International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2021, 11(6), 27-34.

Modelling of Prognosis for Bioenergy Production in Ukraine

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Received: 14 June 2021 **Accepted:** 28 August 2021 **DOI:** https://doi.org/10.32479/ijeep.11741

ABSTRACT

Promoting renewables, in particular bioenergy, is vital to move Ukraine towards a low-carbon economy. Decision-makers might turn to bioenergy projections for developing their policies or investments. This paper presents statistical calculations and economic-mathematical modeling of the state of the bioenergy sector in Ukraine. Using Spearman's rank correlation coefficient, correlations between different factors influencing biofuel production were investigated. Modeling of the forecast of biofuel production was done with the use of a multiple regression equation, which provides for the creation of a standard linear model. It enables predicting future development of renewable energy and bioenergy, highlighting and choosing the most appropriate factors to be stimulated by the government in order to achieve the goals of renewable energy development and energy security as a result.

Keywords: Bioenergy, Renewables, Energy Security, Energy Strategy
JEL Classifications: Q42, Q38, O13, P28

1. INTRODUCTION

Due to the limited fossil energy sources, the necessity of energy security for Ukraine, sustainable biomass production is an obvious solution to a number of issues. Leading countries are actively developing bioenergy and other renewable energy resources, according to the 7th Sustainable Development Goal ("Ensure access to affordable, reliable, sustainable and modern energy for all"), by 2030 it is planned to significantly increase the share of energy from renewable sources in the world energy balance (United Nations General Assembly, 2015). SDG 7 is a strategic reference point for the development of the energy sector in the world.

A lot of research attempts to seek ways for implementing this goal, as well as to predict future development of renewable energy and bioenergy in particular (Salerno et al., 2017; Panukhnyk et al., 2021; Pruntseva et al., 2021; Was et al., 2020, Yakubiv et al., 2019; Yakymchuk et al., 2021). Xingang and Pingkuo (2014) noted the fact that bioenergy is one of the most effective ways of achieving a country's energy security. Matsumoto and Shiraki (2018) evaluated energy security performance in Japan under alternative scenarios of future socioeconomic and energy conditions by using three energy security indicators.

In order to find out which factors play the most important role in the bioenergy sector in Ukraine and what exactly should be stimulated, we conducted statistical calculations and economic-mathematical modeling.

The research aims to analyze the correlations between the production of bioenergy and different factors and to construct a model for forecasting bioenergy future production. It will help to highlight the factors to be stimulated by government in order to achieve the goals of renewable energy development and energy security as a result. To determine correlations between bioenergy production and selected factors, the following hypothesis was formulated: The level of bioenergy production is dependent on the certain factors of economic, energy, ecological sphere. Stimulating these factors by the government will boost the growth of the sector.

2. METHODS

2.1. Bioenergy Production: Basic Dimensions for Research

In order to study the dynamics and further forecast the potential of bioenergy production, we performed a correlation analysis of the main indicators that affect the sector. We included the following factors: biofuel and waste production, total primary energy supply, coal and peat production, coal and peat import and export, crude oil production and import, oil products import, natural gas production and import, nuclear energy production, hydroelectric power generation, production of wind and solar energy, share of natural gas imports. Also we took into account the official hryvnia exchange rate against the dollar, "feed-in" tariffs, the price of electricity and natural gas for the population, the price of natural gas for businesses, the price of Brent oil, subsidies for liquefied gas, solid and liquid household fuel, base tax on profit and the base rate of the Single Contribution for Compulsory State Social Insurance. All the mentioned factors affecting bioenergy production were calculated for the last 12 years.

Statistical analysis was performed using the Python 3.7.7 software environment and open source libraries (modules) for scientific calculations: numpy 1.18.1, pandas 1.0.3, statsmodels 0.11.0 and graphical display of the results: matplotlib 3.1.3, seaborn 0.10.1.

At the initial stage of the study, a correlation analysis was made, where the dependent variable (Y) is "Biofuel and waste production", all other 25 variables are independent (X_1 +,… X_{25}).

Due to the fact that the data set includes only 12 observations (in all variables one observation for each of the 12 years), the distribution of such data in the variables may deviate from normal. Therefore, in order to identify the relationships between the dependent and independent variable, we calculated the Spearman correlation coefficients (ρ).

The next stage of the study was to create a model for the indicator "Biofuel and waste production," which is a dependent variable (Y), while all the other 25 variables are independent (X). To create the model, the method of multiple linear regression was used, which involved deriving an equation of the type:

$$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + \ldots\ldots + a_nX_n,$$

Where a_0, a_1, a_2., an - parameters of the multiple regression equation; X_1, X_2, X_3., X_n - factor features.

3. RESULTS AND DISCUSION

3.1. The Main Indicators of the Bioenergy Sector and Their Effects on the Bioenergy Production

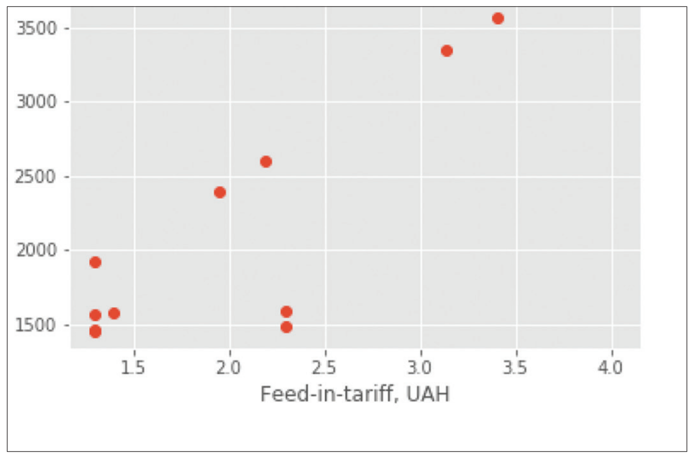
3.1.1. Correlation analysis of indicators

Applying the Spearman rank correlation coefficient for the main indicators of the bioenergy sector of Ukraine, a positive correlation was found (ρ = 0.752, P = 0.005) between the indicators of biofuel production and the rate of the "feed-in" tariff (Figure 1). The "feed-in" tariff is one of the most effective mechanisms to stimulate the development of the biofuel market and, accordingly, significantly impacts its production.

Meanwhile, the rate of the "feed-in" tariff for electricity from biogas and biomass (0.12 Euro/kWh) is among the lowest in European countries (Figure 2). Therefore, we think that it should be increased for this type of energy.

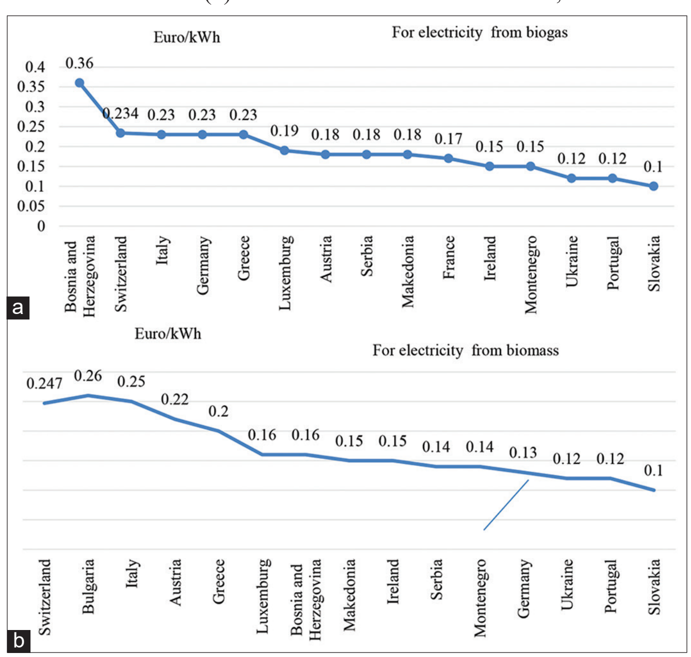
The detected correlation between the biofuel production and the electricity price for population (ρ = 0.910, p = 0.00004) and the natural gas price for companies (ρ = 0.867, p = 0.0002) shows the presence of positive relationships: the growth of biofuel production is observed at the growth of prices for electricity and natural gas (Figure 3). It is also worth mentioning that the natural

Figure 1: Scatter plot of biofuel production indicators and the "feed-in" tariff



Source: The authors' calculations

Figure 2: The rate of the "feed-in" tariff for electricity from biogas (a) and biomass (b) in some countries and in Ukraine, 2019

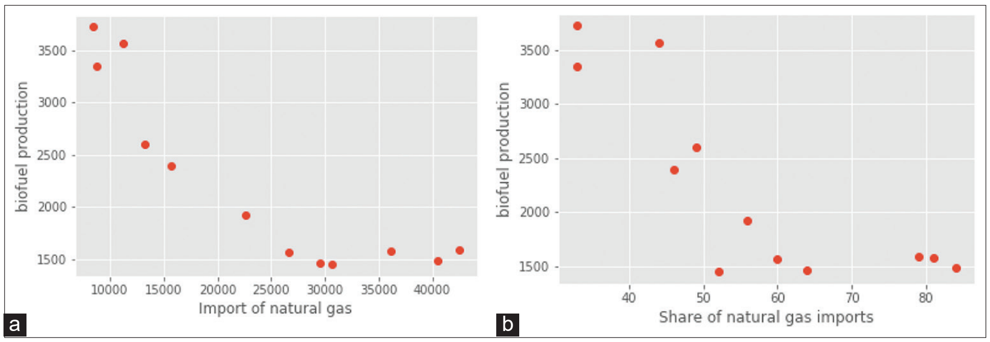


Source: based on the data from (Legal sources on renewable energy, 2021)

Figure 3: Scatter plot of biofuel production indicators and electricity price for the population (a) and natural gas price for enterprises (b)

Source: the authors' calculations

Figure 4: Scatter plot of biofuel production indicators and natural gas import (a) and the share of natural gas import in TPES (b)



Source: The authors' calculations

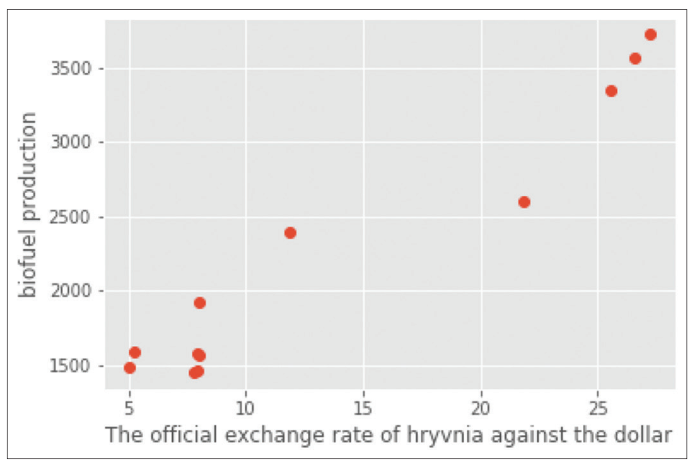
gas prices for enterprises are set according to the cost of alternative fuel in some European countries (like France, Italy, Belgium). In Ukraine, natural gas prices have been unreasonably understated for a long time. The tariffs were increased under the Memorandum on Economic and Financial Policy signed on 27 February 2015. In general, the gas tariffs increase for all categories of consumers amounted on average to 285% (Markevych and Omelchenko, 2016).

Meanwhile, the weighted average tariff for electricity for the population in Ukraine amounts to UAH 1.03 per 1 kWh, and the same average tariff in the EU countries is € 0.20, which is almost 6 times higher. It is obvious that the increase of electricity tariffs is inevitable and will make biofuel use more cost-efficient.

The detected reverse correlation analysis between natural gas import ($\rho = -0.811$, $P = 0.001$), natural gas import share ($\rho = -0.757$, $P = 0.004$) and biofuel production indicators shows the trend of growing biofuel and waste production and falling import of fuel resources (Figure 4). Energy security of Ukraine is among the strategic priorities of the country. Meanwhile, it substantially depends on the reliability of natural gas supply. Reduction of blue-dyed fuel import dependence is among the most important tasks faced by the bioenergy sector.

Substantial direct correlation ($\rho = 0.879$, $P = 0.00016$) was detected between biofuel production and dollar rate (Figure 5). The dependence is explained by the fact that the hryvnya rate against foreign currency generates the country's expenditures on imported energy products, which are not enough to meet the economy's needs.

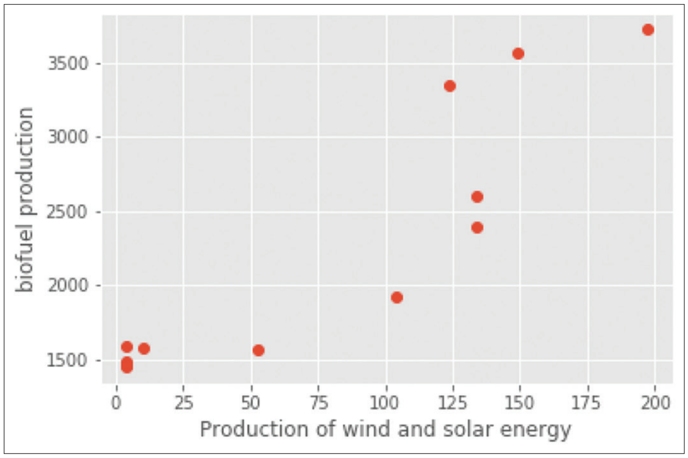
Figure 5: Scatter plot of biofuel production indicators and hryvnya rate against dollar



Source: the authors' calculations

There is a statistically significant relationship between the indicators of biofuel production and wind and solar energy production ($\rho = 0.909$, $P = 0.00004$) (Figure 6). In particular, Figure 6 shows that there is a similar dynamics of growth in renewable energy parameters with the trend towards biofuel production growth. It can be caused by the relevance of transition to sustainable energy resources, efficient stimulating measures, and the demand for them.

Figure 6: Scatter plot of the indicators of biofuel production, thous. toe and wind and solar energy production, thous. toe



Source: The authors' calculations

Meanwhile, Figure 7 shows that the total capacity of RES facilities mainly consists of solar and wind energy that are rapidly evolving. Considering the available biofuel capacity, a similar development can be expected in the sector if the necessary stimulating mechanisms are elaborated and implemented.

All the results of calculations are given in Table 1. As P > 0.05 for coal and peat exports, natural gas production, nuclear energy production, Brent oil price and the base rate of the Single Contribution rate, the obtained correlations are not statistically significant and were not taken into account.

3.1.2. Bioenergy production model

For the application of the second research method, the data for analysis were taken for the 2005-2018 period. It included 14 observations. Yet, considering the fact that the rate of produced bioenergy has been growing considerably since 2006, we assume that the rate of the parameter in 2005-2006 could have been caused by the trends of emerging sector or inefficient statistical data collection in the 1st years of the rates recording by the state. Therefore, the rates for 2005-2006 could have been caused by different trends than in the following period, so they can affect the accuracy of the prognosis in the model constructed based on more recent data. Hence, observations for 2005-2006 were excluded from the analysis.

Therefore, the statistical data for analysis was taken for the 2007-2018 period, so the model includes 12 observations. The absent statistics (NaN) in certain variables were replaced by average rates of the respective variable.

It is obvious that there are interdependent parameters among 25 factors impacting the industry development. Due to the multicollinearity problem, the regression models can turn out to be unsuitable for quality economic and reliable prognosis. Therefore, we calculated the univariate (simple) regression models for each variable with subsequent inclusion of other models with the largest R^2 until R^2 grows in the multiple model and predictor variables have the statistically significant p-value. First, the R^2 coefficients were calculated for a simple linear regression alternatively for all predictor variables (Table 2). The received R^2 were ranged in ascending order and the model with the highest R^2 was selected.

Table 1: Spearman coefficient and probability values for main factors impacting the development of the bioenergy sector

Parameters	Spearman coefficient (ρ)	Sig. (2-tailed) P
Biofuel and waste production	1.000	-
Total primary energy supply	−0.755**	0.005
Total production	−0.643*	0.024
Coal and peat production	−0.643*	0.024
Coal and peat import	0.916**	0.00002
Coal and peat export	−0.545	0.067
Crude oil production	−0.874**	0.0002
Crude oil import	−0.741**	0.006
Oil products import	0.846**	0.001
Natural gas production	−0.161	0.618
Natural gas import	−0.811**	0.001
Nuclear energy production	−0.420	0.175
Hydroelectricity production	−0.594*	0.042
Wind and solar energy production	0.909**	0.00004
Share of natural gas import	−0.757**	0.004
Official hryvnya rate against dollar	0.879**	0.00016
"Feed-in" tariff	0.752**	0.005
Electricity price for the population	0.910**	0.00004
Natural gas price for the population	0.809**	0.001
Electricity price for enterprises	0.867**	0.0002
Brent oil price (annual average)	−0.3986	0.1993
Subsidies, number of households	0.594*	0.042
Subsidies, mln UAH	0.811**	0.0013
Basic income tax rate	−0.894**	0.00008
Basic single contribution rate	−0.335	0.2867

Source: The authors' calculations

Table 2: Coefficients of determination of models with one predictor variable

Variables	Factors influencing the development of bioenergy sector	Coefficient of determination R^2
X_1	Natural gas production	0.00987
X_1	Hydroelectricity production	0.295975
X_1	Nuclear energy production	0.314746
X_1	Brent oil price (annual average)	0.323167
X_1	Crude oil import	0.46566
X_1	Coal and peat export	0.598383
X_1	Basic single contribution rate, %	0.608156
X_1	Share of natural gas import, %	0.655817
X_1	Basic income tax rate, %	0.669047
X_1	"Feed-in" tariff, €	0.673243
X_1	Import of oil products	0.702043
X_1	Subsidies (number of households)	0.708585
X_1	Coal and peat import	0.734971
X_1	Natural gas import	0.779457
X_1	"Feed-in" tariff, UAH	0.779602
X_1	Total primary energy supply	0.781226
X_1	Crude oil production	0.781827
X_1	Total production	0.81273
X_1	Production of coal and peat	0.817794
X_1	Production of wind and solar energy	0.821504
X_1	Natural gas price for the population	0.838954
X_1	Subsidies (total)	0.839493
X_1	Electricity price for the population	0.924996
X_1	Official hryvnya rate against dollar	0.936332
X_1	Natural gas price for enterprises	0.940015

Source: The authors' calculations

In this case, the model looks like:

$$Y = a_0 + a_1X_1,$$

Where X_1 - predicative changes from Table 2.

Next, R^2 was calculated for models with two variables, one of which is "Natural gas price for enterprises," as this variable received the best indicator in the calculation of single models (Table 3). The model looks like:

$$Y = a_0 + a_1X_1, + a_2X_2$$

Where X_1 - variable "Natural gas price for enterprises"
X_2 - predicative variables from Table 3.

Table 3: Coefficients of determination of models with two predictor variables

Variables	Factors influencing the development of bioenergy sector	Coefficient of determination R^2
X_2	Share of natural gas import, %	0.940017
X_2	Wind and solar energy production	0.940021
X_2	Oil products import	0.940027
X_2	Total primary energy supply	0.940822
X_2	Basic income tax rate, %	0.940939
X_2	Natural gas import	0.941098
X_2	Hydroelectricity production	0.941547
X_2	Total production	0.94185
X_2	Crude oil production	0.942668
X_2	Coal and peat production	0.943232
X_2	Crude oil import	0.944278
X_2	Coal and peat import	0.944827
X_2	Natural gas price for the population	0.945379
X_2	Nuclear energy production	0.946278
X_2	Natural gas production	0.946433
X_2	Brent oil price (annual average)	0.94876
X_2	Coal and peat export	0.952458
X_2	Official hryvnya rate against dollar	0.955012
X_2	"Feed-in" tariff, €	0.958676
X_2	Subsidies (number of households)	0.969871
X_2	"Feed-in" tariff, UAH	0.972917
X_2	Subsidies (total)	0.973078
X_2	Electricity price for the population	0.973791
X_2	Basic single contribution rate, %	0.976241

Source: The authors' calculations

Next, a variable was selected and included in the model, which when included in the multiple regression model together with the above selected variables, determines the largest R^2.

The model looked like:

$$Y = a_0 + a_1X_1, + a_2X_2 + a_3X_3$$

Where X_1 - variable "Natural gas price for enterprises"
X_2 - variable "Basic single contribution rate"
X_3 - predicative variables from Table 4.

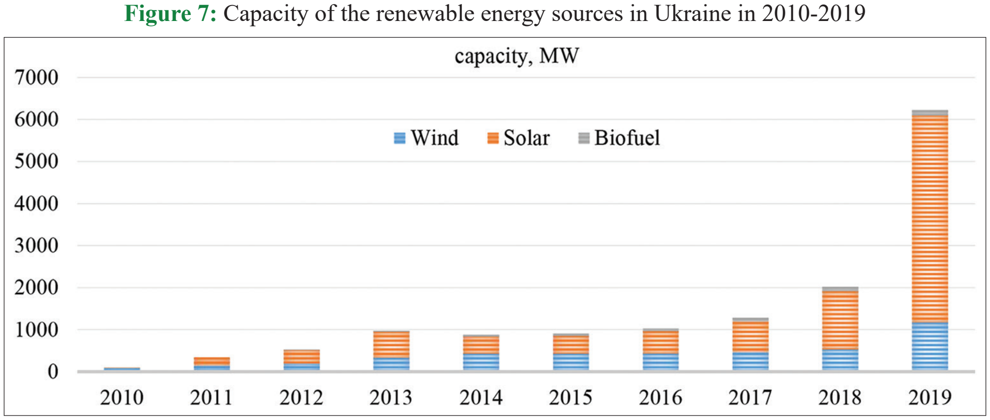
Next, a variable was selected and included in the model, which stipulates the largest R^2 if included in multiple regression along with the abovementioned variables, etc. The final model is the following:

Table 4: Coefficients of determination of models with three predictor variables

Variables	Factors influencing the development of bioenergy sector	Coefficient of determination R^2
X_3	Brent oil price (annual average)	0.976253
X_3	Coal and peat export	0.976327
X_3	Oil products import	0.976337
X_3	Official hryvnya rate against dollar	0.976341
X_3	Share of natural gas import, %	0.976356
X_3	Natural gas production	0.976473
X_3	Natural gas price for the population	0.976502
X_3	Coal and peat production	0.976526
X_3	Total production	0.97667
X_3	Natural gas import	0.976696
X_3	Crude oil production	0.976713
X_3	Nuclear energy production	0.976817
X_3	Hydroelectricity production	0.976864
X_3	Electricity price for the population	0.976927
X_3	Total primary energy supply	0.97713
X_3	Subsidies (total)	0.978418
X_3	Coal and peat import	0.978588
X_3	"Feed-in" tariff, €	0.978864
X_3	"Feed-in" tariff, UAH	0.979704
X_3	Subsidies (number of households)	0.979807
X_3	Crude oil import	0.981432
X_3	Wind and solar energy production	0.98661
X_3	Basic income tax rate, %	0.988974

Source: The authors' calculations

Figure 7: Capacity of the renewable energy sources in Ukraine in 2010-2019



Source: based on the information from (State Agency on Energy Efficiency and Energy Saving of Ukraine, 2021)

$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4$

Where X_1 – variable "Natural gas price for enterprises"
X_2 – variable "Basic single contribution rate"
X_3 – variable "Basic income tax rate"
X_4 – predictor variables from Table 5.

Predictor variables have the statistically insignificant P-value ($P > 0.05$) in the model with five and more of them. So they were not included in the analysis. Therefore, the model with R^2 close to 1 and with 4 predictor variables was calculated.

The key statistical parameters of multiple regression are in Table 6.

Table 5: Coefficients of determination of the models with four predictor variables

Variables	Factors influencing the development of bioenergy sector	Coefficient of determination R^2
X_4	Total primary energy supply	0.988978
X_4	Natural gas production	0.988992
X_4	Official hryvnya rate against dollar	0.989066
X_4	Electricity price for the population	0.989074
X_4	Brent oil price (annual average)	0.989365
X_4	Coal and peat import	0.9894
X_4	Oil products import	0.989432
X_4	Natural gas price for the population	0.98964
X_4	Nuclear energy production	0.98969
X_4	Wind and solar energy production	0.989775
X_4	Total production	0.989974
X_4	Hydroelectricity production	0.990134
X_4	Subsidies (total)	0.9903
X_4	Subsidies (number of households)	0.990833
X_4	Crude oil import	0.991118
X_4	Coal and peat production	0.991148
X_4	Crude oil production	0.991649
X_4	Coal and peat export	0.991726
X_4	Share of natural gas import, %	0.991827
X_4	Natural gas import	0.992108
X_4	"Feed-in" tariff, €	0.992976
X_4	"Feed-in" tariff, UAH	0.994954

Source: The authors' calculations

Table 6: Statistical parameters of multiple regression

Parameter	Value
Coefficient of determination (R^2)	0.995
Adjusted R^2	0.992
F-test	345.1
P-value	4.09e-08
Omnibus	10.338
Kurtosis	4.467
Durbin-Watson	2.391
Cond. No.	1.14e+03

Source: The authors' calculations

The statistical analysis shows that the coefficient of determination is very high (0.995), i.e. the model describes 99.5% of the variation of the dependent variable. The significance of the multiple regression equation, in general, is estimated based on F-test, which confirms the significance level. The obtained multiple regression parameters show both the relationship between the variables under research and the fact that they are quite accurately described by the final equation.

Table 7 shows that $P < 0.05$ in all the equation coefficients, which confirms their statistical significance.

Therefore, the final equation of the relationship between biofuel production and other factors is the following:

$y = 4359.0797 + 78.4946*x_1 - 36.4406*x_2 - 84.7952*x_3 + 185.0419*x_4$

Where x_1 – Natural gas price for enterprises;
x_2 – Basic single contribution rate;
x_3 – Basic income tax rate;
x_4 – "Feed-in" tariff.

The correlation/regression analysis of the data in the energy industry shows the relationship between the parameters and contributes to predicting the value of the dependent variable *y* ("Biofuel production"). The results testify to the statistical significance of the developed model.

Meanwhile, it is worth mentioning that the regression equation has a rather significant (against other variables) y-intercept. In our opinion, it can indicate that additional factors were not taken into account. Their research can require additional examinations.

3.1.3. Bioenergy production forecast

Prognosis is the next research stage. The 2035 Energy Strategy of Ukraine outlines the national goals regarding the share of biomass, biofuel, and waste in TPES. In 2035, the share should amount to 11 mln. toe or 11.5% of TPES. In our calculations, we focus on "production", while the Strategy concentrates on "supply." Export outside Ukraine constitutes the gap between these parameters. Arguably, these resources should be attracted to be used on the domestic market of Ukraine in full on condition of creating favorable conditions.

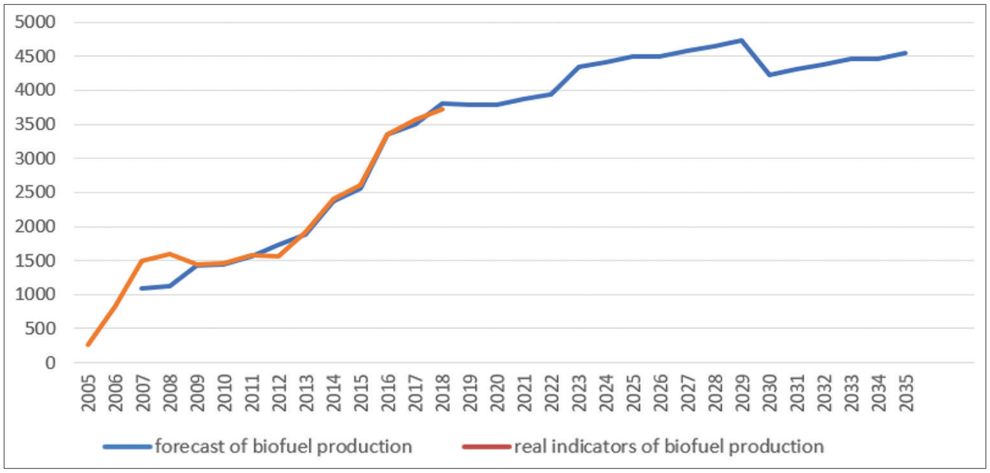
The constructed models help to predict the development of bioenergy in the future taking into account the change of main components and monitor whether the Strategy goals will be achieved. Predicting the growth in natural gas prices for enterprises, which can objectively be predicted considering the

Table 7: Results of the regression analysis of the factors' impact

Factor	Equation coefficient	Standard deviation	t	P-value	CI, lower 95%	CI, upper 95%
Y-intercept, a_0	4359.0797	654.658	6.659	0.000	2811.059	5907.101
Natural gas price for enterprises	78.4946	19.807	3.963	0.005	31.658	125.331
Basic single contribution rate	−36.4406	7.913	−4.605	0.002	−55.153	−17.728
Basic income tax rate	−84.7952	18.436	−4.600	0.002	−128.388	−41.202
"Feed-in" tariff, UAH	185.0419	64.244	2.880	0.024	33.128	336.955

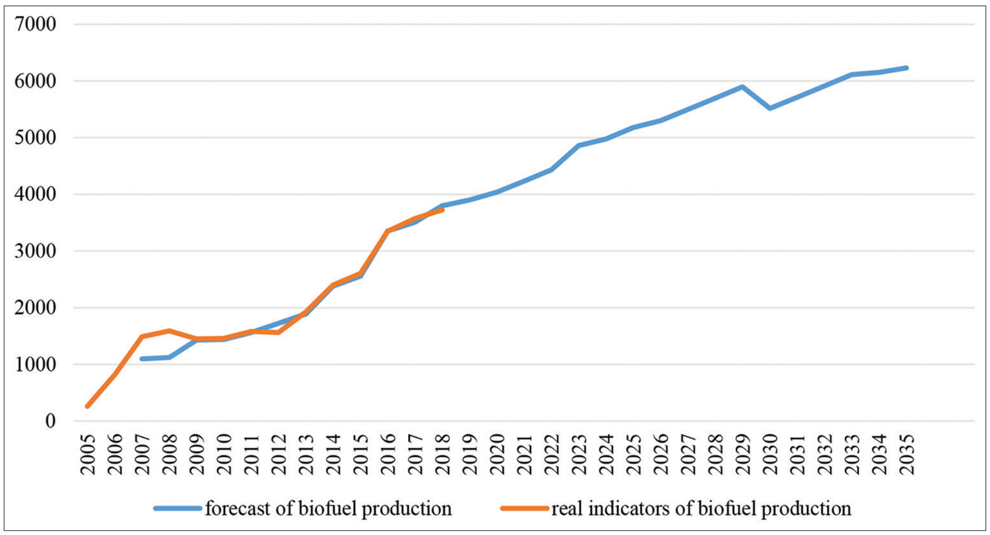
Source: The authors' calculations

Figure 8: Biofuel production prognosis till 2035 under Scenario I



Source: the authors' calculations.

Figure 9: Biofuel production prognosis till 2035 under Scenario II



Source: The authors' calculations.

industry's import dependency and market preconditions, and the decline in the size of the "feed-in" tariff, we get the result of 4,500,000 toe in 2035 (Scenario I). According to the scenario, the tax rates remain unchanged (Figure 8). The rate we get is twice lower than the one provided by the Strategy.

The second scenario stipulates the gradual tax reduction for agricultural enterprises-biofuel producers. The factor's impact is related in the first place to the fact that social contributions constitute a significant proportion in the structure of the biofuel cost, so the single contribution rate reduced to optimal level will stimulate the biofuel production. It also impacts the reduction of the corporate income tax base. Having tried various options, we settled upon the single social contribution rate of 8% and income tax rate of 7%, which are reasonable to recommend as amendments to the Tax Code of Ukraine. The Strategy also provides the gradual growth of prices for natural gas for enterprises with an achievement of 30 UAH per cubic meter in 2035. The "feed-in" tariff is established only till 2030. At these rates, the largest biofuel production growth was achieved. The results of prognosis under Scenario II (Figure 9) show that the biofuel production in 2035 will be at the level of 6,200,000 toe, which is also substantially lower than the expected rate.

4. CONCLUSION

Based on statistical methods, the condition of bioenergy sector is analyzed. The Spearman rank correlation coefficient is the ground for examining the correlation relationship between various factors impacting the biofuel production. The modeling of biofuel production prognosis is carried out using the multiple regression equation, which stipulates the development of the standard linear model.

In the model, R^2 is close to 1, which confirms the statistical reliability of received results. The obtained multiple regression parameters show both the relationship between the variables under research and the fact that they are quite accurately described by the final equation. Meanwhile, it is worth mentioning that the regression equation has a rather significant y-intercept, which can indicate that additional factors were not taken into account.

The developed model helps to define the priority directions to increase biofuel production. According to the multiple correlation/regression model, biofuel production grows at the growing gas price for enterprises and "feed-in" tariff rate. Meanwhile, a lower tax burden positively impacts the development of priority industry for national security.

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