Playing with fire:
Measuring emissions from the world's oil and gas fields

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Highlights

- There are significant differences in the greenhouse gas (GHG) footprint of oil and gas fields
- Apart from so-called heavy oil fields, the geological nature of the resource is not connected to the GHG footprint
- For both crude oil and natural gas production, methane emissions are the main driver of GHG intensity. For crude oil, flaring of associated gas is another major source of GHGs
- The extent of flaring and escaped methane differs greatly based on the interplay between geography and regulation. Countries with strong regulatory oversight, such as Norway, rank well, while areas with less rigorous rules, including Iraq, Algeria, and Texas, perform poorly
- We believe an assessment of GHG intensity and practices around venting and flaring at oil and gas producers should be a central part of any climate engagement by investors
- Investors can and should favour producers with the lowest GHG intensities

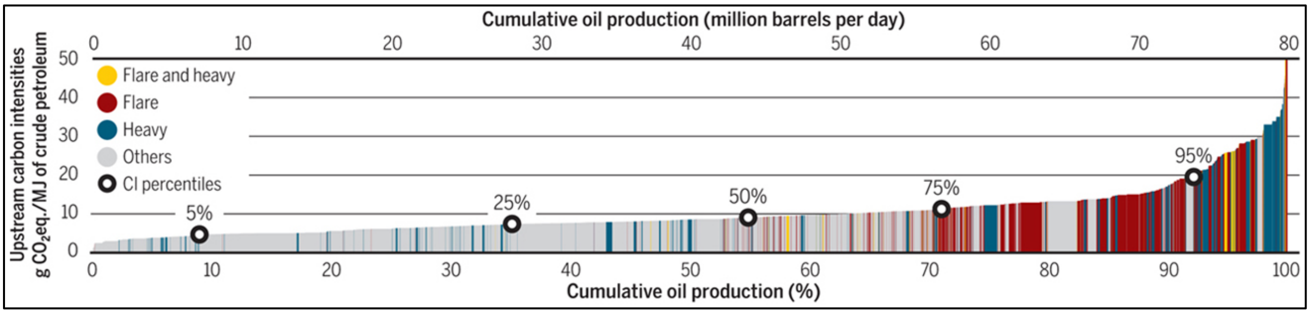
Crude oil and natural gas account for 57% of the world's primary energy consumption. They also account for between 40% and 45% of GHG emissions[1]. Most of those emissions (typically 75% to 85%) come from the combustion phase, when diesel drives an engine or natural gas fires a power plant. At this stage, it doesn't matter where the fuel came from – it all burns the same – but at the point it was extracted there can be important differences for investors to consider as they seek to decarbonise portfolios.

The goal of the energy transition is to reduce steadily and substantially that burning – to develop alternative solutions and technologies which make good on state-level commitments for a net zero world. It will take time to detach fossil fuels from the heart of our economies, and in some instances their use will endure. This makes it vital that we understand and address the operational, geographical and technical factors behind oil and gas emissions generated before they are consumed.

Heavy going: Oil fields

A crucial piece of analysis in the study of oil fields and emissions was published in the magazine *Science* in 2018 covering 8,966 fields, representing more than 98% of world oil production as of 2015. The purpose was to measure systematically the well-to-refinery carbon intensity of those fields. The following chart presents the outcome:

Breaking down global emissions intensity



Source: "Global carbon intensity of crude oil production", Mohammad S. Masnadi et al., Science 2018

The study concluded that the average barrel of oil has an intensity of 10.3 grammes of CO_2 equivalent per megajoule (gCO_2e/MJ). CO_2 represented 65% of total emissions and methane 34%. In terms of the sources of emissions, flaring alone (the burning of gases associated with oil production) accounted for 23%. Most interesting perhaps was the widespread range revealed in the data. The worst 5% of oil fields emitted more than twice as much as the average field, while those in the best 5% emitted less than half of the average. Those oil fields showing the highest emissions intensity did so largely thanks to two characteristics:

- **Nature-made:** Heavy oils are dense and viscous[2]. To be extracted and to flow, they require large quantities of heat – often delivered as steam – and the high energy input explains the high GHG intensity. Canadian tar sands are a typical example, as well as crudes from Venezuela or California

[1] BP Statistical Review of World Energy 2021
[2] Heavy oils in this study were defined as having an API gravity below 20°. This measure from the American Petroleum Institute looks at how oil compares to water. For reference, light crude is generally considered to have an API gravity above 35°, while extra heavy oil would tend to have an API gravity of below 15°. Source: McKinsey Energy Insights

- **Human-made:** Most oil fields also produce natural gas (the gas-oil-ratio or GOR is the standard measure of the proportion). If this gas is not properly handled, it ends up being burned (flared) or directly passed into the atmosphere (vented). This ramps up GHG intensity as flared gas becomes CO_2 and the methane molecule (the major component of natural gas) is 28-36 times more potent than CO_2 on 100-year horizon[3]

To illustrate the point, in the top quartile for intensity, 51% of the fields are high-flared fields and 18% are heavy oil fields. For the other three quartiles combined, that stands at 4% and 9% respectively.

A notable observation is that beyond these two factors, the nature of the resource was not a determining factor. Whether an oil field was onshore or offshore, fracked or not fracked, in the Arctic or close to the equator, these factors proved largely irrelevant to its GHG intensity.

In its World Energy Outlook 2018, the International Energy Agency (IEA) published its own detailed analysis of crude oil's GHG footprint. This differed slightly from the *Science* analysis as it used a different metric – kilos of CO_2 equivalent per barrel of oil equivalent (kgCO_2e/boe) – and captured more of the pre-consumption impact by including transportation of crude and products as well as refining. Although there was no distinction by crude category, venting and flaring were clearly identified.

The agency concluded that the average barrel of oil requires 93.6 kgCO_2e/boe to be brought to the customer. It also revealed a very large range of intensity, with the worst decile emitting more than four times more than the best decile.

Several other points stood out:

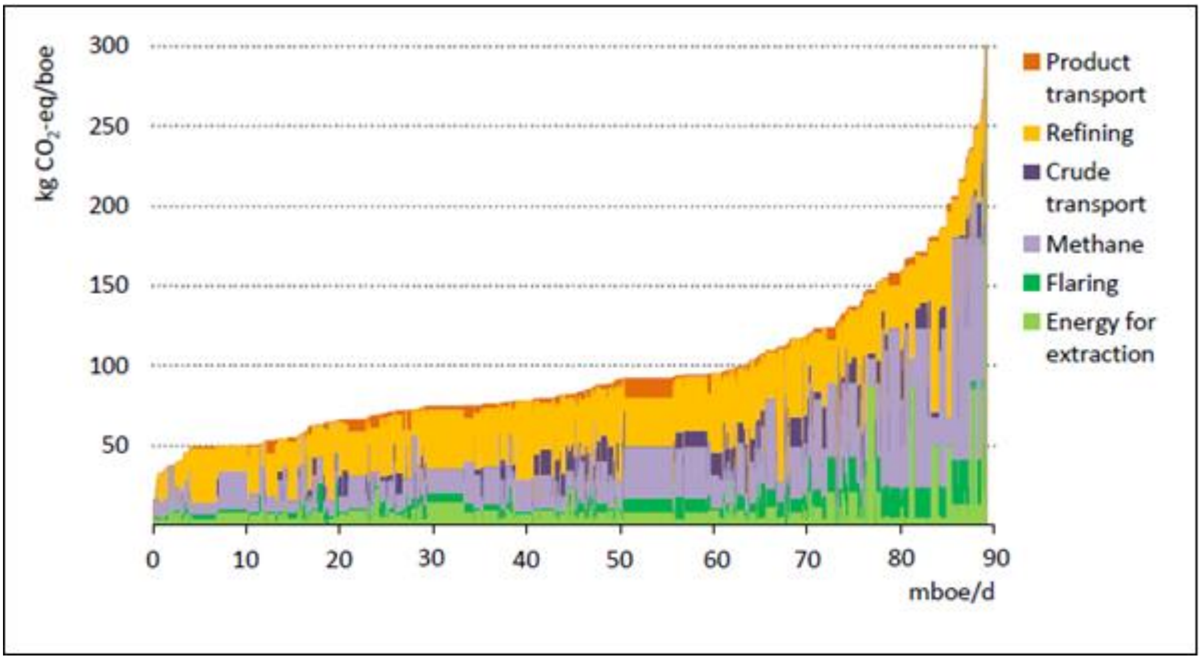
- Extraction *per se* accounted for "only" 15% of emissions pre-consumption
- Methane emissions, either through flaring or venting, accounted for 40% of the average intensity and were the main driver of GHG emissions
- The GHG intensity of refining is shows sharp contrasts, with the worst refining operations emitting five times more GHGs than the best. The technical configuration of refineries was the main source of any differences: simple refineries processing light crude were able to do so with relatively low energy consumption, while complex refineries treated heavy crudes in a series of energy-intensive steps. Heavy crude oils not only generate more emissions while being extracted, but in processing as well

The IEA reached similar conclusions to the *Science* authors – heavy oil fields and fields with poorly managed associated gas are on the high end of the emission intensity curve. Once again, other factors were found to be far less significant for GHG intensity.

One comment should be added: Measuring methane leaks and so-called fugitive emissions is a challenging task[4]. Actual leakage is very likely to be higher than reported by many studies, implying a higher level of GHG emissions.

[3] Climate Change 2014. Synthesis Report",IPCC, page 87
[4] A climate change conundrum: Is there a sweet spot for natural gas in the energy transition?

Indirect emissions intensity of global oil production, 2017



Source: IEA, World Energy Outlook 2018. Mboe/d = million barrels oil equivalent per day

Another element to keep in mind is that the GHG intensity of oil fields tends to rise as the fields age. As oil is produced, the pressure in the reservoir declines. This means either less production for the same energy input or maintaining production levels with increased energy input.

From an oil producer perspective, there are two key conclusions from the studies:

- For tar sands and heavy oil, the choice is to invest or not. Several companies have exited Canadian tar sands given their high GHG intensity (and financial volatility), although the tendency is to sell the assets, rather than close them. The industry is now very much consolidated amongst a few Canadian companies. Those companies are often not investable for investors with a tar sands policy, such as AXA IM.
- For fields with a high GOR, any company serious about reducing emissions must develop the required infrastructure to collect the associated gas instead of flaring or venting it.

Methane maths: Natural gas fields

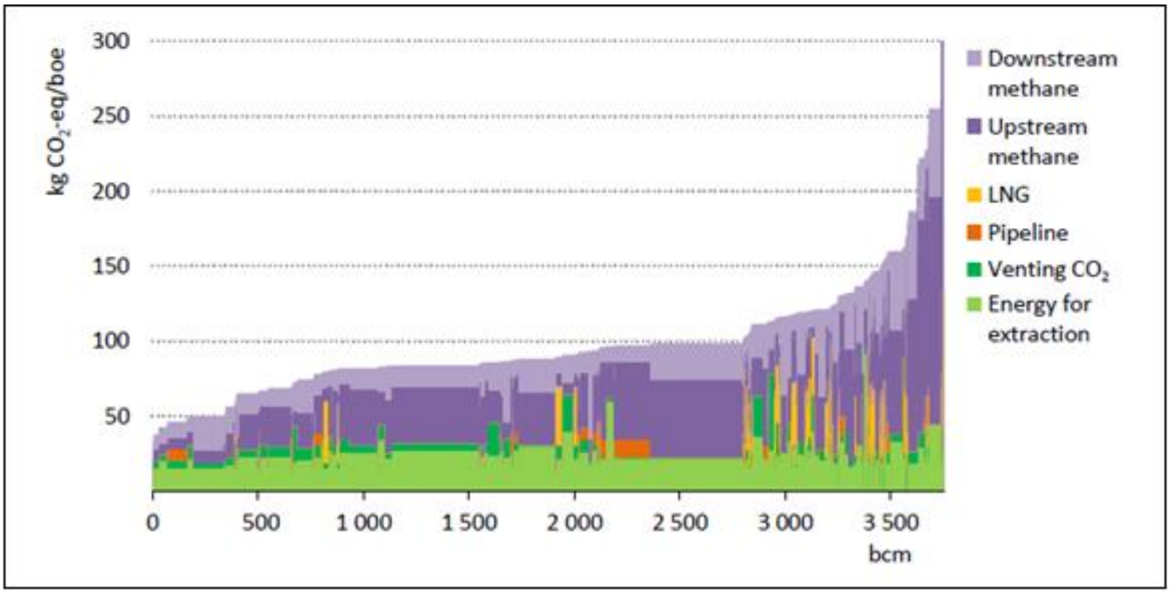
The IEA has carried out the same analysis for natural gas as it did for crude oil. The emissions profile from natural gas differed as flaring was not an issue, but methane emissions along the entire value chain were shown to be problematic. The agency concluded that the average unit of natural gas requires 95.5 kg CO_2e/boe to be brought to the customer. In a similar pattern as for crude oil, the worst offenders emit four times more GHG to produce natural gas than the best producers do, looking at the best versus worst deciles.

Several points stand out from this analysis:

- Extraction is a bit higher than for oil with a 27% share of emissions pre-consumption
- Methane emissions are very critical, both upstream and downstream (i.e. in pipelines), as they account for 60% of total emissions
- Liquefied Natural Gas (LNG) shows an overall higher intensity (118 kg CO_2e/boe), explained by the energy consumption to liquefy and ship the gas, and despite lower methane emissions
- Vented CO_2 is specific to natural gas production: Most gas fields contain CO_2, from traces to double digit percentages, which is stripped out in processing plants and most often released in the atmosphere

Overall, the highest GHG emitting natural gas production – on the right of the curve – is that with the highest level of methane emissions, especially upstream.

Indirect emissions intensity of global gas production, 2017



Source: IEA, World Energy Outlook 2018. bcm = billion cubic metres

As is the case for oil, it is widely acknowledged that actual methane emissions are higher than those reported, in this case mostly in the transportation and distribution phase.

For companies involved in the natural gas value chains, there are a couple of conclusions to reach:

- Controlling methane emission ought to be a priority, both at the well head and in the sometimes very long transportation phase. Technologies and equipment to do so exist and are most often economic

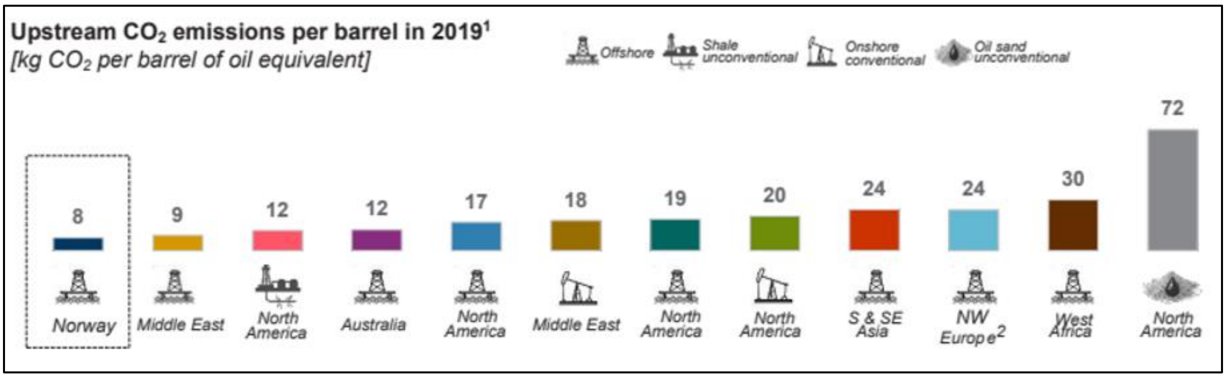
- Vented CO_2, although a small part of the GHG footprint (on average 7% of emissions), ought to be either reinjected underground or utilised. Companies without a proper associated CO_2 approach should not develop CO_2-rich gas fields

Flare up: Geographical analysis

When looking at the GHG footprint through a geographical angle, the outcome largely reflects how flaring and venting practices interact with regulation and geology.

The following chart, based on data from energy consultant Rystad, shows the 2019 emission intensity at the upstream level by region and by nature of resources, distinguishing onshore conventional, onshore unconventional, offshore, and Canadian oil sands.

Tar sands stand alone



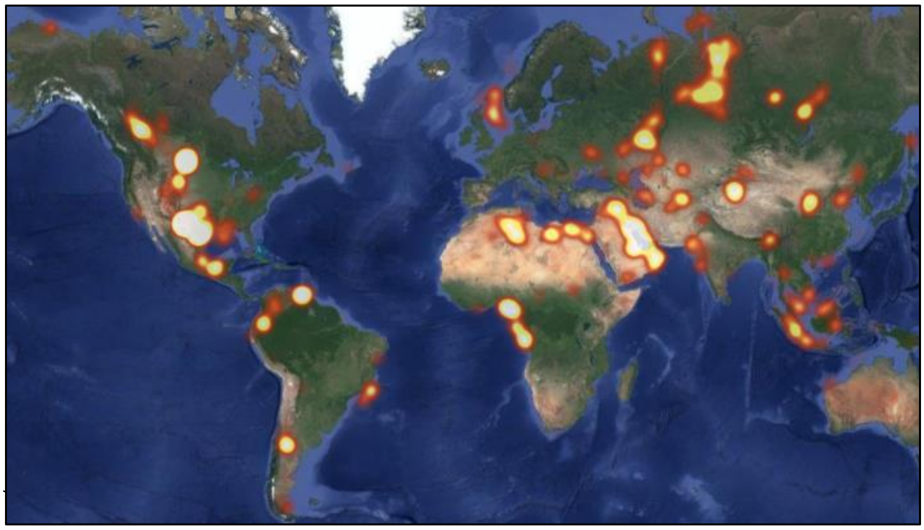
Source: Rystad data as published in The energy industry of tomorrow on the Norwegian continental shelf. Konkraft, 2021

This chart shows significant geographical variability in GHG intensity. This is not surprising given the intensity curves observed for both crude oil and natural gas. It also highlights a few realities that are not widely known, or differ from supposedly common wisdom:

- The shale industry in North America is well below average. This data fails to factor in fugitive and unreported methane emissions, but this nonetheless shows that well-managed shale operations are relatively benign in terms of GHG intensity. Shale faces other specific environmental issues, mostly around access to water and wastewater management
- Canadian tar sands are in a category of their own. This extreme high intensity, alongside the substantial environmental footprint of mining operations, is the basis for AXA IM's exclusion policy for any mining or pipeline company deriving 20% or more of revenues from tar sands extraction[5]
- Offshore operations can be found in many places on the intensity curve, from best-in-class Norway, where the regulation is stringent, to Nigeria where gas flaring is significant
- Onshore Middle East is a region of contrasts. If Saudi Arabia is at a low level – around 10 $kgCO_2e/boe$ – Iraq and Iran are much higher as they are guilty of large-scale associated gas flaring

[5] AXA IM Climate Risks Policy, April 2021

Tracking leaks around the globe

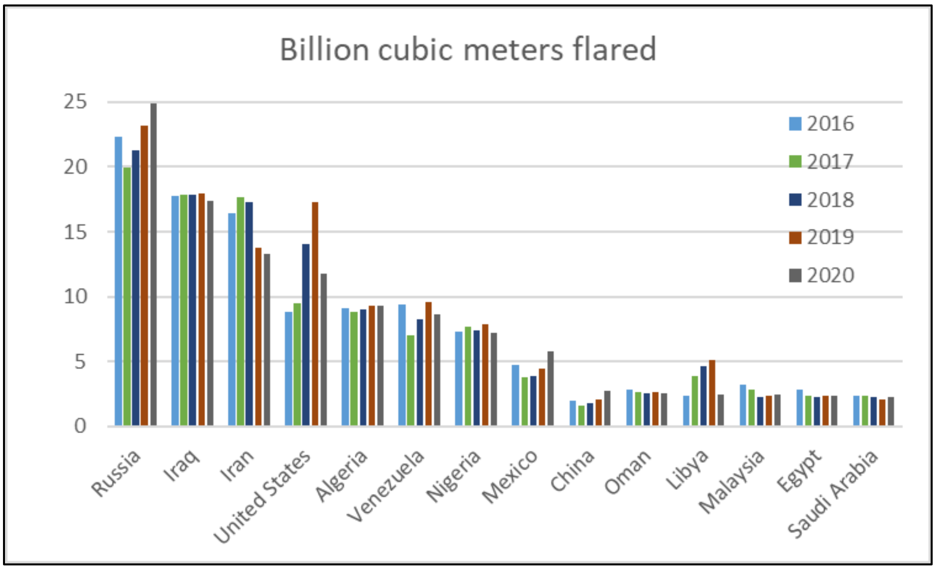


Source: The World Bank. 2020

As mentioned earlier, natural gas flaring is a major driver of GHG intensity. In 2015, the World Bank launched a "Zero Routine Flaring by 2030" initiative and created a website with a wealth of data and information. The following satellite picture shows clearly where flaring occurred in 2020. The subsequent chart indicates which countries flare the most in absolute.

Once again, flaring – and venting – are operational choices. They can be prevented, either by strict regulation or by companies' choices. In most cases, the economic equation is favourable, and technologies are freely available.

Evolution of flaring 2016-2020

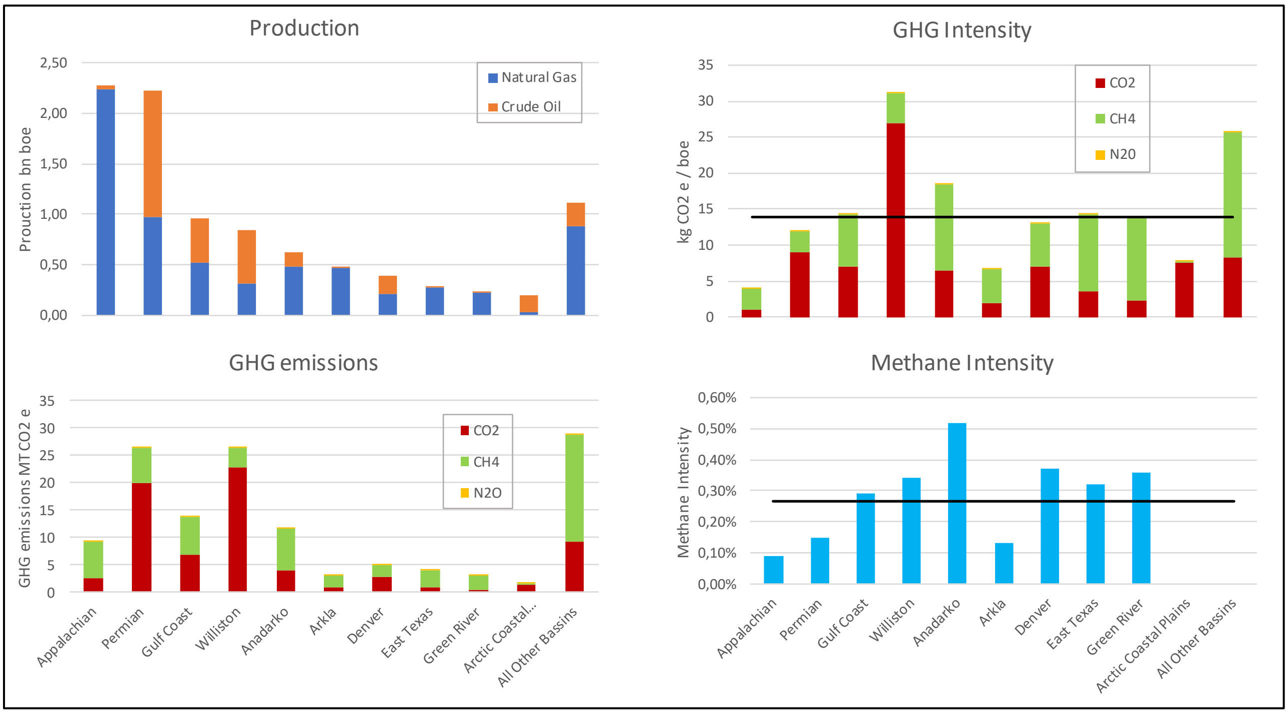


Source: The World Bank – Global Gas Flaring Reduction Partnership

Drilling down: The US in detail

Finally, we take a closer look at US oil and gas production. A systematic study of GHG and methane intensities by basin of production was published in June 2021 by MJ Bradley & Associates, on behalf of Ceres, a non-profit organisation. The following charts highlight the main results.

Charting drivers of emissions in the US



Source: "Benchmarking Methane and Other GHG Emissions of Oil & Natural Gas production in the US", MJ Bradley, Clean Air Task Force and Ceres, June 2021

As seen in the previous analyses, there is a wide discrepancy between basins, and indeed within basins as well. And once again, venting and flaring are the two key drivers of GHG intensities.

It is also worth noting that smaller companies, on average, have higher intensities. Out of the 295 companies covered in this study, the smallest 80% – 235 producers in total – account for 21% of production but 40% of GHG emissions.

Those 235 producers have an average GHG intensity of 25.6 kgCO_2e/boe versus a result of 10.6 kgCO_2e/boe for the largest 20%. This highlights the importance of scale in the development of shale fields, as the need for infrastructure, especially to manage associated-gas production, is critical.

Lessons for investors

The energy transition is about changing the energy mix of our societies and economies – in other words, replacing fossil fuels with decarbonised energy sources. This will take many years and require significant effort from all stakeholders.

For investors who choose to accompany corporates in their transition journey, engagement and selectivity will be critical, most significantly in the oil and gas industry. At AXA IM, we strongly believe in a broad, consistent and demanding approach[6].

Evolution of carbon intensity at key players

Date from annual and sustainability reports

	2016	2017	2018	2019	2020
Aramco				10.4	10.5
BP	34.7	30.4	27.8	25.9	24.1
Chevron - Crude oil	41.9	36.8	37.0	33.3	28.3
Chevron - Gas	32.6	35.0	34.7	30.4	26.8
EOG		17.1	17.7	14.8	13.6
Equinor	9.8	8.8	9.0	9.5	8.0
ExxonMobil	25.8	25.8	26.6	24.8	24.0
Lukoil	25.4	23.954	21.1	21.0	21.62
Petrobras		21.0		17.3	15.8
Rosneft			25.1	27.3	30.2
Shell	23.0	22.0	21.0	22.0	21.0
TotalEnergies			20.0	19.0	18.0
O&G Climate Initiative Members		22.7	22.1	21.1	19.5

Source: Annual reports and Sustainability reports. AXA IM. The O&G Climate initiative consists of 12 companies accounting for 28% of global O&G production in 2020. Figures in kgCO_2e/boe

We believe that an assessment of GHG intensity and practices around venting and flaring at oil and gas producers should be a central part of any climate engagement for an active responsible investor. The GHG intensity per barrel of oil equivalent will be an important metric in AXA IM's analysis as we seek best-in-class transition companies. The table above provides a sample of this indicator for a few large oil and gas producers.

We also believe that oil and gas producers with the lowest GHG intensities can and should be favoured by investors and that any truly active and responsible asset manager should be transparent and vocal about this approach, its rationale and its hoped-for outcomes as we seek to decarbonise client portfolios and protect them against key risks in the energy transition.

[6] AXA IM's announcement of a strengthened climate policy, 8 November 2021