating disparate sources of HFC emissions are being developed with the help of new traceability technology. Existing mitigation pathways can also be applied in new regions. However, for these pathways to operate in the market, new methodologies may need to be developed, and regional capacity needs to be built. Furthermore, funding would be required for field testing, measurement, and analysis to meet the rigors of carbon credit markets.

Lead the charge: Address near-term warming by supporting superpollutant mitigation

Companies can "bend the curve" of warming by supporting superpollutant mitigation. With more certain demand, supply will follow. Purchasing high-quality superpollutant credits sends a signal that will accelerate new mitigation projects. Currently, high-quality superpollutant credits trade at prices far below lower-quality credits.[23] In other words, companies can have more impact at a lower cost by supporting superpollutant mitigation.

Join companies, including Google, Netflix, and Workday, that have made tackling superpollutants part of their climate action playbooks. Many companies are creating carbon credit portfolios. Some are going further by entering into forward offtake agreements and helping to build new projects with their investments and technical support. We believe it is worthwhile to consider such credits—alongside CO_2-focused credits including removals—as part of a company's climate strategy. **The fact is, we need it all.**

About us

Carbon Containment Lab

The Carbon Containment Lab is a nonprofit organization that creates an enabling environment for emerging climate solutions by applying scientific, entrepreneurial, and investment expertise. Founded in 2020 at Yale University, it became an independent 501(c)(3) charitable organization in 2024. The Lab partners widely and draws inspiration from academics, practitioners, past efforts, and parallel fields. Our superpollutant publications can be found at: https://carboncontainmentlab.org/programs/super-pollutants

Calyx Global

Calyx Global empowers companies to make high-impact carbon credit decisions through independent, rigorous carbon credit ratings, investment decision tools and research. Their expert team provides unbiased analysis of carbon credit integrity across greenhouse gas claims, Sustainable Development Goals and social and environmental safeguards. Recognized as the most reliable carbon credit rater by Carbon Market Watch, Calyx Global has evaluated the majority of credits available on the market, with over 1,000 projects and counting. To learn more about superpollutant carbon credits and credit quality, visit www.calyxglobal.com.

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Citation

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Endnotes

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