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Article

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Does the Development of Renewable Energy and Smart Grids Pose Risks for Russian Gas Projects? Scenario Forecast for Partner Countries

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ABSTRACT

In this article we examine the risks of reducing the consumption of natural gas in the countries that are the largest exporters of Russian natural gas (Germany, Italy, Turkey, China) caused by the development of renewable energy. The forecast of natural gas consumption is built up to 2030 by extrapolating the trend of time series, while selecting the type of trend takes into account the S-shaped development of new energy technologies. Two scenarios are considered: the first involves the development of the electric power industry in the way of "business as usual," while the second takes into account the development of intelligent grids and the Internet of energy (IoE). The results show that the intensive development of renewable energy in combination with the digitalization of electric grids can create the most significant risks for the development of gas energy in Germany and Turkey. In Germany, these risks are determined to a greater extent by the desire of the authorities to maintain the achieved level of energy security, which will inevitably fall with a decrease in coal generation and an increase in the share of gas. In Turkey, these risks are determined by the purely technical and technological development of the country, its dynamics and nature.

Keywords: Renewable Energy, Natural Gas Exports, Risk Analysis, Forecast
JEL Classifications: O33, Q42, Q47, Q48

1. INTRODUCTION

Nowadays renewable energy plays an increasingly important role in the energy balance of most of the industrialized countries of the world. Many recent studies show that implementation of smart grids provides an opportunity for the expanded integration of generating capacities based on renewable energy sources (RES) into a united power grids, increasing the level of penetration of RES into the energy balance of different countries, and, as a result, a partial rejection of traditional energy sources (Fadaeenejad et al., 2014; Smart Grids, 2017; Milchram et al., 2018; Ratner and Nizhegorodtsev, 2018; Nikolic and Negnevitsky, 2019). For the Russian economy, which still has a high degree of dependence on hydrocarbon exports (Paltsev, 2014; Orlov, 2017), this prospect creates certain threats and risks that must be taken into account in strategic planning of the development of the oil and gas complex, in particular, in the implementation of large gas projects. And, although the use of natural gas is not limited only to energy sector and the risks of completely abandoning it are minimal, the growing political and economic conflicts around gas projects of Russia, which are well described in the studies (Orlov, 2016; Lee, 2017; Stulberg, 2017; Vatansever, 2017; Bouwmeester and Oosterhaven, 2017; Richman and Ayyilmaz, 2019), attract additional attention to this topic and require a more detailed study of the real and emerging technical and technological capabilities of exporting countries to ensure its energy consumption in alternative ways.

The export of hydrocarbons, in particular, natural gas, remains one of the most important sources of income for the Russian economy (Orlov, 2017; Kolpakov, 2018; Makarov and Miktrova, 2018;

Proskuryakova, 2019). In the period from 2000 to 2018 natural gas exports grew from 130 billion cubic meters up to 200 billion cubic meters, which is more than 1.5 times (CEDIGAZ, 2018). The largest consumers of Russian gas are Germany (58.5 billion cubic meters), Turkey (23.96 billion cubic meters), Italy (22.7 billion cubic meters), Great Britain (14.26 billion cubic meters), France (12.92 billion cubic meters), and Austria (12.31 billion cubic meters). Together, these countries consume more than 70% of all exported Russian gas (CEDIGAZ, 2018).

Several large gas projects are currently at various stages of implementation, which, according to the expectations of the initiators, will make it possible to increase Russian gas exports to the European direction, as well as diversify its supplies through the development of new directions (Vatansever, 2017; Visenescu, 2018; Dastan, 2018; Chumakov, 2019). The most well-known projects include "Nord Stream-2," with a total cost of about 40 billion euros and a design capacity of 55 billion cubic meters of natural gas per year and "Power of Siberia" with the total cost of more than 1 trillion rubles and a design capacity of 38 billion cubic meters of natural gas per year (GAZPROM, 2019).

Worldwide, the highest demand for natural gas exists in the electricity and residential sector: it reaches up to 77% of total consumption (Karpov, 2019). The industry uses only 10% of global natural gas consumption. According to the long-term forecast of the International Association "CEDIGAZ," the demand for gas in the world will grow by 1.6% annually, at least until 2030. The main drivers of expected growth will be the power industry of European countries due to the abandonment of coal, as well as in developing countries that still have their own reserves, but in the future may come to their depletion (CEDIGAZ, 2018).

Such forecasts inspire optimism in the natural gas exporting countries and push them to develop new gas projects, including extremely difficult in terms of access to the field and conditions for development (shale, offshore projects, development of fields at critically low temperatures, etc.) and requiring huge amounts of investment (Choi and Kim, 2018; Kim and Choi, 2019; Chumakov, 2019). The risks of reducing gas demand due to the development of RES in such forecasts are considered insignificant, despite the fact that in the last 5 years the increase in renewable energy capacities around the world has outpaced the increase in the capacities of other types of electricity generation, including gas power generation (IEA, 2018).

The aforementioned forecasts also lose sight of the growing trends in digitalization of power systems of an increasing number of developed countries, which can significantly improve the energy efficiency of power generation, increase the utilization rate of installed capacity, thereby reducing the demand for them and increasing the efficiency of renewable energy (Smart Grids, 2017; Ratner and Nizhegorodtsev, 2018).

For example, (Phuangpornpitak and Tia, 2013; Brown, 2014; Ratner and Nizhegorodtsev, 2018) analyzing the outcomes of numerous pilot European and American projects on the implementation of smart-grids presented declare an increase in the capacity factor in the power system by an average of 10-15%, and in some cases, up to 20%. This means that the need for generating capacity is reduced by an average of 10-15%, thus allowing for the accelerated decommissioning of low-efficiency or ecologically dirty generating sources. In addition, the introduction of smart grids allows, on average, to reduce the overall energy consumption by 2-3% (Ratner and Nizhegorodtsev, 2018).

Another expected result of the implementation of intelligent networks is the development of microgeneration based on RES and the expansion of the possibilities of connecting RES to the general network, which allows a significant increase in the maximum possible penetration rate of renewable energy in the overall energy balance (Ton and Smith, 2012; Eissa, 2018; Liu et al., 2018). All this together can significantly affect the current trends in the global electric power industry and reduce the demand for traditional hydrocarbon sources, including natural gas. In this context, the risks of gas projects in Russia require a more thorough analysis.

The purpose of this work is analysis of long-term risks for Russian gas projects based on forecast of the share of gas and RES for the period up to 2030 in the electrical balance of Germany, Turkey, Italy and China, as the main partner-countries in the implementation of Russian gas projects. As renewable sources in this study we considered only solar PV and wind generation, as the most dynamically developing and commercially mature technologies.

2. METHODOLOGY

The forecast of the volumes of solar PV and wind electricity generation in each country and the forecast of total electricity production in each country was made by extrapolating trends based on raw data from the World Energy Agency for 1990 to 2016 (IEA, 2018). The selection of specific type of trend was made according not only to the accuracy of data approximation on a known part of the time series (coefficient of approximation quality R^2), but also to the main provisions of the theory of technological development (Anderson and Tushman, 1990; Ayres, 1994; Linton and Walsh, 2004; Jamasb, 2007; Schilling and Esmundo, 2009). This theory claims that any technology in its development after a period of rapid growth will inevitably reach a period of diminished returns and, therefore, allows to assume a logarithmic (or similar in form) trend for the growth of total electricity demand and the extension of renewable energy in developed countries, and exponential (or similar in form) trend for China and Turkey (as a countries with a rapidly growing economy and developing renewables).

Let's illustrate this approach by selecting the type of trends for extrapolating time series data on the volumes of solar and wind energy generation in Germany. As one can see from Figure 1, the volumes of wind and solar energy generation in Germany increased very rapidly during the beginning of the development of renewable energy. Until about 2012-2013, the growth in volumes of solar and wind energy generation can be described by an exponential function. However, since about 2013, the growth of generation volumes has slowed significantly and its character can be further described by a logarithmic curve. The logarithmic nature of further growth is fully consistent with the ideas of the theory of technological development about a decrease in the return on technology over time.

Next, we consider in more detail the growth in solar and wind generation in Germany since 2011 (Figure 2). If one selects a trend only by the criterion of approximation quality (R^2), then for a time series of wind energy, a linear trend is better suited (R^2=0.83 for linear trend, while for logarithmic trend R^2 is 0.66). However, we still choose the logarithmic trend, because we believe that the theory gives us a more accurate idea of the nature of future growth, rather than just statistical data for a limited time interval. As for the type of trend for solar generation, the choice is obvious: the logarithmic trend not only more consistent with the theory of technological development, but also has a higher approximation coefficient (R^2 for logarithmic trend is 0.98, while for linear is 0.91).

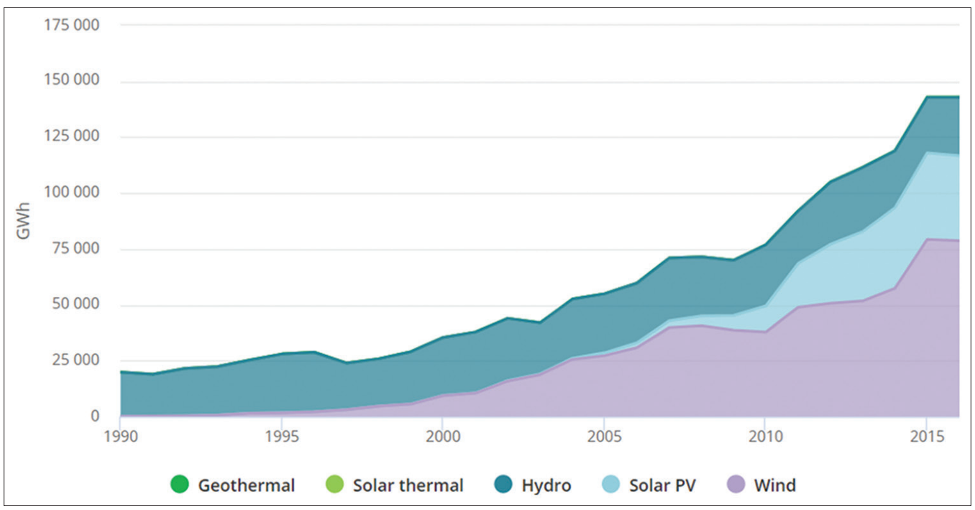
The specific trends used to build forecasts are presented in Table 1.

On the next step of research the forecast of the electricity generation was carried out according to two scenarios: Scenario I assumes an increase in electricity generation in each country, due to the development of the economy (insignificant effect of the digitalization of the energy system and growing electricity demand), while the scenario II assumes that electricity generation would remain at the current level. It is possible only when electric power industry influenced with significant impact of digitalization processes, which is reflected in the increase of the in the installed capacity utilization rate of the most modern and energy efficient generating capacities and leads the decommissioning least environmentally and energy efficient power plants. Despite the fact that gas power plants are one of the most environmentally friendly (Iosifov and Ratner, 2018; Hoang et al., 2018), the second scenario considers the risks of partial replacement of not only coal, but also old gas generating capacities by RES.

3. RESULTS AND DISCUSSION

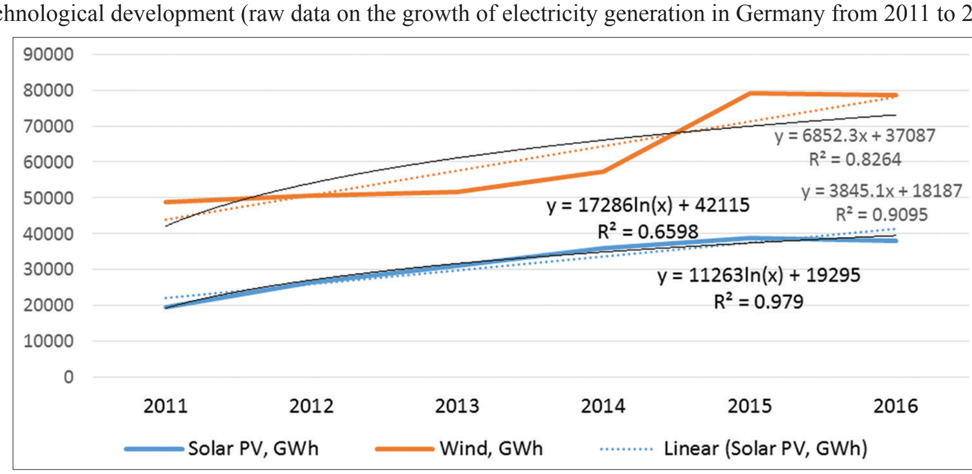
The forecasts made according to the trends presented in Table 1 show that under the first scenario, the share of solar and wind

Figure 1: Electricity generation from renewables by source in Germany 1990 – 2016



Source: IEA (https://www.iea.org/statistics/?country=GERMANY&year=2016&category=Renewables&indicator=RenewGenBySource&mode=chart&dataTable=RENEWABLES)

Figure 2: An example of choosing the type of trend according to the criteria of accuracy of approximation and compliance with the theory of technological development (raw data on the growth of electricity generation in Germany from 2011 to 2016)



Source: Authoring

power generation in Germany's electric balance will reach 40.25% by 2030 or in absolute terms will be 269,222 GWh (Figure 3). According to the second scenario, the share of wind and solar energy will increase to 41.47%, which, however, is slightly different from the first scenario. Given that the share of coal generation in this country is currently 42.09% (or 273,196 GWh), this will reduce the amount of coal generation down to 140,366 GWh in the first scenario (almost twice compared to the current level) and down to 120,670 in the second scenario (or in 2.3 times). However, in the event of geopolitical contradictions with Russia or technology obsolescence of some gas-fired power plants, which currently account for 12.68% of Germany's electrical balance (capacity 82,294 GWh), they also can be partially decommissioned.

According to the first scenario, the share of solar and wind power generation in Italy's electric balance will reach 16.57% by 2030 or 53 384.7 GWh. According to the second scenario it will be 18.42%. Considering that coal generation currently contributes to 14.68% in electric generation of Italy (or 38,403 GWh), this will make it possible to decommission 13,592 GWh of coal generation (decrease in 1.54 times) only in the second scenario. In the case of an increase in demand for electricity (the first scenario), we can expect an increase in demand for gas generation by 18,815 GWh and maintaining the volume of coal generation at the current level (Figure 4).

According to the first scenario, the share of renewable energy in Turkey's electric balance by 2030 will reach 25.89% (or 163,039 GWh), and according to the second scenario it will grow up to 59.41%. Considering the present share for coal-fired power generation in Turkey is 33.63% (or 92,273 GWh) it can be expected that this share will remain at the same level in the first scenario, and will decrease to zero in the second scenario (Figure 5). In addition, according to the first scenario, the growing demand for electricity can be met by an increase in gas generation up to 297,975.7 GWh (a three-fold increase), and in the second scenario, on the contrary, the electricity demand will decrease to 35,020 GWh (or 2.5-fold decrease from the current level).

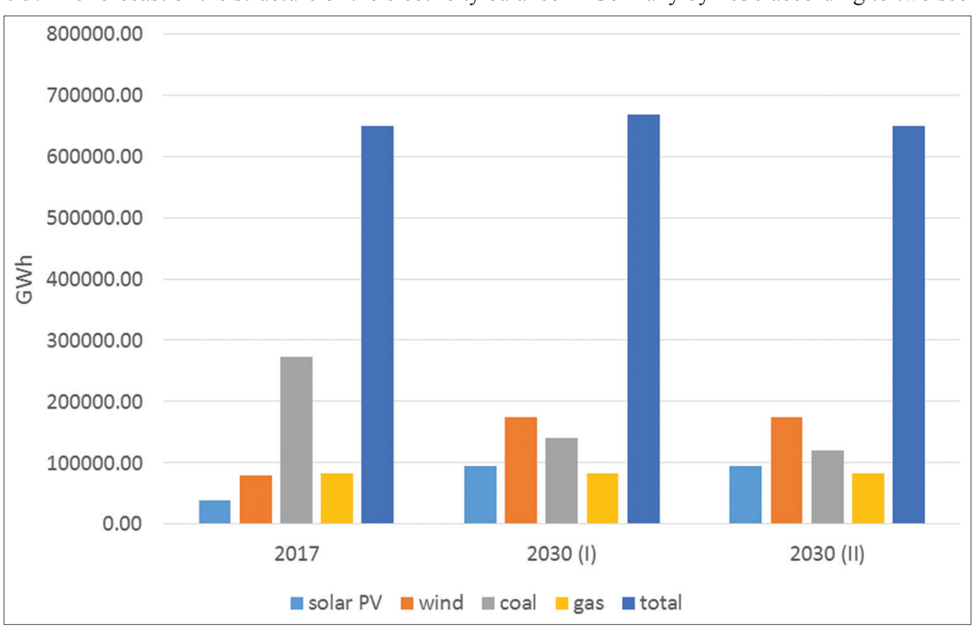
As for China, despite the high growth rates of solar and wind generation, it will reach the amount of no more than 9.45% in the country's electric balance by 2030 in the first scenario, and no more than 15% in the second (or 935,794 GWh). Considering that at present the share of coal electric power industry in China is more than 68% (or 4,266,555 GWh), for the midterm future RES are not able to compete with either coal or gas power plants in this country. The demand for gas in this country from a technological point of view is huge, and the extent of its satisfaction can be determined more by the volumes of possible state support for the development of gas generation than by only market drivers.

Table 1: Trends, selected to make forecasts of growth in renewable energy generation volumes and total electricity generation for Russian partner countries in the gas projects

Country	Trend for wind energy (electricity generation, GWh)	Trend for solar PV energy (electricity generation, GWh)	Trend for total electricity generation, GWt
Germany	Y=17268ln(t)+42115	Y=11263ln(t)+19295	Y=18298ln(t)+614269
Italy	Y=3700.3ln(t)+10254	Y=6465.4ln(t)+12677	Y=38.635ln(t)+204.55
Turkey	$Y=346.07t^2-356.53t+4970.6$	$Y=88.446t^2-453.01t+453.1$	$Y=879.61t^2+2521.2t+227368$
China	Y= 31941t+35944	Y=14066t-20290	Y= 295225t+4000000

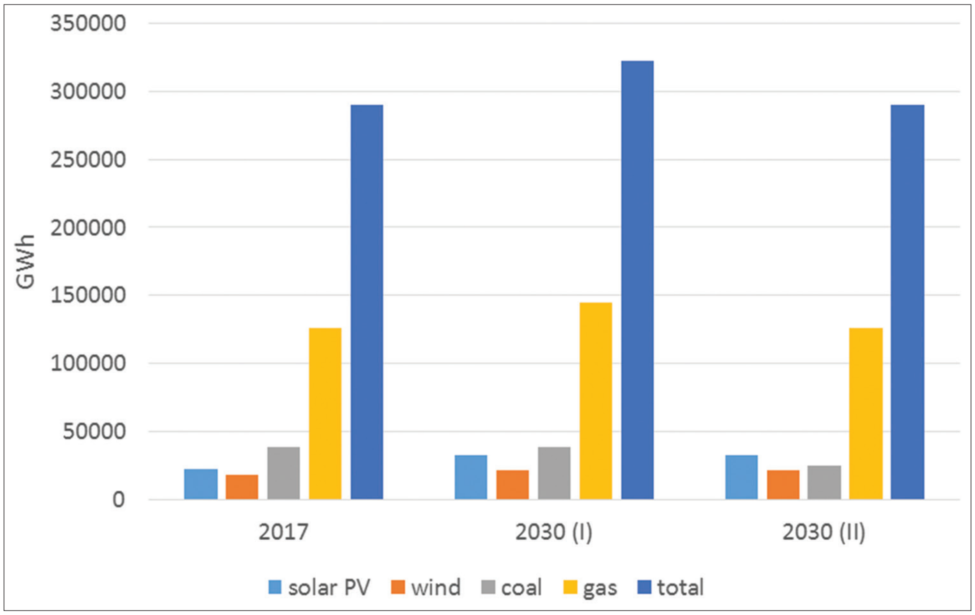
Source: Authoring

Figure 3: The forecast of the structure of the electricity balance in Germany by 2030 according to two scenarios



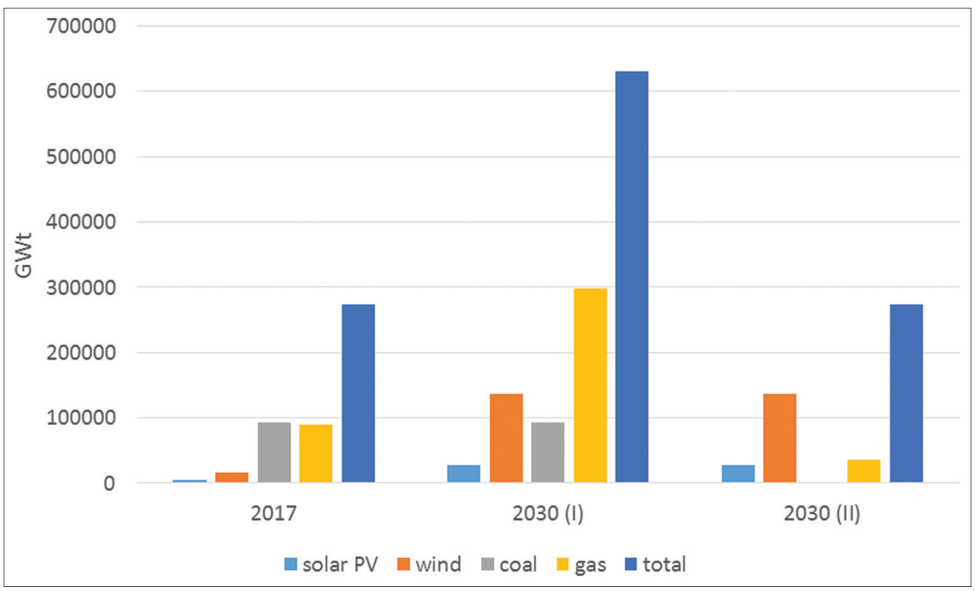
Source: Authoring

Figure 4: Forecast of Italy's energy balance structure in 2030 according to two scenarios



Source: Authoring

Figure 5: The forecast of the structure of Turkey's energy balance in 2030 according to two scenarios



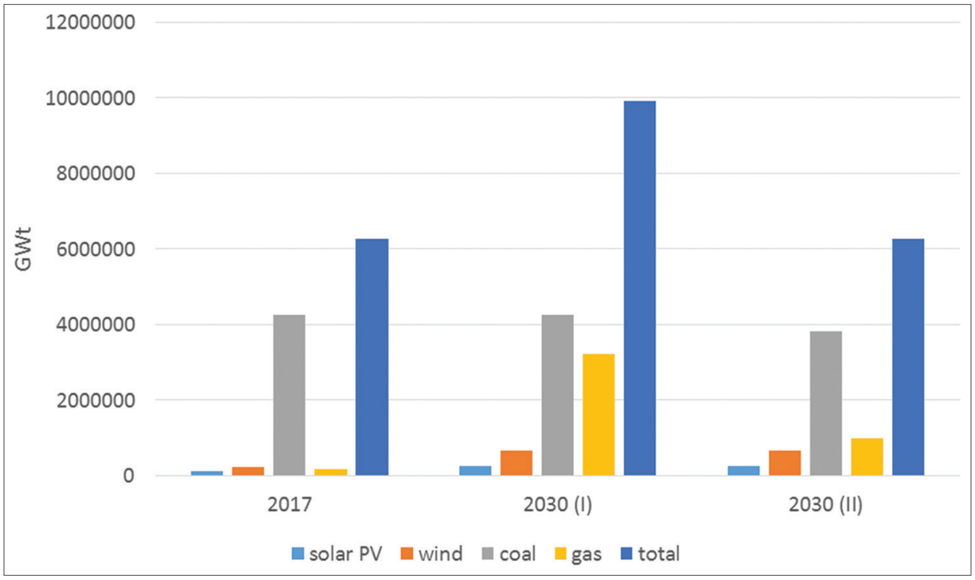
Source: Authoring

So, if we assume only compensation for the growth in electricity demand due to the construction of new gas stations according to the first scenario, then the increase in gas generation between 2017 and 2030 may be more than 17 times (Figure 6). In the case of the active development of smart grids and the current demand for electricity in China (which seems unlikely for this country), then even in such a situation, just a partial substitution of coal-fired power plants (for example, decommissioning 10% of coal-fired power generation plants) will create the need to commission new 1,000,000 GWh of gas power plants, which will increase the volume of gas generation by more than 5 times.

Thus, the intensive development of renewable energy in combination with the digitalization of electric grids can create the most significant risks for the development of gas energy in Germany and Turkey. Moreover, in Germany, these risks are determined to a greater extent by the desire of the authorities to maintain the achieved level of energy security, which will inevitably fall with a decrease in coal generation and an increase in the share of gas. In Turkey, these risks are determined by the purely technical and technological development of the country, its dynamics and nature.

For further calculation of the possible volumes of reduction in natural gas consumption, we assume that the replacement of coal energy due to the development of wind and solar will not occur in Germany in full, but only with a probability of 50%, and for both scenarios of digitalization. We also assume that a possible increase

Figure 6: The forecast of the structure of China's energy balance in 2030 according to two scenarios



Source: Authoring

in the share of gas generation in Turkey to cover the growing demand under scenario I will also occur with a probability of 50% (the remaining 50% of the generating capacities will be covered by the development of other generation sources, for example, nuclear or geothermal energy).

In order to convert the volumes of electricity generation into indicators of natural gas consumption, we use the data on fuel consumption of the Adler power station (CPP) situated in Krasnodar region. This CPP was chosen because it was commissioned before the Olympic Games in 2014 and got one of the most modern equipment due to severe environmental restrictions of Olympic Committee. It has two gas turbines manufactured by Ansaldo Energia (Italy) and a steam turbine of the Russian manufacturer "Kaluga Turbine Plant" and uses high-efficient technology of steam-gas cycle. The efficiency of steam-gas reaches 52%, while the efficiency of traditional steam cycle is just a little over 30%. Besides, it gives low fuel consumption and an average atmospheric emission reduction of 30% compared to traditional steam-powered plants. According to OGK-2 Energy Company, which includes the Adler CPP, the consumption of the fuel (natural gas) is 0.0044 million cubic meters per 1 GWh of generated electricity (OGK-2, 2018).

The results of calculations of possible reductions/growth in demand for natural gas in Germany and Turkey are presented in Table 2.

As can be seen from the data Table 2, the volumes of potential reductions in natural gas consumption in Germany and Turkey are insignificant, even taking into account the digitalization trend of electric grids and the growth in energy efficiency of energy generation. However, in case of initiating the new projects to expand the supply of natural gas in these countries, they should still be taken into account when planning the pricing policy and calculating the potential profitability of gas projects.

Table 2: Forecast of potential reduction/growth in natural gas demand in Germany and Turkey

Forecasted parameter	Germany	Turkey
Change in demand for electricity generated by gas-fired power plants according to scenario I	−66,414 GWh	103,374 GWh
Change in demand for electricity generated by gas-fired power plants according to scenario II	−76,263 GWh	−27,103 GWh
Change in demand for natural gas under scenario I	−292.2 millions m^3	454.9 millions m^3
Change in demand for natural gas under scenario II	−335.6 millions m^3	−119.6 millions m^3

Source: Authors' calculations

4. CONCLUSIONS

Our analysis has shown that the intensive development of renewable energy in combination with the digitalization of electric grids can create the most significant risks for the further development of gas energy in Germany and Turkey. The demand for gas in Chine will only grow because even rapidly developing renewables are not able to replace coal in electrical power industry. The pace of development of wind and solar energy in Italy is still insufficient to replace coal and compete with natural gas. Converting the volumes of electricity generation into indicators of natural gas consumption, we can also state that the volumes of potential reductions in natural gas consumption in Germany and Turkey are insignificant even taking into account the digitalization trend of electric grids and the growth in energy efficiency of energy generation. Thus, the future risks of Russian gas projects from renewable energy are very small.

However, there are a number of limitations of this analysis. The first limitation is related to the economic aspects of modernization of the electric power industry. Traditionally, if there is a possibility of replacing existing facilities, the oldest power plants should be the first to be decommissioned, which, as a rule, operate using already outdated technologies and have low economic and environmental efficiency. In this case, if there are a lot of old natural gas-fired power plants in the country, then they can be decommissioned first, despite the fact that the fuel itself is more environmentally friendly than coal. The second limitations is dealing with the necessity to include into consideration and forecast some other types of renewable energy, such as bioenergy, geothermal energy, etc. Despite the fact that at present they, as a rule, occupy a modest share in the electrical balance of the studied countries, the trend may change over time.

Despite these limitations, however, we believe this study offers several important insights. From a methodological point of view, it shows the possibility to combine traditional methods of analyzing time series with the theoretical provisions of the theory of technological development to obtain more plausible forecasts. From a practical point of view, the obtained forecasts can be used to develop and correct long-term development strategies for the gas industry of the Russian Federation, and to form a marketing strategy of Gazprom and other Russian companies exporting natural gas. They can also be useful for potential investors in Russia's partner countries for consideration new gas projects.

The improvement of the accuracy of the forecasts obtained in this study can be achieved by considering the following important factors that can have a significant impact on the dynamics and the structure of electricity's source balance: (i) The age structure of generating capacities of the studied countries; ii) trends of development of other innovative types of power generation in the studied countries. These factors are planned to be taken into account in further studies of the authors on the indicated topic. As for political risks, their predictability can be slightly improved by constantly monitoring the concepts and strategies of energy security of partner countries, as well as monitoring the dynamics of the market for alternative natural gas supply technologies.

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