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Short communication

Is China really ready for shale gas revolution—Re-evaluating shale gas challenges

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ABSTRACT

Tackling climate change and reducing reliance on energy imports justify the exploitation of unconventional energy around the word. Influenced by the U.S. shale gas massive development, Chinese government set an ambitious plan to produce 6.5 billion m^3 of shale gas by 2015, 60–100 billion m^3 by 2020, and then 13 provinces were given priorities for exploitation. China's shale gas production will go ahead. Local government's ambitious targets combined with technical bottlenecks, lack of drilling experience, poor extraction operations, lagging infrastructure construction, imperfect price mechanism, water shortages, water contamination, and other undesired environmental effects with significant levels of uncertainty, are major impediments for shale gas revolution in China. Exploitation of shale gas reserves offers opportunities for China to meet its growing energy demands and reduce the reliance on energy imports. But China's ongoing shale gas plans should be seriously re-evaluated with reference to eco-environmental and social impacts. This is a unique and great opportunity for China to be a demonstration model, especially for other countries wanting of shale gas.

1. Introduction

Global economy is continuously growing. Natural resources especially the fossil energy has been exploited heavily or even overexploited. Renewable energy technologies diffuse so slowly (Negro et al., 2012). The Fukushima accident posed a negative impact on the acceptance of nuclear energy (Wang et al., 2012). Tackling climate change and reducing energy imports reliance justify the exploitation of unconventional energy around the word. New mining technologies – horizontal drilling and hydraulic fracturing to be widely known as "fracking", make the extraction of tightly bound natural gas what were previously inaccessible resources from deep shale formations economically feasible (Vidic et al., 2013). Especially in the North America, U.S. natural gas production increment is largely due to the expansion of the fracturing methodology (Souther, 2013), posing a significant impact on the international natural gas market, even the world energy landscape.

Natural gas is increasingly held up as a relatively clean energy source, it has recently emerged as domestic "bridge fuel" that offers the opportunity for a number of countries

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around the world to pave the way toward energy independence (Souther, 2013; Vidic et al., 2013). It can also allow for the shift from coal to renewable energy resources while helping to reduce the carbon emissions and other pollutants by the power sector (Vidic et al., 2013), especially cap coal consumption and stem $PM_{2.5}$ pollution.

2. Shale gas expansion plans in China

China is the largest energy consumer now, energy is essential for China's rapid economic growth. Owing to the rapid industrialization and urbanization progress in China, natural resources have been exploited heavily or even overexploited. Environmental degradation has also accelerated. Chinese government has faced the dilemma for a long time, always trying to harmonize economic growth and environmental protection. China relies on coal, which accounts for 68.4% of national power supply in 2011, oil accounts for 18.6%, natural gas only accounts for 5.0%, and other 8.0% are renewable energy. Current economic development is faced with the dual constraints, namely, natural resources and eco-environment, as well as the increasing dependence on external oil and other energy sources. Shale gas will serve as a transition fuel that will allow for the efforts to harmonize economic growth and environmental protection. Developing a relatively low-carbon fossil energy source is of great help for China's energy development strategy. Natural gas may be undoubtedly the right choice.

To date the significant exploitation and development of shale gas has been performed in the U.S. Influenced by U.S. shale gas massive development, the world's major resources – countries have increased their interest in shale gas exploration and development. In these countries, China is credited with great potential. Ministry of Land and Resources estimated China's shale gas reserves at 25 trillion m^3 (CNDRC, 2012b), exceeding the conventional natural gas reserves. And an earlier estimate from the Energy Information Administration of the U.S. Department of Energy was 36 trillion m^3, making China the world's largest shale gas reserves country (Tollefson, 2013a; Yang et al., 2013a).

During the ''Twelfth-five years'' period, estimate of the annual average increment of natural gas consumption in China will be more than 20 billion m^3, and natural gas consumption will reach 230 billion m^3 by 2015 (CNDRC, 2012a). Meanwhile, China's external dependence of natural gas is expected to more than 35% in 2015. Chinese government set an ambitious plan to produce 6.5 billion m^3 of shale gas by 2015, 60–100 billion m^3 by 2020, and 13 provinces were given priorities for exploitation (CNDRC, 2012b). China's leaders wish that shale gas would play an important role in boosting natural gas from 5% of the energy mix in 2011 to 10% by 2020, and capping coal consumption in the meantime over the whole country.

3. Progress of hydraulic fracturing for shale gas

Americans have taken 60 years and 200 thousand wells to lay the groundwork for the shale gas revolution (Tollefson, 2013a). Horizontal drilling and hydraulic fracturing are most widely used extraction methods now. These two technologies were first experimented in Texas about 15 years ago (Howarth et al., 2011b). In a single well pad, high-pressure water with fracking additives is used to increase fissures in the rock (Howarth et al., 2011b). High-pressure fracking fluid opens networks of fractures in the shale, holes in the well casing allow fluid to exit and gas to enter, and then gas flows from the fractures into the pipe follow the contour of a shale layer access to as much as 3 km or more at depths of more than 2 km (see Fig. 1).

Once fracturing is in process, water is essential to help keep the fissures open in the shale and let the gas flow into the pipe. Hydraulic fracturing consumes large amounts of water resources. Each well consumes 20 thousand m^3 of water on average one day during the fracturing process (Hu and Xu, 2013), ranging from 7.5 thousand m^3 to 26 thousand m^3 across the United States (Zeng et al., 2013). In addition, fracking fluids contain a range of hazardous materials, including biocides, acids, friction reducers, surfactants and scale inhibitors et al. (Howarth et al., 2011b), many of them are toxic, carcinogenic or mutagenic. Although many years extraction experience make the U.S. have a leading role in fracking techniques, recently, some researchers have paid more attention to the potential adverse environmental effects of this extraction method except the water issues.

4. China's shale gas challenges

China has rich shale gas resources, whether China can reproduce the success of the United States shale gas massive development is not a simple thing. At present, China's shale gas development is still in the initial exploration stage, we must have a sober understanding of this reality.

4.1. *Technology*

Hydraulic fracturing allowed the abundant recovery of natural gas from shale formations economically feasible. China has just preliminarily copied the horizontal drilling and hydraulic fracturing technologies from the U.S. experience. So it will take years to make breakthroughs in the key technologies. China's shale gas accumulation and geological formation is more complex than the U.S. China's widely distributed shale rocks are thick (Xingang et al., 2013). Many of them have a high clay content, which makes them more pliable and less apt to fracture (Tollefson, 2013a). Besides, many of the shale gas reserves are kept deep in the geological structure (Tollefson, 2013a; Xingang et al., 2013). The burial depth of shale gas in the United States is 800–2600 m, but the burial depth of Sichuan Basin in China is 2000–3500 m, which makes them hard to extract (Jiang, 2010). Americans took 60 years and 200 thousand wells to lay the groundwork for the shale gas revolution, China has just drilled fewer than 100 wells (Tollefson, 2013a). Exploitation is so difficult that it is not very suitable to directly copy the United States mining technology.

Advances in horizontal drilling and improvements in hydraulic fracturing are credited as the most influential factors allowing the possible expansion of natural gas