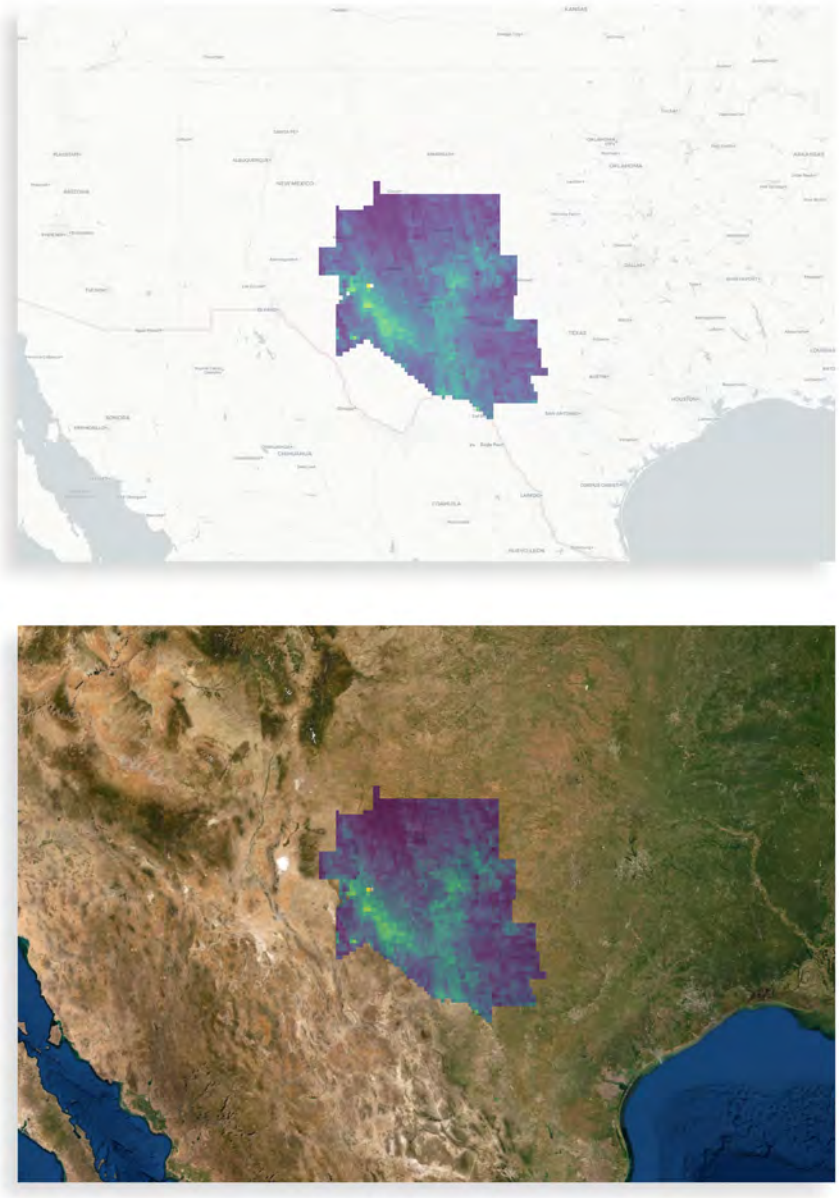
ATTACHMENT BB

U.S. METHANE EMISSIONS FROM FOSSIL FUELS AT RISK OF WORSENING IN 2022, EXTENDING 2021 TREND

Q12022 data raise concerns about greenhouse gas footprint amid calls for higher oil and gas production.

Aggregate of emissions in Permian for 2022



Source: Sentinel-5P data

Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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Methane emissions from some of the most prolific U.S. oil, natural gas and coal basins look at risk of significantly increasing in 2022 after bouncing back from Covid lows in 2021, the latest Kayrros basin-level measurements indicate.

Using its Methane Watch technology, Kayrros has run full inversion models for select oil, natural gas and coal basins historically associated with high methane emissions, including the Permian and Appalachian basins of the U.S., Iraq, Iran, Kuwait, Algeria's Hassi R'Mel natural gas basin and Turkmenistan. The results provide a comprehensive assessment of emissions from these regions, including both "super-emitters" that can be detected and measured from space as well as smaller leaks that may not register individually on satellite imagery but whose cumulative impact over time is measurable. The findings for FY2021 and Q12022 are worrisome:

- **In the Permian basin, the most prolific U.S. oil field,** preliminary data show methane emissions jumped by about one third in the first quarter of 2022 from the previous quarter and by nearly half year-on-year, averaging about 15% above pre-Covid levels. The basin had achieved substantial reductions in methane intensity in 2020 amid small average production gains, but emissions started bouncing back and ran ahead of supply in 2021. The increase gained momentum in Q1 2022 and looks at risk of accelerating further as drilling and frac'ing activity respond to high oil and gas prices and calls for more production.

- **The Marcellus & Utica basins, two prolific shale gas plays in the Appalachian, offer a similar story.** Emissions fell steeply in 2020 despite a small average gain in natural gas production, but started retracing their decline in 2021. The methane intensity of Appalachian gas reached its highest level in Q12022 since Q3 2020.

- **In the Appalachian coal sector, the situation is even more concerning.** When production from Appalachian coal mines fell in 2020 amid lower demand due to Covid-19, methane emissions were slower to decline. But as production started to bounce back in 2021, emissions grew faster. The rising methane intensity of Appalachian coal production means that its contribution to climate change has steadily increased even as its contribution to power generation has declined.

- **In total, emissions from the Permian, Appalachian and Anadarko fossil fuel basins,** accounting for a large share of total US onshore production, reached their highest level in three years in Q12022, extending 2021 gains, while signs of rebounding oil and gas field activity suggest even faster emission gains might be on the cards for the remainder of 2022.

- **Outside of the U.S., methane emissions were a mixed bag in 2021,** with steep increases in Turkmenistan and Algeria's top gas producing basin, but apparent declines in both absolute emissions levels and methane intensity in Kuwait and Iran compared to 2019 levels. In Iraq, emissions followed production lower in 2020 but bounced back with it in 2021.

The latest gains in the U.S. occur despite growing awareness of the urgent need for methane abatement and of the opportunity for large emission cuts provided by the fossil-fuel sector. In November 2021, the U.S. Government joined the European Commission in launching the Global Methane Pledge at COP26 in Glasgow. The pledge's 110 signatory nations commited to cut methane emissions by 30% by 2030 from 2020 levels. The U.S. Environmental Protection Agency will soon release new methane rules to that effect.

The reversal of earlier reductions in U.S. methane emissions from fossil fuels is of concern at a time when tight energy markets and high fuel prices following Russia's invasion of Ukraine have prompted mounting calls for more U.S. oil and gas supply.

While it's only six months since the launch of the Global Methane Pledge, the overall trend in global methane emissions so far appears to be going in the wrong direction, as evidenced by recent developments in these major producer countries. Given the high warming power of methane -- more than 80 times than of carbon dioxide in the first 20 years -- and the short window available to significantly reduce emissions, the lack of progress achieved so far is a concern.

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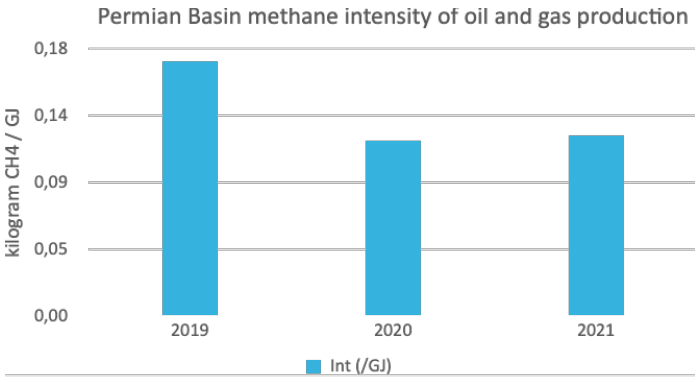
PERMIAN BASIN (Oil & Gas)
Overall emissions

Unlike the U.S. as a whole, oil production in the Permian, a major tight-oil production basin that straddles the border between Texas & New Mexico and that comprises some of the nation's most prolific sub-basins, increased in 2020 at the peak of the Covid-19 pandemic and has since continued to expand.

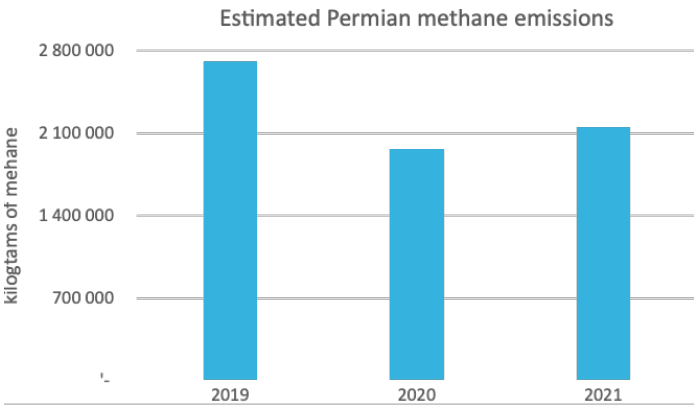
Despite the higher production volumes, methane emissions from the basin declined in 2020, thanks in part to new pipeline capacity that brought more associated natural gas to market, as well as steps taken by some of the region's leading operators to reduced their footprint. Kayrros basin-level measurements show that overall methane emissions from the basin decreased by 27% to 1.97 million tons in 2020 from 2.71 MT in 2019, even as crude production rose by 5% to 3.92 million barrels a day from 3.75 Mb/d.



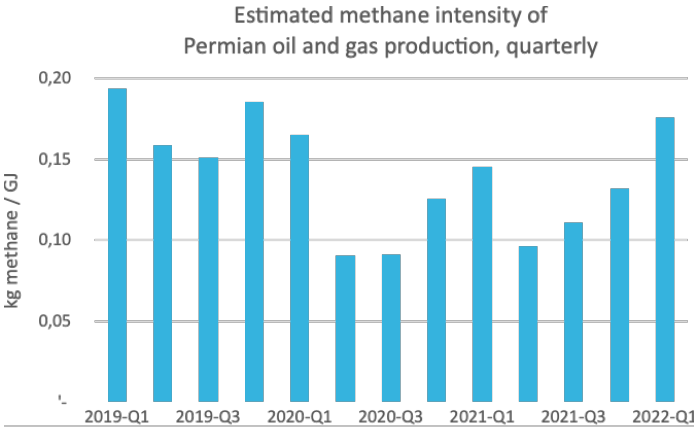
(source: Kayrros Methane Watch, U.S. EIA)

Aggregate oil and gas production from the basin rose by 6% to 7.47 million barrels of oil equivalent a day (Mboe/d) in 2020 from 7.08 Mboe/d in 2019. In 2021, however, Permian emissions bounced back to 2.15 million tons, up 9% year-on-year, while crude production grew by another 5%, to 4.13 Mb/d. Combined oil and gas production gained 5.4%, to 7.90 Mboe/d. As a result, the reduction in methane intensity of Permian oil and gas production achieved in 2020 ground to a halt.

In the first quarter of 2022, Kayrros Methane Watch shows Permian methane emissions have continued to increase and appear to have reached their highest level on record, even as U.S. Energy Information Administration (U.S. EIA) data point to a slight decline in Permian oil production to 4.38 Mb/d, from 4.39 Mb/d in the previous quarter. As a result, the implied methane intensity of oil and gas production from the Permian basin rose to the highest level since end-2019. (U.S. EIA data remain subject to evision.)



(source: Kayrros Methane Watch)



(sources: Kayrros Methane Watch, U.S. EIA DPR)

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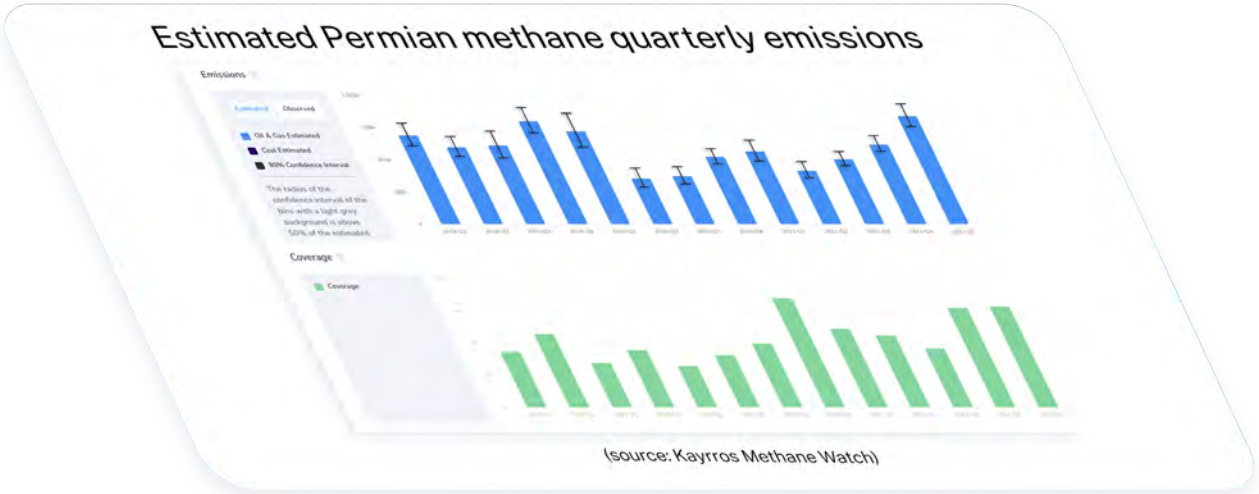


Super-emitters

Even as Permian overall methane emissions gained momentum, so too has the pattern of super-emitters detected in the basin. (These detections presumably account for only a portion of the total number of events in any basin.)

In 2019, 75% of all super-emitters attributed to the U.S. Lower 48 onshore oil and gas sector came from the Permian alone, or 133 out of 177. In 2020, the number of those very large but intermittent methane dumps, with minimum rates of 5-25 tons/hour, fell to 80, of 54% of the US total, a drop likely helped by the start-up of new natural gas pipelines built to bring associated Permian natural gas to market. By 2021, that number had dipped further to 48, less than half the number of US releases overall.

Echoing the overall US-wide pattern, however, the numbers of super-emitters in the Permian bounced back strongly in 2022. As of June 15, 41 super-emitter events had been detected so far this year in the Permian alone, or nearly 60% of the U.S. total.

Number of super-emitters from US oil and gas

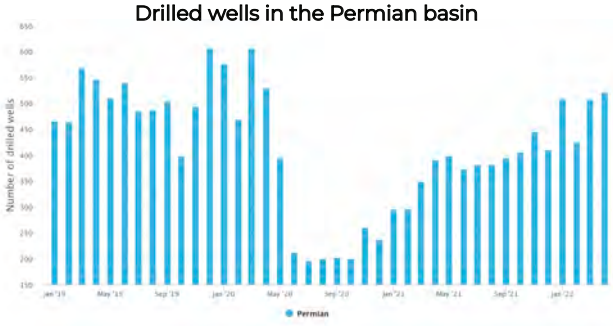
	2019	2020	2021	Jan-May 2022
U.S.	**177**	**149**	**105**	**70**
Permian	**133**	**80**	**48**	**41**
Permian share	**75%**	**54%**	**46%**	**59%**

Oilfield activity

Resurgent Permian emissions in 2022 occur against the backdrop of a rebound in drilling and well completions in the basin, a trend dominated by small, private operators that may be less dilsciplined about methane abatement than publicly-traded, larger producers.

Kayrros Ops Tracker data show Permian oilfield activity bounced back strongly in early 2022 from Covid-19 lows, with completions rising 14% month-on-month in April to 507 wells, the highest count since March 2020. Private operators led the trend with a gain of 31% on the month. Drilling activity also rose considerably in the first five months of the year, setting the stage for further completions down the road.

Drilled wells in the Permian basin



Well completions in the Permian Basin

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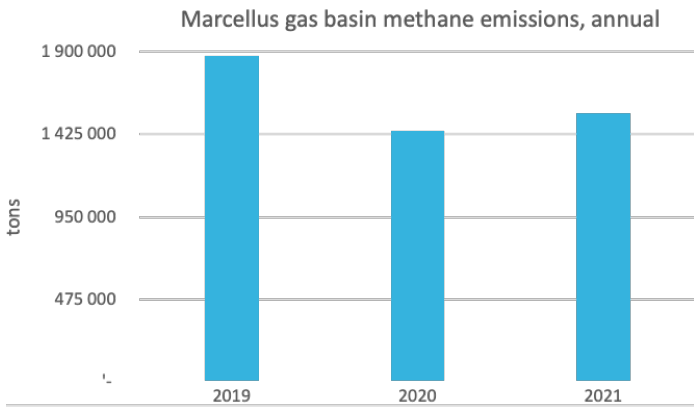
MARCELLUS & UTICA (Natural Gas)
Overall emissions

Basin-level emissions in the Marcellus and Utica shale gas plays of the U.S. Appalachian region fell by nearly one fourth in 2020 even as production inched 3% higher, a trend similar to that observed in the Permian.

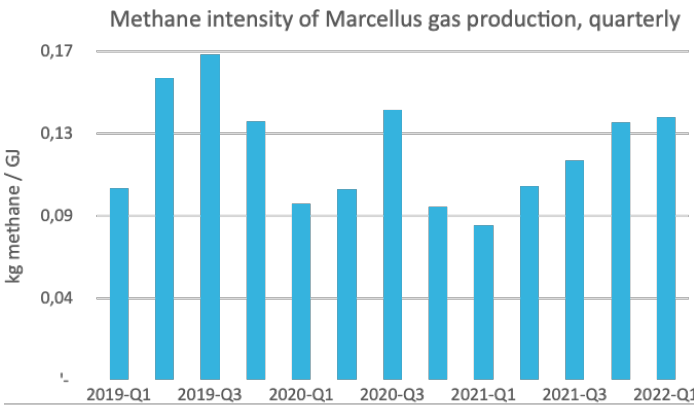
As in the Permian, emissions staged a partial rebound in 2021, rising by 7%, while gas output continued to grow, edging 5% higher on the year. As a result, after plunging by 25% in 2020, the estimated methane intensity of Marcellus and Utica gas edged back marginally higher in 2021.

Quarterly data suggest Marcellus and Utica methane emissions growth accelerated significantly in Q12022, however, although the confidence interval for that quarter is relatively large. If confirmed, the data would point to much higher methane intensity of U.S. gas at a time of rapidly rising import demand for U.S. LNG.

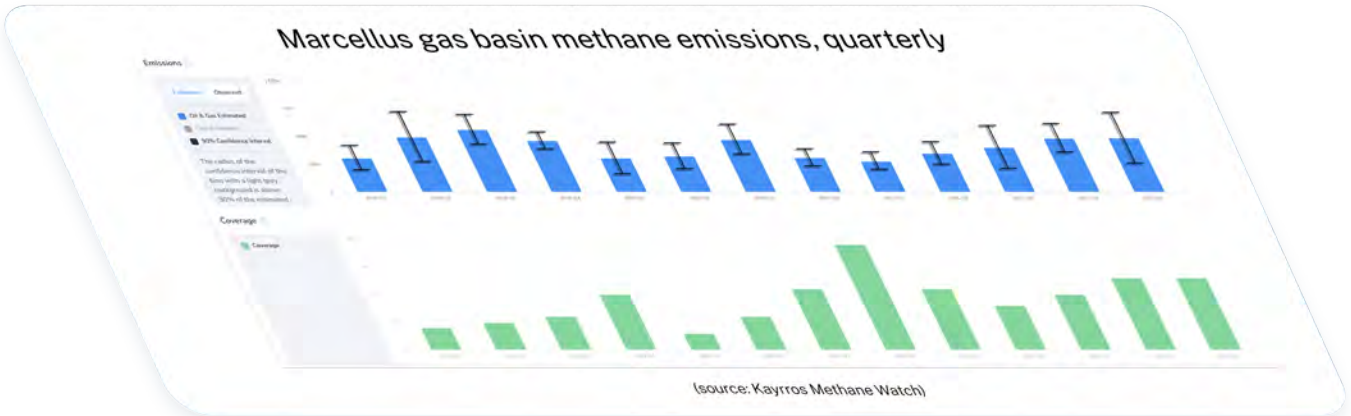
Having entered the 2021-2022 heating season with unusually low natural gas inventories, import-dependent European economies saw the situation further exacerbate as Russia kept its westward gas exports below normal ahead of its invasion of Ukraine. The resulting strong European demand for U.S. LNG only increased further after the invasion as EU nations are now looking to wean themselves off Russian gas. Amid surging natural gas prices, U.S. LNG exports to Europe, and European appetite for U.S. natural gas, have never been greater. Against this bullish backdrop, the methane intensity of Marcellus and Utica gas production jumped to 0.14 kg/ GJ in Q12022, its highest level since Q3 2020, from 0.11 kg/GJ on average in 2021. While it remains below pre-pandemic highs, the methane intensity of Marcellus and Utica gas has risen significantly from the lows of the last two years.



(source: Kayrros Methane Watch)



(sources: Kayrros Methane Watch, U.S. EIA DPR)



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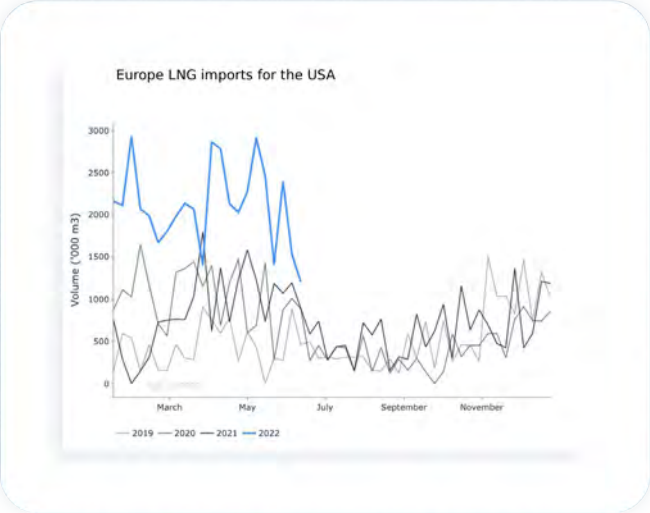
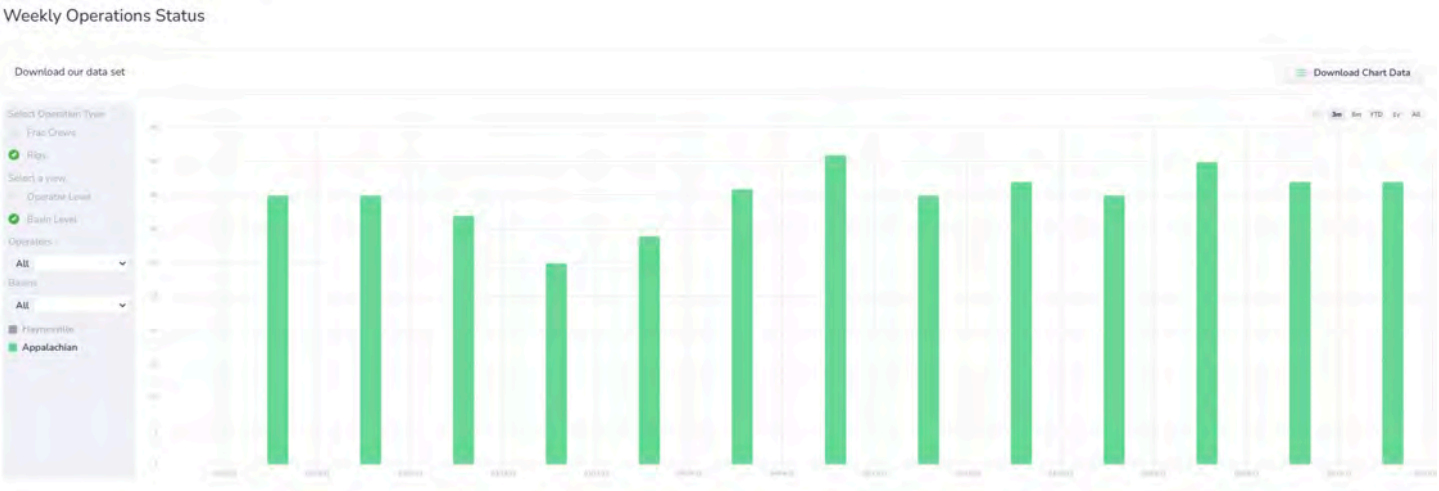
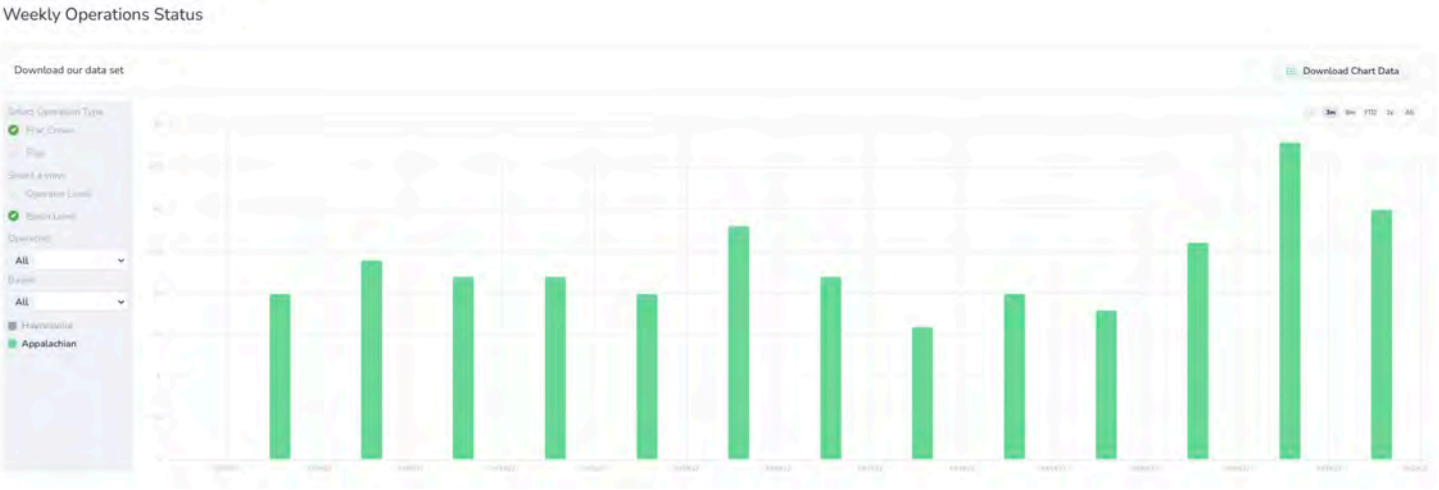
Field activity

As in the Permian, there are signs of a price response in field activity in the Marcellus and Utica plays of the Appalachian basin, one of two major US tight-gas producing regions in the U.S. with the Haynesville.

The rig count and the number of frac crews in the Marcellus has recently been on the rise amid high prices and strong import demand for U.S. LNG. U.S. exports of LNG to Europe have been exceptionally high so far in 2020. Ring field activity and production levels could lead to higher methane emissions.







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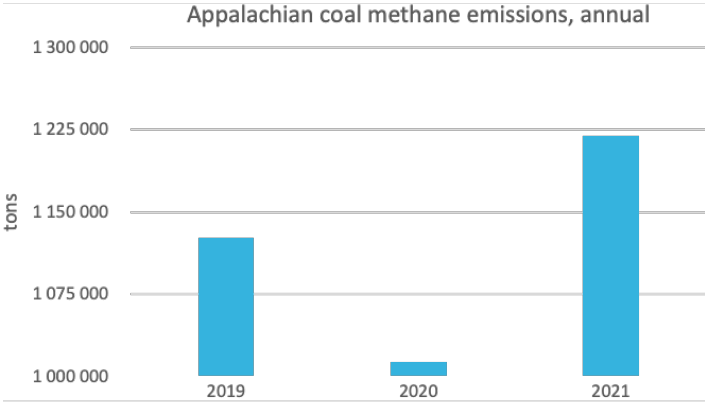
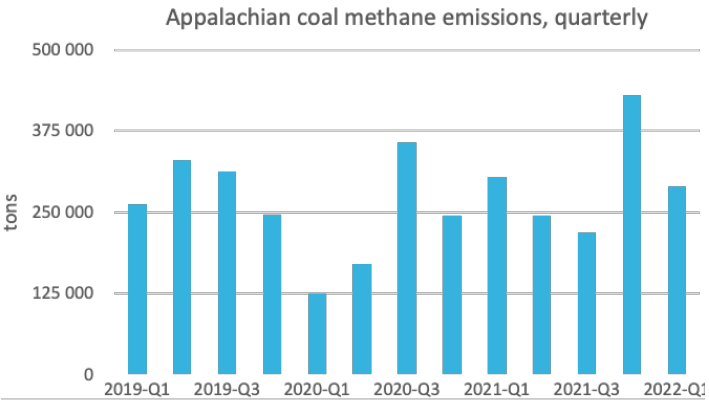
Appalachian coal

Kayrros' database of US fossil-fuel producing assets enables it to distinguish between methane leaks due to coal extraction and those associated with natural gas in the Appalachian.

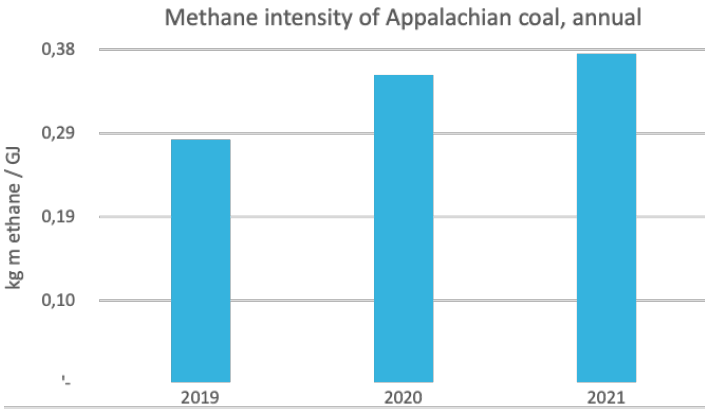
Unlike production of oil and gas in the Permian and the Marcellus, Appalachian coal production dropped heavily in 2020 as the Covid-19 pandemic reduced demand, falling by nearly 30% on the year. Production only partially recovered in 2021, up 13% on then year. In contrast, methane emissions from Appalachian coal lagged behind the initial drop production in 2020, down only 10%, and in 2021 bounced back by 20%, averaging for the year well above pre-Covid levels, even though production remained comparatively depressed.





(source: Kayrros Methane Watch)

In contrast with oil and gas in the Permian and Marcellus, the rise in methane emissions from Appalachian coal has thus occurred against a backdrop of diminishing production, resulting in a significantly higher methane intensity than prior to the pandemic.



(sources: Kayrros Methane Watch, U.S. EIA

Super-emitters

The number of super-emitters detected in the Appalachian rose in 2020 from 2019 despite lower basin-wide estimated emissions from natural gas and coal production.

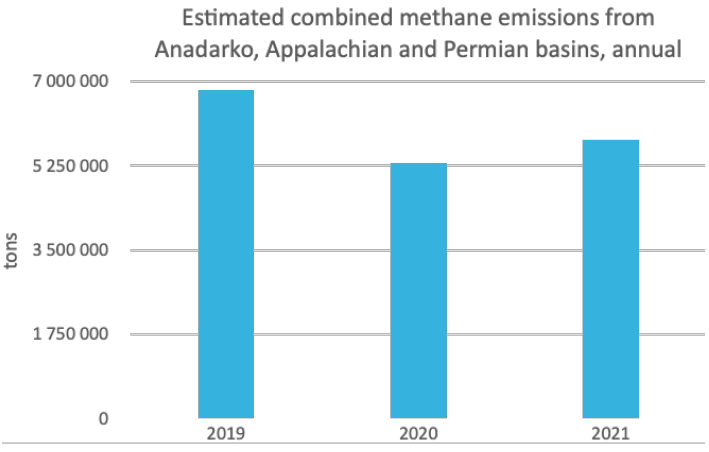
Most of the super-emitters in the Appalachian are attributable to coal production, with only one event pinned on gas output in 2020.

Number of super-emitters from the Appalachian basin

	2019	2020	2021	Jan-May 2022
Appalachian	**18**	**30**	**25**	**1**

US aggregate: Anadarko, Appalachian & Permian oil, natural gas and coal basins

In aggregate, methane emissions from the Anadarko, Appalachian and Permian fossil fuel basins of the U.S. bounced back in 2021, as did the methane intensity of U.S. fossil fuel production.



(source: Kayrros Methane Watch)

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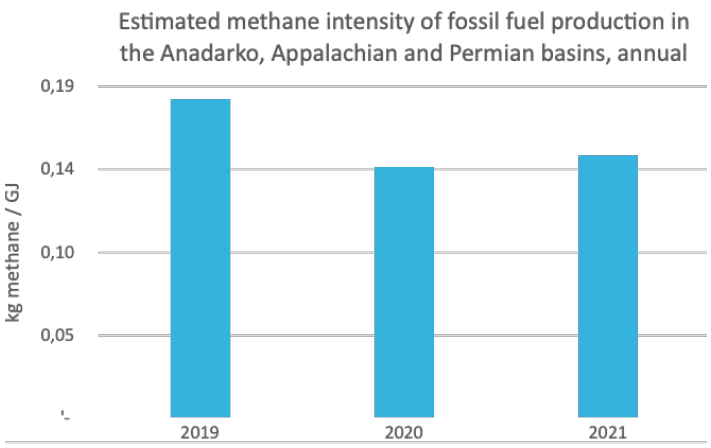
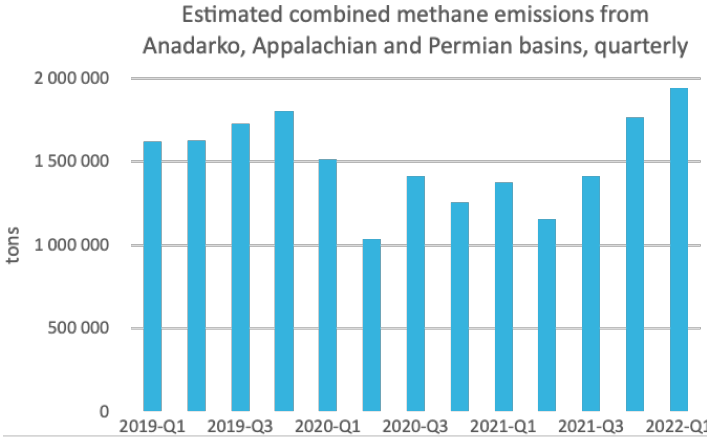
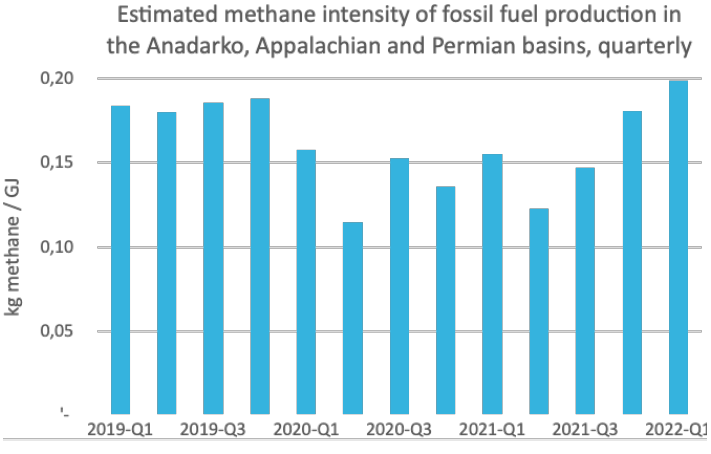


(source: Kayrros Methane Watch)

Moreover, the increase in both total methane emissions and average methane intensity in these three major producing basins significantly accelerated in the first quarter on 2022, reaching ther highest level on record on both counts (subject to revisions in preliminary U.S. EIA production data and uncertainty factors in methane emissions).

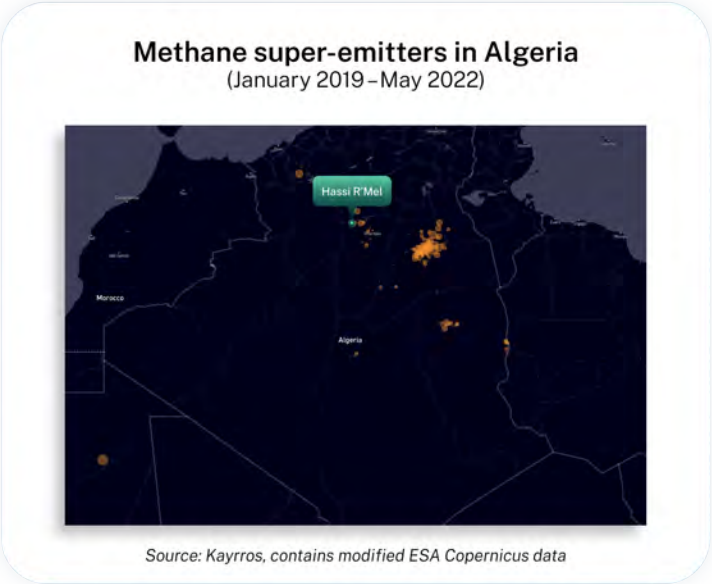


(source: Kayrros Methane Watch)



(source: Kayrros Methane Watch)

ALGERIA HASSI R'MEL (Natural Gas)



Source: Kayrros, contains modified ESA Copernicus data

Outside of the U.S., changes in methane emissions and emission intensity are a mixed bag. In Algeria, a major gas exporter to Europe, basin-wide emissions from the giant Hassi R'Mel gas field fell slightly in 2020 but bounced back with a vengeance in 2021. The growth has continued into Q12022, reaching highs well above pre-Covid levels.

The Hassi R'Mel field is Algeria's largest, accounting for an estimated 90% of the country's overall gas production. The eponymous village that borders it is some 340 miles south of Algiers. The field has production capacity of about 100 billion cubic meter per year. Its gas is piped to the ports of Arzew, Algiers and Skikda and from there feeds into the Maghreb-Europe, Trans-Mediterranean, Medgaz and Galsi export pipelines to Southern Europe. Hassi R'Mel is at the heart of Algeria's hope to boost ouput and export volumes in response to growing demand from Europe as a replacement for Russian gas. Under current conditions, however, the prospect of higher output inevitably raises concerns about the field's large climate footprint.

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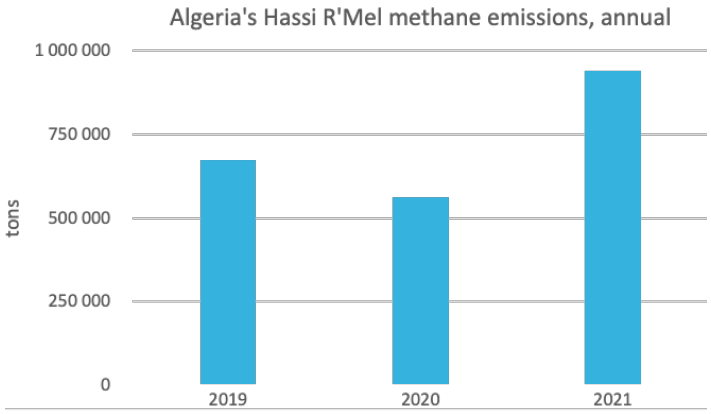
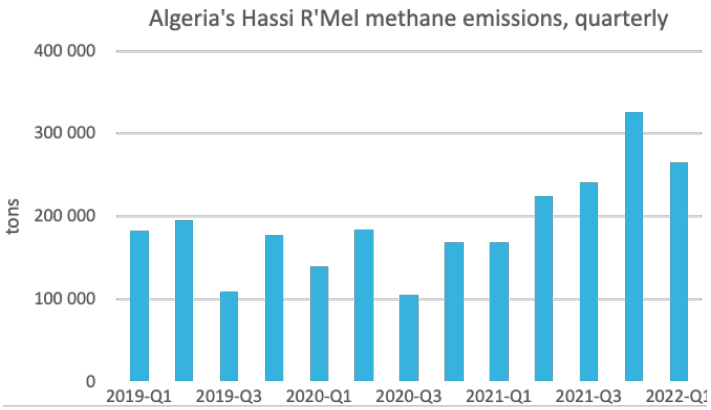


(source: Kayrros Methane Watch)



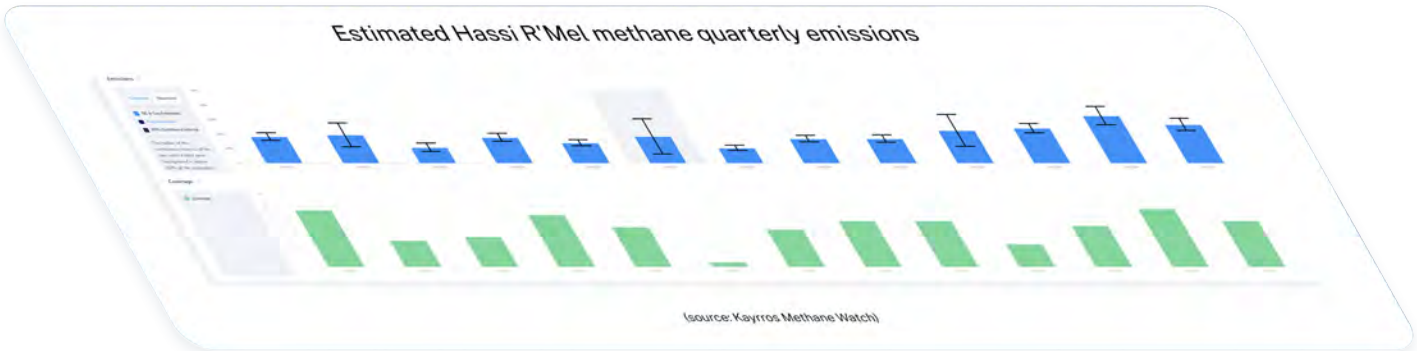
(source: Kayrros Methane Watch)

The gas field was discovered in 1956, along with the giant Hassi Messaoud oilfield, and production started in 1961. It appears to emit considerably more methane than other gas fields that have been more recently developed.

This suggests that part of the associated infrastructure might be ageing and in need of fixing, a hypothesis bolstered by the fact that Hassi R'Mel only accounts for a minute fraction of the overall number of super-emitters detected in Algeria. Large basin-wide emissions without frequent super-emitters suggests the emissions are more likely to be caused by steady leaks rather than big sporadic releases, such as blowouts performed during pipeline maintenance. Thus, a recent study of satellite data by Spain's Valencia Polytechnic University found out that a single compressor station at the Hassi R'Mel field might leak as much as 4.5 tons per hour, or nearly 40,000 tons per year, according to a Bloomberg News report. This would be equivalent to 4% of the overall methane emissions attributed by Kayrros Methane Watch to the basin last year. The same report quoted the CEO of state-owned Sonatrach as saying the company had cut gas flaring at the Hassi R'Mel by a factor of three, to 3 billion cubic meters per year. Still, methane emissions from the field totalled 939,000 tons last year, or 1.25 billion cubic meters -- more than a third of the volumes reported as flared. As methane has more than 80 times the warming power of carbon dioxide in the first 20 years, their release into the atmosphere woud have a much more deleterious effect. Overall methane emission volumes could further increase with higher gas production in 2022.

Number of super-emitters from U.S. oil and gas

	2019	2020	2021	Jan-May 2022
Algeria	**48**	**38**	**30**	**14**
Hassi R'Mel	**1**	**4**	**5**	**1**



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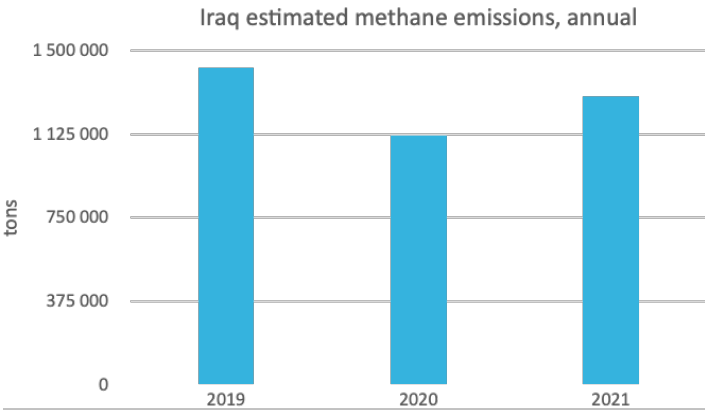
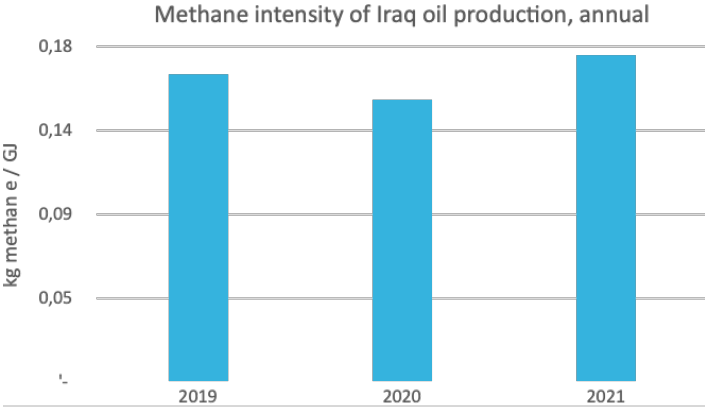
IRAQ

Iraqi methane emissions dipped in 2020 year-on-year in line with crude oil production but retraced some of the decline in 2021, despite continued production loss. As a result, the methane intensity of Iraqi crude production exceeded pre-pandemic levels last year.



(source: Kayrros Methane Watch)



(sources: Kayrros Methane Watch, IEA)

Kayrros measures emissions from southern Iraqi fields -- excluding KRG oilfields and parts of central and northern Iraq under federal government jurisdiction – that it estimates account for more than 80% of total Iraqi crude production capacity. Production volumes estimated by the International Energy Agency have been prorated for the calculation of emission intensity, and associated natural gas was not taken into consideration for this purpose.

Number of Iraq super-emitters of methane				
	2019	2020	2021	Jan-May 2022
	15	**4**	**5**	**2**

On a brighter note, the number of super-emitter events detected in Iraq has declined since 2019. So have the rates of emission, whenever they could be calculated. Some of the methane plumes detected over Iraq in 2019 were truly monumental, including a release estimated at 512 t/h. Some of the more recent releases remain very large, including three of the five events detected in 2021 that all had estimated rates well in excess of 100 t/h, but none revisited the 2019 highs.

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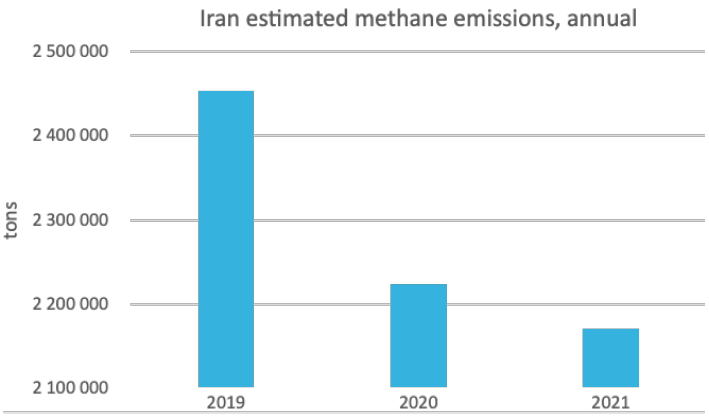
IRAN

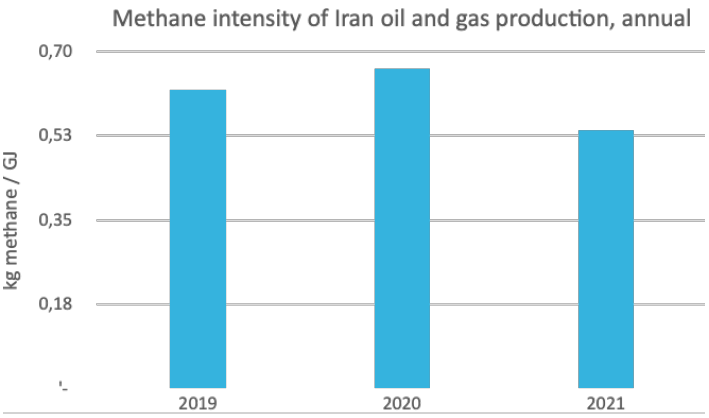
Similar to Iraq, Iranian methane emissions followed oil production followed lower in 2020, down by nearly 10% versus a 15% drop in crude output.

In 2021, estimated production recovered by more than 20% following the election of Joe Biden to the U.S. Presidency and what may have been the expectation of a more relaxed enforcement of U.S. unilateral sanctions but emissions continued to edge marginally lower by 2%. Although the methane intensity of Iranian oil production declined as a result, that drop came from a very high baseline, leaving Iran among the producer countries with the highest methane intensity.

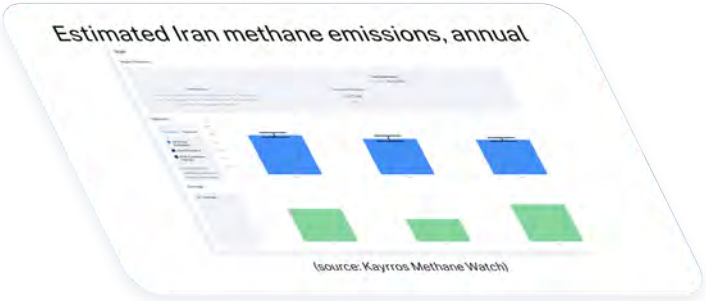
Kayrros monitors emissions from oilfields in eastern and southern Iran that together account for an estimated 75% of the country's crude production capacity. Production volumes estimated by the International Energy Agency have been prorated for the purpose of estimating emission intensity. Associated natural gas production was not factored in.



(source: Kayrros Methane Watch)



(source: Kayrros Methane Watch, IEA)

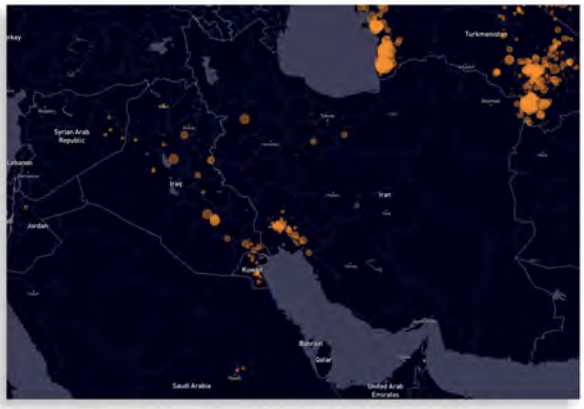


The number of super emitters detected in Iran fell in 2020 along with crude output, only to bounce back in 2021 as estimated production swung back above pre-pandemic levels.

Number of super-emitters of methane in Iran				
	2019	2020	2021	Jan-May 2022
	27	**9**	**22**	**6**

The prospect of higher Iranian output in the event of an international nuclear deal and the lifting of U.S. sanctions raises concerns about a potential rebound in still-high methane emissions. As a gas producer in its own right, however, Iran is incentivized to capture fugitive methane and reduce venting, so as to maximize revenue and/or use its gas for domestic needs. The lifting of sanctions could also help Tehran import spare parts needed to upgrade its oil and gas industrial infrastructure and fix or replace leaky equipment, which would ultimately reduce its methane footprint.

Methane super-emitters in select Middle East Gulf countries
(January 2019 – May 2022)



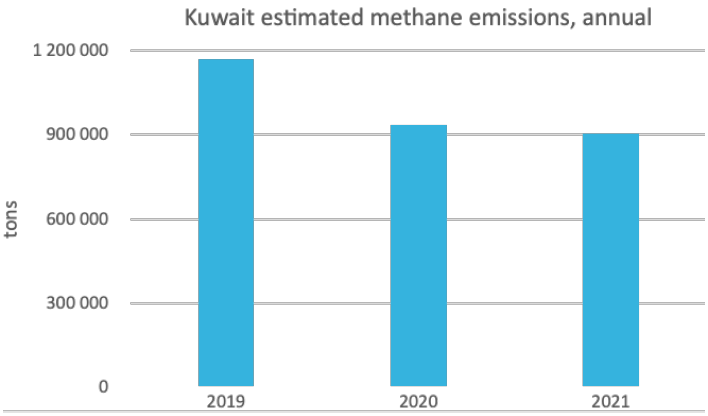
Source: Kayrros, contains modified ESA Copernicus data

U.S. METHANE EMISSIONS FROM FOSSIL FUELS AT RISK OF WORSENING IN 2022, EXTENDING 2021 TREND

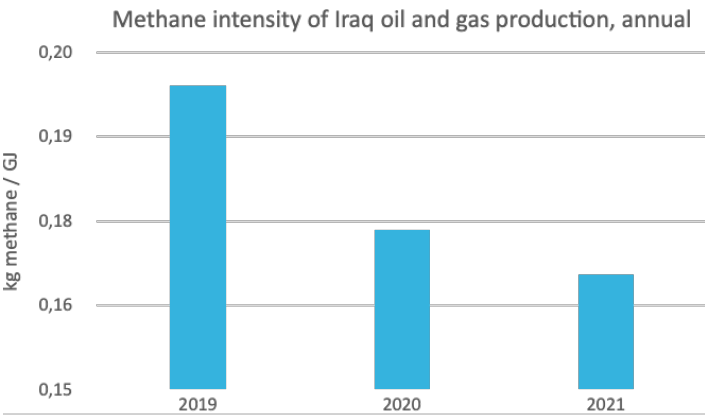
Q12022 data raise concerns about greenhouse gas footprint amid calls for higher oil and gas production.

KUWAIT

Kuwaiti methane emissions plunged by an estimated 20% in 2020, double the rate of decline of crude production. This translated into an improvement in methane intensity of Kuwaiti crude of about 13%. In 2021, crude production barely bounced back, while emissions continued to edge down by 3%. The implied methane intensity of crude production contracted by a further 4%.



(source: Kayrros Methane Watch)



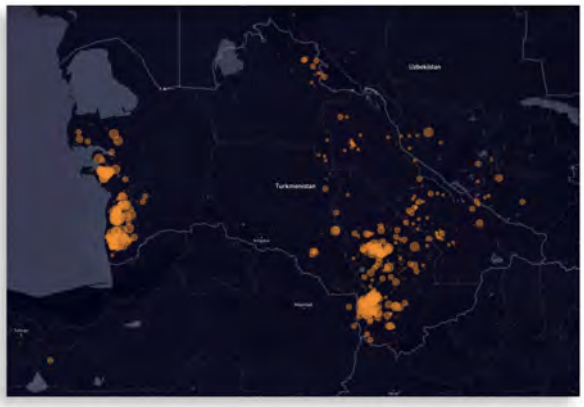
(source: Kayrros Methane Watch, IEA)

There are relatively few super-emitters of methane in Kuwait than can be seen from space. In 2020, the number of super-emitters detected in the country fell by half to four, with estimated rates of 1 t/h to 45 t/h over the 2019-2020 period (not all super-emitters can be rated). In 2021, the number of super-emitters was virtally unchanged.

Number of super-emitters from Kuwait oil production

	2019	2020	2021	Jan-May 2022
FY	**8**	**4**	**5**	**1**

Methane super-emitters in West & East Turkmenistan
(January 2019 – May 2022)



Source: Kayrros, contains modified ESA Copernicus data

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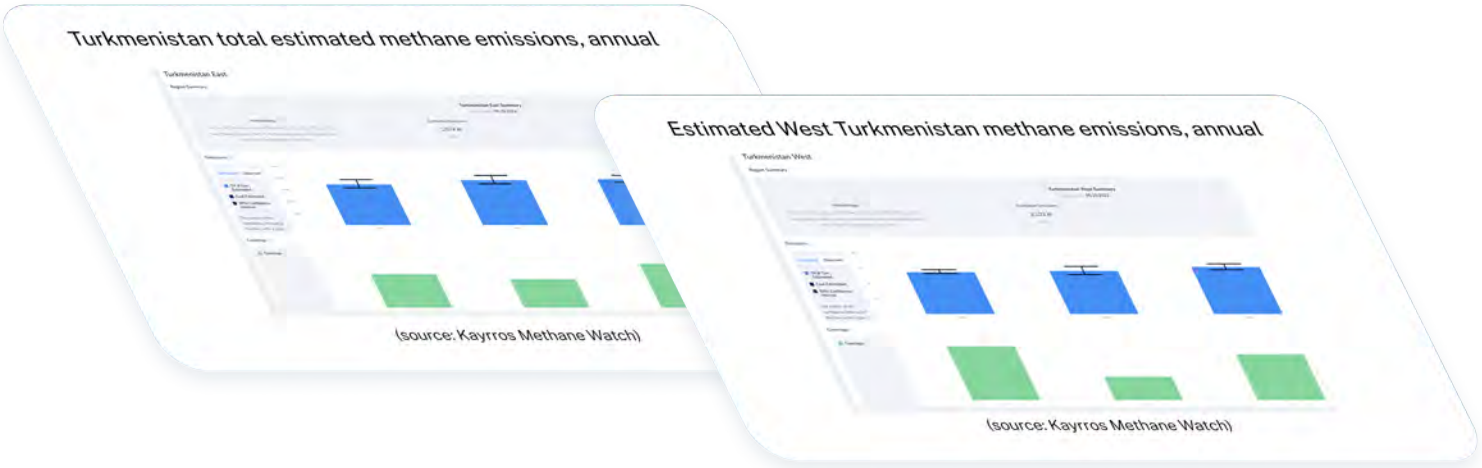
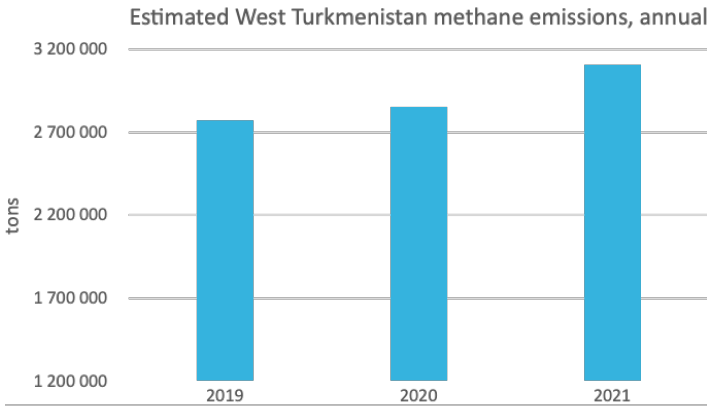
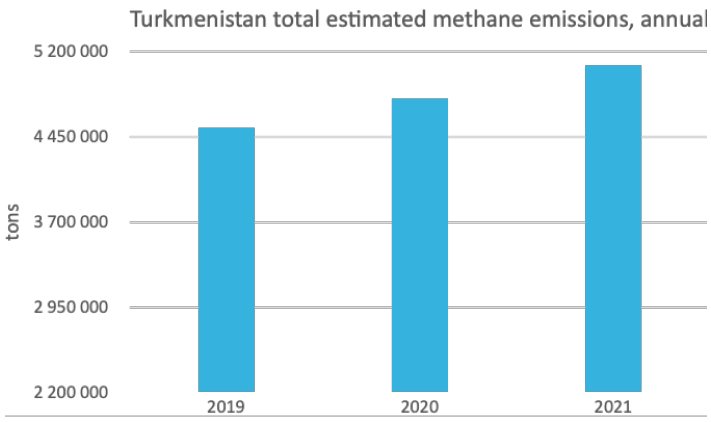
WEST TURKMENISTAN (Natural Gas)



Turkmenistan, a country endowed with a large resource base of oil and natural gas, holds the record for the fossil fuel producer with the highest frequency of super-emitters — as many as 300 in 2019 – including many events with huge emission rates.



(source: Kayrros Methane Watch)



(source: Kayrros Methane Watch)

Emissions from both the western and eastern producing regions increased consistently in 2020 and 2021, with growth for the country as a whole averaging 6% for both years.

Most of the super-emitters in West Turkmenistan were spotted over pipelines transporting gas produced offshore or in some onshore fields. These pipelines appear to be transporting the gas to Iran.

Number of super-emitters from Turkmenistan

	2019	2020	2021	Jan-May 2022
Turkmenistan total	**300**	**126**	**201**	**33**
West	**153**	**28**	**52**	**15**
East	**137**	**92**	**142**	**15**

U.S. METHANE EMISSIONS FROM FOSSIL FUELS AT RISK OF WORSENING IN 2022, EXTENDING 2021 TREND

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THE TIME IS NOW

The urgency of methane abatement is by now clearly established. If not slowed, methane emissions are on track to make as large a contribution to climate change in the next 20 years as carbon dioxide. Monitoring technologies leveraging satellite imaging and AI make it increasingly possible to monitor both super-emitters worldwide – the low-hanging fruits of climate action – and basin-wide emissions through inversion models that can now be accurately deployed in a growing number of regions.

The fallout from Russia's invasion of Ukraine, including the move by western countries to wean themselves off Russian oil and natural gas, and the current tight market conditions are reviving calls for renewed investments in oil and gas extraction capacity and higher export volumes from other producing countries. At the same time, Russia's incentives to reduce the methane footprint from its gas industry have been significantly reduced by the loss of western markets.

Basin-level monitoring provides a critical check on the state of methane abatement and progress towards 2030 emission targets set out by the Global Methane Pledge at a time of increasingly fraught market conditions. The latest readings show things are moving in the wrong direction. Despite progress in some regions, in many others the drop in emissions that initially resulted from the Covid-19 pandemic has been either partially or fully reversed and the pace of emission growth appears to be accelerating. This is especially true of the U.S., a country called upon to play a crucial role in addressing current European energy security concerns.

It doesn't have to be that way. Unlike carbon emissions, methane emissions are not an inevitable consequence of fossil fuel consumption. On a bright note, advances in monitoring technology now make it possible to design and implement effective abatement policies and enable companies to both reduce their methane footprint in a cost-efficient way and communicate about it verifiably. Not all regions can yet lend themselves to basin inversion assessments based on Tropomi imagery, but many can. Furthermore, Kayrros is finalizing new technologies that will dramatically expand the scope of basin-wide measurements.

New methane regulations currently being worked out in the U.S. and Europe will not come a moment too soon. Let's hope the next quarterly report will show the trend moving back again in the right direction.

IN A NUTSHELL

Kayrros has developed a proprietary, satellite-based full-inversion model to measure methane emissions from key onshore oil and gas producing regions. ***Here's how it works:***

- Methane concentration grids from satellite images provide the primary input.
- Raw images are corrected for atmospheric conditions and ground reflections.
- Background methane concentrations are filtered out to separate anthropogenic emissions from natural concentrations in the atmosphere.
- Gas diffusion simulation models are applied.
- Ground operational data derived from satellite and geolocation data (well completions, flaring intensity, etc.) are used to identify potential emission sources and statistically attribute methane emissions to specific areas.

Basin-level estimates have an uncertainty factor of 10-20% due to the scope of Sentinel-5P coverage, not including simulation modeling-related uncertainties.