CORRESPONDENCE:

Greenhouse gas emissions from synthetic natural gas production

To the Editor — China is developing technology to process coal into synthetic natural gas (SNG). This process would both attain energy security and implement clean coal technology. Yang and Jackson's claim[1] that the life-cycle greenhouse gas (GHG) emissions associated with converting coal to SNG are seven times those associated with conventional natural gas has been widely cited and used in discussions regarding SNG production and the direction of clean coal technologies in China. Here we show that the 'seven times' result is incorrect.

Life-cycle GHG emissions are defined as the emissions during the entire life of the fuel: from fuel mining to consumption in end-use equipment. These values are traditionally calculated using equation (1):

$$\text{Life-cycle GHG emissions per unit product} = \frac{\sum_{i=1}^{n} C_i}{P_e} \quad (1)$$

where C_i is the GHG emissions of the sub-process i, and P_e is the end-use product output of the defined scope.

There are two problems with the original paper[1]. First, the scope definition used for the GHG emissions does not match its end-use product as defined in the scope for the natural gas pathway. Although the scope for GHG emissions included gas combustion in power plants[2,3] (the solid horizontal line in Fig. 1a), the reference base for the natural gas pathway was defined as the GHG emissions associated with providing 1 MJ heat value of natural gas (P_{NG}) to a power plant[1,3] instead of 1 MJ electricity out of a power plant (P_e). When treating natural gas as the reference base, the traditionally used GHG emission scope is denoted by the dashed line in Fig. 1a; that is, the inclusion of gas production, processing, transmission and distribution, but not gas combustion.

Second, the reference bases used by Yang and Jackson (see figure 1 of ref. 1) for the GHG emissions associated with the pathways from coal to SNG and natural gas were not comparable. The functional unit of the coal-to-SNG pathway was defined as the GHG emissions associated with providing 1 MJ electricity to the end user[2,4], but the unit for the natural gas pathway was defined as the emissions associated with providing 1 MJ natural gas to a power plant[3] (Fig.1 b).

Similarly, Yang and Jackson[1] did not normalize the scope and reference-base differences when comparing the life-cycle GHG emissions associated with the coal-to-SNG and coal-to-electricity pathways. Their figure 1 was also incorrectly analysed.

We have recalculated the life-cycle GHG emissions associated with these pathways based on the data[2–4] used by Yang and Jackson[1], and the results are shown in Fig. 2 (see also Supplementary Information). The life-cycle GHG emissions for coal to SNG (if SNG is used for electricity generation) are 2.6–3.3 times (rather than seven times) those associated with the conventional natural gas pathway. Similarly, the life-cycle GHG emissions associated with converting coal to SNG are 1.35–1.60 times (rather than four times) those associated with the coal to electricity pathway.

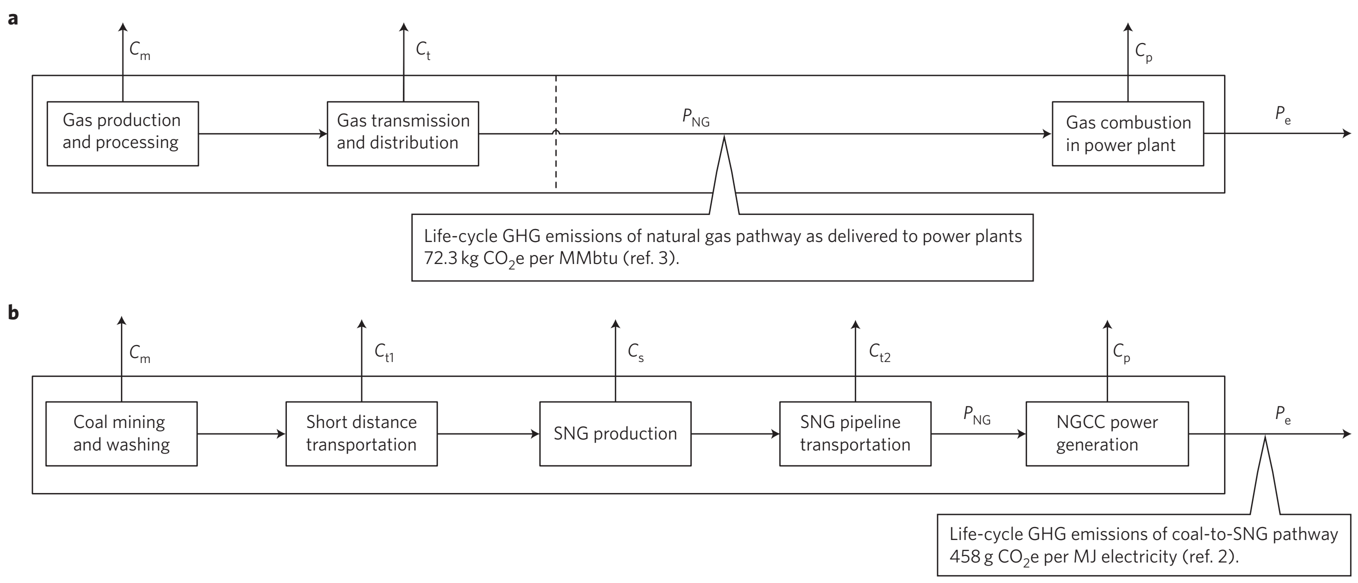

Figure 1 | Scope (solid horizontal lines) and reference bases for life-cycle GHG emissions from Yang and Jackson's paper[1]. **a**, Scope and reference base (1 MJ natural gas, P_{NG}) of GHG emission data for a conventional natural gas pathway. **b**, Scope and reference base (1 MJ electricity, P_e) of GHG emission data for a coal-to-SNG pathway.

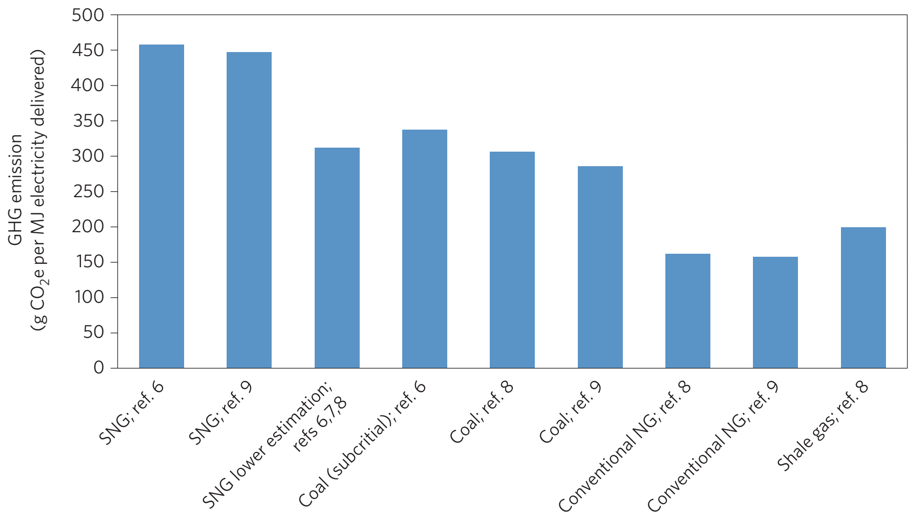

Figure 2 | Comparison, using revised data, of the life-cycle GHG emissions associated with the coal-to-SNG, coal-to-electricity, conventional natural gas and shale gas pathways. The SNG lower estimate is based on coal-to-SNG (refs 6,7) and natural gas combined cycle (ref. 8).

Following ref. 2, Yang and Jackson[1] assumed a relatively low energy efficiency of the existing coal-to-SNG process of 50%. The above corrected calculations of the life-cycle GHG emissions of the coal-to-SNG pathway are also based on existing, more efficient technologies.

Although China remains highly dependent on coal for energy, its use of gas increased from 5.6% in 2008 to approximately 29% in 2012[5]. If the efficiency of the coal-to-SNG pathway could be improved to approximately 60–65%[6,7], the life-cycle GHG emissions would be reduced and would be comparable to those associated with current coal-to-electricity pathways. Moreover, in coal chemical plant that emit high concentrations of CO_2 (such as coal-to-SNG plant), it is possible to capture CO_2 with relatively low energy consumption and cost penalties. Therefore, the life-cycle GHG emissions from the coal-to-SNG process can be further mitigated if CO_2 capture is applied.

China faces climate mitigation, energy efficiency, and energy security challenges and thus must and will develop a new generation of clean coal technologies because China's energy structure will be highly coal dependent for a long time. ❐

References

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Acknowledgements

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Additional information

Supplementary information is available in the online version of the paper.

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Reply to 'Greenhouse gas emissions from synthetic natural gas production'

Yang and Jackson reply — Sheng and Gao[1] correctly point out a mistake we made in our original calculations in our Commentary[2], attributable to our misinterpretation of the units used in the work by Ding and colleagues[3]. Here, we revise our calculations, which lower the estimate of CO_2 emissions associated with the production of synthetic natural gas (SNG) but do not alter the broad conclusions of our Commentary.

The revised calculations indicate that the life cycle of SNG has 3.3–3.9 times more CO_2 emissions than natural gas does, but not 7 times more as originally stated[2]. We revised the function unit to that of electricity, assuming that all these fuels are used to generate electricity. Because wet cooling is banned in China's arid regions, we assume dry cooling in power generation. The revised figure 1 from our Commentary[2] should then look like Fig. 1 here.

In our Commentary[2] we correctly stated "If SNG is used to generate electricity, its life-cycle GHG emissions are ~36–82% higher than pulverized-coal-fired power." This finding is consistent with Gao and Sheng's finding[1] that the coal-to-SNG-to-electricity pathway produces 1.35 to 1.6 times the CO_2 emissions of the coal-to-electricity pathway. In contrast, Sheng and Gao also argue that future improvements in SNG technology will reduce the emissions of coal-to-SNG-to-electricity to a level that is comparable to the conventional coal-fired electricity. However, even if the carbon footprint of coal-to-SNG-to-electricity might someday become comparable to coal-to-electricity, it remains a technology of relatively high CO_2 and water footprints.

Sheng and Gao[1] correctly point out that the life-cycle GHG emissions from the coal-to-SNG process can be further mitigated if CO_2 capture is applied. However, none of China's SNG projects plan to capture CO_2. Based on a recent review of experiences at the Great Plains Synfuels Plant[4], even with current carbon capture and storage practices, the carbon emissions from SNG are still more than twice as high as for natural gas.

Another major conclusion in our original paper[2] concerned the high water consumption of SNG. A recent analysis of China's first SNG demonstration project suggested a number of shortcomings for water use and water pollution[5]. The Correspondence from Sheng and Gao[1] does not address or mention the many important water issues or other environmental impacts created by SNG.

Correction

In the Correspondence 'Greenhouse gas emissions from synthetic natural gas production' (*Nature Clim. Change* **6,** 220–221; 2016), the Acknowledgements section should have read: 'The authors acknowledge support from the National Natural Science Foundation of China (NSFC) (grant no. 51306185), the 'Strategic Priority Research Program — Climate Change: Carbon Budget and Related Issues' of the Chinese Academy of Sciences (grant no. XDA05010102), and the Youth Innovation Promotion Association, CAS.' This was corrected online on 11 March 2016.