Low methane leakage from gas pipelines

A switch from coal or oil to natural gas could mitigate climate effects in the short term.

Using natural gas for fuel releases less carbon dioxide per unit of energy produced than burning oil or coal, but its production and transport are accompanied by emissions of methane, which is a much more potent greenhouse gas than carbon dioxide in the short term. This calls into question whether climate forcing could be reduced by switching from coal and oil to natural gas. We have made measurements in Russia along the world’s largest gas-transport system and find that methane leakage is in the region of 1.4%, which is considerably less than expected and comparable to that from systems in the United States. Our calculations indicate that using natural gas in preference to other fossil fuels could be useful in the short term for mitigating climate change.

The global production of natural gas (which is about 90% methane) at present amounts to roughly 2,600 billion cubic metres (b.c.m.) per year. The high energy efficiency of modern gas-fired power plants (about 60%) and the large reserves of natural gas stimulate annual investments of about US$100 billion (ref. 3). Russia, which has gas reserves of 47,000 b.c.m., is the largest producer (580 b.c.m. per year) and is the principal supplier of natural gas to the European Union (115 b.c.m. per year); the United States is the second-largest producer (550 b.c.m. per year).

Methane has an atmospheric lifetime of about a decade, whereas carbon dioxide remains in the atmosphere–climate system for about a century. However, methane also makes an indirect chemical contribution to climate change, and its global-warming potential compared with carbon dioxide (mole/mole) is about 22 for a time horizon of 20 years, and about 8 for 100 years. This implies that a reduction in methane emissions could be beneficial in the mitigation of climate change over relatively short time-scales of a few decades or less.

For a short-term scenario (considering global-warming potential over 20 years), we estimate that switching from coal to natural gas would mitigate climate change if gas-associated leakage of methane was kept below 5.6 ± 0.7%; if gas is swapped for oil, losses need to be less than 3.1 ± 0.3%. For global-warming potential over 100 years, methane losses should remain under 11.3 ± 0.7% and 7.0 ± 0.3% for changing from coal and oil, respectively. We conclude that, provided methane leakage into the atmosphere is below about 3%, the use of natural gas as fuel should contribute least to climate forcing under all scenarios.

It has been suggested that up to 10% of Russian gas is lost during production and transport. Although some analyses indicate that leakages are lower than this, the database from which these figures were derived included only a few measurements. We therefore carried out extensive measurements of methane emissions along the Russian gas-transport system (Fig. 1), focusing on components from which leaks would be expected to occur and investigating nearly 2,400 km of pipelines, including compressor stations, valve knots and machine halls, as a representative selection of equipment types and ages (for details and methods, see supplementary information).

Our results indicate an overall loss of methane during natural-gas transport within Russia of 0.7% (range, 0.4–1.6%). Exporting gas may sometimes be associated with further release of methane, depending on transport conditions and distances (for example, the gas may be liquefied or pipeline extensions introduced). We assume that the onward distribution of gas in the Russian low-pressure networks for domestic and industrial purposes makes up 0.5–0.8% of emissions, or about 30–50% of the total, as in the United States. To determine gas spills at wells, we re-evaluated earlier measurements, arriving at a slightly higher leakage value of 0.1 ± 0.04%. It is therefore likely that, overall, the leakage from Russian natural-gas transport systems is about 1.4% (with a range of 1.0–2.5%), which is comparable to the amount lost from pipelines in the United States (1.5 ± 0.5%).

Measurements from global air-sampling networks show that atmospheric methane increased by about 10% per decade between the 1960s and 1980s, but that this has levelled off since, owing in part to the reduced production of fossil fuels after the collapse of the Soviet Union in 1992 (refs 9, 10). This event also affected Russian natural-gas throughput, which varied by 7–8% over the past decade; however, worldwide gas production has increased by 25% since 1990 (refs 1, 2). The technology and maintenance of Russian gas-transfer systems may have improved. It is likely that sources and sinks of atmospheric methane are now roughly balanced and that emission controls have taken effect even before implementation of the Kyoto Protocol.
We conclude that the use of natural gas as a preferred fuel, particularly as a replacement for coal, could reduce climate forcing during the transition to cleaner-energy technologies. Cutting methane emissions is cost effective and will be beneficial both directly and indirectly by reducing tropospheric ozone, even as atmospheric carbon dioxide continues to increase at an accelerating pace. J. Lelieveld*, S. Lechtenböhmer*, S. S. Assonov*, C. A. M. Brenninkmeijer*, C. Dienst†, M. Fischkoch†, T. Hanke†

*Max Planck Institute for Chemistry, 55128 Mainz, Germany
e-mail: leelievd@mpch-mainz.mpg.de
†Wuppertal Institute for Climate, Environment, and Energy, 42103 Wuppertal, Germany


Supplementary information accompanies this communication on Nature's website.
Competing financial interests: declared (see online brief communication).

Planetary science

Constant illumination at the lunar north pole

Images returned by the spacecraft Clementine have been used to produce a quantitative illumination map of the north pole of the Moon, revealing the percentage of time that points on the surface are illuminated during the lunar day. We have used this map to identify areas that are constantly illuminated during a lunar day in summer and which may therefore be in permanent sunlight. All are located on the northern rim of Peary crater, close to the north pole. Permanently sunlit areas represent prime locations for lunar outpost sites as they have abundant solar energy, are relatively benign thermally (when compared with equatorial regions), and are close to permanently shadowed regions that may contain water ice.

Because the Moon’s spin axis is nearly perpendicular (about 1.5°) to the ecliptic plane, astronauts have long considered that areas of illumination extremes may exist near the lunar poles. Topographic lows, such as the floors of impact craters, can be permanently in shadow, whereas high areas could in theory be in constant sunlight. Permanently shadowed regions are extremely cold and may contain deposits of water ice.

Conversely, the temperature in a permanently lit zone is relatively mild and constant because of the grazing insolation. The temperature at the lunar equator fluctuates from ~180°C to 100°C, but the surface temperature for a constantly sunlit polar region has been estimated from modelling to be roughly 50 ± 10°C. A region with this relatively benign temperature range represents an attractive site for building hardware designed for long-term use.

The lunar north pole is in a highland region, in between three large impact craters — Peary (88.6°N, 33.0°E; diameter, 73 km), Hermite (86.0°N, 89.9°W; diameter, 104 km) and Rozhdestvensky (85.2°N, 155.4°W; diameter, 177 km). Because the pole lies just outside the crater rims, it is likely to be at a relatively high elevation, increasing the likelihood that some areas could be permanently illuminated. By contrast, the lunar south pole is just inside the rim of the South Pole–Aitken impact basin (2,500-km diameter), and there is no area at this pole that is constantly illuminated during the southern winter, as measured at the scale of the Clementine UVVIS data (500 m per pixel). The Clementine spacecraft orbited the Moon in an elliptical orbit with a 5-hour period for 71 days in 1994, arriving in the northern hemisphere just after mid-summer (that is, when the spin axis was pointing towards the Sun). We have identified 53 images taken by the craft’s UVVIS camera that cover the north pole with a spatial resolution of roughly 500 m per pixel. Each image encompasses an area of about 190 × 140 km. The images show which areas are illuminated as a function of solar azimuth during a lunar day in summer.

Our quantitative illumination map for the north polar region shows the percentage of time that a point on the surface is illuminated during a lunar day in summer. Left, several areas on the rim of Peary crater (78 km in diameter) can be identified (white) that were continuously illuminated. The spatial extent of the map is within about 1–1.5° of the pole. Scale bar, 15 km. Right, colour illumination map superimposed on a greyscale composite Clementine mosaic, for spatial reference.

Figure 1 A quantitative illumination map of the Moon’s north pole. The colour scale indicates the percentage of time that a point on the surface is illuminated during a lunar day in summer. Left, several areas on the rim of Peary crater, that are illuminated for the entire day (Fig. 1). There are several regions, all on the rim of Peary crater, that are illuminated for the entire day (Fig. 1, white areas). With the information available, it is not possible to state definitively that these areas are permanently sunlit because the data correspond to a summer rather than a winter day. But we can be certain that they are the most illuminated regions around the north pole and that they are also the areas on the Moon most likely to be permanently sunlit, given that there are no constantly illuminated areas in the south polar region.

Our quantitative illumination map also identifies permanently shadowed areas. These are associated with small impact craters (3 km or less in diameter) on the floor of Peary crater, with two larger craters (14 and 17 km in diameter) on the rim of Peary, and with the area just outside Peary’s rim, in the highland region (Fig. 1).

D. Ben Bussè*, Kirsten E. Fristad†, Paul M. Schenk‡, Mark S. Robinson§, Paul D. Spudis*

*Planetary Exploration Group, Space Department, The Johns Hopkins Applied Physics Laboratory, Laurel, Maryland 20902, USA
e-mail: ben.buss@jhuapl.edu
†Macauley College, Saint Paul, Minnesota 55105, USA
§Center for Planetary Sciences, Northwestern University, Evanston, Illinois 60208, USA


Competing financial interests: declared none.