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The Fast Road of Shale Gas Development in China —Reflections on Building a Special Test Areas for National Shale Gas Development

Abstract China's shale gas development has had a good start. It is necessary that the developers take advantage of the opportunity to make further efforts to promote shale gas development in China, in particular by rolling out a comprehensive plan on a national level. The author makes a proposal to establish a special shale gas test area in and adjacent to the Sichuan Basin as the most important way to promote the rapid development of shale gas in China. For this purpose, the author analyzes the current situation and problems of shale gas development in China, addresses the necessity and feasibility of establishing a special test area for shale gas development, and draws up the scope of this shale gas special test area of about 450 thousand square kilometers, covering Sichuan, Chongqing, Guizhou, and part of Yunnan, Hunan, Hubei provinces, and proposes the establishment of a shale gas test area in China. This consists of an overall plan, targets, and contents in 10 aspects, along with organization and implementation modes. The shale gas exploration and development in the shale gas zones is promoted vigorously by introducing special policies and innovating exploration, development and utilization model. While at the same time, the shale gas zones of continental facies in the Ordos Basin and marine-terrigenous facies in South Hubei Basin will be established. The experiences of the reform in the shale gas zones will be the good practice for the reform of petroleum organization system.

Keywords: China, shale gas, exploration and development, reform, special shale gas test area (shale gas zone)

1 Introduction

Shale gas resource investigation and assessment in China started in 2004, while its exploration and development started in 2009. After years of continuous efforts and hard work, the developers have finished shale gas resource assessment in China. The exploration and development technology have made a significant breakthrough. The equipment is mainly domestic made. The oil industry has discovered four shale gas fields of hundred-billion cubic meters resources in place in and adjacent to Sichuan Basin which are being developed on a large scale. China has become a world pioneer in shale gas development besides North America. The developers have a good start and need to take advantage of the opportunity to promote. The development of shale gas is a systematic project involving many aspects. At this stage, the development of shale gas in China cannot be promoted by single departments, provincial and municipal governments or enterprises. It needs to be promoted on a national level and a top-level plan is required. The author believes that the establishment of special shale gas test area (hereinafter referred to as the shale gas zone) in Sichuan Basin and its adjacent areas, where shale gas exploration and development has been successful, is an important way to implement China's shale gas development quickly.

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2 Current situation of shale gas development in China

As a clean and efficient new energy resource, the Chinese government attaches great importance to shale gas development (Development Research Center of the State Council, 2015). Central and local governments have rolled out a series of encouraging policies to promote shale gas development in China. Oil companies invest continually in shale gas. The public also pays a great deal of attention to shale gas development. The shale gas development momentum is excellent in China. It took 30 years from the late 1970 for the United States to carry out research on shale gas exploration and development and to achieve technological breakthrough and development. In China, it took only 5 years from exploration to development.

2.1 Major breakthrough in shale gas exploration and development

By the end of 2011, the Ministry of Land and Resources of China had carried out two projects to investigate and assess shale gas resources in China, mainly on the continent (The Strategy Research Center of Oil and Gas, Ministry of Land and Resources, 2011). Based on this, by the end of 2014, 54 shale gas exploration blocks had been leased within an area of about 170 thousand square kilometers. About 23 billion CNY had been invested, about 780 wells had been drilled, including more than 150 horizontal wells and 400 test wells; more than 21,818 km of 2D and 2134 km^2 of 3D seismic was completed; about 500×10^9 m^3 of shale gas resources in place have been discovered and the measured resources in place is about $10{,}675\times10^9$ m^3; more than 200 km of pipelines have been laid. Shale gas production was 1.3×10^9 m^3 in 2014 and China can expect it to reach or exceed the planned objective of 6.5×10^9 m^3 in 2015.

Sinopec has discovered shale gas resources of about 250×10^9 m^3 there and the measured resources of about $1{,}068\times10^9$ m^3 in Jiaoshiba, Fuling, Chongqing, which is the first to submit proven shale gas reserves that passed through national assessment. The shale gas production reached 1.08×10^9 m^3 in 2014 and it will reach 3.5×10^9 m^3 in 2015. China National Petroleum Corperation (CNPC) has achieved the shale gas exploration and development breakthrough in Changning and Weiyuan of Sichuan Basin and adjacent regions. CNPC has discovered shale gas resources in place more than 200×10^9 m^3 and expected to produce 2.5×10^9 m^3 in 2015. Yanchang Oilfield has found shale gas in continental formations in more than 30 wells in the Ordos Basin; Sinopec has found shale gas in continental formations in the western and northeastern Sichuan Basin; China Geological Survey explored shale gas in continental formations in the Qaidam Basin but without success. The Ministry of Land and Resources has leased 21 shale gas blocks via two rounds of bidding that brought in 17 new investors who invested more than 2.5 billion CNY. Most of the blocks have completed 2D seismic exploration and most of the blocks have implemented drilling. The blocks of Nanchuan, Qianjiang, and Chengkou in Chongqing, Cen'gong in Guizhou, Longshan, Baojing in Hunan, Laifeng in Hubei, Zhongmou in Henan have found shale gas. All the exploration and development of the leased blocks are moving forward steadily.

2.2 Geological understanding and technology developing for shale gas are becoming more and more mature

By taking on board foreign experience and by combining this experience with the geological characteristics of China, the developers have established geological theory for China shale gas forming and accumulations, revealed a shale gas accumulation mechanism in high-mature marine, low-mature continental, and the widely-distributed marine-continental facies, and formed a specific geological theory on shale gas in China. A geological model of shale gas accumulation has been proposed. Shale gas resources assessment methods have been established. All these theories and technologies on shale gas play an important role in guiding shale gas exploration and development in China.

Today, China has mastered the geophysical exploration, well drilling and completing well logging, multi-stage fracturing and mud configuration techniques on shale gas. Horizontal developed well drilling to the depth of 3500 m can be finished skillfully. Indeed, the depth of some pilot horizontal wells is more than 5000 m. The longest horizontal section drilled has reached 2130 m while multi-stage fracturing has reached 22 segments. Some technologies such as horizontal well drilling, multi-stage fracturing in long horizontal segments, well pad drill and completion and joint fracturing can compete with the famous international oilfield service companies. The cost of horizontal well drilling has decreased from 10 million to 5−7 thousand CNY. The period of well drilling and completion has been shortened from 150 to 70 days and has even been achieved in 46 days.

2.3 Technical services and equipment manufacturing have become domestic

The technical service for shale gas development has made great progress. There are hundreds of teams that provide shale gas technical service. The developers learn from foreign experience on advanced technologies and engineering operations, and introduce foreign talent and techniques to China. By cooperating with foreign companies, they try to build up an integrated system of technical service from shale gas survey and resources assessment to exploration and development to pipeline transport and distribution.

Most technical services and equipment manufacturing has been domestic and has become a new source of economic growth. The type-3,000 fracturing trucks and other equipment have been developed and used domestically. Well rigs and fracturing trucks have been exported to the US and other countries represented on the worldwide manufacturing level. The electric cable bridge plugs can be bulk produced domestically and cheaply, and reduce the cost effectively for shale gas development.

2.4 Strong support from government

Since 2009, the Ministry of Land and Resources of China, Development and Reform Commission, the Ministry of Finance, the Ministry of Commerce, the Ministry of Science and Technology, Ministry of Environmental Protection, the National Energy Administration and other central governments, have done a lot of fruitful work on

shale gas. Shale gas resources surveys and assessments have been completed. Shale gas is separated from oil and gas as new kinds of mineral resources. Shale gas blocks are leased by bidding and a development plan is formulated. Policies such as fiscal support and foreign investment encouragement have been published. Guidelines for the development and marketing of the shale gas have been draw up. Some technical standards and regulatory norms have also been drawn up. Several shale gas developing demonstration zones have been established. Scientific and technological research, along with environmental regulations is continuously being promoted. The reforms of shale gas management have promoted the marketing of shale gas exploration and development and have encouraged social investment. The formation of an exploration and development market has facilitated shale gas development in China.

A good investment environment for shale gas exploration and development is forming through the full support of local governments. The provincial and municipal governments of Chongqing, Sichuan, Guizhou, Hunan and other provinces have organized surveys and assessments of shale gas resources, have made development plans to create new sources of economic growth and industry, including investment, financing and equity, equipment manufacturing, infrastructure and transportation. The governments from city and county level have also placed great importance on shale gas exploration and development, mostly as a key to the development of their local economies. Their strong support of road building, land development, water and environmental protection etc. give impetus to the development of shale gas.

Overall, China's shale gas development is currently experiencing very positive momentum. However, there are still problems mainly in the following aspects:

The first is the lack of a top-level comprehensive developing plan. There are five departments in the US that form a leading group for unconventional oil and gas to coordinate the shale gas industry. China has at least 9 departments involved in shale gas exploration, development, and utilization. Although all departments and local governments try to do their best, the policies are dispersed and poorly coordinated as they are concerned with their own interests. It lacks coordination on the national level and a program for the comprehensive development of shale gas. This results in the ambiguity in the ideas for integrated development, objectives and tasks, policies and measures.

The second is that there are relatively few blocks and little investment. At present, China's shale gas development is limited to 3 oil companies in Sichuan and the Ordos Basin. Although the oil companies have increased several shale gas blocks, the investment is still not big enough. Therefore, it is difficult to form a scale of reserves and production. Most areas rich in shale gas have not started work and the relevant information cannot be shared. The investment in bidding blocks and level of work is low. Meanwhile, the social capital of large and medium state-owned energy enterprises and other social capital including private enterprises is waiting for opportunity to enter the shale gas exploration and development community.

The third is that the existing demonstration zones are scattered and overlapped. In order to speed up shale gas exploration and development, the National Energy Administration has approved the establishment of national shale gas demonstration zones in Changning and Weiyuan of Sichuan Province, Fuling in Chongqing, Yan'an in Shaanxi; the Ministry of Land and Resources has approved the establishment of demonstration bases of comprehensive shale gas utilization in Huangping of Guizhou , Yan'an in Shaanxi, Fuling in Chongqing and Northern of Guizhou shale gas comprehensive exploration and development experimental zone. These demonstration zones and bases not only overlapped with each other, but they also only focus on status that lacks the qualification of demonstration zones and related experience. Thus, they have not played an appropriate role in the exploration and development of shale gas.

The fourth is that outstanding problems still exist. The main aspects are as follows: the resources for shale gas need to be profoundly investigated, the "sweet spots" need to be sought out and the resource bases need to be confirmed; the development of core technologies for shale gas needs to be sustained and the independent innovation abilities need to be strengthened. The other aspects include lagging behind of mechanism and system reform, low market participation, low market opening; single development and utilization mode and too much focus on saving but little on high-efficiency utilization. The infrastructure lacks comprehensive planning, and instead is redundant with low-level constructions. Furthermore, regulation on the environment is weak lacking common standards and evaluation of environmental protection.

Policy support is not strong enough. The policies from several departments are poorly coordinated; the interests of the local governments and local residents are not taken into account, resulting in disputes; the financing channels are sluggish and the funds cannot easily enter. Due to a lack of governmental regulations, a unified and effective regulatory system has not yet been formed. In addition, compared to conventional oil and gas, shale gas exploration and development bears high costs, difficulty and low efficiency. These are key problems that restrict shale gas exploration and development in China.

If these problems cannot be solved effectively, China's shale gas cannot develop on a large scale. Therefore, it is necessary to know the current situation and reality, to come with a spirit of reform and hard work, to explore new ways to speed up the development of China's shale gas and to make the shale gas an important part of China's energy portfolio.

3 Necessity and feasibility of establishing special shale gas zones

The Sichuan Basin and its adjacent areas, including Sichuan, Chongqing, Guizhou, and parts of Yunnan, Hunan, Hubei, cover an area of about 450×10^3 km^2. By establishing China's first special shale gas zone and giving it special policies and status, and by creating innovative approaches and mechanisms for its development and utilization, the exploration and development of shale gas can be vigorously promoted in China. Meanwhile, it will also play a pilot role for the future establishment of continental and transitional phase shale gas zones and reform for oil and gas in China.

3.1 Necessity

3.1.1 Establishment of shale gas zones can make a starting point to promote energy revolution

A revolution needs a "base". By relying on the special zone to promote energy supply, by establishing multiple supply systems and by increasing domestic shale gas supply, China can realize the environmental protection to provide support for economic growth. By focusing on shale gas to promote the energy consumption, China can expect to have a clean, efficient, safe and sustainable energy supply. By promoting a technological revolution, following the new trend of world shale gas technological development, industrial upgrading, and innovation of industry and business modes, China can foster shale gas technology and its associated industries to become the new source of growth of China's industrial upgrading. By promoting an energy revolution, going through the fast-tracking of energy development, and by restoring shale gas as a kind of energy commodity, China can build a competitive and orderly energy system.

3.1.2 Establishment of shale gas zone can provide clean energy for new economic model

Under the new model for the Chinese economy, although the growth of energy demand is slowing down, the demand for natural gas will maintain rapid growth in the future. In 2014, China's natural gas consumption was 183×10^9 m^3, accounting for 5.8% of total energy consumption, while it accounted for 23.8% worldwide at the same time. China's urbanization process and the control of air pollution will drive natural gas consumption upward. China's shale gas does not just have a great reserve potential, it can also be put into production. According to conservative estimates, under the existing system, shale gas production can reach 30×10^9 m^3 by 2020 and 80×10^9 m^3 by 2030. If shale gas zones are constructed, shale gas production will reach 100×10^9 m^3 by 2021 and by 2030 it will reach 150×10^9 m^3. Thus, the capacity for clean energy supply will be improved significantly.

3.1.3 Establishment of shale gas zones can help protect national energy security

As international geopolitical politics change all the time, China's energy policy should be based on domestic development. According to the analysis, in 2030 the domestic conventional natural gas consumption will continue to grow. The production will reach 280×10^9 m^3 and the consumption demand will be about 580×10^9 m^3. If shale gas cannot achieve large scale production, China's dependence on foreign natural gas will reach more than 50%. Furthermore, the high prices of foreign natural gas will restrict the expansion of natural gas demand. Therefore, secure natural gas supply becomes problematic. This will affect the strategic orientation in China which considers natural gas as an efficient, safe and sustainable energy.

3.1.4 Establishment of shale gas zones can provide experiences for the reform of the oil and gas industry

China's market-oriented oil and gas reform lags behind which places it in the passive position in the global market. The high cost of the production and utilization of oil and gas and the dropping profit has made state-owned capital gains low. The oil and gas enterprises are big although not exceptional and active; the mining rights for oil and gas is mainly controlled by three major companies, but investment is insufficient for exploration; the oil and gas market system is not in good shape and there exists a monopoly segmentation between the upper, middle, and lower enterprises; the management system of oil and gas is weak, the functions played by multiple branches are dispersed, leading to the poorly-coordinated departmental management; the oil and gas regulatory system is not perfect and incompetent. All these make the reform of the oil and gas industry very imperative. Years ago, shale gas took the lead in exploring the market and has accumulated a certain amount of experience. The establishment of shale gas zones will provide useful experience for the next step reforms on the oil and gas system.

3.1.5 Establishment of shale gas zones can provide economic support to Wumeng and Wuling Mountain area for overcoming poverty

The shale gas zone covers most of the district and county of Wumeng and Wuling Mountain areas which are "Regional Development and Poverty Alleviation Areas" as determined by the State Council. These areas used to be old

revolutionary bases, ethnic minority areas and poor areas, where poor populations are widely dispersed, and minorities congregate. Speeding up the development of shale gas is very important for improving the livelihood of the local people, for constructing the Wumeng Mountain and Wuling Mountain area into an innovation area and important national energy base for poverty alleviation and the coordinated development of the ecology and populations.

3.1.6 Establishment of shale gas zone can provide a driving force for economic growth

When the shale gas zone reaches a production of 100×10^9 m^3, a direct investment of 400−500 billion CNY will be needed. It will drive the development of multiple industries related to shale gas. An investment of more than one trillion CNY will be needed in the whole industry chain that is very important for pushing forward national economic growth.

3.2 Feasibility

3.2.1 Shale gas resources are abundant and exploitable

The results of shale gas resource investigation and evaluation shows that shale gas reserves reach a geologically 65×10^{12} m^3 and recoverable resources are around 10×10^{12} m^3 in the Sichuan Basin and its peripheral areas. This accounts for almost half of the whole country's reserves. The shale gas in Longmaxi formation has achieved an exploration breakthrough, the favorable area is 75×10^3 km^2, the core area is 35×10^3 km^2 and the recoverable resources are about 3×10^{12} m^3. In addition, the favorable area with Niutitang, Xujiahe, Ziliujing formations account for more than 40×10^3 km^2, with recoverable resources of a total of 8×10^{12} m^3. Although the surface condition in these areas is bad compared to the US, the formation pressure coefficient, the organic type and abundance, the brittleness of the shale formation and the compressibility of the shale are excellent. Thus, it is possible to find other "Fuling shale gas areas" from Longmaxi formation in this area.

3.2.2 The exploration and development have obtained breakthroughs that can form scale productivity

In the Sichuan Basin and its surrounding area where shale gas exploration has obtained a breakthrough, the relevant ministries have established a number of state-level shale gas demonstration zones and bases. Sinopec has built China's first shale gas field in Fuling of Chongqing, and CNPC in Changning and Weiyuan in Sichuan province, Zhaotong in Yunnan province has also realized commercialized exploitation of shale gas. In Western Hubei and Hunan, northern Guizhou and other blocks, shale gas of economic exploitation value was also found.

3.2.3 The exploration and development technology have become more mature, and the equipment production has become more domestic

At present, Chinese developers have mastered the technology of geophysical exploration, drilling, completion and fracturing of shale gas in this area. A set of technologies that is suitable for local characteristics has been developed, such as horizontal drilling, matching technology for production test, non-seismic technology for geophysical identification and prediction, horizontal long-section fracturing, water-based drilling fluid etc. Independent R&D of mobile drilling rigs, type-3000 fracturing truck, bridge plug and others have all reached international level.

3.2.4 Water supply is guaranteed, the environment is basically under control

The area is located in the upper part of the Yangtze River, the rich water resources provides water required for large-scale development of shale gas. According to estimations, 100×10^9 m^3 of gas needs to consume about 0.4×10^9 m^3 of water, which accounts for 1.6%−1.8% of local water consumption. At present, the United States has more than 100 thousand shale gas wells without any environmental accidents that impact on the community. As long as the operating rules are strict enough, accidents can be completely prevented and no groundwater and surface pollution will happen.

3.2.5 Local governments have an active attitude, I/O benefit is excellent

Sichuan province has listed shale gas development as the first of five major high growth industries; Chongqing City has made plans for shale gas development and identified shale gas a new source of economic; Guizhou, Hunan, Hubei, Yunnan and other provinces have taken a number of measures to increase their efforts to support shale gas exploration and development. Local governments have realized the importance of shale gas in the local economic growth from all aspects of increasing the supply of energy, increasing output value, the optimization, and upgrading of equipment manufacturing industry, increasing raw materials and fuel for heavy chemical industries, increasing alternative fuels and replacing oil with gas, reducing greenhouse gas emissions, increasing profits and taxes, etc.

4 Conceptions of shale gas zones construction

4.1 Overall plan

Our government has proposed the energy revolution

strategy, and prepared to reform the organization system of petroleum. In the area of shale gas, reform needed to be implemented to increase gas production through marketization as well as strengthening of the regulation is needed. Shale gas zones in and adjacent to the Sichuan basin for marine facies shale gas, in the Ordos basin for continental facies shale gas, in the South Huabei basin for marine-terrigenous facies shale gas should be set up by taking example from the Shenzhen special zone, Shanghai Free Trade Zone and to support overcoming poverty in the Wumengshan and Wuling Mountain regions. In the shale gas zones, the most important thing is to establish a fair competition market environment, so that the market mechanisms get the decisive factor in resources disposition. So a test platform needs to be set up. Based on the platform, developers can explore and try to integrate resources, to concentrate advantages, to synthesis experiments, to establish an efficient system and mechanism for shale gas development, to balance relations of benefit of central and local governments as well as oil companies and investors, so as to push forward shale gas exploration and production in an orderly, healthy and rapid manner.

4.2 Targets of setup the shale gas zones

4.2.1 General goal

The shale gas developing management system and mechanism will be setup in the shale gas zones from 2016 to 2020, and will be implemented effectively. The shale gas zones will be developed as an integrated demonstration zones including tectonic development, equipment manufacturing, infrastructure construction and environmental protection, policy and management system construction. The shale gas zones will be the main production region of shale gas. At the same time, they also will be the main developing regions of tectonic, equipment, gas use, as well as the reform of the petroleum organization system.

4.2.2 Objectives of the shale gas zones

(1) There are about 3×10^{12} m^3 shale gas proven reserves, 10×10^{12} m^3 proven reserves in place will be found in 2020. Shale gas production will be 1000×10^{8} m^3 in the end of 2020, nearly 1/3 of the natural gas production in China in 2020.

(2) The local companies of China can finish seismic exploration, horizontal well drilling and completing, fracturing, and mud configuration independently. The majority of equipment and materials are domestically made, well rig and fracturing equipment are advancing internationally. The state innovation system of science and technology in shale gas is developed.

(3) New systems and mechanisms for shale gas development and usage is established.

(4) Policies in Mining Rights transfer, investment and financial support, tax and profits allocation, land and water use, environment and regulation, public services and information sharing are formulated.

(5) A series of good practices that can be copied and popularized is taking shape, and experiences for petroleum system reforms are gathered.

4.3 Contents of the practice

4.3.1 System and mechanism of innovation

Collaborative development mechanisms in shale gas zones need to be fully set up. Development plans for the shale gas zones need to be designed, coordinated and implemented to co-ordinate shale gas development and social management in the shale gas zones. Shale gas data platforms need to be established for shale gas information sharing. Several main shale gas developing regions will take shape in south west China including Yudongbei, Yudong-Exi, Chuannan and Chuandong, Qianbei and Qianxi, Diandong, Xiangxi, through shale gas exploration and production, regional connection of infrastructure and regional ecological environment system co-construction. Shale gas development management functions need to be transformed regularly to reduce the approval items, standardize the approval process, and set up an institutional environment that all sections of ownerships can take part in and participate equally.

4.3.2 Reconfiguration blocks, open the access right

There are about 50 oil and gas exploration rights in the Sichuan basin, the acreage of the exploration rights is about 24×10^{4} km^2; there are about 117 oil and gas production rights; the oil and gas developing acreage is about 13,375 km^2. There are 20 exploration rights adjacent Sichuan Basin with of acreage is 10×10^{4} km^2. There are no oil and gas or shale gas favorable blocks left in and adjacent Sichuan Basin. This is the core issue for the development of shale gas in and adjacent to Sichuan Basin which must be solved. The author suggests that the ownership of the blocks will not be changed if the blocks are in production, under development, or have proven reserves. If the blocks do not fall into one of the aforementioned situations, and has shale gas recoverable resources, the oil company who owns the oil and gas exploration rights will also have the priority to explore and develop the shale gas. The oil company must invest enough workload each year in the block, otherwise, the government will terminate its exploration rights according to the law. The Ministry of Land and Resources will re-divided exploratory regions

(blocks) and transfer the exploration rights by way of public bidding.

4.3.3 Finding shale gas sweet point through geological survey

The shale gas survey and shale gas resources assessment that has been finished in China, Guizhou, Chongqing, Sichuan, etc. is the basis for the further shale gas survey. The overall plan for shale gas survey should be changed. To find and assess shale gas sweet point, works should be emphasized as well as shale accumulating mechanism and developing factors assessment. Basic theory research on shale gas formation and accumulation mechanisms need to be implemented. The shale gas survey work should involve all parts of the central and local governments, the research institutes and the universities. And the governments should invest in the shale gas survey.

4.3.4 Key technologies development jointly

Shale gas technologies need to be optimized and developed based on the practice in Fuling, Nanchuan of SINOPEC, in Changning, Weiyuan, Zhaotong of CNPC, including pad drilling, fracturing, water-based drilling mud etc. The key technologies must be researched and developed jointly such as geo-steering, measurements while drilling (MWD), nano-scale pore structure analysis etc., forming technology system which have the proprietary intellectual property rights. The technology systems developed would be used widely in the shale gas zones.

4.3.5 Unified planning and construction of infrastructures

New management models need to be setup to separate the pipeline network from gas transformation allowing all the gas products to be accessed fairly. The pipeline network will be multi-invested and multi-operated. A united operating and marketing system needs be set up to allow all sections of ownerships to supply natural gas. Shale gas, CBM will also be allowed to be transported by pipeline network. All sections of ownerships can invest and operate the pipeline network, LNG receive stations and gas storage as independent legal personality. Water supply and waste water recycle system and roadway in the concentrated shale gas developing region should be built to ensure the shale gas development and protect of the environment.

4.3.6 Optimizing of the pattern of gas usage

Local shale gas usage plans will be launch out to encourage gas use locally, economically and effectively. The gas industry will be developed through various usage of shale gas. Natural gas use for domestic, commercial and public service facility is given a higher priority. Then the plan should focus on the usage at gas-stations, fuel, chemical engineering, and distributed energy facilities such as co-generation power stations. Market receivable pricing mechanisms will be established through reform. The price lever will be used to control gas supply and consumption.

4.3.7 Establishment of environment regulation standards

Environmental standards equivalent to or slightly less restrictive than those of the USA need to be implemented using the USA experience on environment regulation as an example while also incorporating Chinese characteristics. This will encourage shale gas development while simultaneously protecting the environment. An environmental protection standard system needs to be established on block optimism, well set choosing, drilling and fracturing, waste water treatment and drainage, solid waste treatment and usage, methane recovery and utilization based on the environmental protection laws of China and the ecological functional zone division, nature reserves and priority zones. The environmental assessment technical guidelines for shale gas exploration and development needs to be carried out based on existing technical capabilities.

4.3.8 Particular policy support

The particular policies need to be rolled out to support the implementation of the planning of shale gas zones. The central governments should increase financial investment in shale gas, public welfare projects and give financial support to the building of infrastructure through subsidized loans. Roll out taxation preference policy, such as corporate income tax exemptions for the first to third years and levied by half the forth to sixth years and/or tariff exemption on the import of equipment and technologies and accessories in accordance with the contract for the equipment. All the income from resource tax comes under local government. The investment of central governments should place emphasis on infrastructure and the environment as well as on developing the industry of shale gas. Social investment should be encouraged in the shale gas zones, and the projects that have been deemed eligible can finance from international organizations and foreign governments. A shale gas industry development policy should be set up to support the development of shale gas exploration and production, the building of a pipeline network, equipment manufacturing and particularly the chemical industry through investment management, land use, and credits. The interests must be balanced between central and local governments as well as oil companies. The income distribution will tilt toward local governments. Rural

Collective Construction Land (MRCCL) needs to be invigorated through leasing or sharing.

4.3.9 New channels and forms of financial support

Innovative financial products and service should be encouraged in the shale gas zones. The financial institutions would be encouraged to enlarge the subsidized loan scale to satisfy the need for capital on shale gas exploration and development in the shale gas zones. The financial channels need to be broadened to include such options as listing financing, the issuing of short-term financing bills, mid-term note and corporate bonds. The Silk Road Fund is encouraged to invest in the shale gas zones. New funds are encouraged in the shale gas zones.

4.3.10 Building of new regulation system

Regulation ideas and models need to be innovated. Duties, divisions of work and the objectives of regulation departments must be clarified. Regulation content and regulation methods must also be clarified. Regulation work procedures must be set up. Regulatory procedures, methods and work practices must be set up. The regulating team needs be organized and specialized through technical and management training. The regulation data platform and public reporting mechanism must be set up, new mechanisms and models of regulation and management must be set up to ensure shale gas exploration and development.

5 Organization and implementation

5.1 Establishment of shale gas zones organizational coordination mechanisms

The State Council should organize the National Development and Reform Commission, the Ministry of Land and Resources, the National Energy Administration, the Ministry of Finance, the Ministry of Environmental Protection, the Ministry of Science and Technology, the State-owned Assets Supervision and Administration Commission, the Bank of China, the governments of Sichuan, Chongqing, Guizhou, Yunnan, Hunan, Hubei provinces, and representative companies such as CNPC, SINOPEC to set up a coordination mechanism. The function of the coordination mechanism is to develop the shale gas planning and work program to resolve vital issues and to coordinate relationships. The governments of state council should enlarge its support in the aspects of policies, finance and projects. The National Development and Reform Commission, the Ministry of Land and Resources, the National Energy Administration, the Ministry of Finance, the Ministry of Environmental Protection, the Ministry of Science and Technology are the contact departments. Each government agency above can contact one province or one municipality to solve the problem and promote the building of shale gas zones.

5.2 Establishment of shale gas zones management committee

The Committee is the working body of a Coordination Mechanism set up by the State Council. The committee can be located in one of the cities in the shale gas zones in the south west such as Chongqing or Chengdu. The Committee can co-ordinate the building of shale gas zones taking Shanghai Free Trade Zone, Liangjiang New District of Chongqing, Gui'an New District of Guizhou as examples. The Committee implements the important decisions made by the Coordination Mechanism and prepares the rollout of shale gas zones development plan, coordinates shale gas development work of attached regions in the shale gas zones and is responsible for the management and operation as well as daily work in the shale gas zones.

5.3 Setting up of shale gas development regions based on the province level administrative divisions

Shale gas development regions based on the province level administrative division need to be set up to strengthen the role of local governments. Each provincial government takes charge of the shale gas exploration and development of the province under the direction of the Coordination Mechanism of State Council through the strengthening of leadership, the optimization of working mechanisms and the completion of duties and responsibilities. Each provincial government organizes the drafting of a shale gas development plan to a clear guiding ideology, fundamental principles, strategic positioning and developmental targets that will prioritize shale gas. The cooperation at province level must be enhanced to ensure resource sharing and exchange and to achieve complementary and comparative advantage.

The development of shale gas in China has had a good start through the efforts of government, universities and enterprises over a short period of seven years. Cooperation, which requires great effort, is a very important factor in the development of shale gas in China. It is necessary to be clear that there are many kinds of barriers to overcome in developing shale gas in China. There are many new problems that need to be solved. And it is reasonable to believe that shale gas development in China will be done in a sound, orderly and scientific manner, and will achieve a leap forward in development based on the shale gas zones.

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