COMMENTARY:

China's synthetic natural gas revolution

Chi-Jen Yang and Robert B. Jackson

China has recently pushed for investments in large-scale coal-fuelled synthetic natural gas plants. The associated carbon emissions, water needs and wider environmental impacts are, however, mostly neglected and could lock the country into an unsustainable development path.

China is rapidly becoming the global leader in converting coal to other energy- and chemical-related products, including natural gas and methanol[1]. China is now building the largest synthetic natural gas (SNG; also known as substitute natural gas) industry in the world. In support of this development, Chinese studies often refer to the success of the Great Plains Synfuels Plant in the USA — the pioneer in commercializing SNG[2–4]. The commercial realization of the Great Plains Synfuels Plant is, however, not easily reproducible. Bankruptcy procedures and government subsidies covered most of the capital costs for the project and ensured the commercial viability of its operations[5]. In addition, the capital-intensive nature of the SNG industry created a technology lock-in effect, with short-term investment enthusiasm leading to a development path characterized by extensive environmental consequences, including increased greenhouse gas (GHG) emissions, water shortages, and air and water pollution. The case of the Great Plains Synfuels Plant should therefore be assessed from a wider perspective than just its economic viability.

China's ambitious plans

China is embarking on the largest SNG investment in history. As of 2013, the central government has approved nine large-scale SNG plants with a total capacity of 37.1 billion m^3 of natural gas per year (Table 1). In comparison, the Great Plains Synfuels Plant has a much smaller annual capacity of 1.5 billion m^3.

Chinese companies are planning many more projects in addition to the nine already approved. There were more than 30 proposed SNG projects in 2012 with a combined capacity of 120 billion $m^3\ yr^{-1}$ (ref. 6). A news report in 2013 stated that the number of proposed SNG projects had grown to over 40, with a total capacity of nearly 200 billion $m^3\ yr^{-1}$, far exceeding China's total natural gas demand[7]. Even if only part of these announced plans will be implemented, the consequences for energy and the environment in China would be substantial for decades.

Potential technological lock-in

Once built, a SNG plant would operate for as long as its revenues exceed fuel and operation and maintenance (O&M) costs, even if it cannot recover initial capital investments. As operation of the plant would probably continue even with low or no profitability, such an investment represents a technological lock-in that will deliver a water- and GHG-intensive fuel for decades.

Synthetic natural gas has a heavy carbon and environmental footprint — the life-cycle GHG emissions are roughly seven times that of conventional natural gas (Fig. 1)[6,8,9]. If SNG is used to generate electricity, its life-cycle GHG emissions are ~36–82% higher than pulverized-coal-fired power[6,8]. If used to drive vehicles, SNG has emissions twice as large as those from gasoline vehicles[6]. Based on these estimates, the nine approved SNG plants in China would emit 21 billion tonnes of CO_2, assuming use of 90% of production capacity over a 40-year lifetime, compared to 3 billion tonnes for conventional natural gas over the same period. Under such a scenario, China will inevitably struggle to reduce its future GHG emissions. If all 40 or so of the projected facilities are built, the GHG emissions would be an astonishing ~110 billion tonnes of CO_2 over 40 years.

In addition to GHG emissions, the production of coal-fuelled SNG emits hydrogen sulphide and mercury that, if not properly scrubbed or treated[10], are potentially harmful. The production of SNG is also water intensive, requiring 6–12 litres of water per m^3 of SNG[4,11], whereas shale gas needs roughly 0.1–0.2 litres of water per m^3 of methane produced, 50 to 100 times less[12]. The nine approved SNG plants, most of them in desert or semi-desert environments in Xinjiang and Inner Mongolia, will therefore consume over 200 million tonnes of water annually, assuming operation at 90% of production capacity. The water consumption for SNG production could worsen water shortages in areas already under significant water stress. Overall, the large-scale deployment of SNG will dramatically increase water

Table 1 | National government-approved SNG projects.

Company	Location (Region/Locality)	Planned capacity (billion $m^3\ yr^{-1}$)
Datang	Inner Mongolia/Chifeng	4.0
Datang	Liaoning/Fuxin	4.0
Huineng	Inner Mongolia/Ordos	1.6
China Kingho Group	Xinjiang/Ili	5.5
CPI Corporation	Xinjiang/Ili	6.0
Xinwen Mining Group	Xinjiang/Ili	4.0
Guodian	Inner Mongolia/Hinggan League	4.0
CNOOC	Shanxi/Datong	4.0
Xinmeng Energy	Inner Mongolia/Ordos	4.0

use, GHG emissions and additional air and water pollution compared to conventional natural gas.

Costs of SNG in China and the USA

To examine the commercial viability of SNG in China, we compared two different published SNG cost estimates to that of the National Energy Technology Laboratory for the USA (Fig. 2). There are three categories of expenditure: the costs of building the plant (capital costs); of the coal used to produce SNG (fuel costs); and those for operation and maintenance (O&M) of the plant. Capital costs are usually never considered in deciding whether to continue a plant's operation. An SNG plant is therefore likely to operate as long as the SNG price is higher than the fuel and O&M costs.

The Chinese figures show higher fuel costs than that for the USA, probably owing to higher coal prices and lower conversion efficiencies. Lower wage costs and cheaper materials may explain China's lower O&M costs. Capital cost estimates in China are unusually low (Fig. 2). This is probably because of a number of reasons. First, Chinese local governments often allocate lands free of charge to preferred industries. Second, China's SNG plants will probably have fewer investments in pollution-control technologies than would similar plants in the USA. Third, China's domestically produced equipment is cheaper than that used in the USA. However, it is also possible that these Chinese evaluations underestimate the true costs of SNG because there are no operating SNG facilities in China. If the cost estimates are in fact too low, the outcome could be both economically disruptive and environmentally harmful.

Finally, it is worth analysing the profitability of the Great Plains Synfuels Plant in the USA, especially in light of what the commercial viability of the Chinese SNG plants might be once they are in place. The plant was originally built in 1983 with US government loan guarantees for US$2.03 billion (ref. 5). Within two years of operation, the plant went bankrupt. The US Department of Energy then bought the plant for US$1 billion in 1985. They resold it to Basin Electric for US$85 million (also providing an additional US$120 million for environmental upgrades and operation of the plant[13]), with a 20-year revenue-sharing clause contingent on the profitability of SNG.

Bankruptcy and government inputs covered most of the plant's upfront capital cost to the benefit of later operators. To Basin Electric in particular, the capital cost was only US$85 million. The SNG plant also benefited from 25-year agreements with pipeline companies that allowed it to sell SNG above the market prices of natural gas. Despite the heavily subsidized nature of the Great Plains SNG plant, Chinese publications regularly refer to it as a commercial success[2–4]. Using the Great Plains Synfuels Plant to justify construction of similar Chinese facilities is, in our view, a mistake.

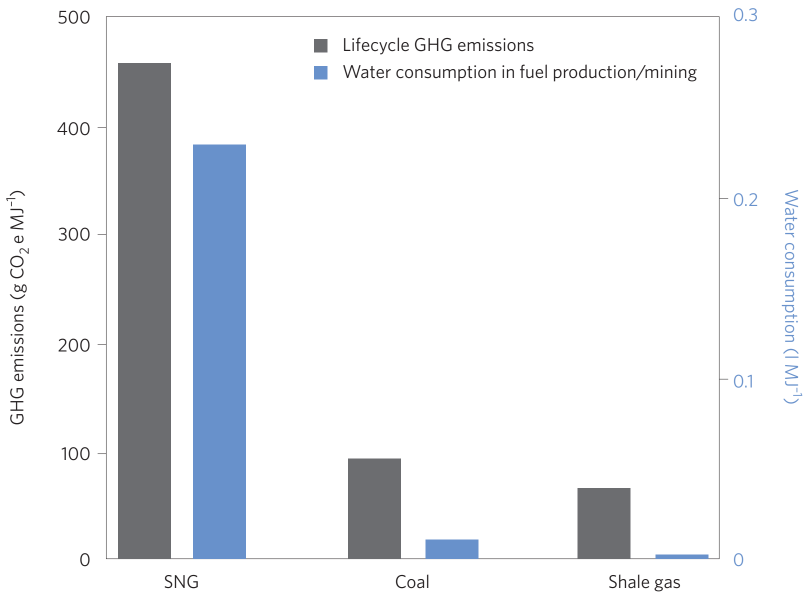

Figure 1 | Comparison of lifecycle GHG emissions and water consumption in the production of SNG, coal and shale gas. Data from refs 4,6,8,9,11,12.

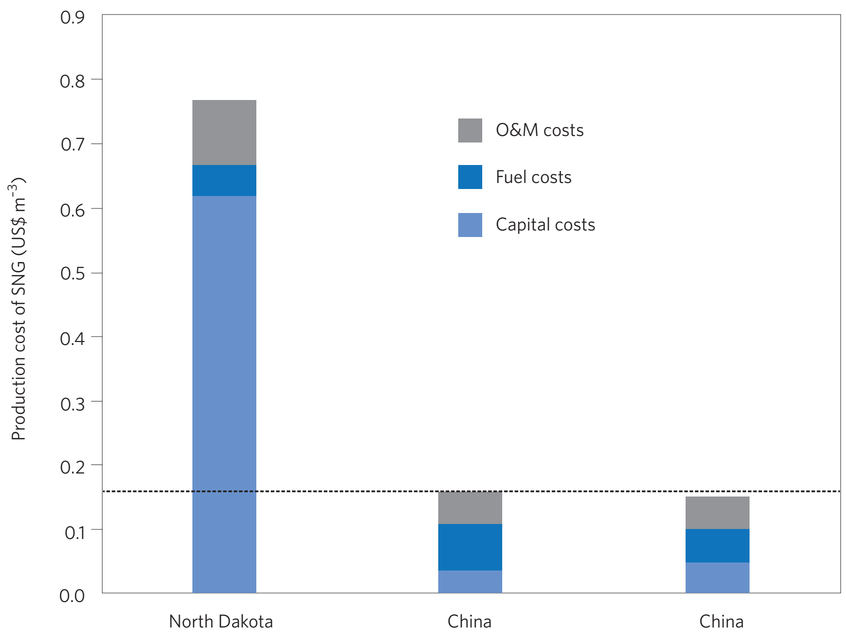

Figure 2 | Cost estimates for new SNG projects in United States and China. The dashed horizontal line indicates the average price of natural gas in the USA in 2010. Data for North Dakota is from ref. 15, and for the two estimates for China from refs 4 (left) and 11 (right).

Conclusions

China's natural gas sector today in some ways resembles that of the USA in the early 1980s. Natural gas prices are just beginning to be decontrolled, and there is considerable optimism about using coal to produce SNG. However, after the USA decontrolled natural gas prices in the 1980s, increased investments in exploration and extraction technologies made natural gas more abundant, reducing the economic viability of SNG but locking in its extensive environmental costs.

Price decontrols and institutional reforms in China could similarly make conventional and unconventional natural gas cheaper and more abundant, reducing costs and environmental consequences, including GHG emissions, water demands and air pollution, compared to SNG[14]. Conventional and unconventional natural gas use come with their own environmental impacts, but they have a substantially smaller carbon and water footprint than SNG. In addition, the broad implementation of SNG could slow the deployment of renewable capacities that have even smaller carbon and water footprints and that generate less air and water pollution (acknowledging that China's renewable energy production is expanding rapidly today).

At a minimum, Chinese policymakers should delay implementing their SNG plan to avoid a potentially costly and environmentally damaging outcome. An even better decision would be to cancel the program entirely. ❐

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COMMENTARY:

Bias in the attribution of forest carbon sinks

Karl-Heinz Erb, Thomas Kastner, Sebastiaan Luyssaert, Richard A. Houghton, Tobias Kuemmerle, Pontus Olofsson and Helmut Haberl

A substantial fraction of the terrestrial carbon sink, past and present, may be incorrectly attributed to environmental change rather than changes in forest management.

In the late nineteenth and early twentieth centuries, forest areas were much smaller and forests more strongly degraded than today in most regions that are now industrialized. During industrialization, fossil fuels replaced fuelwood and chemical fertilizers allowed farmers to reduce or abandon practices such as forest grazing and litter raking. Are these changes in forest management important enough to change our current understanding of the forest carbon sink, and perhaps even the global terrestrial carbon balance?

Terrestrial ecosystems play two roles in the global carbon balance[1–4]. First, land use, land-use change and forestry (LULUCF) are resulting in net emissions of carbon to the atmosphere, mainly driven by deforestation. Second, the global carbon balance requires a residual terrestrial carbon sink, which was negligible before ~1950 but has been growing ever since[5]. That residual sink is determined by difference from the other terms in the global carbon balance (that is, atmospheric carbon concentration, emissions from fossil fuel combustion and LULUCF and known land and ocean sinks). The residual sink has been attributed to the effects of environmental change (for example, climate, CO_2 and nitrogen deposition) on terrestrial carbon storage[2,3,5], but its location, causes and exact magnitude are uncertain. If the emissions from LULUCF are overestimated, so is the residual terrestrial sink.

Book-keeping models are widely used to quantify the effects of LULUCF on regional to global carbon fluxes[6–8]. Generally, these models assess vegetation responses to land-cover changes and wood harvest on a yearly basis, using constant values of standing biomass at harvest time to calculate areas subject to clearing and regrowth (for details see Supplementary Information). Book-keeping models reflect only LULUCF effects. They are commonly used to separate LULUCF and environmental effects — for example, by contrasting C flows calculated by book-keeping models with forest-inventory derived results[9], or results from atmospheric measurements[2–4] (both of which include environmental and land-use effects). Based on these approaches, it is generally estimated that global net annual carbon emissions resulting from LULUCF were 1.1±0.2 Pg C yr^{-1} between 1990 and 2009 (including flows from deforestation and forest regrowth)[8], contrasted by a terrestrial net sink of approximately 1.4 Pg C yr^{-1}. The resulting global residual sink, necessary to close the terrestrial balance, is estimated at 2.5±0.8 Pg C yr^{-1}.

Here, we show that calculations of Austria's carbon balance with a book-keeping model severely underestimate both