CARBON LIMITS

GHGSAT

Low Cost, High Impact: Satellite Insights on Global Methane Super-Emitters



Significant reductions in methane emissions are necessary to meet global targets and reduce the effects of climate change. According to IEA's Net Zero Emissions by 2050 Scenario, "just over USD 75 billion in cumulative capital and operating expenditure is required globally over the period to 2030 to achieve [a reduction of 2 Gt CO_2eq] in oil and gas methane emissions".[i] Abatement of super-emitters offers a low-hanging fruit to achieve this: but at what cost?

In this review – supported by the McCall MacBain Foundation – of thousands of methane super-emitting points based on **GHGSat satellite detections** from 2021 and 2022,[ii] the capital expenditure (CAPEX) to abate these super-emitting sources was calculated. This report does not present a complete inventory of super-emitters in the analysed countries and regions but provides investment cost (in USD/tCH_4) estimates for addressing super-emitters from specific emission sources. Details on the methodology are presented in a separate document.[iii]

To determine super-emitting methane sources and associated costs, GHGSat methane emissions monitoring of the oil and gas sector over 2021 and 2022 was compared with satellite imagery and oil and gas infrastructure databases[iv] in a desktop analysis to determine the most likely source of emissions. For each source, an average annual emission rate was determined (as presented in a separate white paper.[v] Globally, over 1 million tCH_4/year were observed and analyzed - see the Methodology paper[iii] for method details).

Capital expenditure (CAPEX) was determined for seven emission categories and abatement solutions: flares (replace flare or gas utilization infrastructure), tanks (VRU), wellheads (casinghead gas capture, reduced emissions completions, routing to sales, etc.), pipeline leaks/vents (pipeline repair/ replacement), gathering pipeline leaks/vents (pipeline repair/replacement), equipment leaks/vents (equipment leak repairs /replacements), unidentified emission sources (gas utilization infrastructure).

Of these, five categories (flares, tanks, wellheads, pipeline leaks/vents, and equipment leaks/vents) accounted for 90% of the total analysed emissions, while unidentified sources represented the remaining 10%.

How much capital expenditure is required to abate oil and gas super-emitters?

In this report, the CAPEX to abate over 1 MtCH_4/yr from these analysed super-emissions was determined to be between USD 2.90 and 7.76 billion (Figure 1), at an investment cost (defined in this document as the CAPEX in USD per ton of CH_4 emitted) of USD 2.86 – 7.66/tCH_4. CAPEX and investment cost **do not** reflect potential revenues of recovered gas sales and should not be compared to other economic indicators presented in other resources such as abatement cost.

CAPEX varies significantly depending on individual scenarios between regions, operators, locations, and infrastructure. CAPEX provided in this report is an estimate based on interviews with providers of abatement technologies and publicly available information and resources collected at the time of publication, many from sources covering the past ~25 years. While all costs have been updated to reflect inflation, values remain high-level estimates.

In many cases, the exact source of the super-emitter cannot be identified by imagery analysis alone, (e.g., cause of emissions at the wellhead, what type of equipment is leaking/venting). On-the-ground detection campaigns need to be conducted prior to any investment in abatement options, which can

lead to additional costs. Further efforts and costs may be incurred to determine specific emission sources and resolve them.

Based on these disclaimers, it is important to treat CAPEX with a degree of caution. See methodology for more information.[ii]

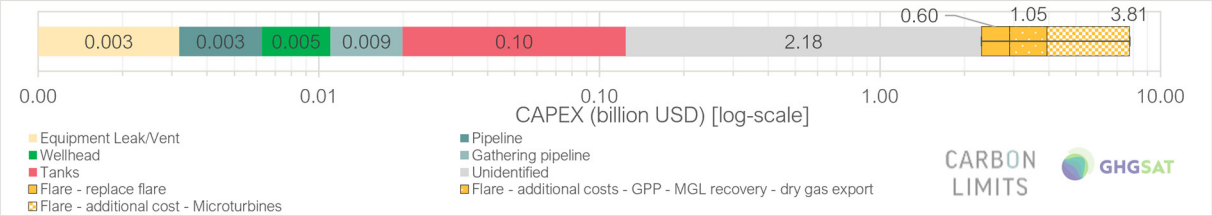


Figure 1 Total CAPEX required to abate super-emitting events.

Which sources of methane emissions are the most cost-effective to reduce?

Table 1 presents annual emission rates, total CAPEX, and investment cost for each emission source type analysed.[vi] Emissions at wellheads, pipelines, gathering pipelines and equipment leaks/vents had the lowest investment cost (≤USD 0.16/tCH_4), but represented only 23% of total emissions. Conversely, mitigation of the unidentified emission sources represented the most significant investment cost (USD 25.5/tCH_4).[vii] In addition, ~65 $ktCH_4$/yr of emissions from tanks could be abated with a CAPEX of around USD 100 million.

Table 1 Total annual emission rates, CAPEX and investment cost for each emission source type

Emission Source		Emissions ($ktCH_4$/yr, % of total)	CAPEX (million USD, % of total)	Investment Cost (USD/tCH_4)[tt]
Pipeline leak/vents		76.0 (7.50%)	3.00 (0.04%)	0.04
Equipment leaks/vents		68.6 (6.77%)	3.00 (0.04%)	0.05
Gathering pipelines leak/vents		87.1 (8.60%)	10.0 (0.11%)	0.10
Wellheads		30.6 (3.02%)	5.00 (0.06%)	0.16
Tanks		65.2 (6.44%)	104 (1.35%)	7.56
Unidentified[‡]		106 (10.4%)	2,700 (30.3%)	25.5
Flares[†]	Option 1: Replace flare	580 (57.2%)	600 (14.8%)	1.03
	Option 2: Mini GPP- NGL		1,650 (32.4%)	3.88
	Option 3: Microturbine		5,460 (61.4%)	13.3

[tt] Investment cost does not consider potential revenue from captured gas.

[†] For unidentified sources, a very conservative investment cost was used based on the most expensive abatement option of installing microturbines for gas utilization. Please refer to the methodology for more information.

[‡] CAPEX and Investment Cost are considered as three separate options, ranging from 600 million USD to install new flares for all super-emitting sources, to 5.46 billion USD to install microturbines

Fifty-seven percent of the observed and estimated annual emissions in 2021-2022 came from flares (which includes both elevated flares and burn or dump pits) and could be abated with a capital expenditure ranging from 599 million USD (replacement with new flare) to 5.46 billion USD (replacement of flare with microturbines).

Although flare replacement has a low CAPEX, a new flare will still result in emitted CO_2 and CH_4 depending on the combustion efficiency and the function of the flare, and the flared gas would not have any economic value. Additionally, this approach does not align with international commitments to eliminate routine flaring. Therefore, alternative gas utilization options are considered, which include replacement with microturbines and small-scale gas processing units (mini GPP-NGL) with dry

gas export, which will both allow for reductions in greenhouse gas emissions and increase generated revenue.

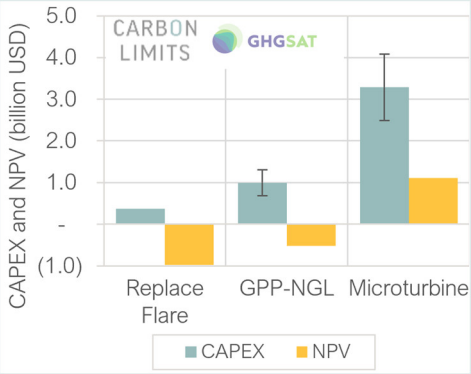


Figure 2 Comparison of CAPEX and NPV for different abatement options for super-emitting flares.

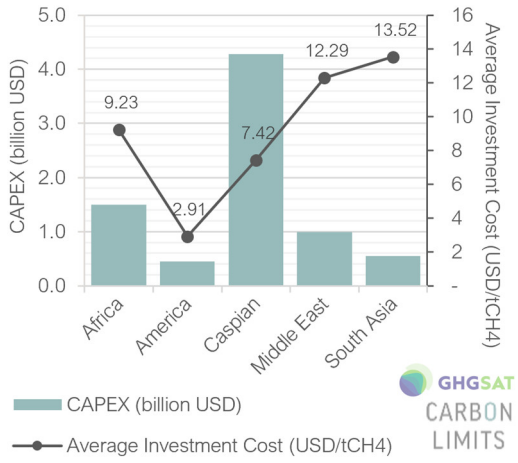
CAPEX is one way to evaluate abatement activities. Another is to present the Net Present Value (NPV) which also takes into account OPEX and revenues generated by the abatement solutions (for example, through sales of gas or its on-site use). In the current project scope, data to determine NPV is limited to flare emission sources. To provide a comparison between flare abatement options, Figure 2 presents the NPV and CAPEX of the three abatement options considered for flares. NPV was calculated using a discount rate of 10%, CAPEX, OPEX and recovered product values from their respective cost models.[iii]

The investment in new flares can be at least two times lower than the investment in a gas utilization project (which involves significantly more complex infrastructure). However, gas utilization projects offer the opportunity to generate economic gain by the use or sale of captured gas. The gas utilization options presented are common, small-scale applications that reflect reasonable CAPEX ranges. Effective gas utilization projects will vary on an individual basis due to e.g. regional differences, existing infrastructure and market availability/conditions.

What is the regional variance of investment cost?

Figure 3 provides an estimate of CAPEX investment costs for the five regions covered in this analysis.[viii]

Figure 3. CAPEX and average investment cost by region



The Americas had the lowest investment cost (USD 2.91/tCH_4). With very few flares being the cause of super-emitting events, abatement can be highly cost effective. This was followed by the Caspian region (USD 7.42/tCH_4), where a CAPEX of USD 4.3 billion would be required to address 577 $ktCH_4$/yr (57% of total emissions), the largest potential from all regions. This may be biased by the amount of satellite focus on super-emitters in this region, or the high share of investment cost attributed to unidentified emission sources. Nevertheless, addressing super-emitters in this region remains pivotal.

Africa and the Middle East presented average investment costs between USD 9–12.5/tCH_4. Interestingly, emission sources in Australia/South Asia (<5% of total analysed emissions) had the highest average investment cost (USD 13.52/tCH_4), requiring approximately USD 550 million in CAPEX. This may be explained by the high number of

flares and unidentified sources among emission sources.

What are the barriers and catalysts for successful super-emitter abatement?

This white paper relies on desktop analysis of satellite detections to calculate the cost of abating super-emitting sources of methane. However, there remains a gap between identification and successful abatement. Several barriers and catalysts could complement this analysis and improve mitigation.

1. Available Funding

Cases presented in this white paper show that flare gas utilization projects can result in high NPV. A common barrier to implementation of these projects is the large CAPEX to kickstart cost-effective solutions. The IEA estimates additional funding of USD 15–20 billion is required by 2030 in low-and-middle income countries to ensure adequate sources of funding beyond what is already available.[i] At the same time, there are low CAPEX opportunities to address methane super-emitters (for example, some leak repairs). However, there is limited willingness to support the oil and gas sector methane mitigation due various reasons, including perceived image of the sector. In 2021/22, the oil and gas sector received less than 1% of tracked methane abatement financing.[ix] There is also significant regional and national variability to fund the necessary abatement activities, with regions such as Latin America and South Asia lacking financial support for methane abatement,[ix] which indicates that targeted investment will be critical to meaningful abatement.

2. Data Availability

Improved data availability will both support operators and help identify investment opportunities. Having a better understanding of emission sources, causes and possible abatement pathways will improve decision making and ultimately reduce methane emissions from super-emitting events. Putting this information in the hands of operators is key to successful abatement of super-emitting events. One successful implementation of this is the Oil and Gas Climate Initiative (OGCI) Satellite Monitoring campaign, where satellite data was used to inform operators of super-emitting events, resulting in methane emissions abatement in the range of 5 to 10 tonnes per hour over several months in 2022.[x] Increased oversight of emissions by the International Methane Emissions Observatory (IMEO) at the United Nation's Environment Program (UNEP) can also empower operators to identify super-emitters at the source.

3. Capacity Building and Maintenance

Cost estimates presented in this white paper do not include capacity building to demonstrate the significance of oil and gas operations and maintenance practices in super-emitting events. As many super-emitting events may be short-lived or episodic, addressing and improving work practices can ensure that implemented actions present a lasting abatement solution.

4. Strong Regulation

As many countries do not yet have strong regulatory structures in place for methane emissions reduction, it is necessary to develop capacity within local regulatory bodies.[i] Specific needs vary and could range from increased staff resources, capacity and technical knowledge, stronger monitoring, reporting and verification (MRV) systems, and a more structured approach to responding to and addressing super-emitting events.

5. The whack-a-mole solution

Methane super-emitter abatement must be more than just throwing money at the

problem and hoping targeted interventions will make methane emissions go away. This whack-a-mole solution to addressing super-emitting events can result in short-term fixes but leaves room for another (or the same) super-emitting source to (re)appear. Adopting this approach will jeopardize the goal of attaining net zero which strongly relies on addressing methane super emitters.

Satellite detection of methane super-emitters is highly effective at identifying super-emitting sources but is only one step in the multi-step process of emissions detection, quantification and mitigation that involves the deployment of other technologies and establishment of robust communication protocol to ensure that information is promptly relayed to parties that can take action. In a nutshell, all must be done to get data in the hands of engaged operators who must pair detections with timely follow up, effective implementation and maintenance of abatement options and backed by strong regulation and adequate project funding to abate super-emitting events

[i] IEA (2023). *Financing reductions in oil and gas methane emissions*. Financing reductions in oil and gas methane emissions. https://www.iea.org/reports/financing-reductions-in-oil-and-gas-methane-emissions

[ii] GHGSat. Greenhouse Gas Emissions Monitoring Service - GHGSat. https://www.ghgsat.com/en/

[iii] Carbon Limits (2024). Translating Satellite Data into Abatement: A Technical Explanation for Satellite Insights on Global Methane Super Emitters.

[iv] Omara, M., Gautam, R., O'Brien, M., Himmelberger, A., Franco, A., Meisenhelder, K., Hauser, G., Lyon, D., Chulakadaba, A., Miller, C., Franklin, J., Wofsy, S., and Hamburg, S.: Developing a spatially explicit global oil and gas infrastructure database for characterizing methane emission sources at high resolution, Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2022-452, 2023.

[v] Carbon Limits (2024). Perspectives on Methane Super-Emitters: Determining Emission Sources using Satellite Detections.

[vi] Costs may vary significantly depending on individual scenarios between regions, operators, locations, and infrastructure. Each cost estimate provided in this report is an estimate based on available information collected at the time of publication. Ultimately, costs may represent a lower bound. Further efforts and costs may be incurred to determine specific emission sources and resolve them. See methodology for more information.

[vii] For unidentified sources, a very conservative abatement cost was used based on the most expensive abatement option of installing microturbines for gas utilization. Please refer to the methodology for more information.

[viii] Abatement cost of flares in this section is assumed to be the cost of replacing with microturbines.

[ix]Pedro de Aragão Fernandes, Baysa Naran, Caroline Alberti, Dharshan Wignarajah, Jake Connolly and Tinglu Zhang. Landscape of Methane Abatement Finance 2023. Climate Policy Initiative. 30 November 2023. https://www.climatepolicyinitiative.org/publication/landscape-of-methane-abatement-finance-2023/

[x] Oil and Gas Climate Initiative (2024). "White Paper: Results of OGCI Satellite Monitoring Campaign 2022-2023 over Kazakhstan, Algeria and Egypt." https://www.ogci.com/download-white-paper