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UNCONVENTIONAL NATURAL GAS DEVELOPMENT AS A REASONABLE
ALTERNATIVE FOR ENERGY STRATEGY AND POLICY: IMPLICATIONS FOR
THE PEOPLE'S REPUBLIC OF CHINA

A Thesis

Submitted to McAnulty College and
Graduate School of Liberal Arts

Duquesne University

In partial fulfillment of the requirements for
the degree of Master of Arts

By

Ekaterina Pushkareva

May 2010

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Ekaterina Pushkareva

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By

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ABSTRACT

UNCONVENTIONAL NATURAL GAS DEVELOPMENT AS A REASONABLE ALTERNATIVE FOR ENERGY STRATEGY AND POLICY: IMPLICATIONS FOR THE PEOPLE'S REPUBLIC OF CHINA

By

Ekaterina Pushkareva

May 2010

Thesis supervised by Kent Moors

This research argues that development of unconventional natural gas is a reasonable alternative for energy future of the People's Republic of China. Four major factors, including economic growth, social development, environmental constraints, and technological breakthroughs and foreign energy expertise, are singled out as the key determinants that encourage development of unconventional natural gas in China and improvement of its energy strategy and policy.

To meet growing demand for energy resources, satisfy socio-economic needs and address environmental issues in a sound manner is a current ongoing challenge for the Chinese energy sector. Unconventional natural gas is proposed as one of the approaches in order to resolve this pressing problem. The potential contributions of unconventional natural gas are analyzed. As explored in the paper, it may provide abundant, affordable,

and cleaner-burning energy to the Chinese, offering stable energy prices, security, and solutions to the climate challenge. The research concludes with policy recommendations in order to promote development of unconventional gas within the energy sector in China.

China provides a useful and illustrative case study because the challenges experienced by this country are the challenges to be addressed by the whole global community which urgently needs to establish wise relationships between energy, economy, and the environment.

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TABLE OF CONTENTS

	Page
Abstract.....	iv
Acknowledgement	vi
List of Abbreviations	ix
Introduction.....	1
Statement of the Problem.....	1
Current Status of the Topic	4
Basic Definitions and Conceptual Framework	4
Hypothesis.....	7
Overview of Methodology	7
Structure.....	9
Chapter 1: Unconventional Natural Gas as an Energy Source	11
1.1 Introduction to Unconventional Natural Gas.....	11
1.2 Types of Unconventional Natural Gas.....	13
1.3 Global Energy Trends and Development of Unconventional Gas.....	16
Chapter 2: Major Drivers of Development of Unconventional Natural Gas in China	22
2.1 Natural Gas Market in China	22
2.2 Analysis of Major Drivers of Unconventional Natural Gas in China.....	30
2.2.1 Economic Growth	30
2.2.2 Social Development	34
2.2.3 Environmental Constraints.....	38
2.2.4 Technological Breakthroughs and Expertise	42

Chapter 3: Policy Implications for China’s Energy Sector.....	49
3.1 Energy Policy and Policy-making in China: New Opportunities and Challenges.....	49
3.2 Recommendations for Promoting Development of Unconventional Natural Gas in China.....	53
Conclusion	56
Bibliography	61

LIST OF ABBREVIATIONS

CBM	Coalbed Methane
EIA	U.S. Energy Information Administration
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
IEA	International Energy Agency
LNG	Liquefied Natural Gas
MHF	Massive Hydraulic Fracturing
NBS	National Bureau of Statistics of China
NDRC	National Development and Reform Commission
NEC	National Energy Commission of China
NEA	National Energy Administration of China
CNPC	National Petroleum Corporation
OECD	Organization for Economic Cooperation and Development
OPEC	Organization of Petroleum Exporting Countries

INTRODUCTION

Statement of the Problem

The beginning of the twenty-first century is characterized by swift and enormous changes in the global energy market. The People's Republic of China, as one of the fastest growing major economic powers and trading states in the world as well as a primary destination for foreign direct investment, is projected to be an important player. Its impact on the international energy market is set to grow considerably. First of all, this is due to the country's sheer scale. China is the world's second largest consumer and producer of primary energy.¹ It is ranked first in the production and consumption of coal, second in the generation and consumption of electricity, second in the consumption of oil and in the capacity of its oil refineries, and fourth in the production of crude oil.² Secondly, China's energy sector is developing quickly, which in turn makes an impact on the performance of the sector as well as its interactions with the rest of the domestic and global economies (Andrews-Speed, 2004: 3).

Despite the current economic slowdown, China's energy needs and the world's as a whole are expected to increase. According to the projections in *International Energy Outlook 2009* made by the United States Energy Information Administration (EIA), total world energy consumption will increase by 44% over the period from 2006 to 2030.³ China and India's energy consumption as a share of the total world energy use has

¹*China Energy Profile*. (2010). US Energy Information Administration. Retrieved from: http://tonto.eia.doe.gov/country/country_energy_data.cfm?fips=CH

² Ibid.

³ *International Energy Outlook*. (2009). Washington, DC: Energy Information Administration, U.S. Department of Energy. P. 7. Retrieved from: <http://www.eia.doe.gov/oiaf/ieo/index.html>

accounted for about 19% in 2006, and will continue to grow, to 28% in 2030.⁴

Conventional fossil fuels, primarily liquid fuels and coal, because of their accessibility and brisk demand, will continue to remain the largest sources of energy in China.

Being such a large producer and consumer of energy, China is likely to resolve an energy dilemma where economic and social sustainability, energy supply security and the environment contravene one another. On the one hand, China's growing energy sector derives from the nation's rapidly developing economy. Growth potential is influenced by population growth, labor force participation rates, capital accumulation, and productivity improvements. In addition, progress in building human and physical capital infrastructures, establishing credible regulatory mechanisms to govern markets, and ensuring political stability play relatively important roles in addressing the issue of energy.⁵ On the other hand, China is certainly the largest contributor to global and regional atmospheric pollution: it is at the top of the list of all countries for energy-related carbon dioxide emissions.⁶ Under such conditions, it is evident that China has a particular challenge of finding secure and sustainable sources of energy to support its socioeconomic growth and stability.

This pressing challenge has provided the Chinese government with the impetus to map out a different strategy for the energy sector – domestic development and production of unconventional natural gas. Among other possible energy resources, unconventional natural gas, including shale gas, coalbed methane and tight gas, is one of the reasonable alternatives that can both to satisfy the domestic demand for energy and to have a

⁴ Ibid., P. 8.

⁵ *International Energy Outlook*. (2009). Washington, DC: Energy Information Administration, U.S. Department of Energy. P. 14. Retrieved from: <http://www.eia.doe.gov/oiaf/ieo/index.html>

⁶ *China Energy Profile*. (2010). US Energy Information Administration. Retrieved from: http://tonto.eia.doe.gov/country/country_energy_data.cfm?fips=CH

positive effect on the global environment. Development of unconventional natural gas has become available to China due to recently introduced technology, especially horizontal-well drilling combined with hydraulic fracturing, and energy expertise offered by American and Canadian specialists. Such a transformation within the national energy policy, together with the liberalization of the energy sector, enables China to play a more active role in the political and economic arena both regionally in Asia and worldwide.

The **purpose** of the present paper is to explore the potential contribution of unconventional natural gas to China's energy future in light of both new opportunities and threats resulting from the development of unconventional natural gas. I aim to address the following **research questions**:

- What are the major factors that determine development of unconventional natural gas in China?
- How do China's current policies encourage or hinder the domestic development of unconventional natural gas?

The **argument** of this paper is that development of unconventional natural gas is a reasonable alternative for energy future of the People's Republic of China. Both internal factors, including economic growth, social development and environmental constraints, and external factors, such as technological breakthroughs and energy expertise, determine the development of unconventional natural gas in China and serve as the key drivers for its improved energy policy.

The **relevance** of this research is apparent. It highlights the energy dilemma the People's Republic of China faces today. The issues of economic and social sustainability, energy supply security, and climate change come into conflict. It is actually the dilemma

for the whole global community, which urgently requires establishing wise relationships between energy, economy, and the environment. In this respect, China provides a useful and illustrative case study because the challenge experienced by this country is also the global challenge.

Current status of the topic

Until very recently, unconventional natural gas has largely been overlooked and underestimated in most of the world. There has been no keen academic and research interest to investigate this issue either. As there has been no comprehensive and substantial research conducted on development of unconventional natural gas in the Peoples' Republic of China and its major energy policy implications, the present research paper, to some extent, begins this discussion. Investigation of this issue seems relevant and well-timed. It will open horizons for other studies and will provide a basis for new research initiatives.

Basic Definitions and Conceptual Framework

The **independent variables** are internal factors (economic growth, social development, and environmental constraints in China,) and external factors (technological breakthroughs and experience of the leading expert nations, including USA and Canada).

- *Internal factors*
 - *Economic growth* is one of the most important factors to be considered in projecting changes in China's energy strategy. Strong economic growth

depends heavily upon energy sources, both domestic and foreign. It can be measured as the rate of change of gross domestic product (GDP), through observations of inflation, unemployment, balance of payments (trade in goods, trade in services, income flows from investments, financial flows, such as shares and loans, and foreign aid), exchange rate (demand and supply of a currency on foreign exchange markets; demand is determined by the purchase of exports, supply by the purchase of imports). In addition, observations of energy consumption, supply and demand can be examined.

- *Social development* is commonly associated with the failure of society to provide certain individuals and groups with those rights and benefits normally available to its members. It can be manifested through improvements in a variety of indicators such as social investment (infrastructure, housing, homelessness, water/sewerage, cost, quality and accessibility to health care and education services), taxation (tax burden, incentives), and quality of life (crime, material wealth, poverty).
- *Environmental constraints* are another essential factor that may result in the domestic development of unconventional natural gas and major energy policy alterations. Without energy efficiency improvements, growing internal energy consumption threatens China's growth and the world energy market. Environmental degradation can be measured by the analysis of the rates of pollution (land, air, sea, and noise), waste (disposal and management), and land use (planning and building regulations,

availability of areas of outstanding beauty, national parks, wildlife, ecology and sites of special scientific interest). Greenhouse gas emissions rates can be considered, including data on carbon dioxide emissions by sectors, and emissions by different fossil fuels.

- *External factors*
 - *Technological breakthroughs and energy expertise* of the leading nations, including USA and Canada, is the fourth determinant. Developed in the United States, the technology for unconventional natural gas exploration, production and processing is rapidly becoming available worldwide through the efforts of major service companies. Technological breakthroughs can be viewed in terms of evaluation of distribution of worldwide unconventional natural gas reservoirs and existing unconventional gas projects.

The list of internal and external factors that likely result in the domestic development of unconventional natural gas and revision of current energy policy is not limited to those mentioned above. Price, access to energy reserves, geopolitics and some other factors could also be taken into account. However, economic growth, social development, environmental degradation and technological breakthroughs are hypothesized to be the key driving forces in the case of China.

The **dependent variables** are effective and adaptive changes in energy strategy and policy associated with the domestic development of unconventional natural gas.

- *Unconventional natural gas* refers to natural gas generated in reservoirs at very low flow rates because of low permeability, geologic complexity, or high fluid

viscosity (Holditch, 2008: 319). This is “natural gas that cannot be produced at economic flow rates nor in economic volumes of natural gas unless the well is stimulated by a large hydraulic fracture treatment, a horizontal wellbore, or by using multilateral wellbores or some other technique to expose more of the reservoir to the wellbore” (Unconventional Gas, 2007: 5). For the present research, development of shale gas, coalbed methane and tight gas are the most common types of unconventional natural gas found in China.

- *Changes in energy strategy and policy* imply effective solutions to the pressing energy issues China faces today. Development of unconventional natural gas, such as shale, coalbed methane and tight gas, is proposed as a reasonable alternative for China’s energy future.

Hypothesis

In this research paper, **I hypothesize that** both internal factors, including economic growth, social development, and environmental constraints, and external factors, such as technological breakthroughs and foreign energy expertise, are the key determinants encouraging the domestic development of unconventional natural gas and significant changes in energy strategy and policy in the People’s Republic of China.

Overview of Methodology

The research is going to follow a non-experimental design. Although a significant volume of information and data has been accumulated over the past twenty years regarding unconventional natural gas, relatively little research has been done on this

subject in terms of policy implications, and even less information is available on the specific case of the Peoples' Republic of China. Therefore, the present project has an explanatory purpose, and aims to identify and assess relevant material from the accumulated record, gain a deeper understanding of the examined issue and relate it to different factors. In other words, it seeks to clarify major determinants encouraging domestic development of unconventional natural gas and significant changes in energy strategy and policy in China.

In order to investigate the stated issue, the following research methods will be employed: descriptive, qualitative, comparative and case study approaches. With the help of the descriptive method, it will be possible to uncover variables associated with the explored phenomenon and define alternatives for addressing the research objective.

Literature review collects data and characteristics about the development of unconventional natural gas in China. Finally, the descriptive method will help to answer two main research questions: *What* are the major factors that determine unconventional natural gas development in China? And *how* do the current policies encourage or hinder the domestic development of unconventional natural gas?

The qualitative method is helpful for exploratory purpose only, in order to analyze available written documents and materials. As one of the qualitative measurements, I will take a case study approach. By nature, a case study lends itself to both generating and testing hypotheses. It also assumes an in-depth study of a single individual, group, incident, or community. In this particular research, I will examine development of unconventional natural gas in China through a systemic secondary data collection, analysis of the information and report of the results. Ultimately, I aim:

1. To produce a detailed understanding of the nature of the independent variables;
2. To understand the characteristics of the dependent variables;
3. To make recommendations on how the issues could be addressed by improved or new policy and positive actions.

I will also use the comparative method to investigate similarities and differences across other countries, including development and production of unconventional natural gas in the United States and Canada. Related case studies will be mainly adopted from North America because they demonstrate the best-practice-examples. I hope to estimate contribution of unconventional natural gas to the energy future of both countries, and afterwards to fit its potential to the Chinese environment.

The present research relies primarily on secondary sources of data, including available literature, official records acquired from the websites of selected energy agencies and other governmental and nongovernmental organizations, scholarly journal articles, as well as case studies. The International Energy Agency (IEA), the U.S. Energy Information Administration (EIA), the United Nations (UN), the World Bank, the Organization for Economic Cooperation and Development (OECD), and the Chinese National Energy Administration (NEA) websites have proved to be good sources for qualitative and quantitative data on China. I have adopted information on policies and regulations from the Chinese National Energy Administration website, the Chinese national archives, ratifications of international and national laws, and other legal texts.

Structure

Following this introduction, the paper consists of three chapters and a conclusion. Chapter one examines global energy trends and development and production of unconventional natural gas worldwide and in China, in particular, and discusses unconventional natural gas technologies. Chapter two provides an analysis of the key drivers of unconventional natural gas development in China. Chapter three introduces energy policy implications for China. The conclusion summarizes major findings and limitations, and provides recommendations for further research.

CHAPTER 1: UNCONVENTIONAL NATURAL GAS AS AN ENERGY SOURCE

This chapter provides an overview of unconventional natural gas. It discusses the importance and attractiveness of unconventional natural gas as an energy source, and its viability as a fuel in the foreseeable future. As such, the present chapter aims to introduce the notion of unconventional natural gas; explore essential information on types of unconventional natural gas, including recent technological breakthroughs and expertise available worldwide; discuss global energy trends; and analyze potential of unconventional natural gas for global energy future. These considerations provide a solid basis for further analysis and detailed comprehension of the research problem of development of unconventional natural gas in China.

1.1 Introduction to Unconventional Natural Gas

Modern scientific literature defines unconventional resources as those opposed to conventional resources. Conventional resources are reservoirs that can be produced at economic flow rates and that will produce economic volumes of oil and gas without large stimulation treatments or any special recovery process. A conventional reservoir is basically a high- to medium-permeability reservoir in which one can drill a vertical well, perforate the pay interval, and then produce the well at commercial flow rates and recover economic volumes of oil and gas. Opposed to conventional resources, unconventional reservoirs are those which cannot be produced at economic flow rates or which do not produce economic volumes of oil and gas without assistance from massive stimulation treatments or special recovery processes and technologies.

The conception of conventional and unconventional resources has been explained in the principle of the resource triangle brought forward by Masters and Gray.⁷ The figure below vividly illustrates the resource triangle:



As interpreted by one of the recognized contemporary energy industry leaders Stephen Holditch, the principle of the resource triangle applies to both conventional and unconventional resources. Unlike conventional reservoirs, which are small in volume and easy to develop, unconventional reservoirs are large in volume but difficult to develop. The character and distribution of unconventional resources worldwide is not yet well understood, even though they are very large. Increasing price and improved technology are considered the key to the economic development and production of unconventional resources.

Unconventional natural gas resources are characterized by Holditch as reservoirs that produce natural gas at very low flow rates because of low permeability, geologic complexity, or high fluid viscosity.⁸ He further defines unconventional natural gas as natural gas that cannot be produced at economic flow rates or in economic volumes

⁷ Holditch, S. A. (2008). Factors that will influence oil and gas supply and demand in the 21st century. *MRS Bulletin*, 33, April. P. 319. Retrieved from: http://www.mrs.org/s_mrs/bin.asp?CID=12527&DID=206720

⁸ Ibid.

unless the well is stimulated by a large hydraulic fracture treatment, a horizontal wellbore, multilateral wellbores, or some other technique such as steam injection.⁹

There is a pronounced tendency to believe that there is no typical unconventional natural gas reservoir. Energy experts agree with the argument that unconventional natural gas reservoirs vary greatly: “they can be deep or shallow, high pressure or low pressure, high temperature or low temperature, blanket or lenticular, homogenous or naturally fractured, and containing a single layer or multiple layers” (Unconventional Gas, 2007: 5). Essentially, however, there are four main categories of unconventional gas. These are tight gas, gas-containing shales, coalbed methane, and gas hydrates.

1.2 Types of Unconventional Natural Gas

As mentioned above, unconventional natural gas deposits are diverse, and therefore, each resource has its own unique characteristics. The following summarizes the unique characteristics of three types of unconventional natural gas relevant to the discussion about China.

Tight Gas Sands

Tight gas is defined as gas held in a very tight formation underground, trapped in unusually impermeable, hard rock, or in a sandstone or limestone formation that is

⁹ Holditch, S. A. (2008). Factors that will influence oil and gas supply and demand in the 21st century. *MRS Bulletin*, 33, April. P. 319. Retrieved from: http://www.mrs.org/s_mrs/bin.asp?CID=12527&DID=206720

unusually impermeable and non-porous.¹⁰ Low permeability is the defining feature of tight gas sands.¹¹

These types of reservoirs cannot be developed by means of conventional methodology. Several techniques, such as fracturing and acidizing, are needed for natural gas to be extracted from tight formations and make its production economically viable. Fracturing increases the area of rock surface in direct communication with the well bore, thereby creating a pressure sink in which gas in low permeability sand may move.¹² Presently, unconventional natural gas production engineering considers massive hydraulic fracturing (MHF) as the most acceptable technique for fracturing.¹³ This technique assumes injecting fracturing fluid at very high pressures for many hours. The fluid is followed by a propping agent such as sand or glass beads. When pumping stops, the fluids are forced back into the well bore, leaving the propping agent behind to hold the fracture apart, thus providing communication over a large area to the well bore.

Coalbed Methane

Natural gas, primarily methane, is also stored in coal deposits. These coal deposits are commonly found as seams that run underground, and are mined by digging into the seam and removing the coal. Many coal seams also contain natural gas, either within the seam itself or the surrounding rock. Because of its large internal surface area, coal stores six to seven times more gas than the equivalent rock volume of a conventional gas

¹⁰ *Unconventional Natural Gas Resources*. Retrieved from:

http://www.naturalgas.org/overview/unconvent_ng_resource.asp

¹¹ Holditch, S. (2006). Tight gas sands. *SPE Distinguished Author Series*, JPT, June. PP. 86 – 94.

¹² Kelkar, M. (2008). *Natural gas production engineering*. Tulsa, USA: Penn Well Corporation. P. 16.

¹³ Ibid.

reservoir at a similar pressure.¹⁴ Gas content generally increases with coal rank, with depth of burial of the coalbed, and with reservoir pressure.¹⁵ Coalbed methane is trapped underground, and is generally not released into the atmosphere until mining activities unleash it.

Historically, coalbed methane has been considered a nuisance in the coal mining industry. Once a mine is built, and coal is extracted, the methane contained in the seam usually leaks out into the coal mine itself. This poses a safety threat, as too high a concentration of methane in the well creates dangerous conditions for coal miners. Therefore, production of natural gas from coal seams was first considered because of safety reasons.

Today, coalbed methane reservoirs have been given more attention as a possibility for unconventional natural gas development.¹⁶ Extraction of coalbed methane results in certain production and environmental challenges. Generally, in order to produce the coal seam reservoir, it is necessary to reduce the pressure for gas to begin to be released, diffuse through the coal and then flow to the well bore. However, in many cases coal seams contain large quantities of water and little gas which in place is mostly adsorbed. For this reason, de-watering of the coal is initially needed. This implies removing the water from the coal seams system in order to deplete the pressure sufficiently so gas can be released and begin flowing. This water, which is commonly saline, must be disposed of in an environmentally accepted manner. Most frequently, water is reinjected into subsurface rock formations; sometimes, it is allowed to be put into evaporation ponds.

¹⁴ Kelkar, M. (2008). *Natural gas production engineering*. Tulsa, USA: Penn Well Corporation. P. 17.

¹⁵ Xiong, H., Holditch, S. (2006). *Will the blossom of unconventional natural gas development in North America be repeated in China?* Society of Petroleum Engineers (SPE). P. 3.

¹⁶ Kelkar, M. (2008). *Natural gas production engineering*. Tulsa, USA: Penn Well Corporation. P. 17.

Depending on coal type, thickness, porosity, continuity, and gas permeability, a wide variety of completion techniques are applied: some wells are completed with cavity completions; many wells are drilled vertically and fracture-treated. However, in recent years, horizontal and multi-lateral technology has been used to develop coal seam reservoirs.

Shale Gas

Natural gas also exists in shale deposits. Shale is a very fine-grained sedimentary rock, which is easily breakable into thin, parallel layers. As with coal seams, some of the gas in shale reservoirs is adsorbed in organic matter in shale and is released when the pressure is reduced.¹⁷ Other layers in the shale may be silty and sandy or fractured and contain free gas in pore space or in fractures.¹⁸ The shale matrix is characterized as an ultra-low-permeability medium which makes the extraction of natural gas from shale formations more difficult than extraction of conventional natural gas. As such, it requires a conductive natural fracture network and hydraulic fracturing to connect the flow networks to the well bore for gas to flow.¹⁹ Energy experts affirm that many shale gas wells continue producing gas at a relatively steady rate for a long time after the flush production period. Presently, horizontal and multi-lateral drilling techniques, along with massive hydraulic fracturing are employed to develop shale gas plays.

1.3 Global Energy Trends and Development of Unconventional Gas

¹⁷ Xiong, H., Holditch, S. (2006). *Will the blossom of unconventional natural gas development in North America be repeated in China?* Society of Petroleum Engineers (SPE). P. 4.

¹⁸ Ibid.

¹⁹ Ibid.

World energy markets and industries face a decade of unprecedented change and uncertainty as a combination of trends reshapes the overall global energy landscape. These trends, including energy demand growth, increase in oil and natural gas prices, technological breakthroughs, and pressing environmental concerns, are certainly the engine for increasing interest in unconventional natural gas resource development.

To illustrate the global energy trends, two recent reports provide good estimates – *World Energy Outlook 2009*, issued by the International Energy Agency (IEA), and *International Energy Outlook 2009*, published by the U.S. Energy Information Administration (EIA). Both reports provide their own in-depth analysis and present several projected world energy growth scenarios. Following, I summarize their findings.

Strong demand for energy resources is the uppermost factor that will have a dramatic impact upon the global energy market. According to the official energy statistics, world energy demand will grow by 1.5% per year on average between 2007 and 2030 – an increase of 40%.²⁰ The present global economic downturn weakens world demand for energy, as manufacturing and consumer demand for goods and services slows. However, with the economic recovery anticipated after 2010, most countries will return to the trend in growth in income and energy demand.²¹

Regionally, growth in demand for energy is moving from developed countries to developing ones, predominantly in Asia. Total energy consumption outside the Organization for Economic Cooperation and Development (non-OECD nations) will grow by 73%, as compared with a 15% increase in energy use among the OECD

²⁰ *World Energy Outlook*. (2009). International Energy Agency. P. 4.

²¹ *International Energy Outlook*. (2009). Washington, DC: Energy Information Administration, U.S. Department of Energy. P.1. Retrieved from: <http://www.eia.doe.gov/oiaf/ieo/index.html>

countries.²² This is explained by the fact that OECD countries have the world's most established energy infrastructure, with advanced electricity markets and mature consuming patterns, while in most non-OECD countries a large amount of potential demand is unsatisfied.

As reported, the type and amount of energy consumed by countries and regions across the world vary greatly and depend heavily on end-users. Intense demand is assumed for the electric power generation and transportation sectors.²³ For this reason, fossil fuels will remain the dominant sources of primary energy worldwide. Oil will see by far the biggest increase in demand through 2030, followed by natural gas and coal.

As a result of significant supply and demand pressures in the last several years, rapid increases in oil prices have occurred. This factor led many energy consumers especially in the industrial and electric power generation sectors to switch from liquid fuels when feasible. Natural gas has become one of the priorities. Reasonable gas price expectations, together with increased crude oil prices, have become sufficient to stimulate additional activity in natural gas exploration and exploitation, especially from unconventional gas resources. On the assumption that the economy begins to recover by 2010, demand for natural gas worldwide is set to resume its long-term upwards trend.²⁴

Technology improvements have played a fundamental role as well. Since the beginning of the modern age of oil and natural gas, technology has been essential in supporting the efficient production of hydrocarbons. It contributes significantly to both reducing energy demand growth and expanding and diversifying supply. During the past

²² *International Energy Outlook*. (2009). Washington, DC: Energy Information Administration, U.S. Department of Energy. P.1. Retrieved from: <http://www.eia.doe.gov/oiaf/ieo/index.html>

²³ *Ibid*. P. 13.

²⁴ *World Energy Outlook*. (2009). International Energy Agency. P. 10.

10 – 20 years, research sponsored by private organizations, public companies and government agencies led to the development of new technology for unconventional natural gas exploration and exploitation. As those technologies in geology, geophysics, drilling, completion, and production were applied by industry, coupled with increases in natural gas price, the development of unconventional natural gas has become economically profitable.

Until recently, most decisions about energy use were based solely on cost and availability. However, with carbon dioxide emissions from fossil fuels contributing to global climate change, environmental concerns are also becoming increasingly important. Economic growth is the key factor underlying the projections for growth in energy-related carbon dioxide emissions, as the world continues to rely on fossil fuels for most of its energy use. According to Energy Information Administration statistics, non-OECD energy-related emissions of carbon dioxide exceeded OECD emissions by 14% in 2006; and it is expected that in 2030 energy-related carbon dioxide emissions from the non-OECD countries will exceed those from the OECD countries by 77%.²⁵ In this respect, both conventional and unconventional natural gas is a powerful tool for reducing the environmental impact of energy consumption in the foreseeable future, mainly because of its low carbon content relative to coal and oil.

From this summary, it is apparent that the world energy sector has entered a new era and continues to change rapidly. Although forecasts vary in their outlook for future demand for energy sources, they all have one thing in common: natural gas will play a significant role in the energy picture for some time to come. Affordable and abundant, it

²⁵ *International Energy Outlook*. (2009). Washington, DC: Energy Information Administration, U.S. Department of Energy. P.109. Retrieved from: <http://www.eia.doe.gov/oiaf/ieo/index.html>

is projected to help provide the energy necessary for economic and social progress as well as to reduce the environmental impact of energy use.

From this perspective, unconventional natural gas is viewed as a reasonable alternative for the global energy future. It represents a vast, long-term, global source of energy.²⁶ As reported, unconventional natural gas resources, including tight gas, coalbed methane and shale gas, constitute some of the largest components of remaining natural gas resources. The table below estimates distribution of worldwide unconventional natural gas reservoirs:²⁷

Region	Coalbed Methane (Tcf)	Shale Gas (Tcf)	Tight Sand Gas (Tcf)	Total (Tcf)
North America	3,017	3,842	1,371	8,228
Latin America	39	2,117	1,293	3,448
Western Europe	157	510	353	1,019
Central and Eastern Europe	118	39	78	235
Former Soviet Union	3,957	627	901	5,485
Middle East and North Africa	–	2,548	823	3,370
Sub-Saharan Africa	39	274	784	1,097
Centrally planned Asia and China	1,215	3,528	353	5,094
Pacific (Organization for Economic Cooperation and Development)	470	2,313	705	3,487
Other Asia Pacific	–	314	549	862
South Asia	39	–	196	235
World	9,051	16,112	7,406	32,560

As mentioned above, during the past several decades, research and development concerning the geologic controls and production technologies required to evaluate and produce unconventional natural gas resources has provided many new technologies. New technologies have enabled operators in the United States and Canada to unlock the vast

²⁶ Holditch, S. A. (2007). *Unconventional Gas. Topic Paper #29*. USA: National Petroleum Council (NPC). P. I. Retrieved from: http://www.npc.org/Study_Topic_Papers/29-TTG-Unconventional-Gas.pdf

²⁷ Holditch, S.A. (2006). Tight Gas Sands. *SPE Paper 103356, Distinguished Author Series*. Data after Rogner, H. (1997). *An Assessment of World Hydrocarbon Resources*. Institute for Integrated Energy System, University Of Victoria.

potential of these challenging resources and speed up the production levels of natural gas domestically. Around the world, unconventional natural gas resources are widespread, but with several exceptions, they have not received close attention. This is due in part to the fact that geologic and engineering information on unconventional resources is scarce, and natural gas policies and market conditions have been unfavorable for development in many countries. In addition, there is a shortage of expertise in the specific technologies needed to develop these resources successfully. As a result, only limited development has taken place to date outside of North America. Meanwhile, interest is growing, and more countries are involved in development of unconventional gas reservoirs today, including USA, Canada, Australia, France, Austria, Slovakia, Germany, Hungary, Poland, Turkey, Sweden, Mexico, Venezuela, Russia, Ukraine, and China.

The unconventional natural gas industry in China is just emerging. Although the country has officially expressed its interest in unconventional gas exploration and development, little work has been done yet on resource evaluation and exploration. The real volume of extractable unconventional gas is uncertain. Domestic and overseas institutions assume that unconventional natural gas is abundant in China, and it could be a significant way to satisfy domestic demand for energy. The country has ambitious plans, even though exploration of unconventional gas in China is a generation behind the US.

CHAPTER 2: MAJOR DRIVERS OF DEVELOPMENT OF UNCONVENTIONAL NATURAL GAS IN CHINA

The present chapter attempts to answer the first research question stated in the introduction and identify the major factors that determine development of unconventional natural gas in China. It begins by summarizing a wide range of information on the natural gas market in China, including gas reserves, gas infrastructure, policy and regulations, the gas industry, demand and supply issues, and recent trends and challenges. This is followed by examination of the factors that will affect unconventional natural gas development in China. These factors are identified as internal and external. Internal factors, including economic growth, social development, and environmental constraints, are the conditions that emerge within the country, while external factors, such as technological breakthroughs and experience of the leading expert nations, are associated with outside forces. I will also discuss other factors, beyond those mentioned above, that will also likely affect development of unconventional gas in China; however, they are not considered to be of real significance.

2.1 Natural Gas Market in China

Historically, natural gas has not been a major energy source in China. Meanwhile, China's natural gas resources are abundant. According to a national survey carried out by the China National Petroleum Corporation (CNPC) in 2005, China's conventional natural gas resources add up to 56 trillion cubic metres (tcm) prospectively and 35 tcm geologically.²⁸ The country's recoverable resources are estimated at 22 tcm.²⁹

²⁸ Higashi, Nobuyuki. (2009). *Natural Gas in China: Market Evolution and Strategy*. Paris: International Energy Agency. P. 6.

China’s major gas fields are located inland, in the western and north-central parts of the country. Three main basins, the Tarim Basin, the Ordos Basin and the Sichuan Basin, include more than half of the country’s total proven reserves of conventional resources. In addition, major gas fields have been discovered offshore – in the East China Sea, the South China Sea and Bohai Bay. The following figure illustrates conventional gas resources in China:³⁰



The table below provides estimates of China’s conventional natural gas resources by basin:³¹

Basin	Prospective (tcm)	Geological (tcm)	Recoverable (tcm)
Tarim	11.3	8.9	5.9
Ordos	10.7	4.7	2.9
Sichuan	7.2	5.4	3.4
East China Sea	5.1	3.6	2.5
Qaidam	2.6	1.6	0.9

²⁹ Higashi, Nobuyuki. (2009). *Natural Gas in China: Market Evolution and Strategy*. Paris: International Energy Agency. P. 6.

³⁰ Ibid. P. 7.

³¹ Ibid.

Yinggehai	2.3	1.3	0.8
Bohai Bay	2.1	1.1	0.6
Qiong Southeast	1.9	1.1	0.7
Songliao	1.8	1.4	0.8
Others	10.8	6.0	3.6
Total	55.9	35.0	22.0

In addition to conventional natural gas resources, there is a huge potential of unconventional gas as well. While exploration of unconventional gas reserves in China is underway, preliminary resource assessments are available. Advanced Resources International (ARI) which is considered a world-recognized research and consulting firm providing services related to unconventional gas reports that China's coalbed methane resources amount to 19.82 – 35.96 tcm with about 2.83 tcm of recoverable resources.³² There is little information published on shale and tight gas resources in China because they have just started to be evaluated. Presently, the total shale gas resource estimates vary from 21.5 to 45 tcm; the average value is 30.7 tcm.³³ Tight gas resources are also considerably lacking in estimates, and special evaluations of promising regions are currently being made.

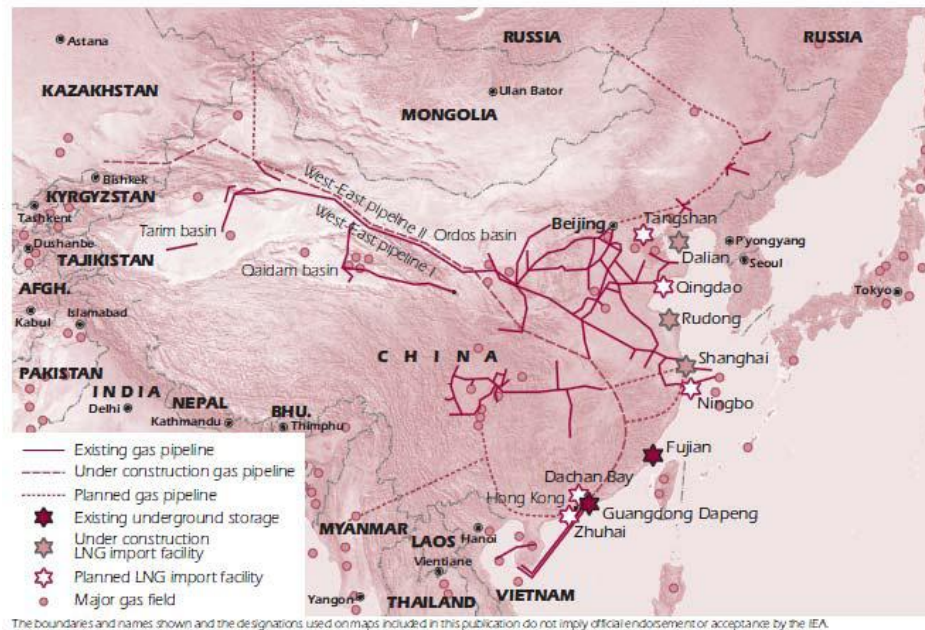
It was only during the last decade that the natural gas market in China showed a notable expansion. This is the result of two main factors: lack of infrastructure, particularly long-distance pipelines connecting inland gas fields to major consumer cities; and the price of natural gas, which has been high relative to the price of coal. However, the whole picture is currently changing.

³² Kuuskraa, V. (2009). *Worldwide Gas Shales and Unconventional Gas: A Status Report*. Advanced Resources International. Inc. Retrieved from: http://www.adv-res.com/pdf/Kuuskraa%20Condensed%20Worldwide%20Uncon%20Gas%2012_12_09.pdf

³³ Liu Honglin, Wang Hongyan, Liu Renhe, Zhaoqun , Lin Yingji. (2009). *Shale Gas in China: New Important Role of Energy in 21st Century*. 2009 International Coalbed and shale gas Symposium. Retrieved from: http://www.petromin.ca/sites/petromin/files/media/reports/shale%20gas/Shale_Gas_in_China_Tuscaloosa_2009.pdf

At the end of 2004, the West-East Pipeline was completed, at a length of 3,900 km. It is the first nationwide pipeline in China used inland for transportation of domestic gas to the coastal cities. As reported: “This pipeline opened a new stage in the evolution of China’s natural gas market from that of a local business to a nationwide business.”³⁴ In addition, in 2006 the first liquefied natural gas (LNG) regasification terminal in Guangdong was built, which opened the window of China’s natural gas market to the international market.

Presently, the country is constructing a second West-East Pipeline from the west to the eastern and southern parts of China. Simultaneously, China is investing in the Central Asia Pipeline to transport natural gas from Turkmenistan, via Uzbekistan and Kazakhstan. Additional LNG terminals are projected to be opened in the foreseeable future. The figure below illustrates natural gas infrastructure in China:³⁵



³⁴ Higashi, Nobuyuki. (2009). *Natural Gas in China: Market Evolution and Strategy*. Paris: International Energy Agency. P. 4.

³⁵ Ibid. P. 9.

Today, China's natural gas sector is dominated by three national oil companies – the China National Petroleum Corporation, or CNPC; Sinopec and the China National Offshore Oil Corporation, or CNOOC – which were established as a result of the economic reform in the 1980s. In 1998, the sector underwent a broad-scale restructuring: both CNPC and Sinopec began to handle entire segments from recovery and production to refining, but their mandates were geographically separated. All three companies were listed on the international stock exchanges in Hong Kong, New York and London in 2000, and several western oil majors bought their stocks.³⁶

As regards the natural gas business, CNPC holds approximately 75% of domestic gas resources and 80% of China's pipeline network.³⁷ CNPC is also in charge of several major gas import projects, such as the Central Asia pipeline and LNG imports in Jiangsu and Dalian. Sinopec's core gas resources are located in Shandong and Sichuan, and it is also seeking LNG business opportunities. CNOOC provides offshore gas by pipeline from the South China Sea to Hong Kong, and from the East China Sea to Shanghai. Following its success on the Guangdong and Fujian projects, CNOOC is currently the leading company in the LNG business; it is now expanding business opportunities in other provinces in China.

Development of unconventional natural gas is also underway in China. The country is currently designing its nationwide shale research projects on basins that have geologic characteristics similar to those in the U.S. During President Barack Obama's visit to China in November 2009, the US and Chinese governments signed a cooperation initiative, which is expected to promote investment and joint studies of China's shale gas

³⁶ Higashi, Nobuyuki. (2009). *Natural Gas in China: Market Evolution and Strategy*. Paris: International Energy Agency. P.11.

³⁷ Ibid.

potential.³⁸ As a result, Royal Dutch Shell and PetroChina, the publicly traded company under CNPC, signed a joint development project for shale gas resources in Sichuan, south-west China, in November 2009. Later, in January 2010, Sinopec and BP discussed potential collaboration in the exploration and development of shale gas in China. BP is already involved in extracting methane from coal in China and has several joint ventures with Sinopec. Both parties are looking for new opportunities – BP to expand in China, and China to use foreign technology to speed up the development of its potentially large shale gas reserves. With regard to CBM, the government established the China United Coalbed Methane Corporation (CUCBM) in 1996 as the sole state-owned company for developing CBM. In 2007, China opened the CBM business to foreign investors in order to accelerate its development.

The Chinese government has been promoting natural gas use in order to improve energy diversification and energy efficiency and to find a satisfactory solution to environmental problems. Under the 10th Five-Year Plan (2001-05), the government set the goal of raising natural gas use to 10% of the energy mix in 2020, which was essentially reiterated in the 11th Five-Year Plan (2006-10).³⁹ The table below demonstrates in coal-equivalent calculation this changing trend in energy mix from 2000 to 2007:^{40,41}

Year	Total Primary Energy Consumption (Million tons of coal equivalent – Mtce)	Coal (%)	Oil (%)	Natural Gas (%)	Others (%)
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³⁸ *Fact Sheet: U.S.-China Shale Gas Resource Initiative*. (2009). The White House, Office of the Press Secretary. Retrieved from: http://www.energy.gov/news2009/documents2009/US-China_Fact_Sheet_Shale_Gas.pdf

³⁹ Higashi, Nobuyuki. (2009). *Natural Gas in China: Market Evolution and Strategy*. Paris: International Energy Agency. P. 9.

⁴⁰ *Ibid.* P. 10.

⁴¹ This calculation is provided in coal equivalent.

2000	1 385.5	67.8	23.2	2.4	6.7
2007	2 655.8	69.5	19.7	3.5	7.3

In addition, in order to develop the natural gas market and promote natural gas use as a substitute for coal and oil, the Chinese government has been trying to set a price level. Considering the situation in each sector, the government has determined the natural gas price on a cost-plus base, but with variations by sector.⁴² Consequently, domestic prices for natural gas have become lower than those in the international market. Such price regulation has been effective in developing China's natural gas market because natural gas has been a self-sufficient fuel in the country until very recently. However, confronted by increasing gas demand, the country started to import LNG and pipeline gas rapidly. In 2007-2008 international gas prices rose sharply and the differential between domestic prices and international prices led to the emergence of controversy in China. What makes the situation with the increased import of natural gas especially problematic is the lack of natural gas price regulation in China.

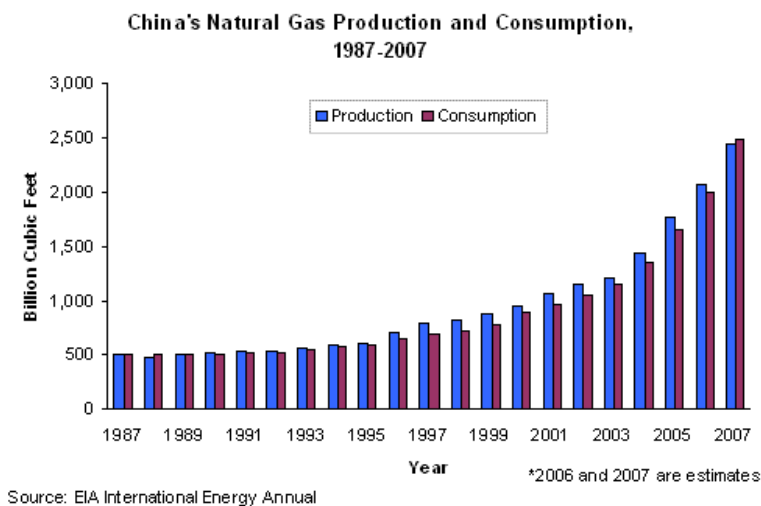
The share of natural gas in the country's consumption and production as compared with other energy sources has been increasing rapidly during the last decades. Both the International Energy Agency (IEA) and the U.S. Energy Information Administration (IEA) have announced substantial growth in consumption and production of natural gas in China. As reported by IEA, natural gas consumption in China reached 69.5 tcm in 2007.⁴³ In 2008 China's natural gas consumption grew by 11.8% and attained 77.7 bcm; subsequently, the annual growth rate accelerated to more than 20% since 2004,

⁴² Higashi, Nobuyuki. (2009). *Natural Gas in China: Market Evolution and Strategy*. Paris: International Energy Agency. P. 10.

⁴³ Ibid. P. 13.

far above the country's GDP growth rate.⁴⁴ Such growth of natural gas consumption in China in the past few years is attributed to all sectors – industrial, electric power generation, residential, and commercial; however, a majority of the gas consumption is dominated by industrial end-users.

China's production of natural gas also rose at an annual average growth rate of 15% from 2000 to 2007, amounting to 69.2 bcm in 2007.⁴⁵ According to the estimates provided by EIA, in 2007 China produced 2,446 Bcf of natural gas, and for the first time in almost two decades, the country became a net natural gas importer.⁴⁶ Consumption for 2007 amounted to 2,490 Bcf and rose from 2006 levels by about 25%.⁴⁷ The graphic below illustrates the rise in China's natural gas production and consumption.⁴⁸



It seems apparent that China's natural gas market is moving towards the next stage of evolution. On the one hand, the country has become increasingly dependent on

⁴⁴ Higashi, Nobuyuki. (2009). *Natural Gas in China: Market Evolution and Strategy*. Paris: International Energy Agency. P.13.

⁴⁵ Ibid. P. 16.

⁴⁶ *Country Analysis Briefs: China*. (2009). Energy Information Administration, U.S. Department of Energy. P.10. Retrieved from: <http://www.eia.doe.gov/emeu/cabs/China/pdf.pdf>

⁴⁷ Ibid.

⁴⁸ Ibid.

imports; on the other hand, it seeks self-sufficiency in its natural gas market.

Development of unconventional natural gas is one element that can help the country realize this self-sufficiency.

2.2 Analysis of Major Drivers of Unconventional Natural Gas in China

Economic growth, social development, environmental constraints and technological breakthroughs are the main drivers that encourage development of unconventional natural gas in China.

2.2.1 Economic Growth

Economic growth is the most significant factor underlying projections for a strong demand for energy and development of unconventional natural gas in China. Economic growth depends heavily upon energy sources, both domestic and foreign. Key economic indicators chart China's economic performance. They include the gross domestic product, industrial added value, fixed-asset investment, retail sales, foreign trade, and foreign direct investment.

The Chinese economy has grown fast in the last few years. According to the National Bureau of Statistics of China (NBS), the country's gross domestic product (GDP) rose 8.7% in 2009 to reach 33.53 trillion Yuan (about 4.91 trillion U.S. dollars).⁴⁹ Such a growth rate went beyond the target set by the Chinese government in March 2009, when Premier Wen Jiabao told the National People's Congress (NPC) – the country's top legislature – that China's economy would grow at an annual rate of around 8% for the

⁴⁹ Retrieved from: http://www.stats.gov.cn/was40/gjtj_en_data_outline.jsp

past year.⁵⁰ The Chinese government has long believed that a GDP growth of 8% is essential to create enough jobs. The country's GDP grew 6.1% in the first quarter of 2009, 7.9% in the second quarter, 8.9% in the third quarter and 10.7% in the fourth quarter.⁵¹ According to the NBS, the annual growth rates of China's GDP between 2003 and 2008 were 10% in 2003, 10.1% in 2004, 10.4% in 2005, 11.6% in 2006, 13% in 2007 and 9.6% in 2008 respectively.⁵²

Industrial added value measures the rise of China's manufacturing-based economy. China applies the industrial added value to measure the business activities of some 430,000 designated large enterprises, each with annual revenues of at least 5 million Yuan.⁵³ As reported by China's Minister of Industry and Information Technology Li Yizhong, industrial output accounted for 43% of China's total GDP in 2008 and contributed 42.8% to the GDP growth in the same year.⁵⁴ According to the NBS, China's industrial added value rose 11% in 2009 from a year earlier.⁵⁵ China's industrial added value grew 5.1% in the first quarter of last year, 9.1% in the second quarter, 12.4% in the third quarter, and 18% in the fourth quarter. In the nine years between 2001 and 2009, the annual growth rates of China's industrial added value were 9.9% in 2001, 12.6% in 2002, 17% in 2003, 16.7% in 2004, 16.4% in 2005, 16.6% in 2006, 18.5% in 2007, 12.9% in 2008, and 11% in 2009.

Fixed asset investment is a third indicator of economic growth in China. Fixed asset investment implies what is used to purchase and build factories, machines, property

⁵⁰ *Key Indicators of China's Economic Performance in 2009 and previous years*. (2010). Retrieved from: <http://www.istockanalyst.com/article/viewnewspaged/articleid/3797970/pageid/1>

⁵¹ Ibid.

⁵² Retrieved from: http://www.stats.gov.cn/was40/gjtj_en_data_outline.jsp

⁵³ *Key Indicators of China's Economic Performance in 2009 and previous years*. (2010). Retrieved from: <http://www.istockanalyst.com/article/viewnewspaged/articleid/3797970/pageid/1>

⁵⁴ Ibid.

⁵⁵ Ibid.

and other fixed facilities. Fixed asset investment is considered the main driver of China's rapid growth in the past several decades. According to the NBS, China's fixed asset investment increased 30.1% in 2009 to nearly 22.5 trillion Yuan.⁵⁶ Urban fixed asset investment climbed 30.5% in 2009 to 19.4 trillion Yuan.⁵⁷ In the four years between 2005 and 2008, the annual growth rates of China's fixed asset investment were 27.2% in 2005, 24.5% in 2006, 25.8% in 2007, and 26.4% in 2008, respectively.⁵⁸

A fourth indicator of China's rapid economic development is retail sales. According to the NBS, China's retail sales rose, inflation-adjusted, 16.9% year on year in 2009.⁵⁹ In the four years between 2005 and 2008, China's retail sales jumped from 6.72 trillion Yuan in 2005 to 10.85 trillion Yuan in 2008. The annual growth rates of the four years were 12.9% in 2005, 13.7% in 2006, 16.8% in 2007 and 21.6% in 2008, respectively.⁶⁰

In addition, foreign trade, including export and import of goods, can demonstrate economic viability. However, with the recent economic downturn these indicators fell and foreign trade slowed. According to data released by the General Administration of Customs (GAC) in 2009, in total, China's foreign trade in 2009 dropped 13.9% from a year earlier to 2.21 trillion U.S. dollars and its trade surplus last year slid 34.2% year on year to 196.1 billion U.S. dollars.⁶¹ GAS reports that China's exports in 2009 stood at 1.2 trillion U.S. dollars, down 16% from 2008, and imports reached 1.01 trillion U.S. dollars,

⁵⁶ Retrieved from: http://www.stats.gov.cn/was40/gjtj_en_data_outline.jsp

⁵⁷ Ibid.

⁵⁸ Ibid.

⁵⁹ Ibid.

⁶⁰ Ibid.

⁶¹ *Key Indicators of China's Economic Performance in 2009 and previous years.* (2010). Retrieved from: <http://www.istockanalyst.com/article/viewnewspaged/articleid/3797970/pageid/1>

down 11.2% from a year earlier.⁶² Meanwhile, from a historical perspective, increased foreign trade activity is the trend. According to statistics provided by the World Bank, between 2005 and 2009, export of goods from China grew from 762 billion U.S. dollars to 1344 billion U.S. dollars; and imports of goods increased from 660 billion U.S. dollars to 1017 billion U.S. dollars.⁶³ These facts imply that as soon as the world's economic situation improves after 2010, China has a strong potential for maintaining robust economic growth.

Finally, foreign direct investment, or FDI, is an indicator of economic performance in China. FDI refers to foreign ownership of productive assets, such as factories and machines. It indicates a country's ability to attract investment from other countries. According to World Bank statistics, China's foreign direct investment increased from 72.4 billion U.S. dollars to 108.3 billion U.S. dollars between 2005 and 2008; but fell to 70.0 billion U.S. dollars in 2009, which is explained by the economic downturn.⁶⁴

From the statistics presented above, China possesses a strong potential for its economy to grow. The 2008-2009 Chinese economic stimulus plan announced by the central government in its biggest move to stop the global financial crisis from hitting the country's economy, is likely to contribute positively. In addition, a number of significant reforms that have been implemented over the past years have improved and are expected

⁶² *Key Indicators of China's Economic Performance in 2009 and previous years.* (2010). Retrieved from: <http://www.istockanalyst.com/article/viewnewspaged/articleid/3797970/pageid/1>

⁶³ *Key Indicators.* (2009). The World Bank published data. East Asia and Pacific (EAP). Retrieved from: http://siteresources.worldbank.org/INTEAPHALFYEARLYUPDATE/Resources/550192-1238574864269/5976918-1239010682147/update_april09_keyindicators.pdf

⁶⁴ Ibid.

to improve China's prospects for recovery and strong long-term growth.⁶⁵

Reconsideration of macroeconomic policies, trade liberalization, more flexible exchange rate regimes, and lower fiscal deficits will definitely lower the national inflation rates, reduce uncertainty, and improve the overall investment climate in China. More microeconomic reform, structural reforms, such privatization and regulatory reform, will also play key roles. Generally, such reforms will result in growth in China's economy and will contribute to recovery from the current recession into the next decades. As a result, with a strong potential for economic growth, China will certainly tend to increase demand for energy resources, and unconventional natural gas in particular.

2.2.2 Social Development

The primary goal of economic growth is an improvement of well-being and quality of life. In this respect, it is worth analyzing social development as another factor that will indirectly have a considerable impact upon energy demand and development of unconventional natural gas in China. The major indicators of social development in China are size, growth and structure of population, labor force, quality of life, income and poverty, and social investment, including expenditure on food, housing, fuel and power, transport and communication, and investment in medical care and education.

China is the world's largest and most populous country. According to World Bank data, China's total population is 1,325,640 people.⁶⁶ The population grows by 0.6%

⁶⁵ *International Energy Outlook*. (2009). Washington, DC: Energy Information Administration, U.S. Department of Energy. P.14. Retrieved from: <http://www.eia.doe.gov/oiaf/ieo/index.html>

⁶⁶ *China Data and Statistics*. (2008). World Bank. Retrieved from: <http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/CHINAEXTN/0,,contentMDK:20601872~menuPK:318976~pagePK:1497618~piPK:217854~theSitePK:318950,00.html>

annually.⁶⁷ Although China's population growth has been slowed by the one-child policy established in 1979, it still increases dramatically. Over the decades, China's population has not only grown. Increased total fertility, births, and life expectancy, lower death rate, and growing urban population suggest that China's population has also changed in terms of its distribution and characteristics.⁶⁸ As population has grown over the past 50 years, China has acquired numerous socio-economic challenges that need to be addressed.

According to the 2008 estimates by China's National Bureau of Statistic, the total number of the urban unemployed was 8.30 million.⁶⁹ The country's total unemployment rate stood at 4.0%.⁷⁰ Year-on-year estimates of China's unemployment rate demonstrate the following: 10.10% (2004), 9.80% (2005), 9.00% (2006), 4.20% (2007), and 4.00% (2008).⁷¹ Over the past five years, the Chinese government has succeeded in controlling its unemployment situation. The Chinese government has also provided basic life-support facilities to workers who were laid-off by state-owned enterprises. Although the official estimates for China's unemployment situation appear to be very promising, this may not be the case. The unemployment figures only include individuals who were registered with the Chinese Ministry of Labor. The registered unemployed belonged only to the urban regions. So, people residing in rural areas were not covered in the estimation of

⁶⁷ *China Data and Statistics*. (2008). World Bank. Retrieved from: <http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/CHINAEXTN/0,,contentMDK:20601872~menuPK:318976~pagePK:1497618~piPK:217854~theSitePK:318950,00.html>

⁶⁸ As of 2009, the total fertility rate in China is 1.79, which means that on average each woman gives birth to 1.79 children throughout her life. Birth rate amounts 14 births per 1,000 of population and death rate is 7.06 deaths per 1,000 of population that implies that birth rate twice exceeds death rate.⁶⁸ Life expectancy at birth is 73.47 years.⁶⁸ China has also the largest urban population of any country even though most Chinese live in rural areas. 43% of total population in China is urban (*East and Southeast Asia: China*. (2009). Central Intelligence Agency. Retrieved from: <https://www.cia.gov/library/publications/the-world-factbook/geos/ch.html>).

⁶⁹ Retrieved from: http://www.stats.gov.cn/was40/gjtj_en_data_outline.jsp

⁷⁰ Ibid.

⁷¹ *East and Southeast Asia: China*. (2009). Central Intelligence Agency. Retrieved from: <https://www.cia.gov/library/publications/the-world-factbook/geos/ch.html>

total unemployment. Even migrant workers who went outside rural areas in search of work were not represented. Therefore, China's unemployment scenario is grimmer than what the government figures may reveal. It was also worsened by the recent global economic slowdown.

Quality of life is the other important indicator of social development in China. According to World Bank estimates, more than 60% of the population was earning under its \$1 per day poverty line at the beginning of the economic reform in 1978.⁷² That poverty ratio had declined to 10% by 2004, indicating that about 500 million people have been lifted out of poverty in a generation.⁷³ As of 2007, 2.8% of population of China is below the poverty line.⁷⁴

At the same time, however, the phenomenal rate of change in China has brought with it different kinds of stresses. Today, China faces serious natural resource scarcity and environmental degradation. It has also seen increasing disparities of different kinds as people in different parts of the country and with different characteristics have benefited from different rates of growth. Income inequality has risen, accelerated by the rural-urban income gap and by the growing disparity between highly educated urban professionals and the urban working class. This is true for inequality in household income or consumption, as well as for inequality in important social outcomes such as health status or educational attainment.

⁷² *Governance, Investment Climate, and the Harmonious Society: Competitiveness Enhancements for 120 Cities in China*. (2006). World Bank: Report No. 37759-CN.

⁷³ Ibid.

⁷⁴ *East and Southeast Asia: China*. (2009). Central Intelligence Agency. Retrieved from: <https://www.cia.gov/library/publications/the-world-factbook/geos/ch.html>

As for the household consumption, the Gini measure of inequality increased from 0.31 at the beginning of reform to 0.45 in 2004.⁷⁵ Some rise in inequality was inevitable as China introduced a market system, but inequality may have been strengthened rather than mitigated by a number of policy features. Restrictions on rural-urban migration have limited opportunities for the relatively poor rural population. The inability to sell or mortgage rural land has further reduced opportunities. China has a uniquely decentralized fiscal system that has relied on local government to fund basic health and education. The result has been that poor villages could not afford to provide good services, and poor households could not afford the high private costs of basic public services. Ironically, the large trade surplus that China has built up in recent years is a further problem, in that it stimulates an urban industrial sector that no longer creates many jobs while restricting the government's ability to increase spending to improve services and address disparities.

In order to eliminate social disparities, the Chinese government has initiated new policies designed to encourage migration, fund education and health for poor areas and poor households, and rebalance the economy away from investment and exports toward domestic consumption and public services. However, the recent global recession has aggravated social instability in the country and led to declines in employment, investment spending, capacity utilization, household incomes, business profits and inflation.

In response to the economic downturn, the Chinese government approved the stimulus package. This stimulus, equivalent to US \$586 billion, aimed to make investment in key areas such as housing, rural infrastructure, transportation, health and

⁷⁵ Dollar, D. (2007). *Poverty, inequality and social disparities during China's economic reform*. World Bank Policy Research Working Paper 4253. P. 6. Retrieved from: http://www.wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2007/06/13/000016406_20070613095018/Rendered/PDF/wps4253.pdf

education, environment, industry, disaster rebuilding, income-building, tax cuts, and finance.⁷⁶ Such progress in building human and physical capital infrastructures, together with the population growth, labor force participation rates, capital accumulation, and productivity improvements, will definitely play important roles in determining the medium- and long-term need for energy resources.

2.2.3 Environmental Constraints

As a result of China's population increase and rapid economic growth, total primary energy consumption rose from 400 million tons of oil equivalent (Mtoe) in 1978 to nearly 1,320 Mtoe in 2004, with an annual average rate of increase of 4.7%.⁷⁷ This has led to increasingly severe degradation of the environment over the last two decades due to heavy dependence on coal.

China is the largest coal-producing and -consuming country in the world. According to U.S. EIA statistics, coal supplied the vast majority of China's overall energy consumption requirements, providing 70% of total primary energy use in China.⁷⁸ Raw coal is typically burned directly the way it is. At least 90% of the nation's combustion facilities have no environmental protection measures, and thus pose serious environmental problems.⁷⁹

⁷⁶ *China plans 10 major steps to spark growth as fiscal, monetary policies ease*. Special Report. (2008). Retrieved from: http://news.xinhuanet.com/english/2008-11/09/content_10332422.htm

⁷⁷ *China Energy Statistical Year Book 2002–2003*. (2004a). Beijing: NSB. *China Statistical Year Book 2004*. (2004b). Beijing: NSB.

⁷⁸ *Country Analysis Briefs: China*. (2009). Energy Information Administration, U.S. Department of Energy. P.10. Retrieved from: <http://www.eia.doe.gov/emeu/cabs/China/pdf.pdf>

⁷⁹ Yamaguchi, K. (2003). Natural Gas in China. *IEEJ*: August 2003. P. 4. Retrieved from: <http://eneken.ieej.or.jp/en/data/pdf/221.pdf>

The electric power and industrial sectors in China are the principal end users of coal. From 1980 to 2004, total installed capacity of electric power generation increased from 66 gigawatts (GW) (of which hydropower was 20 GW, accounting for 31%) to 440 GW (of which hydropower was 100 GW, accounting for 23%).⁸⁰ In the same period, electric output increased from 300 terawatt hours (TWh) (of which hydropower was 58 TWh, accounting for 19%) to 1,870 TWh (of which hydropower was 220 TWh, accounting for 12%).⁸¹ EIA projects that coal consumption in China's electric sector will increase considerably. As reported, at the beginning of 2006, China had an estimated 350 GW of coal-fired capacity in operation.⁸² To meet the demand for electricity, an additional 600 GW of coal-fired capacity is expected to be brought on line in China by 2030.⁸³ Coal also remains the leading source of energy in China's industrial sector. More than one-half (52%) of China's coal use in 2006 was in the non-electric sectors, primarily in the industrial sector.⁸⁴

Environmental problems have occurred in many cities and regions in China. Air pollution, water pollution and soil degradation are the most serious problems. According to EIA, China's average carbon dioxide intensity from fossil fuels combustion is relatively high, amounting to 2.8% per year.⁸⁵ Energy-related carbon dioxide emissions per capita increased from 2.0 metric tons per person in 1990 to 4.3 metric tons per person in 2006, with an annual average growth rate of 5.3%.⁸⁶ Because of the large proportion of

⁸⁰ Drysdale, P., Jiang, K., Meagher, D. (Eds.) (2007). *China and East Asian Energy: Prospects and Issues*. Volume 1. Canberra: Australia-Japan Research Centre. P. 67.

⁸¹ Ibid.

⁸² *International Energy Outlook*. (2009). Washington, DC: Energy Information Administration, U.S. Department of Energy. P. 51. Retrieved from: <http://www.eia.doe.gov/oiaf/ieo/index.html>

⁸³ Ibid. P. 52.

⁸⁴ Ibid.

⁸⁵ Ibid. P. 113.

⁸⁶ Ibid. P. 115.

coal in China's energy mix, China is also the largest emitter of sulphur dioxide (SO₂), PM10 (respirable particulate matter under 10 microns in diameter), and nitrous oxides (NO_x) in the world. Although there have been improvements over the last decade, by 2002 the number of Chinese cities reaching air quality standards was still below 40%.⁸⁷

In addition to poor air quality, Chinese cities suffer from emission-induced acid rain and serious pollution problems in major rivers. Pollution in rivers increases the costs of providing water suitable for drinking and irrigation, exacerbating drought conditions. About one-third of China's population lacks access to clean drinking water.⁸⁸ Nearly 70% of the country's rivers and lakes are polluted, with roughly two hundred million tons of sewage and industrial waste pouring into Chinese waterways in 2004.⁸⁹

Desertification is a serious environmental issue in China as well. It leads to the loss of about 5,800 square miles of grasslands every year.⁹⁰ Desertification also contributes to China's air pollution problems, with increasing dust causing a third of China's air pollution.

The accelerating urbanization process in China also contributes to environmental degradation. China's urbanization level has increased from 26.41% in 1990 to 41.76% in 2004.⁹¹ It is expected to reach about 55% - 60% by 2020.⁹² As previously described, urbanization is accompanied by employment pressures, consumption and large-scale

⁸⁷ Drysdale, P., Jiang, K., Meagher, D. (Eds.) (2007). *China and East Asian Energy: Prospects and Issues*. Volume 1. Canberra: Australia-Japan Research Centre. P. 68.

⁸⁸ Zissis, C., Bajoria, J. (2008). *China's Environmental Crisis*. Council on Foreign Relations. Retrieved from: <http://www.cfr.org/publication/12608/>

⁸⁹ Ibid.

⁹⁰ Ibid.

⁹¹ *Understanding China's Energy Policy: Economic Growth and Energy Use, Fuel Diversity, Energy/Carbon Intensity and International Cooperation*. Research Centre for Sustainable Development, Chinese Academy of Social Sciences. P. 13. Retrieved from: http://www.hm-treasury.gov.uk/d/Climate_Change_CASS_final_report.pdf

⁹² Ibid.

construction of infrastructure and buildings that increase demand for materials and have significant impacts on China's energy demand and emissions in the future. The growing residential sector is also one of the biggest energy consumption sectors, following the industrial and electric power sectors.

Recent years have witnessed that China has begun to make environmental protection a policy priority. Sustainability has become a key concept for the Chinese government, and the government has formulated policies and measures toward specific goals for sustainable development. China is also paying more attention to matters directly related to climate change. The government established the inter-ministerial National Climate Change Policy Coordinating Committee in 1990, making it responsible for policies and measures to address climate change. China signed and ratified the United Nations Framework Convention on Climate Change in 1992, and ratified the Kyoto Protocol. In addition, the Chinese government has cooperated with other governments and multilateral organizations in a number of international programs in the broad field of climate change.

In this respect, development and production of natural gas, including unconventional gas, seems to be a reasonable alternative for the Chinese government. Because natural gas burns cleaner than oil and much cleaner than coal, it could be a powerful instrument for reducing the negative environmental impact of energy use.

At the same time, however, negative environmental impact occurs in extracting and utilizing unconventional gas as well. It is generally greater than in the case of conventional oil extraction, processing and production, but less than in case of coal. In order to facilitate and maximize the flow of gas, extraction techniques require large

amounts of water. To aid the process, various forms of grit and lubricating chemicals are mixed in. Used process water that is not recycled is released into tailings ponds, some of which remain in use for a decade or more, and which can pose leaching threats to surface and groundwater.

Thus, to some extent, unconventional natural gas development does not entirely resolve the dilemma of economic growth and energy versus environment. However, its development and utilization would help China diversify its energy resources and partially shift from coal, thereby reducing emissions.

2.2.4 Technological Breakthroughs and Expertise

Technological breakthroughs are a fourth factor influencing development of unconventional natural gas in China. Although many do not still realize it, energy has become a high-tech industry: new innovations in energy technology continue to advance the potential for all energy sources. During the past 10-20 years, prominent technological improvements in gas exploration, drilling and production have occurred in North America. These technological breakthroughs have spurred the development and production of unconventional natural gas.

The United States and Canada are prime examples of the benefits of technological breakthroughs, as the recovery of the unconventional natural gas reserves has grown dramatically since the beginning of this decade and currently constitutes the lowest-cost source of natural gas in North America.⁹³ Since 1990, the annual production from

⁹³ *Unconventional Gas. Topic Paper #29.* (2007). National Petroleum Council.

unconventional gas resources has increased at 40% per year in the US.⁹⁴ According to estimates provided by Halliburton, unconventional natural gas production in the US reached a peak of 24 bcfd (8.6 tcf per year) in 2006, up from 14 bcfd (5.0 tcf per year) 10 years ago.⁹⁵ With a 43% share, it is now the dominant source of natural gas production.⁹⁶ Starting in the late 1970s, as conventional U.S. gas production was projected to peak and decline and natural gas prices were increasing, the U.S. government and industry started to focus on increasing production from unconventional gas sources. Solid investments were made in basic and applied unconventional gas research projects by the U.S. Department of Energy (DOE), Bureau of Mines (USBM), Gas Research Institute (GRI), private industry and others. A tax credit incentive was offered by the federal government to encourage companies to develop gas from unconventional formations. As a result of these efforts, unconventional natural gas now accounts for more than one third of U.S. gas production and is expected to increase in importance to U.S. production over the next several decades.⁹⁷

Significant advances in drilling, completion, stimulation, and reservoir characterization technologies made since then are routinely applied today. Reservoirs that were either ignored (tight sands) or thought relatively insignificant (coals and organic shales) are now major U.S. gas drilling plays.

Currently, the most active development of shale gas occurs in the so-called “Magnificent Seven” gas shale basins of the U.S. - Antrim, Barnett, Devonian,

⁹⁴ Xiong, H., Holditch, S. (2006). Will the blossom of unconventional natural gas development in North America be repeated in China? Society of Petroleum Engineers (SPE). P. 2.

⁹⁵ Wylie, G., Eberhard, M., Mullen, M. (2007). Unconventional Gas Technology. *Oil and Gas Journal*. PennWell Corporation. Retrieved from: <http://www.halliburton.com/public/common/trends.pdf>

⁹⁶ Ibid.

⁹⁷ *Filling the Gap: Unconventional Gas Technology Roadmap*. (2006). PTAC: Petroleum Technology Alliance Canada.

Fayetteville, Woodford, Haynesville, and Marcellus. The resource endowment in these “Magnificent Seven” gas shales, equals 5,146 Tcf (146 trillion cubic meters (Tcm)), with an estimated 715 Tcf (20 Tcm) recoverable.⁹⁸ CBM, which had its start in the U.S. San Juan coal basin, provides over 5 Bcfd (150 Mcmd); and tight gas sands provide nearly 18 Bcfd (500 Mcmd) in the U.S.⁹⁹

The technology developed in the United States has become available for application in other countries, mainly through efforts of major service companies. Until the mid 1990s, Canada’s gas production was predominantly from conventional gas formations. This conventional gas filled the available pipeline capacity and unconventional gas resources, which are more difficult to produce, were largely ignored. However, as pipeline capacity was expended and conventional gas production began approaching a peak, market conditions in Canada began to favor development of unconventional gas. Initial Canadian unconventional activity was dominated in the 1990s by infill drilling in the shallow gas play of southeast Alberta and southwest Saskatchewan and the deep basin of the Western Canadian Sedimentary Basin (WCSB). Despite the lack of significant fiscal incentives and any specific definition of tight gas, increased recovery by infill drilling has boosted current tight gas production to several billion cubic feet per day (Bcf/day).¹⁰⁰

More recently, advances in horizontal drilling and completion technology have led to the development of tight limestones in northeast British Columbia (B.C.). In 2001, the first commercial CBM production in Canada was established in the Horseshoe

⁹⁸ Kuuskraa, V. (2009). *Worldwide Gas Shales and Unconventional Gas: A Status Report*. Advanced Resources International, Inc. P. 3.

⁹⁹ Ibid. P. 3.

¹⁰⁰ *Filling the Gap: Unconventional Gas Technology Roadmap*. (2006). PTAC: Petroleum Technology Alliance Canada.

Canyon/Belly River coals of central Alberta. Today, there are more than 6,000 CBM wells in Alberta and production is expected to reach 700 million cubic feet per day (Mcf/day) by 2007.¹⁰¹ Other Canadian coals in Alberta, B.C., Saskatchewan, and Nova Scotia are being evaluated and the first commercial development of the Mannville CBM play (about a 300 Tcf resource) was announced in 2005.¹⁰² With as much as an estimated 550 Tcf of gas-in-place, the CBM potential of Canadian coals now rivals American coals, and the National Energy Board (NEB) estimates Canadian CBM production will reach more than 2 Bcf/day in the next two decades, some 12% of current total Canadian gas production.¹⁰³ Several studies have shown hundreds of Tcf of organic shale gas resource and thousands of Tcf of gas hydrates resource potential across Canada and offshore. Several companies are building upon the U.S. shale experience to evaluate organic-rich shales, and the Canadian government is involved in gas hydrates evaluation projects (onshore and offshore) around the world.

Unconventional gas production experience in the USA and Canada shows that better resource assessment strategies can help find the right places to drill; other technologies in the geosciences, reservoir engineering, drilling, well completions, stimulation and production are also very important. Application of stimulation techniques, especially hydraulic fracturing, 3-D seismic, horizontal and directional drilling, is almost always necessary for unconventional natural gas production. In addition to these technologies, continued improvements in core technical areas have resulted from industry's continuing efforts to search for more cost-effective ways to find,

¹⁰¹ *Filling the Gap: Unconventional Gas Technology Roadmap*. (2006). PTAC: Petroleum Technology Alliance Canada.

¹⁰² *Ibid.*

¹⁰³ *Ibid.*

develop, and operate natural gas fields. This trend is especially evident in the production of CBM, shale gas, and tight sand formations. New designs in drilling bits, improved well planning, and modern drilling rigs have lowered drilling costs in many regions. Advances in remote sensing, information technologies, and data integration tools have served to keep operating expenses in check. As the US National Petroleum Council reports:

“Advanced technologies contribute 4.0 trillion cubic feet (Tcf) per year of the 27.8 Tcf per year produced in the United States and Canada. This amounts to 14% of the natural gas produced during that year [for all gas sources, not just unconventional gas].”¹⁰⁴

It is apparent that technological innovations and improvements have played an important role in increasing unconventional natural gas development in North America. This technology, advanced over the past three to four decades, promises to become a worldwide commodity through efforts of many service companies. China, with its sizable unconventional natural gas potential, has every prospect of success to repeat the experience of the U.S. and Canada in adopting new technologies.

In summary, China’s demand for energy is large and growing, and its motives for development of unconventional natural gas are high. The country is undergoing a massive realignment of economic activity together with rapid population growth, social challenges, and environmental constraints. Meeting this demand in an economic and environmentally sound manner is an ongoing challenge for the Chinese energy sector. Unconventional natural gas is a reasonable alternative for China. It provides abundant,

¹⁰⁴ *Unconventional Gas. Topic Paper #29.* (2007). National Petroleum Council. P. 30.

affordable, and cleaner-burning energy to the Chinese, offering stable energy prices, security, and solutions to the climate challenge. The transfer of knowledge from North America, combined with new technology and processes tailored to specific resource plays, makes possible development of extensive resources of unconventional gas in China.

One might argue that energy security is not an issue for China, whose economy essentially relies on domestically produced coal. However, this is an erroneous opinion. With the country's shift to being a net importer of oil in 1993, energy security became a common theme of Chinese public discourse on energy. Energy security now refers to adequate, affordable and reliable supplies of imported commodities to China. In this sense, the issue of Chinese energy security and the country's growing reliance on foreign oil and gas remains a focal point of debate.

The issue of energy security and vulnerability is currently of more concern to global economies than it has ever been before. As demand grows, energy resources become strategic commodities susceptible to being used for geopolitical leverage. The growing influence of geopolitical factors on the global energy market has profound implications for the interests, strategies, and policy-making of nations as well as for the ways that oil and natural gas companies conduct their business. As a major energy consumer, China finds that its dependence on imported energy increases its strategic vulnerability and constrains its ability to pursue a broad range of foreign-policy and national-security objectives. As a solution, China appears to be determined to take action to reduce both the likelihood of supply interruptions and the economic impacts they may have on its economy and welfare. Developing substitute and alternative fuels is one of the

most important strategies for dealing with the energy shortage and energy dependence. Domestic unconventional natural gas reserves may be considered to diminish increasing concerns about security of energy supplies and to minimize dependence upon imported oil and natural gas.

Until recently, the majority of energy resources have been held by a very small group of players in OPEC, Russia, and former Soviet Union countries. However, development and production of unconventional natural gas enables China to control and operate in the global market as well. With high world oil prices expected to return when economies begin to recover from the current downturn, there is a huge potential for unconventional gas to become increasingly competitive in the global market and the more opportunities countries with abundant unconventional natural gas resources will have. Development and production of unconventional natural gas could enable China to operate in the global market while better meeting its own energy needs in a more stable and sustainable way.

CHAPTER 3: POLICY IMPLICATIONS FOR CHINA'S ENERGY SECTOR

The purpose of the present chapter is to evaluate the potential contributions of unconventional natural gas to China's energy future and to address the second research question stated in the introduction: How do current policies and regulations encourage or hinder the domestic development of unconventional natural gas? I analyze new opportunities and challenges that development of unconventional gas presents, and introduce policy implications for China's energy sector. Finally, I provide recommendations to promote development of unconventional gas within the energy policy-making process in China. In this connection, I try to map out short-term and long-term strategies as well as implications in the global context. Finally, I assess the current policies and regulations that encourage or hinder the domestic development of unconventional natural gas.

3.1 Energy Policy and Policy-making in China: New Opportunities and Challenges

From the analysis in the previous chapter, we have derived that China is a big and developing country that faces challenges in the energy sector. China is experiencing three rapidly evolving and energy-related trends that run parallel to one another: economic development, the improvement of people's living standard, and environmental degradation. On the one hand, socioeconomic transformation generates a significant amount of new energy demand. On the other hand, energy consumption causes environmental problems. China's leadership grasps the seriousness of these energy challenges. To meet them, the Chinese government has worked out a series of energy

policy initiatives. These initiatives are constituent parts of the 11th Five Year Plan (2006 – 2010).

The 11th Five Year Plan aims at sustainable social and economic development based on expansion of domestic demand, optimization of the industrial structure, conservation of resources and protection of the environment, reinforcement of the capacity for independent innovation, deepening of the reform, and a more open and humane approach.¹⁰⁵

The 11th Five Year Plan places high priority on energy conservation and environmental protection. It sets up two major energy-related objectives. The first is to reduce energy consumption by 20% per unit of GDP; the second is to ensure a more secure supply of energy and major mineral resources.¹⁰⁶

According to the Plan, China intends to achieve the resource-conserving and environment-friendly targets with the help of four key approaches: structural adjustments, technical improvement, enhancement of management, and deepening of the reform. Structural adjustment implies reorganization of the industrial, agricultural and service sectors, acceleration of development of the service sector and non-energy intensive industries, and optimization of energy utilization. Technical improvement suggests speeding up research and development of advanced energy conservation techniques and products and their dissemination and application; implementing the main energy conservation projects; promoting energy conservation services; and strengthening

¹⁰⁵ *The Outline of the Eleventh Five-Year Plan: For National Economic and Social Development of the People's Republic of China.* (2006). National Development and Reform Commission: the People's Republic of China. P. 5. Retrieved from: http://ghs.ndrc.gov.cn/15ghgy/t20060529_70793.htm

¹⁰⁶ Yan, Yangtze. (2006). Facts and Figures: China's Main Targets for 2006-2010. *NPC & CPPCC National Committee Annual Sessions 2006*. Retrieved from: http://www.gov.cn/english/2006-03/06/content_219504.htm

international cooperation. Enhancement of management entails improving energy efficiency (EE) legal regulations and standards, establishing an EE objective-based responsibility and evaluation systems, establishing an EE evaluation and appraisal framework for fixed capital investment projects, strengthening EE management in major energy consumption enterprises, improving the EE labeling and EE product certification systems. Deepening the reform means strengthening energy pricing reform and giving the market correct price signals, broadening the sources of funds to provide stable EE investments, implementing preferential EE tax policies, improving urban heating systems, and providing EE incentives.

As reported in the Plan, in order to deal with environmental problems caused by energy use, China plans to expand and promote application of renewable energy by establishing a reliable and sustainable renewable energy market, providing financial investment and tax incentives, and establishing a renewable energy industry service system. To ensure a secure supply of energy, China hopes to increase domestic energy production by developing efficient and clean use of coal, such as coal liquefaction, gasification, and coalbed methane; accelerating the advancement of the nuclear and hydro power sectors; stabilizing production of oil; and strengthening the natural gas industry.

Development of China's gas industry and unconventional natural gas in particular will also bring substantial benefits to the country and its people by providing an enhanced supply of energy and a solution to environmental problems. Natural gas use has already been distributed across several sectors of the economy: it is an important energy source for the industrial, commercial and electrical generation sectors, and also serves a vital role in residential heating. Recently discovered abundant unconventional natural gas

resources definitely open new opportunities for China. The Chinese government is moving forward a number of major exploration, development and pipeline projects. However, all these steps occur without a coherent gas policy and in the absence of a clear energy policy which integrates energy considerations with environmental targets.¹⁰⁷ The main questions regarding the future structure of the gas industry and the nature of the incentives for investors have yet to be addressed.

Presently, all energy-related decisions are made project-by project.¹⁰⁸ While an advantage of this approach is that specific projects can move ahead without becoming stuck in too many policy debates, on the other hand each new project requires a separate round of negotiations. This is time-consuming, full of risk and uncertainty for all parties, and projects are entirely dependent on project-specific contracts and have no grounding in sector-wide policies, laws or regulations.¹⁰⁹

Formulating a policy for the gas industry would require an integrated approach to a number of related energy issues, including pricing and environmental policy.¹¹⁰ Until recently, there has been no Ministry of Energy or equivalent agency in China with sufficient and appropriate staff, resources, tools, authority and autonomy to carry out such a task.

In March 2008, however, there was an attempt to create an effective national-level energy institution, and China's new National Energy Administration (NEA) was established. NEA has a broad mandate, which includes managing the country's energy industries, drafting energy plans and policies, negotiating with international energy

¹⁰⁷ Andrews-Speed, P. (2004). *Energy policy and regulation in the People's Republic of China*. The Hague: Kluwer Law International. P. 136.

¹⁰⁸ Ibid.

¹⁰⁹ Ibid.

¹¹⁰ Ibid.

agencies, and approving foreign energy investment. Though NEA's capabilities in each of these areas are great, the agency still struggles to perform its mandate.¹¹¹ Partly, this is because of two major obstacles.

Firstly, bureaucratic infighting continues to impede energy decision-making.¹¹² NEA lacks the authority to resolve disputes among more powerful actors, such as the National Development and Reform Commission (NDRC), the National Energy Commission (NEC) and major state-owned energy companies. Their competing and conflicting interests undermine not only policy design and implementation but also the drafting of laws and regulations and further restructuring of the energy bureaucracy.

Secondly, China's politically powerful and relatively autonomous state-owned energy companies play a large role in shaping the country's energy policy.¹¹³ Large energy companies take advantage of the failure of the national-level energy bureaucracy to promote their own interests.

Consequently, the challenge of formulating a gas policy within the framework of a coherent energy policy remains to be addressed.

3.2 Recommendations for Promoting Development of Unconventional Natural Gas in China

The scale of challenges China faces today is perhaps larger than what any country has experienced before. China needs additional sources of energy to meet the demand. In order to satisfy the needs of economic development and population growth in an

¹¹¹Downs, E. S. (2008). *China's "New" Energy Administration*. P.. 43. Retrieved from: http://www.brookings.edu/~media/Files/rc/articles/2008/11_china_energy_downs/11_china_energy_downs.pdf

¹¹² Ibid. P. 45.

¹¹³ Ibid. P.. 43.

environmentally sound manner, China has to ensure sufficient, reliable, cheap, clean and convenient forms of energy.

Review of the 11th Five Year Plan (2006 – 2010) suggests the country is already in the right way, but further work is needed. The Chinese government should continue to encourage promotion of energy resource diversification and search for alternatives to conventional energy resources. It is apparent that China has an abundance of unconventional natural gas that may help the country to achieve its socio-economic goals and meet its environmental aspirations. Therefore, the Chinese government should take seriously expansion of the natural gas market and give considerations to the potential of unconventional gas, such as tight gas, coalbed methane, and shale gas.

In this connection, the following approaches would be helpful:

1. *Continue to encourage increased efficiency and conservation through various market-oriented incentives and consumer education.* The Chinese government and energy industry should focus on promoting energy resource diversification and natural gas utilization. They need to convince the public that they can produce gas in an environmentally friendly and responsible way. Industry should work on improving the public understanding of energy infrastructure, focusing on education of local opinion leaders on the scientific and economic aspects of the topic. Greater cooperation between the users (oil and natural gas exploration and production companies) as well as governmental agencies is central to this task.
2. *Strengthen exploration and detailed research in order to assess potential of unconventional natural gas in China and its extractable volumes.*

3. *Reinforce collaboration with foreign companies and government agencies on unconventional natural gas development.* Collaboration and partnership are vital because they lead to access to additional expertise and resources.
4. *Stimulate research, development and application of new technology specifically for unconventional natural gas.* As more unconventional gas resources are developed, the average permeability of the producing reservoirs will continue to decrease, requiring the industry to find and apply new technologies and best practices that enable low permeable wells to produce at economic flow rates. Investment initiatives should be taken by the government agencies and energy industry. It is also essential for researchers and developers to investigate key unconventional natural gas issues in a proactive, comprehensive and strategic manner.
5. *Design and enact legislation aimed at unconventional natural gas development.* Legislation should address: the near-term issues of the streamlining of permitting unconventional gas reservoirs development and energy efficiency; the mid-term issues of unconventional gas facility construction and the opening of reservoirs for development; and the long-term issues related to development of pipelines and LNG, and encouragement of advanced production. Collaboration of several agencies is needed with the National Energy Administration at the head. This legislation should be worked out in the framework of the overall formulation of a policy for the gas industry. Special emphasis should be placed upon developing of the regulatory framework that protects the environment.

Taking these steps will yield the following outcomes:

1. Contribute to sustainable economic and social development.
2. Limit negative environmental impacts.
3. Improve energy efficiency.
4. Contribute to the development of a self-sufficient natural gas market.
5. Increase development and penetration of advanced technologies and expertise.
6. Reinforce the country's position in the global energy market by integrating into the international natural gas market.
7. In the global context, help to strengthen collaboration and reach mutual understanding on the vital energy-related issues. Development of unconventional natural gas in China will definitely help to reduce emissions of greenhouse gases and promote energy efficiency and conservation throughout the world. It will also help China to perform an important role in the international energy market and provide opportunities to export both pipeline gas and LNG.

At this moment, as China is preparing the new 12th Five Year Plan, the proposed recommendations are particularly timely and relevant. They may help to address the current economic, social, and environmental challenges in a new way and contribute to the formulation of an improved energy strategy in China.

CONCLUSION

Theoretical framework and factual analysis outlined above have addressed two main research questions and confirmed the hypothesis. Economic growth, social development, environmental constraints, and technological breakthroughs have proved to be the key determinants encouraging the domestic development of unconventional natural gas in the People's Republic of China. These factors are also emphasized as fundamental for improvement of the current energy strategy of the country.

Economic growth is the most significant factor underlying a strong demand for energy and development of unconventional natural gas in China. The country's economic growth depends heavily upon energy sources, both domestic and foreign. The recent global economic downturn weakens China's demand for energy, as manufacturing and consumer demand for goods and services slows. However, with the economic recovery anticipated after 2010, China will return to the trend in growth in income and demand for energy resources. In addition, increase in China's economy will be stimulated by current reconsideration of macroeconomic policies, trade liberalization, more flexible exchange rate regimes and lower fiscal deficits as well as microeconomic and structural reforms, including privatization and regulatory changes.

China's aspirations to settle urging social problems are the second factor that will indirectly have a considerable impact upon energy demand. In response to the economic downturn, the Chinese government approved the stimulus package aimed to make investment in key social areas. Such progress in building human and physical capital infrastructures, together with the population growth, labor force participation rates,

capital accumulation, and productivity improvements, will definitely play a significant role in determining the medium- and long-term needs for energy resources.

Rapid economic growth, population increase and intensive social development led China to severe environmental constraints. Over the last two decades, heavy dependence of the country on coal has caused increased greenhouse gas emissions which in turn resulted in serious air and water pollution, and soil degradation. The electric power and industrial sectors are the principal end users of coal and major contributors to environmental degradation. In addition, accelerating urbanization process accompanied by employment pressures, consumption and large-scale construction of infrastructure and buildings affects the increase in demand for materials accompanied with the overall energy demand and emissions. Finally, the growing residential sector as a big energy consumer also has a negative impact on the environment.

Thereby, the scale of challenges China faces today in the energy sector is perhaps larger than what any country has experienced before. In order to satisfy the needs of economic development and population growth in an environmentally sound manner, China needs energy resources, but has to ensure sufficient, reliable, cheap, clean and convenient forms of energy.

The whole situation is worsened by the imperfection of China's energy sector itself. The lack of national ministry of energy or equivalent agency for a long time period led to many energy-related challenges. The recently established National Energy Administration has initially inspired high hopes for being an effective national-level energy institution. However, continuous bureaucratic infighting and competing and conflicting interests of major state-owned energy companies hinder the design and

implementation of an effective energy policy, and the drafting of laws and regulations and further restructuring of the energy sector.

To this end, it is vitally important for China to take the right decision and reconsider the current energy strategy and policy. This is particularly timing and relevant because the country is presently preparing the new 12th Five Year Plan. As a possible approach to addressing the dilemma of energy, economy and the environment, development of unconventional natural gas, such as tight gas, coalbed methane and shale gas, is proposed. This approach becomes feasible due to two major factors – technological breakthroughs which overwhelmed North America and available abundant unconventional natural gas resources in China.

The transfer of knowledge from North America, combined with new technology and processes tailored to specific resource plays, makes possible development of extensive resources of unconventional gas in China. This technology, advanced over the past three to four decades, promises to become a worldwide commodity through efforts of many service companies. China, with its sizable unconventional natural gas potential, has every prospect of success to repeat the experience of the U.S. and Canada in adopting new technologies.

Unconventional natural gas sounds to be a reasonable alternative for China. It provides abundant, affordable, and cleaner-burning energy to the Chinese, offering stable energy prices, security, and solutions to the climate challenge. Development of unconventional natural gas can help the country realize its energy self-sufficiency and reinforce its position in the global energy market by integrating into the international

natural gas market. Policy recommendations provided in this research might be helpful to strengthen China's energy strategy.

China provides an interesting and illustrative case study. By means of this specific case, I tried to emphasize the importance of the research issue as a whole. The challenges experiences by China reflect the dilemma of the global community which urgently requires establishing wise relationships between energy, economy, and the environment.

Besides major findings listed above, this research had some limitations. The major limitation arose from the novelty of the examined issue. As already mentioned, there has been no comprehensive and substantial research done on unconventional natural gas development in the Peoples' Republic of China, especially with regard to the analysis of future opportunities and threats of unconventional natural gas development, and reevaluation of the China's overall energy strategies. The data as well as theoretical base was scarce.

However, the present topic opens a wide and unexplored research area that provides opportunities for new innovations and ideas. It opens horizons for other studies and secures a basis for new research initiatives.

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