Shale Gas in China: Can We Expect a "Revolution"?

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Abstract

Natural gas in China has a substantial potential to grow from its current small share of the total energy use. The growth will contribute to lower air pollution and carbon emissions. Shale gas resources provide an opportunity for expansion and their development reduces dependence on energy imports. We estimate the costs of shale gas supply in China and use the MIT Emissions Predictions and Policy Analysis (EPPA) model to consider the impact of shale gas development on production, consumption, and international trade in natural gas. China's shale gas production is assessed to be more expensive in comparison to the current shale gas production in the U.S. The large shale resource might be a potential game changer in terms of energy production and consumption in China. However, even with favorable economic conditions, a substantial development of this resource might take a considerable amount of time.

1. Introduction

Natural gas has gained its popularity as a fossil fuel due to its relatively lower carbon emissions and air pollutants during the combustion process in comparison to oil and coal (EPA, 2012). In addition, a boom in a shale gas output in the U.S. has sent its natural gas prices to the lowest levels in a decade. Some analysts characterize this transformation of the U.S. natural gas industry as a "revolution" (Deutch, 2011; Jacoby et al., 2012). An expansion of natural gas use and the

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resulting decrease in coal use have also contributed to about 10% reduction in the 2012 U.S. energy-related carbon dioxide emissions relative to their peak in 2007 (EIA, 2012). With shale driven growth, the U.S. has become the world's largest natural gas producer (BP, 2012). As shale resources exist in many regions of the world (EIA, 2011), other countries are looking to replicate the U.S. experience. International Energy Agency (IEA) believes that natural gas is poised to enter a golden age (IEA, 2012).

Among countries with the plans to develop shale gas is China, which has even larger estimated shale resources of 1,275 trillion cubic feet (Tcf) than the U.S. resources of 862 Tcf (EIA, 2011). These is a lot of uncertainty in these resource numbers, and one of the goals of the current paper is to provide an estimate of shale gas resources in China, including the cost of its supply and an impact of shale gas development on the patterns of domestic production, consumption and international trade in natural gas. Projections to 2050 have been made with the MIT Emission Prediction and Policy Analysis (EPPA) model (Paltsev et al, 2005), which a multi-region multi-sector representation of the world economy. Among the important inputs to the model are the amount of energy resources and the costs of extracting them. The MIT Future of Natural Gas study (MIT, 2011) provided re-evaluation of unconventional natural gas resources for the U.S. and Canada. We use a similar approach for shale resources in China.

The shale gas development in China has been relatively slow. To speed up production, China has developed its shale gas development plan for 2011-2015 (NDRC, 2012). It calls for 6.5 billion cubic meters (bcm), or 0.23 Tcf production of shale gas in 2015, rising to 60-100 bcm (or 2.1-3.5 Tcf) of production in 2020. In comparison, China's total natural gas production in 2011 was 102 bcm (or 3.6 Tcf) of gas (BP, 2012). From these numbers, in less than 10 years China seeks to double its natural gas production.

Looking at the U.S. experience with shale gas, the current (2012) dry production of natural gas in the U.S. is about 24 Tcf with shale gas contributing about 30% to the total production (EIA, 2012). While the U.S. shale gas production in ten years has grown to its current level from almost nothing, that growth has occurred in a matured natural gas sector with a long history of substantial production. Even ten years ago, when the U.S. produced 19.6 Tcf of natural gas, the majority of the required distribution infrastructure has already been in place for a long time. The goal of China to rapidly increase its natural gas production is more challenging than the U.S practice as it needs to develop both an expertise in production and distribution networks at the same time.

The rise of shale gas in the U.S. has not been without controversy, however, with important concerns raised regarding water pollution and greenhouse gas (GHG) emissions, particularly those related to hydraulic fracturing (O'Sullivan and Paltsev, 2012). IEA provides "golden rules for a golden age of gas" to overcome the public concerns that shale gas production might involve unacceptable environmental and social damage (IEA, 2012). They include dealing with water and emissions issues.

A development of shale resources has changed the U.S. from being considered as a major market to receive natural gas from other countries via liquefied natural gas (LNG) trade to a country with a potential to substantially increase its exports of natural gas. Energy security is a major concern in China and it seeks to develop a fuel that will be produced domestically rather than imported. Shale has provides such opportunity. The future of natural gas in China hinges critically on the successful development of its shale resource.

The paper is organized in the following way. In Section 2 we discuss the historic trends of natural gas production and consumption in China and provide several forecasts made by different institutions. Section 3 discusses our shale gas supply estimates for China and compares them to the U.S. estimates and its experience with shale gas. In Section 4, based on the EPPA model,we consider several scenarios for production and consumption of natural gas in China and their impacts on global natural gas trade development in the next 20-40 years. Section 5 provides concluding remarks.

2. Natural Gas in China: historic trends and major forecasts

In 2011 China produced 3.6 Tcf and consumed 4.6 Tcf of natural gas (BP, 2012), which is a relatively small (about 5 percent) share of the total China's energy use. The production and consumption volumes are growing over time (for example, in 2001 China produced and consumed about 1 Tcf), but its natural gas production volumes are still quite far from bigger producers like the U.S with 23 Tcf of dry natural gas production per year or Russia with 21.4 Tcf per year in 2011.

The government of China considers natural gas as a clean and efficient fuel and its latest 5-year plans have mentioned several goals for a substantial increase in natural gas use, with the latest aspirational goal of getting 10% of China energy needs out of natural gas by 2020 (NDRC, 2012). Before shale gas received its attention, China has planned for a substantial increase in natural gas imports both by LNG and pipelines from Turkmenistan and Russia. A current enthusiasm about shale gas in China has slowed down an urge in planning the gas import infrastructure, but substantial import volumes are still envisioned.

According to BP (2012), the amount of proved natural gas reserves in China is about 100 Tcf. At the current level of gas consumption, they would last about 20 years. The proved reserves indicate the quantities that can be recovered under existing economic and operating conditions. Shale gas and other more speculative resources are not included in this category. The amount of the proved reserves in China is relatively small in comparison to the gas-endowed regions like the Middle East with about 2,680 Tcf or Russia with 1,580 Tcf. At the same time, the U.S. is experiencing natural gas boom while their proved reserves are about 300 Tcf. The key is unconventional gas, which a relatively more recent and more speculative phenomena. EIA (2011) has estimated 862 Tcf of technically recoverable shale gas resources in the United States. For China, the number in the EIA estimate is even larger at 1, 275 Tcf, which is the largest in the world. Figure 1 shows the relative size of China recoverable shale resources to its current proved reserves.

The large shale resource might be a potential game changer in terms of energy production and consumption in China. An important characteristic for the future dynamics is the cost of these shale resources. MIT (2011) estimated the costs for the U.S. unconventional gas and concluded that a substantial amount can be developed at a relatively low cost. For China, cost estimates of shale resources are very limited and in the following sections we provide our assessment, which confirms the large potential of the shale resource with a notion that China's shale gas might be more expensive to produce that the shale gas in the U.S.

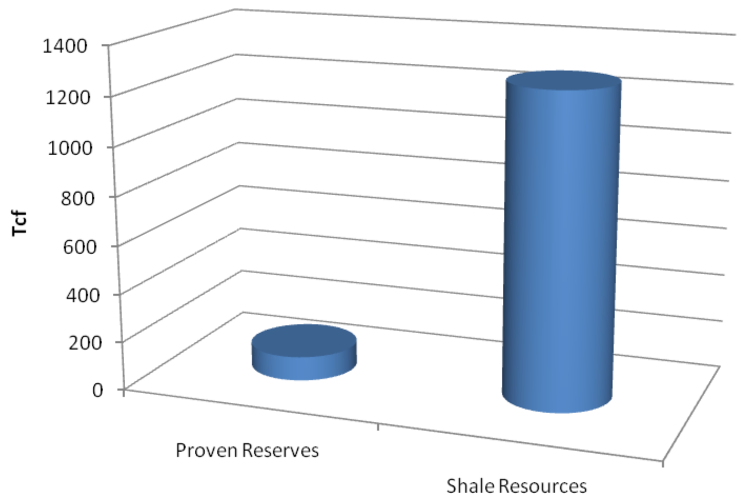

Figure 1. Natural gas in China: proved reserves (BP, 2012) and shale resources (EIA, 2011).

It is informative to put the numbers for China's reserves into the global context. Figure 2 shows the proved reserves history for natural gas (BP, 2012) in exajoules (EJ)[2]. It is worth noting that the proved reserve numbers are growing over time as additional resources are moved into the proven category (in the period from 1980 shown in the figure the additions are mostly in Russia, Iran, Qatar, and Turkmenistan). The global estimates have increased in the last 30 years from about 3,000 Tcf to 8,000 Tcf of natural gas. Asia Pacific region, which includes China, is a relatively small contributor to the global reserves. As mentioned, the current estimates for China's shale are about 1,000 Tcf. Even if only a fraction of the current estimates turned out to be proven, it will add substantially to Asian and global natural gas endowment. The global natural gas consumption in 2011 was about 110 Tcf. Globally, the proved reserves can support gas consumption for many decades even with an increased use.

[2] For natural gas, an absolute number in terms of energy in exajoules (EJ) is comparable with the number in terms of volume in Tcf (i.e., 1 EJ is about 1 Tcf). It is a useful relationship when one compares with other fuels measured in energy units.

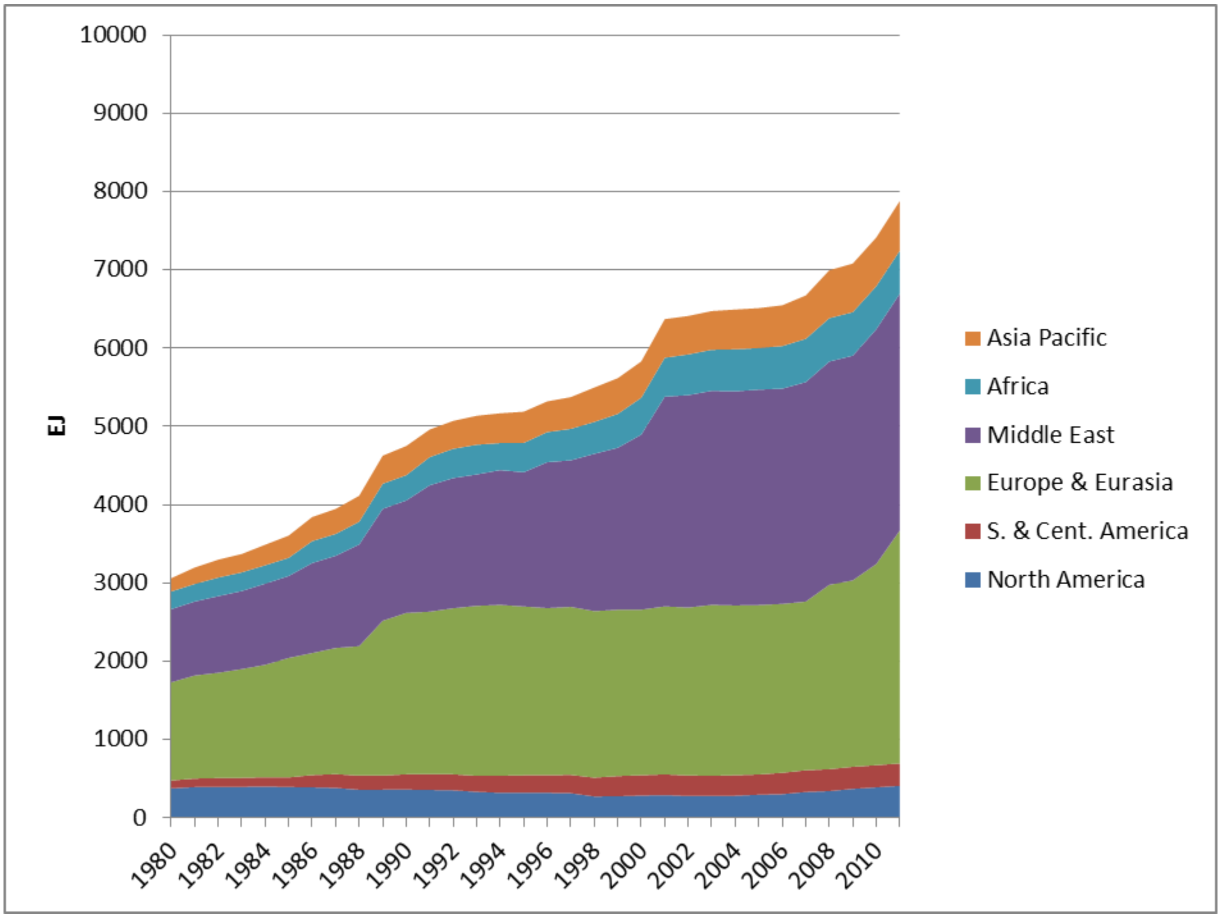

Figure 2. Proved reserves history for natural gas (Data source: BP, 2012)

Natural gas is a fossil fuel and just one of the potential sources of energy. It should be considered with other fossil fuels as there is a certain degree of substitutability among the fuels. Figure 3 shows the current estimates for global proved reserves of fossil fuels: coal, oil, and natural gas (BP, 2012). Coal dominates the reserves with about 18,000 EJ. Oil reserves are about 9,500 EJ and natural gas reserves are about 8,000 EJ. Asia is a region with the fast energy growth and many experts predict that Asia will be one of the dominating energy consuming regions (IEA, 2012). As shown in Figure 3, proven oil and gas reserves in Asia are relatively small (shown in light blue color at the top of the bars), while coal reserves are substantial. If domestic shale gas resources developed in Asia, they will be extremely useful for Asian region in terms of reducing energy dependence from suppliers from other regions of the world.

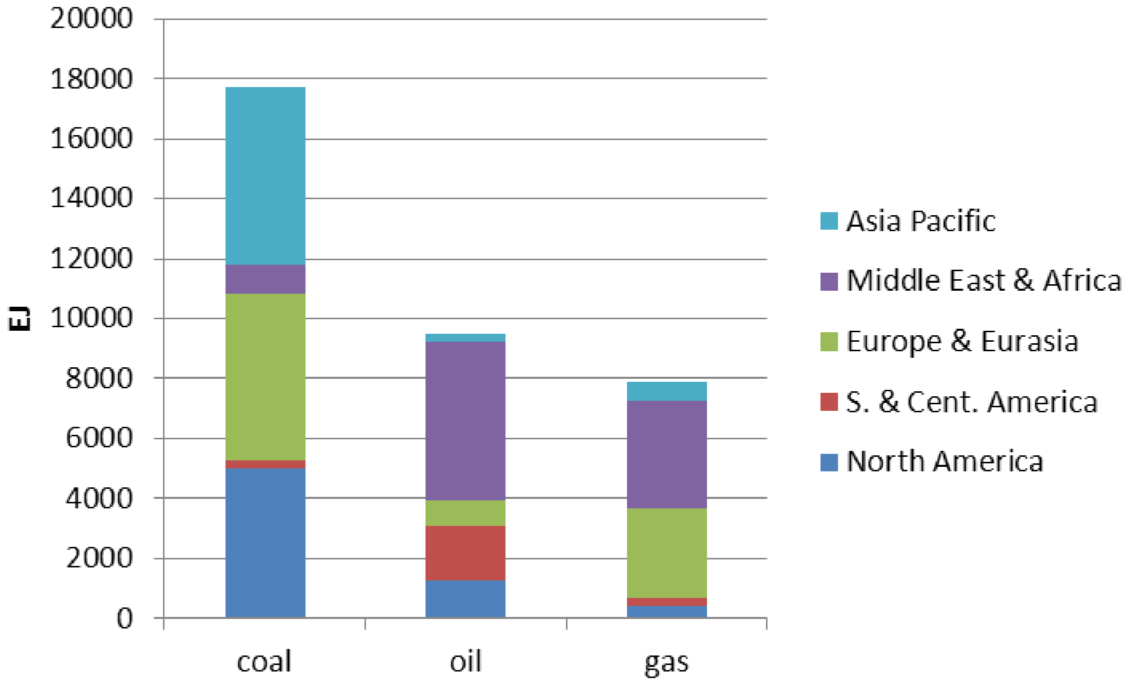

Figure 3. Global reserves of fossil fuels (Data source: BP, 2012)

Most projections from energy companies and agencies show that globally natural gas will be the fastest growing fossil fuel in the next 20-30 years (IEA, 2012; BP, 2013, Exxon Mobil, 2013). Recent editions of the energy outlooks have increased their projections for global use of natural gas even further. For example, International Energy Agency (IEA) in its 2011 outlook increased the projections of global natural gas use for 2020 from 123 Tcf to 130 Tcf and for 2030 from 139 Tcf to 155 Tcf (IEA 2010, 2011). The U.S. Energy Information Administration (EIA) kept its projections for 2020 roughly the same in its 2010 and 2011 outlooks with a slight decrease from 136 Tcf to 133 Tcf, but also increased its 2030 projection from 150 Tcf to 157 Tcf (EIA 2010, EIA 2011a). A majority of the increases in production is projected from so called unconventional gas (shale gas, tight gas, coal-bed methane).

Most of the increase in natural gas consumption is projected to be in Asia, and in China in particular. IEA (2012) projects an increase in China’s natural gas consumption from 3.9 Tcf (110 bcm) in 2010 to 10.7 Tcf in 2020 and 16.6 Tcf in 2030. EIA (2011) has slightly lower numbers with 6.8 Tcf in 2020 and 10.2 Tcf in 2030. BP (2013) projects an increase in consumption in

China by 283% in 2030 relative to 2011, which translates to 17.6 Tcf of natural gas consumed in 2030.

Production is also expected to grow, but at a slightly slower rate. As a result, imports of natural gas to China are expected to grow over time. In comparison to 0.5 Tcf imported in 2010, IEA (2012) projects 4.6 Tcf of imports in 2020 and 7.2 Tcf of imports in 2030. IEA (2011) numbers for natural gas imports are 3.1 Tcf in 2020 and 4.2 Tcf in 2030. BP (2013) projections convert to about 7.4 Tcf of imports of natural gas by China. IEA and BP numbers for 2030 consumption and imports for China are of comparable sizes with the current EU consumption and imports of natural gas.

3. Shale Resources in China

Our estimates of China's natural gas production and consumption are derived from the MIT Emissions Prediction and Policy Analysis (EPPA) model (Paltsev et al., 2005), which is discussed later in Section 4. Among the important inputs to the EPPA model's component of energy resource development and depletion are estimates of the amount of resources and the costs of extracting them. These natural gas supply functions are based on estimates of recoverable volumes of gas categorized as proved reserves, reserve growth and undiscovered resources. The representation of the gas resources in the EPPA model is described in Paltsev et al (2011). However, in that study only conventional resources for China were considered. We have revised these estimates to include shale gas resources for China.

To estimate the shale gas resources in China, we use the resource information reported for Sichuan and Tarim basins by the US EIA (2011). We then apply the same methodology as in MIT (2011) to get the cost estimates at different well spacings. The resulting representation of China's shale gas resource supply used to benchmark the EPPA model was benchmarked are illustrated by the curves in Figure 4, which show the quantity of gas that could be commercial at different extraction cost levels at chosen well spacings. These are long run resource supply curves. It is important to note that in the economic model production in any period is subject to dynamic processes that add reserves from resources and deplete reserves and resources. These features slow development, allocating the available resource over time while creating resource rents. As a result the gas price in any period is higher than the extraction cost of the least cost resource available at that time.

We choose 80 acres and 120 acres for well spacing as our main scenarios. In these scenarios, China has about 1100 Tcf and 750 Tcf of recoverable shale gas, respectfully, with the majority of the volumes with a cost of production at $7 to $10 per thousand cubic feet (mcf). Lower spacing brings higher volumes of gas. Higher spacing reduces the amount of recoverable gas. Figure 4 presents the curves for more and less optimistic assumptions about spacing, which leads to a wide range for recoverable gas. In China's conditions where shale plays are in mountainous regions rather than in flat areas like many U.S. shale plays, these closer well spacing scenarios are less plausible.

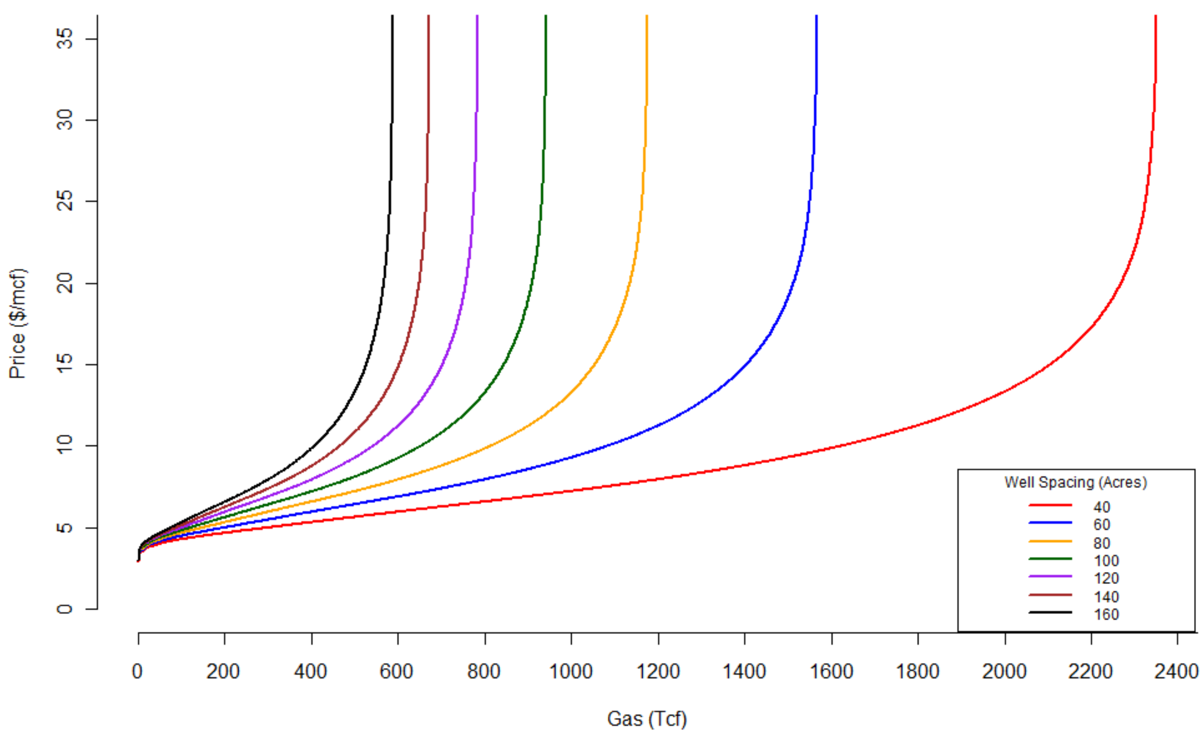

Figure 4. China shale gas supply curves for different well spacing.

Figure 5 provides a map of the major shale gas basins in China. We have based our estimates only on information for the Sichuan and Tarim basins. Other basins are even more speculative at this point. There are several reasons for higher costs of China shale gas in comparison to the U.S. The basins are different in terms of geology. They have different depth, pressure and clay content. Lower well spacings, even with U.S. practices of multi-well pads will be difficult to replicate in the mountainous regions of China as moving the drilling equipment and creating additional infrastructure will be more challenging. There are other aspects of production costs that are harder to quantify, such as management practices, land ownership issues, water rights and availability and access to capital. We have made some attempts to include it in the cost curves but we may easily underestimate these, mostly non-market, constraints.

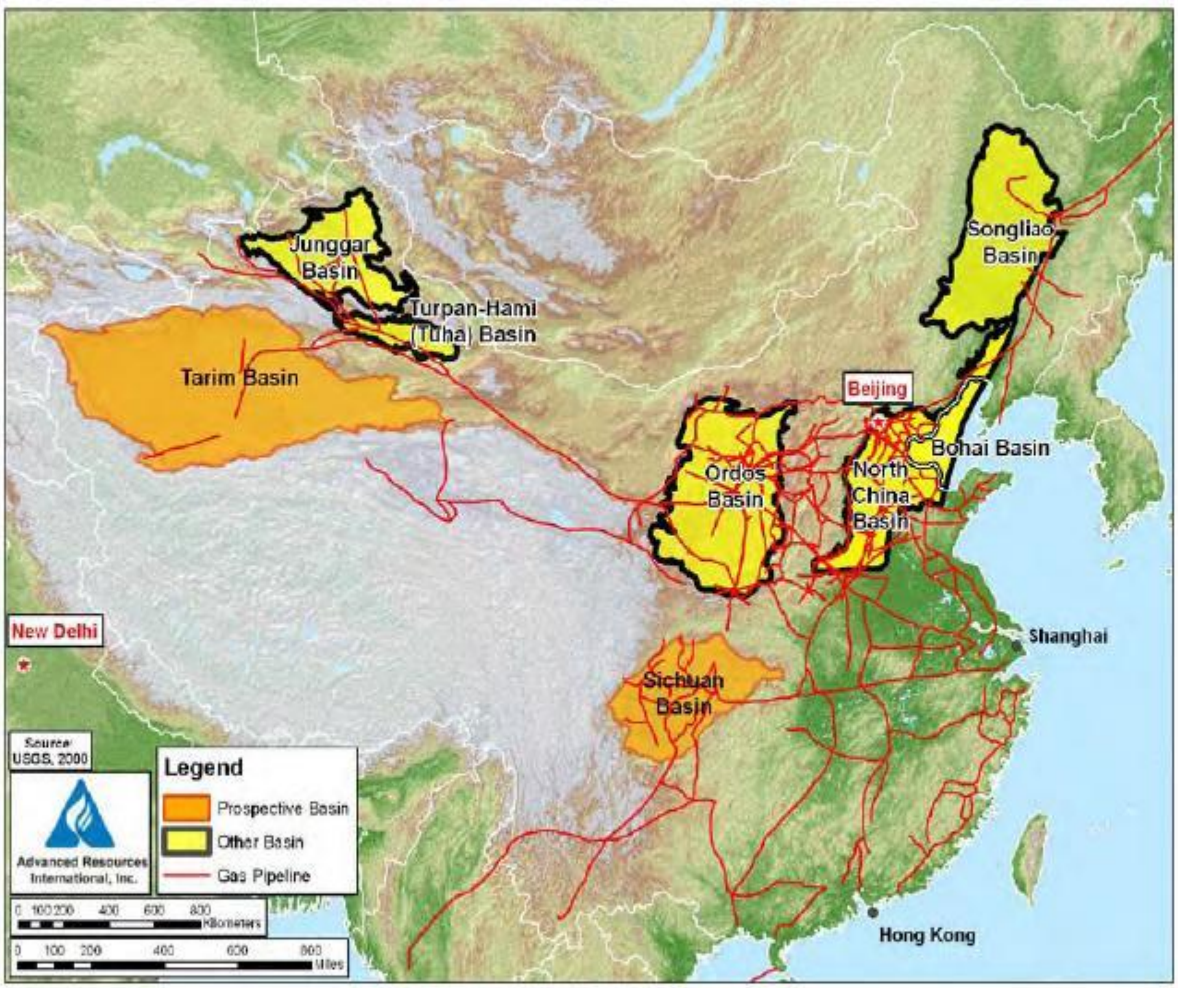

Figure 5. Geography of shale gas in China (Source: EIA, 2011)

4. Impact of shale gas on production, consumption and trade

To estimate natural gas production, consumption, and trade, we apply the MIT Emissions Prediction and Policy Analysis (EPPA) model which is a multi-region, multi-sector representation of the global economy (Paltsev *et al.*, 2005; Paltsev *et al.*, 2011). It is a computable general equilibrium (CGE) model that solves for the prices and quantities of interacting domestic and international markets for energy and non-energy goods and factor markets. The model identifies sectors that produce and convert energy, industrial sectors that use energy and produce other goods and services, and households that consume goods and services (including energy)—with the non-energy production side of the economy aggregated into five industrial sectors.

These and other sectors have intermediate demands for all goods and services determined through an input-output structure. Final demand sectors include households, government, investment goods, and exports. Imports compete with domestic production to supply intermediate and final demands. Demand for fuels and electricity by households includes energy services such as space conditioning, lighting, *etc.* and a separate representation of demand for household transportation (the private automobile). Energy production and conversion sectors include coal, oil, and gas production, petroleum refining, and an extensive set of alternative generation technologies. The EPPA model has been applied to a number of published economic and policy studies and to the MIT series of studies on the future of specific energy technologies. The EPPA model was a central tool for the interdisciplinary MIT studies: The Future of Coal (MIT, 2007) and The Future of Natural Gas (MIT, 2011).

The EPPA model solves every five years and it is designed to depict long-term trends rather than annual variability. We consider three scenarios for 2015-2050: shale gas is developed with 120 acres spacing (denoted as "Shale 1"), shale gas is developed with 80 acres spacing (denoted as "Shale 2"), and no shale gas is developed (denoted as "No Shale") in China. For other regions we use the same assumptions as in the Reference scenario in the MIT Future of Natural Gas study (MIT, 2011). Shale scenario is based on the assumption of 120 acres spacing described in Section 3.

Figure 6 presents the results for natural gas production in China in these scenarios. Without shale gas, natural gas production increases only slightly from the current 3.5 Tcf per year to 4.6 Tcf in 2025 and then starts decreasing to 2.7 Tcf in 2050. Shale gas makes a substantial difference in the production profile as the total gas production in 2030 reaches 10 Tcf in the Shale 1 scenario and 12 Tcf in the Shale 2 scenario. In 2050 production grows to 28 Tcf (which is about the level of current production in the U.S.) in the Shale 1 scenario and to 36 Tcf in the Shale 2 scenario.

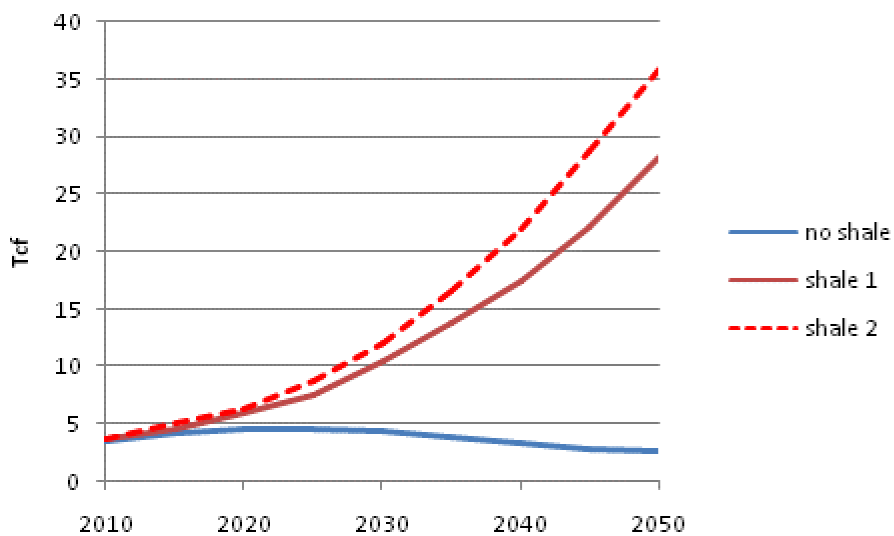

Figure 6. Natural gas production in China in different scenarios

Natural gas consumption in China is represented in Figure 7. Without shale gas, gas consumption grows to 12.5 Tcf in 2050. Shale gas scenarios increase consumption to 31-35 Tcf in 2050.Most of the increases in gas consumption happened in industrial and residential and commercial sector. Electricity sector consumption of gas increases not as fast because coal still is competitive fuel. We have not modeled any government support to gas consumption in these scenarios. Subsidies to residential use, natural gas transportation, or air pollution or carbon policy for electricity can substantially alter sectoral use of natural gas.

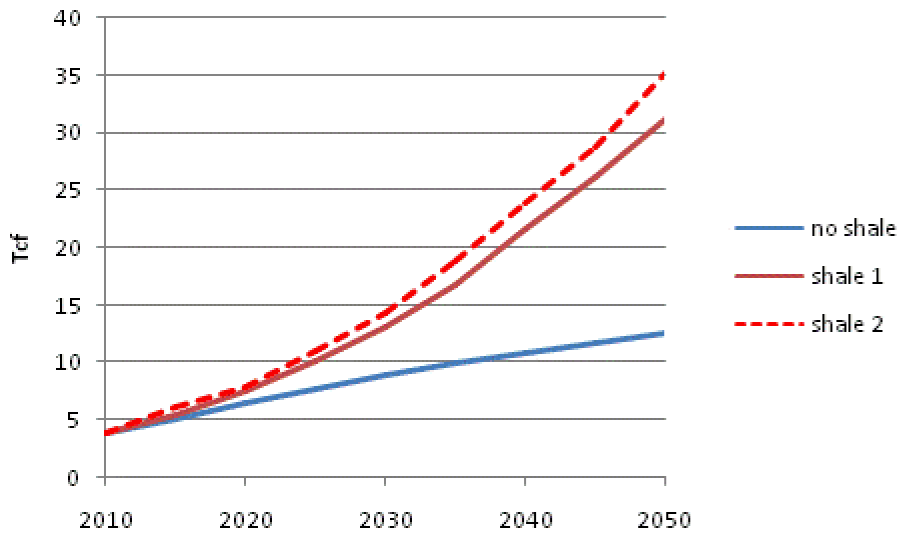

Figure 7. Natural gas consumption in China in different scenarios

Figure 8 shows the resulting imports. Without shale gas, import volumes grow substantially over time from 0.4 Tcf in 2010 to about 10 Tcf in 2050 (for a comparison, currently Russian exports to Europe are about 4 Tcf). This amount of imports requires development of both LNG receiving terminals and pipelines from Russia and Central Asia. Availability of domestic natural gas reduces the need for imports of gas. In the Shale 1 scenario, they grow at a slower rate to about 4 Tcf by 2040. In more optimistic shale gas scenario (Shale 2), they increase to about 2 Tcf and declining after 2040. Potentially in 2050, China is in a position to export some small volumes of natural gas. Again, these results crucially depend on the assumptions about the domestic support for natural gas use in China. An aggressive promotion of natural gas may lead to the higher required volumes of imports.

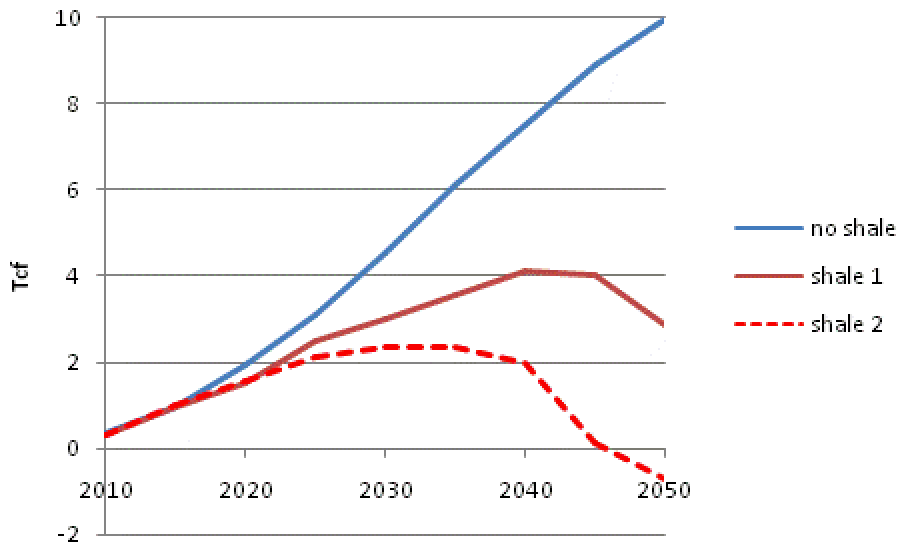

Figure 8. Natural gas imports in China in different scenarios

Availability of shale gas in China also alters the flows of international trade in natural gas. Figure 9 depicts the major flows (larger than 1 Tcf) of natural gas between major trading regions in 2040 in the scenario with no shale gas developed in China. Asian market attracts substantial flows (5 Tcf from Russia and Central Asia, 4.2 Tcf from Australia, 3.4 Tcf from Africa, 2.9 Tcf from the Middle East, and 1.1 Tcf from North America).

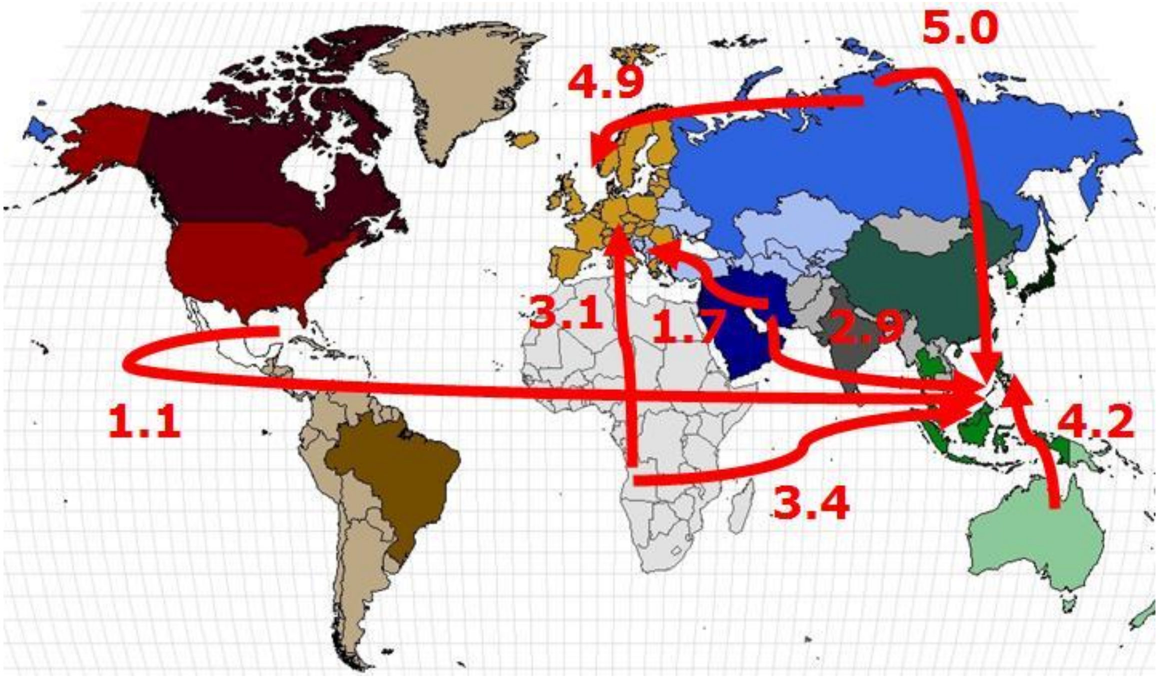

Figure 9.Major flows of natural gas trade in 2040 with no shale developed in China

Shale gas development in China reduces the needs for imports and lowers prices for natural gas in the Asian region and elsewhere because of the globalized international trade by LNG. Europe, as a result, sees increased volumes of imported gas. In 2040, in the No Shale scenario China imports about 7.5 Tcf, while in the Shale 2 scenario, it imports about 2 Tcf. Other Asian countries increase their imports only slightly, and it affects the total imports to the Asian region. Russia, Australia, and North America are mostly affected by the reduction in their export flows. In the Shale 2 scenario Asia imports 2.4 Tcf from Russia and Central Asia, 3.1 Tcf from Australia, 3 Tcf from Africa, and 2.5 Tcf from the Middle East.

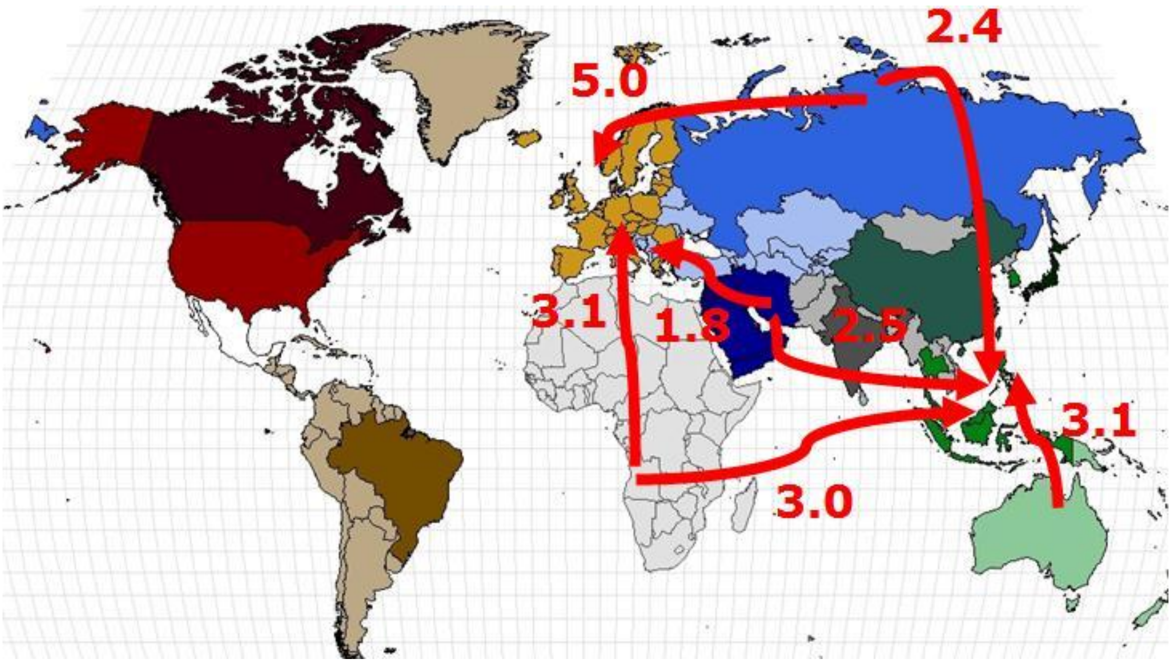

Figure 10. Major flows of natural gas trade in 2040 with shale development in China (in the Shale 2 scenario)

5. Conclusion

China has made shale gas development one of its priorities, as development of this fuel lowers air pollution and contributes to China's energy security reducing the needs for energy imports. China seeks to replicate the U.S. shale gas "revolution" where substantial volumes of gas from shale resource are produced in a relatively short period of time. China's shale gas might be more expensive than the shale gas in the U.S. where most of the cost estimates range in $4-6/mcf. The estimates of the recoverable resource and its costs have a large range. Depending on assumptions about the extraction regimes, our estimates range from 500 Tcf to 2,300 Tcf of natural gas recoverable from the shale resources in China. Most of the volumes can be produced at $6-10/mcf.

The large shale resource might be a potential game changer in terms of energy production and consumption in China. However, even with the favorable economic conditions, a substantial development of this resource might take a considerable amount of time. We estimate that it might reach the current U.S. levels of natural gas production, but it will take about 25-30 years. So we expect that the “shale gas revolution” in China will not be quick. Most of the delays are connected to the geology of the shale resource in place (pressure, depth, clay contain, mountains), and a need to develop a substantial gas distribution infrastructure, but other issues like water availability (especially in Tarim basin), land ownership, management practices also may play an essential role.

The U.S. experience shows the importance of public acceptance of “fracking”, a process that is used to produce shale gas. Perceptions or mis-perceptions that shale gas production may lead to water contamination, water scarcity, pollution, or even earthquakes will be important for a proper development. For China with its reliance on coal, natural gas development is crucial both in terms of energy supply but also because of lower air pollution and carbon emissions. Without shale gas, imports of natural gas will be substantial. Large expenditures for natural gas imports most likely will slow down its use and government support for residential and commercial use of gas. Therefore, we believe that China will significantly push its natural gas use only if it develops domestic production. China tries to incentivize natural gas development by considering liberalizing investment rules to allow private investment and plans to remove government controls on gas prices, but it still has many obstacles to overcome.

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