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SOLUTION TO THE UKAINIAN GAS CRISES AND ACHIEVEMENT OF ENERGY EFFICIENCY OF UKRAINE THROUGH THE DEVELOPMENT OF COALBED METHANE

A Thesis

Submitted to the McAnulty College and

Graduate School of Liberal Arts

Duquesne University

In partial fulfillment of the requirements for

the degree of Master of Arts

By

Valeriya Denisenko

August 2010

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Valeriya Denisenko

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SOLUTION TO THE UKAINIAN GAS CRISES AND ACHIEVEMENT OF ENERGY EFFICIENCY OF UKRAINE THROUGH THE DEVELOPMENT OF COALBED METHANE

By

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ABSTRACT

SOLUTION TO THE UKAINIAN GAS CRISES AND ACHIEVEMENT OF ENERGY EFFICIENCY OF UKRAINE THROUGH THE DEVELOPMENT OF COALBED METHANE

By

Valeriya Denisenko

August 2010

Dissertation supervised by Kent Moors

Historically, Ukraine has been a net energy importer, needing oil and natural gas for the effective functioning of its industries and satisfaction of domestic needs. Ukraine's independence immediately followed the disintegration of the Soviet Union in 1991, resulting in its ultimate dependency on oil and natural gas imports from Russia. During the last few years, the parties had undergone a number of disagreements that led to the disruption of natural gas supply to Ukraine, and political instability within the country. The necessity to redevelop Ukraine's domestic energy industry and adjust it to an available domestic natural gas source became vitally important for the national government. The present project provides a summary of the Ukrainian energy policy dynamics from 2006-present time. It specifies current energy trends, renewable energy sources, alternatives, and provides recommendations for the Ukrainian government on

how to integrate successful international experiences into the development of coalbed methane in the local environment.

ACKNOWLEDGEMENT

I would like express my sincere gratitude to my Thesis Director, Dr. Kent Moors, for his immediate assistance, guidance and inspiration while working on my research. I would also like to thank my second Thesis Reader, Dr. Joseph Yenerall, for his invaluable contribution and cooperation. I am very thankful to my family, friends and beloved people for their support and belief in me and what I am doing.

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LIST OF ABBREVIATIONS

AEA Austrian Energy Agency

CBM Coalbed Methane

CEE Commonwealth of Independent States

CIA Central Intelligence Agency

CMM Coalmine Methane

EBRD European Bank for Reconstruction and Development

EIA Energy Information Administration

EPA Environmental Protection Agency

EU European Union

GDP Gross Domestic Product

GHG Greenhouse Gas

IEA International Energy Agency

IER Ukrainian Institute for Economic Research and Policy Consulting

IMF International Monetary Fund

JI Joint Implementation

NEP National Energy Policy

OECD Organization for Economic Cooperation and Development

OPEC Organization of Petroleum Exporting Countries

R&D Research and Development

UA Ukraine

UNFCC United Nations' Framework Convention on Climate Change

USDW Underwater Source of Drinking Water

USSR Union of Soviet Socialist Republics

Chapter 1

Introduction to the Problem

1.1 Definition Statement

The present research is a case study of the Ukrainian energy policy dynamics influenced by the severe double gas crises that made Ukraine entirely dependent on key energy sources such as natural gas and crude oil. The import of energy resources coupled with geopolitical issues, insufficient amount of local indigenous energy sources and lack of relevant infrastructure impede the country from becoming a fully developed, self-sufficient and energy independent state. Given the existing energy crises, the Ukrainian industrial complex and economy have developed a significant dependency on the supply of natural gas which eventually intended to satisfy the vital needs of the Ukrainian population. Moreover, such dependency created difficulty for the country's further development, and produced a negative impact on the relations with key energy exporters.

The main emphasis of the present project is placed on the analysis of available energy alternatives suitable for Ukraine's geology and environment. The aim of the research is seen in finding effective, medium term solution based on the most available energy trend which could be easily integrated in the existing infrastructure and would require minimum amount of capital investment. Such a solution would help develop a rational national energy policy and reduce Ukraine's dependency on energy imports.

Historically, Ukraine has been a net energy importer, needing oil and natural gas for effective functioning of its important industries and satisfaction of domestic needs.

Ukraine's independence followed immediately after the disintegration of the Soviet Union in 1991, resulting in its ultimate dependency on oil and natural gas imports from Russia. During the last few years, the parties had undergone a number of disagreements that led to the disruption of natural gas supplies to Ukraine, and political instability in the country. The necessity to redevelop domestic energy industry and adjust it to the most available domestic natural gas source has become vitally important for the national government.

The present project provides a summary of the Ukrainian energy policy dynamics from 2006-present time. It specifies current energy trends, renewable energy sources and alternatives, and provides recommendations for the Ukrainian government on how to integrate the most successful international experiences related to the development of domestic energy resources into the local environment.

Analysis of the Ukrainian energy policy and gas crises is based on the overview of basic economic indicators, energy demand and supply, energy production and imports, coal mining industry statistics, and government projections. Secondary data provided by the International agencies, along with the information obtained from the Ukrainian governmental bodies and research institutions, will be utilized for the completion of the analysis mentioned above.

The primary emphasis will be placed on the overview of the Ukrainian coal mining industry which provides ample opportunities for the development of a sustainable domestic unconventional energy resource. The comparison between available energy alternatives, renewable energy, on one hand, and unconventional natural gas on the other hand, will be made to find the most effective, quick, and economically viable solution to the existing gas crises and effective industrial complex operation. Presently, most renewable energy technologies developed in Ukraine specify utilization of hydropower and biomass fired heating boilers, wind power plants, and geothermal heating systems. In contrrast, the development of unconventional natural gas extracted from coalbeds will be viewed as a major key component to the transition to a cleaner energy economy.

As aforementioned, one of the options for the development of the Ukrainian energy industry is seen in the extraction of unconventional gas sources trapped in the form of coalbed/coalmine methane. According to the most modest calculations, Ukrainian coalbed methane resources amount to approximately 71 million cubic feet,[1] which places Ukraine in the first nine countries leading worldwide coal production.[2]

Extraction of this type of unconventional natural gas is a relatively new but already a highly prosperous industry. Countries such as the US, China, India, Australia, Poland, Germany, and many others have successfully introduced this experience into their domestic energy sector.

Heretofore, the national policies on the increase of the domestic energy sources production only stated the facts about coalbed methane availability excluding the policy of the Ministry of Coal Industry of Ukraine [as of 1996]. The downfall of the project is found in the poor wells' development and the ineffective method of coalbeds treatment. According to preliminary estimates of the Razumkov research institute based in Kiev,[3] with the utilization of contemporary technological achievements in coalbed methane

[1] 2, 000, 000 cubic meters (1 cubic meter= 35.3 cubic feet)

[2] A. Perrodon (1996). Coalbed Methane. *Tsentr Razumkova*. Retrieved from http://www.razumkov.org.ua/ukr/article.php?news_id=5 on 18 April 2010

[3] A. Perrodon (1996). Coalbed Methane. *Tsentr Razumkova*. Retrieved from http://www.razumkov.org.ua/ukr/article.php?news_id=5 on 18 April 2010

extraction, through adoption of the relevant legislation base and taxation policy stimulating the production of coalbed methane, it is possible to increase natural gas production almost two times.

The introduction of relevant policy recommendations related to the strengthening of the domestic energy complex operation through the industrial development of unconventional natural gas will lead to gradual improvement on the overall economic situation, reduce external state debt, and redirect the investments into the development of domestic light and heavy industries. Policy implications, in turn, will help predict the overall outcome and reduce financial risks involved in the realization of the project.

1.2 Rationale for the Research and Current Status of the Problem

The current state of the problem with natural gas supply and gas crises – caused mainly by the heavy reliance on natural gas imports due to scarce availability of domestic energy resources and insufficient funding of the domestic gas industry – resulted in deterioration of the country's overall economy highlighted by an increase in both unemployment and inflation rates.

The geopolitical factor and issue of energy efficiency make an impact on the overall situation, as Ukraine is seen as one of the key transit states whose pipelines allow the delivery of the Russian natural gas to the European Union. The decisions of the Russian state-owned natural gas company, Gazprom, to construct two major pipeline systems abiding the territory of Ukraine – the Nord and the South Streams – only contribute to the deterioration of the situation with the natural gas supply in Ukraine.

The present research project focuses on the most affordable and easily integrated energy crises solution as seen in the development of natural gas from Ukrainian coalbeds.

Although the trend associated with the development of such unconventional gas is relatively new, it has drawn a lot of attention and interest worldwide. Numerous developed and developing countries rich in coal deposits are trying to replicate the US experience, which has pioneered the production of unconventional natural gas mostly through the development of shale gas and coalbed methane. Ukraine is one of these nations. In order to start production of domestic natural gas, Ukraine needs an effective energy policy and a relevant legislation base to be designed, assistance from international service and research companies, and necessary equipment to be provided. Cooperation with the international service, research and development (R&D) companies is seen to be of great benefit for the Ukrainian industrial complex. The core assets of such companies include direct funding of the research projects, road construction and transport infrastructure inside the country. Even the fact that such research and development companies take control over large businesses in industrial areas of Ukraine, such as Donetsk and Lugansk regions, through their subsidiaries, their contribution to the development of Ukrainian industrial complex is of great significance. Most of the service and R&D companies are ready to provide highly qualified assistance and upgraded equipment for coalbed methane exploration, drilling, utilization and recovery.

Taking into consideration the interest of domestic and foreign investors in the development of coalbed methane, one can hardly deny the importance of the introduction of the relevant policy recommendations for the Ukrainian government on these matters.

1.3 Statement of the research objectives

The present research paper has the objective to investigate national energy efficiency and the availability of energy resources to find the most effective resource and process for reducing Ukraine's dependency of Ukraine on energy imports.

1.4 Research Question

What is seen as the most efficient and sustainable solution to the Ukrainian gas crises which would significantly reduce dependency of Ukraine on energy imports and contribute to energy independence?

1.5 Definition of Terms: Conceptual Framework

The list of the following terms will be frequently used throughout the present project:

- **unconventional gas –** gas sources coming from: (1) tight gas formations (especially Western Sands) ; (2) mineable and unmineable methane rich coal beds; (3) gas bearing shales (especially in the Appalachian basin); (4) geothermal-geopressured dissolved methane in formation waters (Gulf Coast area); (5) methane hydrate;[4]
- **coalbed methane (CBM) –** methane gas recovered from un-mined coal seams;[5]

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[4] R. Walter and H.O. Pfannkuch. Unconventional Ideas About Unconventional Gas. *SPE Unconventional Gas Recovery Symposium*, 16-18 May 1982, Pittsburgh, Pennsylvania; Copyright 1982, Society of Petroleum Engineers of AIME. Retrieved from http://www.spe.org/elibinfo/eLibrary_Papers/spe/1982/82UGR/00010836/00010836.htm on 18 April 2010

[5]Coalbed Methane. World Coal Institute. Retrieved from http://www.worldcoal.org/coal/coal-seam-methane/coal-bed-methane on 19 April 2010

- **coalmine methane (CMM)** – methane recovered from working mines;[6]
- **NEP (National Energy Policy) –** proposed policy recommendations which are signed to help bring together business, government, local communities and citizens to promote dependable, affordable and environmentally sound energy for the future;
- **Adsorption -** is a process where a solid is used for removing a soluble substance from the water. In this process active carbon is the solid;[7]
- **Permeability –** a measure of how easily a fluid can pass through porous medium;[8]
- **Macropores –** spaces between the cleat system and other natural fractures essential for the transport of water and methane through seams but relatively unimportant for methane storage;
- **Micropores –** capillaries and cavities of molecular dimensions in the coal matrix which are essential for gas storage in the adsorbed state.
- **Hydraulic fracturing (**or **"fracing") -** is a technique used to allow oil and natural gas to move more freely from the rock pores where they are trapped to a producing well that can bring them to the surface. The technology was developed in the late 1940s and has been continuously improved and applied since that time. The process of hydraulic

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[6] Coalmine Methane. World Coal Institute. Retrieved from http://www.worldcoal.org/coal/coal-seam-methane/coal-mine-methane on 19 April 2010

[7] Adsorption/Active Carbon. Water Treatment Solutions LennTech. Retrieved from http://www.lenntech.com/library/adsorption/adsorption.htm#ixzz0herMZWXn on 19 April 2010

[8] Permeability. Geoingenieer Society. Retrieved from http://www.geoengineer.org/files/permy-Sivakugan.pps on 20 April 2010

fracturing plays a major role in the development of virtually all unconventional oil and natural gas resources;[9]

- **energy infrastructure** - the ongoing effort to provide sufficient primary and secondary energy sources to satisfy needs of population which involves both installation of established technologies and R&D to create new energy-related technologies. Major considerations in energy planning include resource depletion, supply production peaks, security of supply, cost, impact on air and water pollution;

- **energy statistics –** refers to collecting, compiling, analyzing and disseminating data on commodities such as coal, crude oil, natural gas, electricity, or renewable energy sources [biomass, geothermal, wind or solar energy, etcetera], when they are used for the energy they contain.[10]

Nowadays it is quite difficult to predict the approximate feasibility of the project of unconventional gas development as many key factors – world's political and military situation, presidential elections in Ukraine, economic crisis, increase or decrease of energy sources prices, currency devaluation, etcetera – make the policy implementation quite dependable on them.

1.6 Research design

The present research paper is based on the use of non- experimental methods as **historical** and **descriptive researches** to gather relevant information. The former helps

[9] Hydraulic Fracturing. Interstate Oil and Gas Compact Commission. Retrieved from http://www.iogcc.state.ok.us/hydraulic-fracturing on 20 April 2010

[10] Energy Statistics. Retrieved from http://www.costaricatourguide.org/hd/index.php?t=Energy+statistics on 18 April 2010

depict the situation with Ukraine's energy resources distribution in the past. This has significantly changed over the last two decades due to disintegration of the Soviet Union, proclamation of independence of Ukraine in 1991, the economic crisis' in the 1990s and 2008, and the presidential elections in 2004 and 2010. The use of historical research rests on the utilization of media reports in the English, Russian and Ukrainian languages, wire services and newspapers, and web-based government and private company data. Illustrations of these data sources include **descriptive research** that depicts the current state of the phenomenon, and generally contains case studies which provide researchers with an insight and details about the problems' status. It is necessary to review such case studies on the successful development of coalbed methane internationally, and introduce this valuable experience to the Ukrainian energy environment.

1.7 Results of the Analysis

Results of the analysis obtained from the research project will help determine the most available and effective solution to the current problem of the energy supply and a list of policy recommendations that would represent significant contribution to the development of effective national energy policy. The aim of these measures is to reduce the risk of continuing energy dependence and the economic and energy crises to a minimum.

Chapter 2

Review of the Relevant Literature

2.1 On Coalbed methane

Natural gas, oil, and coal are defined as fossil fuels that release energy while burning to produce electricity for the industrial and household utilization. Unlike coal, which is typically formed in non-marine environment from the remains of land vegetation, oil and gas are formed from the organic remains of marine organisms which become entrained within sea-floor sediments.[11]

Historically, conventional natural gas deposits have been the easiest ones to explore, develop and mine. With the introduction of new geological survey technologies and advances in the discovery of different forms of natural gas formations (known as 'unconventional natural gas'), the overall worldwide supply picture has significantly changed. Thus, unconventional gas has been defined as gas that is more difficult, and less economically sound to extract, usually due to the lack of fully developed technology or high extraction cost.[12] According to the same information source, The Natural Gas Policy Act of 1978 has made significant contribution into deregulation of the gas industry by providing incentives towards searching and extracting of unconventional natural gas by spurring investments into the field exploration and development of drilling techniques by making this type of natural gas commercially extractable. Following this act, the Federal Energy Regulatory Commission established price ceilings for natural gas

[11] R. Shepherd and R. Randell, Discovering Fossils. Retrieved from http://www.discoveringfossils.co.uk/fossilfuels.htm on 21 April 2010

[12] Unconventional Natural Gas Resources. Retrieved from http://www.naturalgas.org/overview/unconvent_ng_resource.asp on 21 April 2010

produced for interstate commerce. Although intrastate markets had no price ceilings and experienced higher prices, their supply appeared to be secure.[13]

Unconventional gas is found in the following categories: deep gas, tight gas, gas-bearing shales, coalbed methane, geopressurized zones and Arctic and sub-sea hydrates. *Deep gas* is typically found at the depths of more than 15,000 feet whose pay-zones are deeper than of the conventional gas. *Tight gas* is usually trapped in hard rock formations that are usually impermeable or non-porous such as tight sand. *Shale gas* is a type of natural gas that is found in shale deposits which are formed from mud of shallow seas that existed more than 350 million years ago during the Devonian period of Paleozoic Era. *Coalbed methane* is found in underground seams which are mined by digging into the seam and removing coal. Such coal seams contain natural gas either within the seam itself or the surrounding rock. Such gas is trapped underground and is usually not released into atmosphere until coal mining activities unleash it. *Geopressurized zones* are known to be located underground at the depth of from 10,000 to 25,000 feet under extremely high pressure for their depths. These areas are formed by considerable amount of clay deposits located on top of the porous or absorbent substance such as sand or slit. The compression of the clay accumulates natural gas deposits in the sand or slit under a very high pressure. *Methane hydrates* resembling melting snow were first discovered in permafrost regions of Arctic. They are made up of the lattice of frozen water that forms 'cage'-alike space around molecules of methane. According to the estimates of the U.S. Geological Survey, methane hydrates may contain much more organic carbon than the

[13] Independent Statistics and Analysis. U.S. Energy Information Administration. Retrieved from http://www.eia.doe.gov/oil_gas/natural_gas/analysis_publications/ngmajorleg/ngact1978.html on 21 April 2010

global reserves of oil, coal and gas combined.[14] *Thus, scientific and technological advances of unconventional gas development have proved its enormous potential in increasing the global supply of natural gas.*

2.1.1 The Coal Resource

Coal is defined as 'a black or black brownish solid combustible substance formed by the partial decomposition of vegetable matter without free access of air and under the influence of moisture and often increased pressure and temperature'.[15]

There are four main types of coal: lignite, sub-bituminous, bituminous and anthracite coal. The texture of low quality coals such as lignite and sub-bituminous is known to be softer, wetter, earthier and possess lower energy content. *Lignite coal* or 'brown coal' is the softest type of all coals of brownish black color and crumbly texture which is mostly used for power generation. The heating content of lignite is approximately 4,000-8,000 Btu's per pound. The carbon content of lignite is 25%-35% with very high water content - about 35 percent. It is predicted that demand for lignite coal will increase by 1 per cent a year through 2030[16]. *Sub-bituminous coal* is a medium soft coal that contains less moisture than lignite and less crumbly. Like lignite it is primarily used for power generation with the carbon content of 35%-45% and heat value 8,000-13,000 Btu's per pound.[17] Other industries that extensively utilize sub-bituminous coal are cement, chemicals and pharmaceuticals production. Harder types of coals such as bituminous and anthracite have darker, shinier color and drier texture. *Bituminous coal*

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[14] Unconventional Natural Gas Resources. Retrieved from http://www.naturalgas.org/overview/unconvent_ng_resource.asp on 21 April 2010

[15] Coal. The World Coal Institute. Retrieved from http://www.clean-energy.us/facts/coal.htm on 23 March 2010

[16] Types of Coals and Their Uses. Factbox. Retrieved from http://uk.reuters.com/article/idUKL1570461420070815?pageNumber=2&virtualBrandChannel=0 on 23 March 2010

[17] Why Is Coal Important? Retrieved from http://www.rocksandminerals.com/coal.htm on 24 March 2010

contains less moisture than sub-bituminous coal, its carbon content varies from 45% to 85% with heating content of 10,500-15,000 Btu's per pound. Bituminous coal can be of two types – thermal steam coal and metallurgical coking coal. Thermal steam coal is mainly utilized for industrial uses. Its demand is expected to grow at 1.5 percent a year until 2030. Metallurgical coking coal is primarily used in the production of steel and iron and its demand is predicted to grow at 0.9 per cent a year until 2030. *Anthracite coal* is the hardest of all four types of coals with 85%-95% average carbon content and the heating value of more than 15,000 Btu's per pound. Main advantages of anthracite coal are that is a clean burning fuel that can not be stored underground without causing environmental problems. It is mainly utilized in water purification and treatment plants for home heating.[18]

Coal can be burned as fuel or gasified to create a synthesis gas with the further utilization as a feedstock for the production of chemicals, fertilizer, and electric power. Moreover, coal is the most abundant and widely distributed mineral fuel with reserves estimated at more than 930 billion short tons[19] as of January 1, 2006. According to some estimators, the resulting ratio of coal reserves to consumption will last approximately 138 years meaning that at current coal consumption rates.[20] Following the coal reserves statistics at the end of 2007 prepared by BP, non-OECD European and Eurasian countries possess 32.1% of global coal reserves. By comparison the US coal reserves make up 29.6%. This makes these areas the biggest coal bearing regions worldwide.[21]

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[18] Types of Coals and Their Uses. Factbox. Retrieved from http://uk.reuters.com/article/idUKL1570461420070815?pageNumber=2&virtualBrandChannel=0 on 17 March 2010

[19] 1 ton of coal=16,200,000 to 26,000,000 Btu. Retrieved from http://www.uwsp.edu/cnr/wcee/keep/Mod1/Whatis/energyresourcetables.htm on 17 March 2010

[20] The Energy Information Agency (EIA) (2010). Retrieved from http://tonto.eia.doe.gov/energyexplained/index.cfm?page=coal_reserves on 23 March 2010

[21] BP Statistical Review of World Energy (2008). Beyond Petroleum. Retrieved from http://www.publicagenda.org/charts/world-coal-reserves on 23 March 2010

In accordance with the US Energy Information Agency, proven coal reserves of Ukraine are estimated at 37.6 billion tons with 17.9 billion short tons of which is anthracite and bituminous coal and 19.7 billion tons of lignite and sub-bituminous coal. In 2004 Ukraine produced 69.3 million short tons of hard and brown coal with the consumption rate of 77.5 million short tons which made Ukraine a net coal importer notwithstanding its reserves.[22] Brown or lignite coal is known to be an important raw material that is used for power engineering, production of liquid fuel, gas and sorbent. The Ministry of Coal of Ukraine predicts a steady rise of its share in total coal output as 4% of world energy is produced from brown coal. The experts believe the development of coal industry of Ukraine is associated with the expansion of coal use in heat power engineering. Brown coal reserves of Ukraine are estimated at 6-8 billion tons and are generally concentrated in the Dnieper brown coal basin as well as in Kharkov, Cherkasy, Zhitomir, Kirovograd and Poltava regions.[23]

Thus, *such high concentration of considerable coal reserves and mines in the country has created a lot of opportunities for the Ukrainian energy industry to develop and produce its natural gas in the form of coalbed methane*.

2.1.2 The Coalbed Methane Resource

Methane is the cleanest burning and a relatively cheap fossil fuel that can be domestically developed. Historically, the presence of methane in coalbeds has been considered as a hazard to coal mining and its extraction has been mainly associated with the reduction of mining hazards. Only a few decades ago the potential of coalbed methane utilization as an unconventional energy source and as an economically producible resource has been widely recognized (Rightmire, 1984,

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[22] Independent Statistics and Analysis, Ukraine. US Energy Information Administration. Retrieved from http://www.eia.doe.gov/emeu/cabs/Ukraine/Coal.html on 23 March 2010

[23] Report on Ukraine's Brown Coal Reserves (2007). The Ministry of Coal of Ukraine. Retrieved from http://www.mvp.gov.ua/mvp/doccatalog/document?id=69710 on 17 April 2010

p. 1). Emission of methane gas into the atmosphere accounted for the large fans apparent in the coal mines. Commercial production of methane took place from 1920 into the Great Depression in southeastern Kansas from the Mulky coat seam where the output from vertical drilling at the depth of 1000 feet was termed shale gas (Stoeckinger, 1990).

Coal rank and maturity depend on the temperature. The generation of methane occurs during the process of coal maturation (Rightmire, 1984, p. 1). Methane, as a rule, is found in coals either adsorbed on the coal surfaces as free gas in fractures and large pores or dissolved in ground water coalbeds. The depth of burial, pressure, rank of coal, and its related porosity distribution influence the amount of coal stored. Rightmire (1984, p.2) pays due attention to the fact that that production of methane from coalbeds began in 1900s and pinpoints that such key factors as depth, rank, permeability, water saturation, and a number of other hydrogeologic characteristics influence coalbed methane producibility (Rightmire, 1984, p. 1). Only recently the development of coalbed methane has become a target of major exploration as the coalbed methane wells were considered to be low-pressure and low-flow producers (Rogers, 1994, p. 10). Hydrostatic pressure is a common factor for the most of the coalbed reservoirs. Once the depletion of free gas in the fractures occurs, methane desorption and diffusion through the matrix to the fractures control the production process. According to Rightmire (1984, p.2), to permit desorption and gas flow to the wellbore, water saturation in the wellheads must be considerably reduced. Moreover, dual matrix and fracture permeability systems tend to exhibit an anomalous decline curve (Rogers, 1994, p. 11):

> Although the “free” gas present in the fractures and macropores may be produced in a typical reservoir response, the continual introduction of gas into the fractures by diffusion - as the zone of influence around the well expands - results in more gas being produced with time. This phenomenon, - a negative decline curve – was first observed for a well in the San Juan Basin, which has produced in excess of a billion cubic feet of gas over a 30-year period, the first 20 years with a negative decline curve (Rogers, 1994, p. 11).

Nevertheless, considering all the expenses related to the discovery of conventional natural gas, Rogers insists that finding costs of coalbed methane are usually lower and this should to be an incentive for development in the countries that develop unconventional natural gas (Rogers, 1994, p. 2).

2.2 Development of Coalbed Methane Industry

Historically, the beginning of the coalbed methane industry has only been seen for a few decades, but has already proven to be one of the most successful ways of unconventional natural gas development. The initial intent of the coalbed methane industry was to make coal mines safe from explosions that caused numerous fatalities among miners over the past two centuries (Rogers, 1994, p. ix). This process resulted in a self-efficient system with considerable extraction of natural gas source. Rogers (1994, p. x) has described the entire process as a highly profitable business that reduces hazards of mine explosions, emission of greenhouse gas into the atmosphere, air pollution (as methane is considered a clean burning fuel) which can dramatically reduce reliance on imported fossil burning fuel, subsequently contributing to the sustainment of a cleaner environment.

Currently, when much is being done to increase global environmental awareness, the development of the coalbed methane industry is a valuable solution. Coalbed methane can easily satisfy following national goals: the *provision of a clean-burning fuel; substantial increase of the natural gas reserve base; improvement of coal mining safety; significant reduction of methane emission in the atmosphere from coal mines; and the* *provision of means to utilize abundant coal resource which is often too deep to mine* (Rogers, 1994, p. 1).

Notwithstanding the fact that the United States has pioneered the project on coalbed methane development, the valuable experience has been borrowed by countries such as Spain, France, Poland, Australia, Canada, the Peoples Republic of China, Great Britain, Germany, Russia, and many others. Those Eastern European countries such as Ukraine, where coal is the only natural energy source, are interested in recovering their methane reserves.

Rogers (1994, p. 2) mentioned that a federal tax credit triggered coalbed methane development. He sets an example of how methane used to be produced from wells drilled into coal seams, and within a certain period of time the fracturing of those coal seams and their dewatering managed to increase the production rates and allowed commercial utilization of methane (Rogers, 1994, p. 14).

2.3 Comparison of Unconventional Gas and Conventional Gas

It has already been aforementioned that the coalbed methane development industry is based on the merged techniques borrowed from conventional oil- and gas-field development. However, the utilization of the new industry required major changes to be introduced into the extraction of conventional natural gas. Such changes concern discoveries and exploration of coalbeds, consideration of their properties, gas accumulation procedures, gas storages techniques, and the introduction of new ways of drilling and water disposal.

Rogers has emphasized (1994, p. 2) that it is *emerging* that is a unique process necessary for coalbed methane production:

> Research behind those innovations has added knowledge often applicable to conventional oil and gas operations, as illustrated by two examples. First, for the first time minethroughs provide visual study of fractures from hydraulic fracturing. Second, the effect on in-situ stresses and extreme rock properties on the coal reservoir performance are so important that their study has added significantly to the pool of oilfield knowledge…

The invention of new methods for the geological exploration, introduction of new computer technologies and 3-D modeling, drilling techniques and equipment has made the development of coalbed methane one of the most successful projects on unconventional natural gas production.

2.4 Gas Composition, Adsorption and Water Production

It has already been discovered that coalbed gas is of high quality, higher in methane than the gas developed using conventional ways, and is suitable for direct input into natural gas pipelines (Rogers, 1994, p. 15). Unlike free gas, which occupies void spaces between the sand grains, the methane adsorbed in micropores adjacent to the solid coal surface and is stored in coal in large quantities (Kuuskra, 1989).[24] After the water is removed, the adsorbed gases are released upon the reduction of pressure in the coal matrix.

[24] A clear illustration of the enormous surface area in the micropores of the coal is that 1 lb of coal has a surface area of 55 football fields, or 1 billion of sq ft per ton of coal – V.A. Kuuskra and C.F. Brandenburg, “Coalbed Methane Sparks a New Energy Industry”, *Oil & Gas Journal* 87, No. 41 (Oct. 9, 1989) 49.

It is important to mention that coalbed methane production is always associated with the prolific generation of formation waters from natural fractures of the coal. It is necessary to make sure that these waters are removed before methane can be desorbed in the early production life of a well (Rogers, 1994, p. 15). After the first couple years of production, the amount of water decreases to small volumes for the remaining life of the well, which, according to some estimates, lasts up to 20 years. As distinguished from conventional gas development, this connate water of the pore spaces would be held immobile and not expected to be produced until the encroachment of aquifer waters signaled and impending demise of gas production (Rogers, 1994, p. 17).

Notwithstanding the fact that the initial costs of disposal of large quantities of water at the very beginning of gas well production are normally high, they keep declining rapidly thereafter (Rogers, 1994, p. 17). The water production rate is proven to decline normally to some low steady-state value (Burkett, 1991). Rogers (1994, p. 17) named one exception to this principle when wells are located near active coal mines which have already been dewatered though years of mining[25]. Other than that, the early cost of water processing and disposal, as well as the environmental concerns caused by that, are among those few factors that should be considered while the development of coalbed methane takes place.

The issue of water production and disposal has greater importance in the production of coalbed methane than in the production of conventional oil and gas. Rogers believed that water disposal costs are crucial factors when it comes to attraction of investments in marginally economic coalbed methane projects, as water disposal costs

[25] Water production is relatively low in some wells of the Central Appalachian basin, and wells in the Big Run Field of the Northern Appalachian basin are reported to have no water production (Rogers, 1994, p. 17)

make or break an economically marginal project (Rogers, 1994, p. 201). It has already been aforementioned that water disposal problems decrease within time which makes the operator experience the greatest economic 'inconvenience' during the first few years. As the history of coalbed methane development shows, water purity ranges from nearly fresh in the Powder River basin of northeastern Wyoming and southeastern Montana, to marginally saline in the Warrior Basin in the State of Alabama, to a brine in the deepest coals. If the water is relatively fresh it can be discharged on the surface, but often it is injected into rock at a depth where the quality of the injected water is less than that of the host rock. According to experts conducting the geological survey, there is another alternative suitable for the regions with high evaporation rates – to evaporate the water and collect the potentially saleable solid residues.[26]

Rogers (1994, p. 202) believed that key factors such as suspended solids, total dissolved solids, and the oxygen demand of produced waters have the most impact on water treatment. Furthermore, he mentioned another major dissimilarity between conventional reservoir and coalbeds – well-to-well interference. This is of great benefit for the water removing process. Such interference, according to Rogers, contributes to more rapid gas production as its characteristics impose commitment to develop the entire field and a large capital investment. Rogers pinpointed that the development of a lone well is highly impractical (Rogers, 1994, p. 202). Thus, the issue of water removal and disposal are among those few factors that affect economic feasibility of coalbed methane projects. According to Lawrence, coalbed methane operations result in 0.31 barrels of water produced per 1000 cubic feet of methane (Lawrence, 1993).

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[26] Energy Resource Surveys Program.USGS Fact Sheet FS-019-97. U.S. Geological Survey. Retrieved from http://energy.usgs.gov/factsheets/Coalbed/coalmeth.html on 21 April 2010

Generally, water production rates vary in different basins. Rogers emphasized the fact that ease of dewatering any well entirely depends on the coal's permeability, interference with other wells or mines and link to aquifer waters (Rogers, 1994, p. 203). The US Oil and Gas Board reports that 420 wells in the Warrior basin in the State of Alabama had the initial water production rates of 17 to 1175 barrels of water per day, averaging 103 barrels of water per day (Pashin, 1990). In the Warrior basin, the initial value is expected to be less than 250 barrels of water per day, which makes up to 70% of all wells. Those wells (developed by Taurus)[27] have an initial water production rate of 10 to 1500 barrels of water per day, with the average rate being 150 barrels of water per day (Luckianov, 1991). In accordance with the researchers from the Montana State University and Wheaton from Montana Bureau of Mines and Geology, each well produces 5 to 20 gallons of water per minute. At 12 gallons per minute, one well produces a total of 17,280 gallons of water per day. It is quite common to have one well per every 80 acres and, as seen in the Powder River Basin in Montana, there may be up to three wells per 80 acres.[28] However, the production rate is dependent upon the location of the basin (Kaiser, Swartz, 1989), and as Rogers has already mentioned, the water production process tend to decline on a steady rate for any well. Furthermore, Rogers set an example that wells located on the periphery of the pattern of the Oak Grove Field in the Warrior basin produced more water that those located in the interior part of the basin due to the vicinity and interference between wells in the midst of the pattern. Burkett, McDaniel, and Hall

[27] Taurus Exploration Inc. – a subsidiary oil and gas company of Energen Corp. (EGN) which was renamed into Energen Resources Corp. Retrieved from http://www.highbeam.com/doc/1P3-33880081.html on 21 April 2010

[28] Kristin Keith and Jim Bauder, Montana State University-Bozeman, John Wheaton, Montana Bureau of Mines and Geology (2003) , Frequently Asked Questions, Coalbed methane (CBM). Retrieved from http://waterquality.montana.edu/docs/methane/cbmfaq.shtml#why_are_people_concerned on 21 April 2010

proved that water production rates in coalbed wells of the Warrior basin decreased significantly by the end of the first month of production (Burkett, 1991).

Another problem associated with water disposal concerns processed water composition, which is relatively high in saline[29] and sodium hazards[30] based on standards used for irrigation suitability. Keith and Bauder (2003) insist on the fact that irrigation of land with coalbed methane water should be treated with care as with time, salts accumulations in the root zone could affect plant growth. Moreover, saline conditions stunt plant growth.[31] The sodium hazard of coalbed methane product water poses additional threats to certain soil resources. Sodic irrigation water causes soil crusting and adversely affects water availability, aeration and subsequent crop growth and yield. Upon wetting of soils containing swelling clay, sodium causes the degree of swelling in the clay to increase, leading to dispersion and migration of clay particles. Current research at the Montana State University shows that water with sodium levels equal to typical Montana coalbed methane product water can degrade the physical and chemical properties of heavier, clay soils, making such soils completely unsuitable for plant growth.[32]

[29] Saline water has a relatively high concentration of dissolved salts. Salt is not just "salt" as we know it - sodium chloride (NaCl) - but can be dissolved calcium (Ca^{2+}), magnesium (Mg^{2+}) sulfate ($S0_4^{2-}$), bicarbonate ($HC0_3^-$) and Boron (B). Water is considered saline when it becomes a risk for crop growth and yield. The U.S. Department of Agriculture defines water with an EC greater than 3.0 dS/m as saline. Retrieved from http://waterquality.montana.edu/docs/methane/cbmfaq.shtml#why_are_people_concerned on 24 March 2010

[30] Sodic water is high in the sodium (Na^+) concentration relative to concentrations of calcium (Ca^{2+}) and magnesium (Mg^{2+}). The U.S. Department of Agriculture defines water with a SAR greater than 12 as sodic. Retrieved from http://waterquality.montana.edu/docs/methane/cbmfaq.shtml#why_are_people_concerned on 24 March 2010

[31] Kristin Keith and Jim Bauder, Montana State University-Bozeman, John Wheaton, Montana Bureau of Mines and Geology (2003) , Frequently Asked Questions, Coalbed methane (CBM). Retrieved from http://waterquality.montana.edu/docs/methane/cbmfaq.shtml#why_are_people_concerned on 24 March 2010

[32] Earthworks. Hydraulic Fracturing of Oil and Gas Wells. Retrieved from http://www.earthworksaction.org/hydfracking.cfm on 24 March 2010

Consequently, it can be concluded that the development of coalbed methane project requires considerable funding in the initial stage of its implementation due to water management issues and operating costs which would significantly decrease within the process of production.

2. 5 Coalbed Methane Water Disposal Techniques

Comparing to the development of oil and gas from conventional reservoirs, the water associated with coalbed methane production is not re-injected into the producing formation. Instead it must be disposed of or used in other beneficial ways.[33]

There are four main types of coalbed methane processed water disposal techniques: well injection, discharge into surface streams, land application, and membrane processes (Rogers, 1994, p. 217). The w*ell injection* method is commonly practiced in the San Juan basin, where coalbed well-and transport-infrastructures are highly developed through an extensive network of pipelines and service trucks. This approach avoids surface discharge. Many opinions exist, and the feasibility - economic, physical, and environmental - of either re-injecting coalbed methane product water to the coal seam from which it was pumped or injecting it into an aquifer above or below the coalbed methane-bearing coal seam is being investigated.[34]

Rogers (1994, p. 217) set examples of the technique of *water discharge into surface streams* in the Warrior basin. The research group from the Montana State

[33] Water Produced with Coalbed Methane (2000), US Geological Survey. USGS Fact Sheet, FS-156-00. U.S. Department of Interior

[34] Earthworks. Hydraulic Fracturing Of Oil and Gas Wells. Retrieved from http://www.earthworksaction.org/hydfracking.cfm on 24 March 2010

University argued that this method is no longer permitted on new wells and all existing operations were “grandfathered” and are still discharging into surface streams in the Powder River basin. This method includes impoundment, which basically denotes creation of a pound where processed water allowed to be penetrated into the surface, will be discharged. Some percentage of seepage flow from impoundments is likely to reach stream channels via subsurface flow.[35]

Land application performed through the irrigation equipment used to be utilized in the earlier stages of the Warrior basin development, but permits are no longer given.[36] Rogers explained that any land application is closely linked to economical and technical development of membrane process (Rogers, 1994, p. 230), which is one of the most commonly used treatment technology for removing salt from produced water.[37] Researchers from the Montana State University also mentioned other types of processed water utilization – mainly for dust control and usage by other coal mines.[38] Thus, the unavoidable process of water production makes the issues of coalbed methane processed water management a key factor in developing marginally economical projects.

2.6 Major Coalbed Methane Development Technologies

[35] Kristin Keith and Jim Bauder, Montana State University-Bozeman, John Wheaton, Montana Bureau of Mines and Geology (2003) , Frequently Asked Questions, Coalbed methane (CBM). Retrieved from http://waterquality.montana.edu/docs/methane/cbmfaq.shtml#why_are_people_concerned on 24 March 2010

[36] Water Produced with Coalbed Methane (2000), US Geological Survey. USGS Fact Sheet, FS-156-00. U.S. Department of Interior

[37] The Energy Lab. Produced Water Management Technology Descriptions. Fact Sheet. Membrane Process. Retrieved from http://www.netl.doe.gov/technologies/pwmis/techdesc/membrane/ on 24 March 2010

[38] Kristin Keith and Jim Bauder, Montana State University-Bozeman, John Wheaton, Montana Bureau of Mines and Geology (2003) , Frequently Asked Questions, Coalbed methane (CBM). Retrieved from http://waterquality.montana.edu/docs/methane/cbmfaq.shtml#why_are_people_concerned on 24 March 2010

Due attention must be paid to major coalbed methane development technologies such as (1) dynamic openhole cavitation completion, and (2) advanced hydraulic fracture treatment, which could be utilized worldwide, depending on the origin of the basin where coalbed methane development is going to take place (Murray, 1996).

The dynamic openhole cavitation completion technique was pioneered in the Sam Juan basin, located in the states of Colorado and New Mexico, which have made it the most prolific coalbed methane basin in the world (Murray, 1996). This particular technique encourages the coalbed methane reservoirs to slough into the wellbore, creating numerous self-propped fractures and linking the reservoir to the wellbore. This technique is described as simple, with minimum risk involved (Rogers, 1994, p. 235) in the following way: (1) A 4 ½"-diameter casing was set above the coal; (2) drilling was completed through the coal; (3) the seam was hydraulically fractured; (4) the well was cleaned with compressed air; and (5) a tubing string and pumping equipment were inserted (Lambert, 1989).

Hydraulic fracturing technology or *"fracing"* developed after 1948 has considerably eased the process of dewatering and made gas production rates economically marginal (Rogers, 1994, p. 265). Typically, fluids are injected underground at high pressures, the formations fracture, and the gas flows more freely out of the formation. Some of the injected fluids remain trapped underground.[39] It well-known that fracing stimulates gas production. It should be taken into consideration that areas that contain a lot of coalbed gas and drinking water aquifers should treat the process of gas

[39] Earthworks. Hydraulic Fracturing Of Oil and Gas Wells. Retrieved from http://www.earthworksaction.org/hydfracking.cfm on 25 March 2010

development through fracing with great care, as the drinking water is at risk of becoming heavily polluted.[40]

The United State Environmental Protection Agency (EPA) conducted a number of studies aimed at assessment of the quality of the underground source of drinking water (USDW) for potential contamination from the injection of fracing fluids by coalbed methane wells in 2004. Based on the information collected and reviewed at the time, the EPA concluded that the injection of hydraulic fracturing fluids by coalbed methane wells posed little or no threat to USDWs. Furthermore, they concluded thatadditional studies were not justified, yet retained the right to conduct additional studies in the future. As a precautionary measure, the Agency also entered into a Memorandum of Agreement with companies that conduct hydraulic fracturing of coalbed methane wells to eliminate use of diesel fuel in fracturing fluids.[41]

In general, production and development of coalbed methane as a new energy source in the United States inspired a number of coal-enriched countries to develop methane from their own coal reserves. The United States' positive experience influenced countries with the developed coal mining industry to seek new opportunities to increase their domestic energy supply with the help of different production methods, provision of necessary equipment and implementation of water disposal techniques which determine overall feasibility of the project.

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[40] There are a number of cases in the U.S. where hydraulic fracturing is the prime suspect in incidences of impaired or polluted drinking water. In Alabama, Colorado, New Mexico, Virginia, West Virginia and Wyoming, incidents have been recorded in which residents have reported changes in water quality or quantity following fracturing operations of gas wells near their homes. Earthworks. Hydraulic Fracturing Of Oil and Gas Wells. Retrieved from http://www.earthworksaction.org/hydfracking.cfm on 24 march 2010

[41] Underground Injection Control Program. Hydraulic Fracturing. US Environmental Protection Agency. Retrieved from http://www.epa.gov/ogwdw000/uic/wells_hydrofrac.html on 24 March 2010

Chapter 3

Findings and Discussion – a Solution for the Ukrainian Gas Crises and Achievement of Energy Efficiency of Ukraine through the Development of Coalbed Methane

3.1 The Ukrainian Energy Policy Dynamics

From a historical perspective, the independence of Ukraine followed immediately after the dissolution of the Soviet Union in 1991, resulting in its ultimate dependency on the importation of fossil fuels necessary for maintaining vitally important industries and infrastructures. Since the year of the independence proclamation, Ukraine has inherited an outmoded political system, a poor legislative and legal base complemented by a primitive financial system, an ineffective economic infrastructure, and a high dependence on the import of energy, raw materials and various kinds of machinery. Such dependency is explained by the fact that most Ukrainian industrial and agricultural sectors have been closely tied to the former USSR markets. At the time, major policy makers were more concerned with the implementation of new political reform than developing an efficient legislation system that could effectively regulate the domestic market. As a result, insufficient funding caused the recession of the state economical and industrial complexes.

Notwithstanding, the geopolitical factor made Ukraine one of the largest Eastern European net energy importers with a heavy reliance on natural gas coming from Russia, and accounted for the absence of availability of easily accessible supply alternatives. At the same time, energy transit through Ukraine was, and still is, vitally important, as the country plays a major role in securing Europe's energy needs: 84% of Russian gas supplies to Europe transit through Ukraine via pipeline.[42]

The increase in tensions between the associated countries over the natural gas supply crisis has encouraged Ukrainian political leaders and high-level officials to pursue the development of Ukraine's energy sector. The key factor to the promotion of energy security is the production of a domestically developed, i.e. more affordable and independent, energy source which would make Ukraine less vulnerable and dependable on external energy exporters.

According to a 2006 report prepared by experts from the International Energy Agency (IEA) who have performed thorough analysis of the Ukraine's energy industry since the year of its independence, the most important factor in the country's not fully developed energy potential is its lack of introduction of the full and long-term costs of production established by domestic prices.[43] Besides that, the same experts believe that in Ukraine most energy prices cover only operational cost. Such low prices had negative impact on investments in the energy sector and had undermined economic stability of the country for years.

To improve the situation, the Ukrainian government must develop an effective energy policy and legislative framework that would decrease energy intensity, stimulate intellectual capacity, spur capital investments in the industry, stipulate the incentives for investors, cover the associated costs, and guarantee a return. According to the Committee

[42] International Energy Agency. Executive Summary and Recommendations (2006). Retrieved from http://www.iea.org/textbase/nppdf/free/2006/ukraine2006.pdf on 20 April 2010

[43] International Energy Agency. Executive Summary and Recommendations of 2006. Retrieved from http://www.iea.org/textbase/nppdf/free/2006/ukraine2006.pdf on 25 April 2010

of Statistics as of 2002, Ukraine has managed to reduce its energy intensity from 1% to 3% per year since 1995, and it is still unable to keep pace with the other former Soviet countries' average decline in energy intensity of 5% a year. It is worth mentioning that following the EBRD's[44] 2001 Transition Report, Ukraine's energy intensity was 1.4 times greater than Russia, 1.6 times greater than Kazakhstan; 1.25 times greater than Bulgaria; 3.5 times greater than Poland, and 5 times greater than the Baltic countries. At the time, Ukraine imported 60% of its oil from Russia, 24% from Kazakhstan, and produced just 16% domestically. It imports 83% of its gas from abroad [Russia, Turkmenistan] and it imports 100% of its nuclear fuel from Russia.[45]

IEA reports that on average, Ukraine uses energy three times less efficiently than Russia, Belarus, or European countries.[46] That is why a carefully designed and strategically planned policy alternative would help reduce energy imports, positively influence energy prices, increase domestic energy supply and, as a result, generate funds to replenish the state budget. Needles to say, the IEA 2006 report mentioned that earlier attempts made by the Ukrainian government to achieve energy efficiency in 1994 failed due to insufficient funding. In 2007, the subsequent work of the State Committee of Ukraine on Energy-savings was considered poorly performed. It was recognized that the

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[44] The *EBRD* (the *European Bank for Reconstruction and Development*) – is an international financial institution that supports projects in 29 countries from central Europe to central Asia; investing primarily in private sector clients whose needs cannot be fully met by the market, the Bank promotes entrepreneurship and fosters transition towards open and democratic market economies. Retrieved from http://www.ebrd.com/index.htm on 25 April 2010

[45] Energy Market Reform in Ukraine (2002). Remarks by the U.S. Ambassador **Carlos Pascual,** Ukraine: Energy Hub of Europe, Second International Oil and Gas Conference: Energy Forum Ukraine – 2002**,** *Energy: Key to the Economy, Key to Society.* Retrieved from http://kiev.usembassy.gov/files/pascual_energy-forum_5-21-02_eng.html on 25 April 2010

[46] International Energy Agency. Executive Summary and Recommendations of 2006. Retrieved from http://www.iea.org/textbase/nppdf/free/2006/ukraine2006.pdf on 25 April 2010

funding had been irrationally used by the Accounting Chamber Board of Ukraine.[47] Thus, state agencies appear to have mismanaged funds in the energy policy sector.

The IEA report lists numerous factors producing negative impacts on Ukraine's energy efficiency. Among them are low domestic energy prices compared to the international oil prices, and the inability of coal prices to cover the production cost and electricity prices to cover the investment cost.[48] In 2006, an internationally recognized agency proposed to the Ukrainian government the reconsideration in the following three areas of operation: development of the strategy for the energy efficiency, cost-pricing, and transparency.

3.2 Sectorial Issues

Acknowledging Ukraine's geographic position, linking East and West, and warm territorial waters of the Black Sea, Ukraine became a trade link of growing importance between the energy markets of the former Soviet Union and Europe.[49] The Ukrainian

[47] The audit proved that authorized central authorities *did not ensure effective management of the funds* of the State Budget of Ukraine in 2004-2006 provided for effectiveness increase of energy resources conservation and introduction of energy-saving technologies. Due to inconsistent and non-coordinated decisions on re-organization of central authority for energy conservation and delays in realization of these decisions, administration of state policy implementation in energy-saving had not been held at all for more than a year… Existing regulatory framework on energy-saving did not ensure energy conservation and stimulation of companies to introduce energy-saving technologies… Concepts and criteria of evaluation of energy effectiveness were not defined in legislative and regulatory way; laws on procedure of energy audit were not adopted as well as on stimulation of energy-saving activities. Increased rates of energy-saving fixed assets depreciation were not set and applied. The Complex State Program on Energy-Saving [adopted 10 years ago] valid for today is not specified by measures, period of realization and authorized executing bodies. Due to the tasks not fulfilled in the previous years, *the Program became economically outdated and needs revision and adjustment*. Official web-site of the Accounting Chamber of Ukraine. Official Announcement (2007). Retrieved from http://www.ac-rada.gov.ua/control/main/en/publish/article/895417;jsessionid=A8B2E69C1138F684253C1B38E2A83FC0 on 25 April 2010

[48] International Energy Agency. Executive Summary and Recommendations of 2006. Retrieved from http://www.iea.org/textbase/nppdf/free/2006/ukraine2006.pdf on 25 April 2010

[49] Energy Information Administration. Country Analysis Briefs. Ukraine (2007). Retrieved from http://www.eia.doe.gov/emeu/cabs/Ukraine/Full.html on 25 April 2010

domestic energy market is entirely dependent on the consumption and production of coal used for power and heat generation, as well as natural gas also used for commercial and residential purposes. Since the year of its independence, the Ukrainian coal, oil, and gas industries have encountered a great number of issues.

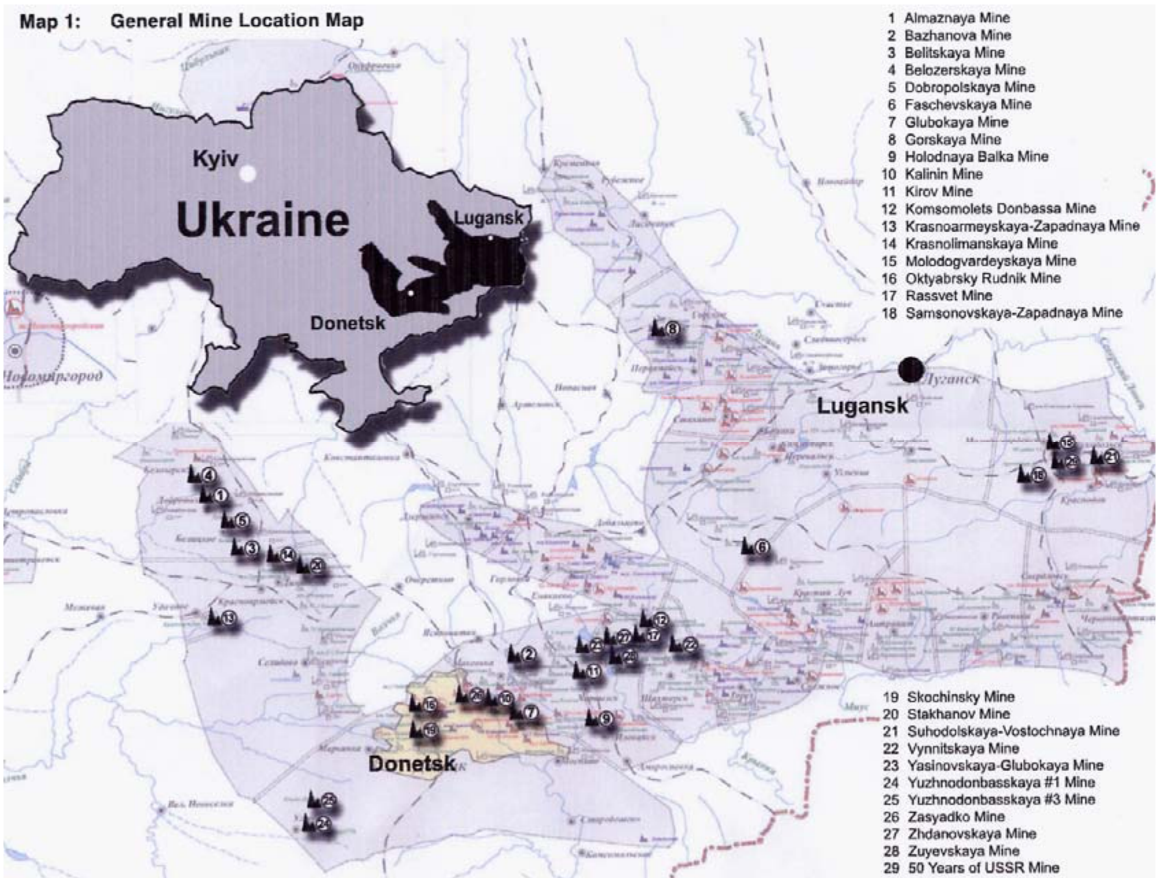
3.2.1 Coal Industry

The Ukrainian coal industry is known to be one of the most important in the provision of the country with such energy sources as heat, power, and coke. Notwithstanding its considerable coal reserves, underinvestment in the coal industry made Ukraine a net coal importer. Based on the information obtained from the Ministry of Coal of Ukraine, in 2005, the Austrian Energy Agency stated that 46% of coal produced in Ukraine was used for power or cogeneration plants, while 29% was used in steel and coke industries. Heat-only boilers in municipal district heating systems utilized 3% of the total supply, while home owners used even less. The remaining 20% were consumed by other types of end-users.[50]

The nation's key mineral resource – the Donbass coal basin located in the eastern Ukraine – has estimated coal reserves of 45 billion tons. The country's next largest coal basins are located in the Luhansk and the Dnipropetrovsk regions. In accordance with the Ukraine Mining Report of 2009, Ukraine has about 200 coal mines. Most of them are

[50] Austrian Energy Agency. Ukraine. Energy Policy (2007). Retrieved from http://www.enercee.net/ukraine/energy-policy.html on 25 April 2010

state-owned and employ 300,000 people.[51] However, according to different statistics, they employ up to 500,000 people.[52]



Source: PEER (2000)

Experts believe that the privatization process would trigger the necessary modernization of the entire coal industry. As the Mining Repots states, the Ukrainian Academy of Science revealed that 80% of the mines in the Donbass basin have been operating without any modernization for at least 20 years, and no new mines have been

[51] Ukraine Mining Report (2009), published by Business Monitor International.

[52] U.S. Energy Information Administration, Independent Statistics and Analysis, Ukraine, Coal (2007). Retrieved from http://www.eia.doe.gov/emeu/cabs/Ukraine/Coal.html n 25 April 2010

opened during the last 25 years. Under the Ukrainian Coal Program, in 2010 there will 133 mines operating and about 31 mines are expected to be closed the same year. As such, the mines are unlikely to produce any impact on the overall coal production, in accordance with the Ukraine Mining Report.

Since natural gas makes the greatest contribution to the national supply of primary energy sources, the Ukrainian government and private sector are still going to pursue the goal to achieve greater energy efficiency, despite the dilapidated and dangerous conditions of coal mines. As of 2006, 164 active coal mines were owned by 24 state enterprises subordinate to the Ministry of Coal Industry of Ukraine.[53] The International Energy Agency (IEA) reports that in 2005, only 7% of coal mines were privately-owned, yet produced 40% of the coal. The IEA refers to the data obtained from the Ukrainian State Statistics Committee as of 2004, stating that 39% of the coal supply went to electricity generation and only 0.2% to district heating.

3.3 Energy Consumption, Demand and Supply. State of Oil and Gas Industry

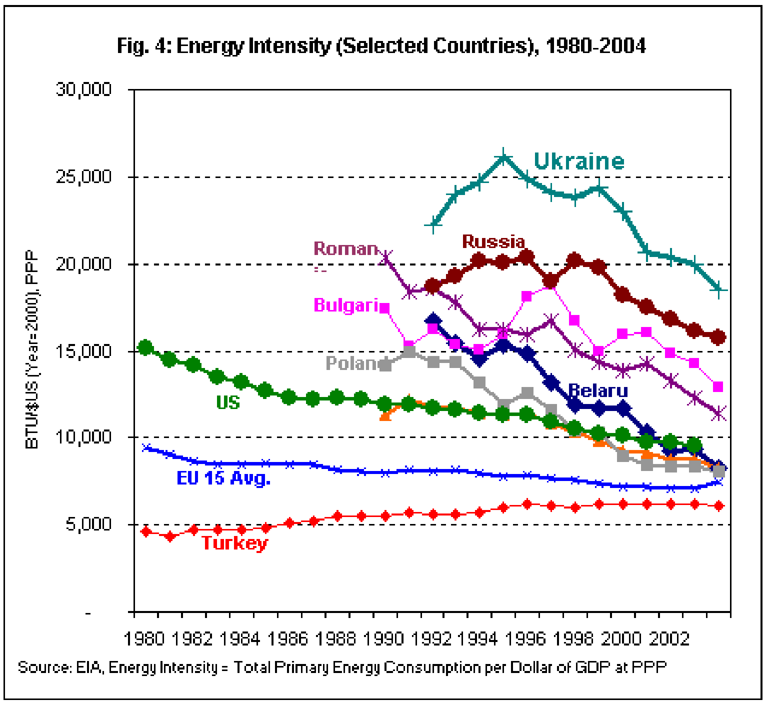
The growing importance of Ukraine's geographic position produced a great impact on the condition of the domestic oil and gas industries. The performance analysis on statistical data on Ukraine's oil and gas supply, demand and consumption rates, is quite problematic due to the unavailability of data after the period of 2006-2008. Another difficulty is seen in the way statistical data are presented – not all of the Ukrainian statistical agencies have switched to the uniform statistical tools utilized internationally.

[53] International Energy Agency. Executive Summary and Recommendations of 2006. Retrieved from http://www.iea.org/textbase/nppdf/free/2006/ukraine2006.pdf on 25 April 2010

3.3.1 Energy Consumption

Nevertheless, Ukraine is reported to be one of Europe's largest energy consumers, and in 2005, it consumed over twice as much energy per unit of GDP than Germany.[54] Most of the energy comes from the utilization of natural gas, which accounted for more than half of total energy consumption. In terms of energy consumption per unit of output, as it is seen from Fig. 1[55] Ukraine is reported to have one of the highest levels of energy intensity in the world:[56]

Fig. 1 Energy Intensity in Selected Countries:



[54] Energy Information Administration. Country Analysis Briefs. Ukraine (2007). Retrieved from http://www.eia.doe.gov/emeu/cabs/Ukraine/Full.html on 25 April 2010

[55] Fig. 1 was taken from the Energy Profile of Ukraine (2008). Retrieved from http://www.eoearth.org/article/Energy_profile_of_Ukraine on 25 April 2010

[56] The Encyclopedia of Earth. Energy Profile of Ukraine (2008). Retrieved from http://www.eoearth.org/article/Energy_profile_of_Ukraine on 25 April 2010

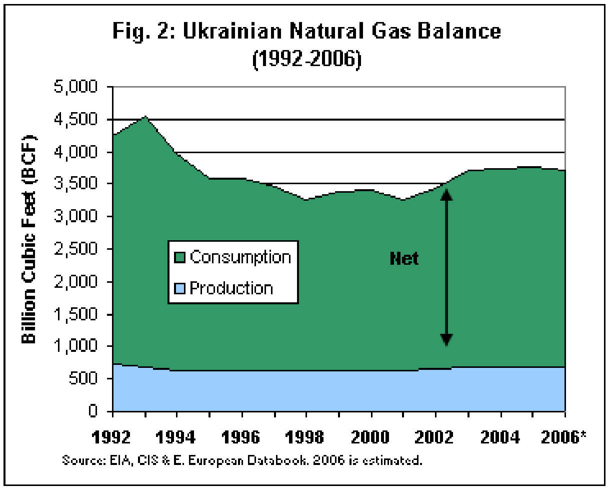
Consumption of natural gas has significantly increased since the years of Ukraine's independence and makes up over half of its energy usage: in 2004, natural gas consumption accounted for 49% of the total energy consumption [as of 2004, 24% of total energy consumption were spent on coal, 12% on crude oil, 14% - on nuclear and 1% - on hydropower].[57] In 2005, natural gas also accounted for almost half of Ukraine's total energy consumption, and 75 percent of this natural gas came from Russia. Moreover, between 2004 and 2007, the price Ukraine used to pay for natural gas had almost doubled.[58] The US Energy Information Administration (EIA) and *Oil and Gas Journal* estimated that in 2005, Ukraine had roughly 40 trillion cubic feet of natural gas reserves, from which roughly 0.68 trillion was produced. In 2003, Ukraine was reported to have produced 0.67 trillion, and consumed 3.1 trillion cubic feet of natural gas, which made it the largest natural gas importer out of all former Soviet countries and amounted 2.4 trillion cubic feet or 78% of total consumption. Judging by the figure below it is clearly seen that since 2002, Ukraine's natural gas production and consumption rates became less volatile and relatively stable. In 2006, a slight increase in consumption rate is noted:[59]

[57] The US Energy Information Administration. Country Analysis Briefs. Ukraine (2007). Retrieved from http://www.eia.doe.gov/emeu/cabs/Ukraine/Full.html on 25 April 2010

[58] The US Energy Information Administration. Country Analysis Briefs. Ukraine (2007). Retrieved from http://www.eia.doe.gov/emeu/cabs/Ukraine/Full.html on 25 April 2010

[59] The US Energy Information Administration. Country Analysis Briefs. Ukraine (2007). Retrieved from http://www.eia.doe.gov/emeu/cabs/Ukraine/Full.html on 25 April 2010

Fig. 2 Ukrainian Natural Gas Balance



It should be noted that Ukraine's largest energy consumers are the industrial and household sectors. As of 2007, the industrial sector accounted for 45.7% of total energy consumption, the household sector – 33.8%, transport sector – 11.4%, and non-energy use accounted for 9.1% of total energy consumption. [60]

In accordance with the energy report prepared by the Russian-American Business electronic magazine, the most recent data provided by the Ministry of Fuel and Energy show that in 2008, Ukraine witnessed a 5 percent decrease in gas consumption, dropping to 66.3 billion cubic meters. The same report explains that the decline in gas use was explained by the economic crisis that began in September of 2008. By December of 2008, according to the Ministry, consumption of natural gas was 21 percent below its levels for the same period of 2007. Comparing to 2008, gas use in 2009 was 25 percent lower on a year-to-year basis. In March 2009, the Ukrainian state-owned gas company, Naftogaz, estimated that consumption during the year would be 55.9 billion cubic meters. Despite

[60] Austrian Energy Agency. Ukraine. Energy Demand per Sector (2007). Retrieved from http://www.enercee.net/fileadmin/enercee/images/Ukraine/sector_ua.gif on 25 April 2010

an optimistic figure given for domestic natural gas production of 20.6 billion cubic meters, Ukraine would still have to import up to 33 billion cubic meters of natural gas. Russian and American experts from Russian-American Business predict a 15 percent decrease in natural gas consumption by the end of 2010. Such a situation is exacerbated by the terms of an IMF loan stipulation providing the increase of internal gas price to import-cost levels by the year 2012, of which Ukraine's government agreed. The cost of imported natural gas is also expected to go up during this timeframe.[61]

3.2.4 Energy Demand

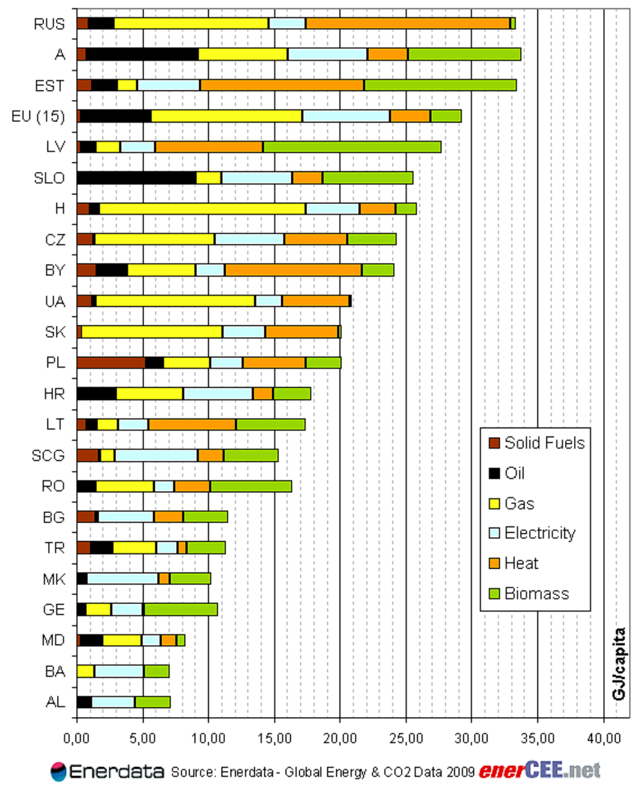
The Ukraine Energy Report of 2009 shows that Ukraine energy demand has significantly dropped since 1990's due to a large scale reduction in the size of the national economy following the dissolution of the Soviet Union in 1991.

As of 2006, Ukraine's residential sector energy demand was primarily based on natural gas utilization, which made Ukraine one of the largest natural gas consumers in Europe: [62]

[61] Ukraine Energy Report (2009). Retrieved from http://russianamericanbusiness.org/web_CURRENT/articles/460/1/Ukraine:-energy-report on 26 April 2010

[62] Austrian Energy Agency. Ukraine. Energy Demand per Sector (2006). Retrieved from http://www.enercee.net/fileadmin/enercee/images/Ukraine/fin_resid_cap.gif

Fig.6 Final energy demand of the residential sector of Ukraine as compared to that of CEE countries, Austria and the EU, 2006:[63]



As of 2007 natural gas accounted for 58.6% of the final energy demand of the residential sector, heat – 21%, electricity – 10.2%, solid fuels – 6.5%, oil – 3%, biomass – only 0.7%, which proves again that Ukraine's effective residential sector functioning is entirely dependent on the utilization of natural gas.[64] According to the US Central Intelligence Agency economy overview, Ukraine's natural gas production as of 2009

[63] Ukraine is represented in the Fig. 6 as UA
[64] Austrian Energy Agency. Ukraine. Energy Demand per Sector (2007). Retrieved from http://www.enercee.net/fileadmin/enercee/images/Ukraine/sector_ua.gif on 26 April 2010

was estimated at 21.2 billion cubic meters, natural gas consumption – 52 billion cubic meters, while natural gas imports made up 26.83 billion cubic meters.[65]

3.3.3 Energy Supply

Historically, oil, natural gas, and since the end of 1970's, nuclear power, formed three main pillars of the Ukrainian energy supply. In 1978, the first nuclear reactor at Chernobyl was put into operation and natural gas remained the second major source of energy supply.[66] Nowadays, Ukraine imports up to 45 percent of all its required energy sources necessary for the operation and maintenance of its primary industries. These energy sources are mostly natural gas, which remains the dominant fuel. In 2009, natural gas accounted for 40.9 percent of all primary energy demand, followed by coal at 28.5 percent, nuclear energy at 16.3 percent, and oil at 12.6 percent.[67]

Although comprehensive data on Ukraine's demand and supply are often lagging and not frequently revised in a timely manner, it has become obvious that Ukraine needs to find a viable domestic energy alternative for its power generation, as it can not entirely rely on natural gas imports.

[65] Central Intelligence Agency. The World Factbook. Ukraine. Economy Overview (2010). Retrieved from https://www.cia.gov/library/publications/the-world-factbook/geos/up.html on 26 April 2010

[66] Consequences of the Nuclear Accident for the Energy Supply. The international communications platform on the long term consequences of the Chernobyl disaster. Retrieved from http://www.chernobyl.info/index.php?userhash=&navID=36&lID=2 on 26 April 2010

[67] Ukraine Power Repert Q2 Summary (2010). Retrieved from http://www.reportlinker.com/p0184908/Ukraine-Power-Report-Q2-2010.html on 26 April 2010

3.4 Internal and External Factors Influencing Ukraine's Energy Policy Dynamics

There are a number of factors influencing the development of Ukraine's energy policy dynamics. The major ones are social and economic indicators, environmental constraints, technological breakthroughs, and expertise.

3.4.1 Social and Economic Indicators

Taking into account lack of statistical data and delays in the process of updating statistics, social and economic factors from the period of 2003 to 2008 are being considered. According to the CIA World Factbook and Index Mundi statistical agency, gross domestic product (GDP) growth rates between 2003 and 2009 were 4.1 percent in 2003; 9.4 percent – in 2004; 12 percent – in 2005; 2.6 percent – in 2006; 7.1 percent – in 2007; and 7.7 percent – in 2008.[68] As of 2009, GDP composition by sector was 10 percent for agriculture; 31.2 percent for industry; and 58.8 percent for services.[69] Capital investment growth rate as reported by the National Bank of Ukraine, made up 120.8 percent in 2001; 108.9 percent – in 2002; 131.3 – in 2003; 128 percent – in 2004; 101.9 percent – in 2005; 119 percent – in 2006; and 129.8 percent – in 2007.[70] According to the same source of information, growth of the population income is reported to be the following: 125.9 percent - in 2001; 117.1 percent – in 2002; 116.5 percent – in 2003;

[68] Ukraine GDP – Real Growth Rate (2009). Retrieved from http://www.indexmundi.com/ukraine/gdp_real_growth_rate.html on 26 April 2010

[69] Central Intelligence Agency. The World Factbook. Ukraine. Economy Overview (2010). Retrieved from https://www.cia.gov/library/publications/the-world-factbook/geos/up.html on 26 April 2010

[70] Macroeconomic Indicators. Main Social and Economic Indicators of Ukraine 2001-1008. National Bank of Ukraine (2009). Retrieved from http://www.bank.gov.ua/Engl/Macro/ on 26 April 2010

127.2 percent – in 2004; 139.1 percent – in 2005; 123.8 percent – in 2006; and 132 percent – in 2007.

The situation involving social indicators of development is a little bit different from the economic statistics. Ukraine has continually experienced negative population growth. The most recent figures [as of July 2009] show a 0.623 percent decline. Moreover, as of 2009, death rates outnumbers birth rates with 15.81 [per 1,000 population] deaths and 9.6 births respectively. The rate of urbanization remains negative, and is estimated at -0.7 percent annual rate of change.[71]

Judging by the information provided by the National Bank of Ukraine, the unemployment level has decreased steadily and made up 3.68 percent – in 2001; 3.7 percent – in 2002; 3.5 percent – in 2004; 3.5 percent – in 2005; 3.1 percent – in 2006; and 2.3 percent – in 2007.

3.4.2 Environmental Constraints

Ukraine is reported to have the seventh largest amount of coal resources in the world, which is estimated at 37.6 billion short tons. Ukrainian coal mines bearing a considerable amount of methane are known to the one of the gassiest in the world. Methane is considered a greenhouse gases (GHG) whose emission in the atmosphere contributes to global warming[72]. The U.S. Environmental Protection Agency (EPA) considers Ukraine the fourth largest emitter of methane emissions from coal mining

[71] Ukraine Demographics Profile (2010). Index Mundi. Retrieved from http://www.indexmundi.com/ukraine/demographics_profile.html on 26 April 2010

[72] Ukraine Energy Data, Statistics and Analysis. Coal. The US Energy Information Administration. Retrieved from http://www.eia.doe.gov/emeu/cabs/Ukraine/Coal.html on 26 April 2010

activities.[73] Since the late 1990's, Ukraine began to actively participate in a number of measures aimed at the reduction of GHG: it became a Party of the United Nations' Framework Convention on Climate Change (UNFCCC) in 1997 and committed to develop policies and actions to reduce emission of GHG. In 1999, Ukraine signed the Kyoto protocol and ratified it in 2004. According to the Ukrainian Institute for Economic Research and Policy Consulting (IER), supported by the World Bank Kiev office, participation in the Kyoto protocol could present a number of ample opportunities for Ukraine. The country could become one of the main beneficiaries because it can sell large amounts of unused assigned emission rights.[74] The IER sees another opportunity in the achievement of additional reduction of emissions that can be sold as further emission rights abroad which would help stimulate the influx of direct foreign investments. Following the Kyoto protocol, Ukraine, being a country with an emission reduction or limitation commitment,[75] and has the right to earn emission reduction units from an emission reduction or emission removal project in another Party. Joint Implementation offers the participants of the Kyoto Protocol cost-efficient means to fulfill their commitments while making Ukraine, in this particular case, benefit from foreign investment and technology transfer.[76]

[73] 31.9 million metric tons of CO_2 equivalent in 2000 – by the U.S. Environmental Protection Agency. Retrieved from http://www.epa.gov/cmop/international/ukraine.html on 26 April 2010

[74] with an annual revenue estimated at USD 740 million till USD 2.9 billion from 2008-2012. Retrieved from http://www.ier.kiev.ua/English/RT/rt04042003_eng.cgi on 26 April 2010

[75] The United Nations Framework Convention on Climate Change, the Kyoto Protocol, Mechanisms of Joint Implementation. Retrieved from http://unfccc.int/kyoto_protocol/mechanisms/joint_implementation/items/1674.php on 26 April 2010

[76] Although eligibility for the creation of emission reduction units has started in 2000, they can be issued for the crediting period starting after the beginning of 2008. Retrieved from http://unfccc.int/kyoto_protocol/mechanisms/joint_implementation/items/1674.php on 26 April 2010

3.4.3 Safety Hazards

Coal mines traditionally have been known for possessing considerable amount of methane released from coalbeds, which represents a serious explosion and fire hazards and causes a lot of fatalities among miners. According to Ukraine Mining Industry Overview, more than 90% of all mines are state-owned[77] and are in a dire physical condition. Such archaic and dangerous state of mines rich in high content of methane puts Ukraine in the list of the countries with the most dangerous mining operation conditions. Since 1998, a number of companies the Ukrainian mining industry have been exposed to the reformation process due to pressure from the International Monetary Fund.[78] The IEA, however, reports that there was consistent decline in fatalities and fatality rates since 2000 due to improvements in mine safety in the context of the coal-mining reforms of 2004.[79] Still, the IEA mentions that the fatality rate in 2000 was more than 2.5 miners per 1 million tons of coal. The only other country where the fatality rate is higher than in Ukraine is China, where there are 5.8 fatalities per 1 million tons of coal in 2000. The same report mentions that the fatality rate tends to increase in conditions of intense pressure to increase production and profitability. The IEA notes the analysis prepared by the Ministry of Fuel and Energy of Ukraine, which specifies the main causes of fatal coal mining accidents. The majority of them are associated with the leakage of methane gas

[77] Ukraine Mining Industry Overview (2009). Retrieved from http://www.buyusa.gov/pittsburgh/urkmining.pdf on 26 April 2010

[78] International Federation of Chemical, Energy, Mine and General Workers' Union, ICEM New Release No. 28/1998. Retrieved from http://www.icem.org/en/77-All-ICEM-News-Releases/976-Ukraine-Mine on 26 April 2010

[79] In February 2004 the Cabinet of Ministers of Ukraine approved a Revised Program to *Raise the Worker Safety in Coal Mines*. 19 million USD were allocated by the government for the program in 2004 and 23 million USD – in 2005. The Program lists 130 actions that the ministries and government agencies must implement in various categories: conduct of research activities, measures aimed at the development of better degasification and ventilation systems, and development of new regulations. Retrieved from http://www.iea.org/textbase/nppdf/free/2006/ukraine2006.pd,and http://www.kmu.gov.ua/control/en/publish/article?art_id=16592161&cat_id=2291893 on 26 April 2010

released from coalbeds and seams. Clearly, the introduction on new technologies from the successful experience of other countries practicing the development of coalbed methane would help dramatically improve the operating conditions for Ukrainian miners and the operation of the Ukrainian energy sector as a whole.

Thus, notwithstanding slow social development, Ukrainian economic indicators show that the country is going slowly out of the recession triggered by the economic crisis in 2008-2009. Nevertheless, currently Ukraine remains the largest European country with the highest energy intensity. Internal factors such as environmental constraints and safety hazards create the necessity to discuss how to achieve greater energy efficiency, decrease energy intensity, develop energy infrastructure, and reduce safety hazards and GHG emission into atmosphere.

3.4.4 Foreign Policy Issues: Creation of International Consortium and the Customs Union

Among the other factors stimulating the development of domestic energy source in Ukraine is the creation of the International Consortium which would include leading state-owned Russian Gazprom, German E.On Rurhgas, and the Ukrainian Naftogaz Ukrainy companies. Some experts believe that the Consortium creation is linked to the idea to control Ukraine's gas transit system,[80] yet there are other opinions as well. Being a member of such Consortium through the collaboration of the Party of Regions of

[80] Vladimir Socor (2009). Russia Seeks Control of Ukraine's Gas Transit System Through a Consortium. The Jamestown Foundation. Retrieved from http://www.jamestown.org/single/?no_cache=1&tx_ttnews[tt_news]=34357 on 26 April 2010

Ukraine with the Russian gas company,[81] Ukrainian pipeline transit system would benefit from investments into its modernization and maintenance. Needless to say, the development of an available energy alternative would represent a fairly ‘independent’ energy source whose utilization would be controlled domestically.

Another factor influencing Ukraine energy policy dynamics and energy efficiency is the creation of the three-way Customs Union between Russia, Belarus, and Kazakhstan, which was officially launched on 1 January 2010. The Customs Union will create a common economic and customs space due to the introduction of adjustments into the countries’ national legislation.[82] As of March 2010, the Russian Prime Minister Vladimir Putin has invited Ukraine to join the Customs Union with the desire expressed by the Ukrainian President Viktor Yanukovych “to considerably adjust its domestic and foreign policy” and make a “sharp turn” in Ukrainian-Russian relations.[83] Notwithstanding the direction of the relations between two states, which have been dramatically changing since the disintegration of the Soviet Union in 1991, the Ukrainian government should remain persistent in the aspiration to develop domestic energy source and put a lot of effort into creation of a favorable investment environment.

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[81] The Party of Regions of Ukraine is the Ukrainian Parliamentary fraction whose leader, Viktor Yanukovych, has been elected the President of Ukraine in February 2010. The Party of Regions aspires to return to good relations with Russia, constitutional changes that would transform Ukraine into a non-bloc (neutral) country, and a referendum on NATO membership. The Jamestown Foundation, *Party of Regions Splits Over Georgia and NATO*, by Taras Kuzio (2008). Retrieved from http://www.jamestown.org/single/?no_cache=1&tx_ttnews[tt_news]=33911 on 26 April 2010

[82] Natalya Kovalenko (2010). The Voice of Russia wire service, Russia, Belarus, Kazakhstan Nod Customs Union Code. Retrieved from http://english.ruvr.ru/2010/02/27/4886654.html on 26 April 2010

[83] Interfax International Information Group (2010). Retrieved from http://www.interfax.com/newsinf.asp?id=150496 on 26 April 2010

Returning to the issue of reducing the dependence of Ukraine on energy imports and achievement of greater energy efficiency, due attention should be given to a number of existing alternatives and finding the most available, cost-effective and medium term solution. Indeed, such measures would contribute to the establishment of political and economic stability, and create an investment-friendly environment.

3.5 Energy Transit and Natural Gas Crises in Ukraine

Energy Policy of Ukraine is highly influenced by its geopolitical location, which plays a determinant role in the country's supply with energy sources imported from a major net exporter on the Eurasian continent – the Russian Federation. The IEA considers energy transit through Ukraine one of the major sources of budget revenue and a guarantee on the energy supply to the country. The IEA sees a strategic interest for the Ukrainian government in maintenance and enhancement of energy transit volumes. According to the same report, the intent of the Russian Federation to build the North European Gas Pipeline [known as Nord Stream[84]] would decrease energy transit volumes through Ukraine, make it highly dependable on gas imports, and make it vulnerable to the volatility of gas prices.

During the last few years, the tensions between the Ukrainian and Russian governments have increased over the natural gas deliveries. Since 2006, the prices per 1,000 cubic meters have increased almost four fold, which have produced an adverse

84 *Nord Stream* is a gas pipeline aimed to link Russia and the European Union via the Baltic Sea [by-passing the territory of Ukraine] which will carry natural gas to supply both businesses and households. The new pipeline will be an important factor of energy security in Europe. Nord Stream is considered a new channel for Russian natural gas exports, and a major infrastructure project which sets a new benchmark in EU-Russia cooperation. Retrieved from http://www.nord-stream.com/en/ on 26 May 2010 effect on the country's energy security and public sectors.[85] Economic disputes about the price Ukraine pays for Russian natural gas resulted in a cut of supplies of natural gas to Ukraine on 1 January 2006. According to BBC News, the Russian state-owned gas company, Gazprom, asked for an increase in price from $50 to $230 per 100 cubic meters.[86] Thus, besides Ukraine, other countries such as Austria, France, Germany, Hungary, Italy, Poland and Slovakia reported a 30 percent pressure drop. The gas crisis of 2006 was settled by a deal under which Ukraine had to buy natural gas from a Swiss-registered company Rosukrenergo,[87] half-owned by Gazprom. As reported by BBC News, under the same agreement, Ukraine purchased natural gas form Gazprom at $230 for 1000 cubic meters and from Turkmenistan and Kazakhstan for much less. Consequently, Ukraine paid $95 per 1000 cubic meters.[88] According to a Reuters columnist Paul Taylor, the Gazprom demand for Ukraine to pay market price for natural gas resulted in the fact that several EU states started increasing their gas stocks to avoid further major gas disruptions. Countries such as Bulgaria, Croatia and Bosnia were caught with no stocks and, as a result, gas supplies to 18 EU countries was disrupted.[89]

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[85] As of 2006 Ukraine paid $50 per 1,000 cubic meters of gas. The Russian state-owned gas company Gazprom wanted to increase the price to the market rate of $230. BBC News. Retrieved from http://news.bbc.co.uk/2/hi/4572712.stm on 26 April 2010

[86] Ukraine Gas Row (2006). BBC News. Retrieved from http://news.bbc.co.uk/2/hi/business/4569846.stm on 26 April 2010

[87] RosUkrEnergo was created in summer 2004 to replace Eural TransGas. Its aim is to act as an intermediary between Gazprom and Naftohaz Ukrainy to transit Turkmen gas through Russia into Ukraine. Eural TransGas managers moved over to RosUkrEnergo. Gazprom, through its Swiss-registered ARosgas Holding A.G., owns 50% of RosUkrEnergo. The remaining half is owned by Centragas Holding, an Austrian-registered company 100% owned by Raiffeisen Investment A.G. European Tribune. Retrieved from http://www.eurotrib.com/story/2006/1/4/83317/94786 on 27 April 2010

[88] Jerome a Paris (2006). Russian-Ukrainian Deal – What's Behind It? European Tribune. Retrieved from http://www.eurotrib.com/story/2006/1/4/83317/94786 on 27 April 2010

[89] Paul Taylor (2009). Ukraine Gas Crisis Spurs EU Energy Policy. Retrieved from http://blogs.reuters.com/great-debate/2009/01/13/ukraine-gas-crisis-spurs-eu-energy-policy/ on 27 April 2010

Even despite the 7% economic growth in 2007 and increase in exports of steel and chemicals, Ukraine's economy became extremely vulnerable and experienced a meltdown. [90] According to the Centre for European Reforms, a think-tank, since 2008 the Ukrainian currency has plummeted 40% against the US dollar. Destabilization of the Ukrainian currency and increase in gas prices contributed to the fact that Ukraine needed a bailout from the International Monetary Fund. The IMF granted 16 billion US dollars to the Ukrainian economy with the condition that any further increase of gas prices would have to be passed on to Ukrainian households. Inflation and the presidential elections of 2010 undermined Ukraine's ability to pay the full prices asked by the Russian state-owned gas company Gazprom. As of January 2009, the gas crisis reached its climax when Gazprom again cut off all natural gas supplies to Europe travelling through Ukrainian pipelines.[91] To mitigate the gas crisis, the European Union agreed to allocate 2.3 billion Euros as a "recovery package" for the economic and Russian-Ukrainian gas crisis as of March 2010.[92]

As of April 2010, construction of the Nord Stream pipeline from Russia to Western Europe under the Baltic Sea was officially launched.[93] The pipeline will be transiting through Russian, Finnish, Swedish and German waters excluding any transit through central Europe. Apart from the Nord Stream pipeline, Russia is reported by BBC

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[90] Katinka Barysch (2009). *Just Another Gas Crisis?* Centre for European Reform think-tank. Retrieved from http://centreforeuropeanreform.blogspot.com/2009/01/just-another-gas-crisis.html on 27 April 2010

[91] Russia supplies a quarter of Europe's gas and 80% of this transits through Ukraine. Retrieved from http://www.guardian.co.uk/business/2009/jan/07/gas-ukraine on 27 April 2010

[92] Valentina Pop (2010). Europe to Spend Billions of Gas Project. Bloomberg Business Week.Retrieved from http://www.businessweek.com/globalbiz/content/mar2010/gb20100310_590206.htm on 27 April 2010

[93] BBC News (2010). Nord Stream Gas Pipeline Underwater Construction Starts. Retrieved from http://news.bbc.co.uk/2/hi/business/8607214.stm on 27 April 2010

News to implement another project called the South Stream, which will run from southern Russia to Bulgaria under the Black Sea, again avoiding the territory of Ukraine. The construction project of Nabucco natural gas pipeline, funded by the European Union, was signed in July 2009. The pipeline will travel across Turkey, Romania, Bulgaria, Hungary, and Austria delivering natural gas from the Caspian and Middle East to Europe:

Fig. 7 Alternative Projects – Nord Stream, South Stream and Nabucco

Source: BBC News[94]

[94] BBC News. Retrieved from http://news.bbc.co.uk/2/hi/business/8607214.stm on 27 April 2010

Combined with the effects of the follow-up inflation and economic crisis, both recent gas crises have created much room for energy policy changes. Taken together, the factors discussed above have negatively impacted Ukraine's energy policy dynamics. The solution to the existing and possible gas crises should be seen in the development of the most available domestic energy source that could easily be integrated into existing infrastructure and require minimum investment. This energy source would significantly reduce dependence on energy exporters and come to succor during hard times.

3.6 The Need for the Domestic Energy Source Development based on Oil and Natural Gas Production and Consumption Data

Being a net energy importer, Ukraine is vulnerable even to the miniscule volatility of energy prices, which mostly determined the country's political agenda. The enhancement of domestic energy production is impossible without reformation of the investment sector. According to the Austrian Energy Agency (AEA), the Ukrainian oil and gas industry is strictly controlled by state-owned companies, however, some incentives have been provided to the private and foreign investors. The state also supervises exploration and production industries, the oil and gas pipeline network, gas imports, transit and distribution. In contrast, the refining and distribution of oil products are mostly concentrated in private hands.[95]

[95] Austrian Energy Agency. Energy Country Profiles. Ukraine (2007). Retrieved from http://www.enercee.net/ukraine/energy-sources.html

The U.S. Energy Information Administration (EIA) reported in 2007 Ukraine's total oil production was estimated at 102.89 thousand barrels per day, in 2008 – only 101.27 thousand barrels per day. Consumption of crude oil in 2007 equaled 369 thousand barrels per day; in 2008 the increase in crude oil consumption totaled only a thousand barrels per day and made up 370 thousand barrels per day. The volume of proved crude oil reserves remained for both years unchanged – 0.395 thousand barrels per day.

Production of natural gas in 2006 and 2007 was flat and equaled 689 billion cubic feet. Natural gas consumption rate in 2006 was 2,560 billion cubic feet, in 2007 it has increased by 0.438 billion cubic feet and amounted 2,998 billion cubic feet. In 2007 proved reserves of natural gas have decreased by 0.6 billion cubic feet and made up 39 billion cubic feet.

Coal production in 2006 equaled 67.981 million short tons and in 2007 – 65.076 million short tons. Consumption rates were the following: in 2006 – 76.646 million short tons and in 2007 – 74.459 million short tons.[96] Judging by the information published, there is a steady increase in crude oil and natural gas consumption, as well as the decrease in crude oil and coal production and reserves of natural gas which proves greater reliance on energy imports. However, consumption rates of coal remained unchanged during the first decade of the 21 century. *From this perspective the necessity for the development of a domestic energy source is undeniable*.

3.7 Existing Energy Alternatives for Ukraine

[96] The U.S. Energy Information Administration, Independent Statistics and Analysis, Ukraine Energy Profile (2010). Retrieved from http://tonto.eia.doe.gov/country/country_energy_data.cfm?fips=UP on 27 April 2010

Considering global experiences and technological breakthroughs, many countries plan on partially switching to renewable energy sources and unconventional natural gas to maintain necessary energy supply and demand. Energy alternatives for Ukraine are mainly seen in the development of renewable energy sources and unconventional natural gas. Atomic energy will also be considered as an alternative energy source. Given conditions of the economic and gas crises that produced a negative impact on the country's development and energy policy dynamics, it is necessary to find the best energy solution that could be realized in timely manner and help Ukraine pull out of recession.

3.7.1 Renewable Energy Sources

Notwithstanding their important role in the Ukrainian Energy Strategy to 2030, the share of renewable energy source remains insignificant. According to Ukraine's Energy Policy Overview, renewable energy accounts for some of 0.9 percent of total primary energy supply. By comparison, as it is reported by the International Energy Agency, renewables account only for 6 percent of total primary energy supply in OECD countries and 13.5 percent worldwide.[97] Only biomass and hydropower are commercially utilized in Ukraine. Hydropower accounted only for 2 percent of the country's energy use in 2007.[98] The use of biomass has undergone slow increases but still

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[97] Ukraine Energy Overview (2006). International Energy Administration. Retrieved From http://www.iea.org/textbase/nppdf/free/2006/ukraine2006.pdf on 27 April 2010

[98] Ukraine: energy report (2009). Russian-American Business. Retrieved from http://russianamericanbusiness.org/web_CURRENT/articles/460/1/Ukraine:-energy-report on 27 April 2010

remains insignificant in providing the country with the necessary energy supply. Most of renewable energy sources are still being at the stage of research and development.

3.7.2 Atomic Power

Half of Ukraine's electricity supply is being generated by 15 water nuclear reactors owned by the state company Energoatom, with the capacity of 13 giga watt. As of 2008, 89.9 billion kilowatt hours of electricity were generated by these nuclear plants.[99] Notwithstanding the ability of nuclear power generators to provide the country with half of its electricity needs, Ukraine imports most of its nuclear fuel and services from Russia. Such dependence on nuclear energy imports proves that complete reliance on nuclear energy (coming mostly from Russia) will not be able to cover Ukraine's energy demand in an independent manner. That is why another source of energy should be considered.

3.7.3 Unconventional Gas in the Form of Coalbed Methane

Major reports previously available viewed the development of coalbed methane as a step forward to the reduction of explosion hazards in coal mines and the improvement of working conditions for miners. Experts believe (Thomas, 2001, p. 384) that Ukraine's coalbed resource is approximately 1.7 trillion cubic meters.[100] The Ukrainian government

[99] Nuclear Power in Ukraine (2010). World Nuclear Association. Retrieved from http://www.world-nuclear.org/info/inf46.html on 27 April 2010

[100] ARI (2202): Hunt for Quality Basins Goes Abroad, Vello A. Kuuskra and Jonothan R. Kelafant, *Oil & Gas Journal*, October 5, 1992

estimates that around 3 billion cubic meters of methane gas escapes from coalbed and only a miniscule part of this gas is being collected and further utilized for operation of the mines. Indeed, by most measures, the realization of coal methane project could represent a major driver for the development of the latest energy trends in Ukraine.

It has already been established that Ukraine has a tremendous potential for its own energy source development through the implementation of coalmine and coalbed methane recovery projects. Through the ratification of the UNFCCC and the Kyoto protocol, opportunities to achieve this goal became even more viable.

3.8 Determining Factors of Coalbed Methane Development

A number of variables impacting the realization of the project on coal methane development are listed below. They emphasize the necessity of coalbed methane development into a profitable domestic energy source determined by a number of environmental and economic issues: increase of mine safety and decrease of fatality rate due to introduction of relevant reforms, reduction of greenhouse gas emission in the atmosphere and opportunities for spurring investments in the energy sector of Ukraine in accordance with the Kyoto protocol. Among geopolitical factors that stipulate the domestic energy source development are (1) the gas crises of 2006 and 2009 between Ukraine and Russia through the energy transit issue; (2) the creation of the international Consortium; and (3) the decision of 2009 to create the Customs Union which comprises Russia, Belarus, and Kazakhstan.

By developing methane from coalbeds and seams, Ukraine would not only follow its commitment to satisfy the Kyoto Protocol but also create favorable conditions to attract climate investments and make itself more competitive among other participants. The Kyoto Protocol mechanisms could provide additional funding for the implementation of the projects on coalbed methane development.

3.8.1 Potential for Coalbed Methane Development

As of 2000, 29 mines have been identified as primary sites for coalmine and coalbed methane development in Ukraine.[101] The Table 1 specifies the list of mines profiled by the Partnership for Energy and Environmental Reform:[102]

Table 1. Major Donetsk Basin Mines with Significant Coalmine methane Development Potential

Name of Mine	Methane Liberated by Mining (million meters^3/year)			Methane Utilized (million meters^3 per year)	Methane Content in Captured Gas (%)	Specific Methane Emissions (meters^3 per tone)	Coal Production (thousand tones per year)
	Ventilation	Degasification	Total Emissions				
Almaznaya	10.93	0.21	11.14	0.00	11-12	20.50	543.20
Bazhanova	22.92	13.25	36.17	9.88	50.0	31.08	1,136.80
Belitskaya	3.08	2.05	5.13	0.00	7.8	22.53	227.70
Belozerskaya	7.99	1.79	9.78	0.00	22.0	24.76	395.50
Dobropolskaya	9.20	0.79	9.99	0.00	3.2	8.23	1,213.00
Faschevskaya	11.97	1.55	13.52	0.00	12.0	47.55	284.90
Glubokaya	33.40	7.90	41.30	5.41	42.0	59.66	692.60

[101] Methane to Markets, CMM Global Overview, Ukraine. Retrieved from www.methanetomarkets.org/documents/toolsres_coal_overview_ch30.pdf on 27 April 2010

[102] PEER (2000): Coalmine Methane in Ukraine: Opportunities for Production and Investment in the Donetsk Coal Basin. Partnership for Energy and Environmental reform, Triplett, Jerry, Alexander Filippov, and Aleksander Pisarenko, Spetember, 2002. Retrieved from http://www.epa.gov/cmop/docs/inventory2002.pdf on 27 April 2010

Gorskaya	8.24	0.00	8.24	0.00	N/A	32.58	252.90
Holodnaya Balka	29.40	15.70	45.10	12.62	66.0	74.08	608.80
Kalinin	44.57	2.94	47.51	0.00	22.0	143.66	330.70
Kirov	8.41	7.31	15.72	0.00	33.0	16.40	958.10
Komsomolets Donbassa	116.81	11.56	128.37	4.20	30.0	93.43	1,373.90
Krasnoarmeyskaya -Zapadnaya	78.73	12.40	91.13	0.00	30-38	25.0	3,137.50
Krasnolymanskaya	40.21	21.56	61.77	0.00	19.5	18.93	3,263.75
Molodogvardeyskaya	10.38	4.23	14.61	0.00	19.6	27.28	535.60
Oktyabrskiy Rudnik	12.30	1.26	13.56	0.00	6.0	40.20	337.22
Rassvet	36.11	5.26	41.37	0.00	20.0	116.44	355.30
Samsonovskaya-Zapadnaya	N/A	N/A	N/A	N/A		N/A	
Skochinsky	34.6	3.99	38.59	0.00	38.0	49.15	784.70
Stachanova	35.45	16.78	52.23	0.00	42.0	33.51	1,558.50
Suhodolskaya-Vostochnaya	52.50	7.10	59.60	0.00	15.0	286.50	208.00
Vinnitskaya	8.80	3.20	12.00	0.00	22.0	37.24	322.20
Yasinovskaya-GLubokaya	19.88	1.84	21.72	0.00	18.0	65.46	331.80
Yuzhno-Donbasskaya No.1	15.38	1.89	17.27	0.00	13.5	15.24	1,133.40
Yuzhno-Donbasskaya No. 3	15.27	2.89	18.16	0.00	25.0	14.83	1,224.90
Zasyadko	79.10	30.60	109.70	12.36	30.0	36.20	3,027.00
Zhdanovskaya	12.98	2.26	15.24	0.00	17.2	30.35	502.10
Zuyevskaya	33.00	3.10	36.10	0.00	30.5	99.60	362.50
50 Years of the USSR	21.76	0.00	21.76	0.00	N/A	34.36	633.20

To address the research question, it is necessary to look into a number of independent and dependent variables, such as market and infrastructure factors, regulatory information, prospective projects with the development sites identified, institutional frameworks that identify policy measures and technical barriers, as well as Research and Development (R&D) framework, which includes a number of companies ready to start the implementation of the project.

3.8.2 Market and Infrastructure Factors

Notwithstanding the fact that in Ukraine's mineral resources are state-owned and existing mines are operating under licenses, development of coalbed and coalmine methane is subject to the approval of the Coal Industry Ministry. According to the same report, due attention is paid to the fact that most of coalmine methane is mainly used for boiler-heating and mine air heating. Potential for further coalmine methane applications is seen in fueling the power generation in gas or dual-fuel power plants, and the supplement of supplies for other residential, commercial, and industrial uses. Considering the fact that prices for natural gas tend to increase, the development of coal methane gas is one of the alternatives that should be given a green light. Experts from *Methane to Markets* society responsible for publication of CMM Global Overview see the main obstacle to expanding use of coalmine methane in poor market access and lack of modern infrastructure to transport methane for internal and external markets.[103]

3.8.3 Regulatory Information Framework

For now, the coal mines and reserves belong to the state, but it often happens that the many successful mines are either leased or privatized. According to the IEA report of 2006, 25 coal mines (which represent approximately 40% of Ukraine's annual coal production) have been privatized. The remaining mines are state-owned and represent the Joint Stock Holding Companies. Among independent mines are the Komsomolets Donbassa, the Yuzhnodonbasskaya No. 1 and the Yuzhnodonbasskaya No. 3, and the

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[103] Methane to Markets, CMM Global Overview, Ukraine. Retrieved from www.methanetomarkets.org/documents/toolsres_coal_overview_ch30.pdf on 27 April 2010

Zasyadko mines. All of them can be viewed as potential site for coalmine and coalbed methane development. CMM Global Overview emphasizes the fact that those state programs that promote advancement of coalmine methane rely on private investment rather than direct government funding.

Interestingly, in 1998 the law on the establishment of Free Economic Zone in the Donetsk Region, which provides various tax incentives for investment attraction, was passed. Moreover, legislation passed by the Ukrainian Parliament – the Verkhovnaya Rada – exempts foreign-manufactured materials and equipment used in coalmine methane development from Ukraine's value added tax through 2008.[104]

In February 2006 the Ukrainian government has officially approved a set of Joint Implementation (JI) procedures stipulated in Article 6 of the Kyoto Protocol.[105] Among other steps towards coalbed methane recovery and utilization made by the Ukrainian government is the adoption of the draft law *"On Coalbed Methane Gas" No. 1123* signed by the President of Ukraine on May 21, 2009. According to the amendment, enacted on January 1, 2010, all companies involved in drilling and utilization of coalbed methane are exposed to tax exemptions. The revenue is intended to be used for the increase of the

[104] Macroeconomic Indicators. Main Social and Economic Indicators of Ukraine 2001-1008. National Bank of Ukraine (2009). Retrieved from http://www.bank.gov.ua/Engl/Macro/ on 26 April 2010

[105] JI procedures formally outline the federal government's procedures for consideration, approval and implementation for domestic coal mining companies to carry out JI projects. – Methane to Markets, *CMM Global Overview (2008)*, Ukraine. Retrieved form http://www.methanetomarkets.org/documents/toolsres_coal_overview_ch30.pdf on 28 April 2010

production volume, re-equipment of materials and technical base, and introduction of new technologies related to utilization of coalbed methane.[106]

The list of the projects and regulations promoting the development of unconventional natural gas in Ukraine should not be limited to the ones mentioned above. Further work and research in legislation stipulating the development of this know-how industry for Ukraine should be conducted with the assistance rendered on the international level. Those countries that have already successfully implemented such projects could serve as role models in terms of borrowing the methodology and techniques of coal methane production, utilization, recovery and water disposal.

3.8.4 Institutional Framework

The Agency for Rational Energy Use and Ecology and the Battelle Memorial Institute have worked developed an analysis for coalmine methane recovery and utilization in January 2009.[107] Since Ukrainian coal industry have both operating and inactive mines, the strategy for coalmine methane recovery and utilization could possibly be expanded to coalbed methane recovery and utilization as well.

National and local authorities of developed countries identify key procedures for the operation of the coalmine and coalbed methane industry, ensuring regulation of

[106] Official web-site of the Ukrainian Parliament, Retrieved form http://portal.rada.gov.ua/rada/control/ru/publish/article/news on 28 April 2010

[107] The Agency for Rational Energy Use and Ecology and Battelle Memorial Institute, prepared for the U.S. Environmental Protection Agency, *Analysis of international Best Practices for Coalmine Methane Recovery and Utilization*, January 2009

methane rights, project approval for leasing land, and licensing and permitting processes.[108] It is stated that such activities facilitate interaction between the stakeholders: the coal leaseholders[109] on one side, and surface land owners, the gas leaseholders, power generators and pipeline operators on the other side. Among the international best practices of coalmine methane recovery and utilization, most of the governments try to introduce and implement specific policies that would allow them to avoid the excessive distribution of responsibilities between various organizations and departments. Historically, ineffective distribution of authority and responsibilities produces a negative impact on the realization of a project. Table 2 lists existing authorities and various governmental agencies specifying in coalmine methane development worldwide[110] whose experience will be of much benefit:

Table 2. Overview of coalmine authorities and regulatory agencies in the countries profiled

Country	**CMM authorities and regulatory agencies**	**Functions**	**State/local level**
Australia	Department of Industry, Tourism and Resources; Australian Greenhouse Gas Office; Department of Environment, Water, Heritage and the Arts	Licensing and permitting	Federal
	Queensland Department of Natural Resources and Mines; New South Wales Department of Primary Industries Minerals	Arrangement of licenses for coalbed/coalmine methane extraction and royalty payments; projects identification and assessment support	State
Canada	Natural Resources Canada	Permitting and licensing trade and commerce in natural resources	Federal
	Alberta Ministry of Energy;	Permitting and licensing	Provincial

[108] Which do not usually have automatic rights to coalmine methane

[109] U.S. Commercial Service, U.S. Department of Commerce, *Ukraine: Mining Industry Report (2009)*. Retrieved on 28 April

[110] 2010 Global Overview of CMM Opportunities, *Coalbed Methane Outreach Program*, U.S. EPA, September 2008. Retrieved on 28 April 2010

	British Columbia Ministry of Energy, Mines and Petroleum Resources		
Germany	Arsnberg Local Government/Department of 8 Mining Industry and Energy	Mining authorization designation of mine gas property rights; administration of exploration, extraction, and processing of mine associated gas	State
	State Ministry for the Environment Nature Conservation and Reactor Safety	Project Identification and assessment support	Federal
United States of America	Bureau of Land Management within the U.S. Department of the Interior	Management of U.S. public lands and leases on federal land	Federal
	U.S. Forest Service within the U.S. Department of Agriculture	Administration of the national forests and leases on federal forest land (*Does not address projects on private lands.*)	Federal
United Kingdom	Department for Business Enterprise & Regulatory Reform	Regulation of methane rights	National

Moreover, the same experts pinpoint that *the development of such project is dependent on the demand side of the methane market, the amount of coalmine/coalbed methane reserves and project funding.* Applying the same knowledge, it is possible to conclude that with most of Ukraine's natural gas demand comes from natural gas markets, electricity markets, heat and power generation. Table 2 specifies governmental bodies, international organizations and private financial institutions that provide financing and loans for realization on such projects.

3.9 Coalbed Methane Resources in Ukraine

It has been internationally recognized that many of the coal seams that are mined in Ukraine are of high methane content. That is why methane drainage and ventilation have been used for many years to ensure safety (Grayer 1996, p. 90). For a few decades, despite the statement of the Ukrainian government about the intention to develop coalbed methane, provisions of funding and technology created a lot of obstacles.

According to the Mining Industry Overview, major coal deposits in Ukraine are concentrated in Donbass (Dnieper-Donetsk Basin), with coal reserves estimated at 96.44% of total coal reserves located in southeaster part of Ukraine. Lviv-Volyn Basin has 3.47% located in western Ukraine, and Pridneprovye Basin has 0.09% of coal reserves.[111] The Austrian Energy Agency, in turn, mentions that Ukraine's coalbed methane deposits belong to the largest in the world and are estimated at 2-12 trillion cubic meters.[112] Nevertheless, of the three basins, the Donetsk one appears to be the largest potential for coalbed and coalmine methane development. The Raven Ridge Resources describes the Lviv-Volyn region as predominantly agricultural and assume that the methane use is likely to be limited to the mines (Marshall, 1996, p. 92).

Furthermore, the Austrian Energy Agency reports that coal reserves of the Donetsk basin range from sub-bituminous to anthracite. Coal mines located in that region are among the gassiest in the world and extremely deep. Over 40% of them have

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[111] U.S. Commercial Service, U.S. Department of Commerce, *Ukraine: Mining Industry Report (2009)*. Retrieved on 28 April 2010

[112] Austrian Energy Agency. Ukraine. Energy Supply (2007). Retrieved from http://www.enercee.net/ukraine/energy-supply.html on 28 April 2010

workings deeper than 700m, and one-third have workings deeper than 1000m.[113] According to the Raven Ridge Resources, methane used by these mines represents 32% of the total drained methane and only 5% of the total methane liberated. In addition, Donetsk Basin mines provide good opportunities for increased methane drainage and utilization (Marshall, 1996, p. 92). The Lviv-Volyn Basin contains highly predominant bituminous coal. The amount of methane vented into the atmosphere represents 5% of total coal mining methane emissions from Ukraine. Project opportunities are believed to exist at several mines in the Lviv-Volyn basin where the Velikomostovsk No. 10 mine is one with the most concentration of methane (Marshall, 1996, p. 93). The Raven Ridge Resources have already concluded that all the estimates mentioned above should be considered carefully and the more detailed data collection plan determines the success of the overall strategy. The same authors provide the method of calculating the coalbed methane potential of each coal basin: it is necessary "to estimate coalbed methane resources and assess what percentage is recoverable using available technologies…this effort will require detailed information on the coal reserves, geological and reservoir characteristics" (Marshall, 1996, p. 98).

The best example of the project that has been approved and received final determination under the Joint Implementation Supervisory Committee of the UNFCCC on 25 August 2008 is the "Coal mine named after A.F. Zasyadko" located in the city of Donetsk.[114] This is the first Ukrainian JI project in terms of emission reduction developed by Global Carbon. As far as coalmine methane utilization is concerned, the project in the

[113] Foreign Broadcast Information Service, *Data on Safety Conditions in Mining Sector/Ukraine*. FBIS-USR-92-085, 8 July 1992, 94. Retrieved on 28 April 2010
[114] GC Global Carbon, Coal mine after A.F. Zasyadko, Ukraine (2006). Retrieved from http://www.global-carbon.com/en/projects/uaprojects/coalmine.html on 25 April 2010

Zasyadko coal mine is the biggest one as well. Among the aspirations of the JI project are to supply electricity generated from the co-generation plants. The generated heat is planned to be delivered to the Donetsk regional heating system. Another aspiration includes construction of filling stations that will supply coal methane to the vehicles of the mine and soon replace diesel fuel.

Implementation of this JI project gives a new start to the development of the Ukrainian coal mining industry with the potential for its rejuvenation and modernization. As it has already been mentioned, many low producing mines are being forced to close, and the most profitable ones appear to be looking for new opportunities that would help increase their profitability. That is why recovery and utilization of coalbed and coalmine methane is a viable solution for the most of them. The Raven Ridge Resources concluded that the value of methane as a substitute for other fuels increases when enrichment, drying and compression of the gas are not required, and, as a result, upgrade of methane for injection into pipelines is considered as an option (Marshall, 1996, p. 101).

The proposed project *has the potential to demonstrate that the development of coalbed methane could significantly reduce reliance of Ukraine on energy imports and have an important demonstration effect for the entire Ukraine coal mining industry*. Successful implementation of this project can make a significant contribution to the strengthening of the domestic energy sector. Nevertheless, to further test the direct research hypothesis, it is necessary conduct a number of economic feasibility studies. Optimistically, Ukraine has recognized its tremendous potential for the development of a domestic source of natural gas through coalmine and coalbed methane utilization and recovery. Further advancement of the project requires the Ukrainian government to focus on the adoption of relevant legal and regulatory framework specifying mining operator and construction companies and equipment manufacturers. Another premium should be placed on the provision for qualified engineering and consultancy assistance as well as for companies that deal with natural gas transmission, distribution, as well as power companies, etc. Moreover, due attention is paid to the fact that it is necessary to conduct t informative and educational trainings for the government and industry personnel to raise the awareness of the coalbed and coalmine methane resources and the available technologies and for its recovery and utilization (Marshall, 1996, p. 102). Policy recommendations for the Ukrainian government concerning the implementation of the project will be discussed in the next chapter.

Chapter 4

Policy Recommendations Related to Utilization and Recovery of Coalbed Methane and Increase of Ukraine's Energy Efficiency

Considering the importance of energy sector advancement, increased energy efficiency, and decreased energy intensity, (through the relatively new for the former Soviet countries energy source development) the proposed policy recommendation might be of high importance for the Ukrainian government. Globally, the establishment of cooperation between governmental agencies responsible for the energy issues and economic development, coal production associations, foreign government, international agencies and various financial institutions ready to provide financial assistance plays an important role in the development of coalmine and coalbed methane recovery and utilization projects in the countries whose energy sector is entirely dependent on energy imports.

Issue: Ukraine has tremendous potential for coalmine and coalbed methane development but a rather limited amount of domestic economic & technical resources, nor a valid scientific and research base. Borrowing of the experience and strategies of developed countries, such as the United States, Australia, China, India or Poland, in the development of coalmine and coalbed methane would guarantee the success of this project. Taking into account all economic and geopolitical factors, the state found itself needing new policy recommendations concerning the effective restructuring of the coal mining industry, the introduction of unconventional natural gas production, and future guarantees of energy supply from the government.

Options: Considering the current state of the Ukrainian energy market supply and demand situation, and the fact that dependency is on major natural gas exporting countries, it is necessary to design a new strategy that would be able to be to provide a solution for the gas crises, making Ukraine less dependent on energy imports and more compatible with the interests of foreign investors and project developers. These priorities should stimulate the development of domestic natural gas production, linkages with other regional programs, and involvement of investment stakeholders. New policy recommendations will foster cooperation with the major natural gas exporting countries that would lead to mutual benefits.

First and foremost, the Ukrainian government should consider further funding on the development of unconventional natural gas from coalbeds and seams, which are the perfect source of domestic natural gas. Second, it is desirable to establish a representative research institution/committee on the base of the Ministry of Fuel and Energy of Ukraine that would control and monitor the relations between the net natural gas exporters, and establish cooperation between the state, foreign governments, & financial institutions that provide loans, grants, carbon financing and other kinds of assistance to projects on coalmine and coalbed methane development. Creation of such a research institution would provide economic, geopolitical and behavioral understanding between the leading producers of unconventional gas. According to famous political economist Dag Claes, economic understanding of the cooperation between energy producers should be supplemented with an understanding of the behavior of [oil-producing] states as economic and political analysis provides with a better understating of international [oil] world (Claes, 2001, p. 4).

Rationale: The necessity of the aforementioned policy recommendations is determined by the fact that the current state the Ukrainian energy sector is quite unstable due to economic and financial crisis, increase of inflation & unemployment, and manipulations performed by major natural gas exporters that influence natural gas prices, supply and demand. Moreover, since the year of its independence, Ukraine's political situation lacks stability. The country has been governed by leaders from different political parties that set different political agendas. In the situation where the ruling political party determines a national political course entirely dependent on the relations with neighboring countries, it is necessary to establish a sustainable production of domestic natural gas, its recovery and utilization.

Key parameters that characterize the development of coalmine and coalbed methane efficient recovery and utilization include institutional development, the introduction of new technologies, the utilization of existing economic incentives, the definition of gas property rights and proper education and information dissemination.[115] The purpose of the policy recommendations is to provide advice on how to improve Ukraine's energy policy by making it less dependent on energy import supplies.

4.1 Recommendation 1: Design of Relevant Regulatory Provisions

The Ukrainian government should design relevant regulatory provisions that would presuppose the establishment of gas property rights regulating the ownership of coalmine and coalbed methane resources as well as permitting and licensing processes. It

[115] *Analysis of International Best Practices for Coal Mine Methane Recovery and Utilization,* the Agency for Rational Energy Use and Ecology and Battelle Memorial Institute, January 2009

is significantly important to develop a uniform regulatory framework that would establish coalmine and coalbed methane ownership and standard mineral licensing procedure.[116] The researchers pay due attention to the fact that coal production is always associated with seam degassing, as it is one of the key factors that determine mining safety rules. Such methane emissions can be regarded as production waste covered either by the mine owner or other entities. The Ukrainian government should find a way to regulate coalmine and coalbed methane legal status to avoid the hindering of coalmine and coalbed utilization by different companies. It is highly desirable to design such regulatory provisions that could be easily adapted to the specifics of the Ukrainian coal mining industry. Another premium should be placed on the regulation of a legal relationship between various stakeholders.[117] According to the Analysis of the International Practices, the most sound solution to the regulation of methane ownership rights was found in Germany, as it has successfully developed an effective way to regulate coalmine and coalbed methane exploration, extraction and utilization.[118]

4.2 Recommendation 2: Institutionalizing of Coalmine and Coalbed Methane Recovery and Utilization

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[116] For example, in Ukraine coalmine and coalbed methane is considered a mineral resource which is regulated at the national level. The Code of Ukraine on Mineral Resources stipulates that the people of Ukraine own country's mineral wealth. (The Agency for Rational Energy Use and Ecology and Battelle Memorial Institute, January 2009, p. 5)

[117] Represented by surface and project owners, government and gas leaseholders

[118] In Germany the methane gas rights belong to a coal mining company for the duration of the license in which "the capture of mine gas requires a renewed license in its own right for at least another 30 years" (U.S. EPA, 2008. Global Overview of CMM Opportunities. Coalbed Methane Outreach Program, U.S. EPA, Washington, DC, September)

The provision of relevant institutional framework would result in creating a clear structure that specifies the relationship between the stakeholders and government bodies. Clearly, the Ukrainian government should take such action that would identify mine operators and project hosts, project planning developers, research institutions for the spot and background research, engineering and construction companies, etc. Moreover, it is important to support the project networking and invite technical and legal specialists that would provide consultancy on the mentioned above issues.

While creating an institutional framework, the Ukrainian government should seek investment opportunities for coalmine and coalbed methane project development. Such funding is usually associated with equity investments, various grants, loans, etc. Policy analysts from the Agency for Rational Energy Use and Ecology mention that the provision of loans requires some degree of equity financing to demonstrate that the developer is certain in the successful realization of the project and awareness of the risks. As international experience shows "that debt to equity ratios of 60:40 [debt:equity] or 72:25 are not common for international coalmine and coalbed methane projects under consideration in China. The actual ratio preferred by any given lender usually reflects the project's perceived risk as well as the borrower's financial stability". There are a number of governmental bodies and organizations providing financial and technical assistance to projects on coalmine and coalbed methane development. The Ukrainian government should appoint a committee that would be responsible for grant writing and application process for funding receipt. The Table 3 specifies major governmental and financial institutions that could provide financial assistance to the projects' realization:[119,120]

[119] Coalbed Methane Extra: A Publication of the Coalbed Methane Outreach Program, U.S. EPA, Fall, 2007

Table 3. Organization providing funding and related assistance to coalmine and coalbed recovery and utilization projects:

Financing	**Government agencies**	**Private institutions**	**International Organizations**
Loans and/or assistance in debt financing	• BISNIS Finance Link – U.S. Department of Commerce • Overseas Private Investment Corporation • Trade Information Center, International Trade Administration • U.S. Trade and Development Agency • U.S. Export-Import Bank	• ABB Financial Services • Caterpillar Financial Services Corporation • GE Capital Global Energy • Global Environment Fund Group • Global Finance Corporation • Heller Financial • Monarch Financial Corporation • Siemens Financial Corporation	• Asian Development Bank • European Bank for Reconstruction and Development • Global Environment Facility • World Bank
Carbon financing and/or assistance in carbon financing	• Austrian JI/CDM Program • Belgian JI/CDM Program • Danish Carbon Tender • Finnish Drive for Emission Reductions	• European Carbon Fund • Natsource GHG Credit Aggregation Pool • Icecap Carbon Portfolio • Japan Greenhouse Gas reduction Fund • KfW Carbon Fund	• Baltic Sea Region Testing Ground Facility • ADB Clean Development Mechanism • IFC-Netherlands Carbon Facility • Multilateral Carbon credit Fund • World Bank Carbon Funds

Besides collaboration with international agencies and financial institutions, the Ukrainian government should establish fruitful cooperation between governmental bodies and local environmental organizations concerned with the safety of mining operations, drilling, water disposal techniques and contamination, gas emissions and etc. Attraction of foreign capital requires the establishment of transparency and competitive mechanisms that would be willing to purchase energy assets. [121] After reviewing the Energy Strategy

[120] Catalog of Coalmine Methane Project Finance Sources. Coalbed Methane Outreach Program, July 2002

[121] The International Energy Agency, *Ukraine Policy Review 2006*

of Ukraine to 2030, the International Energy Agency emphasizes the necessity to shift the focus from the supply to energy demand side as well as to improve statistics on energy consumption. To implement this, the Ukrainian government should adopt international statistical methodology and provide assistance to the institutions engaged in data collection, processing and publication of the results.

4.3. Recommendation 3: Provision of Economic and Financial Incentives

According to the Coalmine Methane Global Overview by the Methane to Markets Partnership, the Ukrainian government has developed a number of incentives that include lowering or eliminating tariffs and value added taxes for Coalmine/coalbed methane equipment. Thus, ratification of JI procedures of the Kyoto Protocol and adoption of the draft law on of the draft law *"On Coalbed Methane Gas"* stipulate the procedures of tax exemptions that foster the development of coalmine and coalbed methane and ensure modernization of the coal mining industry in Ukraine. As another option, the Ukrainian government could conduct further research into economic and financial incentives successfully employed by other developed countries, such as feed-in tariffs in Germany and France, Gas Electricity Certificated and provision of the grant to cover half of a project cost in Australia, and introduction of the Climate Change Levy under the Finance Act 2000 in the United Kingdom. Further research on the development of incentives is needed.

4.4. Recommendation: 4: Conduct of Educational Trainings and Information Distribution

Ukraine represents the country whose economy and industrial complex have undergone severe recession after the disintegration of the Soviet Union. Development of unconventional gas from coalmine and coalbed methane is a relative venue for most countries with considerable coal reserves. Those countries that have already established the production of natural gas from coalbeds and seams could share their experience with those that are only on the threshold of a new era in natural gas industry. The Analysis of the Best International Practices pinpoints the necessity of a professional networking establishment which could be of great benefit to countries such as Ukraine. Projects on coalmine and coalbed methane education are being actively subsidized by various international institutions and governmental agencies of developed countries. Following their experience, the Ukrainian government should invite experts engaged in the realization of projects on coalmine and coalbed methane and borrow their experience in creating special clearinghouses[122] and information centers, as well as provide local specialists for participation in different training programs and seminars on international cooperation. Two organizations dealing with the advancement of coalmine and coalbed methane outreach programs – the EPA Coalbed Methane Outreach Program and the Methane to Markets Partnership – have already published several reports on Ukraine's

[122] Creation of a clearinghouse helps promote "coalmine and coalbed methane recovery by providing assistance on technical, economic, financial, and policy issues to interested companies and government agencies" (*Analysis of International Best Practices for Coal Mine Methane Recovery and Utilization*, the Agency for Rational Energy Use and Ecology and Battelle Memorial Institute, January 2009)

coalmine and coalbed methane reserves. The same outreach programs periodically publish information related to the adoption of the regulatory framework in Ukraine.

Another action that can be performed by the Ukrainian government is the establishment of what the Analysis of the International Best Practices calls – bilateral coalmine/coalbed methane technology transfer programs. Following this trend, it is possible to establish bilateral United States-Ukraine technical cooperation as the United States has all the knowledge, capacity and facilities to provide professional trainings for the Ukrainian high-level officials, policy makers and analysts, engineers and researchers and raise the awareness of unconventional gas potential. Plus, a newly established governmental research institution could conduct background and spot research into the existing successful bilateral programs, adopt and adjust the experience to the Ukrainian industrial sector as the host party.

The cooperation with the foreign experts would also cover the careful study of Ukraine's market opportunities and find the most effective solutions on how to promote economic growth and increase the efficiency of the domestic energy sector. Professional technological, financial and research assistance would help design the national concept aimed at the attraction of investments into Ukraine's economic and industrial sectors. Moreover, it is highly desirable for the government to make sure that necessary funds are available for the participation of key officials, engineers and researchers in various international meetings, conferences and exhibitions on coalbed and coalmine methane development that ensure exchange of experience, and views on how to achieve successful implementation of the project.[123]

[123] Technical Review of a Proposed GEF Projects, *Ukraine Coalbed Methane Project (GEF)*, Annex 3, January 22, 1998

4.5. Recommendation 5: Utilization of Coalmine and Coalbed Methane Technologies

As aforementioned, international experts divide the process on methane extraction into three stages: before mining takes place (pre-drainage coalbed methane extraction), in an abandoned or closed mine (abandoned mine methane), and in an operating mine (coalmine methane extraction).[124] According to the UN Economic Commission for Europe Ad Hoc Group of Experts on Coalmine Methane, a “drainage system is a system that drains methane form coal seams and/or surrounding rock strata. The systems include vertical mine wells, gob wells and in-mine boreholes”.[125] Therefore, considering the experts’ advice, the Ukrainian government should adopt mining technologies and regulate the procedures of water disposal techniques to create competitive environment for foreign investors. At the same time, best practices show that it is quite necessary to raise the awareness if mine owners of project potential. Moreover, the government should establish cooperation with the mine owners that will indenture their adherence to methane recovery and utilization, provision of carefully managed methane drainage system providing well-control air ventilation, sustainable gas capture and appropriate infrastructure.[126] Raising the public awareness of Ukraine’s unconventional natural gas

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[124] The Analysis *of International Best Practices for Coal Mine Methane Recovery and Utilization*, the Agency for Rational Energy Use and Ecology and Battelle Memorial Institute, January 2009, p. 12

[125] Ad Hoc Group of Experts on Coalmine Methane, *Glossary of Terms for Coalbed/Coalmine Methane*, UN Economic Commission for Europe, Geneva, 2008

[126] The Analysis *of International Best Practices for Coal Mine Methane Recovery and Utilization*, the Agency for Rational Energy Use and Ecology and Battelle Memorial Institute, January 2009, p. 13

potential is basically based on the provision of transparency, public information and education about efficient methane gas utilization.

All in all, the present policy recommendations encourage the adoption of the Rational Energy Utilization Act, including a conceptual framework for the coalmine and coalbed methane development to serve as a valuable supplement to the existing the Energy Strategy of Ukraine to 2030.

Replicability and Sustainability of the Project on Coalmine and Coalbed Methane Development: Technical review of the projects show that Replicability and sustainability might be quite difficult to achieve due to the fact that Ukraine's coal mining industry is heavily reliant on government subsidies. That is why such projects could only refer to "viable mines with relatively long commercial lives".[127] Otherwise, investment into uneconomic mines would entail major risk to fail satisfying the project's requirements because the mining operations and coalmine and coalbed methane recovery techniques would be less stable.

Degree of Commitment and Report of the Success: the Ukraine Coalbed Methane Project of 1998 suggests to reach the highest level of commitment to the project among mining sectors and the Gas Production and Sales company staff as the commitment to success is usually demonstrated through the fact that the all benefits of the project are achieved through the direct involvement of all people mentioned above. The report describes the importance of the reports of benefits in a timely manner as the people involved in the realization of the commercial side of the than reducing project are likely

[127] Technical Review of Ukraine Coalbed Methane Project (GEF), January 1998, p. 4

to be more interested in “the potential economic and safety benefits” than reducing carbon emissions.[128]

The present policy recommendations suggest the opportunities for expansion of methane recovery and utilization, ways to obtain financial and technical assistance, and ways to raise national awareness of the unconventional natural gas resource could reduce the dependence of Ukraine on energy imports and increase its energy efficiency.

[128] Technical Review of Ukraine Coalbed Methane Project (GEF), January 1998, p. 5

CONCLUSION

For the first time after Ukraine announced its Independence followed by the disintegration of the Soviet Union, the country is able to make a transition from being a net importer of natural gas to a self-sufficient state that develops its own domestic energy source through coalmine and coalbed methane extraction. The topic has already been put forward for discussion more than a decade ago but a number of circumstances created a lot of obstacles for the project to gather further momentum, coupled with the country's industrial sector suffered severe recession. Lack of effective legislation and taxation policy and insufficient funding only contributed to the overall deterioration of the state economy. As a result, the coal mining industry experienced a considerable decline in coal output, as many coal mines were uneconomical and dangerous to maintain. Nowadays, Ukraine has the capacity to become an energy efficient state, but reformation and privatization of the coal mining industry are needed. The realization of the proposed project would represent an ample opportunity to attract investment into the domestic industrial complex in case the government remains adamant in its efforts to achieve self-sufficiency and establish a favorable investment climate.

The introduction of existing international experiences, availability of new technologies and equipment, design of relevant regulatory and institutional framework, and the establishment of cooperation with foreign governments, potential project developers, investors and environmental protection groups could guarantee the successful implementation of coalbed and coalmine methane development in Ukraine. The present thesis addresses an important issue in reducing Ukraine's dependence on energy imports and increasing its energy efficiency through the development its own natural gas. Ukraine is considered one of the largest coal and coalmine producing countries in the world with the most limited coalbed methane being locally recovered and utilized[129]. This project has the potential to demonstrate how coalmine and coalbed methane can serve as a viable solution to constantly increasing volumes of imported natural gas and consumer's demand for energy. Moreover, the present research paper describes existing methane production and water disposal techniques that could be adopted in accordance with the domestic geological characteristics. Ukraine has the ability and opportunities to borrow the best international practices of coalmine and coalbed methane development through the establishment of professional networking with the foreign governmental bodies, key stakeholders, major project developers and professional associates. Proposed analysis of the past and present political situation, influenced mainly by Ukraine's geopolitical location and the overview of the coal mining industry condition and its potential, emphasized the importance of switching to development of unconventional energy source.

Currently, the Ukrainian coal mining industry is slowly making technical and legislative improvements that will significantly help increase methane recovery and utilization. Proposed policy recommendations could be considered as a supplement to the Ukraine Energy Strategy to 2030, as they help assimilate current knowledge and available experience in unconventional gas production and serve as a single unity for those who seek opportunities on how to develop coal industry and increase efficiency of the energy sector. Since the United States pioneered the project on coalmine and coalbed methane development, further research on adoption of their experience is needed. At the

[129] Technical Review of a Proposed GEF Project, Ukraine Coalbed Methane Project (GEF) Annex 3, January, 1998

same tine, the Ukrainian government should encourage participation of the interested parties in methane extraction and raise public awareness of its tremendous potential. All in all, securitization of the domestic natural gas production would significantly reduce Ukraine's vulnerability and sensitivity to the disruption of natural gas supply through transit pipelines, oil price volatility, changes in the tax legislation and geopolitical situations. The present thesis contains analysis of secondary data on the recent Ukraine's energy production and consumption rates and predicts the trend for energy consumption increase. *Without production of domestic natural gas, Ukraine would find itself more dependent on energy imports and the political agendas of exporting countries. Therefore, development of a domestic sustainable energy source would enable financial development of the country and be less dependent on the political course of its leaders.*

Nevertheless, the development of the coal industry can not solely rely on coalmine and coalbed methane extraction, as the reformation of the legislative system and ease of bureaucratic process are needed. Otherwise, lack of efficient regulatory framework, transparency, and complicated bureaucratic procedures will deter investors to look for other opportunities outside Ukraine. Commitment to the development of unconventional gas would also create positive signs for Ukraine's industrial sector and alleviate the stress caused by economic and financial crises. Furthermore, modernization of the coal mining industry through the development of coalmine and coalbed methane would significantly reduce the loss of lives during coal mine explosions and provide the nation with a clean, environmentally friendly fuel.[130] Consideration of proposed recommendations combined with utilization of qualified assistance would offer a solution

[130] Coalbed Methane: Principles and Practice, R.E. Rogers, Mississippi State University, 1994

to the energy supply issues. Further research concerning the development of coalmine and coalbed methane in Ukraine is needed.

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