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# DEVELOPMENT TENDENCIES OF HEAT AND ENERGYRESOURCES: EVIDENCE OF KAZAKHSTAN

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**Abstract.** The article provides an analysis of the heat and energy resources of the Republic of Kazakhstan. A study of the global energy market, the trend of its development, raw materials for electricity production in the developed countries of the world. The basis of the energy potential of the Republic of Kazakhstan are large thermal power plants, therefore, an analysis of the development of the electricity sector of the Republic of Kazakhstan has been made. We will conduct a quantitative analysis of the prediction of the dynamics of the main resources in the fuel and energy complex of the Republic of Kazakhstan for the time series for 2010-2017 using the harmonic weights method, a forecast for the period 2018-2020 is given. Based on the models, recommendations for increasing the fuel and energy complex of the Republic of Kazakhstan were developed. Nowadays energetics is the most important driving force of world's economic progress and the electric power industry is one of the basic sectors of the economy, which plays an important role in political, economic and social spheres of any state.

**Keywords:** heat and power resources; world energy market; quantitative analysis; forecasting the dynamics of basic resources

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**JEL Classifications:** Q32, Q43.

## 1. Introduction

In one way or another structural changes have taken place in the economy of CIS countries, which, in their turn, predetermined the functioning and development of the entire energy sector including the electric power industry.

At the same time, the enormous and increasing pressure on the energy sector of Kazakhstan is already imposed by the task of diversifying the economy and accelerating the development of its manufacturing sector.

Another factor that contributes to the load increase on the energy sector is the problem of the survival and development of small cities, which are about 60 in Kazakhstan. And the main problem here is their electricity and heat supply (Mozglyakova 2016). Small cities, remote from fuel and energy sources that have a strategic demographic significance face a number of problems:
- lack of energy resources to ensure sustainable socio-economic development;
- need for an annual budget subsidies for the heating season;
- deterioration of the socio-economic situation with a decrease in production volumes or stop of city-forming enterprises (Ansoff 2015).

However as a result of the global financial crisis in the country, there was a decrease in production in industrial sectors and consequently a decrease in electricity consumption by the industrial sector, which accounted for 68.7% of the total electricity consumption in Kazakhstan.

According to the «World Energy Perspectives» report of the International Energy Agency global electricity demand growth rates outpace demand for all other types of energy. Since the 1970s the share of electricity consumption in the total volume of energy demand has increased from 9% to more than 17%, while by 2050 its share will increase to 25%. Nevertheless, regional growth rates and real demand will differ significantly: electricity consumption by OECD countries will remain almost unchanged, demand growth will be 16% in average; non-OECD regions' increase in demand will be more than 300%. By 2035 oil consumption will be concentrated in two sectors –transport and petrochemistry. High oil prices will contribute to the increase of the energy efficiency of production, which will weaken the position of oil in those sectors where alternative energy sources are available (International Energy Agency)

## 2. Literature review

The enormous and increasing pressure on the energy sector of Kazakhstan is already imposed by the task of diversifying the economy and accelerating the development of its manufacturing sector (Concept and Development Strategy for Sustainable Energy of the Future of Kazakhstan until 2050, 2013).

The current trends in the global energy market make it possible to predict a further increase in demand for energy resources (Thompson, Strickland 2016, Tvaronavičienė 2017; Melas et al. 2017; Tvaronavičienė 2018; Tvaronavičienė et al. 2018; Baltgailis 2019; Rezk et al., 2019; Energy Transformation towards Sustainability 2019; Masood et al. 2019; Sarma, et al., 2019).

Herewith, certain changes are predicted in the structure of the used energy carriers in the world. It is expected that there will be an increase in the use of almost all types of traditional and renewable energy sourcesin the entire world. In particular, the use of coal, gas, nuclear fuel and renewable energy sources will be increased in the production of electricity. At the same time, in the countries with the established industry, the fastest growth in the use of energy carriers will be noticeable in the field of using renewable energy sources and nuclear energy (Satkaliyev 2011; Shindina et al., 2018; Lisin et al., 2016; Kasperowicz et al., 2017).

## 3. Methodology

In most developed countries there has been a decrease in energy and material intensity of production in recent years. Energy consumption per unit of GDP and per capita is decreasing. Consequently, there is no longer a close relationship between GDP growth rates and energy production. In accordance with the existing forecasts for the development of the world energy complex, the trend towards a reduction in specific energy consumption will

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continue in the upcoming decades (Korinko 2017; Borshchevska, 2016; Simionescu et al., 2017; Simionescu et al., 2019).

The production of electricity and heat is 80% dependent on coal, and the dependence of ferrous metallurgy is 100% in turn.

In several countries, coal is the main raw material for generating electricity.For example, the electric power output by using coal is 52% in the US, 54% in Germany, 72% in China.In our country, the coal industry, as well as oil and gas industries is the basis of the energy complex and the guarantor of the energy stability and security of our country. Today the Ekibastuz basin accounts for 65-70% of the total amount of coal mined by the country. There is more than 283 billion tons of coal in the coal fund of Kazakhstan, which makes it possible for coal self-sufficiency, being the largest exporter of coal products, holding a leading place in the region.

Most of the coal fund is located in Central Kazakhstan. Today such coal basins as Karagandinsky, Maikubensky, Ekibastuzsky and also fields as Shubarkolsky, Borlinsky, Kuu-Chekinsky and Yubileinoye are brought under. Since coal is not only fuel, but also a technological raw material, the intensive development of technologies for the deep processing of coal is possible, i.e. gasification, synthetic liquid fuels, chemical products.

According to experts, the demand for coal in Kazakhstan will increase in the near future.There are several largest coal producing companieson the territory of Pavlodar region: «Bogatyr» LLP (30.7% of country's total mining) «North» LLP (21,7%), «Maykuben-West» LLP (2,3%) , and also on the territory of Karaganda region: «Mittal Steel Temirtau » JSC (13,1%), «Borly» OJSC and «Kazakhmys» LLP (8,8%). On top of that coking coal, which is the most valuable, is mined only in the Karaganda basin.

When deciding on the development of the coal industry in Kazakhstan, it is necessary to keep in mind technological and economic factors. The technological factor determines the quality of coal of various grades, as well as their use in the national economy and the economic factor is the economic efficiency of the coal industry.
The republic’s energy potential basis consists of 59 large thermal power plants with a total capacity of about 19,000 MW. Practically in every major city, mainly in regional centers, there is a powerful heat and power plant; there are several state district power stations, in particular, Ekibastuz State District Power Station-1 and State District Power Station-2, the first blocks of which were put into operation during the USSR.At the moment, it is expanding with the introduction of new energy units. Most of the large power plants (80%) run on coal.

Kazakhstan has 15 hydraulic power plants with a total capacity of more than 2,270 MW, five of which have a capacity of more than 100 MW (Shulbinskaya – 700 MW, Bukhtarminskaya – 675 MW, Ust-Kamenogorskaya – 330 MWon Irtysh River, Kapchagaiskaya – 364 MW on Ile river, Chardarinskaya – 100 MW on Syrdariyariver). Other state power plants have less than 10 MW power capacities.

The Unified Energy System unites all major energy sources using power lines in Kazakhstan. The energy sector state policy is aimed at increasing the efficiency of energy resources usage and creating the required conditions for shifting the country's economy to an energy efficient development path; sustainable provision of the population and the economy with electricity and heat; ensuring sustainable development in the conditions of market relations; increase the export potential of electricity; reducing the negative impact on the environment; ensuring the energy security of the country (I llashenko 2016).

For today, ensuring the required volumes of expansion, modernization of existing and construction of new power facilities, as well as the creation of export, transit potential of the essential power reserves is the most important state task.

Fixed enterprise facilities of fuel and energy complex of Kazakhstan, which include the technological level and technical condition, predetermine their competitiveness.

Fuel and energy complex is Kazakhstan's locomotive of economic growth, which includes major non-renewable resources, such as the coal industry, the oil and gas sector, electricity and heat and power engineering.Dynamics are shown on Table 1.

**Table 1**.Dynamics of main resources in fuel and energy complex of Kazakhstan between 2010 and 2017

| Types of economic activity | Industrial output by year | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| Coal mining, including coal concentrate, thousand tons | 111072 | 100854 | 110929 | 116449 | 120528 | 119574 | 114563 | 107318 |
| Oil production, including gas condensate, thousandtons | 70671 | 76483 | 79685 | 80061 | 79225 | 81787 | 80826 | 79459 |
| Electricity generation by thermal power plants, Million KW/h | 80 341 | 78 729 | 76 621 | 78651 | 82900 | 84760 | 78049 | 73078 |
| Heat energy production, thousand GCal | 94102 | 93734 | 96387 | 98021 | 103350 | 94099 | 80975 | 80792 |

*Source:* compiled by authors according to the statistical data

Analysis of the development of the electricity sector of the economy is important in terms of forecasting the reliability and energy supply of the country's economic growth.

We will conduct a quantitative analysis of forecasting the dynamics of the main resources in the fuel and energy complex of the Republic of Kazakhstan between 2010 and 2017 using the harmonic weights method.This method is proposed by a Polish statistician Z.Helvig. The main idea of the method is that the observations of the time series are valued in such a way that more value is given to later observations.The advantages of the harmonic weights method compared to other methods, which also use time series level weighting, is that no assumptions about the trend type should be made when applying it (Fedoseev & Garmash 2000).

For the calculated values we use the data given in Table 1.In such a situation, it can be conditionally taken that a certain approximation of the true trend $\hat{f}(t)$ is a broken line $f(t)$ smoothing a given number of points in the $y_t$ time series. Changing the positions of individual segments of the broken line describes continuous changes in its individual phases. To determine the individual phases of the moving trend movement, choose the number k<n. Each phase of this movement is described by the equation. Based on the fact that it is intended to carry out medium-term forecasting, we will take = 5.

According to Table 1, equations were found to describe the individual phases of the sliding trend movement, given in Table 2. The method of least squares was used to estimate the parameters of the equations. The number of equations is n – k + 1 = 8 – 5 + 1 = 4.

**Table 2**. Equations for calculating the sliding trend

| | Equations | Time moments |
|---|---|---|
| 1 | $y_1(t)$= 101614,3+ 3450,70t | t=1,2,3,4,5 |
| 2 | $y_2(t)$= 94851,20+ 4703,90t | t=2,3,4,5,6 |
| 3 | $y_3(t)$= 111212,1+ 1039,30t | t=3,4,5,6,7 |
| 4 | $y_4(t)$= 130222,6–2422,70t | t=4,5,6,7,8 |

*Source:* compiled by authors

Based on these equations, the values of the sliding trend were determined. Calculated values of each$y_i(t)$ and average value $\bar{y}_i(t)$ using formula:

$$\bar{y}_i(t) = \frac{\sum_{q=1}^{t} a_q + t\sum_{q=1}^{t} b_q}{t} \quad \text{for } 1 \le t \le k \qquad (1)$$

**Table 3**.Trend time series, sliding trend values, deviations from the trend in absolute terms and as a percentage

| t | $y_t$ | $\bar{y}_j(t)$ | $\varepsilon_t$ | E | $\omega_{t+1}$ | $C_{t+l}^n$ |
|---|---|---|---|---|---|---|
| 1 | 111072,0 | 105065,0 | -6007,0 | 5,40 | 0,00 | 0,000000 |
| 2 | 100854,0 | 106387,4 | 5533,35 | 5,50 | 1322,35 | 0,020410 |
| 3 | 110929,0 | 111753,1 | 824,100 | 0,70 | 5365,75 | 0,044220 |
| 4 | 116449,0 | 116246,3 | -202,75 | 0,20 | 4493,15 | 0,072790 |
| 5 | 120528,0 | 117939,1 | -2589,0 | 2,10 | 1692,80 | 0,108500 |
| 6 | 119574,0 | 118736,3 | -837,70 | 0,70 | 797,25 | 0,156120 |
| 7 | 114563,0 | 115875,5 | 1312,45 | 1,10 | -2860,85 | 0,227550 |
| 8 | 107318,0 | 110841,0 | 3523,00 | 3,30 | -5034,45 | 0,370410 |

*Source:* compiled by authors

The computational method consists of the following main steps:

First we find the increments$\omega_{t+1}$off(t):

$$\omega_{t+1} = f(t+1) - f(t) = \bar{y}_{t+1} - \bar{y}_t \qquad (2)$$

Further we calculate the average increments:

$$\bar{\bar{\omega}} = \sum_{t=1}^{n-1} C_{t+l}^n \omega_{t+l} \qquad (3)$$

Where $C_{t+l}^n$ - coefficients, satisfying the following conditions:

$C_{t+l}^n$>0 , t = 1, 2, …, (n-1)

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$$\sum_{t=1}^{n-1} C_{t+l}^{n} = 1 \qquad (4)$$

According to this expression information relating to later periods is given greater weights, since weight increments are inversely proportional to the time that separates the earlier and the later information for the momentt=n (Poplavskaya 2018). If the earliest information has weight of

$$m_2 = \frac{1}{n-1}$$

Then in formation weight, related to the next point in timeline is:

$$m_3 = m_2 + \frac{1}{n-2} = \frac{1}{n-1} + \frac{1}{n-2}$$

In general the series of weights is determined by the equation (Sedelev 2016):

$$m_{t+1} = m_t + \frac{1}{n-t}\ , \ t = 2, 3, \ldots, (n\text{-}1) \qquad (5)$$

The solution of this equation is:

$$m_{t+1} = \sum_{i=1}^{t} \frac{1}{n-i}\ , \ t = 1, 2, \ldots, (n\text{-}1) \qquad (6)$$

Calculation $S_\omega$ of number sequence $\omega_{t+1}$ is carried out according to the formula:

$$S_{\omega}^{2} = \sum_{t=1}^{n-1} C_{t+1}^{n} (\omega_{t+1} - \overline{\overline{\omega}})^2 \quad , \quad S_{\omega} = \sqrt{S_{\omega}^{2}} \qquad (7)$$

As noted earlier, $\omega_{t+1}$ isinterpreted as a random variable with a mathematical expectationM(ω) and dispersion D(ω).

By Chebyshev's inequality we get:

$P\{ | \omega_{t+1} - M(\omega) | > a\sigma_\omega \} < 1 / a^2$

Where*a*– a given positive integer.

Characteristics of *a* in the above expression are constant. It can be assumed that in the prediction the value of *a*will be variable. This assumption is based on the fact that$\omega_{t+1}$are correlated with each other, i.e. even if not so much, they will differ from each other and slightly deviate from $\overline{\overline{\omega}}$ and these deviations will increase as you move

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to the left and right of the point$t_0$along the abscissas. It means that parameter *a* should be a function of distance from *l*, where *l* = 0, 1, 2, …, (n-1). This function *a(l)* is definedby formula (Rozanova 2013):

$$a(l) = a\sum_{t=1}^{l+1} C_{n-t+1}^{n} \quad , \; l = 0, 1, 2, \ldots, (n\text{-}1) \qquad (8)$$

Find values of *a(l)* by making *a* in Chebyshev's inequality equal to 4 (Lepitanova 2015). To obtain confidential intervals, we calculate the $a(l)S_\omega$ product. Predicted values will be obtained by the formula:

$$\bar{y}_{t+1}^{*} = \bar{y}_{t}^{*} + \omega_{t+1}^{*} \quad , t = n - l + 1 \qquad (9)$$

And confidential intervals by the formula:

$$\bar{y}_{t+l}^{*} - a(l)S\omega \leq \bar{y}_{t+l}^{*} \leq \bar{y}_{t+l}^{*} + a(l)S\omega \qquad (10)$$

The results of all these calculations are presented in Table 4.

**Table 4**. Forecast of the dynamics of main resources in fuel and heat complex of Republic of Kazakhstan in 2018-2020.

| Year | t | $\overline{\overline{\omega}}$ | $\bar{y}_t^*$ | *l* | *a(l)* | $a(l)S_\omega$ | $\bar{y}_t^*$ - $a(l)S\omega$ | $\bar{y}_t^* + a(l)S\omega$ |
|---|---|---|---|---|---|---|---|---|
| 2018 | 9 | -1616,34 | 109224,7 | 1 | 2,39184 | 8225,498 | 100999,2 | 117450,2 |
| 2019 | 10 | -1616,34 | 107608,3 | 2 | 3,01632 | 10373,07 | 97235,25 | 117981,4 |
| 2020 | 11 | -1616,34 | 105992,0 | 3 | 3,45032 | 11865,59 | 94126,39 | 117857,6 |

*Source:* compiled by authors

Imagine the results of the predicted values in tabular form as follows:

**Table 5**. Forecast of the dynamics of the main resources in fuel and energy complex of the Republic of Kazakhstanin 2018-2020.

| Types of economic activity | Estimated parameters of trend models by type of economic activity | | | |
|---|---|---|---|---|
| Coal mining, including coal concentrate, thousand tons | | Equations | | Points in time |
| | 1 | $y_1(t)$= 101614,3+ 3450,70t | | t=1,2,3,4,5 |
| | 2 | $y_2(t)$= 94851,20+ 4703,90t | | t=2,3,4,5,6 |
| | 3 | $y_3(t)$= 111212,1+ 1039,30t | | t=3,4,5,6,7 |
| | 4 | $y_4(t)$= 130222,6–2422,70t | | t=4,5,6,7,8 |
| | Year | Forecast | Upper confidential interval | Lower confidential interval |
| | 2018 | 109224,7 | 117450,2 | 100999,2 |
| | 2019 | 107608,3 | 117981,4 | 97235,25 |
| | 2020 | 105992,0 | 117857,6 | 94126,39 |

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Oil production, including gas condensate, thousandtons

| | Equations | Points in time |
|---|---|---|
| 1 | $y_1(t)$= 71019,20+ 2068,60t | t=1,2,3,4,5 |
| 2 | $y_2(t)$= 75389,00+ 1014,80t | t=2,3,4,5,6 |
| 3 | $y_3(t)$= 78312,80+ 400,80t | t=3,4,5,6,7 |
| 4 | $y_4(t)$= 80033,40+ 39,70t | t=4,5,6,7,8 |

| Year | Forecast | Upper confidential interval | Lower confidential interval |
|---|---|---|---|
| 2018 | 80577,59 | 82467,67 | 78687,52 |
| 2019 | 80804,19 | 83187,73 | 78420,64 |
| 2020 | 81030,78 | 83757,28 | 78304,27 |

Electricity generation by thermal power plants, Million KW/h

| | Equations | Points in time |
|---|---|---|
| 1 | $y_1(t)$= 77936,40+ 504,00t | t=1,2,3,4,5 |
| 2 | $y_2(t)$= 72995,80+ 1834,10t | t=2,3,4,5,6 |
| 3 | $y_3(t)$= 75713,70+ 896,50t | t=3,4,5,6,7 |
| 4 | $y_4(t)$= 89085,80–1599,70t | t=4,5,6,7,8 |

| Year | Forecast | Upper confidential interval | Lower confidential interval |
|---|---|---|---|
| 2018 | 74865,12 | 79547,59 | 70182,65 |
| 2019 | 73442,04 | 79347,05 | 67537,03 |
| 2020 | 72018,96 | 78773,60 | 65264,32 |

Heat energy production, thousand GCal

| | Equations | Points in time |
|---|---|---|
| 1 | $y_1(t)$= 90283,90+ 2278,30t | t=1,2,3,4,5 |
| 2 | $y_2(t)$= 94041,00+ 769,30t | t=2,3,4,5,6 |
| 3 | $y_3(t)$= 111939,4–3474,60t | t=3,4,5,6,7 |
| 4 | $y_4(t)$= 125547,2–5683,30t | t=4,5,6,7,8 |

| Year | Forecast | Upper confidential interval | Lower confidential interval |
|---|---|---|---|
| 2018 | 75492,78 | 83025,80 | 67959,76 |
| 2019 | 70904,76 | 80404,56 | 61404,96 |
| 2020 | 66316,74 | 77183,41 | 55450,07 |

*Source:* compiled by authors

## Conclusions

Based on the calculated indicators and their recommended values, we can make a conclusion about the degree of confidence in the obtained forecast models. The volume of coal production depends on the mode of operation of energy companies and has a seasonal nature (Omarova et al. 2018). Coal demand is reduced due to seasonality in order to prevent large amounts of coal from being stored in warehouses in order to avoid endogenous fires and loss of coal quality.These reasons determine the seasonal decline in domestic consumption. It can be assumed that under the conditions of increasing the production volume and export of oil and gas products, the share of crude oil and gas in the overall structure of the fuel and economic balance will increase in near future.Kazakhstan can be attributed to countries with excess energy resources. The power industry of Kazakhstan is a fundamental component of this resource base.It is also a powerful sector of the economythat creates the basis for integration of economic, social and environmental components of the country's sustainable development into the world economy.

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