ANALYSIS AND ESTIMATION OF ELECTRIC POWER DEMAND IN RUSSIAN FAR EAST

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Abstract. This article reviews the current situation in the fuel and energy complex (FEC) of the Russian Far East, distinguishes its specific features, estimates the volume of investments required for further development of FEC in the Russian Far East. The use of econometric models makes it possible to get a forecast of electric power production, which serves as a basis of evaluation of the region’s electric power demand. It is noted that the main problem of the region development is surplus of energy production and a continuous population decline. The authors offer major strategic directions of development and mechanisms of energy policy implementation.

1. Introduction
Fuel and energy complex of the Russian Far East, even in the situation of the decrease of production volumes of fossil energy sources (Table 1) and dropping of energy prices, still remains the important source of financing to support and further develop the region’s economy. On the vast territory of the region and adjacent shelf zone, all sorts of primary commercial energy sources are concentrated.

| Energy source type | Oil, mln tons | Gas, bln cubic m | Coal, mln tons |
|--------------------|--------------|-----------------|---------------|
| Extraction         |              |                 |               |
| 2012 г.           | 20.9         | 29.6            | 35.4          |
| 2015 г.           | 12.46        | 20.9            | 22.0          |
| Decrease, %       | 40.4         | 29.4            | 37.9          |
| Consumption, %    |              |                 |               |
| Far East Federal Territory | 33     | 24          | 42             |
| Russia            | 16           | 58             | 22             |

Source: [1]

Fuel and energy complex of the Russian Far East was initially formed to meet the regional internal demand. Development of the Far East territory due to its vastness, harsh climate and low population density reasonably followed the way of creating local industrial “growth points”. Power generating capacities were isolated with a perspective of the capacity increase along with the population growth; the electric power supply always exceeded demand. The share of transportation costs in the coal price...
is around 30% on the average in Russia, whereas in the Far East Federal Territory it reaches 50%. Electric power in the Russian Far East is much more expensive than on the other Russian territories. This is explained by a number of factors: presence of a large number of isolated electric power consuming territories, high fuel spending per production unit, high share of losses in the electrical grids and others.

2. Literature Review
Let us analyze the situation in the fuel and energy complex (FEC) and electric power demand. Versatile approaches to evaluation of FEC importance to achieve economic growth of the territory demonstrate the challenging nature of the problem. The works [2, 3] distinguish the following specific features of the RFE FEC:

– prevalence of heat power stations in the generating structure (over 70% of installed capacity, whereas 30% falls on hydro power generation), non-even distribution of major generating sources in the north-western part, whereas major consuming areas are located in the south-east of the system, technological isolation is caused by insufficient connection with the Unified Energy System of Russia;
– presence of areas of decentralized power supply (predominantly in the northern and hardly accessible territories) and necessity to utilize fuel brought from other territories;
– low reliability of power supply for the consumers, necessity to maintain power generating reserves at the higher level compared with other energy systems of the country, considerable differentiation of electrical and heat power cost (even within the limits of one region) and high cost of electrical and heat power in the northern and remote areas, as well as lengthy power and transmission lines and one of the Russia’s highest share of communal load in the electric power consumption.

The level of electric power consumption by 2013 reached 98% of the level of 1990. The population is migrating from the territory, generating capacities are not fully loaded, costs are increasing, electric power production cost is growing up, and equipment is depreciating more quickly. Table 2 shows the profitability level for the RFE FEC.

| Territory              | 2005 | 2010 | 2013 |
|------------------------|------|------|------|
| Profitability of electrical power sales, % |      |      |      |
| Far East Federal Territory | -2.6 | -4.1 | -8.2 |
| Russia                 | 5.3  | 7.1  | 3.9  |
| Installed capacity utilization ratio, % |      |      |      |
| Far East Federal Territory | 38.6 | 37.9 | 43   |

Source: [4]

Energy types of activity are, as a rule, capital-intensive ones with long payback and return of investments periods, while many energy facilities are considered socially significant and have a low level of profitability. According to [6], the growth of electric power consumption at the Far East Federal Territory from 2008 to 2012 was provided for by the growth of electric power consumption by industry (2,370.3 million kWh, 14.1% growth) and population (even with continuing outbound migration of the population, 1,841.2 million kWh and 30% growth was observed), as well as the growth of electric power consumption by the transport and communications sector of economy (the growth by 1,101.3 mln kWh, 23.4%). Required investment volumes are shown in table 3. The Far East Federal Territory is one of the least populated regions of the Russian Federation (36% of the country’s territory is populated by less than 4.4% of the country’s people). Growth rates of outbound migration from the Far East Federal Territory are gradually declining, but the absolute outbound migration values are still very high.
Table 3. Estimation of required volume of investments to RFE FEC

| Indicator                      | Period         |
|-------------------------------|----------------|
|                               | 2008 | 2011-2015 | 2016-2020 | 2021-2030 |
| Investments to FEC, bln rubles| 72   | 1395      | 665       | 850       |
| of which state budget funds   | 18   | 120       | 75        | 168       |
| Proportion of state budget funds, % | 12   | 9         | 11        | 20        |

Source: [5]

In [7], the growing demand for energy carriers in APR countries is noted, especially in Japan (because of closedown of atomic power stations) and in China (Figure 1).

![Figure 1. Natural gas consumption by country and end-use sector, 2012–40 (trillion cubic feet)](https://www.eia.gov/outlooks/ieo/pdf/0484%282016%29.pdf)

Therefore, there exists an opportunity to cooperate with APR countries with a focus on energy markets of these countries where surplus of produced energy sources may be directed.

3. Research Methods

To evaluate electric power production and demand, the authors make use of the universal approach towards building econometric models described in [6], combined with Box-Jenkins approach [7-8], to analyze the residuals of regression models.

The general view of the electric power production model is:

\[ Y_t = T + E_t \] (1)

where \( Y \) is electric power production volume, billion kWh; \( T \) is trend components; \( E \) is random component. To calculate model ratios and projected values, Gretl application software package was used.

To build trend \( T \), the model of multiple linear regression was used, regression ratios were calculated with the use of the least-squares method.

\[ T = f(t) = \alpha_0 + \alpha_1 X_1(t) + \alpha_2 X_2(t) + \alpha_3 X_3(t) \] (2)

where \( X_1 \) is the volume of fossil fuel and energy sources, in % compared with the previous year; \( X_2 \) is the growth of prices of energy sources producers, in % compared with the previous year; \( X_3 \) is the number of the territory population, thousand people;
To model random component $E$, ARIMA model was used:

$$E = Y - T - y_0$$  \hspace{1cm} (3)

Results autocorrelation and partial autocorrelation functions analysis (table 4) made it possible to determine the ARIMA model order $(2,0,0)$, which is autoregression of the $2^{nd}$ order.

### Table 4. Autocorrelation and partial autocorrelation functions for $E$

| Lag | ACF | PACF | Q-statistic | [p-value] |
|-----|-----|------|-------------|-----------|
| 1   | -0.4107 | -0.4107 | 2.0870 | [0.149] |
| 2   | -0.2510 | -0.5047 *** | 2.9778 | [0.226] |

*** indicate significance at the 1% levels using standard error $1/T^{0.5}$

Ratios of this model are calculated with the use of the maximum likelihood estimation.

$$E = \varphi_0 + \varphi_1 Y_{t-1} + \varphi_2 Y_{t-2} + \varepsilon$$  \hspace{1cm} (4)

$Y_{t-1}$ and $Y_{t-2}$ are lag variables, $\varepsilon$ is ARIMA model residuals $(2,0,0)$;

### 4. Results

The period of observation is within 2000-2016. Results of trend modeling with the use of the least-squares method (LS method) are shown in table 5, the dependable variable is $Y$.

### Table 5. Results of the LS method application

| Ratio | Statistical error | t-statistics | P-value | Significance level |
|-------|-------------------|--------------|---------|--------------------|
| const | 490.869           | 16.9163      | 29.0175 | <0.0001 ***        |
| $X_1$ | 0.0548517         | 0.0181102    | 3.0288  | 0.0291 **          |
| $X_2$ | 0.0559755         | 0.012523     | 4.4698  | 0.0066 ***         |
| $X_3$ | -0.0727667        | 0.00305007   | -23.8573| <0.0001 ***        |

| Median dependable variable | 47.30361 | Statistical divergence of dependable variable | 3.807841 |
|---------------------------|---------|-----------------------------------------------|---------|
| Sum of square residuals   | 4.270024| Statistical model error                       | 0.924124|
| R-square                  | 0.963189| Corrected R-square                            | 0.941102|
| F(3, 5)                   | 506.2091| P-value (F)                                   | 1.26e-06|

3Estimation by authors based source: Regions of Russia. Socio-economic indicators. www.gks.ru/bgd/regl/B12_14p/ Main.htm Date Accessed: 27/11/2016

The negative ratio for $X_3$ factor reflects a decreasing demand on electric power caused by outbound population migration from the region.

Results of random component modeling are shown in table 6, the dependable variable is $E$. It is estimated with the use of the maximum likelihood method.

### Table 6. Results ARIMA $(2,0,0)$ application

| Ratio | Statistical error | $z$ | P-value | Significance level |
|-------|-------------------|-----|---------|--------------------|
| phi_1 | -0.570771         | 0.272141 | -2.097 | 0.0360 **          |
| phi_2 | -0.501775         | 0.275008 | -1.825 | 0.0681 *           |
Median dependable variable: 6.47e-14
Log likelihood: −7.396201
Statistical divergence of dependable variable: 0.730584
Statistical divergence of innovations: 0.528330

3Estimation by authors based source: Regions of Russia. Socio-economic indicators. www.gks.ru/bgd/regl/B12_14p/Main.htm Date Accessed: 27/11/2016

Estimated electric power production in the region in 2018 is shown in table 7.

| Indicator | Forecast, billion kWh | Statistical error | 95% confidence interval |
|-----------|-----------------------|-------------------|------------------------|
| T         | 50.496                | 0.943214          | (48.071372; 52.920590) |
| E         | -0.159                | 0.528330          | (-1.19443; -0.876585)  |
| Y_{2018}  | 50.388                |                   |                        |

Following the results of the calculations obtained with the help of the econometric model, electric power production, taking into account declining population and demands of the priority development areas, will reach 50.388 billion kWh by the year 2018 (compared with 52.087 billion kWh in 2013).

5. Discussion

Growth of industrial production, cargo turnover, gross regional product at the Russian Far East does not require a notable growth of energy and fuel consumption. Within 1998–2003, the actual GRP of the Far East Federal Territory increased by around 28.8%, whereas gross electric power consumption increased by only 12% (by 20.4% in the southern territories). In 2004, the industrial production growth equaled 6.7%, while electric power consumption increased by 2.7% (by 2.2% in the south). Even less growth rates are demonstrated by consumption of centralized heating and primary power as a whole.

On the whole, this proportion between economic growth and electric power consumption growth is not typical for the world trends. As a rule, proportion, or elasticity of electric energy gross products equals 0.8–0.9 (that is, 1% of gross product output growth accounts for 0.8–0.9% of electric power consumption growth) [9, 10].

According to the authors’ estimations, taking into account the aforementioned trends, by 2018, electric power consumption should reach 90.09% of the electric power production in the Russian Far East. Therefore, internal electric power consumption (U) is:

\[ U = Y_{2018} \times 90.09\% + y_0 = 46,561 \text{ (billion kWh, or 92.5\% of the produced volume)} \]

where \( y_0 = 0.807 \) billion kWh of electric power reflects additional demand on electric power following the plan of putting into operation the facilities in the Far East Federal Territory growth areas, which are priority development areas. Estimation of \( y_0 \) was made by the authors.

Under the influence of positive general economic dynamics, international market situation for the energy sources, as well as due to the attraction of financial and industrial groups of Siberia and the Russian Far East to management of FEC enterprises, extraction and production of fuel are increasing. At the same time, production of electric power and heat is characterized by balance surplus of generating capacities and is rigidly conditioned by the dynamics of internal consumption of these energy sources, which on the whole significantly falls behind the economic growth rates.

The Russian Far East witnesses a paradox situation, which is one of the major problems of the territory development, that is, surplus of produced energy sources and continuous population decline. The region is facing the geopolitical challenge of attaching population to the Russian Far East territory by the way of creating developed economy and comfortable living conditions, as well as by achieving
the medium Russian level of socioeconomic development. Energy policy should provide the reasonable balance of interests of the government, business and society.

![Diagram of energy policy implementation mechanisms]

**Figure 2.** Major strategic directions and mechanisms of energy policy implementation

Consequently, it is closely connected to other types of the state economic policy (Figure 2).

6. **Conclusion**

Growth of consumption of energy sources in the South-East Asia countries is inevitable. The energy sector of the region should stimulate human capital reproduction (through the development of power energy infrastructure and providing energy goods and services at socially affordable prices, raising living standards of the population, including those employed in the energy and adjacent sectors), as well as promote well-balanced development of energy and transportation infrastructure, so that to avoid the perspective of becoming the raw material supplying colony for the APR countries.

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