Natural gas and the greenhouse

SIR—Wallis in a recent Scientific Correspondence[1] claimed that use of natural gas instead of coal in power stations will lead to 0.8 to 3.0 times the emissions of greenhouse gases. His argument is flawed by an arithmetical error in the treatment of leakage of natural gas, and by his failure to realize that such incremental uses will not lead to any significant increase in natural gas leakage.

Wallis uses the concept of relative carbon coefficients of 0.43 for natural gas, 0.62 for oil and 0.75 for coal[2] but does not give the units: they are gigatonnes (Gt) of carbon per terawatt year (TW yr) energy (1 TW yr = 31.536×10^{18} J). He takes natural gas losses of 3–10% of final use, assumes 75% methane content, multiplies by 25 to take account of the enhanced infrared absorption of atmospheric methane compared with CO_2 and by η the ratio of their lifetimes. He then adds the quantity 0.75 (0.03 to 0.1) 25η to 0.43 as an absolute quantity instead of as a proportion, thus increasing the apparent effect of leakage by 1/0.43. Neglecting the emission of methane from coal mining he derives the relative greenhouse effects G_{gas}: G_{coal} as 0.95 to 4.1. Correcting the arithmetic gives 0.73 to 2.1.

Wallis uses 20 $m^3\,t^{-1}$ to make allowance for mine methane and gives a factor of 0.21η to add to the carbon coefficient. It is not clear how he derives this factor: 20 m^3 contains about 832 moles of methane. The calorific value of power-station coal is about 24.5 GJ t^{-1}, leading to 0.321η Gt carbon equivalent per TW yr.

On this basis the final result should be

$$G_{gas}: G_{coal} = \frac{0.43\,(1 + 0.75\,(0.03 \text{ to } 0.1)\,25\eta)}{0.75 + 0.32\,\eta}$$

giving the range 0.61 to 1.31.

The above equation accepts all Wallis's assumptions, but many of these are at least questionable. I suggest the following alternatives. First, natural gas in the United Kingdom contains about 93% methane. Second, unaccounted-for gas includes financial losses due to undercharging (declared calorific value is less than actual; pressure and temperature factors generally favour the customer) and theft as well as leakage losses. For the sake of argument (only), unaccounted-for gas will be taken as an upper limit for leakage and put at 3%.

Third, off-shore venting of methane has been given as 270 kt for the United Kingdom[3], with the main part relating to oil production[4]. Attributing 40% to gas production gives a loss rate of less than 0.4% on a gas-supplied basis. Fourth, methane from coal mining is given by Eyre[5], quoting British Coal, as 340 g GJ^{-1}, which is equivalent to 12.5 $m^3\,t^{-1}$.

Finally, it is widely accepted that the lifetime of the methane molecule in the atmosphere is 10 years and its effectiveness compared with CO_2 is about 25. The appropriate lifetime for CO_2 is much more contentious but the effect of anthropogenic emissions appears to be long-lived. Derwent[6] has analysed the relative effectiveness of methane and CO_2 over various time horizons, taking into account CO_2, ozone and stratospheric water vapour resulting from the atmospheric destruction of methane. Converting Derwent's results from mass into moles gives the relative effect, a_t, at time t from emission of 1 mole of each at $t = 0$. This factor would replace 25η in Wallis's treatment. Its use leads to the results in line 3 of the table, which demonstrate the generally low emissions for gas compared with coal.

1	Time horizon (years)	20	50	100	500
2	a_t	30.5	16.8	10.5	4.4
3	G_{gas}: G_{coal} 3.5% loss	0.86	0.75	0.69	0.63
4	G_{gas}: G_{coal} 1.0% loss	0.55	0.56	0.57	0.57
5	Relative emissions per kWh (e) for 1% loss	0.47	0.47	0.48	0.48
6	Break-even loss %	4.6	6.8	9.6	20.2

Wallis's claim relates specifically to power generation. Gas supplies to power stations will be from welded high-pressure steel pipes, and the gas will not pass through the low pressure system where most losses occur. A very generous allowance for losses would be 1%, giving the relative emissions per unit of input shown in line 4 of the table. The relative emissions per unit of electrical output are shown in line 5 — taking 45% conversion efficiency for gas in combined cycle compared with 38% for coal in new conventional units with flue-gas desulphurization. The conclusions, using Wallis's argument but more reasonable assumptions — several of which are more favourable to coal than his — show the opposite of his claim. Natural gas gives only about half the greenhouse emissions of coal in power generation. As a bonus, the sulphur emissions from gas firing would be only 1% of those from the coal plant.

Finally, gas losses from the low-pressure system are governed by pressure rather than throughput. New loads will not necessarily incur extra losses: all new pipes are laid in polyethylene or steel and are essentially leak-proof. The existing cast-iron mains are being progressively replaced.

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WALLIS REPLIES—Several relevant data have been published since I conjectured[1] that methane leakage from gas fuel production and distribution may tip the relative greenhouse balance in favour of coal combustion. James legitimately criticizes my first estimate of the 'greenhouse' ratio for electricity generation by gas compared with coal combustion of 0.8–3.0 and claims values of 0.55–0.86. But he does not comment on my revised detailed estimate of 0.53–2.0, including new data, available as a University of Wales, Cardiff preprint (March 1990).

One difference is that leakage from North Sea gas wells is probably much higher than the unauthenticated 0.34% James cites from UK Department of Energy sources. The 3% upper limit for land-based leakage is disputable, as British Gas reported 4.5% "unaccounted for" gas in 1986, more than half their pipework is pre-1969, designed for lower pressure town (CO) gas, and leakage from their pumping, pressure-reducing and conditioning plant is additional. The third main difference arises through disputing the box-diffusion model of the CO_2 cycle used by Derwent[6] that gives 'components' as long-lived as 815 years or even thousands of years[7]. Nevertheless, it is reassuring that his result lies within the revised range of 0.53–2.0 and, as expected, comes at the low end — but the verdict is still not proven.

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JAMES REPLIES—Wallis's new data use a multiplier of up to 250 for methane which assumes a lifetime for CO_2 of 7 years; an enhanced infrared absorption of methane of 70 times CO_2 to allow for degradation products; and a reduction in the effectiveness of CO_2 by 60% to allow for a biological feedback.

Derwent's treatment of the effect of methane has been accepted by the Intergovernmental Panel on Climate Change but with factors 25% lower than those used here. Further, British Gas does not report unaccounted for gas. □

1. Wallis, M.K. *Nature* **344**, 25–26 (1990).
2. Smith, I. *CO_2 and Climate Change* (IEA Coal Research, London, 1988).
3. Energy Paper 58 *An Evaluation of Energy-related Greenhouse Gas Emissions and Measures to Ameliorate them* Department of Energy (HMSO, London, 1990).
4. House of Lords Select Committee on Science and Technology *Greenhouse Effect Report* No. 6 Vol II (HMSO, London, 1989).
5. Eyre, N.J. *Gaseous Emissions due to Electricity Fuel Cycles in the United Kingdom.* (Energy Technology Support Unit/ Department of Energy, Harwell, 1990).
6. Derwent, R.G. *Trace Gases and their Relative Contribution to the Greenhouse Effect.* AERE R 13716 (UKAEA, Harwell, 1990).
7. Lashof, D.A. & Ahuja, D.R. *Nature* **344**, 529–531 (1990).