Super emitter gas flares in Nigeria

Summary of a study using satellite data and publicly available production data to explore very large gas flares and their relation to oil facility operational performance in Nigeria.

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Acronyms used

bopd	barrels of oil per day
LNG	Liquefied Natural Gas
MMscf/d	million standard cubic feet per day
MMt	million metric tons
Mscf	thousand standard cubic feet
VNF	VIIRS Nightfire satellite

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Purpose and focus of the study

This note summarises a study using detailed satellite observations of two groups of very large (super emitter) gas flares on oil production facilities in Nigeria (one group onshore and one offshore). The study combined satellite data with publicly available oil production data to show how flaring activity and oil facility operational performance are interrelated. **The aim of this analysis was to both identify events indicative of much increased methane emissions and to use this to improve understanding of background trends and opportunities for further flare reductions**. The study was carried out in two steps: the first focussed on the onshore sites and was completed in August 2022, while the second concentrated on the offshore sites and was completed in April 2023. The study was carried out by EnergyCC (https://energycc.com) on behalf of the FCDO-funded and Oxford Policy Management-managed Facility for Oil Sector Transformation (FOSTER) programme in Nigeria. More detailed accounts of the study and its findings are available in separate full reports for the onshore (Romsom & McPhail, 2022) and offshore (Romsom & McPhail, 2023) elements.

The problem of gas flaring

Gas flaring occurs when natural gas (methane) is produced as a by-product of oil extraction (associated gas). Flaring (the disposal of unwanted gas by burning) may occur for safety reasons – to cope with sudden increases in gas pressure during oil extraction for instance and so avoid a potential explosion. Flaring also occurs routinely however, for example where a producer deems it uneconomic to capture and process the gas for use or sale.

According to the Global Gas Flaring Reduction Partnership, around 139 billion cubic meters of gas were flared in 2022 which, assuming a flare combustion efficiency of 98%, resulted in 350 million tonnes of CO_2 equivalent emissions. However, the methane emissions resulting from the 2% of natural gas that was released un-combusted due to flare inefficiency added a further 100 million tonnes of CO_2 equivalent emissions to this figure, as methane is over 80 times more powerful than carbon dioxide as a warming gas on a 20-year timeframe (World Bank, 2023). It should be noted that the assumption that flares routinely achieve 98% combustion efficiency may itself be over-optimistic. The operational effectiveness of oil production facilities can have a significant impact on the combustion efficacy of flares and, if the combustion of a flare is incomplete, the emission of harmful chemicals increases by orders of magnitude (Romsom & McPhail, 2022). In practice, actual global emissions could therefore be significantly higher than the above estimates.

In addition to its climate impacts, flaring can have detrimental health impacts on populations close to flare sites. Black carbon, naphthalene and benzene can all be released into the air and may lead to increased levels of respiratory and heart disease, eye and liver damage, headaches, tremors and irregular heartbeats (BBC, 2022). The flaring of gas is also incredibly wasteful. The current annual global amount of gas flared would be sufficient to power the whole of sub-Saharan Africa (World Bank, 2023).

Progress on flaring reduction in Nigeria

According to BP (BP, 2022), Nigeria is Africa's largest oil producer - 1.6 million barrels per day (bopd) in 2021 - and it is the world's 6th largest Liquefied Natural Gas (LNG) exporter - with 17.9 million metric tons (MMt) in 2021 (S&P Global, 2022). It is also **one of the most successful countries to reduce flaring: in 2020, Nigeria ranked as 7th highest flaring country globally, down from 2nd in 2005**; and gas flaring reduced by 66 percent between 2005 and 2015.

Whilst recognising the progress made so far in Nigeria, in 2020, there were still 197 flares observed in the country. Of these, 124 flares each burn on average more than 1 million standard cubic feet per day (MMscf/d) and 19 burn more than 10 MMscf/d.

Super emitters in Nigeria

The term ‘super emitter’ refers to the top two to three percent of the 10,390 flares currently estimated to operate globally, ranked by volume of gas flared annually. The top **300 super emitter flares account for 42.5 percent of all gas fared globally**. Over the combined four-year period 2017-2020, **Nigeria had 19 of the largest 300 flares in the world and ranked 6th among the 29 countries** that have Top 300 super emitter flares.[1]

The use of VIIRS Nightfire (VNF) satellites as a diagnostic tool

Flare data from satellites provide complementary benefits to other flare assessment solutions, such as gas-flow meters and hand-held devices that can be brought to the emitting flare sources for detailed local evaluation and measurement. Benefits of satellite measurements are specifically:

- Flare detection accuracy (spatial and rate) by VNF satellites is high, and flare rates spanning four orders of magnitude can be measured.
- Gas flare rates are measured on average twice-daily, lack of cloud cover permitting. Flaring point sources are easily identifiable, particularly in combination with open source Landsat / Copernicus / Maxar images. This information is particularly useful for remote and off-shore locations, helping regulators to prioritise production site visits.
- In the absence of flare gas metering, VNF satellite data are a reliable source for determining flare rates. When gas meters are present, satellite flare data can validate that gas meters are operating correctly, and indicate issues such as ‘drift’ that would require recalibration of a gas meter.
- The results from independent VNF flare metering outputs are readily available to regulators, which may not be the case with metering outputs from operators.
- Regularity in VNF measurements over prolonged time periods creates comprehensive datasets for flare sources, with thousands of flare rate measurements per flare source. This allows flare trends to be continuously assessed throughout the asset lifecycle.
- VNF data analysis can distinguish routine flaring from system upsets which are likely to correlate with methane emissions. Policymakers need to be increasingly cognisant of these inter-relationships.
- Regional and country-wide VNF data assist development of regulations and fiscal measures (including methane). Satellite measurements allows all gas flares to be measured and penalised regardless of their permitting status.

Study findings

The super emitter flares examined in the study were all on facilities that were designed to operate under ‘zero routine flaring’ conditions, connected either to infrastructure to evacuate gas for commercial use or to reinject into reservoirs. In practice zero routine flaring is not being achieved to the extent that these facilities rank amongst some of the largest super emitter flares globally.

The study found that the four on-shore super emitter sites investigated were all connected to infrastructure that should allow for the evacuation of associated gas for productive use (either to fuel a grid-connected electricity generation plant or for export via the Bonny Island NLNG terminal). Significant synchronicity in flaring rates across the facilities indicates a mutual dependency between assets that could be due to ‘bottlenecks’ in oil and gas evacuation. For example, a temporary restriction in the plant processing for gas for onward transport to Bonny Island and export could mean facilities supplying the plant are forced to find other ways of managing associated gas. In the past, oil was developed from this region under gas-reinjection schemes. It appears however that these **reinjection schemes may no longer be maintained**

[1] EnergyCC confidential study

and used and that when gas infrastructure is unavailable or constrained, **gas is no longer reinjected but flared instead**. Remarkable synchronicity between flares also shows that the **interconnectivity of oil and gas infrastructure allows gas volumes of high rate flares to be reallocated over a larger number of nearby flares**, particularly if these are located in the same oil and gas production license area. This suggests that **evaluation of flare performance trends should include a regional analysis of all flares.**

Three of the four onshore super emitter sites analysed are classified as marginal fields (producing less than 10,000 bopd). Currently the Nigerian Government applies a penalty of USD 0.50/Mscf of gas flared to marginal fields, while fields producing more than this face a penalty of USD2/Mscf. **This study finds that the assumption that marginal oil producers flare less and therefore should attract lower penalties does not hold** and suggests the low tier of flare penalties should therefore be scrapped in favour of a uniform penalty at a realistic level (USD2 or higher).

With respect to the offshore super-emitting offshore assets evaluated, all five were designed to be a ‘zero routine flaring’ facilities in accordance with environmental policy, but this has not been achieved in practice. Flaring of gas at the five offshore facilities studied appears to be related to two distinct causes.

The first is flaring caused by operational issues such as process trips and equipment failures. **To address this there needs to be a more consistent long term follow up by Regulators to ensure that producing assets maintain compliance with conditions granted at the time of development approval.** An example of this is the need to maintain gas reinjection performance.

The second is flaring exacerbated by oil production rates being in excess of stable reservoir deliverability rates. This leads to much more gas and water being produced, resulting in significant increases in process trips, low well head pressures, slugging well performance, and thus higher flare variability. In addition, oil decline rates are also negatively affected due to declining reservoir pressures, reservoir gas and water coning and cusping, and thus higher flare intensity. **Exceeding stable reservoir delivery rates can then result both in greater flaring and potentially a reduction in the overall potential yield of oil from a reservoir over time.** This implies that **oil production rate targets should be complemented by maximum flare rate limits to optimize oil production and recovery of reserves**.

In summary, **these studies demonstrated high levels of flaring for oil assets in Nigeria that would not have been accepted in other regulatory regimes, such as the EU, UK or offshore US.**

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