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Inter-fuel competitiveness of Russian natural gas and electric power supply to China: assessment and forecasting

Competitividad entre combustibles del gas natural ruso y de la fuente de energía eléctrica a China: Evaluación y previsión

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Content

ABSTRACT:
The goal of the research is economic assessment of the competitiveness of electric power supply to northern China for electric heating versus natural gas and coal, as well as economic and mathematical forecasting of gas and power demand. The article examines the competitiveness of Russian natural gas and electric power supplies for electric heating to the People's Republic of China (PRC) in the context of inter-fuel competition. A comparative assessment of thermal power production efficiency in terms of various types of fuel, such as gas, coal, and electricity for electric heating, has been carried out. An economic and ecological assessment of their effective use has been prepared, an econometric forecast of their production and consumption has been provided.
Keywords: inter-fuel competitiveness, natural gas supply, electric power supply, economic forecast, mathematical forecast, thermal power production efficiency.

RESUMEN:
El objetivo de la investigación es la evaluación económica de la competitividad del suministro de energía eléctrica en el norte de China para la calefacción eléctrica frente al gas natural y el carbón, así como la previsión económica y matemática de la demanda de gas y energía. El artículo examina la competitividad del suministro ruso de gas natural y energía eléctrica para la calefacción eléctrica en la República Popular China (RPC) en el contexto de la competencia entre combustibles. Se ha llevado a cabo una evaluación comparativa de la eficiencia de la producción de energía térmica en términos de diversos tipos de combustible, como el gas, el carbón y la electricidad para la calefacción eléctrica. Se ha preparado una evaluación económica y ecológica de su uso efectivo, se ha proporcionado un pronóstico econométrico de su producción y consumo.
Palabras clave: competitividad entre combustibles, suministro de gas natural, suministro de energía eléctrica, pronóstico económico, pronóstico matemático, eficiencia en la producción de energía térmica.

1. Introduction

According to a forecast of the International Energy Agency (IEA), by 2030 China will overtake European countries in respect of gas consumption standard, and demand for it will grow to 480 billion cubic meters, more than 50% of which are planned to be imported (Li, 2015; Golovina, 2013). In China, the

need for such volumes of natural gas supplies is primarily dictated by huge CO2 emissions of coal power plants into the atmosphere and by its multi-billion-dollar fines for emissions above the quota assigned to the country. Russia has already made progress in advancing to the gas market in China: thus, in May 2014, a contract was signed between Russia and China at the sum of 400 billion USD to deliver natural gas over the main pipeline 'Power of Siberia' with the capacity of 60 billion cubic meters. Annually, 38 billion cubic meters of gas will be supplied from the oil and gas condensate fields of Eastern Siberia (the Kovykta OGCF) and the Republic of Sakha (Yakutia) (the Chayandinskoye OGCF) for 30 years (Gazprom, 2017).

However, to date, no comparative assessment has been made of supply efficiency between the competitive types of energy: natural gas and electricity as electric heating for thermal power production in the Northern provinces of China.

According to the goal to be sought, the following tasks were developed: to consider methods for analyzing product competition and models describing the competitive environment; to research works of scholars and experts studying gas reserve prediction in view of its exhaustibility; to assess the natural gas and electricity export market in China; to analyze strategic competitive advantages of electricity and natural gas in the Chinese market; to propose new approaches to the development of the state price policy of the Russian Federation for natural gas and electricity export to China.

2. Research Method

To generate predicted values, a calculation model is used for future values using historical data through exponential smoothing with defining confidence intervals (the ETSAAA algorithm). Thus, predicted values are based on the existing data and continue the timeline.

For calculations, the additive model of triple exponential smoothing of Holt-Winters is used (Mandelbrot, 1963; Goodwin, 2010; Winters, 1960).

The time series is expressed as Yt:

$$\hat{y}_{t+d} = a_t (r_t)^d \textcircled{M}_{t+(d \bmod s)-s},$$

$$a_t = \alpha_1 \cdot \frac{y_t}{\textcircled{M}_{t-s}} + (1-\alpha_1) a_{t-1} r_{t-1},$$

$$r_t = \alpha_3 \cdot \frac{a_t}{a_{t-1}} + (1-\alpha_3) r_{t-1},$$

$$\textcircled{M}_t = \alpha_2 \cdot \frac{y_t}{a_t} + (1-\alpha_2) \textcircled{M}_{t-s},$$

Where s is seasonal period, s-1 is seasonal profile, rt is trend parameter, atis prediction parameter cleared of a trend and seasonality influence.

3. Results and Discussion

China is the country with the fastest growing economy in the world, as well as the largest energy consumer and producer. The constantly growing demand for energy, including heat, has made China one of the most influential participants in the world market (Tyapukhin, 2015). A large share in the power industry is held by coal as a source of primary power. However, the deteriorating ecological situation in the country caused by a huge rate of coal consumption makes it necessary to consider alternative sources of energy. In this paper, potential sources of thermal energy in the country are considered (BP Statistical Review of World Energy, 2015; Yemelyanov, 2012).

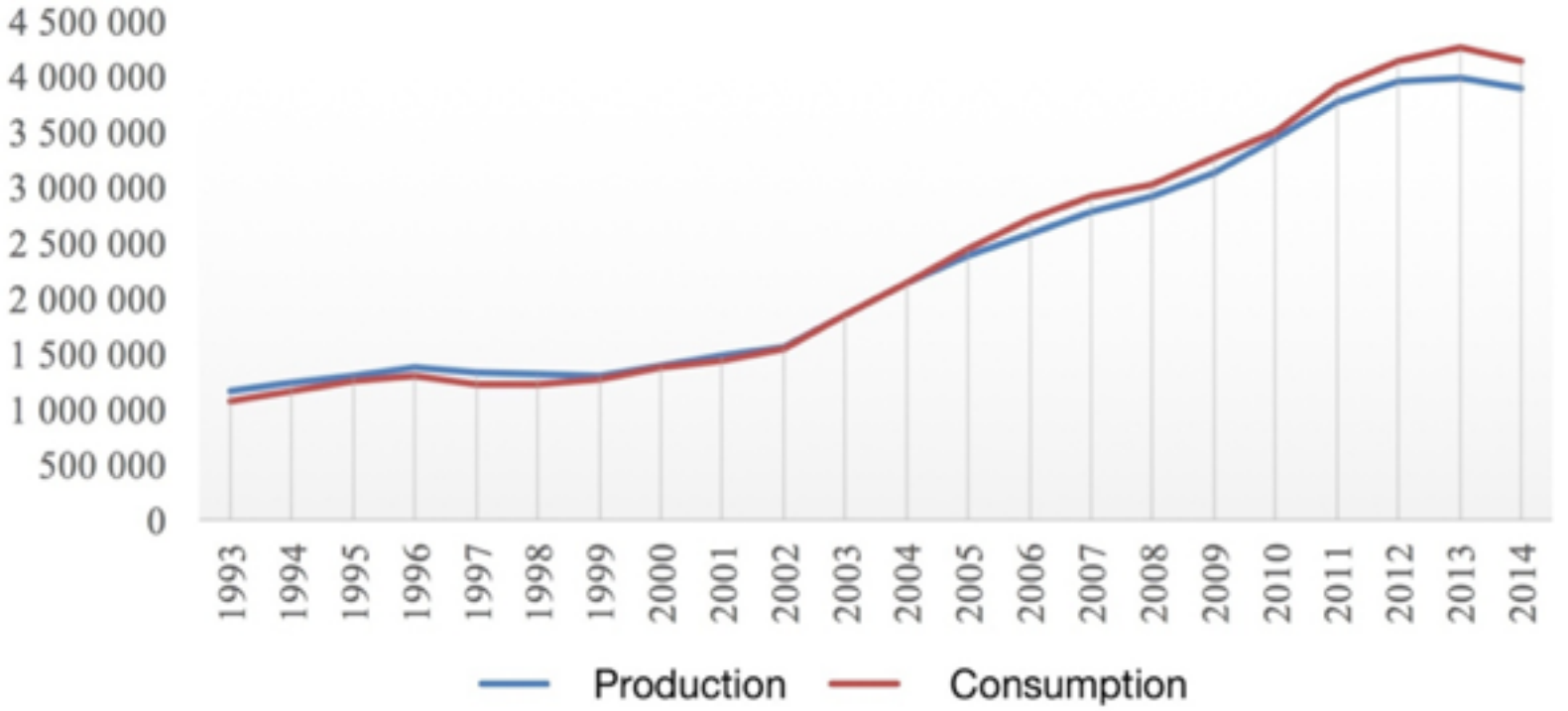
3.1. Consumption and Production of Coal in China

To assess the thermal power market range, the coal market has been analyzed, as it is the main fuel used to generate heat energy in China.

Large domestic coal reserves allow it to remain the main source of energy in the country and maintain a rapid economic growth over the past 10 years. China has been the leader in coal production and consumption since the early 1980s, and consumes almost half of the world's coal production. This has caused serious environmental problems in the region and, therefore, the Chinese government has begun to develop programs to reduce coal consumption (EIA. U.S. Energy Information Administration, 2015).

Figure 1 shows a linear diagram of change in coal production and consumption in China in 1993-2014.

Figure 1. Extraction and consumption of coal in China, kt., in 1993-2014



Source: EIA. Independent Statistics and Analysis. U.S. Energy Information Administration, 2017

As can be seen from Figure 1, the extent of coal production decreased by approximately 3% in 2014;thisbreaksthe established trends in coal mining industry growth for the first time over 14 years. These trends reflect an economic decline in coal consuming industries, such as metallurgy and construction, a slowdown in the power industry, an increase in the share of hydroelectric power plants in power generation, and an environmental protection clampdown.

The presented dynamics of coal consumption in China shows that in 2014, China consumed more than 4 billion tons of coal. Coal consumption in 2013 is almost three times as high as in 2000, which reflects very high growth rates over the past decade. In 2012, the growth rate of coal consumption decreased due to tighter standards of environmental protection and a slowdown in growth rates of the country's industry. The implementation of plans to reduce CO2 emissions involved closure of 2,000 small coal mining sites in 2013-2016 to increase the efficiency and safety of the coal industry. At the same time, half of coal consumption is used to generate heat and electricity.

The growing need for energy sources against the background of coal demandcurtailment policy provides opportunities for growth to other sources, such as natural gas and renewable energy sources (BP Statistical Review of World Energy, 2015).

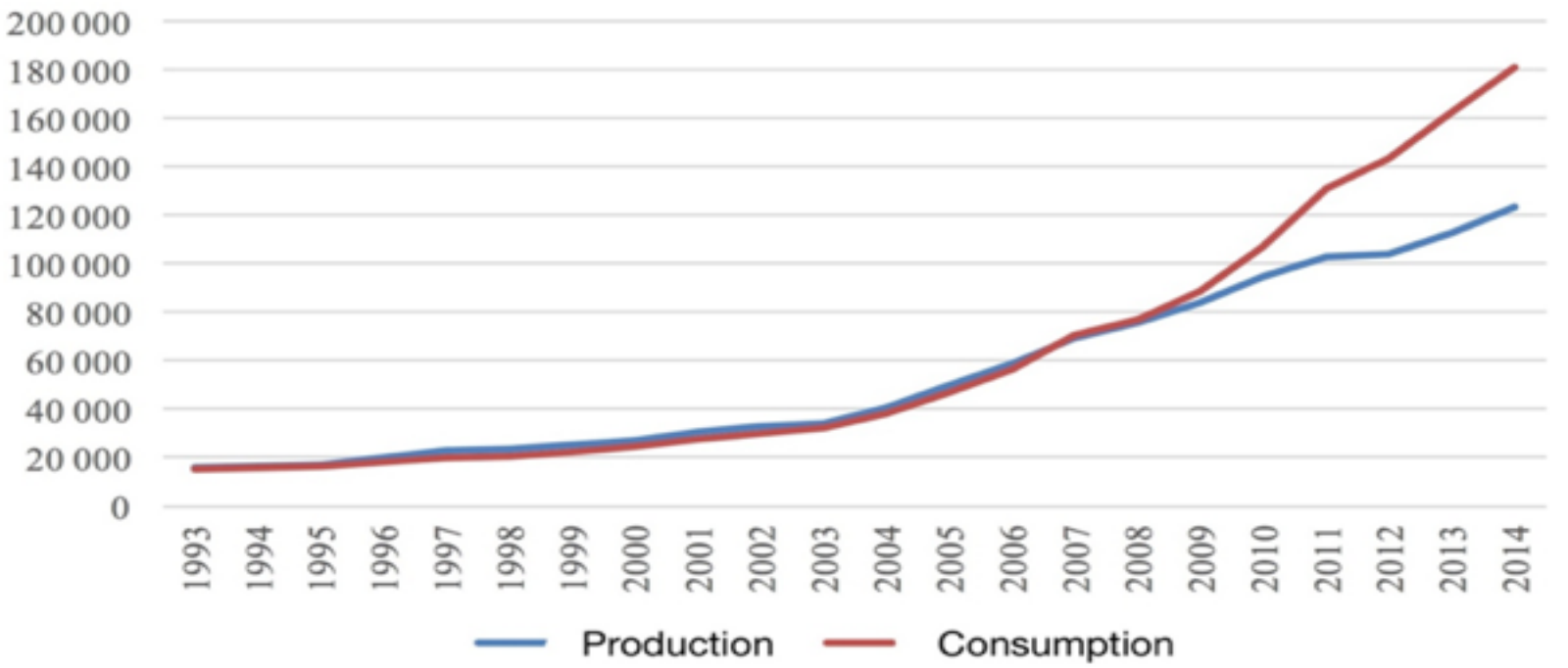
3.2. Consumption and Production of Natural Gas in China

For economic evaluation of the competitiveness of Russian natural gas and electricity supplies to China in the context of inter-fuel competition, a historical analysis of consumption and production of natural gas in China has been carried out.

Figure 2 shows a linear diagram of change in production and consumption of natural gas in China in 1993-2014.

Figure 2. Production and consumption of natural gas in China, million cubic meters, in 1993-2014

Figure 2. Production and consumption of natural gas in China, million cubic meters, in 1993-2014



Source: EIA. Independent Statistics and Analysis. U.S. Energy Information Administration, 2017

As can be seen from the graph, the volume of natural gas production is constantly growing, and, moreover, for 20 years, the volumes have grown more than 7 times: from 15,801 million cubic meters in 1993 to 123,461 million cubic meters in 2014. In 2013, China outperformed Norway by outputand became the 6th largest natural gas producing country (Li, 2015).

At the same time, there is a growth not only in the production of natural gas, but also in its consumption. The main reason for the growth in natural gas consumption is the power industry switching from coal to natural gas. Consumption of natural gas is growing faster than its production. This calls for importing natural gas (EIA. U.S. Energy Information Administration, 2015; Ivanov and Matveyev, 2016; ITAR-TASS, 2014).

The natural gas produced in the Russian Far East is most profitable for imports. The best possible geographic location of the Russian Far East and the availability of developed natural gas deposits make Russia the most beneficial source of natural gas for imports (Neftegaz.RU, 2016).

As of 2014, the share of natural gas in China's energy sector is lagging behind. However, government plans suggest active development and investment in natural gas-fired power plants. In general, China is trying to depart from coal-fired power stations towards natural gas stations in the long term (International Energy Agency, 2012). For the development of such power plants, gas output is increasing, and the main pipeline 'Siberia Power' from Russia is under construction (Gazprom, 2017). This is a massive construction, its implementation being aimed at socio-economic development not only in Russia and its eastern regions. Accordingly, the export of Russian natural gas to China is of universal importance as well. In May 2014, Gazprom and the Chinese company China National Petroleum Corporation (CNPC) signed a 30-year-long agreement to supply Russian natural gas to China (Khodyakova and Serov, 2014). Under this contract, 38 billion cubic meters of natural gas are to be supplied annually, the total contracted volume of gas supplies amounts to 1,032 trillion cubic meters, and the total contract value is 400 billion USD (ITAR TASS, 2014). Gas production is scheduled to commence in late 2018, the first natural gas export supplies to China are due in 2019.

The main gas pipeline 'Power of Siberia' will eliminate the necessity for liquefied natural gas in the Northern provinces of China. This pipeline has a very high capacity and is capable of exporting up to 38 billion cubic meters per year from Russia. In 2014, China's need for imported gas was about 57 billion cubic meters, while in 2020, according to the below forecast made by the authors, the demand for gas will increase to 287.9 billion cubic meters. Thus, construction of the 'Siberia Power' gas pipeline will remove the need for gas imports to the Northern provinces of the People's Republic of China from the Far Eastern region of the Russian Federation (Mitrova and Galkina, 2013; Uyanaev, 2013).

3.3. Assessing the Competitiveness of Natural Gas Supplies to China

To assess the natural gas competitiveness, forecast values of production and consumption of natural gas in 2015-2020 have been compiled. The forecast results are presented in Tables 1 and 2, respectively.

Table 1. Natural gas consumption forecast in PRC through to 2020, million cubic meters

Year	Forecast	Lower confidence interval	Upper confidence interval
2015	198,806	190,380	207,231
2016	216,637	201,454	231,820
2017	234,468	210,193	258,744
2018	252,300	217,272	287,328
2019	270,131	222,980	317,282
2020	287,962	227,484	348,441

Source: Authors

According to the forecast, a further growth of natural gas consumption is expected. However, the model does not take into account China's policy in the energy sector associated with thermal power plants switching from coal to natural gas due to the environmental problems in the region. Thus, possible gas volumes may be higher than expected and exceed the upper confidence forecast interval (Kulagin and Kozina, 2008).

Table 2. Natural gas production forecast in PRC through to 2020, million cubic meters

Year	Forecast	Lower confidence interval	Upper confidence interval
2015	133,284	127,394	139,174
2016	143,112	131,256	154,969
2017	152,941	134,054	171,828
2018	162,770	135,899	189,640
2019	172,598	136,885	208,312
2020	182,427	137,085	227,769

Source: Authors

According to Table 2, an increase in the volume of natural gas production is also expected. The volume gain is anticipated by means of developing new deposits and of the government energy policy that encourages development of gas fields. This is primarily due to the environmental situation in the region and CHP plants switching from coal to natural gas. Thus, an increase in demand for natural gas helps to accelerate the growth of supply (BP Statistical Review of World Energy, 2015; Kulagin and Kozina, 2008).

3.4. Electricity

However, natural gas is not an ideal energy source for heat in China. Natural gas, like other traditional sources of energy, releases carbon dioxide when used in power engineering. In terms of environmental compatibility, the use of electric heating is the most promising. At the same time, electricity must be generated by renewable energy sources, such as the sun, wind, and water. Hydrogeneration is the optimal source of energy to use in generating heat energy on a large scale.

Normally, hydroelectric power plants can produce more power and work continuously, regardless of weather conditions, in contrast to solar and windpower plants (BP Statistical Review of World Energy, 2015; EIA. U.S. Energy Information Administration, 2015; Mitrova and Galkina, 2013).

Development of renewable energy sources, especially construction of new hydroelectric power plants, will significantly reduce the volume of coal production and consumption in the country.

China ranks first internationally in terms of the amount of electricity generated. In 2014, it exceeded 5 thousand TW/h in 2013. Both in terms of generation and consumption, China shows stable growth in the energy sector: electricity generation from 2005 to 2014 doubled. This is caused by economic growth and industrial demand that reduced their growth rates in 2008-2009, but continued their steady growth after 2012. The industry of China consumes almost three quarters of the generated electric power (JSC "South-Yakut State Energy Company". RusHydro, 2017). Table 3 presents data on generation and consumption of electricity in China.

Table 3. Electricity production and consumption in China in 1993-2014, bln kWh

Year	Electricity production, bln kWh	Electricity consumption, bln kWh	Year	Electricity production, blnkWh	Electricity consumption, bln kWh
1993	796	739	2004	2,104	1,955
1994	880	819	2005	2,373	2,196
1995	956	877	2006	2,717	2,524
1996	1,005	921	2007	3108	2,892
1997	1,070	983	2008	3,297	3,071
1998	1,104	1,017	2009	3,527	3,290
1999	1,172	1,077	2010	3,975	3,704
2000	1,281	1,178	2011	4,483	4,200
2001	1,427	1,315	2012	4,750	4,450
2002	1,585	1,459	2013	5,207	4,882
2003	1,810	1,677	2014	5,388	5,067

Source: EIA.Independent Statistics and Analysis. U.S. Energy Information Administration, 2017

The country is planning to develop energy generated by renewable energy sources, nuclear power plants, and natural gas. This will help to lower coal consumption and reduce the release amount of carbon dioxide into the atmosphere. Given the current environmental situation, this is one of the main trends of China's energy industry.

However, due to the large volumes of domestic coal reserves, China will continue to use coal as the main fuel for power plants. Nevertheless, it is planned to gradually reduce the share of coal-fired power plants. As in the case of coal mining, the Chinese government is planning to close small and inefficient power plants in favor of more efficient and environmentally friendly plants. Also, China has enjoined companies from building new coal-fired power plants in the vicinity of three major cities – Beijing, Shanghai, and Guangzhou due to the deteriorating environmental situation (BP Statistical Review of World Energy, 2015; EIA. U.S. Energy Information Administration, 2015; Gazprom, 2017).

Hydrogeneration of electricity is the most environmentally compliant. Due to heterogeneity of production

and consumption of electricity, China imports electricity to its Northern provinces from Russia. The import of hydrogenerated electric power solves a number of environmental problems that can arise in case of domestic energy production from traditional energy sources. This is the optimal source of energy for China and a promising energy outlet for Russia (International Energy Agency,2014; EIA. Independent Statistics and Analysis. U.S. Energy Information Administration, 2016).

Hydraulic power industry operates on virtually non-depletable water resources and has a possibility to recover the funds invested in the construction of hydroelectric power stations in a short period of time. The government energy policy of Russia and China is aimed at the priority development of renewable energy sources as a replacement source of exhaustible fuels for electric and thermal energy production. In this regard, it is quite important to build and develop hydroelectric power plants working renewable water resources. The construction of South Yakutia hydraulic power complex remains one of the most promising facilities due to the growing demand for electricity exports t006F China, as well as to South Korea and Japan. China alone annually seeks to purchase electric power of at least 50-60 billion kWh from Russia (JSC "South-Yakut State Energy Company". RusHydro, 2017).

In the period until 2050, in light of the balance situation taking into account the development of energy-intensive industries, including ferrous metallurgy and metal mining industry of Southern and Eastern Yakutia, as well as prospects of electric power export to Asian-Oceanian countries, it is advisable to consider possibilities of using the hydraulic potential of the rivers of South Yakutia for generating electricity with the construction of the South Yakutia hydropower complex (SYHPC) (JSC "South-Yakut State Energy Company". RusHydro, 2017). Table 4 provides a brief description of the South Yakutian cascade of hydroelectric power stations.

Table 4. Brief description of the South Yakutian cascade of hydroelectric power plants

HPP name	Installed capacity, MW	Average annual generation, bln kWh
Sredne-Uchurskaya HPP	3,330-3,700	15-17
Uchurskaya HPP(Nizhne-Churskaya HPP)	360	2.2
Nizhne-Timptonskaya HPP	930	4.8
Kankunskaya HPP	1,200	3.8
Olekminsk HPP	1,500-2,000	6.7-7.6
Nizhneolekminsk HPP	230	1.0
Aldan HPP	1,000-1,250	4.5-5.4
Total:	8,550-9,670	38-41.8

Source: JSC "South-Yakut State Energy Company". RusHydro, 2017

The total installed capacity of the cascade is about 8000 MW with an average annual output of 38 bln kWh. In 2013, the design of Kankunskaya HPP was completed as part of project documentation development for the 'Integrated Development of Southern Yakutia' project.

To estimate the electricity market, forecasts for production and consumption of electricity presented in Tables 5 and 6 have been compiled.

Table 5. Electricity generation forecast in PRC through to 2020, bln kWh

Year	Forecast	Lower confidence interval	Upper confidence interval
2015	5,627	5,406	5,849

2016	5,844	5,389	6,299
2017	6,061	5,310	6,812
2018	6,278	5,184	7,372
2019	6,495	5,016	7,973
2020	6,711	4,812	8,611

Source: Authors

Table 6. Electricity consumption forecast in PRC through to 2020, bln kWh

Year	Forecast	Lower confidence interval	Upper confidence interval
2015	5,276	5,062	5,490
2016	5,485	5,026	5,943
2017	5,693	4,939	6,447
2018	5,902	4,809	6,994
2019	6,110	4,641	7,580
2020	6,319	4,437	8,201

Source: Authors

As the forecast shows, China will continue to show surplus in terms of electricity generation. However, this is general information on the development in the country, and local deficiencies and surpluses of electricity in some provinces of the country can occur, as they do today. The model shows that in 5 years, a significant growth of the energy sector is possible – on average, it is expected to grow by 20% in 5 years in generation and consumption of electricity. Given the increase in electricity consumption, the supply of electricity to China can be more profitable than domestic generation, in view of the environmental situation in the northern region of the country.

To evaluate the economic efficiency forecast of natural gas and electricity supplies, calculations should be made on economic evaluation of inter-fuel competitiveness.

3.5. Inter-FuelCompetition

To calculate the efficiency of using electric heating in the Northern provinces of China, calculations have made out to find the cost of producing 1 Gcal of heat by various types of fuel. The calculation results are presented in Table 7.

Table 7. Production cost calculation for 1 Gcal of heat from natural gas, coal, and electricity

Fuel type	Calorific capacitance	Unit of measure	Output to generate 1 Gcal of heat	Measuring unit cost, USD	Cost of 1 Gcal of heat, USD
Natural gas (98% methane)	11,711	kcal/cub.m.	85.39	0.185	15.80

Coal	6,710-8,680	kcal/kg	132.1±16.9	0.08095	10.69±1.37
Electricity for heating	864	kWh/ kcal	1,157.41	0.042	48.61

Source: Authors

For the calculations, the average export price of natural gas from PAO Gazprom to European countries (Slav, 2017), the current spot price for Australian coal in the amount of $ 80.95 per ton (8 cents/kg) (EIA.Independent Statistics and Analysis. U.S. Energy Information Administration, 2017), and the export electricity price of RAO Energy Systems of the East to China in 2011 in the amount of 0.042 $/kWh (4.2 cents/kWh) (Uyanaev, 2013) were taken.

As can be seen from Table 7, electricity for electric heating is one of the most expensive types of energy for generating heat due to the fact that the electricity export rate of RAO Energy Systems of the East was used for calculations, not forecasted electricity production tariffs in the South Yakut cascades of hydroelectric power plants with the planned average annual generation of 38-41.8 billion kWh, where electricity rates will be much cheaper.

However, targeted supply of electric power for electric heating can be effected with a lower production cost of 1 Gcal of heat. A discount on electricity is possible, especially against the backdrop of constructing new hydropower plants in Russia. Permanent export power delivery will help Russia to avoid idle water discharge, improve the commercial balance, attract new funds and investments; and for China, to get the required electricity at a substantially lower price.

To compete with natural gas in the area of heat energy generation, electricity generation of 1 Gcal of heat for electric heating should cost about the same. The following calculations show that for competition in the production of heat energy versus natural gas, 1 kW/h of electricity should cost as follows:

$$1\ kWh\ cost = 15.8\$/1157.41\ kWh\ /h/ = 0.0136\ \$ = 1.36\ cents$$

With this cost of 1 kW/h, the cost of generating 1 Gcal of heat is equal to $ 15.74, which is slightly lower than the cost of generating heat of natural gas. It is this cost of electricity that will simultaneously reduce the escapage amount and extend Russia’s export potential, as well as lead to an improvement in the environmental situation in China.

Electricity is necessary for the energy infrastructure of the region and can be used not only for heating. Coal, despite its low cost, is not a priority source of primary energy for heating, as the environmental deterioration does not allow safe use of this fuel type. At the moment, the ecological situation in the Northern provinces of China is at the brink of ecological catastrophe. For a long period, China has exceeded the quotas of carbon dioxide emissions into the atmosphere. China’s energy strategy calls for an increase in the natural gas share in energy consumption from 5% in 2014 to 10% by 2020, with a decrease in the natural gas share from 66% to 62%, respectively.

In the absence of priority development of coal energy, the use of natural gas, as calculations have shown, is the most cost-effective in the short and medium term. In the long term, in the Far East of Russia and in the People’s Republic of China, electricity for electric heating produced by hydroelectric power plants on a large scale will be the cheapest, environmentally friendly, and renewable source of thermal energy.

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4. Conclusion

For China, the results of the assessment of inter-fuel competition between gas and electricity have revealed the advantage of importing electricity over natural gas. Also, the experience of effective use of electric heating instead of coal and natural gas as an energy carrier for heating residential areas and production facilities in the western and southern power districts of Yakutia, due to excessive cheap hydroelectric generation at the Vilyuy Dam, gives real opportunities to introduce this effective model of electricity supply for electric heating to the Northern territory of China.

As a result of the analysis, it has been revealed that, based on the total estimated deposits of the Chayandinskoye (the Republic of Sakha (Yakutia)) oil and gas condensate field, which amount to 1.4 trillion cubic meters, and taking into account the capacity of the gas pipeline of 38 billion cubic meters per year, the reserves will be exhausted in 36 years.

The import of electricity from South Yakutia to the PRC, with China's environmental problems because of the operation of coal-fired power plants, is the most effective option because electric heating is an environmentally friendly and renewable commodity (natural gas power plants also release harmful emissions of nitrogen oxides into the atmosphere). Electric heating is also cost effective due to low electricity tariffs at hydroelectric power stations, and also, to construct high-voltage power transmission lines will be less costly for the government than building a main gas pipeline route to reach end consumers.

Despite modern trends in the China's power industry transition from coal to natural gas, exporting electricity as electric heating will be most effective in the long term. In addition to diversification of Russian exports, this will improve the environmental situation in Asia-Pacific region, which, in the long term, will be more economically viable for the PRC given the reduction in the volume of emission allowances around the world.

For Russia, the assessment results of inter-fuel competition between natural gas and electricity have revealed a long-term prospect need to hold exhaustible natural gas in trust for successive generations and to export it taking into account keeping the energy balance of the eastern territories of the country when natural gas price advantages occur in the gas market. But it is even more profitable to develop the country's own gas processing, to sell finished products of gas chemical production.

As a result of the comparative analysis of inter-fuel competition, taking into account the growing needs of changing China's energy balance towards environmental compatibility, the electric power of hydro power plants in South Yakutia is the most efficient clean energy carrier. The development of hydro power plants in Yakutia by its cheap electricity tariffs will entail an increase in production of competitive products for commodity markets of the Asia-Pacific Region. However, considering the commencement of the 'Power of Siberia' main gas pipeline construction, and based on the analysis of energy resources competitiveness, the authors propose new approaches to development of the national policy of the Russian Federation for natural gas and electric power export to China, which must be based on the following principles: the principle of preserving non-renewable energy resources for the people; the principle of exporting natural gas taking into account the exhaustibility of reserves and electricity as electric heating with regard to rational fuel and energy balance of the eastern territories, including the Republic of Sakha (Yakutia); the principle of priority development of renewable energy environmentally friendly and safe for the environment.

For the PRC, the results of the assessment of inter-fuel competition in the long term between natural gas and electricity have revealed the advantage of importing electricity over natural gas. Also, the experience of effective use of electric heating instead of coal and natural gas as an energy carrier for heating residential areas and production facilities in the western and southern energy districts of Yakutia gives real opportunities to introduce this effective model of electricity supply for electric heating to the Northern territory of China due to the excessive cheap hydroelectric generation at the Vilyuy Dam.

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