Russia’s Blueprint for a Nuclear Energy Renaissance:
Its Domestic Policy and International Role

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ABSTRACT

JIE SHEN: Russia's Blueprint for a Nuclear Energy Renaissance:
Its Domestic Policy and International Role
(Under the direction of David McNelis)

Russia's economy and energy security could not rely solely on oil and gas for the long-term strategy based on their economic dependence, geologic availability, and reserve policies. This thesis answers why and with what percentage will nuclear power take part in Russia's future energy portfolio, draws political indications from the interface of Oil & Gas—Economy—Nuclear—Policy. By doing Stakeholder and S.W.O.T. Analyses, nuclear power is the most reasonable choice to diversify Russia's energy portfolio. The predicted role of nuclear power by 2020 is indicated herein by its percentage out of the country's projected total electricity output, which is plotted from the Russian GDP and Electricity Output regression model. The percent range from 21.2% to 25.9% is calculated by a Russian nuclear electricity output equation. Concomitantly with a significant increase in nuclear power implies needs for aggressive fuel and technology policies and Rosatom's financial preparedness needs to be affirmative.

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INTRODUCTION

Being the world's leading gas exporter and one of its largest oil exporters, Russia has become one of the most attractive emerging energy markets in the world. Russia has experienced a remarkable economic revival over the past decade, especially during Putin’s administration. Based on the real GDP growth data of Russia, the average annual growth has been high, hovering around 7%. In 2008, Russia's GDP grew an estimated 6.0%[1]. In the second half of 2008, however, the global financial crisis and a steep fall in the price of oil slowed Russia’s economy significantly. The roughly 1% drop in GDP growth indicated an imbalance in the structure of Russia’s economy—the country depends greatly on its natural resource exportation for its economic growth. The President of Russia, Dmitry Medvedev, has addressed in a recent speech that “achieving leadership by relying on oil and gas markets is impossible[2]”. This structure, dependent mainly on the exportation of those two commodities, would not be expected to be stable with the historical fluctuation of oil and gas prices; the relatively weak sustainability to serve as a long-term solid mainstay of export; the lack of diversity in product forms; and the great potential to raise multiple political issues.

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[1] Central Intelligence Agency (CIA). “CIA - World Factbook - Russia.” https://www.cia.gov/library/publications/the-world-factbook/geos/rs.html.

[2] Dmitry Medvedev. “Go Russia!” *President of Russia Speeches*, September 10, 2009. http://eng.kremlin.ru/speeches/2009/09/10/1534_type104017_221527.shtml.

Before discussing the weaknesses of the Russian energy-economy structure, the question of the role of the energy sector, especially the oil and gas part, in the Russian economy should be addressed. Russia's economy is heavily dependent on oil and natural gas exports. According to International Monetary Fund (IMF) and World Bank estimates, the oil and gas sector generated more than 60 percent of Russia's export revenues (64% in 2007)[3], leaving the country particularly vulnerable to swings in world prices. In the 2003 *Summary of the Energy Strategy of Russia for the Period of Up to 2020*[4] prepared by the Ministry of the Russian Federation is noted that the government set aims, tasks and guide lines for a long-term State energy policy and phases of its realization. It is stated in the summary that the energy strategy will be carried out in two phases. By the end of the first phase (2009-2010), the two most important scenario objectives are:

1) "the realization of the export potential of oil and gas complex and attainment of stable positions of energy companies at the internal and external fuel and energy markets;

2) the transition from the impellent role of the fuel and energy complex in Russian economy to the role of an effective and stable supplier of fuel and energy resources for needs of economy and population."[5]

From these two objectives in the first phase, it is apparent that Russia has great confidence in the export potential of its oil and gas complex, and is ready to develop it to play a relatively

[3] Energy Information Administration (EIA). "Russia Energy Data, Statistics and Analysis – Oil, Gas, Electricity, Coal." http://www.eia.doe.gov/cabs/Russia/Background.html.

[4] The Ministry of the Russian Federation. *Summary of the Energy Strategy of Russia for the Period of Up to 2020* (Moscow, 2003), 3.

[5] ibid., 3.

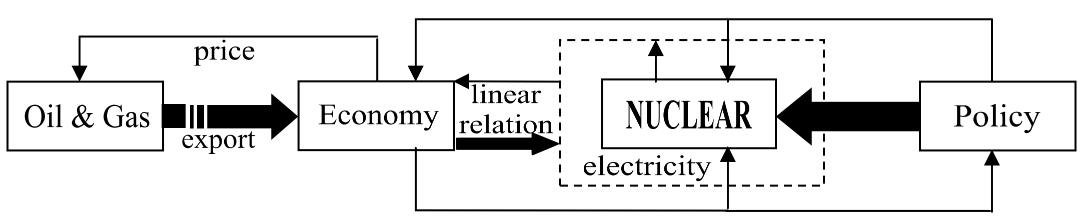
dominant and necessary role in the internal economy and civil needs of Russia as well as its external markets.

For the second phase, objectives include "rapid use of the existing odds (opportunities) in nuclear power and hydro energy sectors, coal industry; … abrupt increase of contribution of the scientific and technical and innovation potential to the Russian energy sector; creation of basis for a substantial increase of the renewable share in the forthcoming period and transition to the energy of the future[6]".

This phase has shifted into a higher level of diversifying the energy sector as compared to the first phase. Among all the energy forms planned for further development, only nuclear energy and the coal industry have solid foundations already established since Soviet times. Other innovations in energy forms including renewables are still highly underdeveloped in Russia.

In this thesis, discussions will be based on a four dimensional conceptual model of major Russian energy-economy relationships:

Figure 1: Conceptual Model



A comprehensive Oil & Gas—Economy—Nuclear—Policy model would in reality, be vast and complex. Therefore, for analytical convenience and focused analysis, only relationships

[6] ibid., 4.

marked by arrows in this model are developed for illustration in the following chapters.

During the past ten years, Russia's economy was boosted greatly by its internal and external oil and gas markets. At the same time, the country and the world have been experiencing fluctuating prices of oil and gas and related regional political issues. And it is widely recognized that these two resources will eventually run out. Under these circumstances and the influence of various other factors and variables not treated in this thesis, the economy needs more sustainable, high-tech, high value-added energy products to provide the base-load capability for its domestic market. Nuclear-provided electricity is one resource that, along with its related services, would help to secure and diversify the economy and provide base-load power. When achieving this, government involvement will be deep and dominant in Russia. Therefore, several major policies could have impacts on the process of nuclear energy development. These policies cover the concerns of population, nuclear technologies and services, uranium availability, environmental issues, public acceptance, and financial readiness. The synergies and tradeoffs among these policies will have important effects on the development of nuclear energy.

CHAPTER 2

OIL & GAS—ECONOMY

Based on this conceptual model, a discussion of the four aspects mentioned at the end of first paragraph of the *Introduction*, which answer the question of why the current energy-economy structure is not stable or healthy for the long term, can be developed. This addresses the relationship between the first two elements in the conceptual model: oil & gas—economy.

The four issues that suggest an economy heavily dependent on oil and gas is not a very stable structure are:

1) the fluctuation of oil and gas prices;
2) relatively weak ability to serve as a long-term mainstay for export;
3) lack of diversity in product forms;
4) and great potential to give rise to multiple political issues.

2.1 Fluctuation of Prices

The first issue relates to the global fluctuating oil and gas prices. As observed for the past year, the price of crude oil in the international market has experienced a huge up-and-down from the highest price of 147 dollars per barrel[7] in the summer of 2008 to the low of nearly 30 dollars per barrel[8] after the financial crisis in the Fall of 2008. As we look into the

[7] BBC News. "Oil hits new high on Iran fears." *BBC News*, July 11, 2008. http://newsvote.bbc.co.uk/2/hi/business/7501939.stm.

[8] Energy Information Administration (EIA). "Cushing, OK WTI Spot Price FOB (Dollars per Barrel)." *EIA Petroleum Navigator*, data retrieved on October 18, 2009. http://tonto.eia.doe.gov/dnav/pet/hist/rwtcd.htm.

numbers of GDP growth of Russia for the last five years (2004-2008), 7.2%, 6.4%, 7.4%, 8.1%, 6.8%[9], the 2008 data showed a dramatic drop of 1.3% from the 2007 growth. This drop in the annual GDP growth, according to the 2008 Russian President's Addresses to the Federal Assembly[10], was mainly caused from the oil price breakdown. On the other hand, the economy revival experienced by the country since Putin’s administration was greatly driven by the unusually high oil price in the new century.

The gas market was not in the same situation as the oil market, but prices still vary in a range for different countries or regions. Russia is the largest exporter of natural gas in the world and gas supply to Europe is mainly dependent on Russia. There are also multiple gas pipelines stretching into the Middle-East and Central and East Asia, and distant customers receive Russia’s gas through compressed shipments. Russia charges differently among customers, and usually the differences are not negligible. In 2006 for example, the most obvious differences were among Belarus, Ukraine, and the European Union. In 2006 Belarus paid only \$46 per 1000 m^3, a fraction compared to \$290 per 1000 m^3 paid by Germany[11]. Russia charged Belarus at a lower price for political reasons as it cannot afford to lose another former ally and close following the collapse of the Soviet Union[12]. Russia charged

[9] Russian GDP data is retrieved from World Bank.

[10] Dmitry Medvedev. “Address to the Federal Assembly of the Russian Federation.” *President of Russia Speeches*, November 5, 2008. http://eng.kremlin.ru/speeches/2008/11/05/2144_type70029type82917type127286_208836.shtml.

[11] People’s Daily. “Russia to adopt market gas price with Belarus from 2007.” *People’s Daily*, China, April 17, 2006. http://english.people.com.cn/200604/17/eng20060417_258874.html.

[12] The annual Russian subsidies to the Belarusian economy were around \$4 billion, as Russian president Vladimir Putin said on January 9, 2007.

Ukraine at about half of what the Europe paid[13] because most of the pipelines that extend to the Europe and provide large earnings pass through Ukraine. Russia will not allow those low prices to exist for long as they obviously decrease the revenue from gas exporting.

2.2 Weak Sustainability

The second issue refers to the relatively weak sustainability of oil and gas to serve as a long-term solid mainstay for export. The fact that it took millions of years for oil and gas to form and accumulate beneath the ground they are considered non-renewable resources for foreseeable generations, and running out is just a matter of time. A conservative estimation of 75 years for oil and gas to run out at today's market prices is based on the same consumptive rate as present.[14] But with the expansive usage of oil and gas into nearly every aspects of modern life, it is not as simple as an estimation based simply on reserves. Several other factors directly influence their sustainability:

a) Technology used in oil refineries. Current technology invested into the oil industry is on a low level of extraction, i.e., around 30%[15] from the oil-bearing formations. This allows the capital to profit easier and faster. Future consideration will include an optimization of investment for smaller and harder to get reserves using improved technology. This may

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[13] Wikipedia. "Russia–Ukraine gas dispute of 2005–2006." *Wikipedia*, retrieved on August 4, 2009. http://en.wikipedia.org/wiki/Russia%E2%80%93Ukraine_gas_dispute_of_2005%E2%80%932006.

[14] World total oil proved reserve is 1,342.207 billion barrels; world total natural gas proved reserve is 6,254.364 trillion cubic feet. Data retrieved from *Oil & Gas Journal*, Vol. 106.48 (Dec. 22, 2008), PennWell Corporation, except United States. Oil includes crude oil and condensate. Data for the United States are from the Energy Information Administration, U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 2007 Annual Report, DOE/EIA-0216(2007) (Feb. 2009).

[15] Grenon, M.. "The world's oil resources." *Revue de l'Energie*, vol. 27 (July-Aug. 1976): 372-377. http://adsabs.harvard.edu/abs/1976RvEn...27..372G.

eventually provide an opportunity for alternative energy sources to bloom, which in turn will positively impacts oil sustainability.

b) Challenges based on environmental considerations. Both oil and gas need a combustion process to realize their value as energy sources. Green House Gases (GHG) abatement has become a global issue since the Kyoto Protocol was formulated. Public awareness of the potential dire consequences of global warming and industrial interests in renewable technologies are pushing the agenda for GHG reductions to a higher level than ever. Thus, cleaner energy forms would occupy part of the existing fossil fuel market in the future, and that is when oil and gas might be expected to phase out gradually.

c) Political considerations on energy security. Basically, countries and regions with different situations of resource conditions will face the problem of securing strategic energy reserves, which currently exists mostly in the form of oil and gas. At the same time, they are trying to develop multiple energy supply chains suited to their own advantages. The most famous example would be Iceland. In 2006, the country's use of geothermal energy to contributed 26.5% of its total energy consumption, and hydro provided 73.4%. Fossil fuels contributed the remaining 0.1%[16]. Iceland is using almost all of its energy from sustainable renewable resources.

All above three factors have a tendency to decrease the consumption of oil and gas.

2.3 Lack of Diversity

[16] Orkustofnun (Iceland Energy Authority). "Energy Statistics in Iceland, 2007". http://www.os.is/solofile/20644.

A third issue is the lack of diversity in product forms and was the main motivation for this thesis. As was suggested in the *Introduction* chapter of this thesis, the Russian energy strategy was based on adding more choices into the energy portfolio. In Medvedev's recent speech[17], he identified five strategic vectors for the economic modernization of Russia, the first vector being to develop new fuels for use in domestic and international markets, and the second being to maintain and raise Russia's nuclear technology to a qualitatively new level.

As the simple rule of financial investment states, "Do not put all your eggs in one basket," energy security needs to follow the same principle. During the first phase of Russia's strategy, oil and gas are set to play major roles as both internal and external economy propellers, considering that Russia does not solely control the prices and is facing a future of eventually running out. Therefore, a third solid and sustainable component in the portfolio is urgently required. A recent trend in the EU to develop renewables like solar, wind, and clean coal technology can be viewed as an action for the same reason. What the EU faces ranges from a scarcity of natural resources to political consequences not even directly related to them (i.e.: the Russian-Ukraine gas dispute). The EU is now a leading role model in the world in implementing multiple energy strategies and developing a strong market for alternative energies.

2.4 Political Issues

The Russian-Ukraine gas dispute is a perfect example for the fourth issue of political

[17] Dmitry Medvedev. "Go Russia!" *President of Russia Speeches*, September 10, 2009. http://eng.kremlin.ru/speeches/2009/09/10/1534_type104017_221527.shtml.

conflicts and related to Russia's current unstable energy-economy structure. The dispute was widely considered as driven by both economic and political purposes. The economic part was partly mentioned in the first issue as Ukraine had been paying a lower price to Russia for gas. But this unique problem has other facets as well. It was already the fourth dispute between the two countries. The two countries hold a bilateral intergovernmental annual negotiation framework of gas trading. Russia attempted to raise the price of gas for Ukraine to a market level; while Ukraine wrestles with Russia by charging high gas tariffs and transit fees to maintain the lower gas prices from Russia. Throughout post Soviet history, Ukraine has owed a large gas debt, and accused of non-payment and gas diversions by Russia. Russia cut off the gas supply to Ukraine in each dispute, and Europe became a third party victim in being cut off from gas supplies. This expanded the conflict from a bilateral one to a multiparty event.

Under the current global financial crisis situation, Russia has been struck by the oil price drop which has significantly affected the country's economy. Russia will require a debt reimbursement from Ukraine. There are other, sometimes historic drivers that contribute to the disputes:

a) the most fundamental cause is Ukraine's de-russification since the collapse of the Soviet Union. For Russia, it does not want to lose Ukraine as being both a buffer and a bridge to the West. One of Russia's strategies was to offer a relatively low price for gas to Ukraine in order to maintain the ties between the two. The price was set at $50 dollars per cubic meter when the market price was about $230. This was the situation before 2006, just two years after the Orange Revolution in Ukraine. The revolution provided a strong signal of a firm step toward de-russification, and resulted in a change from a pro-Russian strategy into a pro-Western one.

b) The second driver relates to the EU and NATO relationships with Russia and Ukraine, Russia's being essentially non-existent and the Ukraine's becoming closer. Member countries of the EU and NATO are highly overlapped, 21 European countries are members of the two[18]. These two organizations are powerful entities that are challenging Russia on economic and national security issues. Geopolitically, Ukraine and Belarus serve as important buffers and bridges with these two organizations. In this case, the relationships of Russia to Ukraine and to Belarus have to be pro-Russian in the interest of Russia. Should Ukraine turn to EU and NATO, it will be a heavy blow to Russia's interests and security. A recent example could be Ukraine's attitude in the Russia-Georgia conflict in the summer of 2008. Some Russian media's accusation of Ukraine aiding Georgia with weapons could indicate a departure of Ukraine from Russia. On the other hand, Russia's cutting off gas supplies to Ukraine provided a strong indication of Russia's relation and a caution to Europe against accepting the Ukraine in the EU. There were 18 countries in Europe that were affected by the 2009 gas dispute[19], and 12 out of the 18 were EU members. Another slightly different set of 13 countries were NATO members; while 11 were both EU and NATO

[18] Countries both in EU and NATO (20): Belgium, Bulgaria, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and United Kingdom.

[19] Countries hit by gas dispute in 2009 (18): Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, France, Germany, Greece, Hungary, Italy, Macedonia, Moldova, Poland, Romania, Serbia, Slovakia, Slovenia, and Turkey.

members. While this action may not represent the main purpose of Russia's firm stance in the dispute, it did send an obvious signal to Europe and the Ukraine that the balance of economic and political interests of Russia needs to be maintained.

c) Another and even larger driver was that Russia was trying to gain more status in the emerging, OPEC-like organization of Gas Exporting Countries Forum (GECF). At the end of 2008, the forum held its annual meeting since 2001 in Moscow, to discuss its proper regulations and name. The establishment of another formal gas exporting country organization will have an obvious impact on the international gas market. As the original organizer and the largest gas exporter, Russia is ambitious to gain the prominent position in the organization, more specifically, the right to set gas prices. This is not hard to understand and should not be hard to achieve once one takes a look at the list of members and observers[20]. The only former Soviet country that is included as one of two observers is Kazakhstan. Kazakhstan has abundant natural resources, particularly fossil fuels and uranium, which could provide an important strategic reserve supplement for Russia. Other members are located all over the world and do not include any EU nor NATO countries. Russia's action toward Ukraine, which is trying to get into the Western circle, is definitely a warning signal to all and a declaration of its own image of an energy superpower.

This fourth issue of political conflicts is the most unstable one among the four. It involves many parties and is actually an issue of energy being a tool for achieving political

[20] Countries in the Gas Exporting Countries Forum (GECF) (15+2): Algeria, Bolivia, Brunei, Egypt, Equatorial Guinea, Indonesia, Iran, Libya, Malaysia, Nigeria, Qatar, Russia, Trinidad and Tobago, the United Arab Emirates and Venezuela. Kazakhstan and Norway are observers.

interests. This is an unstable confounder in a purely theoretical model of energy-economy structure. Stated another way, political factors have taken up too much in an energy availability and sustainability problem. Thus, one or several energy forms having less political implications need to be introduced into the Russian energy portfolio. Specifically in this case, Ukraine may eventually become an antagonistic entity toward Russia which will still control the main pipeline from Russia to Europe. Russia cannot depend too much on the revenues through its Ukraine pipelines. GECF is a tentative try, but according to the characteristics of natural gas[21], this organization might not achieve its function of setting the production and price of gas like the OPEC does for oil.

These four issues that relate to the instability of Russia's energy-economy structure have suggested the following requirements of change: 1) relative stable price; 2) large amount of demand; 3) abundance in reserve; 4) clean and environmental-friendly in use; 5) less politics involved. In *Chapter 3*, the question of what energy form best fits these requirements will be answered.

[21] Liquid natural gas (LNG) is uneconomical to store and requires immediate consumption at the end of the pipelines. The relation between supply and demand has its instantaneity, it is not intended to store in order to influence the price. Other than this, pipelines are large initial capital investments, and restrict its flexibility to dispatch on gas and on cash flows.

CHAPTER 3

WHY NUCLEAR?

As mentioned at the end of *Chapter 2*, Russia needs new blood in its energy portfolio and several requirements were set to be met. Several choices of energy form is being compared in this chapter. The element of “nuclear” in the four dimension conceptual model will be discussed.

As we see it is already a fact that Russia is moving steadily forward with plans for much expanded role of nuclear energy, at least doubling output by 2020. This requires a large increase in electricity capacity with an effective portfolio of energy sources. This chapter presents six major aspects of problem concerning the selections of new major energy form. By doing a stakeholder analysis matrix and a quantitative alternative S.W.O.T. analysis[22] based on criteria of various costs, benefits, and equity, robustness, this chapter concludes with an optimized plan of Russia’s portfolio of electricity.

At present, Russia’s electricity is generated from three kinds of power plants. Roughly 63% from fossil fuel plants, 21% by hydropower and 16% comes from nuclear reactors[23]. Major part of the electricity generation is coming from the thermal plants.

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[22] S.W.O.T Analysis is a strategic planning method used to evaluate the Strength, Weakness, Opportunities, and Threats involved in a project or business venture. This technique is credited to Albert Humphrey.

[23] BBC News. “Russia: Energy overview.” *BBC News*, February 13, 2006. http://news.bbc.co.uk/2/hi/europe/4699942.stm.

Russia has an explicit objective of doubling gross domestic product within a decade[24]. Efficient and reliable electricity services will be critical to the success of this policy. Therefore, Russia will need to build more power plants to meet the demands. Under the global trends to initiate more clean and efficient power plants, Russia will have to create a responsible portfolio of electricity sources both for its domestic economy and the international society.

3.1 Russia's New Electricity Portfolio Obstacles

The portfolio of electricity generation is a multidimensional decision that could be affected from various angles. Those angles are further affected by different country's own condition. The following are aspects of the issue concerning Russia:

3.1.1 Economy Condition

Before the collapse of the Soviet Union, Russia remained as the nucleus of a superpower. This superpower had developed its heavy industries and military industries to a historical height, under a secluded condition. After its collapse, what used to be the economic circulation within the Soviet Union would become, if it continued to happen, the form of exportation and importation between Russia and those former Soviet States. In this transition, resource circulation takes a major part of the contribution of Russia's increase of exportation data, which is brought by the collapse of the Union.

Russia, therefore, is a unique emerging market. Its exports are primarily resource

[24] International Energy Agency. *Russian Electricity Reform - Emerging Challenges and Opportunities*. OECD/IEA, 2005.

based. And Russia's exports reached 20% in its GDP in the year of 2000[25]. Payments from the fuel and energy sector in the form of customs duties and taxes accounted for nearly half of the federal budget's revenues[26]. Among the exported resources, oil and gas take the majority. In fact, Russia is already the largest natural gas exporter and the third oil export entity after Saudi Arabia and the EU. Resource exports can bring the government large and steady revenue.

Under this kind of economic situation, Russia would have to allocate major parts of its oil and gas extracts to the pipelines for exportation, rather than to bet its future increase of electricity capacity completely on new thermal plants by using a substantial part of its fossil fuel extracts. In another word, Russia has an economic driving tendency to make money from fossil fuel exportation for its country's development, and that requires support from developing other electricity sources.

3.1.2 Natural Restriction

Russia though has the largest land area in the world; unfortunately, its territory is longitude-spread on a very high latitude range. This natural geography restriction results in a variety of disadvantage in developing alternative energy.

High latitude area lacks sun shine in time duration and appropriate angle for solar energy. Low temperature in most area of Russia makes the soil non-cultivable even frozen

[25] Kommersant. "Rosstat Confirms Record GDP Growth." *Kommersant*, Russia's Daily Online, April 15, 2008. http://www.kommersant.com/p882678/r_527/macroeconomics/.

[26] Wikipedia. "Economy of Russia." *Wikipedia*, retrieved on August 4, 2009. http://en.wikipedia.org/wiki/Economy_of_Russia.

permanently, this could be a problem for developing biomass fuel. These two every obvious disadvantage alone has taken away big part of mainstream alternative energy from Russia's choice for its portfolio.

3.1.3 Sustainability of Fuel Supply

In respect to the fuel supply, the most important thing is to have a cheap, steady, controllable, self-sufficient source.

For thermal plants, coal, oil and gas are adequate for current generations, but they are non-renewable energy resources that will eventually run out. As previously mentioned in *Chapter 2*, oil and gas reserve would last 75 years at current production rate in the world; and coal reserve would last 164 years at current production rate[27].

Situation for Russia is not better. In Table 1, estimated years to last for oil, gas, and coal based on Russia's reserves and its annual consumption and production (including export) is calculated in the last column. Notice that based on current oil production rate of Russia, oil will run out in less than two decades, and coal will last longer than the world projection.

These estimations are based on recent data of world and Russian reserves. Different estimations may exist based on data of resources. Reserves are currently economically feasible; resources are currently or potentially economically feasible. They both answer the question of how much is left with geologic and economic considerations. Reserve can be viewed as subset of resources. The McKelvey Box simplifies this difference by identifying

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[27] Office of Integrated Analysis and Forecasting. Chapter 5: Coal, *International Energy Outlook 2007*. Energy Information Administration (EIA), May 2007.

increasing geologic assurance (speculative / hypothetical / inferred / proved reserves) and economic feasibility (sub-economic "resources" as compared with economic "reserves" depending on price and cost levels and available extraction technologies).[28]

Table 1: Sustainability Statistics for Russia's Major Types of Energy Resource

Resources	Reserve[29]	Annual Consumption[30]	Annual Production[31]	Years Estimated (Consumption / Production)
Oil (billion barrels)	60.00	1.10	3.33	55 / 18
Gas (trillion cubic feet)	1680.00	16.60	23.20	101 / 72
Coal (billion short tons)	173.10	0.26	0.32	666 / 541

This worry of thermal fuel shortage brings another problem, the fluctuation of the prices. The global market of oil is undergoing huge up-and-downs in recent years. The price of natural gas was even manipulated by Russia to use as a political instrument toward some former Soviet States. Although now Russia is at a vantage point of operating the global energy market; and its domestic use of fossil fuels are not affected by the unsteady outer environment, it still needs to create a robust plan for its own energy supply, reducing the influence of fuel price to a practical minimum.

[28] United Nations Statistics Division. "Environment Glossary, McKelvey Box." http://unstats.un.org/unsd/environmentgl/gesform.asp?getitem=744.

[29] Data retrieved from *Oil & Gas Journal*, Vol. 106.48 (Dec. 22, 2008), PennWell Corporation, except United States. Oil includes crude oil and condensate.

[30] Energy Information Administration (EIA). "Russia Energy Data, Statistics and Analysis – Oil, Gas, Electricity, Coal." http://www.eia.doe.gov/cabs/Russia/Background.html.

[31] ibid..

3.1.4 Intelligence Reserve and Technology R&D

Russia has a pool of technical talent in aerospace, nuclear engineering, and basic sciences inherited from the Soviet Union. Take nuclear science for example, Russia launched the world's first nuclear reactor. Since then this country has never stopped its efforts on research of better reactor, even after the Chernobyl accident. Large human resources have been invested into this field of science. Recently, Russia has initiated an innovative nuclear power development based on its decades of nuclear technology R&D. The aim of this innovation is to shift this industry to a new fast reactor phase by using more out of a same amount of fuel. This provides a solid base for alternative R&D of electricity portfolio of Russia.

3.1.5 Environment Issues

Global warming is an inevitable issue nowadays for any energy related development. A broader influence is the rising of green house gas proportion that would affect earth ground surface area and the global climate. A direct influence from energy related activities is the use of thermal power plants would greatly harm the local ecology by mining and burning the fuels. Russia is the largest country in the world. If take the area as the unit, it has a relatively the largest responsibility to the earth environment.

3.1.6 Political Concerns

After the collapse of the Soviet Union, many of the former Soviet States either have been or are undergoing the revolution toward Democracy. This brings a problem serious to the Russian government—their former brothers have turned to the other side. One famous example is the Russia-Ukraine gas dispute. Ukraine controls the main pipe from Russia to the Europe, as Russia lost this former brother, the export gas price offered to Ukraine was not a unilateral decision anymore. This would definitely affect Russia's main export business. In fact, while Russia was trying to make the best out of its energy resource exports, it also created an energy security problem to the Europe. As long as fossil fuels are needed, Europe cannot reach its energy independence; but by turning Russia-neighboring former Soviet States into their allies, the Europe gained more balance on the leverage.

A fatal flaw of having limited kinds of energy exports is emerging, not to say this contributes the major part of exportation. Russia needs to develop the variety on its energy products in order to alleviate the political pressure from its image of gas and oil monopoly. Nuclear electricity as a product, its technology and services can be an underlying break point for Russia to establish its own electricity portfolio.

3.2 Nuclear, Wind, Clean Coal?

Based on the above six aspects, this section will focus on how Russia optimize its electricity portfolio according its own interest.

3.2.1 Stakeholders

A stakeholder analysis [32] will identify people, groups, and institutions that will

[32] Stakeholder analysis is a term used in conflict resolution, project management, and business administration to describe a

influence or be influenced by the change of electricity portfolio (either positively or negatively); anticipate the kind of influence; and develop strategies to get the most effective support possible and reduce any obstacles to successful implementation of new electricity portfolio.

In this analysis, stakeholders concerning optimizing the Russian electricity portfolio are sorted into three groups, community, government sectors, and businesses. Community stakeholders are categorized according to different groups of people related to electricity industry chain segments; government stakeholders are from local, departmental, to central powers; business stakeholders are from different energy companies. See Stakeholders Analysis Matrix on the next page.

According to the impact index in the Matrix, all stakeholders considered are either having overall positive influence or getting overall positive influence. The potential strategies that suggested in the Matrix focus on residents getting job opportunities and preferential electricity price; government sectors providing financial, political, and juristic supports; businesses enhance market exploit, industry self-discipline, and facilities construction. The analysis reveals a positive momentum from each side of the stakeholders.

3.2.2 S.W.O.T. on Alternatives

Among all the alternative choices of energy, the following three are alternative choices to Russian electricity portfolio. Russia's alternative portfolio of electricity will not end up on a

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process where all the individuals or groups that are likely to be affected by a proposed action are identified and then sorted according to how much they can affect the action and how much the action can affect them.

Table 2: Stakeholder Analysis Matrix

Stakeholder	Stakeholder Interest(s) in the Project	Assessment of Impact*	Potential Strategies for Obtaining Support or Reducing Obstacles
Community			
Residents adjacent Power Plants	May have steady, cheap power supply; May migrate due to new construction; Health under potential risks; Water, soil, and air contamination	N	Job opportunities like logistics support, dining, entertainment services for plant employees; Government supported immigration plan; special residential electricity price offer by company of plants; contamination risk and data release on certain time base; state standards on emission
Residents adjacent the Mining Sites	More labor job opportunity; Ecological damage; Water, soil and air contamination	B	Job opportunity offering; ecology protective mining; state standards on water, soil and air contamination control
Residents in Cities	May have steady, cheap power supply; May be under risk of nearby plants; May have to pay environment tax on certain commodity	C	Education of environmental problem and alternative energy; upgrade city power grids; proper selection on location of new plant sites; comprehensive emergency plan by government
Government Sectors			
Municipal Government	Maintain and improve city grid; Integrate more kinds of energy companies	B	Ensure stable fiscal revenue; commercialize city grid with proper government support; strengthen regulations for electricity companies
Rosatom (State Owned Nuclear Company)	More investment on nuclear R&D; Public pressure on storage and reprocessing of spent nuclear fuel;	A	Allocate more funds for nuclear R&D; Proper selection of spent fuel storage sites; open and transparent reprocessing; strengthen regulation on management of weapon-grade material
Ministry of Energy	Restructure based on new energy portfolio	A	Submit state law on management of alternative energy
Businesses			
Gazprom	Investment on environment control; Less percentage on domestic market	B	Exploit and consolidate foreign markets; promote the establishment of OPEC-like organization of natural gas
Oil/Pipeline Companies	New pipeline to build for more countries; New pipeline detouring certain countries; Investment on clean extraction	A	Implement the construction of new pipelines to Europe, Far East, and west Asia; gain more power on the price decision of gas on the global market
Rosenergoatom	More reactors to build home and overseas; Investment on reactor safety technology; Large cost on decommision of old plants	A	Expand nuclear reactor construction contracts in global market; provide fuel reprocessing service; maintain the old plants with stable operation performance and apply for extension on operation licenses
Inter RAO UES	Upgrade the state power grids; Balancing cost and price from different electricity sources	A	Adopt SMART grid; full and effective market research on optimizing electricity portfolio distribution

*Assign A for extremely important, B for fairly important, C for not very important, N for overall negative.

single choice of one kind of new major electricity source. There would be a timeline to develop a mature portfolio. Choices not ready for adopting may be adopted in the future. But for current situation and due to the country's natural restrictions, many kinds of alternative choices, such as solar power and biomass, are precluded from the pool of selection for latitude and soil reasons (see previous section of 2.1.2). The three most reasonable choices are nuclear, wind, and clean-coal, the S.W.O.T. analysis (strengths, weakness, opportunity, and threats) will explain each of their arguments respectively.

1) Nuclear Energy

Nuclear technology is designed to extract usable energy from atomic nuclei via controlled nuclear reactions. The most common method is through nuclear fission. It has already been used as one of the major technologies to generate electricity. Today, more than 15% of the world's electricity comes from nuclear power, with the U.S., France, and Japan together accounting for 56.5% of nuclear generated electricity[33]. There are 439 nuclear power reactors in operation in the world at present[34], operating in 31 countries[35]. Conventional nuclear power plants use uranium 235 as its fuel, some use plutonium 239; Russia is planning to use innovative technology to switch to a new energy resource – Uranium 238 – by the middle of the 21st century, while the fact is that uranium 238 is more abundant than uranium

[33] International Energy Agency. *Key World Energy Statistics 2007*. OECD/IEA, 2007.

[34] International Atomic Energy Agency. "Nuclear Power Plants Information, Number of Reactors Operation Worldwide." http://www.iaea.org/cgi-bin/db.page.pl/pris.oprconst.htm.

[35] World Nuclear Association. "World Nuclear Power Reactors and Uranium Requirements." Retrieved on June 9, 2008. http://www.world-nuclear.org/info/reactors.html.

235 in Russia and the world.[36] This would secure the fuel supply and technology support for Russia in nuclear sector.

Strengths: a) Nuclear plants are more efficient than other conventional thermal plants in the amount of fuel they use. A typical nuclear reactor produces 3 cubic meters (25–30 tons) of spent fuel each year[37]. Less fuel means less transportation of fuel, which contributes a reduction on transportation green house gas emission.

b) Nuclear plants have no actual burning process like conventional thermal plants do. This part greatly reduces the green house gas emissions, and most importantly, no air pollutant.

c) The uranium fuel used for nuclear plants has no other application until today. Based on the limited market of 439 operating commercial reactors and many other small reactors for research or military use, the market price of uranium is relatively stable and it is not affected by political and world economic situations.

d) Overall, nuclear electricity has the lowest generation cost per kWh, a price of \$0.025 per kWh[38], compared to \$0.029 per kWh of a coal-fired plant[39].

Weakness: a) Nuclear plants' most disputed weakness is its spent nuclear fuel, which is still

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[36] Chebeskov, Alexander and Viktor Dekusar. *Evaluation of the Scenario for Innovative Russian Nuclear Power Development*. 2007 ANS/ENS International Meeting, "Making the Renaissance Real", Washington D.C., November 11-15, 2007.

[37] Uranium & Nuclear Power Information Centre. "Radioactive Waste Management." 2002. http://www.uic.com.au/.

[38] Bodansky, David. *Nuclear Energy: Principles, Practices, and Prospects*. Second Edition, Springer New York, 2004. 565.

[39] Cost of decommissioning of nuclear power plants is not included. The Virtual Nuclear Tourist. "Cost Comparison for Nuclear vs. Coal." http://www.nucleartourist.com/basics/costs.htm.

highly radioactive. Current management of nuclear waste concentrates on two major methods—storage and reprocessing. Storage has a potential future contaminant problem while reprocessing has a potential risk of proliferation.

b) Nuclear plants have a relatively large initial investment on its construction. For a nuclear plant this may be higher than for other energy forms because the buildings used for containment or for safety-related equipment must meet higher standards than the traditional structures. This will put the company who runs the nuclear plant under larger financial risk.

c) Building nuclear plants faces a pressure coming from public opinion. The fact of the Three Mile Island and Chernobyl accidents cannot be ignored and have long been clouded over the public attention on nuclear civil application.

Opportunity: An innovative technology of nuclear plant is being initiated in Russia. This program solves two major issues. One is to secure the fuel supply by using its isotope of 238 instead of uranium 235. Uranium 238 is 10 times higher in resource compared to coal and 25 times higher compared to natural gas[40]. The other opportunity is to alleviate the radiation of waste fuel to the minimum by adopting closed fuel cycle technology, eliminating most of the short half life element, and reuse other effective fuel again in breeder reactors. If this program is achieved, the largest barriers of further civil application of nuclear energy are

[40] Chebeskov, Alexander and Viktor Dekusar. *Evaluation of the Scenario for Innovative Russian Nuclear Power Development*. 2007 ANS/ENS International Meeting, “Making the Renaissance Real”, Washington D.C., November 11-15, 2007.

leveled down to the ground.

Threats: The major threat to the nuclear industry is coming from its decommissioning. Decommissioning involves many administrative and technical actions. It includes all clean-up of radioactivity and progressive demolition of the plant. This is not only a time consuming process that requires years of plant cooling down, but also highly in cost. For example, in USA many utilities estimates now average $325 million per reactor all-up (1998 $)[41].

2) Wind Energy

By using wind turbines, wind energy is converted into electricity. Although wind produces only about 1%[42] of world-wide electricity use, it is growing rapidly, increasing more than fivefold globally between 2000 and 2007[43]. Wind energy as a power source is favored by many environmentalists as an alternative to fossil fuels, as it is plentiful, renewable, widely distributed, clean, and produces lower greenhouse gas emissions, although the construction of wind farms is not universally welcomed due to their visual impact and other effects on the environment.

Strengths: a) Wind power has a flexible dispatch function. It can be connected to the main grid, and can also provide electricity to isolated locations. This makes it a first-

[41] Wikipedia. "Nuclear decommissioning." *Wikipedia*, retrieved on August 4, 2009. http://en.wikipedia.org/wiki/Nuclear_decommissioning.

[42] World Wind Energy Association. "World Wind Energy Association Press Release." February 21, 2008.

[43] Global Wind Energy Council. http://www.gwec.net/.

rank supplementary alternative.

b) Wind energy is free energy eventually from solar energy, which means no fuel cost on its operation. This advantage is not comparable by nuclear and thermal plants.

Weakness: a) The intermittency of wind seldom creates problems when using wind power to supply a low proportion of total demand. Where wind is to be used for a moderate fraction of demand, additional costs for compensation of intermittency are considered to be modest. Recent studies have attempted to determine the actual cost of intermittency, and they indicated it is currently in the area of 2-5 tenths of a cent per kWh[44].

b) Since wind speed is not constant, a wind farm's annual energy production is never as much as the sum of the generator nameplate ratings multiplied by the total hours in a year. Wind turbines have relatively low capacity factors, typical range from 20% to 40%[45], compared to 70%-80% of coal plants and about 90% of nuclear plants[46].

c) Wind farms take a large area of land to build. Footprint of power plants seems not to be a problem for Russia, but will be critical to small territory countries.

Opportunity: Off-shore wind farm is the major and most effective way of using wind energy.

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[44] Renewable Energy Research Laboratory. *Wind Power: Capacity Factor, Intermittency, and what happens when the wind doesn't blow?* University of Massachusetts at Amherst.

[45] ibid..

[46] Nuclear 60% to over 100%, U.S. average 92%. Worldwide average varied from about 81% to 87% between 1995 and 2005. *15 Years of Progress*. World Association of Nuclear Operators. 2006. http://www.wano.org.uk/PerformanceIndicators/PI_Trifold/WANO15yrsProgress.pdf.

Off-shore locations may offset their higher construction cost with higher annual load factors, thereby reducing cost of energy produced. And it does not occupy land territory.

Threats: Unfortunately most of the wind potential is located in sparsely inhabitant territories, where the population density is less then 1 person per square kilometer. This means that there are not industrial energy consumers, to develop enough electrical grid and electrical generating equipment, which could compensate unstable wind nature. And it also has a problem of high cost on long distance transmission power lines.

3) Clean Coal-fired Plants

Coal is a vital fuel in most parts of the world. Current running Russian coal-fired power plants are high in particulate pollution due to its old age and low technology in flue gas cleaning. Over 25% of coal-fired power plants in Russia have an ash content of above 40%[47]. This does not only requires a more practical combination of different kinds of environmental-friendly electricity sources, but also a more advanced clean coal technology, which is under discussion of implementation. The most promising “clean coal” technology involves using the coal to make hydrogen from water, then burying the resultant carbon dioxide by-product and burning the hydrogen[48]. The greatest challenge is bringing the cost of

[47] Kakaras, E. and A. Tumanovsky, etc.. 2005. Current Situation of Coal fired Power Plants in Russia Federation and the Implementation of Options of Clean Coal Technologies. *5th European Conferences on Coal Research and Its Applications*. http://www.lignite.gr/OPET/CFF/WP3/WP3_Annex_3_11.pdf.

[48] World Nuclear Association. "*'Clean Coal' Technologies, Carbon Capture & Sequestration*." Retrieved on June 9, 2008.

this down sufficiently for "clean coal" to compete with nuclear power on the basis of near-zero emissions for base-load power.

Strengths: Clean coal technology consists of three major parts as pre-burn cleaning of coal, clean burn process (gasification processes), and post-burn cleaning of emissions. This technology has the potential to provide what may be called “zero emissions” - in reality, extremely low emissions of the conventional coal pollutants, and as low-as-engineered carbon dioxide emissions.

Weakness: The three steps make the clean coal technology fairly complicated process. It is even not using the same theory as a conventional coal-fired plant. This could accompany very high cost of its construction.

Opportunity: Though with high cost of construction, a practicable plant can be built based on a re-modification of an existing coal-fired plant. Scientists hope that by the year of 2012, a commercial designed plant with an electricity cost of only 10% greater than conventional coal plant will be available[49].

Threats: Projections say that at the current production rate, coal reserve would last 164 years[50]. When coal price goes up in the future, the cost of electricity production from any kind of coal plants will rise drastically. And this will increase the financial threshold of operating such a high-tech plant.

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http://www.world-nuclear.org/info/inf83.html.

[49] ibid..

[50] Office of Integrated Analysis and Forecasting. Chapter 5: Coal, *International Energy Outlook 2007*. Energy Information Administration (EIA), May 2007.

3.2.3 Comparison Measurement Criteria

There are 4 major criteria for summarizing the S.W.O.T. analysis and creating plant integrated value matrix. The four criteria are cost, benefit, equity, and robustness.

The cost criterion consists of implementation cost and negative externality cost. The cost of the implementation is expressed in electricity cost per kilowatt-hour. The calculation of the figures is briefly concluded in Table 3 with specific item costs for plants of similar age and size with a unit of dollars per Megawatt-hour ($10 / MWh = 1 cent / kWh).

But when creating the matrix (Table 4), the implementation cost, which is indexed by electricity price per kilowatt-hour, is substituted by the fuel cost. This is because a wind turbine power plant's capacity is usually not comparable to a nuclear or a coal-fired one. When considering this factor, other subsections of implementation cost have relatively small influences compare to fuel cost.

Table 3 shows what the implementation cost is composed of. Followed is a description of how the fuel cost is calculated.

Table 3: Implementation Costs of Three Types of Plant

Item	Cost Element	Nuclear	Commercial Wind (City)	Residential Wind (Rural)	Clean Coal
1	Fuel	4.0	0	0	12.0
2	Operation & Maintenance	5.0	2.0	2.0	5.0
3	Pensions, Insurances, Taxes	1.0	1.0	1.0	1.0
4	Regulatory Fees	1.0	0.1	0.1	0.1
5	Property Tax	2.0	2.0	2.0	2.0
6	Capital	7.0	6.0	2.0	10.0
7	Waste Cost	4.0	0	0	1.0
8	Administrative / overheads	1.0	1.0	1.0	1.0
Total		25.0	40.0*	100.0*	32.1

*Total numbers of wind power are scaled up to match the same capacity size of other two kinds of plants.

The fuel cost is calculated as follow:

A 1,000 Megawatt-hour nuclear plant consumes an average of 30 tons of uranium. The cost of uranium is about $100 per pound. That equals to a rough price of $200,000 per ton of uranium. Therefore, the annual cost of fuel of a 1,000 Megawatt-hour nuclear plant will be around $6,000,000.

On the other hand, the average market price for coal is $100 per ton. A 1,000 Megawatt-hour coal-fired plant will consume 200,000 tons of coal, which makes the fuel cost around $20,000,000.

Considering the pretreatment, protection measurements, transportation, and other fees of uranium are higher than coal, the fuel cost ratio is around 1:3 between nuclear and coal-fired plants.

Negative externality consists of three parts: emission, public concern, and waste. Basically these three alternatives can all be considered as “zero-emission” plants. But with a lowest thermal efficiency, nuclear power plants have large thermal emissions. On the other hand, clean coal plants usually run under a cogeneration mode with heat product to the local community. Public concern is a bigger problem for nuclear plants for its security issues; for wind plants, killing of migrating birds has been a voice of complain from the beginning; Waste problem of nuclear plants raises large costs on its treatment while the other plants almost have no waste products.

Positive externality also consists of three elements, political, scientific, and economic benefits. Nuclear plants may raise the country's statue by technology level and military threats. Using of clean coal technology is a substantial political capital to show its endeavor on global warming. Nuclear plants have a unique scientific benefit. The reactors produce various kinds of isotopes in the fuel cycle. Many of those isotopes are indispensable to medical treatment, especially on tumors. In respect of economic benefits, nuclear plants can be exported as a whole unit or as services. Russia is also ambitious on regulating the international market of spent fuel reprocessing.

Other important criteria include equity and robustness. All three kinds of electricity industries seem fairly independent to others. Nuclear power industry has even been completely taken over by a state company of Russian government, Rosatom. Wind power serves efficiently as supplementary electricity supply, as it can satisfy area that cost high for large-scale grids. Only the coal-fired plants occupy major part of electricity industry may have negative equity for others. Nuclear power holds a neutral robustness because the future problem of decommissioning cancels out the solidity of this technology; Wind power's negative robustness is coming from its unstable capacity due to intermittency of wind energy; Coal-fired plants will continue to dominate Russia's electricity industry due to its stability, solid facility foundation, and coal reserves.

A summary of all these criteria is presented in Table 4 with integrated value scale ranges from -15 to 15 at 0.5 unit of interval.

In the Matrix, nuclear has a highest score among the three. This result singled out nuclear power plant as the most suitable choice for Russia to adopt as the new major electricity source to sustain the country’s energy-economy structure.

Table 4: Criteria Matrix of Three Types of Technology

<table>
<tr><th colspan="2"></th><th>Nuclear</th><th>Wind</th><th>Clean Coal</th></tr>
<tr><td colspan="5">Cost</td></tr>
<tr><td colspan="2" rowspan="2">Implementation</td><td rowspan="2">$0.025 / kWh</td><td>City $0.04 / kWh</td><td rowspan="2">$0.032 / kWh</td></tr>
<tr><td>Rural $0.1 / kWh</td></tr>
<tr><td colspan="2">Fuel</td><td>-4</td><td>0</td><td>-12</td></tr>
<tr><td rowspan="3">Negative Externality</td><td>Emission</td><td>0</td><td>0</td><td>-0.5</td></tr>
<tr><td>Public concern</td><td>-2</td><td>-1</td><td>-1</td></tr>
<tr><td>Waste</td><td>-3</td><td>0</td><td>0</td></tr>
<tr><td colspan="5">Benefit</td></tr>
<tr><td rowspan="3">Positive Externality</td><td>Political</td><td>2</td><td>0</td><td>3</td></tr>
<tr><td>Scientific</td><td>2</td><td>0</td><td>0</td></tr>
<tr><td>Economic</td><td>4</td><td>1</td><td>2</td></tr>
<tr><td colspan="5">Other</td></tr>
<tr><td colspan="2">Equity</td><td>0</td><td>0.5</td><td>-0.5</td></tr>
<tr><td colspan="2">Robustness</td><td>2</td><td>-0.5</td><td>0.5</td></tr>
<tr><td colspan="2">Total</td><td>1</td><td>0</td><td>-9.5</td></tr>
</table>

Based on the country’s particular advantages, a proper proportion of nuclear, clean coal, and wind power can be added to the existing scenario—roughly 63% from thermal plants, 21% by hydropower and 16% comes from nuclear reactors[51]. Combine Russia’s blueprint of nuclear power development, a percentage of 25% is set to be achieved before the year of 2030. On the other hand, burning coal without adding to global carbon dioxide levels is a major technological challenge which is being addressed. Thermal power plants will still be in dominant role due to its cost and adaptability for Russia.

Therefore, considering the capacity growth factor, the percentage of coal-fired plants will drop slightly in percentage, but with large actual increase in capacity. This is because of

[51] BBC News. “Russia: Energy overview.” *BBC News*, February 13, 2006. http://news.bbc.co.uk/2/hi/europe/4699942.stm.

the rocketing electricity demand coming from every sector of domestic development. Wind power may take at most 1% in total according to its zero current status. Nuclear power will reach a higher percentage not only in Putin's nuclear blueprint, but also in an actual fast way. The following chapter will discuss the proper role of nuclear power in the country's energy future.

CHAPTER 4

ECONOMY—NUCLEAR

The *Introduction* and *Chapter 2* have addressed that there is a potential lack of sustainability of current energy-economy structure in Russia. *Chapter 3* has singled out nuclear energy from the comparison among major forms of electricity energy supply for Russia. Then this chapter will develop the discussion of the proper role of nuclear energy in Russia in the future.

4.1 Russian Electricity Output Prediction

For determination of a proper role of nuclear power in the whole picture, a prediction of the country's electricity output is essential. There are myriad factors that affect the annual electricity output for a country, the climate situation, the population and its distribution, the industrial demands, the natural resource portfolio, the energy policies, and the economy, etc.

For Russia, several of the major factors are as follows. As being the largest country in territory in the world and located near the Antarctic Ocean, it has a longer winter duration and colder climate than most of the other countries. This will produce a large demand in heating supply, which is also correlated to the population. Though Russia has a population of 145 million[52], which is small consider its large territory, the population distribution is highly

[52] According to 2002 Russian Census carried out on October 9 through October 16, 2002 by the Russian Federal Service of

skewed to the European part of Russia, with a wide spread distribution of small population in the Ural, Siberia, and Far East regions[53]. This will require intensive, steady, sufficient energy supply in highly populated urban areas in the European part; and flexible, economical energy supply in extremely low density areas in the Asian part. But the factor of industrial demands creates a relatively balanced or even greater demand from the low density regions in the Asian part of Russia, since most of the country's heavy industry are scattered away from the major cities. Russia has large amount of fossil fuel reserves that can be used to generate electricity, while at the same time, the country's energy policy suggests that the government is counting on the earnings from exporting those resources. All together, they produce a comprehensive drive for a large electricity demand while fossil fuels were dragged away to export. This is the point where we see the chance of the booming of nuclear electricity in Russia.

Based on these listed, but not all, factors, the electricity output is hard to predict since every factor has its own model of development. Thus, a mediator is needed here to summarize the overall trend of all these factors and better to be highly correlated to the electricity output. In this way, a macro point of view would better inspect this problem.

As we know, the general gross production (GDP) is a commonly used indicator of the general condition of a country's economy. The energy projections are highly sensitive to underlying assumptions about GDP growth—the primary driver of energy demand. Energy demand has

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State Statistics, the total population of Russia is 145,166,731.

[53] ibid., European Federal Districts (4), 106,003,702 and Asian Federal Districts (3), 39,129,729.

tended to rise broadly in line with GDP growth in the past three decades or so.[54] And on the other hand, the electricity generation supports the residential and industrial needs of energy, which all contribute to the accumulation of GDP. This proposed relation will be tested in the following part of this chapter.

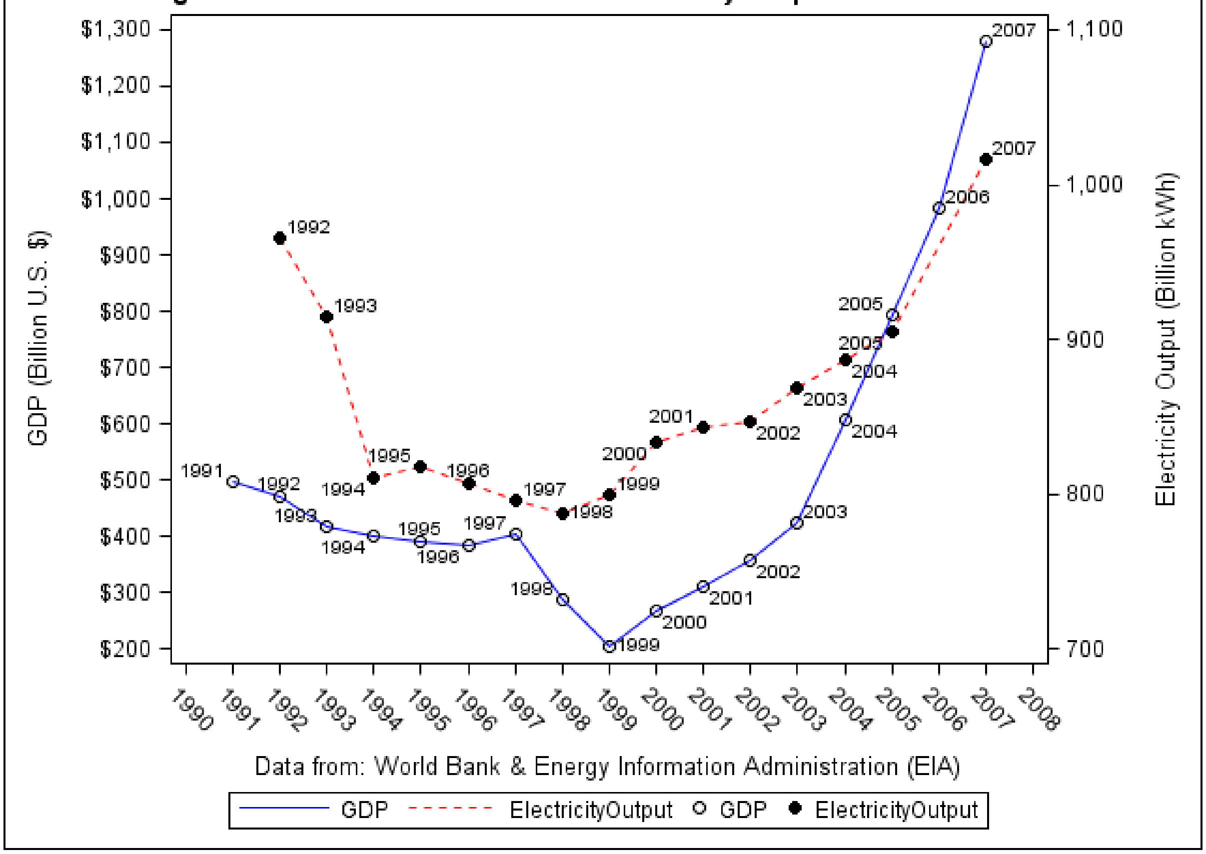


Figure 2: Plot of Russian GDP and Electricity Output from 1991 to 2007

First of all, the actual data on annual electricity output and the GDP net value of Russia from 1991 through 2007 is plotted in Figure 2[55]. The two lines representing real GDP and electricity output are both in an approximate V shape. Both the electricity output and the

[54] International Energy Agency. Key Assumptions and Macroeconomic Factors of Chapter 1, *World Energy Outlook 2006*. OECD/IEA, 2007. 53, 57.

[55] Russian GDP data is retrieved from World Bank; and Russian electricity output is retrieved from the EIA, outputs of 1991 and 2006 are not available from the data source.

GDP dropped considerably through the Yeltsin administration, which is from 1991 to 1999. And they both went up from the year of 2000, when Putin took over the power. This rise continued through 2007 (after a decade of high growth averaging 7% during 1999-2007, Russian economy still gained a solid growth in 2008 of 5.6%[56], but the electricity output of 2008 is not available at the moment of writing this thesis). The same trend indicates that there might be a strong correlation between the two.

Notice that the electricity output and GDP are changing in the opposite directions during three short periods (1994-1995, 1996-1997, and 1998-1999), which were shown in Figure 2. This suggests a possibility that the relationship between the two variables may not be linear. To test this possibility, a quadratic regression is developed where GDP is the independent variable and the electricity output is the dependent variable. The result of the quadratic regression is shown as the curve in Figure 3 and the quadratic regression equation is below:

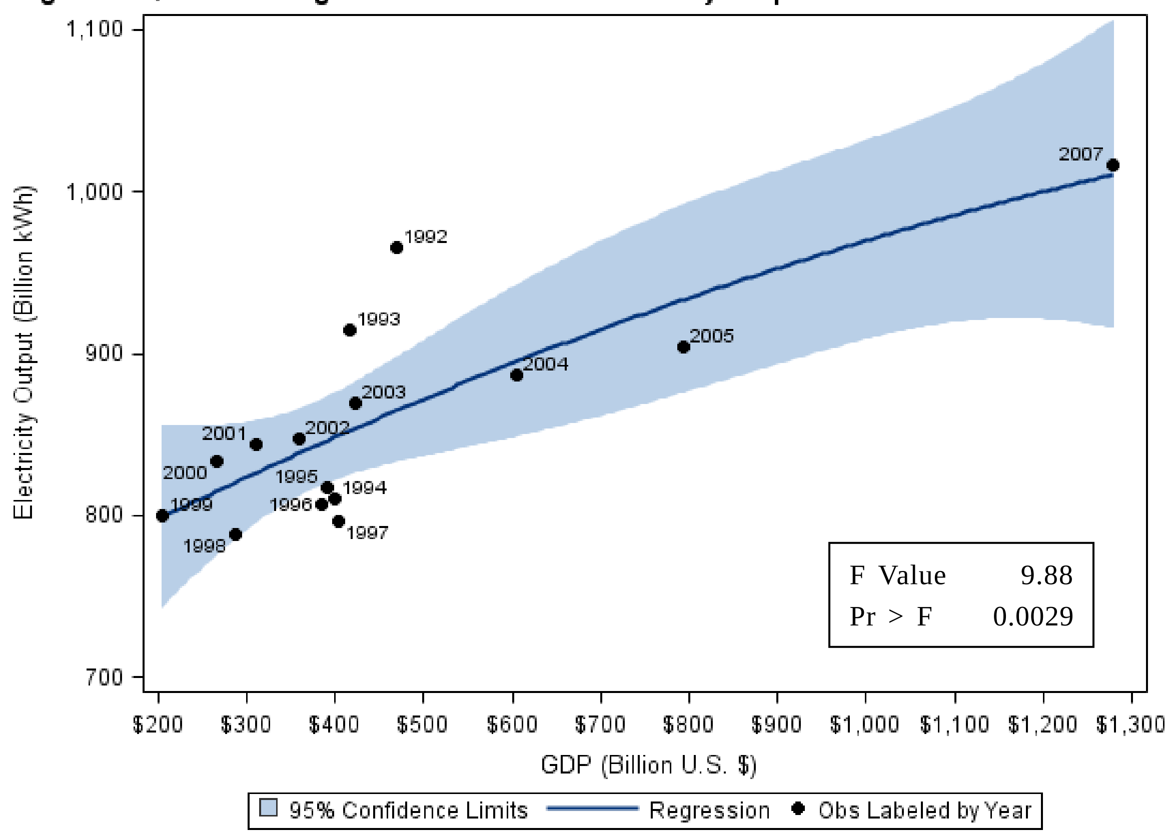
Electricity Output = 741.83 + 0.29*GDP - 0.000064*GDP^2.

The F-test value on this quadratic regression model is 9.88 and its p value is 0.0029 ($p<.05$). This p value suggests the quadratic regression model a significant one. But the curve is close to a straight line which suggests that the relation between the two variables may be closer to linear than quadratic. This indication can be proved by the coefficient of the quadratic GDP in the quadratic regression equation. The coefficient of GDP square is -0.000064, its p value is 0.6559, which is not statistically significant ($p>=.05$). This insignificant p value on the

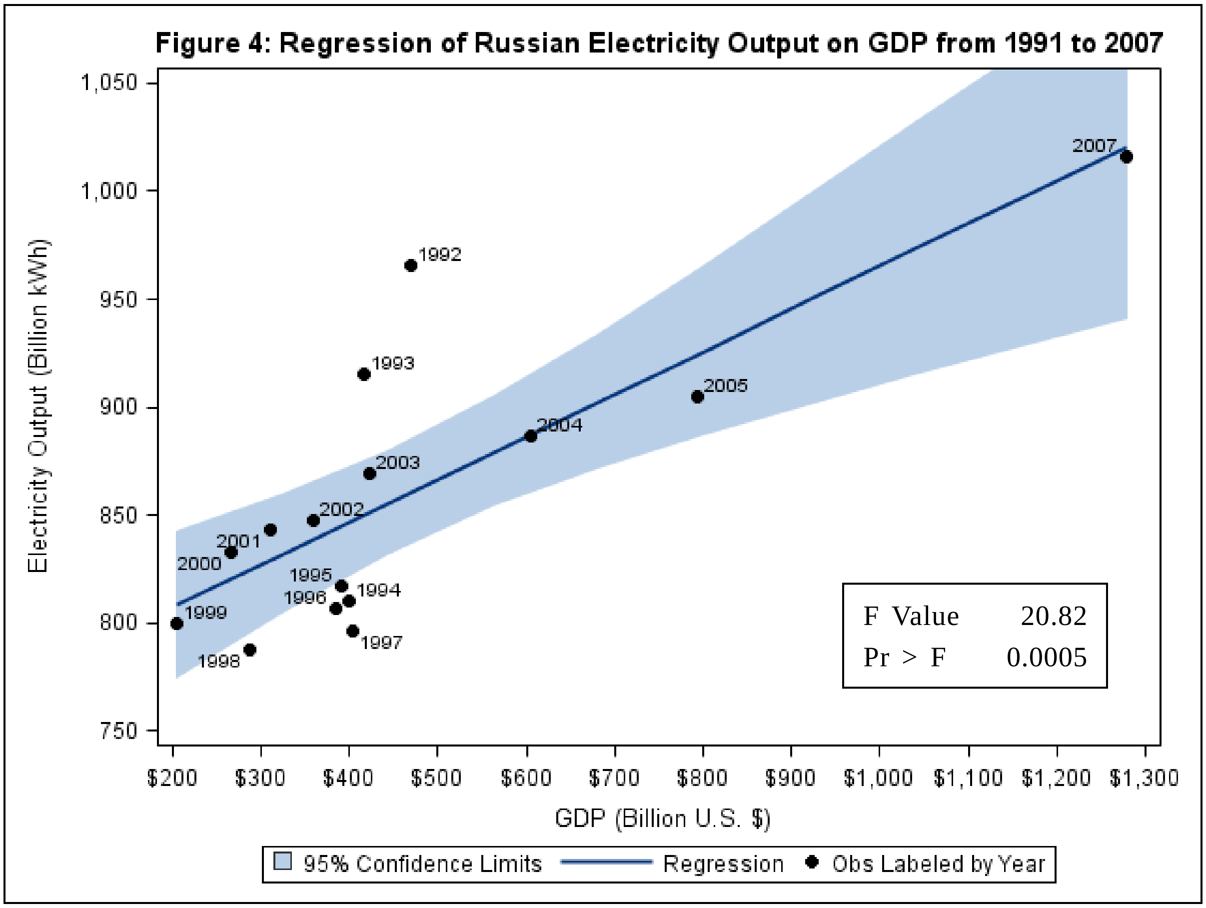
[56] According to data from *Russian Economic Report 18*. Worldbank, April 2009.

quadratic GDP coefficient plus the significant p value of the f-test on the whole model indicate that the quadratic variable does not help on explaining the relationship and it is mostly explained by the intercept and the GDP coefficient. Therefore, the possibility of the relationship between the two variables to be quadratic is proved excessive.

Figure 3: Quadratic Regression of Russian Electricity Output on GDP from 1991 to 2007

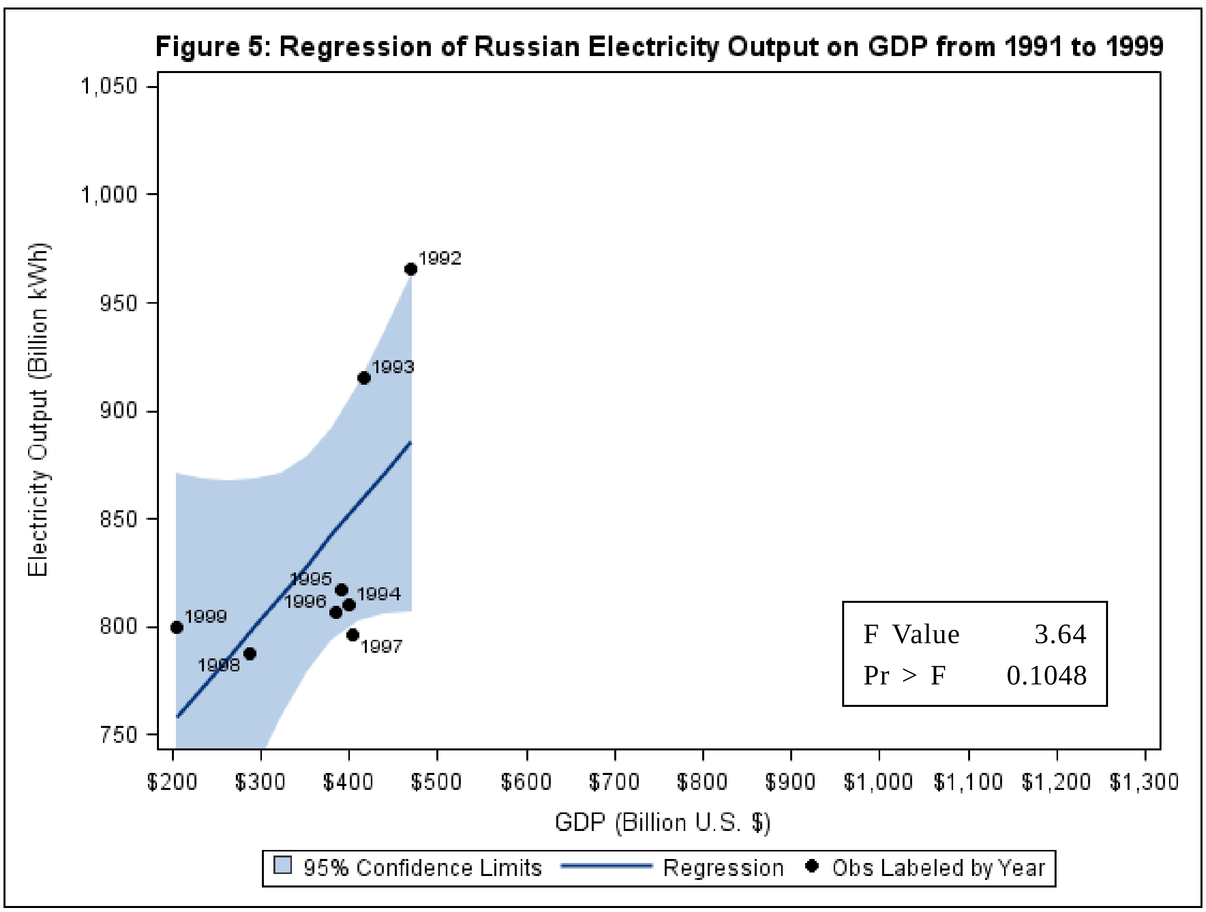


To properly inspect the relationship, the two sets of data were put into a linear regression. The aim of the linear regression analysis is to justify the impression from Figure 1 that they were changing in a similar trend (positive correlation) and find out how close are these two variables correlated in a statistical way.



The result of the linear regression is shown as the solid fit line in Figure 4. The result tells that the years from 1999 to 2007 (2006 missing) are scattered around the regression line within the 95 percent confidence interval (block area along the fit line). And all the outliers are the years from 1991 to 1998 (1991 missing). This result indicates that the correlation between the two variables from 1999 to 2007 can be explained by a linear function more accurately, which is better for electricity output prediction based on GDP. Furthermore, the start point of year 1999 coincides with the turning point of both electricity output growth and GDP rebound shown in Figure 1. These results suggest that further analysis could split the data into two parts and do regression on both periods respectively, in order to find out a more accurate periodical linear function for electricity output on GDP.

According to the result from the previous regression, the data set is split into Group A from 1991 to 1999 and Group B from 2000 to 2007. Year 1999 is not an outlier in the previous regression, but it is moved into Group A of outliers for two reasons. One is because it is the turning point as shown in Figure 1, it will not affect the result of either split regressions, it can serve as either the end point of Group A or the start point of Group B; more importantly, Group A covers the Yeltsin administration and Group B covers the Putin administration, the results of the two groups like this will better reveal the effect of policy changes during the Putin administration.



The result of Group A regression is shown as the solid fit line in Figure 5. The result shows that the years from 1991 to 1999 (1991 missing) are scattered away from the fit line, and the 95 percent confidence interval is wide. This result indicates that the correlation between electricity output and GDP may not be a statistically significant linear relationship.

The result of Group B regression is shown as the solid fit line in Figure 6. In this regression, similar as shown in Figure 4, years 2000 to 2007 (2006 missing) are closely scattered along the regression line, and the 95 percent confidence interval is narrow and close to a parallel pattern. This result indicates a good linear relationship for electricity output prediction based on GDP.

Figure 6: Regression of Russian Electricity Output on GDP from 2000 to 2007

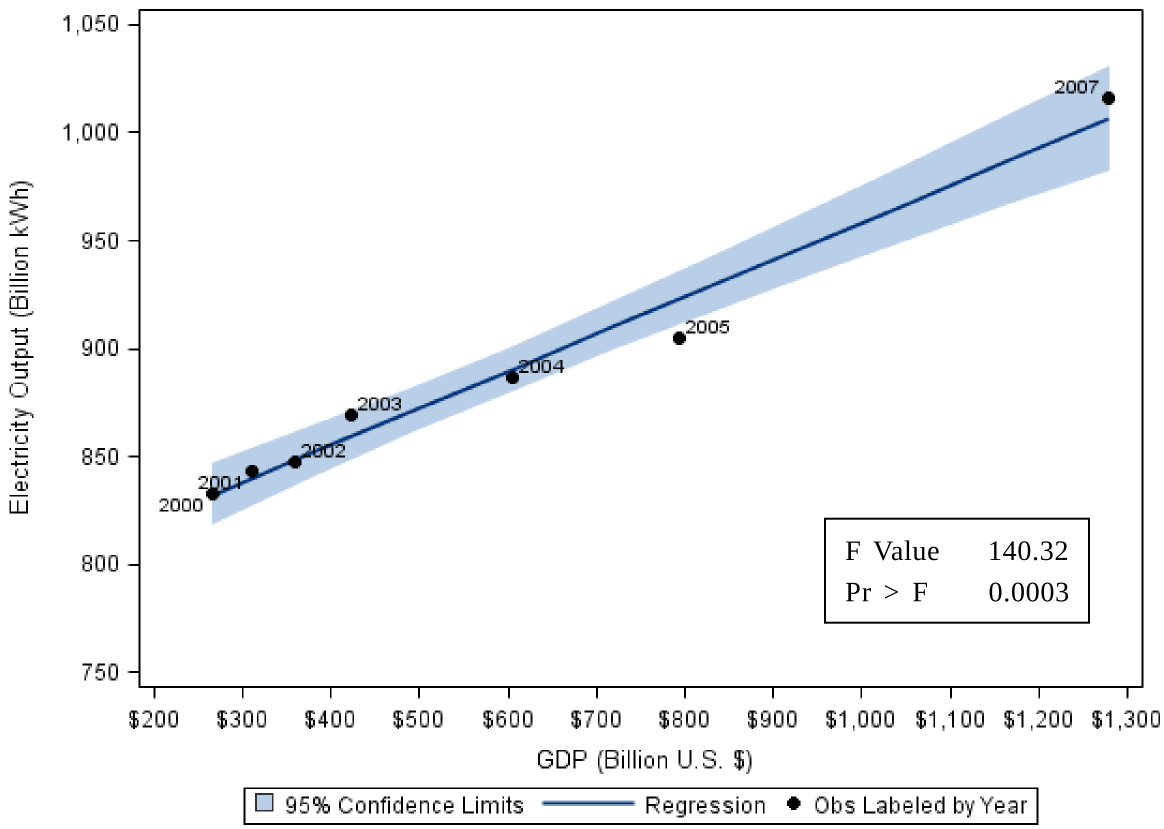


Table 5 is a summary of basic statistics from the above three linear regressions. The p value of the coefficient of Group A (1991-1999) is not statistically significant ($p>=.05$), therefore, statistically this period is not suitable for electricity output prediction. This will be supported by the statistics from the Pearson Correlation Tests that follows Table 5.

Table 5: Linear Regressions of Russian Electricity Output on GDP

	1991-2007	A: 1991-1999	B: 2000-2007
Intercept	767.76***	658.75***	786.33***
GDP	0.20***	0.48	0.17***
N	15[a][b]	8[a]	7[b]

* p<.05; ** p<.01; *** p<.001
[a] one observation missing on Electricity Output of 1991
[b] one observation missing on Electricity Output of 2006

The Pearson Correlation Tests are summarized in Table 6. This test gives out direct values of the correlation between the two variables. As have indicated from the third linear regression of Group B, the data of the period from 2000 to 2007 would better predict the electricity output; the Pearson Correlation Tests also show that the two variables are extremely correlated during this period.

Table 6: Correlation between Russian Electricity Output and GDP

	1991-2007	A: 1991-1999	B: 2000-2007
Correlation	0.79***	0.61	0.99***

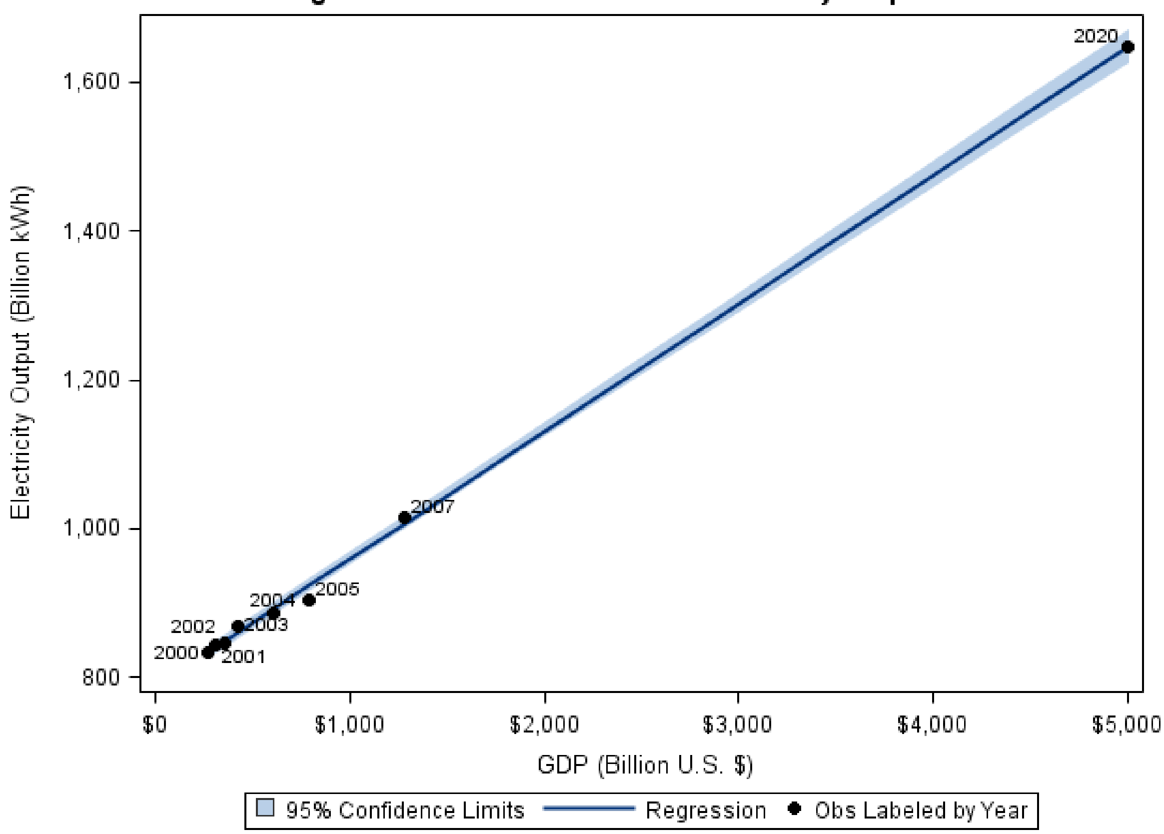
* p<.05; ** p<.01; *** p<.001

Therefore, the prediction equation is generated from the third linear regression based on data from 2000 to 2007. The equation is:

Electricity Output = 786.33 + 0.17*GDP

Using this equation, we can predict electricity output value with a given projected GDP value. Russia's Ministry of Economic Development and Trade drew up in November 2007 a forecast for national economic development until 2020. Under the forecast, GDP is expected to reach $5 trillion in 2020.[57] After putting this GDP value into our prediction function, we get that the predicted electricity output of Russia at the year of 2020 will be 1647.30 Billion kWh. The result is plotted in Figure 7.

Figure 7: Prediction of Russian Electricity Output 2020



[57] RIA Novosti. "Russia may become world's fifth largest economy by 2020." December 24, 2007.

The next section in this chapter will discuss the nuclear share out of the projected electricity output in the coming future according to several important nuclear related policies.

4.2 Nuclear Share

To evaluate the role of nuclear power in Russia in the coming future, two indicators can be representative, one is the percentage of nuclear electricity, and the other is the country's overall nuclear capacity. Especially the former one, a percentage can be more direct in answering the question of how much the country's electricity is generated by nuclear power plants. The goal of the two indicators by 2020 has been set by Rosatom. To cross test whether the two indicators are consistent, the total electricity output and the nuclear power plant capacity factor will be needed in addition to fulfill the equation of Russia's nuclear electricity output below:

$$C * H * f = O * P \quad ,$$

where C is the country's total nuclear electricity generation capacity (GWe); H is a constant of 8760 hours in a year; f is the capacity factor; O is the total electricity output of the year (billion kWh); and P is the nuclear electricity percentage.

The expressions on the two sides of the above equation represent two different ways to calculate Russia's nuclear electricity output of a designated year. By calculating with current true value of C, f, O, and P[58], the credibility of the equation is proved.

[58] Values of the four variables retrieved from World Nuclear Association. "Nuclear Power in Russia." September 22, 2009.

In order to evaluate the role of nuclear power in Russia by 2020, values of C, *f*, O of 2020 are projected. In September 2006 Rosatom announced a target of nuclear providing 23% of electricity by 2020, thus commissioning two 1200 MWe plants per year from 2011 to 2014 and then three per year until 2020.[59] According to this plan, the value of C would be around 52.9 GWe by 2020. However, by April 2009 reduced electricity demand expectations due to the recession caused the whole construction program outlined above to be scaled back, and some projects put on hold. In July 2009 a revised federal target program (FTP) for 2010-2015 and until 2020 was approved and signed by the President, 43.3 GWe of nuclear electricity is being on line. These two different figures are considered as high and low scenarios for Russia's nuclear capacity by 2020.

The capacity factor and the total electricity output of 2020 will be held constant in the calculation. Energoatom, a company under Rosatom who owns all civil reactors, aims the capacity factor for 90% by 2015[60]. Capacity factor of Russia in 2020 is taking current U.S. average nuclear power capacity factor of 92%. And total electricity output is projected by the regression in previous section of 4.1, 1647.30 Billion kWh by 2020.

By calculation with these numbers, the projected nuclear electricity percentages are 21.2% and 25.9% for low and high scenarios respectively. The Rosatom projection of 23% sits between the two scenarios. This indicates that the projections of 43.3 GWe and 52.9 GWe as total nuclear capacity are also reasonable.

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[59] ibid..

[60] ibid..

A summary of data used for the equation is presented in Table 7.

In either scenario, nuclear electricity percentage will exceed 20%, and may surpass a quarter in the high scenario, reaching nearly 26%. This would be a large progress from the current 15.7% under the circumstance of steady GDP growth until 2007 and early 2008. Although Rosatom revised the nuclear plan slightly at the beginning of 2009 due to the world financial crisis, recent revision has scaled up the plan again with more conservative extending capacity, and this will still push the percentage at least to 21.2%.

Table 7: Projections of Russia's Nuclear Electricity Share in Low & High Scenarios

	C: Total Capacity (GWe)	f: Capacity Factor	O: Total Electricity Output of the Year (billion kWh)	P: Nuclear Electricity Percentage
Current	21.7	79.5%	1016.0	15.7%
2020 (Low)	43.3	92.0%	1647.3	21.2%
2020 (High)	52.9	92.0%	1647.3	25.9%

CHAPTER 5

NUCLEAR—POLICY

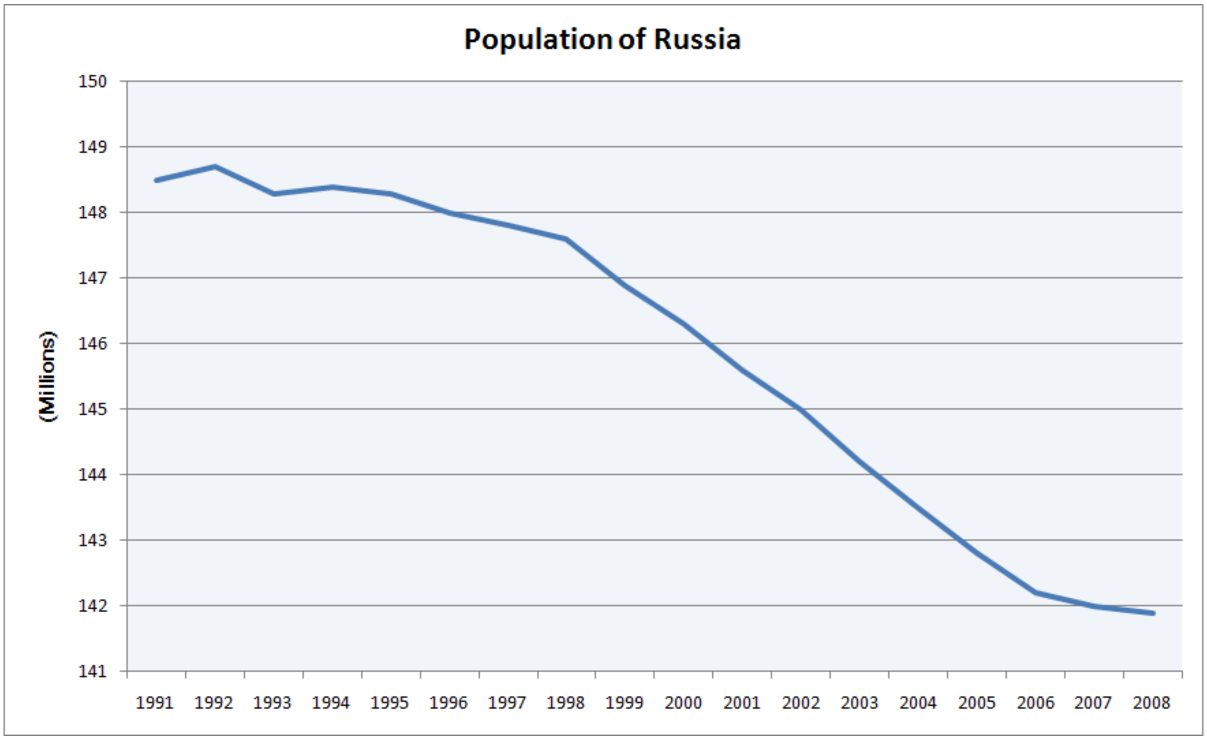
In order to make the numbers projected in *Chapter 4* happen, certain policies targeting the nuclear energy industry need to be implemented properly. Although during the Putin administration, Rosatom announced a target of nuclear energy share in electricity production of 23 percent by 2020 and 25 percent by 2030, there are still several important factors to be considered, and they will affect the nuclear power percentage in a certain way. Beside GDP discussed before, these factors include population growth, new nuclear technologies and services, uranium availability, environmental issues, public acceptance, and financial readiness. These factors are highly related to nuclear industry development, the synergies and tradeoffs among them will have important effects on the development of nuclear energy.

5.1 Population

Russian population experienced a continuous decline of about 5 million since it peaked shortly after the collapse of the Soviet Union. Currently, population growth is nearly stagnant, with an overall population growth of -0.085% in 2008.[61] The general population curve is shown in Figure 8.

[61] Population estimates as of 1 January 2009, State Statistical Service of the Russian Federation. Retrieved on February 20, 09. http://www.gks.ru/bgd/free/b09_00/IssWWW.exe/Stg/d01/7-0.htm.

Figure 8: Population of Russia 1991-2008



Source: Federal State Statistics Service, Russia[62]

This decline will continuously exist in a foreseeable future. Every year there are fewer and fewer Russians. And the emerging rise in births has not compensated for our declining population.[63] An APEC report predicted that by the year of 2020, Russian population will drop to 121 million, over a 20 million loss from current population[64]; and the UN warned in 2005 that Russia's then population could fall by a third by 2050 if trends did

[62] Data of 1991-2007: Федеральная служба государственной статистики. “Численность Населения.” 2008 г. Россия в цифрах. http://www.gks.ru/bgd/regl/b08_11/IssWWW.exe/Stg/d01/05-01.htm; Data of 2008: Федеральная служба государственной статистики. “Демография.” 2009 г. Информация о социально-экономическом положении России. http://www.gks.ru/bgd/free/b09_00/IssWWW.exe/Stg/d01/7-0.htm.

[63] Dmitry Medvedev. “Go Russia!” *President of Russia Speeches*, September 10, 2009. http://eng.kremlin.ru/speeches/2009/09/10/1534_type104017_221527.shtml.

[64] Asia-Pacific Economic Cooperation. *APEC Energy Demand and Supply Outlook 2030*. 79.

not improve[65].

But as have shown in Figure 1 that since the collapse of the Soviet Union, neither the GDP nor the electricity output dropped like the population did. The opposite trends have its reasons according to Russia's special situation.

Russia's population is predominantly urban, with 73% of its population of 141,903,979 citizens residing in urban areas[66]. The urbanization level is expected to increase from 73% to 78%, over the period from 2002 to 2030[67]. This increase could have chance to cancel out some of the influence from population decrease, or even over take it. As standard of living improves across the economy recovery, urban electricity consumption from residential and commercial sectors will rise dramatically.

Other than this, Russia's industrial electricity consumption takes the major part of the whole usage. With the Soviet industrial legacy, especially Russia's heavy industry will be a major propeller for its economic development. This part could also balance out the influence of population drop somehow.

But this is not to say that population growth policy is not important for Russia's electricity generation increase. The high urban population rate and heavy industry consumption have over taken the negative influence of population decline, this is proved by the increasing electricity output for the past decade. With a series of hortative policies, population may not go down that bad as predicted. The lesser the population declines, the

[65] Eke, Steven. "Russia's population falling fast." *BBC News*, June 23, 2005. http://news.bbc.co.uk/2/hi/4125072.stm.

[66] на 1 января 2009 года и в среднем за 2008 год. "Человек." Retrieved on March 29, 2009.

[67] Asia-Pacific Economic Cooperation. *APEC Energy Demand and Supply Outlook 2030*. 79.

more it can contribute to the residential electricity consumption.

5.2 Nuclear Technologies and Services

Russia currently has an installed nuclear capacity of 21.2 megawatts, distributed across 31 operational nuclear reactors at 10 locations[68]. In October 2006, the government of Russia approved the *Federal Program for development of the nuclear industry until the year 2015*. The program includes reorganization of the industry and state owned facilities. Under this program, it is expected that 10 GW of nuclear electricity generation capacity will be commissioned by the year 2015, and the construction of another 10 reactors will be started. Rosatom's long-term strategy is 23% by 2020, 25% by 2030, and up to 2050 involves moving to inherently safe nuclear plants using fast reactors with a closed fuel cycle and MOX fuel. Starting from 2020-25 fast neutron reactors will play an increasing role in Russia, and under optimistic scenario nuclear capacity by 2050 has expansion plans to 90 GW.[69]

One of the major barriers that inhibited the development of civil usage of nuclear energy comes from the spent nuclear fuels (SNF). More specifically speaking, the open fuel cycle is leaving untreated SNF to store in the repository. The problems concerning SNF can be categorized into two major aspects: its radioactive chemical nature and its undecided future treatment and usage.

From a technical point of view, to dodge the problems brought by the open fuel cycle,

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[68] Energy Information Administration (EIA). "Russia Energy Data, Statistics and Analysis – Oil, Gas, Electricity, Coal." http://www.eia.doe.gov/emeu/cabs/Russia/Electricity.html.

[69] Asia Pacific Energy Research Center. *APEC Energy Overview 2008*. March 2009. 144.

SNF should be reprocessed in a closed cycle. This is a technology that will reuse the remaining energy in the SNF and leave out materials only with low level of radiation and short half life to storage. Theoretically, this will minimize the environmental threats from the SNF, but there are a lot of realistic issues to think about.

These issues raise policy concerns when introducing closed cycle and implementing reprocessing. Environmental positive externalities of reprocessing are finite and they will not be the major reason for a government to choose reprocessing. The policy concerns will focus on the cost-effectiveness of reprocessing versus open fuel cycle with SNF storage and the potential risk of proliferation during reprocessing.

Russia has long history of nuclear technology research and development. Even suffered from the world's most severe nuclear accident so far, the country has never stopped its steps on construction of nuclear power plants.

In the new century, Russia has made an important change in its nuclear sector. The government reorganized the former Ministry for Atomic Energy into Federal Agency on Atomic Energy in 2004 and then reformed it into a state-owned corporation, Rosatom, in 2007[70]. The purpose of this change is to put the nuclear sector into a market environment, and to avoid potential lags brought by the command and control supervision. This may open the possibility of cooperation with foreign nuclear companies and governments.

The currently most important cooperation initiated by state-owned corporation Rosatom is the Global Nuclear Power Infrastructure (GNPI) capable of providing secured

[70] Wikipedia. "Rosatom." *Wikipedia*, retrieved on August 4, 2009. http://en.wikipedia.org/wiki/Rosatom.

and non-discriminatory (equal) access to the benefits of nuclear energy to all interested countries in strict compliance with non-proliferation requirements. This initiative is aimed primarily at countries that are developing nuclear power but not planning to establish indigenous uranium enrichment and SNF reprocessing capabilities. As a first step, Russia volunteered to initiate a joint project to establish an International Uranium Enrichment Center (IUEC) on the basis of its enrichment plant in the city of Angarsk (Irkutsk region). This whole project is situated under the IAEA's Multilateral Nuclear Approaches (MNAs).[71]

Russia's idea of this project grew out of its 2005 (Nov.) proposal that Iran share ownership of a uranium-enrichment plant located in Russia[72]. This proposal did not go through and Russia then on 25 January, 2006 committed to the establishment of IUEC in Angarsk. The IUEC has three prime objectives:[73]

1) Promote a wider use of nuclear energy worldwide, and, first of all, in emerging nuclear energy countries,
2) Reduce the risk of nuclear proliferation by discouraging foreign IUEC member states from developing indigenous nuclear fuel cycle capabilities, uranium enrichment in particular,
3) Provide additional assurances of nuclear fuel supply to the IUEC member states, which may voluntarily choose to rely on international routes of nuclear fuel supply.

This is a policy innovation with a magnitude of worldwide collaboration. It will involve not only the world's four leading uranium enrichment services suppliers, AREVA

[71] International Atomic Energy Agency. "Securing the Nuclear Fuel Cycle." IAEA Bulletin Volume 48, No.1. http://www.iaea.org/Publications/Magazines/Bulletin/Bull481/htmls/nuclear_fuel_cycle.html.

[72] Kerr, Paul. "IAEA Unlikely to Refer Iran to Security Council." Arms Control Association. http://www.armscontrol.org/act/2005_11/NOV-Iran.

[73] Ruchkin, Sergey. *International Uranium Enrichment Centre (IUEC) in Angarsk (Russia) and the International Assurances of Supply*. April 17, 2007.

(France), TENEX (Russia), URENCO (Germany, the Netherlands and UK), and USEC (US), but also many countries as emerging nuclear power users.

Initiatives on multilateral approaches to the nuclear fuel cycle are not new. Early back in 1946, the Baruch Plan had proposed an International Atomic Development Authority. And the establishment of IAEA was also an important step toward this direction. The merit of this policy innovation is that it is a multinational approach to try to restructure the market of uranium and SNF treatment and provision. It is proposed under the consensus of major uranium users and greatly promoted by the government of its practitioner, Rosatom. Russia is the only country now has the sufficient technology, intelligence, law, and willingness to allow this multilateral nuclear approach to be taken on its territory. With some concerns from the international society and actual administrative requirement, IAEA will take its role to monitor the project. But still, close scrutiny should be considered in evaluating the policy robustness.

The development of the IUEC will be in three phases:

1) Use part of the existing capacity at Angarsk in cooperation with Kazatomprom and under IAEA supervision,
2) Expand capacity (perhaps double) with funding from new partners,
3) Full internationalization with involvement of many customer nations under IAEA auspices.

The most substantial phase among the three is the second one. Insufficient funding is the current fact for Rosatom and the Russian government. As have mentioned in previous section of 4.2, a reduced nuclear power plants construction plan of commissioning from 52.9 GWe down to 43.3 GWe was approved in July 2009 due to the recent worldwide recession. The synergy of multinational approach on reprocessing and uranium enrichment with sufficient funding support could be vital to the effect of implementation of these innovative policies. Sufficient funding would enhance the capacity of the conversion plants and bring along service demands from customer nations. As a result, increasing income from Russia's services on the multinational approach would provide more funds for domestic nuclear power developments.

5.3 Uranium Availability

Uranium supply consists of two consecutive parts, one is uranium mining, and the other is uranium enriching.

The availability and mining of uranium are prevalent concerns. The World Nuclear Association said in the document of nuclear power in Russia that the uranium supply is expected to suffice for at least 80 years, or more if recycling is increased. However, estimates of available uranium ore vary, the Uranium Information Centre in Melbourne, Australia estimates the known uranium ore will sustain the once through fuel cycle for another 50 years at current price levels. It is worth noting that, however, as uranium becomes scarcer and prices rise, the need for more resources will greatly increase mining research and the amount of known uranium.[74] For Russia, there is a substantial economic resources of uranium, with about 10% of world reasonably assured resources plus inferred resources up to 130/kg U.S.

[74] Uranium Information Centre. *Nuclear Electricity*. Seventh Edition, Melbourne, 2003. http://www.uic.com.au/ne3.htm.

dollars—546,000 tons of uranium.[75] The World Nuclear Association's summary of Russia's current uranium industry points out that in 2007 Russia produced 3413 tons of uranium from mines but this needs to increase substantially to match increased domestic demand. Estimate for 2008 is 3880 tons. In 2006 there were three mining projects, in 2008 there are three more under construction and a further three projected.

Uranium enriching in Russia is carried out by uranium enrichment centers and serve as a secondary fuel supply source. By extracting more energy from the spent uranium using reprocessing, less uranium will have to be mined. Some 2500 tons of uranium have so far been recycled into RBMK reactors in Russia. They came from reprocessing used fuel from VVER-440, fast neutron and submarine reactors.[76]

As stated in section 5.2, the policy instrument of building more of uranium enrichment centers mainly aimed at international uranium service cooperation, and thus affects political and economic strategy of worldwide nuclear fuel security and supply.

5.4 Environmental Issues

Clean and efficient energy supply is not only a responsibility of technology development, but is also an agenda relates to economic and political considerations. From a policy point of view, how to regulate and guide the development of nuclear power under the global trend of green house gas (GHG) emission remission is a big concern.

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[75] A Joint Report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency. *Uranium 2007: Resources, Production and Demand*, also known as the Red Book. OECD, Paris, 2008.

[76] World Nuclear Association. "Nuclear Power in Russia." September 22, 2009. http://www.world-nuclear.org/info/inf45.html.

For country like Russia, strict cap on GHG emission is not practical at the moment. Andrei Illarionov, Putin's top advisor, said in St. Petersburg in April 2004 that the restraints put on carbon dioxide emissions by the Kyoto Protocol would stifle the Russian economy like "an international gulag or Auschwitz."[77] The country is still under recovery of economy from the collapse of the Soviet Union and the financial crisis in 1998, not to mention the one just happened in 2008. Great economic incentives are required under the circumstance of its relatively low GDP net value and lack of variation in investment sources. Therefore, a potential economy revive could be undermined by the implantation of strict emission caps for the fact that fast growers are often heavy polluters. In the electricity generation realm, conventional fossil fuel power plants are heavy polluters and give out large amount of GHG during operation.

But the fact is that Putin has signed the Kyoto Protocol during his administration. Besides the immediate benefits of visa-free travel offered by the EU within the 25-country bloc and EU's support for Russia's membership in the World Trade Organization[78], Russia has its own realistic concerns about the leverage on emission remission.

Two major long-term considerations can be identified. First is that Russia could be an immediate victim of global warming of losing territory for sea level rising along its long Antarctic coast line. That would result in losing part of its land mined natural resources in the northern part, and under water extraction would be more costly. The second one is that the

[77] Dyer, Gwynne. "Why Putin Is Backing Kyoto Again." *Toronto Star*, October 5, 2004. http://www.commondreams.org/views04/1005-32.htm.

[78] ibid..

ratification of Kyoto Protocol can serve as one of the policy drivers for the development of nuclear energy. Nuclear power plant has the lowest GHG emission among all kinds of power plants, though there were arguments for hydro plant being the lowest in emission. A life cycle analysis centered around the Swedish Forsmark Nuclear Power Plant estimated carbon dioxide emissions at 3.10 g/kWh, where other data source show hydro plant is estimated 11 g/kWh, and 950 g for installed coal, 600 g for natural gas generation in the United States in 1999. This low GHG emission fact gives nuclear power plants a huge advantage in environmental protection than other kinds of power plants. This may earn nuclear power some votes for its future development.

Another nuclear environmental issue concerns about the SNF storage and reprocessing.

As have discussed in section 5.2, environmental positive externalities of reprocessing are finite and they will not be the major reason for a government to choose reprocessing. The positive externality is that Russia is using its advanced technology and accumulated experiences to process and reprocess nuclear fuels for the international market, in this way, greatly reduced the risk of radioactive leakage to the environment if operating respectively in each country, especially in emerging nuclear energy countries with different levels of nuclear technologies. This has two dimensions of reducing the risk. One is that geographically it shrinks scattered locations to one; and the other is that all countries using nuclear fuels, regardless of their technology level, get the same high level of risk-treatment.

Uranium reprocessing requires high level technology that is called PUREX, which stands for plutonium/uranium extraction. This is the current commercial reprocessing technology. The technology will be used in the IUCE for reprocessing is a more advanced technology called UREX+ with transmutation. The UREX+ technology with accelerated transmutation of waste (ATW) improves on the conventional PUREX technology by mixing the plutonium with minor actinides, making the process more proliferation-resistant. Advanced fuel cycles could decrease the time it takes for SNF to return to natural uranium radiation levels from 100,000 years down to less than 1,000 years.[79] This means the dosage of radiation from the treated SNF is much lower than from an open fuel cycle. Dosage reductions through transmutation could also help the approval process for repositories and eliminate some of the long term uncertainty of the waste storage.

Another important positive externality is that with reprocessing, current storage repositories can be utilized more efficiently and it will greatly reduce the need to build more of these expensive repositories. The small percentage of fission products account for most of the heat load in SNF, so separating the less radioactive uranium, plutonium, and other short lived isotopes would require only a small amount of waste (the fission products) to be transported and stored at the repository. In current PUREX practice without transmutation, France reduces its spent volume by a factor of four. Advanced fuel cycles with transmutation would further increase volumetric savings since the small amount of fission products contributing to most of the heat load can be transmuted into more stable products. With

[79] Johnson, R. S.. “A Roadmap for Developing Accelerator Transmutation of Waste (ATW) Technology.”

transmutation, the storage capacity could increase by a factor as large as 100.[80]

Fewer repositories could save time and money for licensing, siting, constructing, and transporting spent fuel to the repositories. While some argue that transportation to the reprocessing plants is similar to that of transportation to a repository, the plants (reactors, reprocessing, and transmutation) can be co-located in energy “parks,” which would decrease both transportation and environmental risks. But the Russian idea of world uranium service will require international, long distance transportation of fresh fuels and SNF. This will increase the chance of leakage to a third party besides Russia and the client country when passing their territory even by air. And the transportation will contribute carbon emissions to the low record of nuclear industry.

But the negative environmental externalities brought by SNF storage are yet to determine and definitely have great risks. Since the environmental risks of SNF storage will automatically be resolved to a standard we can control once reprocessing is widely applied, policy concerning storage in the process of nuclear power development is still not clear in Russia. The negative externalities of reprocessing would also be derived from this high collectiveness of the service. Since Russia will be treating nuclear fuels for multiple country clients, the inevitable contaminant to local environment and ecosystem is bound to rise in volume and probability. Angarsk is located near the world’s deepest and Asia’s largest fresh water lake, the Baikal. The potential negative environment influence will be profound.

[80] Finck, Dr. P.. “Nuclear Fuel Reprocessing.” Testimony, United States, Cong. House, Energy Subcommittee of the Committee on Science, Hearing, 16 June 2005, 109th Cong., 1st Sess.. http://www.house.gov/science/hearings/energy05/june15/index.htm.

In addition to GHG, uranium storage and reprocessing issues, there are also the direct environmental impacts of uranium mining in terms of tailings waste, production and mining processes and their impact on the local environment. Current technology and method of uranium mining is using massive amount of water per day, about 15 million liters in a typical mine. This will severely damage the local hydrology. Tailings from uranium mining contain 80% of the level of radioactivity of the original ore as a result of the presence of uranium decay products such as Thorium 230, Thorium 234 and Radium 226.[81] Therefore, reprocessing reduces the uranium mining and eventually will have positive externalities on the environment.

5.5 Public Acceptance

The question of public acceptance will always be raised when considering the nuclear choice. The radiation of the fuel can bring catastrophic outcome throughout the whole cycle when a plant is out of control at any point. This gives people fear rather than reluctance, especially when they have seen the dire consequence of the actual nuclear accident in Chernobyl. This fear will grow larger if they weren't satisfied with enough further information feeds from the authorities. And this transparency is actually what tests the government's endeavor on the public acceptance issue of nuclear power.

The accident of nuclear power plant reactor unit meltdown at Chernobyl is a heavy mark on the civil nuclear history. However, this was not the first large-scale radioactive

[81] "Report on Uranium Mining and Milling in Australia."
http://www.aph.gov.au/Senate/Committee/uranium_ctte/report/d03.htm.

release in the Soviet Union. An earlier accident that contaminated a large area in the southern Ural Mountains was covered up by the Soviet government. An explosion in a tank containing radioactive waste occurred near Kyshtym, USSR in September 1957. Direct casualties were estimated in the hundreds and more than 10,000 people were evacuated from surrounding villages. The contaminated region remains closed today.

Despite significant growth of nuclear capacity within the Soviet nuclear industry later in the 1970s, an effective safety culture was considerably undermined. There is a clear indication from this cover up made by the Soviet government, they needed a safe nuclear developing “fact” to legislate for their state command and control policy on nuclear development; and at the same time, to block the information circulation away from the outside world. In retrospect, it seems to have been almost inevitable that some accident would occur—events at Chernobyl in 1986 merely served to confirm this. This accident alerted Western nuclear experts, as well as the public worldwide, to the risks taken in the Soviet industry. While, in practical terms, Soviet and East European nuclear development slowed considerably, it was not until the collapse of communism that the official standpoint on nuclear power changed and Western operators gained the opportunity to co-operate in safety work. However, the associated political upheaval and economic depression introduce deeper concerns about transparency versus public acceptance.

Since Russia now is reviving its nuclear industry after over 30 years of Chernobyl, the government has to face the public acceptance problem under the new circumstance of democratic social structure. This public acceptance would consist of two parts, one is on the safety of nuclear power plants, which focuses on the operation; the other is on the transparency of administration. There were lessons the Russians can learn from the Chernobyl accident to improve and enhance the public acceptance.

The Chernobyl accident occurred at a subtle moment that Gorbachev had just launched his glasnost policy not for long. And glasnost was compromised by the accident when consider the handling of the post-accident issues by the Soviet government. According to Gibbs[82], he sees the accident the first serious test for glasnost in the mass media. The accident was reported on, but, from a hard-news perspective, its handling was a failure. The fact is that the Soviet media were quiet on the accident. We have reason to speculate that they were forced to remain silence first because when glasnost was implemented, they were urged to have candor about administrative shortcomings. A second reason is that the break of the silence was demanded by external world after the nuclear technicians of a Swedish plant in Forsmark, located two thousand kilometers away, detected high levels of radiation not coming from their own plant, but carried by northern winds[83]. The contrary action of silent against glasnost at the beginning and the reluctance in reporting the accident after the fact was exposed highly indicate a direct force coming from outside the media sphere to limit the mass media to act in the traditional Soviet way.

True evidence can be found in Gorbachev's memoirs and Ryzhkov's Perestroyka.

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[82] Gibbs, Joseph. *Gorbachev's Glasnost—The Soviet Media in the First Phase of Perestroika*. Texas A&M University Press, 1999. 40.

[83] Patterson, Philip. "Reporting Chernobyl: Cutting the Government Fog to Cover the Nuclear Cloud." Lee Wilkins, Lynne M. Walters, Tim Walters, eds. *Bad Tidings: Communication and Catastrophe*. Hillsdale, N.J.: Lawrence Erlbaum, 1989. 131-147.

Gorbachev said that the accident "severely affected our reforms by literally knocking the country off its tracks." But at the same time, he pleads ignorance of just how bad the situation was[84]. He also accounted that one opinion in the Soviet Politicheskoye Buro (Politburo) "was that information should be given out gradually so as not to cause a panic and even greater harm"[85]. On the other hand, Premier Nikolay Ryzhkov said the Soviet leadership was informed of the extent and scope of the disaster after its occurrence. And members of the Politburo were told of the probable consequence from the accident. The members held a discussion two days after the accident, prior to the establishment of an emergency commission. A main topic of the discussion was about how much information should be released. A majority was against the idea of releasing any, but the idea to release some was strongly opposed also. The final decision was that only TASS would issue reports[86].

Whatever the case was, TASS issued first brief report around 65 hours (two and half days) after the accident, said only that an accident had occurred at the reactor with no further comments. In addition to this, TASS released another report within forty minutes about a nuclear accident in the United States[87]. Though this was an often used political tactic, it implicated the struggling within the Politburo. The media was itchy to experience some real change under glasnost, and Gorbachev was also ambitious about his serious political innovation in his second year as general secretary. But as mentioned above, Gorbachev said

[84] Gorbachev, Mikhail. *Memoirs*. Doubleday, 1996. 181.

[85] ibid., 192.

[86] Roxburgh, Angus. *The Second Russian Revolution*. BBC Books, 1991. 41.

[87] Gibbs, Joseph. *Gorbachev's Glasnost—The Soviet Media in the First Phase of Perestroika*. Texas A&M University Press, 1999. 41.

himself that this unexpected severe accident became a crucial test not only to glasnost, but also the efficiency and real ability of the Soviet government. As stated before, inside the Politburo there were two totally different ideas on how much information to release. One was even addressing not to release any. Glasnost seemed to have no affect on procedure among high hierarchy in the Buro, especially in severe situation like this accident which needs extreme prudence when taking care of information release strategy. The battle between the soft implementation of glasnost and the hard fact that no concrete law or regulation that existed to guarantee necessary information release and to guide a timeline of continuous information feed to the stakeholders had showed the Soviet government's preference on non-transparency.

Further manipulation on the media was followed. A counterpropaganda campaign soon got under way, intended to diminish the impact of the accident. A Radio Moscow commentary paraphrased a long-standing Soviet propaganda line: Nuclear reactors presented some dangers, but these paled in comparison with the dangers presented by the Reagan-era nuclear buildup in the West. TASS released a letter from Gorbachev to six world leaders "criticizing continued American nuclear testing."[88] But Gorbachev, who only recently had elaborated upon the merits of glasnost, stayed largely silent on the matter for more than two weeks. Only a handful of sources, all highly placed and centralized (Pravda, TASS, Izvestiya, and central television) reported the story; TASS reports were used by all lower-level organs[89].

[88] Remington, Thomas F.. *The Truth of Authority: Ideology and Communication in the Soviet Union*. University of Pittsburgh Press, 1989. 118-119.

[89] ibid., 119.

When the accident was not able to be wrapped from the outside world, domestic media in Soviet Russia continued to be carefully controlled and coordinated. For example, on May 8, Kiev radio announced that schools were being closed early and young children were sent out of the city; but on the same day, Pravda carried a comment specifically denying that schools were being closed early and children evacuated from Kiev. Not until May 13 did the central media acknowledge this decision.[90] This example perfectly echoed what Gorbachev had said on "not to cause a panic and even greater harm." But an ostensible calm situation did not keep the civilians from the actual radioactive harm. At no point did the Soviet media disclose the effects of Chernobyl's radiation on the environment of neighboring countries. No data were given that would allow comparison of the scale of the disaster with other nuclear accidents.

Whatever efforts the Soviet Politburo had made to divert and conceal the accident from the civilians and the outside world, they had distracted their manpower and resources from what they really should do—to control the consequence of the accident to the minimum range, but not the release of the information to the minimum range. Meanwhile, during the summer of 1986, glasnost remained viable on paper and in propaganda. The Soviet government had highlighted the limitation of glasnost by handling and hesitating to give the information on the Chernobyl accident.

For the new Russian government, a transparent information and media handling is important not only when emergency occurs, but is also required throughout any procedure

[90] ibid., 119-120.

both domestically and worldwide, especially if it is about nuclear issue. According to a document "Key Steps in Building a New Reactor" prepared recently in January of 2009 by the Nuclear Energy Institute of the United States, the estimated time period for a new plant to put into commercial operation from the initiate planning is about 11 to 12 years[91] in the U.S. Another document explains that a nuclear power plant is originally licensed to operate for 40 years, and can obtain a 20-year extension of its license from the U.S. Nuclear Regulatory Commission (NRC)[92]. In addition, there is another 60-year limitation on the decommissioning of a ceased plant after its license has expired[93]. Throughout this life expectancy of rough 130 years of a nuclear power plant, there are multiple issues need to be handled carefully with information transparency: site selection, design selection, application development and review, construction safety, operation protocol, maintenance, spent fuel storage and reprocessing, license renew, and decommissioning. As for Russia, there are old plants from the Soviet times running and phasing out, and new plants being constructed and proposed, all at the same time. Setting up good communications is definitely praised if Russia wanted to transit from old irresponsible image into a new identity of reliable energy superpower.

The first firm step completed by the new government is the establishment of the state-owned corporation Rosatom, successor of Ministry of Nuclear Engineering and Industry of

[91] Nuclear Energy Institute, United States. "Key Steps in Building a New Reactor". January 13, 2009. 2.

[92] Nuclear Energy Institute, United States. "Nuclear Power Plant License Renewal". February, 2008.

[93] United States Nuclear Regulation Commission. "Fact Sheet on Decommissioning Nuclear Power Plants". January 22, 2008.

the USSR. Unlike its predecessor, which was a ministry administrated directly under the central Politburo, Rosatom has less attachment to the government in operation being as a state-owned corporation. This only gives the possibility of having less manipulation pressure from the upper leadership, but does not guarantee its willingness of releasing responsible information to the public.

Further steps should be taken in various aspects. The selection of plant site is the most obvious procedure needs to be publicized. This issue could involve large number of community members and affect their daily lives even when everything is under control. In a macro and ideal way, the selection of a plant site is mostly based on its economic and safety concerns. But when think it in a micro perspective to decide the exact location within the region selected in the macro sense, the site selection should involve water availability and community concerns. The planning of a new plant site in Russia is still a procedure highly involved with politics, but not a community thoughtful one.

A recent contest for a new nuclear power plant settlement between Ozersk and Snezhinsk served as an up-to-date example. The United States Department of Energy's Moscow office reported on January 27, 2009 that a long-standing political crisis in Ozersk had brought tangible economic aftermaths as losing its contract on the construction of South Urals nuclear power plant[94]. While at the same time, another nearby closed city Snezhinsk had approached Mosow asking to register a branch of the Energoatom concern in their city, which would be responsible for the construction of South Urals plant and other new plant in

[94] U.S. Department of Energy, Moscow Office. *Weekly Report*. January 26-30, 2009. 6.

the city. Their argument is based on Ozersk's current unstable political situation, saying that Snezhinsk could guarantee public consensus and constructive assistance of the local self-government. This is crucial for attracting investment of such magnitude.

Both cities were closed nuclear cities that were built early in the last century around 40's to 50's, when they were originally named with numbers as secret regions. Many of the Russian plants are constructed in such region, where majority of the local population are plant related employees, others are mainly service personnel and descendants. With such a population composition, the community concern issue seems like an easy resolve, like the city of Snezhinsk did. But notice that many of the employees were assigned here during the Soviet times under central power dispatches. Though whole sets of life facilities are guaranteed, it is not easy for them to choose different life especially when their next generation are born and raised in the nuclear city. Consensus of the community could be a necessity of continuous political, professional, and personal life for these people. In this way, the community consensus could be viewed as a not fully representative, not community oriented decision, but affected by political choice of interests.

In this Ozersk and Snezhinsk contest, the decision making process was mainly of correspondences between the Mayor of Snezhinsk, Mikhail Zheleznov, and Rosatom, Atomenergoprom, and Energoatom[95]. There were neither public hearings nor review of application like the United States Nuclear Regulation commission does[96]. This indicated that

[95] ibid..

[96] Nuclear Energy Institute, United States. “Key Steps in Building a New Reactor”. January 13, 2009.

state-owned companies like Rosatom are actually set up to act more freely dodging the accusation of using political influence.

There is a long way for the government of Russia to operate a transparent administration. This requires profound change within the system, from legislation to real effective election among multiple parties. Besides meeting a satisfaction of information transparency to the public for acceptance, the technical ensuring on a safe and guided operation is also important part of public acceptance on nuclear issues. The Chernobyl also set a negative example on bad plant operation.

5.6 Financial Readiness

A very direct outcome from the Chernobyl and Three Mile Island accidents for the United States is that the government called on a red light on new nuclear power plants construction. From the Bush administration to the current Obama administration, the calling on nuclear renaissance has revived the willingness on government and policy support on new nuclear plants construction. This is well proven by the recent hearing held on March 12, 2009 with Senators from 50 States and the new Energy Secretary Steven Chu. Nearly half of the 50 States mentioned the nuclear issue and Senators from States like the Carolinas, Pennsylvania, New Hampshire, Idaho, Washington, and etc. have urgent requests on State regulations and policies on approving new plants licenses and funding supports.

Funding for plant construction and operation could be coming from various ways. The nuclear industry shall have strong contribution to the local economy in order to attract state investments and government funding allocation. South Carolina's current nuclear power generation accounts for 51.2 percent of the state's electricity, which make it the most successful nuclear state in the United States[97]. The State government is eagerly to invest in new nuclear plants to enhance the energy economy. And now they also have another argue point that nuclear can fulfill the requirement of emission remission target.

The situation is not alike in Russia for political willingness to fund nuclear power plant construction and development. The Soviet government continued to allow existing plant construction sites to complete the constructions after the Chernobyl accident. These progress goals are set in those five-year plans and are set to be achieved as political goals eventually. Back in the Soviet times, especially during the Cold War era, nuclear power plants were built along with reprocessing plants that can produce weapon grade plutonium. Though concrete evidence is not able to be found by now, there is still high possibility to believe that this was also partly funded from military expenditures. The government did not only fund the projects with capitals, but also with intelligences and manpower. The political willingness of allocating investments into nuclear plant construction is high because it is first a national security matter rather than economy based concerns.

But the Soviet government did consider the economy factor when thinking of investing more in the nuclear power industry. The Arctic region and Northern Siberia area are geographically north and hence habitant places in these areas need extra more energy on heating system than other places. The Soviet government was trying to provide them with

[97] Wolfe, Clint. *Nuclear Power: Mainstay for South Carolina*. March 27, 2009.

cheap and reliable heating supply system. An idea of nuclear heating was presented by Soviet experts at the Fourth UN Conference on Peaceful Use of Atomic Energy in Geneva in 1971[98]. But because of the rapid loss of heat in steam or water circuits, heating reactors need to be as close to their end-users as possible. This requirement made the idea unpopular in Western Europe and in the United States where anti-nuclear lobbies were strong, climates are mild, and the economic advantages of nuclear heating might be wiped out by the reduction in property values as a result of prevalent reluctance to live too close to nuclear reactors. In the Soviet Union these problems did not exist because the government owns all houses and the heating was free. As such, the government rather than the customers was interested in reducing the heating bill. Based on the fact that nuclear reactors have a relatively low efficiency on thermal energy transmission to electrical energy, it can provide more heat for local heating than traditional plants like coal-fired and gas plants can do. Also, nuclear plants require small amount of 30 tons in average of cheap fuels for annual operation. And this part of cost was only 15 percent of total plant operation cost, comparing to the coal-fired or gas plant which takes up to 70 percent. The Soviet government then invested the first heating reactor in the early 1970s at Bilibino, in the Soviet far north-east. The reactor was built to reduce the life expenses of local people and supply a mining city, where transportation for diesel and coal are extremely hard and expensive. Throughout the Soviet history, the government invested 17 such kind of reactors[99].

[98] Mackay, Louis and Mark Thompson, eds. 1988. *Something in the Wind: Politics after Chernobyl*. Pluto Press. 36.

[99] ibid., 37.

We have reason to say that though the Soviet government's willingness to invest in nuclear plants did not resemble the United State's way, the funding was guaranteed in order to support the industry for economic, political, and military reasons. But as Russia has transitioned from its Soviet society into a democratic one, privatization and private investment became possible and actually prevailed during the first decade after the collapse of the Soviet Union. The Russian government is facing a new situation of competing with private investment and government investment. Another concern is to balance the interests of traditional power plants versus the interests of nuclear industry.

The establishment of the state-owned corporation Rosatom has again played an important step against private investment invasion into this crucial industry. Rosatom took over all things related to the country's civilian nuclear industry and was marketized as a state-owned corporation. This structure change would bring the nuclear sector of Russia more chances to attract private investments worldwide. Other similar changes occur in various fields. The military arms exporter Rosoboronexport may soon follow Rosatom and be turned into a state-run corporation. The national corporation on nanotechnology is likely to be set up following the same pattern[100].

Russia's willingness to allocate funding into the nuclear sector is high. The reason for this kind of ownership change in the energy and high-tech sectors of Russia reflected that under high percentages of GDP growth for the recent years, the Russian government is eagerly to attract foreign and private investments to boost the economy. The projection of

[100] Kommersant. May 13, 2005.

Putin's administration on nuclear power generation toward 2030 is leapfrogging from 16 percent to 25 percent in electricity mix, 32 new nuclear power plant is planned for 2020, 44 is planned for 2030[101]. Russia is also moving forward with steady steps to build new reprocessing centers in the country. Other research and potential development in the nuclear is the Rosatom scheme for floating nuclear power plants. With all these ambitious projections and develop plans, Rosatom, representing the country's interests, will have to invest great amount of money into the sector.

The political willingness to allocate funding comes from these aspects: 1) National security reasons. Russia is currently taking steps to decommission its nuclear weapons. But with the expansion of NATO and missile facilities set up by the United States in Eastern Europe and even Caspian region, Russia still needs to consider long-term strategy for its national security. Nuclear power plants with reprocessing center can secure material supply for potential needs of nuclear weapons. 2) Energy security reasons. With the world trend to switch from fossil fuel consumption to electrical energy consumption, large scale of cheap and steady supply for base load electricity generation is essential. Nuclear power is also more independent energy choice because its fuel is abundant and is not a strategic reserve for a country. 3) Economic reasons. Russia has large reserve of nuclear intelligence and technology. Its long history development can also bring foreign contracts on plant construction and fuel services. It is now collaborating with the International Atomic Energy Agency (IAEA) to build a reprocessing center in Arkhangelsk which will be capable of providing spent fuel

[101] World Nuclear Association. "Nuclear Power in Russia." March 30, 2009.

reprocessing for other countries. Russia has even mended its law and regulations to allow storage of other countries' nuclear spent fuel on its soil in favor of this multinational approach reprocessing service for the global market[102]. Another well-know example is the contract between Russia and Iran on building nuclear facilities, Russia has also set up cooperation agreement with the United States and China[103]. 4) Environmental concerns. Nuclear power plants has the lowest green house gas emission among all kinds of power plants, though there were arguments for hydro plant being the lowest in emission.

Based on these four driving motives, Russia could have high willingness to develop nuclear industry. In fact, Putin and Rosatom have said not only for once that Russia will allocate its earnings from exporting oil and gas into sectors concerning national development demands. Russia is currently levying about 25 percent on gas companies like Gazprom[104]. But this reallocation of capital could raise problem of balancing the interests among different energy sectors. Nuclear power contributes 16 percent to the country's electricity supply currently, while natural gas has a percentage around 55[105]. Lobbying in Duma would be strong to keep the money for further expansion of gas industry. The 2009 Russia-Ukraine gas dispute has indicate that the EU is stepping into the water of pipeline construction and facility improvement for Ukraine. As a result, a new pact signed by the European

[102] IAEA website.

[103] Sokolski, Henry. "The U.S.-Russia Nuclear Cooperation Agreement: The Case for Conditioning." Presented before a Hearing of The House Committee on Foreign Affairs, June 12, 2008.

[104] Offical energy statistics from the U.S. Government, Energy Information Administration. Retrieved from http://www.eia.doe.gov/cabs/Russia/NaturalGas.html.

[105] ibid..

Commission, international banks and the Ukraine government outlines $3.4 billion in European investments in Ukraine's natural gas pipeline system [106]. This would greatly increase the demand for government subsidies from the gas sector to initiate the proposed new pipelines to Europe through Turkey. And the funding would go biased toward the gas companies because Russia is now counting on gas export to generate revenues for domestic development.

On the other side, Rosatom is actually running short on funding for its contracts with domestic and foreign clients. On February 24th, 2009, Rosatom and the far northern Siberian Republic of Yakutiya signed an agreement to mobilize investment for the construction of four floating nuclear power plants for use along the Republic’s coastal areas on the Arctic Ocean[107]. The announcement of the new floating plants comes a day after Rosatom and Germany’s Siemens AG signed a memorandum of understanding to team up on a joint venture that would encompass all aspects of the nuclear fuel cycle, from fabricating fuel to decommissioning old nuclear installations. The two companies predicated their union on a forecasted 400 new nuclear reactors expected to be built worldwide by 2030. But Alexander Nikitin, director of Bellona’s St. Petersburg offices, said these things have no economic basis, Rosatom has no money available to fulfill these collaborations. This lack of funding is proven by the head of Rosatom in a speech in the industrial city of Podolsk, near Moscow, he indicated that, “the demand for equipment for construction in Russia of three to four nuclear

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[106] EU Observer reported Tuesday, March 24, 2009.

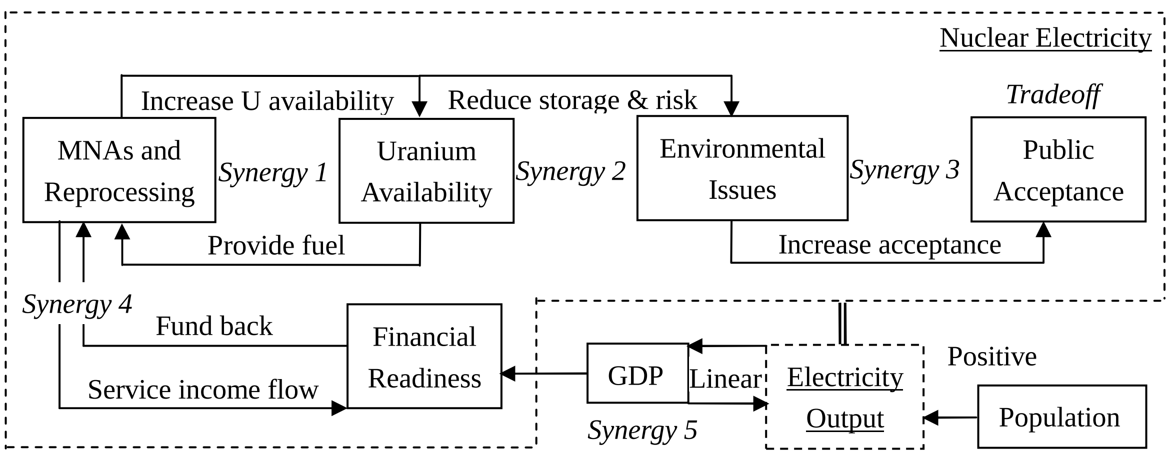
[107] http://www.minatom.ru/News/Main/view?id=62093&idChannel=705

reactors a year will likely appear later than expected."[108]

All these evidences point to the potential lack of funding support from the government, who though has a relatively high willingness to fund nuclear industry. And the transformation of government ministry into state-owned corporation is a clear sign that investment attraction should be done mainly through the company. Report said that the corporation would be directly accountable to the Russian President who would appoint its board[109]. This tight relationship to the highest power showed that even it has been put into the market, the government would not want to lose control over it, and the fact that the former Prime Minister Sergey Kiriyenko was pointed as the first head of the corporation enhanced this impression.

5.7 Policy Synergies and Tradeoffs

Figure 9: Policy Synergies and Tradeoffs



With the above six aspects of nuclear power related policies, plus the GDP (economy)

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[108] Bellona and Interfax. Rosatom attracting investment for four more floating nuclear power plants – while first still languishes in dry dock.
[109] Russian Spy. "Putin to Set up State-Owned Nuclear Giant in Russia." April 27, 2004.

factor discussed in *Chapter 4*, there are seven major policies that affects the nuclear energy development in Russia. Among them, there are several strands of synergies that reveal the interactive within these policies. It is summarized in Figure 9.

CONCLUSIONS

The spine of this paper is the four dimension concept model: Oil & Gas—Economy—Nuclear—Policy and the central element among the four is “nuclear”. The government of Russia is determined on developing its civil nuclear sector. They see nuclear power as a future strategic energy source, and are planning on building its fuel reserves and technology in order to become a world nuclear superpower.

The first two elements in the model indicate that the current energy-economy structure of Russia is not stable as the oil and gas prices fluctuate widely; they will be unable to sustain a long-term domestic plus export performance; new energy form(s) should be developed; and all of this can result in multiple political issues. This unstable structure calls for the following requirements of new energy form: 1) relative stable price; 2) large amount of demand; 3) abundance in reserve; 4) clean and environmental-friendly in use; 5) less politics involved.

A few potential sources of energy supply meet those requirements above according to Russia’s own situation. By doing Stakeholder and S.W.O.T. Analyses among nuclear, wind, and clean-coal, nuclear appears to be the best choice for expansion in Russia. This result is gained by quantifying detailed cost, benefit, equity, and robustness for the three energy choices and then comparing their overall values. This step confirms the choice of nuclear power as the best option for Russia's energy future.

To evaluate the role of nuclear power in Russia in the future, two indicators can be representative, one is the percentage of nuclear electricity, and the other is the country's total nuclear capacity. By using the available values into the Russian nuclear electricity output equation, $C * H * f = O * P$, the validity of the equation is demonstrated. To cross test whether the two indicators are consistent in the future by year 2020, with the country's total nuclear capacity and the percentage of nuclear electricity projected by Rosatom, the total electricity output and the nuclear power plant capacity factor of 2020 will be needed in addition.

To get a general idea of Russian electricity output projection, a regression model based on Russian GDP was developed. The highly correlated linear function between electricity output and GDP since Putin's administration was adopted to project Russian electricity output in the year 2020. Russia's nuclear power plant capacity factor 2020 is estimated from the value of current U.S. average nuclear capacity factor based on Energoatom's aim of 2015.

Rosatom revised their plan of building new plants several times since 2006, especially after the 2008 financial crisis. The most conservative number for nuclear power total capacity for 2020 was released in Fall 2009. Considering that the economy will recover gradually, the range created by the lowest and highest total nuclear capacity was considered within the realm of possibility. Therefore, Russian nuclear electricity percentage by 2020 is estimated to be in the range of from 21.2% to 25.9%. The Rosatom projection of 23% lies between the two scenarios. This indicates that the projections of 43.3 GWe and 52.9 GWe as total nuclear capacity are also reasonable.

A proper analysis of the role of nuclear power in the Russian electricity portfolio includes a consideration of the synergies among several important policy concerns including population growth, new technologies and services, uranium availability, environmental issues, public acceptance, and financial readiness. And although there will potentially be some negative factors, for example public non-acceptance of nuclear power, the comprehensive policy environment in Russia will provide a positive influence on further nuclear power development.

In sum, nuclear energy is a necessary and efficient component for Russia’s electricity supply and economic development. The significant increase in nuclear power will necessitate the development and implementation of aggressive fuel and technology policies and an affirmative financial preparedness on the part of Rosatom.

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