

## ARTICLE

# Assessment of the Methodology for Studying the Pricing Mechanism in the Transition Time of the Ukrainian Electricity Sector to the Free Market Principles

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### ARTICLE INFO

#### *Article history*

Received: 14 January 2019

Accepted: 25 January 2019

Published Online: 30 April 2019

#### *Keywords:*

Electricity market

Law

Pricing risks

Demand Side Management

Testing model.

### ABSTRACT

Electricity Market Act № 2019-VIII passed in 2017 by the Verkhovna Rada of Ukraine enacts in July 2019 and causes the transition of this segment of the economy to the free market principles. The implementation of this Act is perceived ambiguous. Many experts criticize this Act, which have numerous risks, especially pricing risks. In order to better understand the implications of the enactment of the adopted Act, a study was carried out on the methodology of the pricing mechanism in the retail segment of the electricity market based on the Demand Side Management (DSM) approach. In the study, one of the varieties of DSM models was used – a dynamic demand-supply model for describing the pricing mechanism and short-term forecast of retail prices. Test and comparative analysis were conducted. The last one based on possibilities of short-term forecasting of prices of DSM model with the well-known Holt-Winters method. For testing were set historical data on electricity prices in England and Wales, during the transition period from a model similar to the current model of the Ukrainian electricity market.

## 1. Introduction

The market transformations have begun in Ukraine since 1992. It had also an influence on the electricity sector of the economy - not only the basic industry of the national economy, but also an important element of the country's energy security. In particular, after a long preparatory work, the wholesale electricity market was created in 1997 by decree №487 of the Cabinet of Ministers of Ukraine. It was the first step towards the creation of the electricity market<sup>[1]</sup>.

However, after 1997, unfortunately, Ukraine has not created a true electricity market. Today, the Ukrainian

electricity market is monopolized and completely isolated from the EU. The lack of reforms has complicated over time such basic issues as the electricity infrastructure deterioration, which had not been upgraded due to lack of investment. It poses a threat to the energy balance providing in the short term. A comparative analysis shows that electricity prices in Ukraine are not economically feasible. It was generating negative consequences in other sectors of the economy through the production of energy-intensive products, which became non-competitive in foreign markets. This situation had developed historically, even before the introduction of market relations. Since Ukraine has inherited access to large stocks of cheap

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energy (gas, coal) and relatively cheap labour (the during electricity production), timely reforms have not been carried out. And as a result, the significant increase of energy prices and unfavourable foreign factors in the last decade put Ukraine's economy ahead of the serious problems decision. To resolve these problems, the Electricity Market Act № 2019-VIII was passed by the Parliament of Ukraine<sup>[2]</sup>. This Act determines the legal, economic and organizational principles of the electricity market functioning and regulates relations related to the production, transmission, distribution, sale and supply of electricity to consumers. The purposes of the implementation of this Law are the development of market relations and minimization of costs for the supply of electric energy and minimization of the negative impact on the environment, taking into account the interests of consumers. According to the Law, since his entry into force, a two-year transitional period is envisaged for developing of all segments of the new market. The Act was developed with the assistance of the European Energy Community, and its content received favorable comments from the EU, the USA and international anti-corruption organizations.

To implement this Act, it is necessary to develop more than 100 normative legal acts, as well as to establish a co-ordination centre for its implementation. Although at the moment, according to the Government, more than 60% of planned regulations have already been passed. This is not enough for the qualitative functioning of the Act. The expert opinions' spectrum about the expediency of this Law extends from a complete denial of its usefulness to restrained optimism. Some experts warn that entry into force of this Law may have negative consequence (Y.Usenko<sup>[3]</sup>, B.A. Kostiukovskii<sup>[4]</sup>). Opponents of the energy market reform also argue that the new model will not produce the desired result in a low-competitive environment, since the price of electricity can be artificially overstated because of the conspiracy of producers, or because of the so-called "concerted actions" or the abuse of production that covers peak load, because the price of electricity can be artificially overpriced, because of the "conspiracy" of the producers, the so-called "concerted actions", or the abuse of generation that covers the peak load. Indeed, today's realities are not the best for full competition, because almost 54% of the whole market is the state-owned Energoatom, more than 6% is Ukrhydroenergo and up to 25% is the manoeuvrable heat generation of DTEK's private business. Today, there are reasons to think that the decisions of the NCREPU allow receiving large profits for DTEK, while the companies, almost 75%, remain underfeed.

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market is the most controversial. In a situation where 92% of electricity is generated by the five largest producers, it is easy to predict that prices for households will almost be guaranteed to increase<sup>[5]</sup>.

That is, the very issue of pricing in the new electricity market is the most controversial. In a situation where 92% of electricity is generated by the five largest producers, it is easy to predict that prices for households will almost be guaranteed to increase<sup>[5]</sup>. These conditions allow for key players to manipulate with prices, since the cost of electricity for the end-consumer depends not only on the tariffs of individual producers, but also on the concerted actions of market players. However, in case of low solvency from the Ukrainian households' side who already suffer from a significant increase in natural gas prices, new burden can upset the social tension limit, especially given that the budget does not have the resources for additional subsidies for the population. At the same time, until today, nobody from authority has unveiled the forecast, how the tariffs for population will change after the transition to market pricing. In our opinion, this is due to the fact that at moment the authorities do not have in hands the correct instrument – a model or methodology, which could more or less accurately estimate volume of electricity needed for whole country and with which price the electricity will be sold on the Electricity Market.

Pricing in a free electricity market is a major problem during the Act implementation. It should be noted that a large attention is paying by scientists for the problems of pricing in Ukraine power sector. However, the radical change of the rules written in new Act has led to the fact that this experience can not help in solving problems that have arisen in this context. Indeed, for many years, researchers have carefully established rules of electricity pricing based on the paradigm of various costs for the production, transmission and supply of electricity to end consumers. So the Institute of General Energy of the National Academy of Sciences of Ukraine were investigating the problems of particular features of the cost indicators calculation in the problems of particular features of the cost indicators calculation in the problems of forecasting the development of power systems in market conditions in recent years<sup>[6]</sup>; choice of simulation methods<sup>[7]</sup>; or optimization<sup>[8]</sup>, equilibrium<sup>[9]</sup> models. The study of O.Bohoslovsk<sup>[10]</sup> has a slightly different direction. She was examining the thermal power stations (TPPs) pricing policy, which stemmed from their TPPs relationship with SE The study of O.Bohoslovsk<sup>[10]</sup> has a slightly different direction. She was examining the thermal power stations (TPPs) pricing policy, which stemmed from their TPPs relationship with SE "Energorynok" in the conditions of

functioning of the wholesale electricity market. One of the first attempts at a pricing study on a new electricity market was an article of Y. Kutsan<sup>[11]</sup>. In this paper a new cost structure was established, that will affect the price for end-consumers, new data sets for calculating electricity tariffs was identified, but pricing issues in terms of demand/proposal in this paper has not been investigated in the conditions of functioning of the wholesale electricity market.

Instead, pricing issues in the electricity markets of the EU, the USA, Canada and many developing countries have become widespread. The reason is clear: the electricity supply system of these countries was transferred to market conditions. In all these countries were problems with implementing the market principles in the electricity sector. And in all of them the problem of pricing was always on the first place. In this article a whole count of all researchers who have contributed to this topic can not be listed. However, the literature analysis<sup>[12]-[17]</sup> shows the peculiarity of these publications, which relate to the first period of the introduction of the electricity market in different countries: the imbalance problems of market relations in not regulated electricity market. This imbalance bases on the next fact: energy generating companies as a supply side in the wholesale sector trying to maximize the profit from electricity sales by raising of prices, and consumers as a demand side were not adequately able to minimize their costs due to lack of alternatives.

Later authors' publications, in particular<sup>[18-20]</sup>, relate to the results of research into problems of already more developed electricity markets. In these markets, deep structural transformations have already taken place, to which the Ukrainian electricity market is not ready yet.

Therefore, we will consider more urgent issues, namely, the estimation of the of consumption volumes in the conditions of pricing in the free electricity market of Ukraine.

## 2. Methodology

Some solutions and instruments are proposed to avoid significant market power from the supply side. These instruments are classified in three different categories<sup>[21]</sup>:

- (1) demand-side management program (DSM)
- (2) Placement of purchases
- (3) Trading strategy

As the experience of developed electricity markets shows, only after the application of these strategies has been able to normalize needs of all market agents. Using DSM programs, demand sides have been able to change load profiles to maximize their profits, reduce the risk of

buying from one manufacturer by diversifying their sources, and create an optimal bid strategy for higher returns.

One of the early demand strategies was to adjust the level of consumption accordingly to price levels, which led to extensive discussion called "Demand Management" (DSM) on the electricity markets. In most cases, the concept of DSM implies the relationship between supply and demand, which leads to mutual benefit. In this paper, we will use the DSM methodology, which proved its effectiveness in the existing electricity markets. To build a consumption estimation model, the kind of DSM known as the dynamic supply-demand model is applied<sup>[22]</sup>.

Next we make some assumptions for the Ukrainian electricity market:

(1) All electricity for consumption is produced by Ukrainian producers

(2) All produced electricity is consumed by Ukrainian consumers

(3) Most of the electricity generation is the base level that should always be produced respectively the perspective of daily consumption. The smaller part, which is mainly produced by small power units, is designed for maneuvering power.

(4) The demand function is inelastic, so we approximate it with the exponential dependence of the supply. The price with such dependence on a certain initial interval will be practically unchanged to a certain minimum declared power.

(5) Above the power - the price will increase sharply on those production volumes, which are already regulated.

(6) The demand function on the electricity market will be considered linear<sup>[23]</sup>.

Based on the dynamic supply-demand model, the overall dependence of demand and consumption looks like:

$$S_t(q; E_t, \theta), D_t(q; E_t, \theta). \quad (1)$$

Where  $E_t$  represents the indicators of the exogenous process at time  $t$ ;  $\theta$  – vector of parameters.  $S_t(q; E_t, \theta)$  – the only offer price for quantity  $q$  at time  $t$ .  $D_t(q; E_t, \theta)$  – the price of demand that consumers are willing to pay for the quantity  $q$  at time  $t$ .

Of course, demand and supply curves are not directly observed. However, the volume of sales and prices are always known. That is way,  $S_t(\cdot; \cdot)$  and  $D_t(\cdot; \cdot)$  are taken, representing paired realization of hidden random processes, which result into equilibrium volumes of electricity purchasing, denoted by  $Q_t$ , which are considered to be equilibrium points:

$$Q_t = \{q : S_t(q; E_t, \theta) = D_t(q; E_t, \theta)\} \quad (2)$$

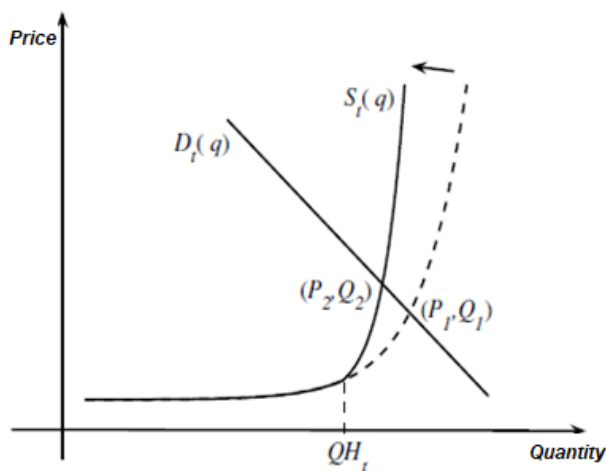
This is a certain idealization that postulates that demand and supply curves are deterministic functions of certain unknown parameters  $\theta$ , as well as exogenous explanatory variables  $E_t$ . Moreover, the observed prices and consumption values are the intersection of these curves.

Dynamic supply-demand model — a dynamic model of demand and supply for the simultaneous accounting of electricity prices and time series of consumption. This model is based on the economic postulate that the price and quantity in a competitive market can be determined every day/month as a crossroads of the demand and supply curves. The model takes into account the influence of various factors, including temperature, seasonal dependence, fuel availability and other factors affecting demand and supply curves. It also allows an internal random variation of curves over time. Since the model is non-linear and non-Gaussian, and demand and supply curves are not directly observed, traditional methodologies for parameter estimation and forecasting are not suitable here.

The connection between actual prices and temperatures is approximately quadratic, as reflected in the model. Another motive for demand is the seasonal component  $SE_t$ , which takes into account the number of weekdays and holidays during the period.

Prices of natural resources also affect production: their growth leads to an increase of production costs, and therefore to a decrease in supply (Figure.1 on which it is seen that the supply curve turns to the left and the equilibrium point moves from  $(P_1, Q_1)$  to  $(P_2, Q_2)$ , showing that production is falling and the price is increasing).

The point  $QH_t$  on the figure 1 shows an energy, which was received from all types of fuel except gas and coal. Above this threshold, the amount of electricity is calculated by adding the production capacity of power plants running in particular on uranium.



**Figure 1.** Changes in the supply curve due to changes in production.

The fact that this aspect is taken into account in this model is quite important, since it is known that a large part of electricity in Ukraine is produced from NPP capacities, and (as can be seen from the figure), and can not participate in the formation of market offers of type “day-ahead”, because it is the necessary minimum, which should be continuously produced, in terms of continuous supply of electricity. Another, manoeuvrable share of electricity generation is provided by the capacity using coal and natural gas. But due to the sharp increase of natural gas price, it is now almost not involved into the generating process.

Let  $CP_t$  – be the price of coal at time  $t$ . In order to take into account the shifts in the supply curve due to the presence of coal and the cost coefficients, the expression  $(q - QH_t) * CP_t$  is introduced into the model into the supply function  $S_t(\cdot; \cdot)$ .

Other changes in production occur when one or more thermal power plants stop for one reason or another. Then the total generation is reduced and the supply curve shifts to the left, because it will be necessary to cover the costs in connection with the repair and restart in the next period. This factor is taken into account by adding to the supply function an expression that represents electricity generation one to three months before the current time  $\sum_{e-30(60,90) \leq \tau \leq t} GQ_\tau$ .

The final equations of supply and demand, including the components mentioned, have the form:

$$S_t(q) = \alpha_{0,t} * \exp(\alpha_{1,t} * q + \alpha_{2,t} * (q - QH_t) * CP_t + \alpha_{3,t} * \sum_{e-30(60,90) \leq \tau \leq t} GQ_\tau) \quad (3)$$

$$D_t(q) = \beta_{0,t} + \beta_{1,t} * (T_t - 19)^2 + \beta_{2,t} * q + \beta_{3,t} SE_t + R_t \quad (4)$$

where

$\alpha_{j,t}$  and  $\beta_{j,t}$  – coefficients to be evaluated;

$QH_t$  – shows the total volume of electricity production by power stations that are not capable of sharp maneuvering;

$CP_t$  – the price of coal;

$GQ_t$  – total amount of electricity produced from natural coal;

$T_t$  – daily maximum temperature of the environment;

$SE_t$  – indicators of seasonality day to day.

The process  $\{R_t, t = 1, 2, \dots, T\}$  – autoregression of the first order, which satisfies

$$R_{t+1} = \phi_t * R_t + e_{t+1}^R \quad (5)$$

where  $\{e_{t+1}^R\}$  – independent and identically distributed sequence of randomly distributed values with mathematical expectation 0 and dispersion  $\sigma_R^2$ .

This process allows consistently correlate the random



variation of the demand curve around its average.

Parameters in the resulting model are combined into a vector:

$$\theta_t = (\alpha_{0,t}, \alpha_{1,t}, \alpha_{2,t}, \alpha_{3,t}, \beta_{0,t}, \beta_{1,t}, \beta_{2,t}, \beta_{3,t}, \phi_t)^T$$

As the supply curve is increasing, let's put on constraints:

$$\alpha_0 > 0 \text{ and } \alpha_1 > 0$$

Also, the parameters  $\alpha_2, \alpha_3$  must be positive to ensure the transition to the left side.

Since the demand curve is downward, the restrictions  $\beta_2 < 0$  are imposed. In addition, to ensure that an increase in temperature leads to an increase in consumption, it is required  $\beta_1 > 0$ . Also, for stationary autonomous regression the restriction is imposed  $|\phi| < 1$ .

Model condition at every moment of time  $t$  includes the value of the autoregressive process  $R_t$  and vector parameters  $\theta_t$ . In order to take into account, the limitations of the parameters and depending on the time, the state transition equation is used:

$$\begin{bmatrix} R_t \\ \log(\alpha_{0,t}) \\ \log(\alpha_{1,t}) \\ \log(\alpha_{2,t}) \\ \log(\alpha_{3,t}) \\ \beta_{0,t} \\ \log(\beta_{1,t}) \\ \log(-\beta_{2,t}) \\ \beta_{3,t} \\ f(\phi_t) \end{bmatrix} = \begin{bmatrix} \phi_{t-1} R_{t-1} \\ \log(\alpha_{0,t-1}) \\ \log(\alpha_{1,t-1}) \\ \log(\alpha_{2,t-1}) \\ \log(\alpha_{3,t-1}) \\ \beta_{0,t-1} \\ \log(\beta_{1,t-1}) \\ \log(-\beta_{2,t-1}) \\ \beta_{3,t-1} \\ f(\phi_{t-1}) \end{bmatrix} + \begin{bmatrix} e_t^R \\ u_{0,t} \\ u_{1,t} \\ u_{2,t} \\ u_{3,t} \\ u_{4,t} \\ u_{5,t} \\ u_{6,t} \\ u_{7,t} \\ u_{8,t} \end{bmatrix} \quad (6)$$

where  $u_{i,t} \approx N(0, \xi_i^2)$   $i = 0, \dots, 8$  is an independent

Gaussian process of white noise and  $f(x) = \log\left(\frac{1-x}{1+x}\right)$ . Log conversion and function  $f$  are used to ensure that the parameters are within acceptable ranges.

### 3. Results

Now it is necessary to estimate how the new market rules will affect the volumes of electricity consumption. However, there is a problem of choosing data to obtain such an estimate. Since such a market is not yet operational, we must use the methodological approach known as the twin method. That is, it is necessary to take the data of the

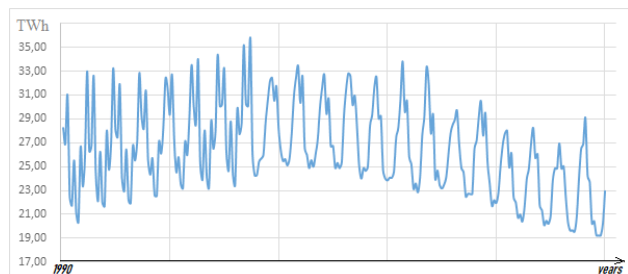
initial period of that market, which is as close as possible to the energy market of Ukraine. The market for England and Wales appears to us as such. The energy market of Ukraine is chosen as the prototype of the energy market of England and Wales for the following reasons:

- (1) The volumes of annual electricity generation coincide in order of magnitude;
- (2) The current model of the energy market in Ukraine is based on the single pool British model, that was 20 years ago;
- (3) In modern England and Wales exists an electricity market, the rules of which must be introduced in Ukraine;
- (4) Great Britain, as an island state, does not export or import electricity;
- (5) Ukraine, being a continental state, also practically does not export and import because infrastructure and foreign policy;
- (6) As in Ukraine, demand fluctuations in England and Wales are covered by shunting capacities of coal-fired power plants.

To calculate how consumption can change, when the Low comes into legal force, we use the above described model. But we still need to find an estimate of the values of the coefficients  $\alpha_{j,t}$  and  $\beta_{j,t}$  or the equations that would correspond to the realities of the transition process.

The coefficients  $\alpha_{j,t}$  and  $\beta_{j,t}$  found in this way obviously "contain" information that would characterize such a transient process.

As the input data, we will accordingly choose consumption volumes, electricity prices, coal prices in England and Wales in the first years after the transition to a free market model<sup>[24]</sup>. After moving to the UK rules of the free market, in the first years the consumption of electricity was rather volatile (Figure 2.), that can be explained by the fact that only in a few years the market participants have developed a constant behaviour in the free market conditions. The same can be expected in Ukraine.



**Figure 2.** Dynamics of change in electricity production (in TWh) in the UK after the transition to the principles of a free electricity market, 1990-2000

To identify the parameters  $\alpha_{j,t}$  and  $\beta_{j,t}$  gradient method of minimizing the sum of squares of deviations is

applied the next procedure:

A. for each period  $t$  we will assume that the price of supply and demand is like that was actually and is equilibrium. The output  $q$  is like that satisfies this equilibrium price.

B. choosing the sample data from the WEB-site of the UK Government<sup>[27]</sup>.

C. we enter formulas (3) and (4), pre-assigning data to arrays,

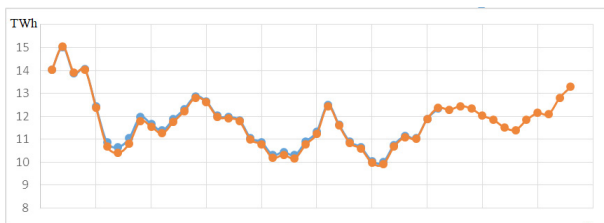
As a calculating tool, the function Minerr ( $x_1, \dots, x_M$ ) of well known mathematical package MathCAD was used.

For the identification of coefficients, data from zero periods were used, on the basis of which the following values of the coefficients were found:

**Table 1.** Coefficients for the 0th period of the matrix  $\theta_t$

| $\alpha_0$ | $\alpha_1$ | $\alpha_2$ | $\alpha_3$ | $\beta_0$ | $\beta_1$ | $\beta_2$ | $\beta_3$ | $\varphi$ |
|------------|------------|------------|------------|-----------|-----------|-----------|-----------|-----------|
| 3.62000    | 0.00007    | 0.00012    | 0.00003    | 350.30100 | 0.07300   | -0.00972  | 6.18000   | 0.7824    |

Source: own development

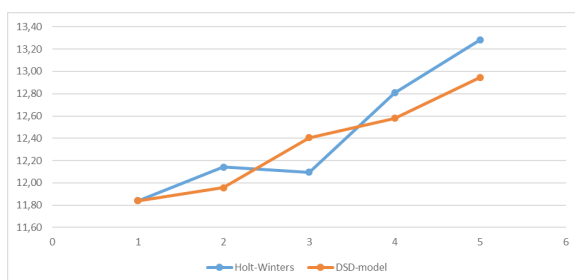


**Figure 3.** Forecasting by the Holt-Winters method, electricity in Twh\*h

Using the coefficients of the model (1) - (4) found above (table 1), we will find consumption volumes and compare them with the data obtained by the Holt-Winters method<sup>[24]-[26]</sup>.

**Table 2.** Simulated consumption volumes for July-November 2019, Twh\*h

| Month, 2019  | Jul.  | Aug.  | Sep.  | Oct.  | Nov.  |
|--------------|-------|-------|-------|-------|-------|
| Holt-Winters | 11.84 | 12.14 | 12.09 | 12.81 | 13.28 |
| DSD-model    | 11.84 | 11.96 | 12.41 | 12.58 | 12.95 |



**Figure 4.** Comparison of the results found

In table 2 and Figure 4 present the results of calculating

the conditional volumes for the first 5 months from the entry into force of the Law on Electricity in the Ukrainian market, calculated in accordance with the dynamic model of demand and supply and the method Holt-Winters.

## 4. Discussion

The results of this study show that the introduction of free market rules in the Ukrainian electricity sector requires thoughtful steps due to the existence of significant risks. One of the most serious risks on the first stage of the electricity market privatization is a significant uncontrolled increase in electricity prices, which may result in non-payment, falling volumes, and blackouts of electricity supply. To reduce such risks, a model is needed to assess the consequences of the decisions taken, as well as to manage demand in the future. Testing dynamic supply-demand model has shown its ability to assess the behaviour of prices in the electricity market of Ukraine. Of course, data using of the prices of one market for using them on another can not give 100% precision for prediction. However, the task is not a precise forecasting, but the behaviour assessment of prices and production volumes in the new conditions. And for this purpose the indicated model is quite suitable. These calculation results show that the model is quite easy to adjust for prices data in other electricity markets, in particular for the data of the future Ukrainian electricity market. The probability of predictive power of the dynamic supply-demand model is confirmed by the independent forecasting method — the Winters-Holt method. However, if the Winters-Holt method is intended only for prediction, then the dynamic supply-demand model is designed not only for forecasting but also for demand management. We have reason to assert that this model could be useful in preparing regulations for the implementation of the Electricity Market Act.

## 5. Conclusion

Based of the study, it can be concluded that the complex problems of implementing the laws of the free market in Ukraine in accordance with the adopted Electricity Market Act require well thought out steps for its realization. First of all, this concerns the problem of pricing, since, as the experience of other countries shows, such market transformations can lead to excessive price increases for consumers. One of the tools for implementation could be a model based on the methodology of Demand Side Management. In this paper, the suitability of the DSM model for short-term forecasting of prices and electricity consumption was tested. Even more interesting is the possibility of using this methodology to influence the behaviour of the consumer in order to reduce losses. However, solving these problems requires further research.

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