Russia and the World Energy Markets: Long-term Scenarios

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Abstract:

The paper focuses on energy markets in Russia. First, we look at the recent developments in the world energy markets and in Russian natural gas, oil, and electricity sectors. Then we consider different scenarios for a potential development of energy markets, both in Russia and in Russian trading partners. Using the MIT Emissions Prediction and Policy Analysis (EPPA) model, which is a general equilibrium model of the world economy, we consider different energy scenarios for the next 20-40 years. Our projections show energy use in Russia growing from 775 mtoe in 2005 to 1200 mtoe in 2050 in primary energy equivalence, while electricity use nearly doubles from about 1000 TWh in 2005 to 1900 TWh in 2050 in our reference projections. The energy system continues to rely heavily on traditional fossil energy. Our long-run reference projection for oil price is a continuous increase from $55/barrel in 2010 to $155/barrel in 2050 and for natural gas from $220/tcm in 2010 to $380/tcm in 2050. The model is not able to capture the volatility in energy prices that is commonly observed. The price projections should be seen as a long run trend around which there will likely continue to be volatility driven by short term events. Achieving the G8 goal of 50% greenhouse gas emissions reduction significantly changes our projections, reducing Russia's fossil fuel production and domestic fuel and electricity use from the projected levels without such a policy.

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1. Introduction

Russia is an important energy supplier. It holds the world largest natural gas reserves, the second largest coal reserves and the eighth largest oil reserves. Russia is also the world's largest exporter of natural gas, the second largest oil exporter and the third largest energy consumer (EIA, 2008). Energy was one of the driving forces of Russia's recent economic recovery From the economic collapse of 1990's. The country enjoyed more that 5 percent annual real economic growth for the period of 2000-2008. The robust growth with ever increasing energy prices had contributed to a sense of a long-term economic stability in Russia. These prospects have changed drastically with a global recession, and the resulting reduction in a demand for fossil fuels, and the collapse of oil and energy prices.

Most experts predict, or at least hope for, a recovery in the world economic activity by 2010. The global recession and potential recovery raises several questions: Will the recovery going to bring higher energy prices and increasing prosperity for energy-exporters? Or was the period of 2000-2008 a prolonged anomaly of higher than normal growth in Russia fueled by abnormally high energy prices? Is the current reduced demand for fossil fuels a temporary downturn or a new long-term trend in energy markets? In this paper we do not attempt to provide definite answers to these questions, rather we try to quantify some plausible scenarios for the future development. The goal of this paper is to analyze the potential scenarios for the Russian energy markets, the world energy markets and Russian place in the world energy trade. We use the MIT Emissions Prediction and Policy Analysis (EPPA) model (Paltsev et al., 2005), which is a computable general equilibrium model of the world economy. In this this study we preview a new version of the model that treats Russia as a separate region.

The paper is organized in the following way. In Section 2 we briefly describe developments in global energy markets over the last 30-40 years with a particular focus on the situation in Russian natural gas, oil, and electricity markets. Section 3 presents the EPPA model used for the analysis and a reference scenario of Russian energy development up to 2050. In Section 4 we provide a projection where a carbon constraint is imposed on developed countries according to their G8 goal of greenhouse gas (GHG) emissions reduction by 50% relative to 2000 by 2050, where we consider different scenarios of Russian participation. Section 5 concludes.

2. Energy markets

Russia has been a significant player in traditional energy markets of oil, natural gas, and coal. These energy sources are likely to remain dominant for years to come. At the same time, developed countries are in a desperate search for energy alternatives. There are several driving forces for this search: a sharp increase in energy prices in 2007-2008; concerns about climate change, where fossil fuel burning is one of the major contributors; and energy security considerations, where the U.S. and Europe remain uneasy about the power of energy-rich countries like Venezuela, Russia, Iran, and Saudi Arabia.

Whether new energy alternatives can compete over the next few decades depends on the price of fuels and the policies that might create advantages for alternatives. Energy markets, like agricultural markets, seem to be subject to massive disruptions every 20 or

30 years, and it looks like we are in the midst of one of those disruptions. If we can understand where we are now and how we got here, then we may have some hope that we can understand where we are going. Will we see a repeat of the history of previous energy turbulence — what now looks different and what is similar?

2.1. World energy: the past 40 years

The 1970's was a period of turmoil in energy markets and of high energy prices. The proximate cause of high oil prices was first an oil embargo created by the Organization of Petroleum Exporting Countries (OPEC) in the early part of the decade followed up by the Iran-Iraq war and other tensions in the Middle East in the later part of the decade that also cut into supply, and caused another wave of price increases.

As a response, energy importers introduced several initiatives focusing at energy alternatives. For example, the U.S. has created a new Department of Energy and a massive effort called Project Independence under which the plan was for the U.S. to supply all of its energy domestically. Under this plan there were efforts to demonstrate and produce synthetic fuel from vast U.S. resources of coal. There was also much interest in shale oil. Other initiatives of the time include the development of the Strategic Petroleum Reserve, Corporate Average Fuel Economy standards for vehicles, Federal excise tax exemptions for ethanol, natural gas price regulation, creation of a National Renewable Energy Laboratory to develop renewables, and research on fusion energy. While some of these initiatives may have been modestly successful, most of those projects and goals collapsed with the price of oil, and rather than the U.S. becoming energy independent, its dependence on foreign oil increased dramatically.

In a large part, the collapse was due to the cancellation of large demonstration projects that were seen as a failure because the alternatives being developed under them were far more expensive than the now collapsed price of oil. Fusion power is still mostly a dream. Solar photovoltaics have found a role in places where grid connection is difficult but are not contributing a significant source of power. Wind energy appears closer to commercial competitiveness but the current success of these technologies is due to tax incentives and other subsidies that significantly lower the private sector cost, but this is paid instead by the taxpayer as a tax expenditure (lost tax revenue that must be made up with other taxes). And it is not clear that current wind costs fully address the variability of these generation sources through some type of storage or back-up. If the wind is not blowing on that hot August day when electricity demand is at its peak the system needs a kilowatt for kilowatt backup capacity unless there is large storage of some form somewhere. An excise tax exemption on ethanol has persisted, and created a viable ethanol industry but did not do much to bring along cellulosic production technologies.

Basically, none of the exotic alternatives to conventional fossil fuels have really panned out yet in any significant way and so the 1970's funding to develop them cannot be seen as responsible for lower prices in the 1980's and 1990's. Coincidentally, the events surrounding nuclear power, Chernobyl and 3-Mile Island accidents, have limited a construction of nuclear power plants for many years.

If none of these things "solved" the energy crisis then what did? The 1970's oil shocks caught energy markets off guard and we saw short-run run-ups because there was little flexibility. But with time, more conventional resources were brought on line. The lesson OPEC learned from the 1970's and 1980's was that pushing the price high in the short term would lead to its collapse and so they at least claim to seek price stability, trying to find that price that would generate revenue for them but that would not bring on alternatives or greatly reduce demand, collapsing the price and leaving them with little revenue. Much of the solution appears to have been due to reductions in demand. Energy use which had been growing each year flattened out through much of the 1980's even with low prices and continued economic growth. Here debate remains with regard to how much of this was purely a response to the high prices (and expectations at least for a while that low prices were temporary) and how much was due to various regulatory programs to promote energy efficiency.

Economic reforms in China starting in the 1980's led to a large improvement in the energy/GDP ratio there that continued through 2000. The Soviet Union collapse and Eastern Europe modernization dramatically cut energy use in those regions, in part by slashing economic activity. Thus, even as demand growth was returning to the U.S. and other regions as the memory of high prices of the 1970's faded, reduced demand pressure on global energy markets from China, Eastern Europe, and the Soviet Union kept overall global demand growth slow through the 1990's. In the U.S. and European electricity markets the rapid build of power plants from the 1960's and 1970's and long planning horizon for them actually led to significant over-capacity by the 1980's and so there was little need to build anything. As time went on, the utility sector managed to make much better use of the capacity it had, capacity factors of base load plants improved, and with gas inexpensive it became a good way to add capacity without the huge capital investment and long lead times of coal or nuclear. It was also a relatively clean fuel.

The slow growth in energy demand in the 1980's and continuing through the 1990's kept prices low and as a result investment in further development of conventional resources (or alternatives) was limited. One trend observed by many analysts is that more of the remaining oil resources were owned by State companies, as conventional resources in other regions were produced, giving the international oil companies (IOCs) less direct control over the development of these supplies. Many of these state-owned resources are not in the most stable places. The IOCs are often invited in when their capital and technology is needed, and then invited out once the resource was developed and the country re-evaluated the agreements under which profits from the development were shared. With such high risk on investments, and continuing low oil prices, investment lagged especially in these regions. That leads us to the situation today where an ever larger share of the undeveloped conventional resources is in countries where the investment climate is risky, and concerns about stability of supply exist.

The changes in Soviet Union, China, and Eastern Europe were one time events where the huge inefficiency of energy use in these planned economies was replaced by an energy using infrastructure that was more consistent with market prices, albeit it took 10 years or more to fully realize the event and so it is another long and variable lagged response. Similarly, any supply response has a relatively long lag. And for investments in energy efficiency or in supply enhancement the relevant price is the expected future price over the life of the investment. At the height of oil prices in the late 1970's well-respected modeling exercises were assuming 6% real price increases through the end of the century. When prices start running up the initial reaction is often that the run-up is temporary, and so the expectation is that prices will return to low levels, limiting the increase in investment. With limited investment supply and demand response is limited, which then leads to ever higher prices. Sooner or later investors decide prices are here to stay or the short term gains from high prices are enough to offset the risk that they might fall. Once prices start falling, how long does the memory of high prices persist so that investors will pay extra for energy efficiency or continue to expand supply figuring the price decline is temporary.[1] Given the many coincident occurrences on both the supply and demand side, good reasons to believe that full responses would lag for several years, and a likely changing way in which observed prices were affecting the unobserved price expectations to which investors are actually responding, it is essentially impossible to statistically separate and attribute price changes to each of these causes.

How does the past explain the present and what is the implication for the future? After the 1970's all of the forces were moving in a direction to drive prices down. The low prices and fading memory of high prices led to rising energy consumption and low investment in the development of new resources, which should have brought about rising prices and if this all could have been foreseen the rise would have been tempered by more investment in resource development and less profligate consumption. The beginning of higher prices might have started in the 1990's if changes in China, Soviet Union, and Eastern Europe had not occurred. But those events, by unexpectedly weakening demand, extended the era of very low prices another 10 years or so and exacerbated the lack of investment in new resources and energy efficiency. By the early part of this decade we were ready for the perfect storm which was played out in 2008 in oil and energy markets, although there were foretaste of in gas markets before that. In some sense the high prices of the last few years are an echo of the 1970's events. And, while the proximate cause of the high prices of those decades were an embargo and political events, the low prices leading up to those events likely contributed to the sharp rise in prices because just as in the recent price run-up a tightening market for oil exploded when political problems in supplying regions combined with strong demand growth. With the markets tight, the Iraq war and tensions in other oil and gas supply regions combined with unexpectedly rapid economic growth in many regions all together led to spiraling prices before new resources could be brought on line. The persistence of low prices for many years had led to disinvestment in the industries that support resource development. The lack of direct control of the IOCs in State-owned resources and the risks of entering into development agreements further limited supply response.

We have now come out on the other side of the price spike of 2008. It had led to the beginning of some large changes in energy use, investment in conventional resources, and in alternatives. The collapse of oil prices, while not surprising given that it is a repeat of the 1970's and 1980's, probably came faster and harder than anyone expected. With oil prices at $140 briefly they were six to seven times what they were just a few years earlier. With that massive a price increase any logic would suggest that many investments that were not economic at $25/barrel on both resource development and demand

[1] If agents had perfect foresight these spikes and declines would be smoothed out, but the reality of situation is that it is very hard to put together all the information on how all components of demand and supply will respond and over what time frame, so that one can avoid over-investing to upside price shocks, and under-investing in price troughs. The herd-instinct—every one holding back, the rushing in, then rushing out tends to exaggerate the shock effect.

reduction suddenly were. The economics of investment in new resource developments was somewhat hard to penetrate as these price run-ups occurred because with the run-up in the fuel prices the prices for equipment/expertise in the resource developments industries also went up. That made it look like the cost of development was in part, at least, a driver for, or at least supporting, these much high prices. However, these cost run-ups were probably largely a result of the attempt to expand very rapidly. There is no obvious fundamental limit on the inputs that go into expanding these resource development industries and so with time these industries might have caught up with the demand for them and cost of development would have eased. The beginning of investments energy supply and demand reductions were seen everywhere. Car buyers in the U.S. abandoned large SUVs for fuel efficient vehicles, Canadian oil sands couldn't be developed fast enough, ethanol experienced a boom that is believed to have contributed to high food prices, and interest in shale oil, shale gas, and conversion of coal to liquids was again high. Finally, some of the investment on renewables may have paid off as they appeared to now have some traction, albeit with tax subsidies. Nuclear plants were again proposed.

Had it not been for the economic crisis that was mostly coincidence rather than caused by the high energy prices, oil prices might have eased down rather than collapsed. Given the oil price collapse how much of the investment in alternatives will persist? Will consumers soon forget high gasoline prices and get back in SUVs? With regard to oil, it looks like prices in the $50 to $80 range are adequate to support considerable expansion of conventional resources, heavy oil/oil sands, and remote resources deep offshore, or in the Arctic regions of Russia, or even coal liquids technology. This could meet demand growth at least for another couple of decades. A deep and prolonged recession might restrain demand growth while some of the investments started over the past few years of high prices are coming on line. This combination could then keep prices below $50 for some years and lead to cancellation of many investments and deter new investments. If we were to witness then another set of one-off events. For example, suppose a deep recession lead to real political problems in China, India, or some of the other rapidly growing developing regions and in so doing leads to stagnant economic growth. This would be a repeat—of a somewhat different character—of Soviet Union/Eastern Europe/China—events of the 1990's. That could then extend low prices and low investment in resource development still further. And, then if finally these things get sorted out again we would be right back in a position to see energy prices explode. This cycle could play out over 10 to 20 years.

If we recover from the recession in a year or so and the developing countries continue to develop, then we will see oil prices in the $50 to $80 range over the next couple of decades and perhaps to $100 by 2050. This higher price scenario is actually the preferred one, as underlying it is the assumption of smooth economic growth, and an economic climate in energy markets that support investments needed to expand supply, and continued signals on the demand side that reflect the full cost of energy resource development. If this can happen then maybe we can avoid the boom-bust cycle in energy markets and at least damp the echo of past energy market crises.

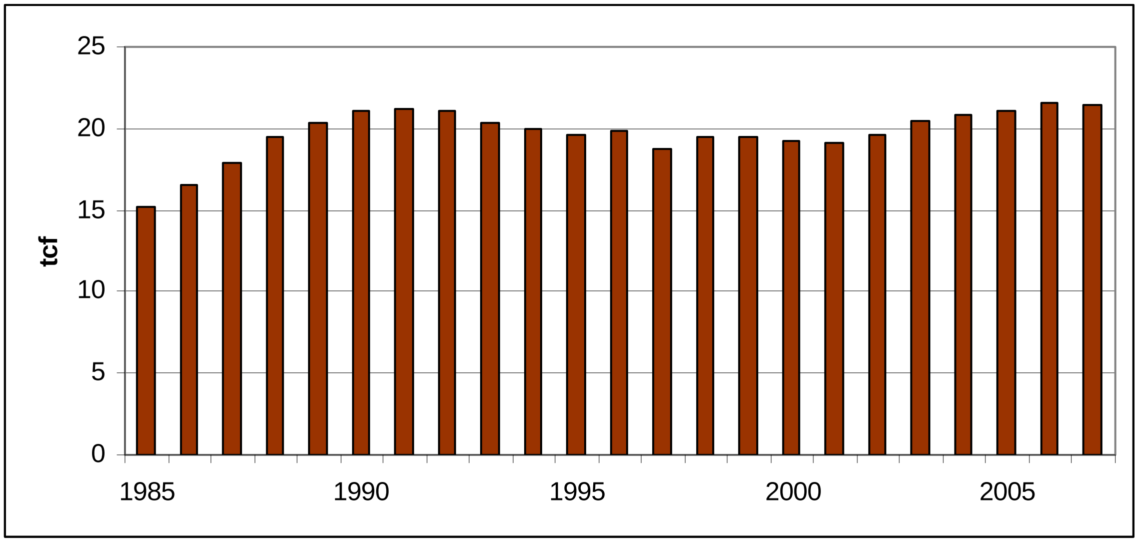
What is missing in this scenario? The answer is: Greenhouse gases and climate policy. With expansion of the resource development industries the costs of developing fossil resources will fall back. Around 2003 estimates of oil sands development was that the cost was less than $30 barrel. With competition for labor, equipment, and such casual estimates were that these costs were at least $80 by 2008. But with the intense pressure off of development these will likely fall down. Coal prices had risen to historic highs but there are ample resources worldwide so that mine expansion these should fall. China is actively pursuing producing liquid fuel from coal and so that alternative fuel may come on significantly as conventional oil peaks. And coal liquids are likely producible with oil prices in the $50 to$100 per barrel range. Much development of natural gas and liquefied natural gas (LNG) facilities are underway in Africa and the Middle East and LNG and new large pipeline developments in Russia/Asia will make these resources available to markets for a nominal rent so that the major final cost will be the transport cost. At these costs, gas and coal will compete for electricity generation and conventional liquid fuels will supply transportation. Renewable electricity sources will be hard pressed to compete and will go only so far as tax credits/subsidies and mandates will carry them. Most likely, second generation biofuels cannot compete, if gasoline prices are only in the $2.00 to $4.00 range. Hybrid vehicles are only nominally competitive at the upper end of this price range, and unless battery technology advances dramatically so that the cost is much lower these fuel prices do not provide much incentive to develop and adopt electric vehicles. This path will thus lead to continued reliance on fossil fuels and a substantial increase in CO_2 emissions, unless a substantial climate policy, like the proposed by G8 reduction of emissions by 50% by 2050, changes the relative prices of energy sources. We return to the issues related to climate-driven energy constrains in Section 4 and now turn to the recent developments in Russian energy markets.

2.2. Natural gas in Russia

For most people people the first things that comes to mind when the topic is Russian energy is natural gas, gas exports to Europe and Gazprom. In part this is due to Russia's disputes with Ukraine about the gas transit that during this past winter disrupted supplies to Europe, the biggest importer of Russian gas. This recent incident gave further reason for Europe to try to diversify supplies by encouraging LNG and to develop the Nabucco natural gas pipeline that does not pass through Russia. Russia's position on disputes with Ukraine and Belarus is that this is an economic issue, a legacy of non-market prices paid by the former Soviet republics. Some experts are not sure about these explanations and attribute the Russian motives to "energy egoism" and "resource nationalism" (Milov, 2008). The transit issues with Ukraine have changed a perception of Russia, which had has a long history of stable natural gas exports to Europe starting in the middle of 1970's. Trade was and still is based on long-term contacts. After the break-up of the former Soviet Union, most of the Russian gas reserves and major pipelines become an asset of a state-owned company Gazprom. For the most part of 1990s and 2000s, the volume of exports to Europe was pretty stable at about 5-7 trillion cubic feet (tcf)[2] and domestic consumption was also stable at about 12-14 tcf. **Figure 1** shows Russian gas production from 1985 to 2007.

[2] 1 trillion cubic meter (tcm) = 35.31 trillion cubic feet (tcf).

Figure 1. Russian natural gas production.



Source: BP Statistical Review of World Energy.

The biggest importers of Russian gas in the EU are Germany (1.3 tcf of imports in 2006), Italy (0.75 tcf) and France (0.35 tcf). Among non-EU countries the largest importers of Russian gas are the Ukraine (2.1 tcf), Turkey (0.7 tcf), and Belarus (0.7 tcf). The Czech Republic, Slovakia, Austria, Bulgaria, Greece, Finland and the Baltic States import much less but for these countries Russian gas supplies more than 75 percent of their consumption. The small non-EU countries of Serbia, Slovenia, and Macedonia also rely heavily on the Russian gas. While several of the Western European countries are among the largest importers of Russian gas, they are less dependent on it than many of the smaller countries of Eastern Europe and the former Soviet Republics.

Western Europe's concerns appear to be based more on what could happen than what has actually happened. In part, this may reflect the fact that Europe's domestic gas production is on decline, primarily in the UK. This is in contrast to the large production potential in Russia. Proven gas reserves[3] in Russia are about 1700 tcf compared with reserves in Europe of only 170 tcf (of which Norway has about 80 tcf and The Netherlands about 50 tcf) (EIA, 2008). At its current annual production of 20-25 tcf, Russian reserves would last for about 70-80 years. Moreover, estimates of the total natural gas resource for Russia, which includes conventional reserves growth and undiscovered gas, is at least three times bigger than the proven reserves.
Despite the large Russian reserves, most projections actually show little increase in the Russian gas share in Europe because of the increasing availability of gas supplies from North Africa and Middle East (EMF, 2007). Some analysis also questions Russia's ability to develop new supplies due to unstable legal environment, inefficient investments (EMF, 2007) or simply high transport costs (Holz et al., 2008). It remains to be seen if these concerns would materialize as Russia is actively engaged in construction of two new gas

[3] Proven reserves are estimated quantities that analysis of geologic and engineering data demonstrates with reasonable certainty are recoverable under existing economic and operating conditions.

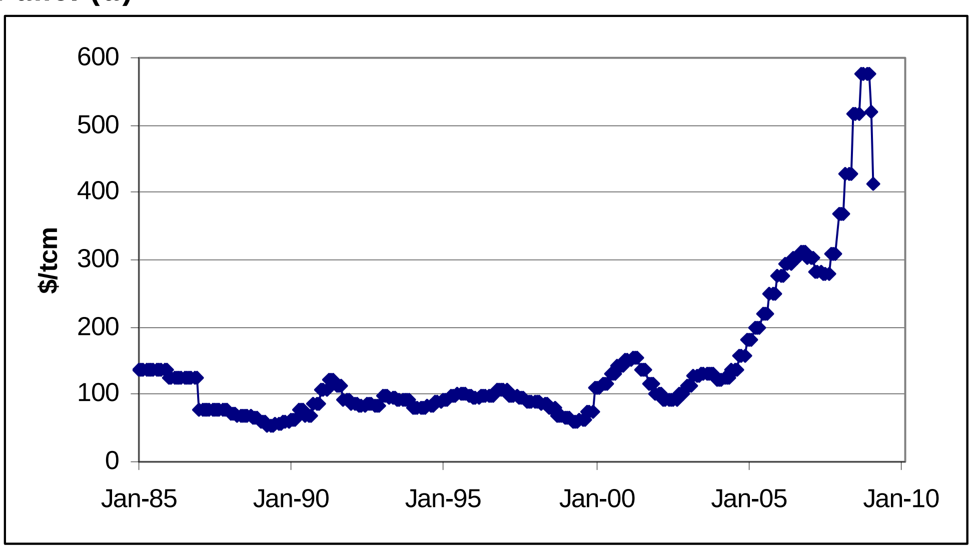
pipelines, North Stream and South Stream, which would go via the Baltic Sea and the Black Sea, respectively. These new pipelines would increase capacity and more importantly eliminate the problem with a gas transit via the former Soviet Republics. Each of these pipelines are expected to have a capacity of 1 tcf per year. Gazprom has also increased the capacity of its Yamal – Europe pipeline by 1 tcf. These additional 3 tcf of capacity are expected to be online by 2015-2020 compare with a current 5 tcf of gas exports from Russia to the EU. Domestic gas use in Russia is generally expected to remain more or less stable with a projected gradual increase of the domestic price for gas, which is currently much lower than in Europe.

Even as Europe plans to diversify its supplies sources, Russia has pursued a policy to diversify its customers, considering pipelines and LNG facilities oriented to Japan, China, and North America. In November 2008 Gazprom organized a subsidiary, Gazprom Global LNG, to expand its LNG capacity. In February 2009 the first LNG plant in Russia, designed by Japanese companies Mitsubishi and TEPCO, started production in Sakhalin. Gazprom announced that most of the gas from Sakhalin LNG plant is already contracted for 20 years with the majority going to Japan. Two pipelines to China, one from Kovykta and another from Sakhalin, are under consideration. There are also plans for a Murmansk LNG facility, that would use gas from the Stockman gas field, and a smaller Ust-Luga LNG facility near St. Petersburg.

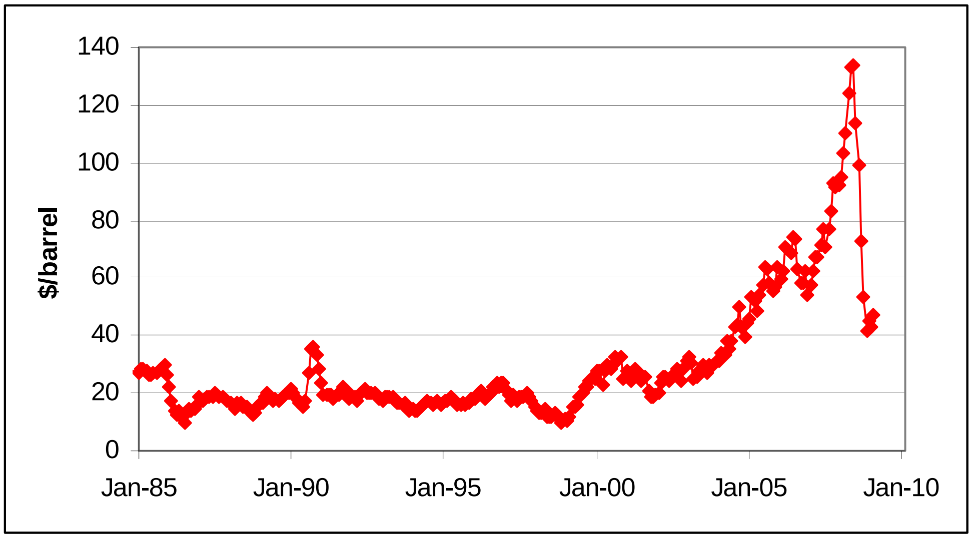
Turning to natural gas prices, those have not been as stable as the volumes of production. As presented in **Figure 2**, where the monthly prices for Russian gas in Germany, who is the major importer of Russian gas, and the monthly prices for Brent crude oil are shown for the period from January of 1985 to March of 2009, it looks like the gas prices are roughly following ups and downs of the oil prices with about a half a year lag.

Figure 2. Panel (a) Monthly Russian natural gas price, border of Germany, **Panel (b)** Monthly Brent crude oil price.

Panel (a)



Panel (b)



Source: www.indexmundi.com

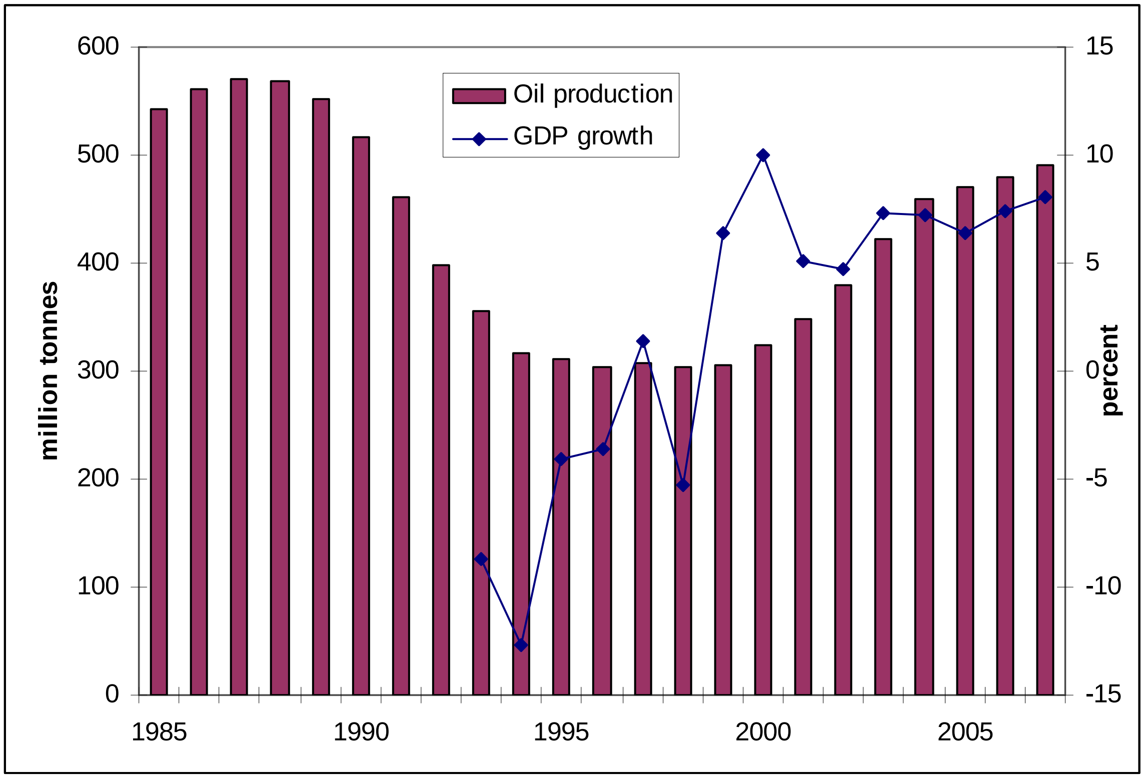
2.3. Oil in Russia

In contrast to gas, the Russian oil market is not dominated by one company. There are four major companies, Lukoil, Rosneft, TNK-BP, and Surgutneftegas, and several smaller companies. Oil reserves, while are also substantial, are only the eighth in the world (after Saudi Arabia, Canada, Iran, Iraq, Kuwait, UAE, and Venezuela). Russian oil productionsaw a steady increase from about 150 million tones (2.5 million barrels a day, mb/d) in 1960 to about 500-550 mln tonnes (11-12 mb/d) in 1980's. Since the 1980's there has been a sharp decline in production to about 7 mb/d in mid-1990s, as illustrated in **Figure 3**. The decline is likely attributable to the break-up of the Soviet Union and uncertainty about the ownership of assets, and to the low world oil prices during this period.

Production increased rapidly from 2000-2004 approaching levels of production of the 1980's. Among the contributing factors were rising world prices, which enabled upstream investment and the use of new and highly disputed methods of stimulating production, such as hydraulic fracturing. The production growth slowdown from 2005 is attributed to state intervention in the industry as well as to stabilization of production volumes at the old oil fields. In 2007 most of the oil production growth in Russia was due to the new projects in Sakhalin-1 and Salym projects.

If Russian oil production is to continue to grow it depends on continued investment and the development of new fields. The present situation on the global oil market is often compared to the end of 1990s, when in 1998 a price of $12 per barrel made Russian exports minimally profitable. Due to fast world price recovery – barrel was up to $18 in 1999 – it looks like Russian oil industry has survived and learned many valuable lessons which were implemented: all companies reduced production costs and stepped into downstream business investing in oil refineries and distribution networks.

Figure 3. Oil production and GDP growth in Russia.



Source: BP Statistical Review of World Energy for production and IMF for GDP growth

Facing a reduction in the oil and gas reserves growth, the Russian government introduced in 2004 a program designed to expand production over the longer term. Under this program all exploration work was to be financed in the federal budget. As a result of increased funding, exploration work increased in 2005. In 2008 the government doubled federal funding for exploration for the period of 2009-2020, with the main focus on East Siberia, Far East, and Arctic shelf. Considering current economic environment, this program may be scaled back.

In terms of energy exports, oil is easier to transport than natural gas, and Russia has more diversified ways to transport oil to its export destinations. As a result, oil exports have not had the disruptions seen in gas transit routes.

The proven oil reserves in Russia are 60-80 billion barrels (350-500 exajoules, EJ, 8500-11500 mtoe)[4]. With 20-25 EJ of annual production, more than half of which is exported, the proven reserves would last for 15-25 years. Again, the resource number for Russia is double the reserves estimate. In addition, Russia has substantial reserves of tar sands and shale oil. Considering all these factors, IEA (2008) and EIA (2008) project a steady increase in Russian oil production from the current levels. Other analysts are more pessimistic as they see gradual depletion of the oil fields that have been developed in Russia with inadequate investments in development of new fields.

[4] 1 Gigajoule (GJ) = 0.165 barrels. 1 mtoe (million of ton equivalent) = 0.042 EJ.

2.4. Coal in Russia

Coal reserves of Russia are vast, the second largest in the world behind the United States. Most of coal producers are independent, because coal is not viewed as a strategic resource as is natural gas and oil. The declared strategy of the Russian government is to increase coal production and build more coal-based electricity to reduce domestic demand for natural gas and thereby leaving more gas for export. About 20 percent of produced coal is exported. In the absence of carbon constraints, China with its reliance on coal for energy, may become a major export destination for Russian coal. In the carbon constrained world, it may also become a reality with a development of carbon capture and storage (CCS) technology (McFarland et al., 2009). At a current level of production, Russian recoverable coal reserves would last for much longer than 100 years.

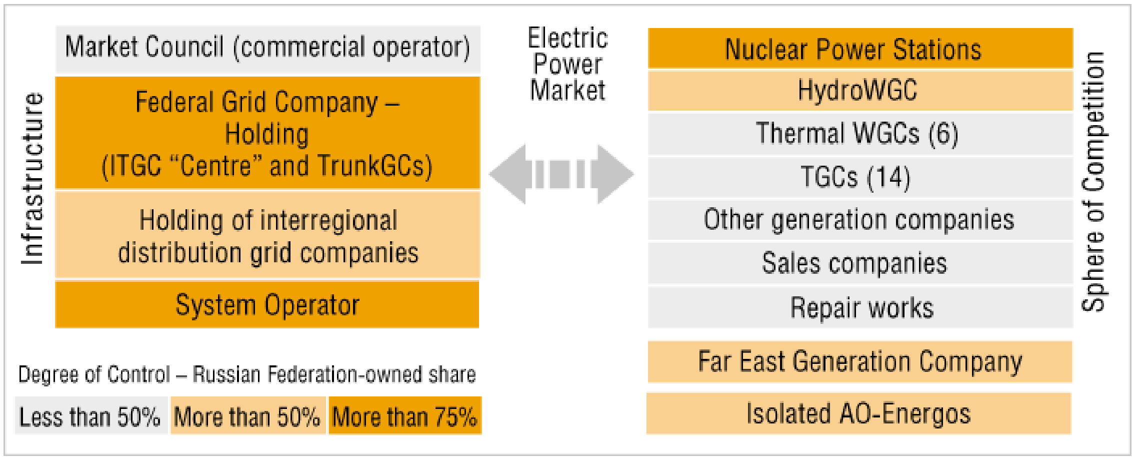
2.5. Electricity in Russia

The Russian electricity market is the fourth largest in the world after the U.S., China and Japan. Until recently, it was dominated by a single company – RAO UES, but with the leadership of Anatoly Chubais, who was the face of Russian privatization in 1990s, the electricity market has been drastically transformed. RAO UES has been reorganized into 14 territorial generation companies (TGC), 6 wholesale generation companies (WGC), and the Hydro wholesale generation company (Hydro WGC). Electricity prices were tightly controlled under the old system. One of the goals of electricity reform is to create wholesale and retail markets for electricity by 2011 through gradual deregulation, and to have these prices better reflect the cost of production. Electricity pricing in Russia was quite different from the U.S and European practices, where residential users pay higher price. For example, in 2004 the U.S. residential and commercial prices were about 9 cents/kWh and industrial prices were about 4 cents/kWh. In Germany the respective numbers are 18 c/kWh and 9 c/kWh. In Russia, before the RAO UES reform, the residential tariffs were subsidized. In 2000 a residential price was about 1 cent/kWh compared with 1.5 cents/KWh for industrial users of electricity.

Attracted by the prospects of the future development, several reputable foreign energy companies, Enel, E.On, and RWE among them, have moved in to the Russian electricity market and become strategic investors in certain WGCs and TGCs. Russian companies, including Gazprom, Lukoil, SUEK, Norilsk Nickel have also bought strategic shares in some WGCs and TGCs. Nuclear and hydro power stations remain under a government control. The target structure of Russian electricity market is provided in **Figure 4**.

Nuclear and hydro electricity each has about 15-17 percent of total electricity generation. The rest of generation is fossil-based, which is currently dominated by natural gas (65% of fossil-based electricity) due to low domestic gas prices. Coal electricity has around 30% of fossil-based production, and oil – 5%. With plans to increase gas prices nearer international market levels, coal electricity would become more competitive.

Figure 4. Target Structure of Russian Electricity System.



Source: RAO UES

3. Long-term Scenarios

To quantify the potential implications of alternative scenarios about energy market development we use the Emissions Prediction and Policy Analysis (EPPA) model, developed at the Joint Program on the Science and Policy of Global Change at the Massachusetts Institute of Technology (http://globalchange.mit.edu). The model has a focus on energy markets as it has been used extensively for an analysis of the future emissions pathways (Reilly and Paltsev, 2006; US CCSP, 2007; Paltsev et al, 2008; Paltsev and Reilly, 2009), and energy-related emissions are the major contributor to the total emissions.

3.1. The EPPA model

The standard version of the EPPA model is a multi-region, multi-sector recursive-dynamic representation of the global economy. The recursive solution approach means that current period investment, savings, and consumption decisions are made on the basis of current period prices. As the version described in (Paltsev et al., 2005) does not have Russia as a separate region, we have updated the economic dataset of the model to the new version 7 of the Global Trade Analysis Project (GTAP) dataset (Hertel, 1997). We have also updated energy flows and GHG inventories. Most of other updates are described in Paltsev et al (2008) and Paltsev et al (2009).

Table 1 broadly identifies final demand sectors and energy supply and conversion sectors. Final demand sectors include five industrial sectors and two household demands, transportation and other household activities (space conditioning, lighting, etc.), as shown in the table. Energy supply and conversion sectors are modeled in enough detail to identify fuels and technologies with different CO_2 emissions and to represent both fossil and non-fossil advanced technologies. The synthetic coal gas industry produces a perfect substitute for natural gas. The oil shale industry produces a perfect substitute for refined oil. All electricity generation technologies produce perfectly substitutable electricity except for Wind and Solar which is modeled as producing an imperfect substitute, reflecting its diurnal and seasonal variability. Biomass use is included both in electric generation and in transport where a liquid fuel is produced that is assumed to be a perfect substitute for refined oil.

Table 1. EPPA Model Details.

Country or Region[†]	***Sectors***	***Factors***
United States (USA)	***Final Demand Sectors***	Capital
Canada (CAN)	Agriculture	Labor
Japan (JPN)	Services	Crude Oil Resources
European Union+ (EUR)	Energy-Intensive Products	Natural Gas Resources
Australia & New Zealand (ANZ)	Other Industries Products	Coal Resources
Russia (RUS)	Transportation	Shale Oil Resources
Rest of Europe and Central Asia (ROE)	Household Transportation	Nuclear Resources
China (CHN)	Other Household Demand	Hydro Resources
India (IND)	***Energy Supply & Conversion***	Wind/Solar Resources
Higher Income East Asia (ASI)	Electric Generation	Land
Rest of Asia (REA)	Conventional Fossil	
Brazil (BRA)	Hydro	
Mexico (MEX)	Existing Nuclear	
Central & South America (LAM)	Wind, Solar	
Middle East (MES)	Biomass	
Africa (AFR)	Advanced Gas	
	Advanced Gas with CCS	
	Advanced Coal with CCS	
	Advanced Nuclear	
	Fuels	
	Coal	
	Crude Oil, Shale Oil, Refined Oil	
	Natural Gas, Gas from Coal	
	Liquids from Biomass	
	Synthetic Gas	

[†] EUR consists of the EU-27 plus EFTA (Norway, Iceland, Switzerland and Lichtenstein);
ROE consists of non-EU European countries, Turkey and Asian republics of the former Soviet Union;
ASI consists of Malaysia, Indonesia, South Korea, Singapore, Taiwan, Thailand, and Philippines.

There are 16 geographical regions represented explicitly in the model including major countries (USA, Japan, Canada, Brazil, Russia, China, India, and Mexico) and 8 regions that are aggregations of countries. While the results in this paper focus on Russia, economic and population growth and policies assumed to be in place abroad, affect world markets, depletion of resources, and therefore the Russian economy through international trade.

The model includes representation of abatement of non-CO_2 greenhouse gas emissions (CH_4, N_2O, HFCs, PFCs and SF_6) and the calculations consider both the emissions mitigation that occurs as a byproduct of actions directed at CO_2 and reductions resulting from gas-specific control measures. Targeted control measures include reductions in the emissions of: CO_2 from the combustion of fossil fuels; the industrial gases that replace CFCs controlled by the Montreal Protocol and produced at aluminum smelters; CH_4 from fossil energy production and use, agriculture, and waste, and N_2O from fossil fuel combustion, chemical production and improved fertilizer use. More detail on how abatement costs are represented for these substances is provided in Hyman *et al*. (2003).

Because of the focus on climate and energy policy, the model further disaggregates the GTAP data for transportation and existing energy supply technologies and includes a number of alternative energy supply technologies. Bottom-up engineering details are incorporated in EPPA in the representation of these alternative energy supply technologies. Advanced technologies endogenously enter only when they become economically competitive with existing technologies. Competitiveness of different technologies depends on the endogenously determined prices for all inputs, as those prices depend on depletion of resources, economic policy, and other forces driving economic growth such as savings, investment, energy-efficiency improvements, and productivity of labor. Additional information on the model's structure can be found in Paltsev et al. (2005).

The cost mark-up defines the cost of the advanced electricity technologies relative to electricity prices in the 2004 base year of the model. Renewables enter the electricity sector in the EPPA model as imperfect substitutes for other electricity. That means that the mark-up costs are the cost of the first installations of these generation sources. We assume these are located at sites with access to the best quality resources, at locations most easily integrated into the grid, and at levels where variable resources can be accommodated without significant investment in storage or back-up. The elasticity of substitution creates a gradually increasing cost of production as the share of renewables increases in the generation mix. Thus, the mark-up cost strictly applies only to the first installations of theses sources, and further expansion as a share of overall generation of electricity comes at greater cost. The mark-ups on nuclear and coal with CCS, which are modeled as perfect substitutes for other conventional generation, were raised, in comparison to the version described in Paltsev et al (2008), from 1.25 and 1.19 to 1.7 and 1.6 respectively. Some current estimates for coal with CCS suggest even higher mark-ups but here we assume this is for the n^{th} plant after some experience is gained in the technology, and assuming that experience leads to lower costs.

When emissions constraints on certain countries, gases, or sectors are imposed in a CGE model such as EPPA, the model calculates a shadow value of the constraint which is interpretable as a price that would be obtained under an allowance market that developed under a cap and trade system. The solution algorithm of the EPPA model finds least-cost reductions for each gas in each sector and if emissions trading is allowed it equilibrates the prices among sectors and gases (using GWP weights). This set of conditions, often referred to as "what" and "where" flexibility, will tend to lead to least-cost abatement. Without these conditions abatement costs will vary among sources and that will affect the estimated welfare cost—abatement will be least-cost within a sector or region or for a specific gas, but will not be equilibrated among them.

The mixed complementarity solution approach of the model means that least-cost is defined in terms of the tax inclusive prices (for fuels, electricity, capital, labor, and other goods) faced by producers and consumers given the technology set at any point in time. It does not necessarily lead to a welfare optimum in the presence of distortions (e.g., energy taxes) or to the extent combined actions of individual agents have macroeconomic consequences such as affecting the terms of trade of a country/region (Babiker *et al.*, 2004; Paltsev *et al.*, 2007).

All fossil energy resources are modeled in EPPA as graded resources whose cost of production rises continuously as they are depleted. In the fossil fuel production sectors, elasticities of substitution were then chosen that would generate elasticities of supply that matched the fitted value in the respective supply curves. Production in any one period is limited by substitution and the value share of the resource, i.e., the technical coefficient on the fixed factor in the energy sector production functions. The resource value shares were determined to represent key differences among regions and fuels. For example, the cost of capital, labor and materials in Middle East crude oil production is quite low relative to the market price, implying a relatively high value share for the oil resource. By contrast, regions with less accessible resources have higher production costs for the same world oil price and similar technology - implying that the value share of resources is lower. For coal, the bulk of the cost of production in most regions is made up of labor, capital and materials, indicating that the cost share of resources in this industry is relatively small. Over time, energy resources are subject to depletion based on physical production of fuel in the previous period. This specification captures the major long-run dynamics of resource prices. The EPPA model also has an option allowing the model user to exogenously specify fuel prices.

3.2. Reference Scenario

The discussion of energy scenarios for Russia begins with the Reference (or Baseline) scenario. To perform a sensitivity analysis of the baseline results, several alternative scenarios are examined, where different assumptions about growth rates, energy efficiency, and energy prices are considered. While the projections from the EPPA model should be viewed as 5-year averages that smooth annual variation, the 2008-2009 world recession has let to a drastic decline in energy prices. In contrast with the U.S., where most of the problems lie in the financial sector, Russia has been hit both in financial and energy markets. These changes have also affected a real sector of the world economies, with car manufacturing and metals in Russia taking a hard hit.

There is no lack of prognoses for Russian economic performance in 2009 and how long a recession would last. The Russian Ministry of Finance is usually on a pessimistic side with projection for a long recession and long-term reduction in demand for Russian fossil fuels. Other experts and agencies are more optimistic with some experts predicting resumed growth by the end of 2009 and gradual increase in demand for Russian metals, oil and gas.

We have reduced our longer term growth rate for Russia in comparison to our previous work, while our long-term rates are still comparable with IEA and EIA forecasts for Russia made in the period of high world growth and high energy prices. EIA (EIA,

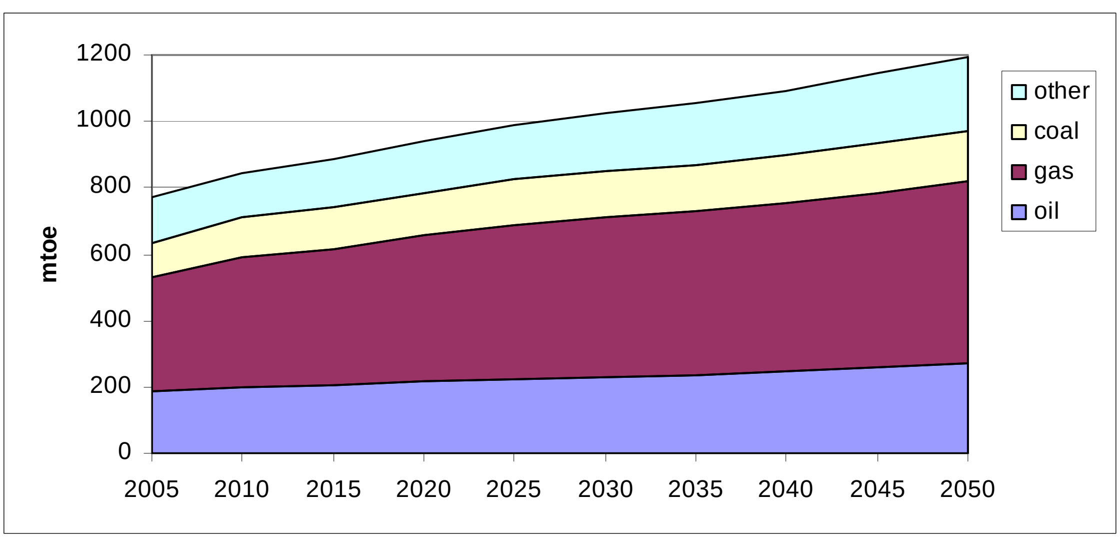
2008) projects Russian growth for 2006-2015 at 5.4 percent and for 2006-2030 at 4 percent. IEA (IEA, 2008) numbers for the respective periods are 5.7 and 3.6 percent. As shown in **Table 2**, our assumptions for these periods are 4.7 and 3.7 percent. For 2006-2010 period, averaging a high growth of 2006-2008 with lower projections for 2009 and 2010 leads to a growth of 5.8 percent. We assume lower growth prospective for Russia as the next period growth is only 3.5 percent and it get lower over time, mostly due to a decrease in population growth.

Table 2. Assumptions for an average annual real GDP growth in Russia.

	GDP growth rate (%)
2006-2010	5.8
2011-2015	3.5
2016-2020	3.2
2021-2025	3.1
2026-2030	2.9
2031-2035	2.6
2036-2040	2.4
2041-2045	2.4
2046-2050	2.4
2006-2015	*4.7*
2006-2030	*3.7*

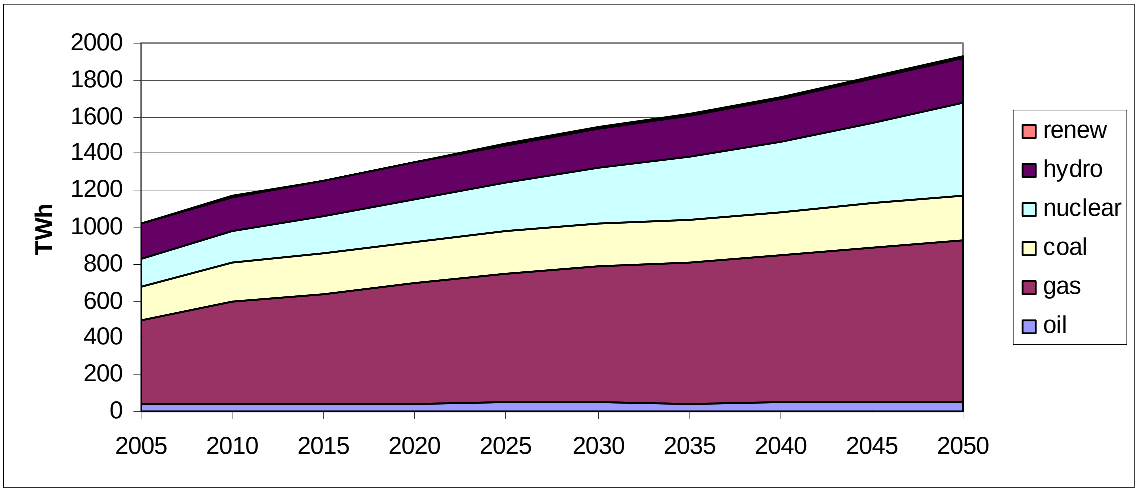
The resulting projections for energy use in Russia are presented in **Figure 5**, where total primary energy grows from 775 mtoe in 2005 to about 1200 mtoe in 2050.

Figure 5. Energy in Russia in Reference Scenario.



Electricity use by type is presented in **Figure 6**, where it grows from 1020 TWh in 2005 to about 1900 TWh in 2050.

Figure 6. Electricity in Russia in Reference Scenario.



Prices, including fossil fuels prices, are determined endogenously in the EPPA model. As presented in **Table 3**, the world oil price is at 55$ per barrel in 2010 and grows to around 155$ per barrel by 2050. Natural gas prices in Europe grow from 220$/tcm in 2010 to 380$/tcm in 2050. The latest available IEA oil price projections (IEA, 2008) show a growth of oil prices from 70$ in 2007 to $100 in 2010 and to $122 in 2030, while their natural gas price projection doubles from 2007 to 2030. Our projections are on a lower side in comparison to 2008 IEA World Energy Outlook.

Table 3. Oil and Natural gas prices in Reference Scenario.

	oil ($/barrel)	gas ($/tcm)
2010	55.73	221.52
2015	64.94	237.94
2020	73.68	253.90
2025	84.85	273.18
2030	98.99	295.68
2035	114.98	319.54
2040	127.22	338.04
2045	138.92	356.58
2050	154.41	377.28

For energy and electricity use, we also can compare with the IEA 2008 World Energy Outlook (IEA, 2008) and the EIA 2008 International Energy Outlook (EIA, 2008). **Table 4** and **Table 5** provide the data for the common years from those publications and from the EPPA model converted to the same units.

Table 4. Primary Energy Use, mtoe.

EIA	***2015***	***2020***	***2025***	***2030***
Oil	160	165	170	175
Gas	476	494	510	530
Coal	126	134	131	144
Other	117	132	147	149
Total	879	925	958	998
IEA	***2015***	***2020***	***2025***	***2030***
Oil	165	167	168	166
Gas	410	410	417	423
Coal	140	148	158	163
Other	83	91	100	107
Total	798	816	843	859
EPPA	***2015***	***2020***	***2025***	***2030***
Oil	208	217	224	230
Gas	413	441	466	485
Coal	125	131	135	138
Other	145	153	162	173
Total	891	943	988	1025

Table 5. Electricity Use, MWh.

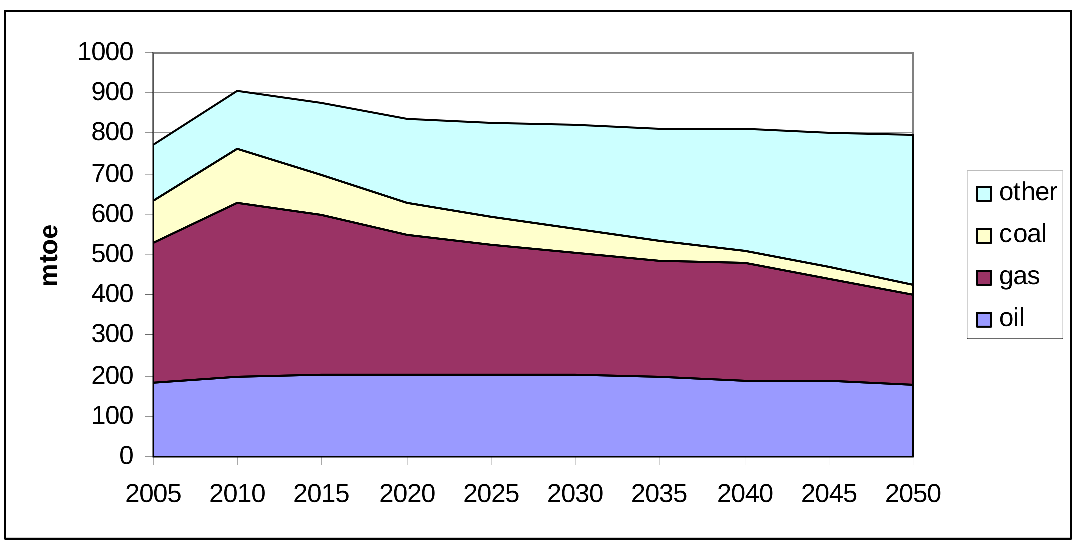
EIA	***2015***	***2020***	***2025***	***2030***
oil	21	19	17	15
gas	590	646	721	774
coal	255	299	299	374
nuclear	190	236	293	305
hydro	209	209	209	209
Total	1265	1409	1539	1677
IEA	***2015***	***2020***	***2025***	***2030***
oil	24	23	19	15
gas	557	545	536	537
coal	280	311	349	382
nuclear	216	227	248	248
Hydro	193	202	211	217
Renew	13	21	31	48
Total	1283	1329	1394	1447
EPPA	***2015***	***2020***	***2025***	***2030***
oil	43	45	45	45
gas	601	656	705	744
coal	214	224	230	231
nuclear	206	234	265	301
hydro	186	192	199	207
renew	6	7	7	8
total	1255	1358	1453	1536

4. Climate Constraints

As mentioned in Section 2, climate policy may change drastically the energy sector. Climate policy—some attempt to price CO_2 or to otherwise favor alternatives—is one of the big changes from the 1970's. Then, energy policy identified shale oil and coal as domestic resources that would solve the energy crisis. Today there is private investment in these technologies but even there it is with at least an eye toward carbon capture and storage. A CO_2 price is a reality in Europe and there is enough talk of it in the US that developers of electric generation facilities or new fuels production facilities must give some weight to the likelihood that an investment in a facility that releases CO_2 or produces fossil fuel is at some economic risk from a CO_2 price within the lifetime of the investment.

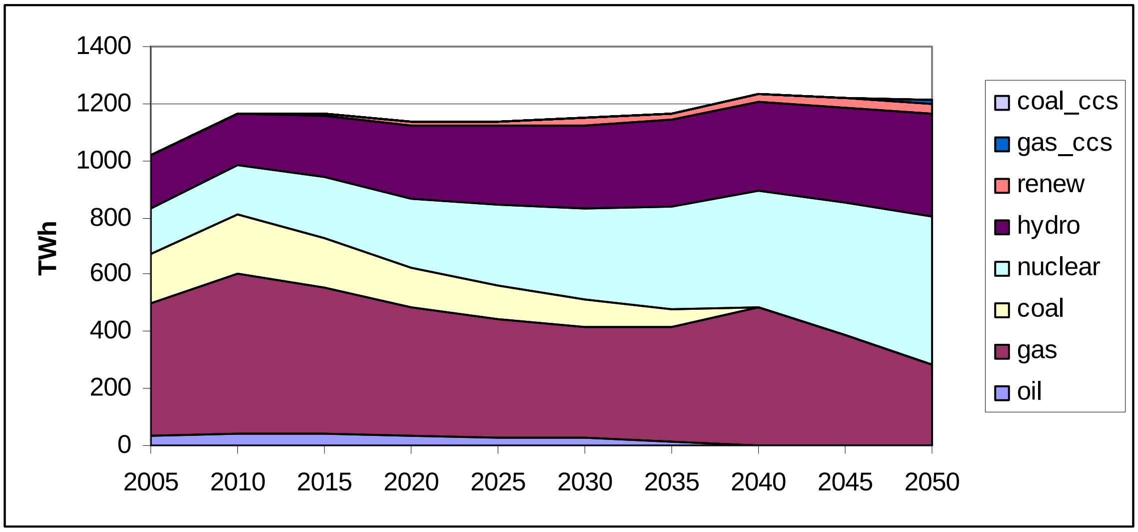
It looks like Russia is far from the serious carbon constraints, despite its approval of G8 targets for 50% reduction in emissions by 2050. **Figure 7** shows the energy use in Russia in the scenario when USA, Europe, Japan, Canada, Russia, Australia and New Zealand are reducing their emissions by 50% relative to their 2000 levels. No other countries impose the carbon constraints. In this scenario, Russian energy use is leveling at about 800 mtoe in comparison to the Reference Scenario, where it grows to 1200 mtoe. Coal use is almost out.

Figure 7. Energy in Russia in G8 only scenario.



Electricity use in Russia in the G8 only scenario is presented in **Figure 8**, where we also disappearance of coal and some entrance of CCS technology. In comparison to the Reference where it grows to 1900 TWh, electricity is reduced to 1200 TWh.

Figure 8. Electricity in Russia in G8 only Scenario.



In the G8 only scenario, China and India still rely on fossil fuels and happily buy them while developed countries try to penalize its use of carbons. Therefore, we consider another scenario, where developed countries (USA, EU, Japan, Canada, Australia&New Zealand) are still reduce their emissions by 50% by 2050, and Brasil, Russia, China, India, Rest of Eurasia and Latin America also starting in 2030 to reduce their 2030-based emissions by 50% by 2070. we call this scenario as EMF-22 and Figures 9 and 10 show energy use and electricity in Russia in this scenario.

Figure 9. Energy in Russia in EMF-22 scenario.

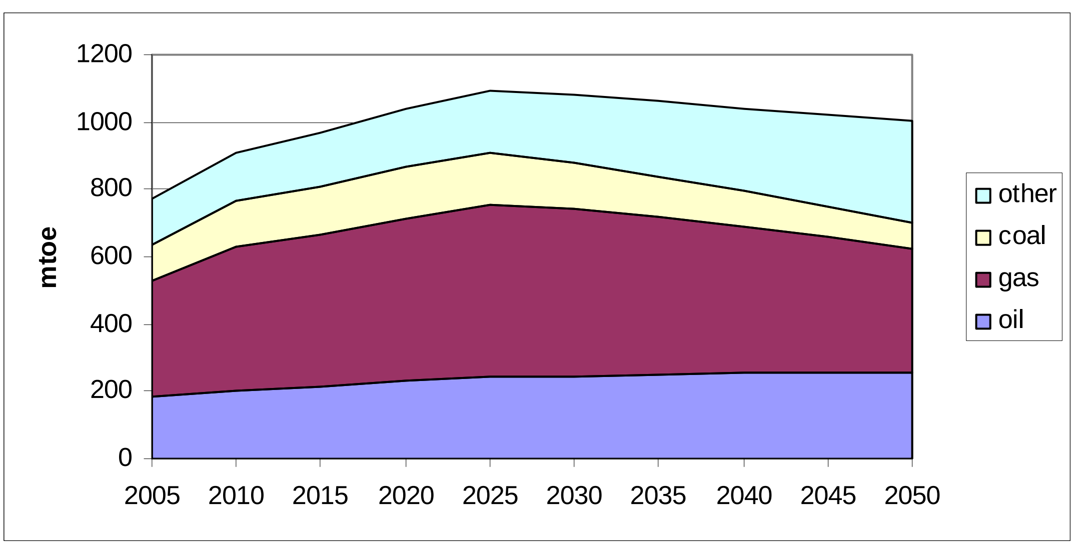
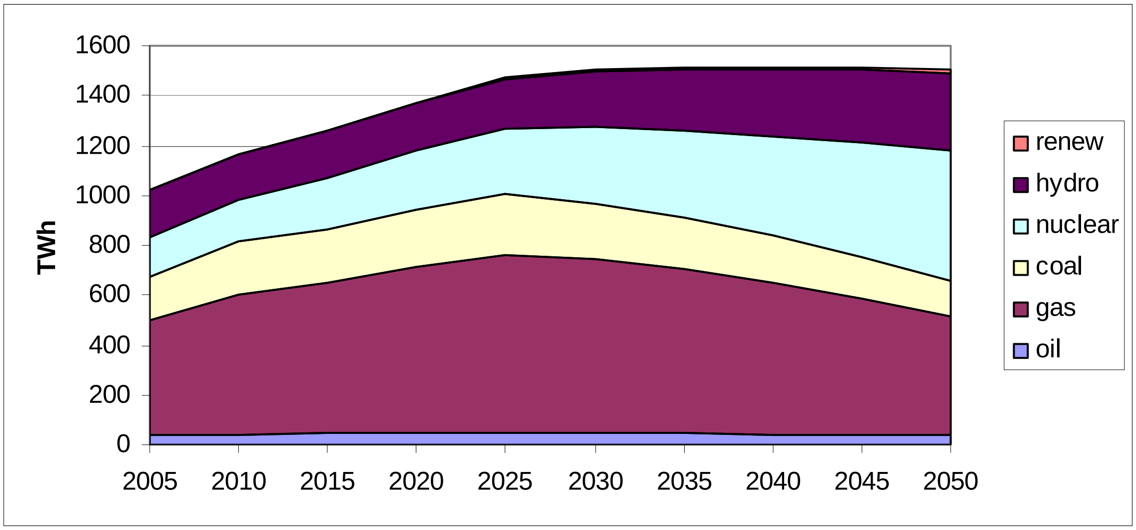


Figure 10. Electricity in Russia in EMF-22 Scenario.



Based on IEA data, 2004 natural gas exports from Russia were 6.7EJ, while Gazprom statistics reports 8.7EJ of exports for major recipients, not counting some additional minor natural gas flows to Japan, South Korea and USA. As we use the IEA energy data in the EPPA model, in **Table 6** we provide an index of natural gas exports relative to 2005 (where the model projects 4 EJ of gas exports to the EU and 6.7 EJ of total gas exports).

Table 6. Russian gas exports (index to 2005).

	Reference		G8		EMF-22	
	total	EU-bound	total	EU-bound	total	EU-bound
2005	1	1	1	1	1	1
2010	1	1	1.1	1	1.1	1
2015	1.3	1.1	1.4	1.2	1.3	1.1
2020	1.5	1.3	1.7	1.3	1.3	1.1
2025	1.7	1.5	2.1	1.4	1.5	1.1
2030	2	1.7	2.4	1.3	1.5	1.1
2035	2.4	1.9	2.7	1.3	1.8	1.1
2040	2.7	2.1	2.9	1.3	2	1.1
2045	3	2.3	3.4	1.3	2.3	1.1
2050	3.4	2.4	4	1.3	2.7	1.1

Table 7 present the projections for crude oil prices that producers are going to get. In the regions where carbon constraints are going to be imposed, the price for a consumer is going to be higher by the amount of carbon charge.

Table 7. World Crude Oil price (net of carbon charge), $/barrel.

	ref	g8	emf-22
2010	56	56	56
2015	65	64	64
2020	74	71	71
2025	85	79	80
2030	99	90	90
2035	115	101	96
2040	127	109	100
2045	139	118	102
2050	154	128	105

As Russia is hit by reduced prices and reduced demand for its fossil fuels, its welfare is decreasing. On top of that carbon constraints make energy prices in Russia more expensive. The scenarios that we have consider lead to substantial welfare losses in Russia, as presented in **Table 8**.

Table 8. Welfare Change in Russia (percent).

	g8	emf-22
2015	-0.5	-0.5
2020	-2.1	-1.4
2025	-3.9	-2.6
2030	-6.3	-4.9
2035	-9.5	-9.1
2040	-12.3	-12.9
2045	-14.3	-17.0
2050	-16.7	-21.6

As our scenarios are based on quite generous assumptions about Russian fossil reserves, the results would be different if the fossil fuels would not come as projected. Among other important variables are assumptions about economic growth, gas market structure, energy efficiency improvement, and energy prices. This sensitivity study is a topic for a separate paper to follow this initial analysis.

5. Conclusion

Predicting the future of energy markets and the success of energy alternatives depends on future energy prices but those prices depend on the cost of conventional and alternative energy sources and demand response to prices. One thus needs to investigate the potential for alternatives within the structure of model of global markets for energy. There are many uncertainties in any projection of the future, as recent volatility in energy markets attests. The volatility we have seen is that volatility around some long term trends that are determined by more fundamental factors of resource availability, the cost of using those resources, and demand growth. That said, the energy shocks we have observed have had longer term effects, and one shock may sew the seeds of future shocks a couple of decades hence. Whether that echo is amplified or damped may depend on coincident events that extend or limit the duration of the shock.

The recent spike was likely amplified by the couple of decades of depressed energy prices that provided little incentive for investment in resource development, creating a condition where once demand growth resumed markets tightened and political turmoil combined to create very high prices. Those likely were unsustainable but the economic crises helped to create a precipitous fall. If the global economy recovers and we return to relatively stable economic times, it is likely that oil prices will be in the $50 to $80 per barrel range over the next couple of decades, perhaps rising to $100 barrel by 2050. Natural gas and coal prices are also likely be lower than we have seen in the recent past. These prices are likely because there are a variety of fossil fuel resources that can be developed, and some of the alternatives (oil sands, shale oil, synthetic fuels from coal) while more expensive to produce than conventional crude oil are probably less expensive than non-fossil alternatives absent a significant price on CO_2 emissions.

In such a no climate policy scenario we see moderate and gradual price increases but continued reliance on gasoline/diesel in transportation and coal and gas in electric generation. Under the stringent climate policies now be discussed, the mix of energy technologies would need to be vastly different. Conventional fuels in transportaion and coal without carbon capture and storage in electric generation are not viable under such policies. At this point, nuclear appears to have a cost advantage and is further along the development line than CCS but if nuclear licensing is a problem or the cost of nuclear escalates, CCS may be viable. Renewables role is likely limited—just where is hard to say—by the variability of the resource.

For development of markets, what matters to Russia? Export demand in traditional markets, expansion to new markets, like Asian market via pipelines and LNG; domestic market development and availability of reserves. Our projections show energy use in Russia growing from 775 mtoe in 2005 to 1200 mtoe in 2050 in primary energy equivalence, while electricity use nearly doubles from about 1000 TWh in 2005 to 1900 TWh in 2050 in our reference projections. The energy system continues to rely heavily on traditional fossil energy. Our long-run reference projection for oil price is a continuous increase from $55/barrel in 2010 to $155/barrel in 2050 and for natural gas from $220/tcm in 2010 to $380/tcm in 2050. The model is not able to capture the volatility in energy prices that is commonly observed. The price projections should be seen as a long run trend around which there will likely continue to be volatility driven by short term events. Achieving the G8 goal of 50% greenhouse gas emissions reduction significantly changes our projections, reducing Russia’s fossil fuel production and domestic fuel and electricity use from the projected levels without such a policy.

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