***can NATURAL gas be a bridge to a GLOBAL low-carbon energy system?***

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## Overview

The aim of this paper is to explore the greenhouse gas (GHG) implications, both globally and for specific regions, of the ‘profound revolution going on in gas’ as some have described the opening up of the potential for widespread exploitation of shale gas (1).The ‘shale gas revolution’ (2) has had profound impacts on the outlook and potential role of natural gas in the future energy system – with many analysts and organisations now viewing natural gas as an attractive ‘bridge’ to a low carbon energy system (3). In the light of the surge of US shale gas production, studies have examined the potential for gas to act as a bridge in the United States (e.g. (4)); however its potential role on a wider global basis remains unclear. The key research question addressed in this work is therefore: under what circumstances, in what regions, and to what extent can shale gas be a bridge to a low carbon energy system?

## Methods

Whether the widespread introduction of natural gas will increase or reduce carbon emissions is dependent on whether it adds to existing and projected demand for fossil fuels (e.g. perhaps by lowering the overall price of fossil fuels), substitutes for higher-carbon fossil fuels (e.g. coal or oil), or substitutes for lower-carbon energy sources (e.g. nuclear or renewables). The magnitude of the impact it will have on GHG emissions can also be expected to vary between different regions, regional and global emission reduction targets, and the extent to which unconventional gas sources have higher associated emissions than other conventional sources.

Here, we use the integrated assessment energy system model TIAM-UCL to inform on the balance between these possibilities. TIAM-UCL is a cost optimisation, partial equilibrium model of the global energy system: energy consumption, energy technologies, energy trade, energy system costs and marginal costs of environmental policies are all included within the model. Present and future demands in the energy system are driven by exogenous forcing such as population growth and GDP evolution. The model incorporates all primary energy sources from resource production through to their conversion, infrastructure requirements, and finally to sectoral end-use.

Scenarios have been devised and model runs implemented that give insights into the above issues and the associated consequences. The scenarios also focus on the robustness of these conclusions by examining those areas of uncertainty in the outlook for natural gas for which quantitative analysis is currently absent. These include the magnitude of fugitive emissions that result during shale gas extraction, an area of controversy (5), the varying ambition of GHG emissions reduction targets, and the availability of carbon capture and storage (CCS).

## Results

The left hand side of Figure 1 presents overall consumption on a global level in a scenario with no explicit GHG reduction polices, and in two scenarios that are required to keep the average global surface temperature rise to below 2oC. One 2oC scenario permits the widespread deployment of CCS from 2025, while the other prevents any processes being used with CCS. It is evident that gas consumption increases in both 2oC scenarios relative to the no policies case in nearly all time periods. In the 2oC case that allows CCS, the difference in consumption peaks in 2025, but this reduces over time, as consumption continues to climb in the no policies case and as the rate of growth slows, before declining from 2045 onwards. Consumption is consequently lower in 2050. Gas consumption in the no-CCS case in 2025 remains slightly larger than the no-policies case, but by a much smaller degree than when CCS is allowed. Thereafter, consumption is significantly lower in all time periods, and indeed it is over 50% lower by 2045.

These global level results do not, however, necessarily describe particularly well the underlying variation in consumption between different regions. The right hand side of shows the differences between regions of the relative changes in consumption between the no policies case and the 2oC scenario that permits CCS. It is immediately apparent that gas has a very different role to play in different regions. In China for example, gas consumption in the 2oC scenario (at 0.8 Tcm) is over double that in the no policies case, while in Canada and Central and South America gas consumption is lower in all periods.

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| Figure 1: Global gas consumption (LHS), and changes between the 2oC and no policies scenarios separated by region (RHS) |
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| **Note:** Abbreviations are as follows: AFR Africa, AUS Australia, CAN Canada, CHI China, CSA Central and South America, EUR Europe, FSU Former Soviet Union, IND India, JPN & SKO Japan and South Korea, MEX Mexico, MEA Middle East, ODA Other developing Asia, and USA United States of America. |

## Conclusions

Results suggest that gas could play a role as a transition fuel to a global low-carbon future: between 2015-2045 gas consumption was found to be larger in a 2oC scenario than when there were no explicit GHG reduction policies. This global pattern was not exhibited by all regions however, and so we conclude that gas could play a role as a ‘bridge’ in some regions but not in others. Nevertheless, we find that even in regions in which it could act as a ‘bridge’, the nature of the rise in consumption varied: in some regions there was a sustained increase reaching a maximum in the 2020s and 2030s, whilst in others there was a much sharper rise followed by a reversion to levels below the no policies case. Furthermore, the magnitude of the relative increase varied between regions, with China exhibiting the largest rise of any region in the low-carbon scenario.

There are a number of important caveats to this interpretation of results, however. First, global gas consumption levels off after 2045 in a 2oC scenario, whilst it continues to rise in higher-carbon scenarios. Any increase in consumption near-term periods must be followed by a subsequent reduction in later periods. Second, the relative increase in gas consumption must occur alongside a much greater relative reduction in coal consumption. On a global level in a 2oC scenario, whilst gas consumption increased by 25% relative to scenario with no explicit GHG reduction policies (in 2025), coal consumption fell by over 80% in all periods from 2025 onwards. Third, carbon capture and storage (CCS) is of particular importance to the role that gas could play as a transition fuel. If CCS fails to become available, gas production peaks in 2025 and terminally declines thereafter, and the role that gas can play is substantially reduced.

## References

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