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Expert energy opinion and insight

# The Phantom Menace: Impact of Methane Leakage on Gas Climate-Friendliness

Natural gas, composed mostly of methane, is considered the most climate-friendly of the three main fossil fuels, with only about half the carbon dioxide emissions of coal. But methane is itself a powerful greenhouse gas, particularly on shorter timescales. Leaks of methane during natural gas production, transportation and use threaten to weaken or even eliminate its climate advantage, and some environmental groups have seized on the issue to oppose natural gas developments. How serious is the leakage problem? And how can companies address it?

Gas leak from the Aliso Canyon gas storage facility, California, seen in infra-red (EDF)

## Executive Summary

- Methane, the main constituent of natural gas, is a powerful greenhouse gas. Natural gas itself releases much less carbon dioxide than coal or oil when burned, but methane leaks reduce its climate benefit.

- Worldwide leakage is estimated at about 3%. On a 20-year timescale, if leakage rates are less than about 8.4%, gas still has a lower global warming impact per unit of useful energy than coal. Nevertheless, any leakage worsens the climate impact of natural gas.

- Methane is released by agriculture, biomass burning and natural wetlands as well as from fossil fuels. Atmospheric methane concentrations have risen steadily in the industrial period, and particularly since 2006, although isotopic measurements suggest the latest rise is *not* because of fossil fuel methane.

- Methane leakage has become an increasingly important issue for environmental activists and greenhouse gas reduction policies.

- There are wide disparities in estimates of methane leakage, even in the well-studied US. Leaks come overwhelmingly from a small number of less careful operators and pieces of malfunctioning equipment. There are also wide gaps in levels of methane leakage between countries, partly due to different situations (such as age of equipment and operating standards and experience), but partly also because of inadequate or inconsistent measurements.

## Implications for leading gas exporters

- Methane leakage weakens the environmental case for using natural gas and, if not addressed, will lead to growing opposition to gas-field development, gas pipeline and LNG terminals, and natural gas-fired power.

- The gas industry can work collaboratively to take proactive steps to measure leakage accurately, and reduce leaks. It is technically feasible to eliminate about 75% of methane leaks, and 40-50% can be prevented at zero or negative cost (depending on how gas is priced). This will help safeguard the industry's future societal acceptance.

- Tackling methane leakage is a straightforward and low-cost way for countries to reduce their greenhouse gas footprint, and hence helping them to achieve their Paris Agreement goals.

- Companies that move decisively on reducing leakage could market their product as having lower greenhouse emissions, giving a competitive advantage.

- Major gas-producing countries could also contribute to reductions in other sources of methane, for example by changing agricultural practices, and capturing landfill (waste) gas.

## Methane is a powerful greenhouse gas

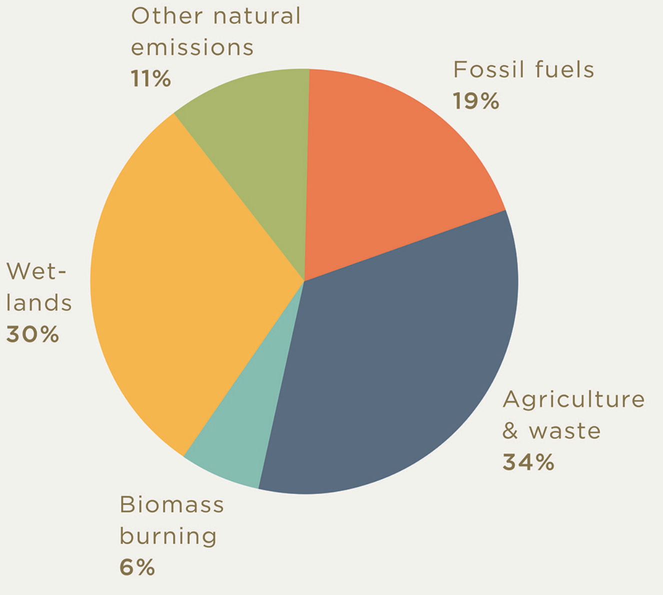
Natural gas is a much lower-carbon fuel than coal. Coal produces about 1.67 times as much carbon dioxide per unit of heat as natural gas when burnt. In addition, gas-fired power plants are typically more efficient at converting heat to electricity, 54% in the US versus 33% for coal. Therefore, per kilowatt hour of electricity generated, coal is 2.73 times more carbon-intensive than natural gas. If comparing fuels used for heating, then gas's advantage is less, but of course burning coal for space heating is strongly regulated in many countries.

This leads to the conclusion that replacing coal-fired (or oil-fired) power, industry and home heating with natural gas has a very beneficial effect in reducing carbon dioxide emissions.

However, methane, the main constituent of natural gas, is itself a powerful greenhouse gas.

Methane is released from oil, gas and coal activities; from agriculture; waste; and from the burning of biomass. It is also produced naturally by wetlands, insects, permafrost melting and other causes (FIGURE 1). Estimates of world methane emissions are highly uncertain, but artificial emissions may be in the range of 327 million tonnes (Mt) annually, of which fossil fuels account for 105 Mt, and the oil and gas industry specifically 76 Mt.

FIGURE 01: **SOURCES OF ATMOSPHERIC METHANE**[1]

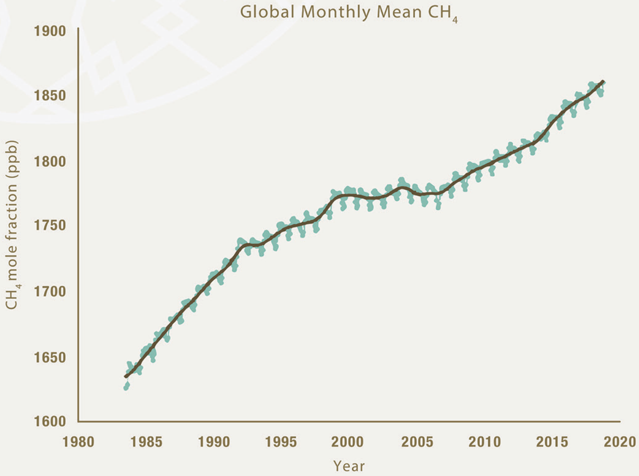



About 60% of methane contributed to the atmosphere comes from anthropogenic (human-caused) sources, the rest being natural. Of the anthropogenic sources, the fossil fuel industry contributes about one-third.

Methane contributes about 17% of the anthropogenic global warming effect[2], making it the second-most important greenhouse gas (carbon dioxide represents 64%, nitrogen oxides 6%, and fluorinated hydrocarbons 11%).

Atmospheric methane concentrations have approximately doubled during the industrial era, and have continued rising sharply over the last decade (FIGURE 2).

FIGURE 02: **ATMOSPHERIC METHANE CONCENTRATION**[3]




Between 2000-2006, as can be seen from FIGURE 2, atmospheric methane plateaued, before starting to rise again. The pause in rising concentrations is probably due to a reduction in leaks from the fossil fuel industry. Measurements of the isotopic composition of atmospheric methane shows a growing depletion in $^{13}C$ versus the more common $^{12}C$. In turn, this suggests that the cause of post-2006 rises in methane is not fossil fuels, which are higher in $^{13}C$, but instead natural wetlands and agriculture[4].

## Even small methane leaks have a significant climate impact

Natural gas for sale typically consists of 85-95% methane. On a short time-scale, methane has a much higher global warming effect per tonne than carbon dioxide. On a longer timescale, methane breaks down by atmospheric processes into carbon dioxide and water, and its global warming effect reduces. Methane's atmospheric half-life is about 8.6 years[5] - i.e. half an emitted quantity remains after 8.6 years, a quarter after 17.2 years, and so on. Consequently, most of its warming impact occurs in the first few years. Continuous release of methane is necessary for it to have an ongoing warming effect.

Still, on average over 100 years, the usual standard, methane's warming impact per tonne is 21 times that of carbon dioxide (FIGURE 3).

Most leakage in the petroleum industry comes from production, gas gathering and processing (FIGURE 4). Only a relatively small proportion is emitted from transportation and distribution, though this may be larger in countries with old, badly-maintained pipeline systems.

## Methane leakage varies widely and is hard to measure

Leaks can be measured either 'bottom-up' by surveying individual pieces of equipment, or 'top-down' by measuring atmospheric methane via plane or satellite.

FIGURE 03: **RELATIVE GLOBAL WARMING POTENTIAL OF METHANE AND OTHER GASES, PER TONNE**[6]

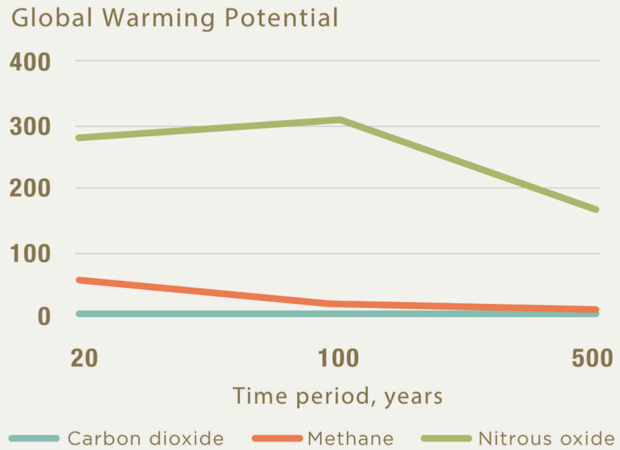
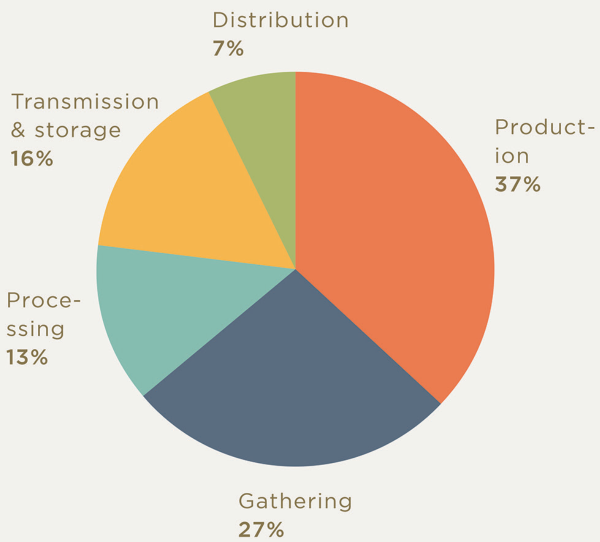



FIGURE 04: **SOURCES OF METHANE LEAKAGE FROM THE OIL & GAS INDUSTRY**[7]




The US Environmental Protection Agency estimates leakage at 1.4% of the amount produced, and the National Energy Technology Laboratory suggested 1.7%[8]. In contrast, studies coordinated by the Environmental Defense Fund, a US non-governmental organisation (NGO), suggest a leakage rate of 2.3%[9]. The higher estimate mainly comes from a small number of 'super-emitters', about 4% of industry sites, with much higher emissions usually due to malfunctions of equipment. Some 70% of emissions come from super-emitters.

These estimates come from US examples. Leakage rates may be very different elsewhere in the world, due to the age of equipment, different standards and regulations, and production and maintenance practices. The US, with many dispersed production sites, may be more vulnerable to leaks than a producer such as Qatar with a small number of very prolific wells.

Estimated leakage by country is shown in FIGURE 5. The countries shown on this chart account for 92% of world gas production but only an apparent 75% of leakage. Worldwide leakage rate is estimated at 1.7% (International Energy Agency (IEA)[10]) to 3% (Rhodium Group[11]).

The FSU countries – Russia, Uzbekistan, Azerbaijan, Ukraine and Kazakhstan – have unusually high leakage rates. However, some leading gas producers, such as the UAE, Qatar, Saudi Arabia, Australia and Norway, have very low rates of reported leakage. This may reflect more modern equipment, production from a small number of prolific wells, and production offshore where leakage would be dangerous and so there is more care to avoid leaks. But it likely also indicates under-reporting, since the implied "rest of the world" leakage rate is unfeasibly high.

These statistics suggest US leakage of 1.8%, whereas, as noted above, the EDF estimates suggest 2.3% (albeit these are from different years). If all per-country figures were underestimated in the same way by 28%, then the total emissions from the main countries would approximately match the world total.

If the countries with the worst leak rates were able to reduce them to the corrected US level of 2.3%, then leakage would be cut by 410 Mt of $CO_2$ equivalent, or about 32% of the methane emissions from the main countries shown here.

## Methane leaks can be cut dramatically by relatively easy measures

Methane is a valuable product, and large leaks are a safety hazard, as well as a cause of local air pollution by forming ozone. Since most leakage is caused by malfunctions of equipment or poor operational practices, it can be reduced at low or even negative cost.

As an example, inspections in Colorado find a methane leak in 90% of sites; there were 2-3 leaks per site on average, of which 88% were small.

Super-emitters are caused by a variety of factors, including operational error (leaving storage hatches open), malfunctions (valves stuck open), and mechanical failure (loose connections, leaking compressor seals). Routine maintenance and operational awareness can solve many of these problems.

Small sensors with remote monitoring are under development, and would alert operators to unusually high levels of leakage, including major leaks that might be safety hazards. Aerial monitoring is another effective way to spot leaks that might otherwise be missed, and drones could be more widely employed here. Surveys using lasers carried on helicopters cost about $85-90 per kilometre of pipeline. Leak Detection and Repair (LDAR) programmes raise awareness and involve regularly-scheduled investigations.

In 2012, the US Environmental Protection Agency set targets to reduce methane leakage by 25-50%. 'Green completions' are now mandatory in the US, and have reduced emissions during completion of new wells by 99%. They include using portable equipment to capture the gas released during flowback and testing of new wells. Devon Energy estimates that the equipment, rented for $1000 per day, saves $50 000 worth of gas per well[13].

FIGURE 05: **METHANE LEAKAGE BY COUNTRY, 2012**[12]

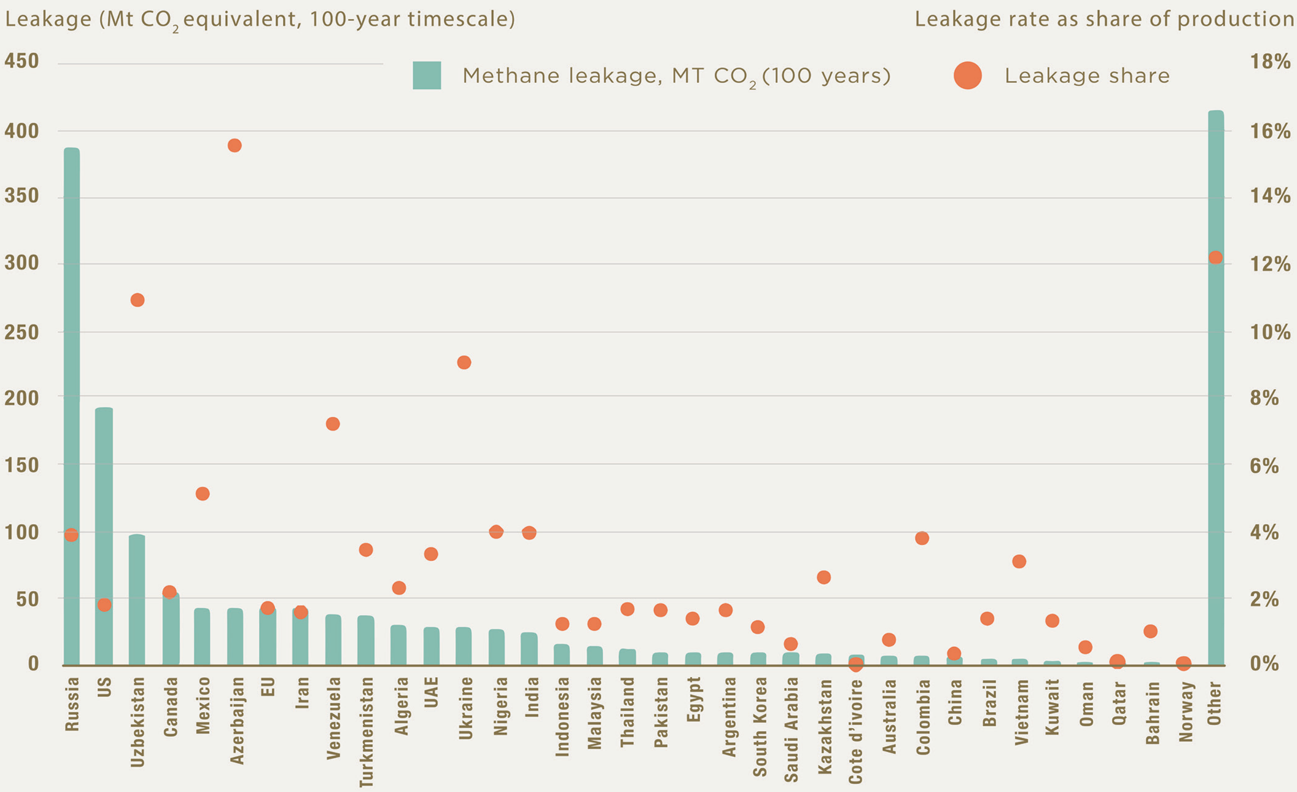
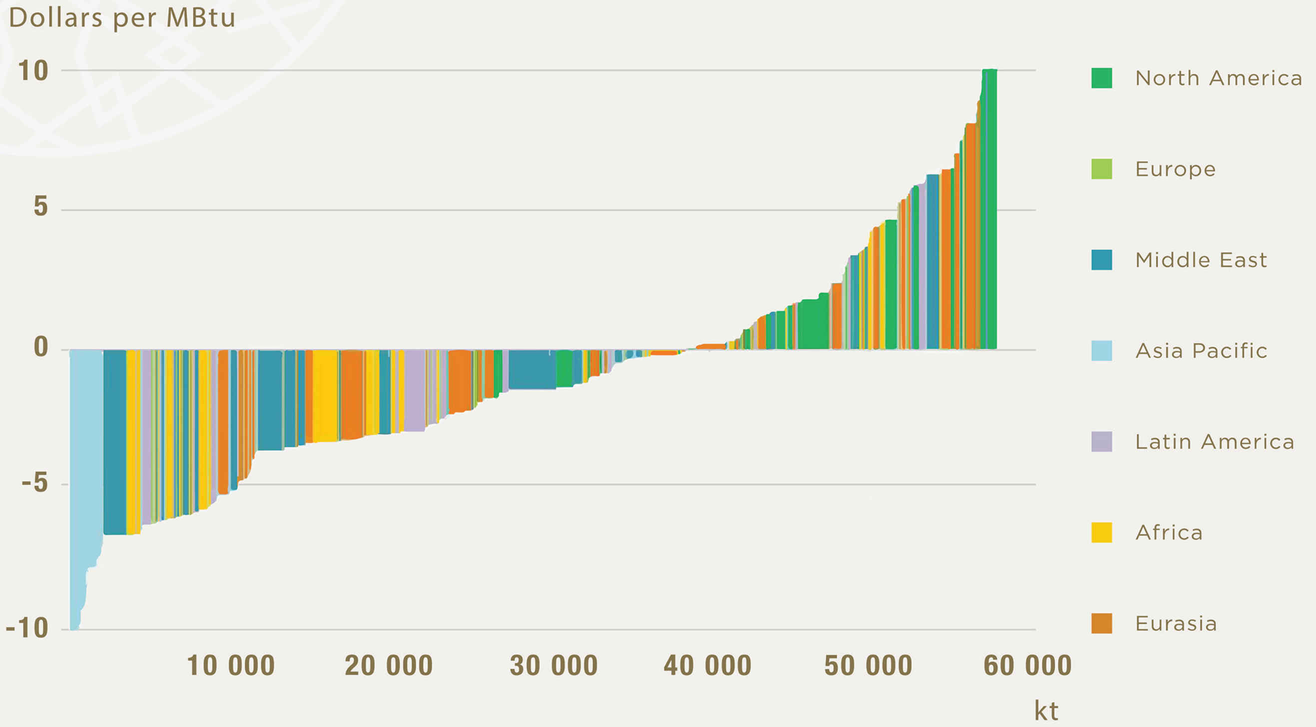


FIGURE 06: **MARGINAL ABATEMENT COST FOR METHANE**[14]




The IEA has estimated that about three-quarters of current global emissions of 76 Mt of methane from the oil and gas industry could be eliminated. About 40-50% of this could be done at zero or negative cost, i.e., the value of the gas saved would more than pay for the measures taken (FIGURE 6). The negative cost opportunities are spread across primarily Asia, Africa, Middle East and Latin America.

The cost of measures depends on factors including labour costs (for inspection and repair), the geographic extent of production (number of wells, length of pipeline), and the local gas price (the higher the price, the more attractive is saving gas leakage). Technologies that would reduce labour requirements would make it more feasible to save leakage.

These methane-saving measures may not have been adopted more widely yet because of lack of awareness, lack of prioritisation, or split ownership between the gas itself and the equipment or pipeline leaking it.

## The gas industry has begun to take steps on

Environmental groups, particularly in the US, have latched on to the leakage issue as a reason to oppose the natural gas industry[15]. This has become associated with other hostile views of the shale gas business, and joined a list of standard objections such as its carbon dioxide emissions, earth tremors, noise, land disturbance, alleged water contamination and so on.

Gas companies have been seeking to reduce methane leakage since at least 1993. Partly, this has been simply a matter of safety and economic considerations. The climate rationale has advanced in prominence more recently. As well as the US, Russia and Norway have adopted emissions standards. Companies have also taken voluntary action.

For instance, the ONE initiative aims to reduce leakage in the US's natural gas industry to 1% or less. ExxonMobil and Chevron, joined by Equinor, Cheniere, and Pioneer Natural Resources, have formed the Collaboratory to Advance Methane Science (CAMS), focussing on research into leak reduction[16].

The Oil and Gas Climate Initiative, grouping thirteen international oil companies including Shell, ExxonMobil, Saudi Aramco, CNPC, Equinor and others, has made methane reduction a priority[17], and invested in companies monitoring the gas, and providing low-leakage valves and control systems.

However, some of the world's major gas-producing companies are still absent from these initiatives, including Gazprom, Rosneft, Lukoil, Novatek, Sinopec, Sonatrach, ADNOC, and others. Of course, some of these individual companies are pursuing their own individual initiatives.

## Long-term methane reductions are essential as part of cutting greenhouse gas emissions overall

In the IEA's view, if no special measures are taken, methane emissions from the oil industry will rise from about 32 Mt annually in 2015 to about 42 Mt in 2040, and emissions from the gas industry would increase from about 41 Mt to 63 Mt. However, in its 'New Policies' scenario, approaches to reduce methane emissions would cut 2040 emissions to about 15 Mt from oil and 35 Mt from gas. In the 'Sustainable Development' scenario, oil and gas demand is lower overall, and more stringent measures would cut methane leaks to about 5 Mt from the oil business and 12 Mt from gas.

This would equate to reducing overall anthropogenic methane release by about 18% from the 2016 level. This indicates that substantial falls would also be required from the coal, waste and agricultural sectors.

The emissions reductions in the New Policies and Sustainable Development scenarios would reduce the global temperature in 2100 by 0.06-0.07°C. This might sound minor, but it is comparable to the impact of cutting carbon dioxide emissions by 160 billion tonnes (Bt) to 2100, more than four years of current emissions levels. This therefore helps "buy time" for more stringent cuts in carbon dioxide.

## Conclusions:

Under almost any realistic leakage scenario, gas achieves substantially lower greenhouse gas emissions than coal and oil, per unit of useful energy. But methane leakage does boost the climate impact of gas, which makes it less attractive versus low-carbon sources (renewables and nuclear).

The use of coal and, ultimately, oil, is expected to go into decline by the 2030s and 2040s, while most scenarios see gas use continuing to increase to at least 2050 (see the Al-Attiyah Foundation Research Series Issue 29, January 2019). Carbon capture and storage (CCS) could be widely adopted, allowing gas to remain a core part of the energy system in the long term by preventing carbon dioxide emissions, but CCS does not address methane releases. Therefore, the climate impact of gas will become increasingly serious, if leakage is not curtailed.

As there are strong economic, safety, environmental and reputational arguments for reducing methane leakage, it would be wise for major gas-producing countries and companies to engage more actively. Even if their leakage rates are low, it helps to be able to demonstrate this conclusively. Understanding the main sources and causes of leaks are vital to reducing them.

Standards such as 'green completions' and LDAR should be rolled out throughout the industry. Collaboration between companies reduces costs and helps spread best practices.

Major gas producers could also consider funding methane reduction activities in other sectors, for instance in agriculture. This would help reduce atmospheric methane concentrations and so lessen concerns about the impact of the gas industry.

Major gas-producing companies and countries can market their gas as 'green' by reducing methane emissions to the lowest practicable levels. Gas-importing countries can require that their suppliers meet minimum standards for leakage, tightening over time.

If gas companies and exporting countries do not take serious, demonstrable steps to reduce leakage, they can expect growing resistance to the industry, making it harder to develop new fields and site new LNG import terminals, pipelines and gas-fired power plants. It is conceivable that some countries might ban the import of gas/LNG that does not meet minimum environmental standards.

Solohiv gas processing plant, Ukraine (Wikimedia Commons)

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