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Analysis of competitiveness: energy sector and the electricity market in Russia

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ABSTRACT

This study provides an overview and conducts a thorough analysis of the current state and development trends of the energy sector in a competitive electricity market in Russia. It scrutinises and outlines the most probable scenarios and outcomes of the innovative development on the electricity market and describes the possible changes. Moreover, a comprehensive study of technology foresight methods that allows one to draw parametric models of the development in the technological industry is undertaken. The results indicate that, in the medium- and long-run, one can identify economic inefficiency and uncontrollability of the existing Russian energy sector as well a clear disharmony with the selected energy strategy. Thence, it is necessary to rely on economic innovations in order to develop predictive models for managing productive development of the industry in a competitive energy market.

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1. Introduction

The feature of any energy sector is embedded in the widespread use of electricity and heat combined production and the provision of the district heating from power plants. This also applies to the Russian energy sector, where heat is produced by about 500 thermal power plants, including combined heat and power plants of general and industrial purpose. The total capacity and the amount of energy generated by thermal power plants accounts for ~ 70% of the capacity and generation by the country's power plants (Lisin, Lozenko, et al., 2015; Ministry of Energy of the Russian Federation, 2010).

With the exhaustion of the existing physical capacity of the available resources and the loss of their further exploitation, there is a clear need for the introduction of novel and innovative technologies (as well as the adaption of renewables, especially with regard to various governmental initiatives such as the 'far-eastern hectare').

Existing thermal power plants, mostly built in the 1960–1970s, and their equipment have been physically and morally outdated (low efficiency, at the level of 36–40% in comparison

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with the global rates: 42–55%, increased scope of repair work, large numbers of maintenance staff, increased emissions into the environment). It is necessary to pull out of service old and inefficient equipment and replace it with the more up-to-date one, providing a significant reduction in the cost of electricity and heat generation, a decrease in fuel consumption and normal-mode ratio, environmental emissions, and maintenance costs reduction (Breeze, 2014; International Energy Statistics, 2017; Lisin, Rogalev, et al., 2015; Russian Federal State Statistics Service, 2017).

The presence of the above issues and major tasks of public significance facing the electric market industry in terms of the state commitment to ensure a competitive energy market and the localization of power engineering industries, determines the relevance of the predictive scenarios design for the innovative development of the nergy industry that we are outlining in this paper.

Innovative development, therefore, means the structural and technological changes in the energy sector aimed at improving its global competitiveness through the new energy-efficient technologies introduction. The innovative development of the industry can be achieved through the innovative activity organising at various levels of the sectoral economy management, involving the conversion of technological innovations to existing technologies and products through the research and development work performance, followed by the industrial development and the creation of the conditions required for the innovative process implementation, i.e. the innovative environment and innovation potential formation.

2. Literature review

For thermal power plants that use natural gas, the transition to new energy-efficient technology means gradual decommissioning of all the condensing steam power units and replacing them with combined-cycle ones (Chiabai, Platt, & Strielkowski, 2014; Smil, 2015). It is reasonable to build combined-cycle power plants under unified projects that correspond to modern standards. In order to implement such projects and to make them economically viable, it is necessary to develop a new regulatory and technical basis which shall take into account the technology solutions evolution in the energy and power engineering.

Coal-fired power plants improving implies the turbines and boilers efficiency increases, thus reducing emissions into environment and the resulting losses decrease. Also, a significant increase in the efficiency of a coal-fired power plant would be possible after the industrial development of the combined cycle technology with coal gasification. Combined-cycle units designed on its basis will significantly increase the plant efficiency (Bugge, Kjær, & Blum, 2006; Lykova, Lisin, & Kocherova, 2012; Tola & Pettinau, 2014; Zhang, 2013).

It is also necessary to stress here that the existing technology base of the energy industry, introduced in the planned economy period, was not, in fact, designed to be competitive. Power plants competition in consumers' supply with electric power was not provided for, as it did not make sense to build several plants at the same time for the power supply of the same consumers at the expense of public funds. Due to this, the formed wholesale electricity market to a great extent exhibits the features of a natural monopoly that does not contribute to competitive pricing as in other sectors of the economy (Abrhám, Bilan, Krauchenia, & Strielkowski, 2015; Janda, Rausser, & Strielkowski, 2013). It is necessary to seek technical and economic solutions that promote the concentration reducing in the industry. In other words, the appearance of small efficient power sources able to compete with large power plants. It is necessary to adhere to the country's energy development strategy, gradually implementing the transition from the predominant natural gas use to a significant use of solid fuels (Lisin, Lozenko, et al., 2015; Lisin, Rogalev, et al., 2015).

3. Innovative energy potential

One of the state innovation policy tools that provide generating innovative potential of the industry, giving support and maintenance of innovative processes is represented by the technology platforms (Zlyvko & Kurdiukova, 2014). Based on a branch principle, these platforms contribute to the cooperation intensification between the power engineering companies, energy companies, financial institutions, scientific and engineering centres in the framework of innovative projects. Innovative projects are made on the basis of the priority technology list for the industry included in a given technological platform. The innovation process funding and industrial development of innovation activity on mutually beneficial conditions for the technological platform participants is then provided through the public–private partnership (Zlyvko & Kurdiukova, 2014). Currently, there are four technological platforms operating in the energy sector with state support:

- Intelligent Energy System of Russia.
- Advanced Renewable Energy Technologies.
- Small Distributed Power Industry.
- Environmentally Friendly High-Efficiency Thermal Power Engineering.

The increasing ageing of the power plants' main equipment leads to a reduction in the operating reliability of the sector, sub-optimal loading of generating capacities in the power system, the presence of 'pent-up capacities', as well as a reduction of the equipment performance, environmental and energy efficiency.

The uncertainty of the long-term rules of the wholesale and retail electricity markets functioning, and the lack of effective mechanisms to ensure the effectiveness of investments in new construction and modernization of power facilities, impede the long-term private investment attraction to the industry and, moreover, result in private investors' willingness to sell business assets acquired in the course of the reform (Gorbacheva & Sovacool, 2015; Lisin, Rogalev, et al., 2015).

The assets redistribution arising in the industry results in the establishment of large vertically integrated companies which operate with public participation, and in gradual monopolisation of the industry. The lack of effective price regulation for fossil fuels (e.g. coal or oil) contributes to this factor, which in independent power producers results in a significant increase in the fuel component costs and has a significant impact on profitability due to high operating costs and fixed assets depreciation.

4. Scenario analysis of the innovative development of the energy sector

The structure of the industry has been gradually changing over the past decades. In particular, due to the heat business operating at a loss, displacement by regional boiler Coal and heat power (CHP) from the heat load schedule occurs and, as a consequence, a significant reduction in the heating cycle production, thereby reducing the technical and economic efficiency of cogeneration capacities (Lisin, Sobolev, Strielkowski, & Garanin, 2016; Lisin & Strielkowski, 2014).

Table 1. Technical and economic parameters of coal-fired generation technologies.

Technical parameter	State of technology: Supercritical parameters (S.C.)	Ultra-supercritical parameters (U.S.C.)	Advanced ultra-supercritical parameters (A.-U.S.C.)
Capacity level, MW	300	660	1000
Efficiency level, %	40	45.3	50
Superheated steam temperature, °C	540	600	720
Superheated steam pressure, MPa	24	30	35
Specific capital investments, U.S. dollars/kW	1680	1900	2240

Source: Own results based on Bugge et al. (2006); Bechtel Power Corporation (1981); Sargent and Lundy (2009).

Efficient highly manoeuvrable plants operating in a purely condensation cycle have preference in the electric power market. C.H.P., being the basic generation facilities for many years, due to the low manoeuvrability in the connection with the heat load bearing in the market economy environment, often find themselves in the red (see Table 1).

The ongoing integration of the energy sector with the extractive industry leads to the large-scale investment programmes in the energy sector and the distributed generation development. To a large extent, this phenomenon causes a steady increase of fuel component costs and high potential for an increase in the operational efficiency of enterprises.

Integration of certain energy systems and energy markets results in the gradual basic prices equalisation and a shift of financial and economic policy of the energy sector companies towards the energy system optimisation. Optimising technologies of energy supply and energy consumption modes have been developed and include the electricity supply smart grid and smart metering, electricity storage technology, energy power transmission over long distances, highly economical and environmentally friendly energy-efficient equipment production, as well as the development of electric transport (vehicle-to-grid (V2G), grid-to-vehicle (G2V technologies)) (Breeze, 2014; Gangale, Mengolini, & Onyeji, 2013; Tan, Ramachandaramurthy, & Yong, 2016).

Decommissioning and preservation of the old inefficient generation also remains another priority issue as well as their payment with the minimum price load on consumers and preserving the reliability of the power system operating.

The innovative industry development in the market economy environment has been significantly determined by the competitive environment. Such a competitive environment for the electric power sector, in the first place, is the Wholesale Market for Electricity and Power (W.M.E.P.).

W.M.E.P. is characterised by a structural division of generation, transmission and distribution of electric energy, as well as by the specific nature of the electric power production and consumption, caused by the lack of opportunities of electricity storage in significant volumes and maintaining a balance between its production and consumption at any given time (Lisin & Strielkowski, 2014).

Significant volumes of electricity have been sold in the framework of long-term bilateral contracts on the terms of electricity and capacity volumes payment, regardless of the actual consumption. The day-ahead market (D.A.M.) allows for making corrective changes in electricity production and consumption volumes not recorded under long-term contracts.

Wholesale market participants acquire the missing power or sell excess electric power through the marginal auction of price bids conducted every hour of a day before the day of the actual delivery of electricity. Balancing Market (B.M.) is a trade of deviations and allows real-time matching of the electricity production and consumption volumes. BM price has been formed, as in the case of D.A.M., on the basis of a competitive selection of applications (Lisin & Strielkowski, 2014).

Bilateral agreements are divided into regulated and free ones. Terms of regulated contracts are established by the Federal Tariff Service. According to the state policy in the field of energy market control, a gradual replacement of regulated contracts by free agreements is being implemented. On the D.A.M. and B.M., the electric power is traded at a price that is not regulated by the state.

In addition to the structural division, the wholesale market is also characterised by the geographical separation caused by the technological reasons. W.M.E.P. is divided into separate little or non-communicating geographic zones: the first price zone (European Russia and the Urals territories), the second price zone (Siberia) and non-price zones (regions of the Far East, the Arkhangelsk Region, the Kaliningrad Region, the Republic of Komi) (Lisin & Lozenko, 2015; Lisin & Strielkowski, 2014).

The price zones are characterised by a large number of suppliers and buyers of electricity, as well as well-developed network infrastructure availability that allows operating of a competitive electricity market. On the territories of the so-called 'non-price zones' it is impossible to create a competitive market for technical reasons and electricity and capacity sales are performed at regulated prices.

The performed analysis of the market shares composition of economic entities and grouping them to price zones reveals a high level of concentration on the wholesale market in terms of production volumes, established and available capacity (Lisin & Lozenko, 2015). The concentration growth leads to the competition reduction in the industry, small energy enterprises are absorbed by large holding companies that are not interested to the full extent in the competition development among their companies.

Major monopolists – suppliers of fuel for power plants, such as P.J.S.C. 'Gazprom' and P.J.S.C. 'SUEK' – which entered the market through the creation of vertically integrated structures, have an increasing impact on the industry. In the medium run, the vertically integrated generating companies will play a crucial role in the market structure formation and innovative development of the energy industry. In this regard, the following predictive scenarios are possible (see Table 2).

Depending on the energy market development scenario, the direction of the industry innovative development also changes, including the production technology selection, electric power transmission and distribution and capacity structure optimization. In a competitive energy market environment, the long-term competitiveness, ensured through the introduction of cost-based innovative solutions, becomes a key factor for the energy sector. One of the fundamental feasibility tools are methods of technology foresight.

5. Technology foresight methods analysis

In order to describe the innovative development of the industry in the medium- and long-run, we apply the methods of technology foresight, which allow for designing parametric models of the industry technological development that include qualitative studies and data analysis, as applied in many other fields (Magruk, 2011; Salo, Gustafsson, & Ramanathan, 2003). In a competitive energy market, such models should be complemented by predicting

Table 2. Predictive scenarios and their analysis.

Energy market development scenarios	Features of the industry innovative development
Scenario 1: There is no competition. Vertically integrated generating companies are under the state control. (Closed monopoly)	The manufacturers' competition is absent and replaced by the manufacturer's ability to protect its price before the regulatory body. For a consumer, tariff shall be imposed by the regulatory body on the basis of the average price for all power plants. Funds for innovation development are included in the tariff.
Scenario 2: There is competition of vertically integrated companies on the wholesale power market before the state-controlled buyer. (Monopsony, Oligopsony)	Manufacturers compete on the wholesale market. For consumers, the tariff shall be imposed by the state controlled buyer at the level of the average price for all the plants. Funds for innovation development are included in the tariff. It is possible to reduce the tariff by the use of a competitive mechanism in manufacturers.
Scenario 3: Competition of vertically integrated companies to the sales companies. (Oligopoly)	Manufacturers compete on the wholesale market. The price of electricity is set based on the marginal auction of price bids. The sales company sets the tariff for the consumer on the basis of a market price and sales premium regulated by the state. Funds for innovative development shall not be included in the tariff. The tariff increases due to the increase in prices of the wholesale market.
Scenario 4: Full competition in the wholesale and retail power markets. (Oligopoly, monopolistic competition)	Manufacturers compete on the wholesale market. The price of electricity is set based on the marginal auction of price bids at the maximum price of price-accepting application of the power plant. In the retail market, the sales premium is added to the price of the wholesale market. Funds for innovative development shall not be included in the tariff. The tariff slightly decreases, due to the competition between retail companies.

Source: Own results.

the value of capital expenditures for modernisation and commissioning of the new power equipment, electric energy cost for consumers and conducting study of the energy market participants' behaviour on agent models. Moreover, in order to describe sustainable innovative development of the industry it is necessary at the level of the model to solve the issue of alignment of the natural resources exploitation, environmental requirements, areas of investment and scientific and technological development, institutional changes in the energy market and the society needs with each other.

The indicators of sustainable innovative industry development model are the assessment of the technological and economic technology capabilities that determine the innovative development of the industry. These technologies are included in the technology platforms of the energy sector, discussed above.

The technological capabilities assessment of the technology can be carried out on the basis of its technological limit analysis (Magruk, 2011), i.e. by the achievement the functional parameters limits by this technology. This technological limit is determined by the technological principles that represent the mechanisms of innovation. The upgrade of each subsequent technology reduces the possibility of its further improvement. The implementation of successive innovations is a process of revealing implementation and exhaustion of the technological capabilities of the technology. Exhaustion of the technological capabilities indicates the need for a new radical breakthrough.

The approach to the technological capacity assessment is also valid for the assessment of the economic potential of the technology. The value of the return parameter from innovations is also a finite value, limited by certain limitations. The maximum possible reductions of resource consumption, production costs and non-production costs may serve as these limitations. However, the economic limitation is a quite flexible term. For example, the economic effect of the resource-saving technology introduction can be enhanced by a simultaneous increase in prices for respective resources. However, there are its limiting mechanisms: the dynamics of demand and the competitive pricing policy.

The research literature (Magruk, 2011; Salo, Gustafsson, & Ramanathan, 2003) shows that the problem of technology foresight is far from being solved. Currently, different methods are used in the practice of foresight that is explained by the continuing theory development due to the changing economic conditions and increased opportunities of researchers. Generally, there are three main methods of technology foresight:

1. Quantitative methods are based on the use of mathematical statistics methods (time-series analysis, regression analysis, econometric models and stochastic modelling methods). These methods aid in making a forecast by extrapolation for a very limited period of time. The variance of the random variable will inevitably increase then, which greatly affects the accuracy of predictive estimates. Furthermore, statistical methods do not allow for taking into account rapidly occurring changes of the observed system, caused, for example, by the implementation of technological innovations.
2. Qualitative methods are based on the use of qualitative assessments, with underlying analysis of highly qualified experts' judgements. The methods are universal and applicable without significant restrictions to address objectives of short-, medium- and long-term forecasting. The methods only provide a general idea of the development direction of the phenomenon studied. Therefore, they are mainly used to predict new scientific and technological developments and the formation of scientific and technological policy of countries (for example, the method of long-term forecasting of scientific and technological development foresight).
3. Evolutionary methods are based on the analysis of the existing technology growth. It is believed that this process is not of a random nature and develops in a certain trajectory. Therefore, if the technological path is assumed to be developed by certain rules, it become possible to predict any point in its development using extrapolation. The complexity of the methods lies in the analysis and the selection of a reliable model of the technological path. In this regard, it should be taken into account that technology shall develop at the expense of the market and one of its main driving forces is an investment.

The most promising novel direction in terms of applied research conducted in the field of forecasting is the development and analysis of non-linear deterministic systems with chaotic behaviour. Thus, today there is no mathematically precise machine of chaos theory application to address the objectives of the technological forecasting.

In general, based on the analysis of technological forecasting methods, one can conclude that, for the purposes of the study of the energy sector innovative development, it is necessary to solve a number of problems associated with both the choice and the improvement of the prediction method and a prediction error estimate and determination of the degree of confidence of the results obtained.

6. Conclusion and implications

Currently, modernization of equipment and assimilation of new manufacturing technologies may enhance the competitiveness of the Russian power engineering enterprises and provide a security of energy supply in the country. This should go hand in hand, of course, with devising strategies for when the oil and gas resources are depleted (perhaps the experience of the Gulf countries that invest their oil dollars into the development of tourism and ecosystems can be taken as an example). However, in order to achieve the current goals under the existing economic conditions, it seems necessary to manage costs of new power equipment manufacturing. Forecasting the costs of the new power equipment during research and development stage becomes a matter of primary importance. This could aid in attracting investments in the power engineering sector from generating companies at early stages.

Regarding the new pathways for the development of the Russian power engineering and energy sector, one can probably mention the recent focus on renewable energy sources (R.E.S.) that include (most notoriously) wind and power renewable energy supply, as well as some additional forms of R.E.S. The popularity of R.E.S. can also be noted in Russia, especially with the new law on the 'far-eastern hectare' adapted by the Ministry of the Eastern Development, according to which Russian physical entities can apply for receiving the hectare (10 thousand square metres of land) at the Russian Far East free of charge but subjected to the construction of dwelling, farming or conducting entrepreneurial activity (so far, 96.3 thousand applications have been submitted and 24 thousand hectares given away according to the Russian government). The new settlers are placed in remote areas with no access to power supply and are virtually 'off the grid'. With that regard, the development of energy generation and supply in remote areas becomes very important and R.E.S. can be an answer to this problem. Russia can look at the examples of the electricity supply in remote areas of India, Africa, Alaska, Canada, or South Asia for inspiration and bring in the new insights into its new energy programme.

The results of our analysis indicate inefficiency and uncontrollability of the existing market model of the Russian energy sector in the medium- and long- term, as well as non-compliance of technical and economic development of the sector with the selected energy strategy. Thence, it appears crucial to develop predictive models and techniques in order to manage innovative development of the electricity sector within the framework of a competitive energy market.

We believe that the basic approach required for achieving this goal can be reached by solving the problem of the methodology development for assessing the technological and economic potential of the technologies that determine the innovative development of the industry and is included in the technology platforms.

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