OVERVIEW OF CHINA'S SHALE GAS DEVELOPMENT

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Abstract

Even though China has been engaged in shale energy development for over 60 years, the only country that is able to turn shale energy into a profitable business is the United States. The shale boom in the US has changed the prospect of shale energy, assuring the rest of the world that shale energy development is no longer a waste of time and money.

After almost two decades of solid economic development at an explosive rate, China is struggling with rising energy demands and costs, rising labor costs, environmental degradations. Therefore, the US shale boom seemed to offer the hope that China eagerly needs – a source of energy that China has rich deposit in. If successfully extracted at a reasonably low cost, shale energy will be able to replace coal, which is causing huge environmental backslash in China; it will also ensure ample energy supply at a relatively low cost which could reduce China's heavy reliance on foreign energy.

The Chinese government is enthusiastic about the potentials shale energy has and is determined to create its own shale boom. However, the shale reserves in China have proven to be poorer in quality and harder and more costly to extract. As a result, China's major national oil companies have been reluctant to invest because of the dismal prospect of financial returns. The general public is mostly against the shale energy development because of the negative environmental consequences associated with it.

China needs shale energy and should develop this energy source at least as a replacement alternative for coal. However, there are real challenges China faces such as its lack of sufficient

market mechanism and policy structure, lack of public support due to perceived negative environmental implications, as well as the geological challenges. Therefore, shale energy development in China requires much more than just zeal, it calls for patience and step by step strategies such as encouraging private and foreign investments, developing appropriate technologies, building necessary technical expertise and professional workforces as well as pipeline networks, etc. to ensure the success of China's shale energy development.

Section I: Media Reactions to Shale Energy Development in China

Shale boom in the US has captured the attention of the western media in the past four to five years. The US shale revolution may have gotten the attention of the Chinese government, the public media outlets in China, didn't seem to share the enthusiasm.

Since the petroleum industry is mostly still dominated by State-own energy companies, it is understandable that the discussion about shale energy development would not have generated much hype and anticipation among the general public, because the subject of energy is far removed from the lives of private citizens. Most discussions or information on shale energy were found either in State run media or industry controlled media outlets. However, as the US shale revolution continues to deepen and China begins to follow suit in pursuing its own shale objectives, more and more discussions related to shale development can be found in mass media.

Shale development brings as much controversy as the hope it offers in China, just as it did in the US and other countries.

Most State-run media have generally supported the idea of shale development. For example, as early as 2008, Xinhuanet (www.xinhuanet.com) published an article titled *Developing Shale Gas: Is to Awaken the Sleeping "Treasure*". Xinhuanet, sponsored by Xinhua News Agency, is recognized as the important information organ of the Chinese central government. The article pointed out that China has confirmed to hold large reserves of shale gas and other shale energy resources. The unconventional energy sources hold great potential for China's social and economic development in the next decade. The article pointed out that China is actively seeking alternative energy sources since its own conventional oil and gas sources cannot meet its growing energy needs. Mr.

Han Hua, Director of the CNPC-Alberta Petroleum Centre (CAPC), an institution under the China Natural Gas and Petroleum Company (CNPC) was quoted to say that the CAPC had been engaged in finding other alternative energy sources, and shale energy could potentially be the answer they had been waiting for.

The article admitted that the US shale gas boom triggered China to re-examine its own shale energy resources. The article also disclosed that CAPC organized a two-day forum on shale gas explorative technology in Changchun of Jilin Province. As China has recognized its lack in technological expertise, establishing the initial network with North America to acquire essential technology and expertise needed to ensure its own shale gas development can get off on a good start. The article also admitted that China is running into some obstacles at the initial stage of its shale gas development. According to the article, conventional shale gas has in a sense slowed the shale development because China's conventional gas exploration is still dominating the domestic market. As a result, there is no real incentives to start shale gas commercial drilling right away. In addition, the article pointed out that shale gas development requires enormous investment in terms of technology, man power and capital investments. The high costs could also potentially hinder shale gas development, hence making shale gas development potentially less profitable. The article stated that compare to return on investment (ROI) ratio of 60% for conventional natural gas, the ROI for shale gas is only between 5% and 60%. The article indicated that even though China is envious of the US success, considering the practical difficulties and drawbacks, shale gas development in China would likely to remain as exploratory until China could possess the technological know-hows to lower cost to increase profit. (Yanli, 2008)

Similarly, Chinese Ministry of Land and Resources (MLR) published an article on its official website titled *Shale Gas: Leading the Way of China's Energy Exploration*. The article announced that the government had granted shale gas the status of an Independent Mineral Resource, making it the 172th mineral resource in China. The status change would enable shale gas to conduct its own independent exploration and extraction process, instead of being at the mercy of conventional gas exploration. The article called shale gas the resource of the future, and believed that it had the potential to change China's energy outlook. (Dawei, 2012) The author of this article was the Assistant Director of the Natural Gas Department in MLR, the government agency that is responsible for developing policies and regulations related to energy exploration. Therefore, this article can be seen as an indicator of the future policy direction regarding shale gas, and government's intention and commitment to shale energy development.

Another category of the media articles tried to give a more balanced analysis of the shale boom in the US and China's shale energy conditions. These articles are usually written by commercial website, newspaper columnists, or media commentators. For example, the web portal of China's Xinhua News Agency Xinhuanet published an article titled *Analysis of the US Shale Energy Development*. The article described conditions of shale development in the US, and concluded that technology advancement only didn't make the shale boom. Growing market demand and high energy costs which attracted the influx of investment, have together led to the US shale boom. The article also attributed the US shale success to government support through legislated tax breaks and subsidies. These supportive polices helped shale energy development to quickly take off. The article also said that around 30% of the initial profits from unconventional energy development in the US had come from government subsidies. The article also noted that finding

loopholes in environmental laws had also allowed the fracking industry to avoid potential environmental backslash or costs, such as the infamous “Halliburton loophole”.

The article also gave suggestions on what China could learn from the US’ shale success. Suggestions included that government should provide tax and policy support, give continual support for technological advancement, adjust current domestic natural gas market to elicit investment from non-government sources, and to change the natural gas pricing structure from a State regulated system to a more market-oriented structure. (Wang Z. , 2013)

Other articles tend to focus more on the different characteristics of China’s shale reserves conditions, stressing the need for China to find itsown path to achieve shale development success. Souhu (www.souhu.com), one of the earliest and most widely recognized web portal in China, reprinted an article on shale energy development from the *Outlook Magazine*. *Outlook* is published by Xinhua News Agency. After discussing the background and conditions of the US shale boom, and how they are different from China’s current situations. The article concluded that instead of rushing to replicate the US’ “shale success story”, China should recognize the long-term and complex nature of shale energy development, and invest to build up necessary infrastructure, technical capabilities and market structures to bring about solid shale energy development.

It is interesting to note that the article is the first and only article in China has challenged the two widely recognized risks associated with shale energy development: water shortage and ground and surface water contamination issues. Mr. Zhang Dawei, the Mineral Resources Reserves Assessment Center Director was quoted to say that even though the average 15 thousand cubic meters water needed to dig one shale gas well was enormous. However, if the amount was spread

over the life span of the well, which is 30-50 years, that amount would be reasonably low. The US experience suggested that the shale development water usage only accounted for 1.8% of the total water usage in the local area where the shale basin was located. This amount was less than the water used by other industrial and agricultural facilities. Regarding the risk of fracking fluid contaminating underground drinking water, the author believed that the risk is real but manageable. The article believed that there had been a lot of research findings indicating new formula for fracking fluid that could reduce or eliminate the contaminants to drinking water. (Wang R. , 2013)

Central government agencies are developing guidelines in greater details regarding shale energy (gas) entry requirements, environmental protection & regulatory standards, etc. The central government is determined to take advantage of the over 2,500 billion cubic meters shale gas reserves to meet China's fast growing energy needs. It announced the *Shale Development Plan* in March 2013. The Plan indicated that the Chinese Ministry of Land and Resources (MLR) and Bureau of Energy were initially focusing on achieving technical breakthroughs. The United States have shown great enthusiasm and willingness to share its technological innovations. China and the US signed the *Memorandum of understanding on China US cooperation in the area of shale gas* in 2009. The two countries have also held five joint forums on energy topics between 2009 and 2013. However, the US technology may not be appropriate in exploring China's shale energy considering the geological differences of the Chinese shale basins. The article also indicated its desire to reduce its reliance on US technology and to encourage and foster domestic research and development capacities. The article also summarized the current difficulties China's shale energy development is faced with. In addition to popular ones such as the age and depth of shale gas

reserves, and the potential environmental challenges, the author also pointed out the lack of sufficient investment, and the market and pricing structure of natural gas in China could potentially hinder shale energy development. (Wang R. , 2013) China Commercial Intelligence Network website published a similar article listing the four major challenges or "bottleneck issues" China is faced with: the depth and quality of the shale gas reserves, the water shortage issue, and government policy and extraction technology. (China Commercial Intelligence Network, 2012)

Other articles in the media are mostly published by private media outlets that focusing more on the risks and potential negative impacts of shale energy development. For example, an article published on a Chinese high-tech platform website named Gold & Silver Island (www.315.com) focused on the potential water contamination from fracking fluid. By referencing the "Halliburton loophole" example and shale energy related water contamination cases in the US, the article proved that the risk of water contamination indeed exists. In addition, the article included the statistics taken from major US shale gas development projects such as the average water usage per well as evidence showing that the massive water resources used by fracking as well as that the harmful chemicals contained in fracking fluid pose real environmental risks. Therefore, the article believes that government should take necessary measures to keep the damage to the environment, especially underground water at the minimum level. By doing so, China would be able to avoid creating another environmental disaster like the one it is currently dealing with as the result of the uncontrolled development over the past two decades. (Pang, 2014) The environmental issue is a very popular subject now in China. With the smog and drinking water issues, people are beginning to realize that development at the expense of the environment is not sustainable.

Developing necessary technological expertise is another major challenge China is faced with if it hopes to accelerate its shale development progress. According to an article published on Caixin.com (www.caixin.com), Sinopec achieved some technical breakthroughs on extraction technics at the Chongqing Fuling shale gas basin in Sichuan Province, making China the third country in the world that has independently developed fracking techniques. However, the article then pointed out that this technology may not be used on other shale formations as geological characteristics of these shale formation are unique to the point that requires different technology for each regional formation. In other words, China still has not developed its own technology that could be used on multiple shale formations.

Then there is the conspiracy theory in the media. Some experts and groups believe that shale energy concept could potentially turn out to be a trap for China. People hold this belief believe first of all that shale energy reserves conditions in China are much more difficult to extract. As a result, the costs of extracting shale gas in China would be 2- 4 times that of the US. The high cost will make shale development in China much less viable commercially. Secondly, some believe that investments that created the shale gas boom in the US was the renegade funding diverted from Wall Street because of the financial market crash. Therefore, the shale energy boom is another economic bubble created by the speculative funds seeking a new outlet. This means that the shale boom in the US is likely not going to be sustainable. (Wang Y. , 2013) Since 2012, the shale industry in the US has started to slow down with wells being closed. A small private shale gas company named WBH Energy was the first shale gas company that filed for bankruptcy protection. (Yin , 2015) Some are beginning to argue that the US is now seeking overseas investors to continue injecting investment into its shale industry, to purchase their technologies and surplus

equipment. (Wang Y. , 2013) Some are questioning the intention of the US government as it is actively promoting shale energy development concept to China and trying to convince the Chinese government that China should and could have its own shale boom, especially when shale gas production is leveling down in the US. (Zha, 2012).

Even though, shale energy development is attracting more and more media attention, the media reaction and general attitude toward shale energy are mixed at best. As one consultant described the general mood in China toward shale energy development. With the heavy promotion coming from the West, especially the US about the benefits of shale energy development and China's rich shale gas reserves, the central government and the academic sectors are eager to see China's shale "dream" come to life. However, the reality is that the energy developers including State-owned energy companies like PetroChina, as well as the general public don't share that enthusiasm. According an unofficial polling of the Tencent web (www.qq.com) news editorial, 81% among the 68,000 readers polled were against China following suit after the US in developing shale energy. (Wang Y. , 2013) Tencent web is one of the most popular grassroots media platforms. It hosts the popular social mobile application "WeChat".

The successful shale development in the US has many implications for China both economically and politically. The most obvious benefit the US shale boom has generated for China and for other energy importers is the low oil price. Even though the oil price drop is more likely to be the result of multiple factors at work, but the influx of US produced shale energy certainly helped in tipping the balance of demand and supply. China was reported to have been taking advantage of the low oil prices to stock up for its strategic reserves. In October 2014 only, China National Petroleum Corp (CNPC) was reported to have purchased 36 cargos which is equal to 18 million barrels of

crude oil from the Singapore spot market. (Yep, 2014) Other reports are showing that this oil price crash could have saved China $100 billion on its oil imports. (DAVOS, 2015)

Another implication is that China has now become the largest oil importer in the world. As the US cuts back on its oil import from the Middle East, China could potentially be the country that takes up at least partially the excess supply. As a result, China might see itself in the position to become more and more involved in the region and the region's conflicts. This could mean further geopolitical cooperation with the US

In addition, some believe that the shale boom has also opened up opportunities for Chinese national oil companies (NOCs) to purchase upstream assets. Since 2010, China's NOCs have spent more than $10 billion to acquire upstream assets in the United States. Most of investment which has been spent on unconventional projects. These investments have helped make North America a key geographic focal point for China's NOCs. On the other hand, as US oil companies sell assets abroad to earn money to invest in shale energy development in the United States, there are more assets available for China's NOCs to buy in third countries. A recent example of this is the Conoco Phillips' sale of its stake in a joint development of Kazakhstan's giant Kashagan oil field. This project is now in the hands of China's National Petroleum Corporation (CNPC). Moreover, as US and other international oil companies are increasingly focused on investing in the American upstream energy assets, they are not competing for overseas assets they otherwise might have pursued. For example, Exxon Mobil, Chevron, BP and BG did not participate in the recent bid to develop Libra, Brazil's largest offshore oil discovery, while both CNPC and CNOOC are members of the winning consortium. Without the US shale energy revolution, there might have been other international players participating in this bid. (Downs, 2013)

Europe as a Case Study

I want to briefly discuss the case of Europe because as an important trade partner with China and traditional ally with the US, Europe's experience with shale gas could also serve for China as a case study that is uniquely different from the US.

Europe, hasn't been as enthusiastic with its shale energy as its North American counterpart. Even though there are enough incentives for Europe to develop its shale energy, majority of Europe seems to have decided against the idea. Data shows that between 2005 and 2012, Europe lost about 35% in overall competitiveness due to rising energy cost. For example, European industry gas price index rose by 35% while the same index in the US declined 66% as a result of cheap shale gas flooding the US domestic market. In the meantime, the European industry electricity price index rose by 38%, while the US declined by 4%. (Barroso, 2013) Higher energy costs will make Europe less competitive for international investments; meanwhile high energy cost could potentially drove companies in energy intensive industry from Europe to the US (Buchan, 2013)

Yet, European countries have mostly decided against shale energy development. In Europe, each member state makes its own energy decisions. France has decided that the benefits from shale energy is not worth the costs, and has banned fracking in fear of its potentially negative environmental impact on its tourism industry; Britain has also decided against shale energy because of its commitment to environmental policy and GHG emission goals. (Buchan, 2013) Germany has announced in July that Germany will stop extracting shale gas for commercial use within 7 years. Germany has been experimenting with fracking technology since 1960s, which has optimized its natural gas production. Germany is calling off fracking due to concern over potential

underground water contamination because of the chemicals used for fracking. (China Security, 2014)

The only country that has made solid attempts at developing its shale resources was Poland. Initially, IEA estimated that Poland has the largest potential shale reserves at the level of 5.3 tcm (trillion cubic meter) in Europe. However, by 2011, the US Energy Information Administration (EIA) revised the estimate by reducing the reserve amount by 90%. As a result, large international energy companies such as Exxon and Marathon have pulled their shale development operations out of Poland. (Buchan, 2013)

It looks like Europe has chosen the environment over shale energy, at least for now. As the President of the European Commission pointed out in his presentation, decarbonisation and increase in energy efficiency may be the best solution for Europe's energy needs for the moment. (Barroso, 2013)

Section II: China's Shale Gas Overview

I. China's Energy Review

After over two decades of rapid economic development, China has become the second largest economy in the world. China's National Bureau of Statistics released the economic data for 2014, China's GDP grew at 7.4% to RMB63.65 trillion yuan ($10.4 trillion), (Xinhua, 2015) making China the second largest economy in the world. Rapid growth also means rise in energy demand. According to the report released by the International Energy Agency (IEA) in 2012, China's energy demand has grown from 420 million tonne oil equivalent (TOE) in 1980 to 2.15 billion toe in 2009.

(IEA, 2012) Among the current total energy consumption mix, 69% comes from burning coal, while oil and gas consumption account for a combined 21.8%. BP published its energy consumption outlook by 2035 in February 2015. The report showed that the economic growth in China and India would be the driver behind the continued increase of world energy for the next 20 years. The total energy demand will grow by 1.4% annually to a total of 37%. According to the forecast, China will be the single largest oil consumption country by 2035. (SINOPEC News, 2015) Since 2006, China's dependence on foreign natural gas has been growing at proximately the same rate as its GDP growth rate. Energy consultant company ATKearney forecasted that the natural gas dependency rate in China will be 31% by 2015, and will likely grow to 42% holding everything consistent by 2035. (Wang Y. , 2013)

The heavy reliance on coal for its industrialization has also resulted in rising environmental problems. Among the environmental problems, the most notable one is air pollution that has been plaguing many of China's major cities. According the US EIA report, China is one of the leading energy related CO2 emitter, releasing 8.7 billion metric tons of CO2 in 2011. (EIA, 2014) Beijing, for example, has been struggling with pollution for over a decade, and it has worsened in recent years. Media reports have often referred to the level of air pollution in Beijing as hazardous because of the alarmingly high air-quality index scale, up to 886 micrograms per square meter. As a result, the air pollution problem has become more than just an annoyance, or a "face losing" issue. It is costing the Chinese economy and could hinder its development progress with flight cancellations, road closures, as well as public health issues such as chronic lung disease, heart disease and cancer. The World Health Organization the World Bank estimated that in 2009 alone,

air pollution cost the equivalent of 3.3 per cent of China's GDP, or about RMB700 billion yuan. (Over $112 billion) (Wheeler , 2013)

Oil & Gas Journal (OGJ) indicated that as of January 2014, China holds the highest Asia-Pacific region 24.4 billion barrels of proven oil reserves. In addition, China is the fourth largest producer of oil and liquids in the world with production rose over 50% over the past twenty years and supports exclusively its domestic market. However, the production growth rate is not enough to accommodate the need for oil and natural gas during the same period. In 2013, China produced an estimated 4.5 million barrels per day (bbl/d) of total oil liquids, of which 93% was crude oil.

China has been a net oil importer since 1994 and gas importer from 2006. Since then, China's oil consumption has almost doubled, hence its oil import. Even though, its total energy consumption growth rate has slowed to less than 14% in 2009, China still now holds second place as the world's second-largest net oil importer in the world behind the United States since 2009. According to EIA energy analysis, China consumed an estimated 10.7 million bbl/d in 2013, and will likely surpass the United States as the largest net oil importer in the world with an estimated net oil imports of 6.6 million bbl/d compared to 5.5 million bbl/d that of the US. This is result of the rising demand in China and the rising domestic production capacity of the US because of the shale boom.

II. Government's Support for Shale Energy Development

The shale energy cooperation between the US and China can be traced back to late last century. In 1988, when George Mitchell dug his first shale gas well in Barnette, Texas, there were four engineers sent from Daqing Oil field, the largest oil field of China visited him in his office. (Qian & Ding, 2012) Forty years later, the US has achieved its Shale Revolution, while China still seems to be wandering outside the gate.

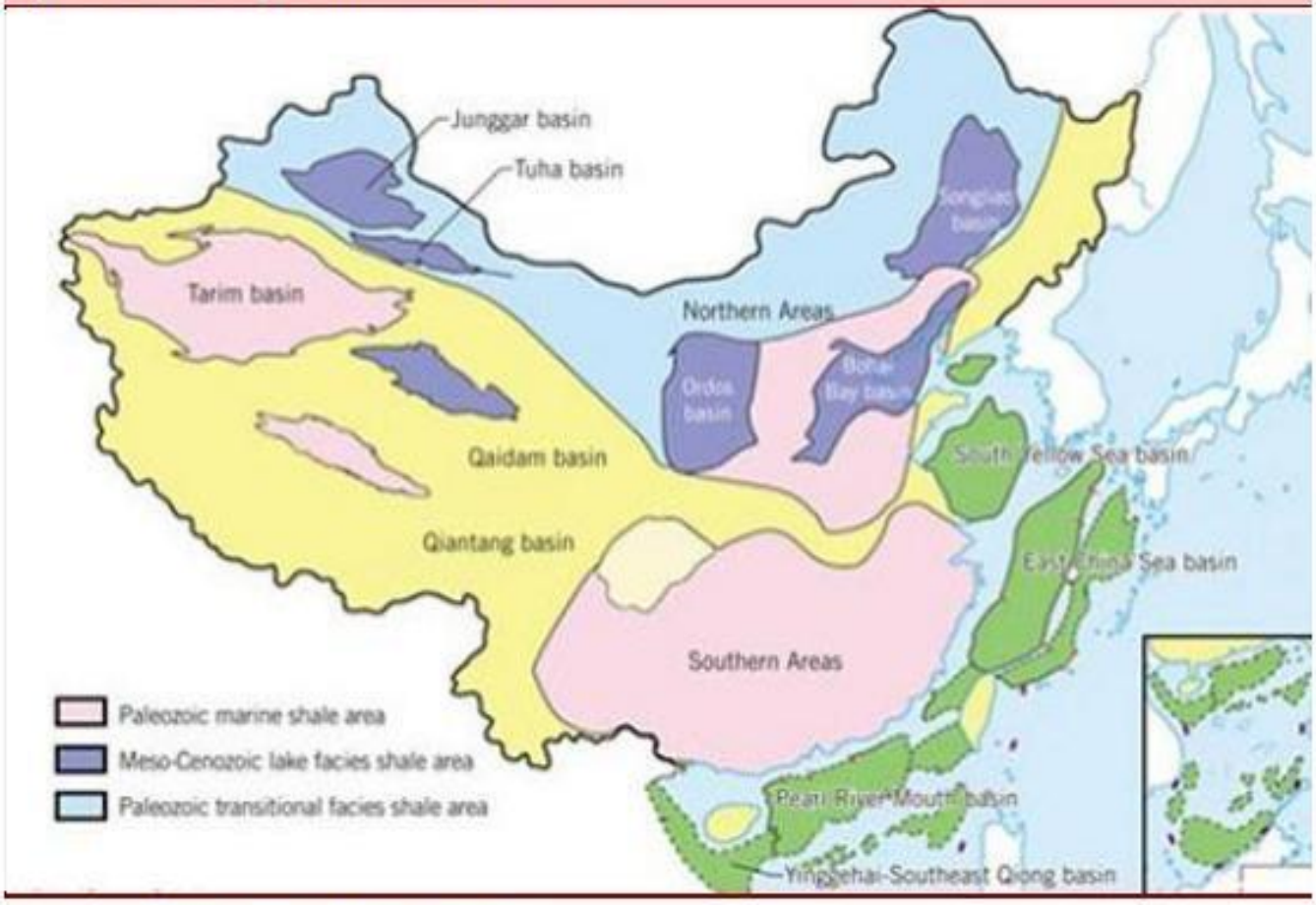
The US success in shale energy extraction rekindled China's zeal for its own shale energy. According to the US EIA data, China holds the world's largest shale gas reserves. (EIA, 2014) The US shale boom also set high hopes that China will also benefit from its own shale energy.

In March of 2012, Ministry of Land and Resources (MLR) announced a 4-year plan on shale gas development. The plan was jointly developed by four agencies including the MLR, the Ministry of Finance, National Development and Reform Commission (NDRC) as well as the National Energy Administration (NEA). The main objectives of the plan included (1) to complete the evaluation and exploration of the domestic shale gas potential; (2) to develop several shale gas exploration and extraction fields, to achieve the initial scale of economy with the annual production target as 6.5 billion cubic meters by 2015; and (3) to achieve breakthroughs on key shale gas explorations technologies, to be able to be manufacture major equipment domestically, and to complete developing shale gas technological standards and specifications in order to prepare for accelerating shale gas development during the 13th Five-Year Plan. (Zhang, 2012)

In addition, the government is providing incentives and implementing favorable policies include providing fiscal support; providing direct subsidy for shale gas production companies; encouraging local governments to provide subsidy for shale gas development companies, and allowing local governments to decide the local level of subsidy. Shale gas development companies are exempted from mineral resources compensations fees and mineral right usage fee; and finally equipment that cannot be produced domestically will be exempted of import tariff. In addition, the government is in the process of promulgating other energy related taxation measures; (National Energy Administration, 2013)

III. Shale Resources in China

Figure 1: Shale gas distribution in China



Source: Ministry of Land and Resources

According to EIA's shale resources analysis, China ranks the third with 32 billion bbls of technically recoverable shale oil reserves behind Russia and the United States; while holding the largest shale gas reserves of 1,115 trillion cubic feet technical recoverable reserves. China has been exploring in the areas of shale energy since 1960s. These early research and development activities were more theoretical and academic partially due to lack of sufficient technological support and tools.

These researches have concluded that there are three types of organic rich shale resources found in China: marine, marine-continental transitional facies-continental coal series, and lacustrine facies. These shale gas resources are found in many areas in inland China, such as Songliao in the Northeast region of China, in Bohai bay area, Sichuan Province, Ordos in Inner Mogolia and in Qaidam Basin in Qinghai Province, but located ad jointly with Haixi Mongol and Tibetan Autonomous Region in western China. The gas formations include those of rock form shale gas and shale fractured reservoirs. As early as in 1966, drilling of Wei Five well in Weiyuan, was able to extract 2.46 X 10 m/day of shale gas from the Paleozoic Cambrian Qiongzhusi Grop marine shale.

Between 1994 and 1998, China also conducted a lot of researches targeting mud and rock fractured shale reservoirs. These researches have yielded some good progress in terms of understanding the unique characteristics of China's shale reserves. These research results have revealed that the formation of the China's shale reserves is very different from that of the US

Basically the shale formations in China are more complex in its structure, and are multiple fractured, and have less natural gas content, and are found at much greater depth, more than 3,500 meters, the Songliao reserve is as deep as over 5,000 meters. However, in the US, the reserves are usually between 2,500 – 3,500 meters in the US.

In addition, the geological conditions surrounding China's shale basin include large mountain terrains, and airy region while the geological conditions of the US shale reserves are located mostly on flat terrain where water sources are plenty. These geological features mean that shale explorations in China will be much more challenging which will make the extraction more costly. (Zheng, Zhang, & Wang, 2014) (Dong, et al., 2012)

The Society of Petroleum Engineers (SPE) held the 2013 SPE Asia Pacific Oil and Gas Conference and Exhibition in Indonesia. The report released by the SPE during the Conference also confirmed the findings by Chinese scholars. The SPE report indicated that even though China had abundant shale resources, but the geological conditions are less favorable than those of the United States. Adding on to the lack of basic infrastructure such as pipeline network, shale energy development requires much more investment into technological advancement and basic structural frameworks buildup. (Stevens, Moodhe, & Kuuskraa, 2013)

IV. Challenges for China's Shale Gas development

After close to five years of intensive exploration, the shale frenzy in China seemed to be running into some major setbacks. Shell was reported to have withdrawn from its cooperation with PetroChina on the Sichuan project due to slow process and lack of prospect. (Sina Financial News, 2014) In August, the Director of China NEA Wu Xinxiong was also quoted to be adjusted the shale gas production target down from 60-100 billion cubic meters to 30 billion cubic meters by 2020. (Sina Finance, 2014)

Besides the geological and formations differences, factors affecting shale energy development in China also include infrastructure, investment and environmental challenges.

A. Lack of Basic Infrastructures

One of the reasons the US was able to take advantage of shale gas relatively quickly is its relatively easy access to readily available pipeline network. Right now, there are roughly 500 thousand kilometers of oil pipeline that connects to major cities and consumption centers. China, on the other hand, has only about 60 thousand kilometers of oil pipeline network throughout the country.

This means that transporting shale gas could be problematic and costly. (China Youth Daily, 2013)Therefore, investment in building basic infrastructure will a necessary step before China could reasonably hope to take advantage of its large shale gas resources. To look at it from an economic stand point, building these pipelines could bring employment opportunities for provinces and areas of the country that have not grown as fast as the cities on the east coast regions.

Provinces with rich shale gas reserves include Sichuan, Jilin, Liaoning and Xinjiang Autonomous District. These provinces have all struggled with economic growth in recent years. Therefore shale gas development and its related infrastructure and service development could bring economic growth opportunity needed for these regions.

B. Market challenges

The US shale boom was partially driven by high energy price. That condition no longer exists, at least temporarily. World oil price has been free falling since the summer of 2014 to around $40 back in January of 2015, and has been hovering around the $50 mark since. Natural gas price has also fallen to around $3 dollars. (Bloomberg Business, 2015) Low energy price will make profiting from shale energy development more difficult since the cost of unconventional gas development is higher than conventional energy development.

Even though hydraulic fracking is able to make shale gas a commercially viable energy source, the cost of shale gas development is still much higher than conventional gas extraction because it requires more advanced technologies and sophisticated equipment. In addition, shale gas wells have high attenuation rate which requires long-term investment commitment.

Therefore, continued high level of investment is essential to ensure the success of shale development. In the US, shale development has been fueled by individual landowners and small to medium size companies. (Crooks, 2014) There are approximately 6,300 companies in shale gas related operations. That number dropped to around 100 companies that hold the license to conduct natural gas type of extraction in China. (Security Times China, 2012)

Between 2009 and 2010, shale gas development attracted over $22.7 billion in foreign investment into the US, while the estimated annual investment in shale gas extraction exceeded $100 billion. While in China, only RMB10 billion which was less than $3 billion was invested in shale gas development in 2012. (Wang R. , 2013)

In addition, when the large amount of investment into the shale energy market were spread among large number of domestic producers and overseas' investors like the case in the US, the risks on individual companies are greatly reduced and became more bearable.

However, in the case of China, since there are but a couple of hundreds of companies, even if some of these companies are large national energy corporations, the high cost and long investment return cycle could serve as a strong deterrent to shale gas development. That is why even though China's central government is committed to provide policy and fiscal supports to ensure that shale gas development could take off during the 13th and 14th Five-Year Plan periods, the major energy companies don't seem to share that enthusiasm. Concerned over their profit potential in shale gas investment, both PetroChina and Sinopec have been reluctant to invest in the shale energy reserves under their "jurisdictions". In fact, the central government handed out "penalty tickets" to companies who failed to meet the promised investment targets. Sinopec

received a RMB 7.97 million fine. (Yang, 2014) One month later, it was reported that PetroChina had joined hands with SDIC Chong Qing Shale Gas Development & Utilization Company and Sinochem Petroleum Exploration & Production Company to form the Chongqing Shale Gas Exploration & Production Company which will invest RMB 26 billion in shale gas development in Sichuan province.

Therefore, it is fair to say that in China, shale energy development is more a political action to achieve government's energy agenda rather than a market driven activity.

Another obstacle that could potentially hinder private investment enthusiasm is the size and quality of the shale energy fields that are open to the private sector. According to Mr. Han Xiaopin, the Chief Information Officer of the China Energy Information Net, even though MLR had held two rounds of shale gas development bidding. The bidding process attracted some private companies. However, given the current conditions and market structure, it would be difficult for private investment to succeed in shale gas development. First of all, these companies lack the necessary expertise and equipment to handle the drilling process. Secondly, all the gas fields available to private investors are marginalized shale gas fields, outside the fields registered under major national oil companies. The size of each field runs about one thousand square kilometers. This size which will require successful bidders to initially invest RMB30 million yuan annually for three consecutive years. In addition, as we have discussed earlier about the high attenuation rate for shale gas wells, follow-up investments are likely to be high as well. (Security Times China, 2012)For private investors, investment of this scale without a guaranteed prospect of profit would be close to committing suicide.

C. Environmental Challenges

Environmental risks have always been at the center of the shale development debate. In a way, shale energy development has inherited a bad reputation because of its negative environmental consequences such as air pollution, water contamination and increased frequencies of earthquakes.

These risks are being highlighted in the shale development effort, because first of all the damage to the environment have occurred else well in the US and in Europe; secondly because China has been under increasing environmental pressure from damage done to the environment as a result of uncontrolled development effort of the past: forest depletion, air pollution, water contamination that not only have made international headlines, but also are threatening to have many potential negative social impacts for China. (Zhou & Sanderson, 2013)Therefore, assessing the environmental implications of hydraulic fracking on the already fragile Chinese ecosystem is critical as environmental degradation is threatening China's social stability, policymaker can no longer afford to brush aside the potential environmental impacts from shale energy development. Shale gas has been promoted as an alternative energy as a "greener" and safer fossil fuel compare to coal.

New studies however, have revealed that shale gas may carry its own air quality concerns. Studies are saying that shale gas actually emits higher level of greenhouse gas (GHG) during extraction period. According to the report, about "3.6% to 7.9% of the methane from shale-gas production escapes to the atmosphere in venting and leaks over the lifetime of a well. These methane emissions are at least 30% more than and perhaps more than twice as great as those from

conventional gas." (Howarth, Santoro, & Ingraffea, 2010) If these findings are confirmed by the scientific community, shale gas as an environmentally friendly energy would be discredited.

Water is another environmental concern that is often associated with shale energy development. Hydraulic fracking requires huge amount (several millions of gallons) of water per well. (Wang & Krupnick, 2013) China is known for its water shortage. China accounts for 20% of world's population, but only has 7% of its fresh water. (The Economist, 2013) Most of China's shale energy reserves are found in the north-east and the western regions, such as the Qiandam and Zhungeer basins in Xingjiang, Songliao basin in Liaoning province etc. These regions are far from major water sources such as rivers or lakes. Therefore transporting water to these regions to accommodate the water needs for hydraulic drilling, if doable, will increase the cost of extraction drastically. Even though the Sichuan basin shale reserves is in an area where water supplies are relatively more abundant, there is the concern of competing with agricultural and residential water needs because Sichuan Province has one of the largest populations in China, which is over 81 million, plus the population of Chongqing, which is over 27 million. (Sichuan Provincial Government Data, 2014)

Another shale energy related water issue concerns possible contamination. There have been cases in the US where residents, environmental activists have that fracking fluid contaminating ground water, surface spills, and methane gas leaks from well contaminating surface water. (Ratner & Tiemann, 2014) China already has severe water contamination problems, according to China's land ministry that more than half of the groundwater in northern China is too dirty for people to wash in, let alone drink. (The Economist, 2013)

If these potential negative environmental concerns over shale energy are not properly addressed during drilling and extraction, China would not be able to accomplish the goal to reduce negative environmental impacts by replacing coal with shale gas. Given the high cost of developing shale energy, the question would remain whether the government is better off at developing other alternative energy such as solar or even nuclear energy.

The last potential environmental risk associated with shale energy development is its link to the increased earthquakes. After 10 years of intense shale development, there is a growing understanding between shale gas/oil extraction activities and the increased frequencies of seismic activities. As early as 2012, the US Geological Survey has released findings linking the "remarkable" increase of earthquakes since 2001 to oil and gas production. (The Canadian Press, 2012) In May of 2014, the Ohio state regulators drew a "tentative link" between shale gas fracking and the increase of local earthquakes. Studies show the number of earthquakes magnitude 3.0 or higher have increased from the average of 21 during the past three decades to be over 100 between 2010 and 2013. The Seismological Society of America also released research results indicating that wastewater disposal wells that hold the fluid from gas and oil wells may be responsible for inducing earthquakes. Scientists have linked two large earthquakes in 2011 with a magnitude greater than 5.0 to wastewater wells. (Walsh, 2014) Sichuan province has conducted the most shale gas well drilling and extraction activities, it also had a string of strong earthquakes, including the mega quake in 2008. Therefore, it is important to confirm whether hydraulic fracking can in fact cause earthquakes. The findings of these research should be included in the consideration of whether the Chinese government should invest or encourage the investment in the development of shale energy.

Finally, there have been several incidences where the original shale energy reserves have been adjusted to lower amount such as the case in Poland. Sources have released that the US EIA will be cutting the resource estimate for the Monterey shale in California by as much as by 96% of its estimate of technically recoverable resources, to 600 million bbl which can only supply 33 days of the US domestic oil supply. (Jian, 2014)

On the other side, the extra oil supply coming from shale boom in the US has contributed to an oversupply that could soon cause fracking production to shut down; as a matter of fact applications for new US well permits dropped by nearly half last month. US oil production is slowing down because of low oil prices. (Austin, 2014)

Given these potential risks and uncertainties in shale energy development, it is no wander that many in China is advising that the government to take cautious steps in shale energy development. Ms. Liu Yanhua, the former Vice Minister of the China Ministry of Science & Technology spoke during the Eco-system Guiyang International Forum pointed out that China should keep a "cool" head with regard to the rollercoaster style of shale energy development. She affirmed China's intent to continue its shale development exploration, however with the understanding that it will be a long-term strategy.

V. Other Energy Alternative Strategies

Even though China is actively pursuing its own shale energy boom, it is also looking at other energy alternatives to satisfy its growing energy appetite. These alternatives are more strategic

and long-term in nature, and could potentially become rivals for government funding and investment against shale development.

A. Importing Energy from others

China has been building business relations with oil producing countries in several continents: Saudi Arabia, Iran, Iraq & Kuwait in the Middle East; Venezuela, Brazil in South America; Congo, Sudan, Oman & Angola in Africa as well as Kazakhstan and Russia. According to Chen Bo, Chairman of Sinopec Kantons Holdings Limited, China has been trying to diversify its import sources. After successfully shifted away from the original oil providers in Southeast Asia, China has added countries in the Middle East, South America, Africa and Central Asia and Russia to its oil import list to ensure stable and secure energy supplies. This could also be perceived as a way to build strategic alliances. For example, China is focusing more on Brazil and Venezuela in South America, both are BRICS countries. In addition, China and Russia signed an oil agreement worth $270 billion in early 2013 for Russia to supply oil to China over a period of 25 years. The two countries also confirmed their strategic partnership. China's Foreign Minister Wang Yi and Russia's President Putin both described its bilateral relationship as the "best in history" and that "Cooperation with China, including that in international issues, is at unprecedented level(s)". (Shinkman, 2014)

China could use energy as its leverage in ensuring partnership with resource producing countries. As the US become an energy producer and potentially an exporter, while Europe has been struggling to regain its economic stamina, China becomes the one booming economy that can fill the void. Therefore, it is an opportunity China should grasp to expand its international recognition

and influence. In addition, the recent international oil price collapse has made such opportunity become much less costly, and being an actual oil exporter much less appealing.

The potential risk with this option is being dragged into geopolitical unrest such as the long-term conflicts in the Middle East, and the current conflict between Russia and Ukraine.

B. Improving Energy Efficiency and Finding Alternative Energy Sources

The Chinese government has announced to reduce its share of coal used to produce energy to 65% by 2017. EIA projects that China will reduce the share of coal use to 63% by 2020, and further to 55% by 2040. (EIA, 2014) In addition to using oil and gas to make up for the energy consumption gap produced by the reduction of coal use, China has also made bold strides in recent years to fund renewable, non-fossil fuel energy sources such as solar energy. China is the biggest investor in clean-energy investment for two consecutive years since 2012 by a large lead with over $50 billion investment each year. China installed 14 gigawatts of electricity generation capacity from wind farms and 12 gigawatts of solar power generating capacity in 2013. (Magill, 2014) Even though solar energy still faces the challenge of connecting to the main power grid for it to become a formable source for future energy, there seems to be general confidence among the solar developers in China that such connections will become available sooner than later, it is just a matter of time. (Duggan, 2014)

C. Overseas Investment

China is also seeking investment opportunities outside of China. According to IEA data, successful acquisitions allowed China's NOCs to expand their overseas equity shares from 1.1 mb/d in 2009 to 1.36mb/d in the first quarter of 2010. In comparison, China's domestic production in the first half of 2010 was 4.1 mb/d. China now has oil operations in 31 countries, and have equity

production in 20 countries. China's equity shares are mostly located in four countries: Kazakhstan, Sudan, Venezuela and Angola. In addition, China has also invested in shale development projects in the US and oil sands development in Canada. (Jiang & Sinton, 2011). (Jiang & Sinton, 2011)

VI. Recommendations on improving China's Shale Energy Development

First of all, I believe China should implement favorable policies to attract private and foreign investments into its shale energy development portfolio by opening up to the market those fields that are currently under the control of national energy companies. This way, these private and foreign investments could help supplement what is lacking in investment from the national energy companies. On the other hand, for private investors that do not have the expertise in gas and oil extraction, teaming up with professional energy companies will reduce their investment risks.

Another change is to reduce the area of the gas/oil fields that are open to public bidding from one thousand square kilometers to a significantly smaller size. A smaller size field will reduce the initial installment of investment which could also help lower the risks of private investment, increase the profit potential of these private investors. In addition, to encourage cooperation between national oil companies with private and local government investors will also make up for the lack of expertise of local government and private sector.

Secondly, to change the public perception on shale energy. Since shale energy has carried with it negative reputation that it is not safe to the environment because of fracking, as a result the general public in China is against shale energy development. Therefore it is important to make the public aware of the benefits of shale gas to the environment and its potential to reduce the level of air and water contamination associated with energy production in China.

Thirdly, to ensure that shale energy development does not cause further damage to the environment. It is therefore essential to implement stringent environmental regulations and to enforce these measurements to ensure that the environmental risks mentioned above do not become a reality. In addition to use administrative measures, China could also invest in water processing technologies and facilities to recycle water used in hydraulic fracking to reduce or even eliminate the pollutants in the wastewater. (Sider, Gold, & Lefebvre, 2012) The technology could potentially resolve the water issues associated with fracking.

Conclusion

The Chinese government is now determined to invest in shale energy development. The debate on whether China should or should not get involved in shale energy is no longer viable. The question now is how China should approach shale energy development. China should take full advantage of the available technologies and equipment that have been developed and to improve its own shale energy development experience through learning from other countries' valuable experiences and lessons as they have either succeeded or failed in shale energy development.

As many in China are trying to caution the government that China should not rush into shale development, especially not in hope of replicating the US shale revolution without recognizing the vast differences between the various factors associated with shale energy development between the two countries. It is also important for China to understand that the US shale success is built upon decades of trials and failures.

Therefore, China should conduct full assessment of its shale energy reserves and the environmental risks associated with their extraction. It is also vital to develop concrete plans to improve the nation's infrastructure, market mechanism and environmental protection framework to ensure the success of shale energy development. In addition, China should adopt a multifaceted energy policy. Rather than relying entirely on shale energy, it should continue its investment in other clean energy alternatives such as wind, solar and nuclear. As shale energy is only a bridge energy and should be treated as such so China could move away from coal in the short run. However, shale energy is not the ultimate energy source if China wants to reduce its GHG emission and improve its overall environmental conditions.

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