IJEEP
INTERNATIONAL JOURNAL OF ENERGY ECONOMICS AND POLICY
EJ EconJournals
ISSN: 2146-4553

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2019, 9(4), 273-282.

EJ EconJournals

Development of Digital Economy in the Energy Industry-specific Modernization

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Received: 02 March 2019 **Accepted:** 24 May 2019 **DOI:** https://doi.org/10.32479/ijeep.8013

ABSTRACT

Digitalization of economy defines the extent of possibility in the use of the single information field that could have defined the possibilities for the forecast of the enterprise's activities. The novelty of the study is in the fact that it implements the aspects of the formation of a single forecasting structure for the consumption of the energy sector's production components within a single energy information system. The paper deals with the digitalization of the energy branch based on the approach to the forecast of possible consumption of products. The practical significance of the study is defined by the fact that there is a possibility of formation of a single component on the modernization of the enterprises if they participate in applying the results of the digitalization of economy in the national production system. The implementation of the approach is illustrated by the example of the Republic of Kazakhstan.

Keywords: Energy, Industry, Modeling, Forecasting, Economy
JEL Classifications: O13, Q47

1. INTRODUCTION

Digital economy implies not only the refusal from the traditional economic forms replacing all the production forms with the products based on the services, but also contributes to the decrease in the expenses due to the decrease in wages. At the same time, we exclude the human factor that may hinder the development of innovations. In this regard, digitalization of economy may even be narrowed to the application of the digital management forms and the information exchange between the economic entities (Hong, 2016).

For the energy companies, the main problem is in the fact that energy consumption should be handled with the practical contracts provided by the extracting companies (Zhou, 2013). In this regard, the supply of the energy products at the modernization will be tightly connected with the decrease in the consumption of the energy extracting companies' products and with the need in the correction of the contract relations on the products supply. In this regard, there is a need in the consideration of the issues on forecasting the products including the primary energy sector (Pesznyák et al., 2007). At the same time, forecasting only based on one enterprise will not meet the criteria of the consumption quality assessment. In this regard, there is a need for forecasting based on the formation of the singe consumption policy within one country (Urbach and Ahlemann, 2019).

In the conditions of the economic instability caused by the economic reconstruction to production, the most relevant method for forecasting is the agent-based method (Bieser and Hilty, 2018). Purely, this method is based on the substantiated standards of the production and delivery of services: Room heating, ventilation of industrial and public facilities, hot and cold water supply, lightening, food service in state-financed organizations, construction standards of energy efficiency (Rabat et al., 2018; Varela, 2018). There are some enterprises regulated by the norms of the raw materials for the manufacture of the final products (Akhmetshin et al., 2018). The energy costs for the production may depend on the kind of technology and decrease at the transfer to higher efficiency. Based on the following indicators of energy efficiency: Energy-output ratio of gross domestic product (GDP), energy-output ratio of gross value added (GVA) and the energy-output ratio of the products considering the energy preservation capacity, we will accept the forecasting method we used as standard-targeted, i.e., as the standard we consider the energy-output ratio of GDP, GVA, the products manufactured or specific costs of production at different hierarchical levels at the observation of the need in the provision of the products manufactured and delivery of services according to the existing standards and at the introduction of the energy preservation measures and events in order to achieve of a particular energy efficiency indicator or to decrease the energy consumption of a deficient kind of the energy resource to the minimum possible volume (Salminen et al., 2017).

One should also consider the peculiarities of the modern planning of economic development. The main task of the economic environment is to ensure the delivery of the additional product and the added value in different ways of cooperation (Ibrayeva et al., 2018). In the conditions, when the country is tightly incorporated to the global structures, there is an opportunity of boosting the efficiency of application of forecasting methods in order to define the perspective directions of development of industrial planning and provision of the contracts of on the capacities specified in advance (Kryukova et al., 2016; Wittmann, 2017). The approach requiring the modernization is the one defining the correlation at the environmental approach which requires the reduction of the energy consumption and at the same time the increase in the efficiency of the industrial products' output. Special attention should be paid to the aspect of allocation of the energy resources by the population because such consumption implies the other rates on the consumption, which are in some cases used at the cross-subsidization.

As part of the paper, we defined the set objectives described in the abstract and the object of study; we chose the country that is currently in a rather interesting economic and social position. In the Republic of Kazakhstan, there is a problem of ensuring the growth of energy consumption due to the economic growth in the industrial sector (Scheer, 2017). Besides, the Republic of Kazakhstan is subject to the EU standards implying specific limitations for the decrease in the energy consumption to the minimum, which should also be accompanied by specific environmentalization of the production process. At the same time, all the energy consumption should ensure sustainable growth of the economy in accordance with the directives of the RK President and the EAEU standards. It is also notable that the Republic of Kazakhstan takes the first position in the EAEU in the possibility of the reverse export of energy resources with high value added. In this regard, it is necessary to forecast the energy consumption by the Republic of Kazakhstan as an exemplary country for the standard consumption in the EAEU (Zhetpisbayev et al., 2017; Mukhamadiyeva et al., 2017; Abikenov et al., 2019).

2. LITERATURE REVIEW

The approach to the forecasting of the fuel-energy resources' and electricity consumption at the structural shifts in the economy was considered in the papers by Li et al. (2017). They suppose that there is a direct connection between energy consumption and a gradual increase in the GDP. They directly connect the economic growth with the consumption of energy and point at the decrease in the consumption of energy from outside as a universal measure of the efficiency of economic development. The less are the energy costs for the production of an output unit, the higher is the profit and thus there is a less need in the economic dotation in order to make the products competitive compared with the others. We guess that this approach is just only in the context of mass production for the mass purpose, which is only used in the completely covered sectors that may be extended without the need in the targeting of a product on the market. Also, such methods may not be applied to the strategically important branches of economy, where the energy-output ratio is the issue of provision of national sovereignty.

Hong (2016) in his paper provided positive results in the approbation of the two-stage method of the energy consumption forecast applied at the consideration of the energy consumption capacity from the structural shifts in economy counted from the volumes of the FER final consumption and their kinds of fuel, electricity and heat energy (Arun and Selvan, 2018). This kind of forecast shows the necessity of a more precise connection between the extraction and the sources of energy production. And the component of the energy-output ratio, at the same time, should be gradually smoothed with the market prices for energy carriers. It is especially relevant for the countries importing the basic volume of energy and consuming it in the population sector. Frischknecht (2018) add the forecast of FER consumption for the energetic purposes, non-energetic expenses and losses to the forecast of final consumer obtained this way. In the paper it is considered that the main task of the state is not in the decrease in the outside energy resources or procurements by the lower prices, but first of all the provision of efficient use of the existing resources and gradual decrease in the losses that may emerge even not by fault of the buyer or consumer but due to the technology. He scientist sees this problem as inner-economical that may be solved through conduction of insignificant technological measures, which to the full extent may be implemented due to the internal resources. Particularly, there is a need in not only personal development of the technology when the possibility of a decrease in the losses is laid as a service solution.

The final consumption of fuel was understood by the interpretation according to the collection of statistics (Choudhury et al., 2018), which says that final consumption of fuel includes the volumes of the fuel's use in all the consumption directions except for the fuel consumption for its transformation to the other kinds of energy or fuel products and used for non-energetic purposes. This collection considered through the prism of analysis of the other authors' papers, explicitly shows that the unsolved task remains the point of untraditional sources. These forms of energy consumption remain underdeveloped because they may only be used for a part of the solved tasks and cannot ensure the economic growth due to the fact that they do not have necessary constant capacities for the industrial enterprises. We suppose that there is a need in the consideration of this branch as a part of the consumers' segment of energy consumption and in the forecast of the demand, this segment should not be calculated in the official statistics.

According to different methods of composing energy balances, the final consumption may include non-energetic use (Khayyat, 2018), as in the methods of the International Energy Agency or the losses as in the methods of the European Statistics. The System of National Accounts also contains the notion of "criterion of final use of GDP based on the functional classifications," which include final consumers' expenses of households, final consumers' expenses of the sector of general public administration, final consumers' expenses of non-commercial organizations servicing households and other categories (Beaumont, 1982). We support the position of John Beaumont, who as early as in 1982 suggested using the simulation models for the understanding of the level of provision with energy in large countries. This approach completely justifies itself for the registration and execution of the international agreements that may be implemented in a series of countries. For the Republic of Kazakhstan, it is relevant as for a part of the former Soviet unit – the country that for a long time forecasted its consumption based on the directive economic planning.

In the monetary measurement, the final consumption includes the expenses of the population, general state management and non-commercial organizations servicing the population, while in the conventional fuel, the final fuel consumption is presented in all the kinds of economic activities and population (Soares and Afonso, 2016). The consumption of electricity and heat energy is divided into the production needs and joint consumption, which, except for the production needs, includes the utility expenses and the allotment of the energy carrier to the population. This approach seen among a series of authors shows that it is necessary to form the integral structure of the consumer's perception and the increase in the demand not only in the consumers' segment but also separately for the legal entities and service enterprises ensuring permanent development and have general structure for the implementation of the complex strategies of the regional development (Kuznetsova and Makarenko, 2018; Suprapto et al., 2018).

As a result, we have revealed that the modeling of the energy consumption should be performed based on different scenarios defining the base for the formation of the programs on energy efficiency and energy consumption not only for industrial enterprises but also for the population. We guess that each source of energy consumption should be put in the volume of consumption resulted from the fact that the economy develops and requires a greater energy volume. Notably, the use of such a solution may be based on the understanding of the energy consumption structure in the long run. For this purpose, one should develop the mechanism that would have considered the joint energy consumption by both industrial and private sector and allowed revealing the directions for a general decrease in the inefficient energy consumption and the opportunity of forming its complex regulation. In this regard, we consider it necessary to use the agent-based type of modeling, which may ensure the general implementation of the project for the purposes of the increase in the economic level of the state development. The agent-based modeling in its turn will require the formation of the complex programs on development by the method of scenario. In this regard, we should denote the research methods.

3. MATERIALS AND METHODS

The attempt to combine the notions of digitalisation and development of the industrial sector provided such an interpretation of the final fuel consumption and the other energy resources, which will be further used in this paper: By energy consumption we mean all the consumption with the transformation and losses; final consumption – consumption of the households, sections "State management and defence; mandatory social insurance" and "households" activities' (San Martin et al., 2017). Final consumption of coal or natural gas in the heating industrial furnaces has been referred by us to the direction of the expenses for the transformation of fuel to the other kinds of energy (to the thermal energy). By using such an interpretation of the final consumption, the definition of the energy preservation capacity at structural changes in the economy and thus the forecast energy consumption at the changes in the economic structure requires methodical changes (Liu, 2016).

For the kinds of economic activities (VED), except for Section D "supply of electricity, gas, vapor and conditioned air" – DOWN – level, forecast levels of consumption of the fuel and energy kinds are calculated according to the following formula:

$$E_{ij}^{tl} = \sum_{i} e_{VDVij}^{b} V_{VDVi}^{tl} \pm \sum_{i}^{I} \Delta e_{ij}^{b-tl} V_{VDVi}^{t} - \sum_{i=1}^{I} \Delta e_{ij}^{tl} V_{VDVi}^{tl} \pm E_{zamj}^{tl} \quad (1)$$

where e_{VDVij}^{b} – coal-, gas-, electrical energy capacity of *VDVj* – kind of fuel or energy in the basic year and the economic sector (large kind of economic activities), is defined according to the following formula:

$$e_{VDVij}^{b} = P_{ij}^{b} / V_{VDVi}^{b} \quad (2)$$

where P_{ij}^{b} – the volume of consumption of *j*-kind of fuel or energy in i-sector of the economy in the basic year;

V_{VDVi}^{b} – the volume of *VDV* produced in *i*-sector of the economy in the basic year;

V_{VDVi}^{tl} – forecast volumes of *VDVi*-sector of the economy in the permanent prices (brought to the prices of the basic year);

Δe_{ij}^{b-tl} – change in the VDV energy-output ratio of j-kind of fuel or energy in i-sector of the economy from the change in the forecast structure of GVA counted according to the methods we developed earlier;

$Øe_{ij}^{tl}$ – the decrease in the *VDV* energy-output ratio of *j*-kind of fuel or energy at the introduction of the measures on energy preservation in the technologies in year *tl*, relating to sector i by the kind of activities;

E_{zamj}^{tl} – volumes of possible replacement of *j*-kind of fuel or energy in the forecast year *tl*.

For Section D, the forecast levels of fuel consumption (coal, natural gas) were defined depending on the forecast structure of the electricity and heat generating sources and forecast need of the economy in the electricity and thermal energy:

$$E_{jD}^{tl} = \sum_{l=1}^{n} Bw_{fj}^{tl} + \sum_{m=1}^{n} Bq_{mj}^{tl} + \sum Be_{inj}^{tl} = k_{lj} w_f^{tl} b_{wj}^{tl} + k_{mj} q_m^{tl} b_{qi}^{tl} + k_{inj} b_{in}^{tl} \quad (3)$$

where E_{jD}^{tl} – the need in *j*-kind fuel for the systems of electricity supply, heat supply, gas supply, etc., (Section D by FEA);

Bw_{fj}^{tl} – *j*-kind fuel consumption for the generation of electricity of f-type (TPP, CHP, etc., generators of electricity based on organic fuel) in the forecast year *tl*;

Bq_{mj}^{tl} – *j*-kind fuel consumption for heat generation of m-type (TPP, CHP, etc., heat generator based on organic fuel) in the forecast year *tl*;

$\sum Be_{inj}^{tl}$ – other needs of j-kind fuel in section D (gas supply, conditioned air supply);

k_{lj} – the share of electricity produced by the electricity generating capacities using *j*-kind fuel;

w_f^{tl} – volume of gross electricity produced by the electricity generating capacities of *f*-type in year *tl*;

b_{wj}^{tl} – specific costs of *j*-kind fuel for the production of electricity in the energy system in *tl* year;

k_{mj} – share of thermal energy produced by the heat generating capacities using *j*-kind fuel;

q_m^{tl} – the volume of thermal energy produced by the heat generating capacities in *m*-type in the year;

b_{qi}^{tl} – specific costs of *j*-kind fuel for the production of the thermal energy in the system of the centralized heat supply in *tl* year;

k_{inj} – the share of *j*-kind fuel used in Section D for other needs;

b_{in}^{tl} – consumption of organic fuel for other needs in Section D in *tl* year.

In the process of the forecast electricity consumption for Section D, we consider the consumption of electricity or own needs at the production of electricity, thermal energy, and distribution of gas and conditioned air.

The calculation of the forecast levels of fuel and electricity consumption for the level of the country (TOP-level) is conducted according to formulas (1) – (3) by the forecast indicators of the energy-output ratio of the GVA of the country and volumes of GVA of the country. Compared to the GDP energy-output ratio in the GVA energy-output ratio of the country the consumption by the population is not considered. It is because the share of the population in the consumption of separate energy resources is different and affects the volumes of general consumption of the energy resource in a different way. So, in coal consumption, this share is equal to 1% from the volume of general consumption, and in the volumes of natural gas, it is equal to 30%.

$$e_{VVP}^{tl} = \frac{\sum E_{ij}^{tl} + E_{jd}^{tl}}{V_{VVP}^{tl}} \quad (4)$$

The forecast at the TOP-level may be also carried out according to the forecast indicators of the GDP energy-output ratio, which does not consider them in the forecast (numerator) the consumption by the population: Where the first and the second components of the numerator are calculated by formulas (1) and (3) respectively, denominator – GDP forecast for the country in the year.

The GVA compared to the GDP does not consider the taxes and subsidies, for which the energy resources are not spent; the calculations of the forecasts of upper and lower levels should be better carried out by the indicators of GVA and the GVA energy-output ratio at the relevant hierarchical level. The forecast of the need calculated at two levels is elaborated using the complex method. The situation, when the suggested approach cannot be applied is the agreement of the forecasts of the upper (country) and lower levels (kinds of economic activities) not considering the forecast of consumption by the population, which was earlier considered as an economic sector.

According to the methods, first of all, the forecasts of the energy resources at the TOP- and DOWN-levels of the normative-target methods are defined (formulas (1)–(4)). For each stage of the forecast period tl, the vector of the consumption indicators FER is formed at the corresponding forecast value of GDP and GVA:

$$F(t_l)=[F_T(t_l), F_{d1}(t_l), F_{d2}(t_l),\ldots, F_{dn-1}(t_l)] \quad (5)$$

where $F_T(t_l)$ – the forecast of energy consumption of TOP-level for the set GDP indicator at the stage $t=t_l$;

$F_{d1}(t_l)$ – forecast of energy consumption of *i*-sector (the kind of economic activities classified according to FEA) of DOWN-level for the set GVA indicator at the stage $t=t$; $i=1$, $n-1$.

After the formation of the vectors of the forecast values of the energy consumption for the chosen years, we define the sum of sectoral indicators – the forecast of fuel consumption or the consumption of energy according to all the FEA:

$$F_d(t_l) = \sum_{i=1}^{n-1} F_{di}(t_l) \quad (6)$$

And the difference between the obtained indicator of energy consumption at the level of the country and the sum of energy consumption in FEA is as follows:

$$R(t)=F_T(t_l)-F_d(t_l) \quad (7)$$

After this, the sectorial forecasts of energy consumption included to the inlet vector $F_{di}(t_l)$ from Equation (5), are aggregated through the unification of the economic activities' kinds to the enlarged sectors and we define their minimum quantity:

$$k(t_l) = \frac{F_d(t_l)}{F_{di}(t_l)_{\max}} \quad (8)$$

where, except for the values mentioned above, $F_{di}(t_l)_{\max}$ – is the largest by the value of energy consumption of *i*-kinds of economic activities.

Value $k(t_l)$ is usually non-integral. In further calculations, we use the integral part $[k(t_l)]$ and the excess:

$$\Delta n(t_l)=k(t_l)-[k(t_l)] \quad (9)$$

Using the coefficient (8), we define the minimum and maximum size of the sectors uniting the enlarged FEA, considering the following equation for the TOP-level:

$$n_{min}(t_l)=[k(t_l)]+1 \quad (10)$$

$$n_{max}(t_l)=n_{min}(t_l)+1 \quad (11)$$

The elaborated indicator ensuring the coincidence of the energy consumption indicators of TOP- and DOWN-levels is the following equation:

$$Y_t(t_l)=F_t(t_l)-S(n(t_l))R(t_l) \quad (12)$$

Where we use the constant $S(n(t_l))$, tabulated up to n=20, the value of which is provided, and value $R(t_l)$, calculated by the Equation (7).

Using the Equation (12), we calculate the elaborated indicators: $Y_t(t_l, n_{min}(t_l))$ and $Y_t(t_l, n_{max}(t_l))$, and then in case of non-integral values – the final value of the indicator of the TOP-level energy consumption:

$$Y_t(t_l)=Y_t(t_l, n_{min}(t_l))(1-\Delta n(t_l))+Y_t(t_l, n_{max}(t_l))\Delta n(t_l) \quad (13)$$

The values of all the indicators of energy the DOWN-level energy consumption are defined according to the following dependence:

$$Y_{di}=(t_1)=q(t_l)F_{di}(t_l) \quad (14)$$

Where coefficient $q(t_l)$ elaborating the value of the consumption levels according to FEA, is calculated by the following formula:

$$q(t_l)=\frac{Y_t(t_l)}{F_{di}(t_l)}, i=1, n-1 \quad (15)$$

Where $F_{di}(t_l)$ – forecast value of fuel or energy consumption in the period *tl*.

Separately we define the forecast for the fuel and electricity consumption for the population according to the following dependence:

$$P_j^{td}=(b_j^b-\Delta b_j^{tl})N^{tl}\pm E_j^{tl} \quad (16)$$

Where b_j^b – specific costs of *j*-kind of fuel or energy consumed by the population in the basic year;

$\varnothing b_j^{tl}$ – the decrease in the specific costs of *j*-kind fuel provided the energy saving measures are introduced to the households in year *tl*;

N^{tl} – forecasted number of population;

E_j^{tl} – volumes of possible replacement of *j*-kind of fuel or energy with the cheaper ones in the households in the forecasted year *tl*.

The approach we suggested combines the forecasting of the prices for the energy resources with the imitation of the suppliers' behavior (energy companies) and large consumers (electricity power plants, boiler plants, industry, transport, population) depending on the change in the prices for the energy resources and possible limitations on the supply of fuel and energy to the region (Daus et al., 2018). This model is selected by the experts of the Institution of Economics of the Siberian Branch of the Russian Academy of Sciences, where this model was applied to the development of the forecasted energy consumption in the Russian regions (Galperova et al., 2018). It is notable for its higher forecastability and the implementation in 87% of cases.

For the stage of elasticity fuel supply of the demand for fuel in the region, the task is formulated as follows: To define the most efficient variant of fuel supply for the satisfaction of the set demand for its production in the region in the expected conditions from the perspective of the considered group of consumers (power plants, boiler plants, transport, industrial plants etc.). The criterion is the minimal price of the produce for the consumer of fuel in the region provided that the prices are formed by the principle of self-sufficiency (self-financing). To solve this task, a complex has been developed consisting of the imitation model of forecasting the fuel and the set of the imitation stochastic statistical models for various groups of consumers. A peculiarity of the models included in the complex is the joint use of the method for optimization and Monte-Carlo technique. The first one is the selection of the rational structure of the consumers' fuel supply, while the second is for the consideration of the uncertainty of future conditions. Another specific peculiarity of the probability distribution model of these indicators inside an interval is the uncertainty assessed and set by the experts (even, normal, lognormal, indicator, etc.). The demand for this fuel of each consumer group is defined considering so-called "consumer effect" – the influence of kind and quality of fuel on its technical and economic indicators, as well as considering the possibilities of the change in the production technologies and the use of fuel, possible limitations on the supplies of different kinds of fuel to the region etc. The process of forecasting a prospective demand for fuel is organized as follows:

1. Based on the analysis and generalization of the existing Russian and foreign forecasts of social-economic development of the countries and regions, as well as the opportunities currently used and perspective processes and technologies in the production the initial indicators are formed for each consumer group in the region (forecast volumes of the products' consumption, the prices for various kinds of fuel, specific investments, specific costs of raw materials and fuel, operating modes of equipment, limitations to the supplies of various kinds of energy resources etc.) and the range borders and their possible values are defined. The experts assess the nature of distribution of the probability inside this range of uncertainty.
2. The result is the volumes of using the competing kinds of fuel by the group of consumers at different conditions of fuel supply in the region.
3. The comparison of the changes in the need for some kind of fuel at the change of it price allows obtaining the idea of the price elasticity of the demand for it on the part of this group of consumers.
4. The generalization of the calculation results provides an opportunity to define both the total volume of consumption of different kinds of fuel in the region in the supposed conditions

and to calculate the values of the regional coefficients of price elasticity of the demand for fuel based on the structure of their consumption.

4. RESULTS AND DISCUSSION

Using the elaborated methods for the calculation of the forecast levels of fuel and energy consumption, and the developed program of calculation, we carried out the forecasts of electricity consumption, consumption of natural gas and coal considering the energy preservation capacity the structural and technological shifts. The volumes of the estimated energy preservation capacity are considered in the calculation of the energy consumption forecast.

In the structure of electricity consumption, the great share is taken by the industrial sector (43-63%) with the trend towards the increase in the consumption for the period of 2001-2018 by 13%. The second by the volumes of electricity consumers is the population, the share of which over the state period has grown from 15.8% to 30.7%. The increase in the share of electricity is also peculiar for the group of the other FEA: From 7.5% to 17.7%; an insignificant decrease is observed for the transport: From 6.4% to 5.7%. The share of construction in the structure of electricity consumption remains almost unchangeable: 0.6%, while agriculture is vice versa characterized by the decrease in the share of electricity consumption from 3.1% to 2.8% from general consumption.

The calculation of electricity consumption at the level of the country is performed according to the methods described above: Formulas (1)-(4), forecast volumes of GDP and GVA together according to FEA for the period up to 2040, GVA energy capacity of the country by the basic year (2018) considering the energy preservation capacity. It is forecasted that for the period of 2018-2040 the gross consumption of electricity will grow almost 2.34 times, considering the energy preservation capacity from the structural shifts – almost 2.12 times, considering the structural and technological energy preservation – about 2 times, at the growth of the GDP in the prices of 2018 – 2.3 times (Table 1).

At the FEA level, the energy preservation capacity from the structural factor was calculated by the change in the structure during the forecast years. For each enlarged economic sector, we applied the above-described methods (1)-(4), which was the way of calculating the energy preservation capacity for each enlarged FEA. Energy preservation capacity by the kinds of economic activities was considered earlier. By the enlarged FEA, we summed up the calculations' results presented in Table 2.

Table 1: Current demand for the kinds of electricity in the republic of Kazakhstan in 2018 (international energy agency)

Indicator	2014	2015	2016	2017	2018
TOP-level by normative method (without population)	46379.14	49870.04	52494.78	55845.51	57572.69
DOWN-level by normative method (without population)	45458.08	49125.29	51970.68	55565.79	57572.18
TOP-level by complex method (without population)	44556.11	48392.52	51452.73	55288.45	57572.69
DOWN-level by complex method (without population), including by the FEA sections	43671.27	47669.83	50939.04	55011.52	57572.18
Agriculture	1739.478	1908.287	2049.405	2224.373	2339.61
Extracting industry	2185.627	2409.782	2600.99	2837.236	2999.22
Processing industry	22957.27	25438.93	27595.4	30253.14	32141.06
Supplies of electricity, gas, etc.	7446.482	8292.904	9041.104	9961.668	10636.5
Transport etc.	3269.629	3659.577	4009.8	4440.278	4764.9
Other FEA	3154.948	3548.963	3908.141	4349.453	4690.889
Consumption by population	16833.8	19031.3	21062.7	23558.92	25536
Gross consumption according to FEA and population – net	53699.24	61014.25	67866.24	76290.78	83108.69
Gross consumption according to FEA and population – gross	66699.35	76166.09	85145.38	96195.83	105319.2
Export	1572.074	1804.222	2027.059	2301.645	2532.6
Demand for electricity	65618.46	75686.77	85462.04	97526.42	107851.8

Table 2: Forecast of the demand for electricity in the republic of Kazakhstan by 2040 considering the structural and technological energy preservation and export, mln kW/tod

Indicator	2020	2025	2030	2035	2040
TOP-level by normative method (without population)	64208.33	77234.79	86805.78	102744.3	115535.3
DOWN-level by normative method (without population)	64548.24	74773.46	88079.47	104108.1	116584.6
TOP-level by complex method (without population)	64353.49	76211.56	87323.78	103293.9	115958.3
DOWN-level by complex method (without population), including by the FEA sections	64353.48	76211.56	87323.78	103293.9	115958.3
Agriculture	2679.425	3346.945	3992.919	4876.452	5553.912
Extracting industry	2834.419	3094.637	3452.064	3262.777	3547.467
Processing industry	34313.5	37783.81	40066.58	45986.07	51666.03
Supplies of electricity, gas, etc.	13399.34	17884.85	22270.41	27277.54	31226.69
Transport etc.	5681.998	7457.66	9488.906	11894.49	12600.88
Other FEA	5444.803	6643.644	8052.905	9996.567	11363.32
Consumption by population	24551.59	23567.25	22582.84	22524.95	22524.95
Gross consumption according to FEA and population – net	91009.31	102514.4	112852	128975.1	141850.2
Gross consumption according to FEA and population – gross	114671.7	128143.1	139936.5	158639.5	173057.3
Export	6300	8400	11200	12600	14000
Demand for electricity	120971.7	136543.1	151136.5	171239.5	187057.3

The results of calculation by the upper and lower levels have an insignificant distinction – up to 3%. Using the complex forecasting method of perspective demand for energy resources according to the developed mathematical program, we calculated the forecast levels of electricity consumption according to the formulas (5)-(15) provided a high degree of coincidence of the results obtained at different levels. Next, to the agreed variant we add the volumes of electricity consumption by the population for the period up to 2040 according to the forecasted number of population and the changes in the population's consumption at the implementation of the measures on energy preservation (the replacement of the existing household appliances with the modern energy efficient ones, the increase in their number and the share in the general electricity consumption, the performance of industrial works in the households, freelance). The obtained results (net consumption) were summed up by the levels of consumption according to FEA and population. The next step was the consideration of the losses of electricity for its transportation in the main power and international networks, in the distribution networks and for their own needs – is gross consumption, then the volumes of the electricity export are considered and thus the general demand for electricity is defined (Table 2).

According to the data of statistical observations, generally in the country in 2018, 34% of natural gas was spent for the transformation from the general consumption, 2.3% – for their own consumption by the energy sector, 9% – for the non-energetic use, 16.6% – final consumption, 35.6% – realized by the population, 1.95% – losses.

At the definition of the forecast conditions of natural gas consumption, we accepted the following structural changes in the economy: The increase in the share of GVA of the section in the GDP structure for agriculture by 1%, by 1.5% of the transport, by 4% of other FEA at the decrease in the share of industry by 4.5%, including the extracting one by 2.2%, processing industry – by 3.3%. Such changes in the structure may provide the saving in the consumption of natural gas equal to 2.2 bln m^3 in 2040. The calculation of the natural gas consumption at the level of the country was carried out by the methods described above, the forecast of the GDP and GVA volumes together with FEA for the period up to 2040, the country's GVA gas capacity by the basic year, considering the structural changes, the volumes of the technological preservation of natural gas in the country. The forecast for natural gas consumption up to 2040 at the level of the country is presented in Table 3.

Energy preservation capacity from structural factor is calculated according to the methods described above. The calculations of the technological energy preservation capacity were carried out by the enlarged kinds of economic activities (FEA). We forecast the decrease in the natural gas consumption in the sections according to FEA up to 6.3 bln m^3 in 2025 and a gradual increase in consumption up to 8.1 bln m^3 in 2040. Besides, we forecast the decrease in natural gas consumption by the population. Up to 2025, there will be the decrease in the consumption of gas due to the replacement of gas among the population with the other kinds of fuel, the mantling of more cost-saving boilers, heat insulation, conduction of other energy-saving measures; changes in the structure of industrial production; introduction of energy saving measures in the industry; replacement of natural gas in energetics and heat supply. After 2025, we forecast the increase in the volumes of gas consumption due to the increase in the volumes of industrial production. The increase in natural gas consumption by the population after 2025 is not forecasted. Particular measures in natural gas saving are described above. The forecasted levels of natural gas consumption by the kinds of economic activities are presented in Table 2.

The difference in the forecasts of the upper and lower levels is equal to 34%. These forecasts obligatory require the agreement by the mathematical methods. Using the complex method (formulas (5) – (15)), we brought to the agreement the forecasts of natural gas consumption by the upper and lower levels (Table 2), which shows a very high level of similarity. To the obtained agreed result we added the calculated by the formula (16) forecasted gas consumption by the population (30% from gas consumption in 2018), which was defined according to the demographic forecast, the indicator of gas consumption per capita as of 2018 and the calculated capacity of energy preservation, and the volumes of replacement of natural gas with electricity and other kinds of fuel. The results are presented in Table 2.

According to the statistical bulletins, "the use of energy materials and oil processing products 2018," the Republic of Kazakhstan consumed 15094.96 thousand tons of coal, including the losses equal to 1.3 thousand tons. The form of statistical accounting by the kinds of economic activities, according to which the bulletin

Table 3: Forecast of the demand for natural gas in the republic of Kazakhstan up to 2040 considering structural and technological energy preservation, mln m^3

Indicator	2020	2025	2030	2035	2040
TOP-level by normative method (without population)	15894.65	17762.1	20314.52	23328.24	25941.74
DOWN-level by normative method (without population)	15634.68	14820.65	14893.59	15743.35	17171.18
TOP-level by complex method (without population)	15789.12	16610.55	18189.85	20321.53	22451.32
DOWN-level by complex method (without population), including by the FEA sections	15789.11	16610.55	18189.85	20321.53	22451.31
Agriculture	270.963	365.113	480.081	605.528	679.882
Extracting industry	1366.33	1564.269	1765.575	1998.171	2157.106
Processing industry	5585.433	6379.051	7439.481	8594.026	9608.921
Supplies of electricity, gas, etc.	7198.03	6771.142	6723.367	7111.419	7889.588
Transport	766.472	728.49	720.93	661.15	572.11
Other FEA	601.86	802.48	1060.43	1351.21	1543.71
Consumption by population	6470.1	6001.8	5590.2	5490.8	5418.7
Demand for natural gas	22259.16	22612.38	23780.19	25812.29	27869.8

Table 4: Forecast of the demand for coal in the Republic of Kazakhstan by 2040 considering the structural and technological energy preservation, thousand tons

Indicator	2020	2025	2030	2035	2040
TOP-level by normative method (without population)	34432.51	39700.5	46320.19	54421.5	61131.07
DOWN-level by normative method (without population)	35131.5	31187.87	39855.41	47974.5	53343.64
TOP-level by complex method (without population)	31365.07	35968.47	43401.38	51482.99	57582.36
DOWN-level by complex method (without population), including by the FEA sections	31365.08	35968.48	43401.37	51482.99	57582.36
Agriculture	129.675	151.088	164.192	183.421	207.662
Extracting industry	549.185	513.359	488.026	351.225	323.022
Processing industry	13192.49	14289.18	14941.73	16888.09	19014.43
Supplies of electricity, gas, etc.	17202.92	20682.27	27433.18	33638.77	37593.73
Transport	26.551	33.845	41.79	51.45	56.091
Other FEA	264.25	298.732	332.465	370.048	387.429
Consumption by population	281.75	254.73	226.94	214.27	200.2
Demand for coal	31646.86	36223.18	43628.34	51697.24	57782.55

was composed provides the general value of the losses equal to 182.36 thousand tons, where 181.2 thousand tons are losses at the extraction and production in the extracting industry, and 1.3 thousand tons (considered in the bulletin) – losses at the transportation and distribution in the energy sector. According to the statistic form 2018, the total amount including all the losses by the directions was the consumption of 15276.2 thousand tons of coal, and together with the consumption of coal by the kinds of economic activities without losses and population is equal to 14933.6 thousand tons. The analysis of the coal use structure by the largest consumers in 2016-2018 showed that the largest coal consumers over the last 3 years are still the energy sector (50-60%) and processing industry (30-40%). In the structure of consumption of coal in 2018, by the enlarged kinds of economic activities and the directions of use, the share of the coal K was equal to 22.2%; while the transformation required 83% of coal: In the industrial TPP, CHP and boiler plants in the agriculture, in the boiler plants by the sections of extracting industry and other kinds of economic activities. In the processing industry, 99% of the coal by the volume spent for transformation (or 67% of the consumed), was used for carbonization, while the rest 32% of the consumed – spent in the industrial furnaces of metallurgy (79%) and cement industry (20.3%). The transportation sector 37% of the consumed coal used for the burning in the boiling plants, while 63% as the fuel in the consumption table "miscellaneous needs" according to the form of statistical accounting (Usenko et al., 2018). The population in 2018 consumed 161.4 thousand tons of coal (1% of the general consumption).

At the definition of the forecast levels of coal consumption, we used the GVA coal capacity indicator 2018, the GDP and GVA forecast up to 2040 and the energy preservation capacity from the structural and technological changes according to the one calculated earlier. We have defined the structural changes in the economy with the laid the increase in the share of the GVA in the GDP structure for agriculture by 1%, transport – by 1.5%, other FEA – by 4% at the decrease in the industrial share by 4,5%, including extracting industry by 2.2% and processing one – by 3.3%. Such changes in the structure may provide the saving in the consumption of coal equal to 10.4 mln tons in 2040. Based on the factual consumption of coal by the directions of use and the changes in consumption over the last 2 years, we defined the main economic directions and assessed their possible volumes up to 2040. The forecasted consumption of coal in the Republic of Kazakhstan at the TOP-level (country) by 2040 is provided in Table 4.

The calculation of forecasting the consumption of coal by the kinds of economic activities was conducted by the indicators of GVA coal capacity of the sections and enlarged sections in 2018 grouped by the largest consumers, GVA forecast by 2040 and estimated energy preservation capacity from the structural and technological changes. The calculation of the coal saving by separate measures with energy preservation in the economic sectors is presented earlier. The forecasted consumption of coal by the population is defined through the indicator of specific consumption of coal per capita in 2018, and the forecasted number of population and energy preservation capacity. Considering the above-described trends and based on the volumes of replacement of natural gas with coal in the industry, the energy sector, and household consumption, we forecasted the consumption of coal up to 2040 according to FEA and by the population.

The difference in the forecasts of the upper and lower levels is within 11-21%, which is connected with different methods for the calculation of the "upper" and "lower" levels. The agreement of the results requires the use of mathematical methods. According to the methods described above, using the complex method we carried out the agreement of the forecasts for coal obtained by the macroeconomic indicators for the country and the kinds of economic activities, grouped by the sectors. The similarity of the forecasts is very high. The forecasted consumption of coal by the population is added to the agreed forecast.

5. CONCLUSION

The paper elaborates the methodical approach to the definition of the forecasted demand for the fuel and electricity at the change of the concept of "final consumption of fuel and energy," which significantly corrects to the methods for calculation of the energy conservation potential from structural changes, namely the need of consideration of the forecasted structure of the energy and heat generating capacities, inner structure of the "transport" section and the forecasted demand for the energy resources with the allocation of the population as a separate consumption group with the other methods for energy consumption forecasting, which takes no part in the calculations at the national level (TOP-level) and the kinds of economic activities (DOWN-level) but is included to the final calculation of the forecasted demand after the agreement of the upper and lower levels.

The authors have developed the methods for forecasting of the fuel and electricity consumption levels based on the complex approach and the improvement of the methods for the forecasted levels of consumption based on the regulatory-targeted method different from the other approaches in the fact that at the national level the changes on the electricity and fuel consumption volumes during the economic digitalisation is studied not due to the changes in the GDP and FEA together, at the exclusion of the tax volumes on the products and the subsidies out of this calculation as not having their own consumption of energy resources, and the volumes of the fuel and electricity consumption by the population, which also does not create GVA. The upper level of energy consumption is calculated according to the indicator of the country's GVA energy capacity, while the lower one – by the total levels of fuel and electricity consumption according to FEA, each of which is defined by the GVA energy capacity indicators according to FEA.

In the future, the obtained result is verified with the use of the elaborated complex method of the forecasted demand, which differs by the fact that the agreement of the levels of consumption of the country and the kinds of economic activities is implemented without the volumes of the populations' energy consumption. The forecasted volumes of the population's consumption are defined separately considering the trends of the changes in the number and saturation of the households with new kinds of home appliances. At the final stage, the agreed complex method of the forecasted energy consumption's results is supplemented with the forecast of the national consumption, while the final results of the demand for electricity consider the forecasted export of electricity.

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