STRATEGY MAP OF ENERGY EFFICIENCY IN INDUSTRY OF THE REGION BASED ON A SYSTEM-DYNAMIC MODEL

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Abstract

This paper is devoted to the problem of energy efficiency for Kharkiv region of Ukraine. This problem is to actual for the Ukraine economy and for its regions, which energy intensity levels are more than twice below than world-average rate of this indicator. For solving problem of low energy efficiency of industrial developed Kharkiv region, the authors propose to develop energy efficiency strategy map and balanced scorecard. The rates of target indicators were determined by using system-dynamic modeling. Energy efficiency scenarios of Kharkiv industry were divided on two groups: scenarios of extensive industry development (passive group) and innovation activity scenarios (active group).

Key words: *Energy Efficiency, Strategy Map, System-dynamic Model.*

JEL Classification: C 53; Q 40; R 11;
Preliminary communications
Received: September 27, 2011

1. Introduction

For a long period of time increasing amount of individual and social needs depletes the natural reserves of energy resources and, at the same time, energy consumption causes negative impact to the environment. The current period of economic growth in the world associated with deficit of the traditional non-renewable energy resources and a high degree of environmental pollution. These two circumstances became the main reasons for the attention of the international community to the problem of energy efficiency (Beravs 2001, Jebaraj 2007, Elek 2010, Michna 2010).

Traditionally there are two directions to overcome energy deficit in the economic system: diversification of energy sources (sources of supply, mining and types of energy resources) and reducing energy demand through efficient energy use. But these two directions to cover the deficit of energy resources are antagonistic for providing the energy needs of society: satisfied energy needs through the opening new energy sources reduce the volume of energy saving. In addition, these directions have different effects on economic growth. The threat of energy deficit, with its sharpest form - energy crisis, is a permanent driving factor of economic development. On the opinion of Russian scientist in the questions of long-term economic cycles S. Glazyev (2009), namely the energy crisis, an expression which is a rapid increase of fuel and energy prices, is causing economy transition to a new technological way of life by the removal of problematic issues of the energy deficit of traditional resources by increasing their efficiency.

Another reason for the urgency of energy efficiency is the need to minimize adverse effects on the environment, including human health, from the energy use that is possible in two ways: firstly, by reducing the consumption of energy resources (energy-efficient direction), and secondly, by raising the technological level of energy consumption and installation of equipment to capture harmful products of combustion (environmental direction).

Based on the above, energy efficiency for Ukraine can be declared as a key component of economic development and environment protection (Gnedoy 2003, Prakhovnik 2010, Bondarchuk 2008, Bachinsky 2012).

Study of energy efficiency requires a clear understanding of essence of this term. The authors of this article suggest understanding energy efficiency as a property of an economic system, which is connected with the possibility of extracting the most useful (minimally harmful) result from the energy resources use under conditions of scarcity of different types of resources.

Problem of energy efficiency pays special different organizations such as the United Nations (UN), World Bank Group (WBG), International Energy Agency (IEA), World Energy Council (WEC), Center for Energy Efficient Use in Russia (CEnEf), Administration Of Energy Information in USA (AEI) Government Committee Of Energy Efficiency and Energy Conservation in Ukraine (GCEEEC).

The object of this article is investigation of specific features of developing of energy efficiency strategy map for regional industry.

2. Strategy Map of Energy Efficiency for Regional Industry

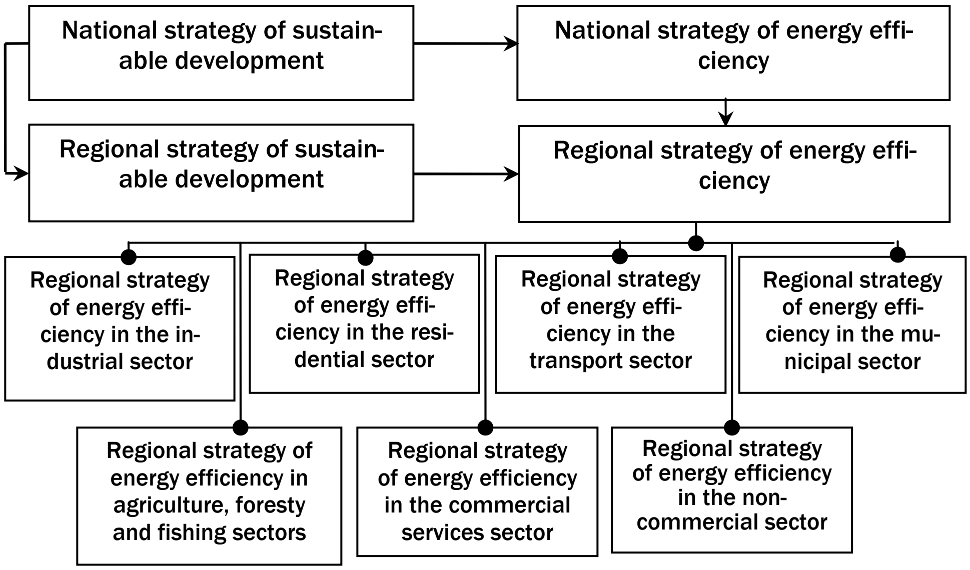
The strategy map as a tool of forming strategy was proposed by D. P. Norton and R. S. Kaplan. It allows describing the logic of the strategy, which is developing, and explain how integrated and combined goals of individual components are united in the unified strategy (2005). Existing experience of developing strategy map evidences of their orientation to the level of individual enterprises, but, as considered, practical value of the proposed by Norton and Kaplan (2005) approach is not limited only on the micro level. Therefore the authors of this article propose to use strategy maps during developing strategy of large-scale economic system (for national or regional economy, and also for all industry or by type of economic activity).

It should be noted a dual subordination of regional energy efficiency strategy to the principles of sustainable development: according to which, on the one hand, regional strategy of energy efficiency is a part of national energy efficiency strategy and, on the other hand, is a part of regional strategy of sustainable development - both of which, in turn, are the components of a national strategy of sustainable development (Figure 1).

Energy efficiency strategy should be developed by sectors of economy (energy consumer groups). In this article, the authors offer to use strategy map in the process of formation energy efficiency strategy in the industry of Kharkov region (Ukraine).

The classic version of a strategy map provides for its developing in four strategy perspectives: finance, relationships with customers, internal processes, training and development (Norton and Kaplan, 2005), but the practical value of the proposed by Norton and Kaplan (2005) approach led to the development of scientific opinions about the diversity of the components (perspectives).

Figure 1: Subordination regional strategy of energy efficiency to the national strategy of sustainable development



Source: Authors' proposition

On the opinion of leading Ukrainian scientists, such as N. Kizim, A. Pilipenko and V. Zinchenko (2007), in the process of developing a strategy map is possible to consider any variations for its perspectives. Since energy efficiency is a component of sustainable development, energy efficiency strategy should cover all components of sustainable development (economic, social, environmental), but functional cut at the level of industry in the region puts on the fore the economic component of sustainable development (reducing energy intensity of production), the environmental component of the energy efficiency is a function from economic, while the social component is solved using the other components of the regional strategy of energy efficiency (in municipal and residential sectors).

At the same time, the economic component of energy efficiency, an expression which in this case is the level of energy intensity of industrial production in the region, depends on the efficiency of other factors of production and efficiency of industry in the region in general. Thus, the current study is proposed to develop a strategy map of energy efficiency taking into account the following strategy perspectives: economic and environmental - as components of sustainable development, and strategy perspectives of internal processes, - as reflecting the efficiency of economic activities, and development perspective - which reflects the possibilities of industry development in the region towards improving energy efficiency.

The method of factor analysis allows us to identify 13 indicators of the strategy map of energy efficiency, which were divided on selected strategy perspectives as follows (Table 1). It is necessary to stay on such indicators as investment per unit of energy consumption. In the earlier work (N. Afanasiev and T. Salashenko, 2011) the authors proved that the indicator investment per unit of energy consumption is a local indicator of efficiency, that reflects energy efficiency of investments. This indicator can be determined by dividing investments to energy consumption. The proposed indicator should be considered a classic indicator according to the resource approach (Rayazkas, 1983) as it comprises the results (attracted investments) and energy consumption (resources). Thus, the ratio of investments energy efficiency (investment per unit of energy consumption) characterizes the orientation of the system on update and upgrades the technical and technological base in the direction of reducing energy consumption.

Table 1: Indicators of industrial efficiency in the region, describing the achievements of local energy efficiency objectives of strategy map

Strategy perspective of energy efficiency	*Local strategy goal of energy efficiency in the industrial sector of the region*	*Efficiency indicator*	*Abbr.*
Economic component	To minimize the energy intensity of industrial production in the region	Energy intensity of products	ER_Y
		Fuel intensity of products	F_Y
		Electricity intensity of products	EI_Y
		Hot power intensity of products	HP_Y
Component of internal processes	To increase the production factors efficiency of industry in the region	Labour productivity	Y_L
		Capital intensity of production	MK_Y
	To increase the efficiency of industry in the region	Profitability of production	P_Y
		Costs per unit of output	C_Y
Environmental component	To reduce emissions of harmful substances into the atmosphere from energy consumption of industry in the region	Carbon dioxide emissions per unit of energy consumption	CO_2^{ER}
		Sulfur oxides emissions per unit of energy consumption	SO_X^{ER}
		Nitrogen oxide emissions per unit of energy consumption	NO_X^{ER}
Component of development	To increase the investment activity in the industrial sector of the region	Investment per unit of energy	K_{ER}
		Investment intensity of production	K_Y

Source: Authors' proposition

At the top of the strategy map is a general goal. However, in the contemporary economic conditions the uncertainty and instability are the permanent factors of development. Under such circumstances, as indicated in work (Kizim, 2010), the strategy based on the one version of forecasting is considered risky for the possibility of implementation, and leads to the falsity of representations about the future because there is not one but there are multiple of such versions. Therefore, forming strategy of different objects is often carried out using a scenario approach to forecasting, which involves the developing of several scenarios according to the quantitative values of the target indicators.

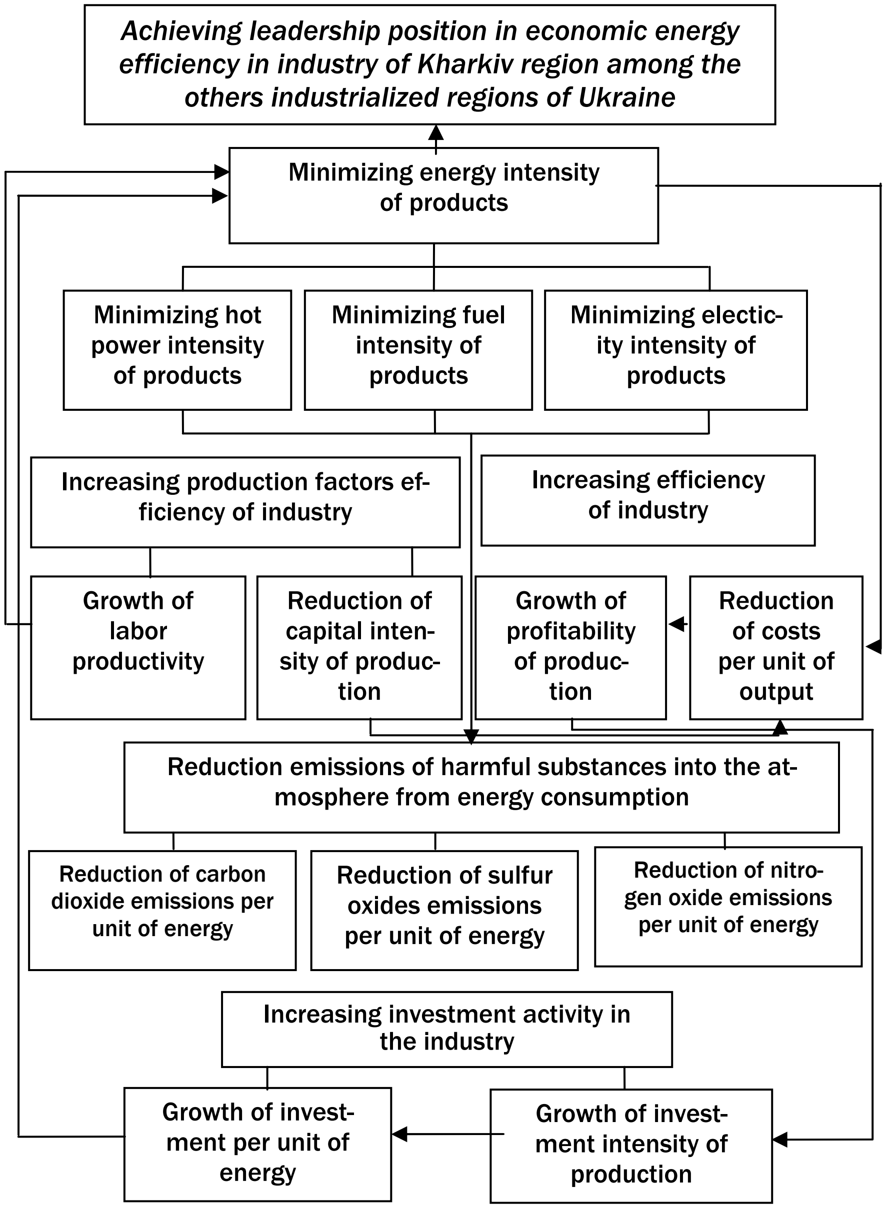
Investigation of economic and mathematical relationships between selected indicators that will be described below, allowed establishing causal relationships. The visual representation of strategy map of energy efficiency in industry of Kharkiv region is shown in Figure 2.

Given the above conditions, the general goal of energy efficiency for the industry of Kharkov region should be presented in the following alternatives:

- Optimistic variant – achieving in the industrial sector of Kharkiv region the contemporary world level of economic energy efficiency (reduction of energy intensity by 40 %);
- Most likely variant - achieving leadership position in economic energy efficiency in industry of Kharkiv region among the others industrialized regions of Ukraine (reducing energy intensity by 30 %);

- Pessimistic variant - achieving in the industrial sector of Kharkiv region the average level of economic efficiency in Ukraine (reducing energy intensity of production by 20%).

Figure 2: Strategy map of industrial energy efficiency in the region



Source: Authors' researches

3. Description of System-Dynamic Model for Forecasting Energy Efficiency of Regional Industry

Developing a strategy map includes setting quantitative values for the strategy goals – target indicators that can be received using different methods of forecasting. It is considered that forecasting of energy efficiency in industry of the region should be conducted using two paths of industrial development of the region - two groups of scenarios: passive and active.

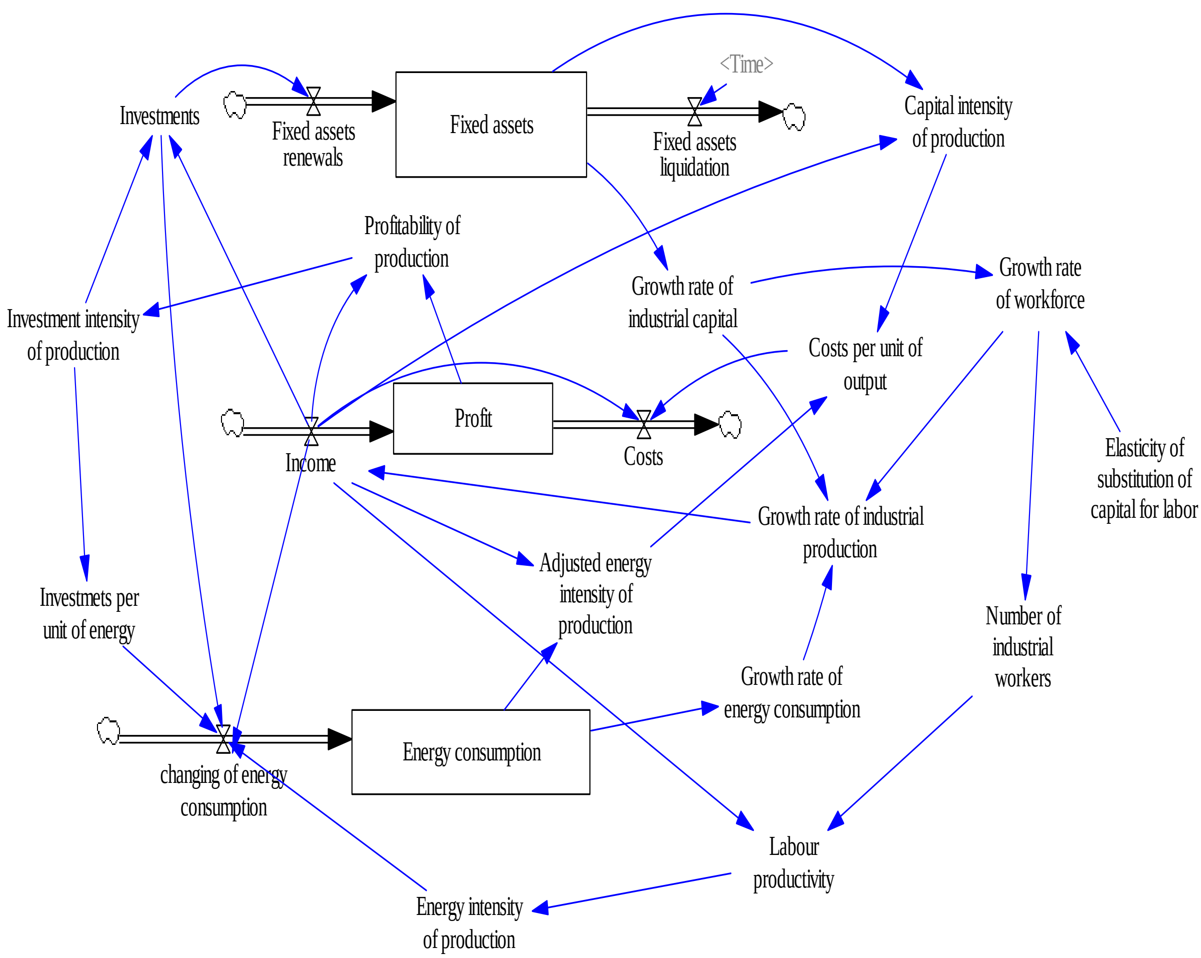
The passive scenarios group is scenarios of extensive industry development in the region, i.e. changes in energy efficiency would occur due to extended reproduction, which allows modernizing the industry. Active scenarios group is innovative scenarios, i.e. crucial role for improving energy efficiency in the region will have a managerial vector of innovation activity under conditions of sustainable development. The innovative scenarios assume intensive development of industry in the region.

Solving the problem of developing scenarios for energy efficiency in industry of the region should be based on the system-dynamic model. This method was proposed by Jay W. Forrester and proved its ability to reproduce the processes of functioning of complex social and economic systems (Kizim, 2010, Aleksandrov, 2010).

3.1 Passive Scenarios Group of Energy Efficiency in the Regional Industry

Developing of passive scenarios of regional industry was carried out using target indicators of strategy map without vector of managerial impact. Formalization of system-dynamic model was implemented in the software environment Vensim PLE (Figure 3).

Figure 3: The system-dynamic model of energy efficiency in industry of the region (extensive way)



Source: Authors' model

Functional dependencies between flows and variables in the system-dynamic model of energy efficiency in regional industry are shown in Table. 2.

Table 2: Functional dependences of flows and variables of the simulation model

Flow or variable of the simulation model	*Functional dependence*	R^2
Volume of industrial production/income (Y), 10^6 UAH	$Y_t = Y_0 \times \frac{Y_t}{Y_0}$	-
Financial result of operational activity/profit (P), 10^6 UAH	$P_t = P_{t,t-1} + \Delta t\,(Y-C)$	-
Operational costs (C), 10^6 UAH	$C = C_Y \times Y$	-
Profitability of production (P_Y)	$P_Y = P/Y$	-
Renewal of fixed assets (N), 10^6 UAH	N=Func(K)	0,9236
Fixed assets (MK), 10^6 UAH	$MK_t = MK_{t,\,t-1} + \Delta t\,(N-U)$	-
Liquidation of fixed assets (U), 10^6 UAH	U=Func(t)	0,8913
Capital intensity of production (MK_Y), UAH/UAH	$MK_Y = MK/Y$	-
Growth rate of fixed assets (MK/MK_0)	MK_t/MK_0	-
Growth rate of the workforce (L/L_0)	$L_t/L_0 = MK_t/MK_0 \times Els$	-
Elasticity of substitution of capital for labor (Els)	Els=const=0,176	-
Investment intensity of production (K_Y), UAH/UAH	$K_Y = 0{,}1028 \times e^{10,29 P_Y}$	0,7004
Investment per unit of energy (K_{ER}), thousand UAH/ t c.e.	$K_{ER} = 6{,}3849 \times K_Y^{1,4766}$	0,9850
Number of industrial workers (L), thousand people	$L = L_0 \times \frac{L}{L_0}$	-
Labor productivity (Y_L), 10^3 UAH/people	$Y_L = Y/L$	-
Energy intensity of production (ER_Y), t c.e./thousand UAH	$ER_Y = 23{,}895 \times Y_L^{-1,2048}$	0,9176
Changing of energy consumption (ΔER), 10^3 t c.e.	$\Delta ER = ER_Y \times Y - K/K_Y$	-
Energy consumption ПЕР (ER), 10^3 t c.e.	$ER_t = ER_{t,t-1} + \Delta ER \times \Delta t$	-
Growth rate of energy consumption (ER/ER_0)	ER_t/ER_0	-
Adjusted energy intensity of production (ER′), t c.e./thousand UAH	$ER_Y{}'_t = \frac{Y_t}{ER_t}$	-
Costs per unit of output (C_Y), UAH/UAH	$C_Y = 1{,}125 \times ER_Y^{0,227} \times MK_Y^{0,094}$	0,8046
Investments (K), 10^6 UAH	$K = K_Y \times Y$	-
Growth rate of industrial production (Y/Y_0)	Ces-function	0,8957

Source: Authors' estimation

The model data was selected industry of Kharkov region in 2001-2009. Simulation of industrial production was carried out in the normalized values using the CES-function:

$$\frac{Y}{Y_0} = 1{,}071 \times \left[0{,}854 \times \left(0{,}992 \times \frac{MK}{MK_0}^{-4.693} + 0{,}008 \times \frac{L}{L_0}^{-4.693}\right)^{\frac{4.25}{4.693}} + 0{,}146 \times \frac{ER}{ER_0}^{-4.25} \right]^{-\frac{1,172}{4,25}}$$

$$R^2 = 0{,}8957$$

$$\text{Re}\, s.std.er = 0{,}0182$$

where Y/Y_0 - growth rate of industrial production, MK/MK_0 - growth rate of fixed assets, L/L_0 - growth rate of the workforce, ER/ER_0 - growth rate of energy consumption in industry of the region.

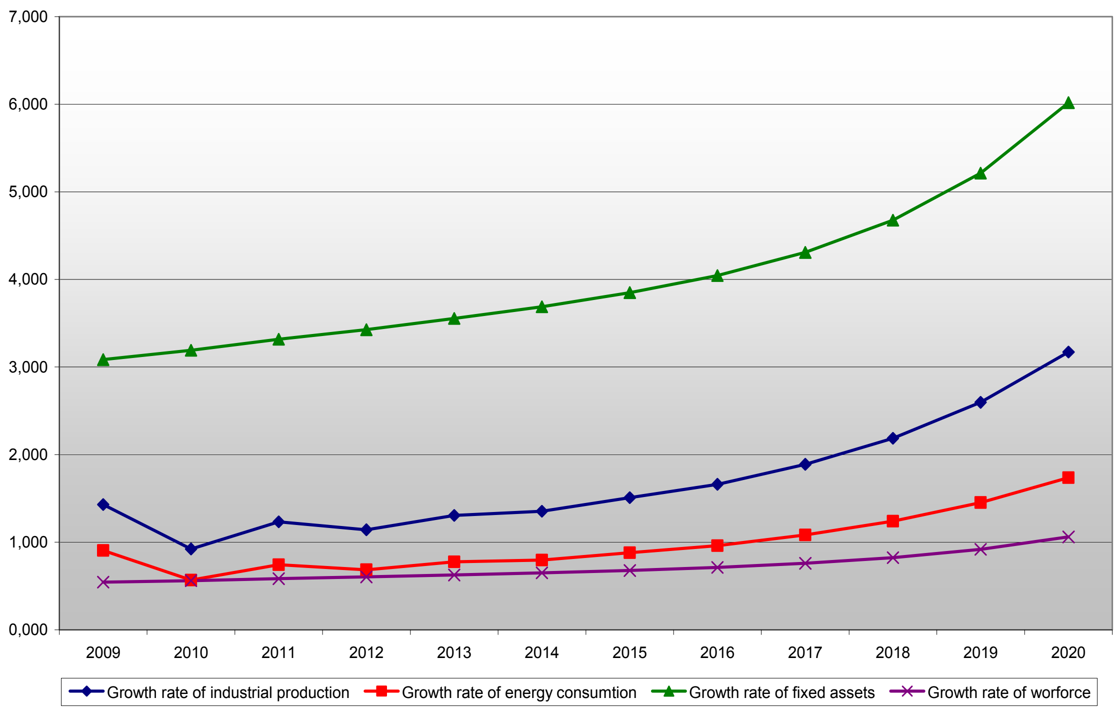
Experimentation and analysis of simulation results assumes development of different scenarios for the simulation model. To construct scenarios of energy efficiency for regional industry has been identified strategy period, as such, which corresponds to the overall regional sustainable development strategy (in accordance with the Sustainable Development Strategy of Kharkov region, the strategy period is 10 years and the step of modeling will be: *i=1 year*, $i \in [1, m], m = 11.$).

The basis for modeling energy efficiency of industry in the region is the forecast of self-development situation (baseline / inertial scenario), the simulation results for which are shown in Figure 4 – Figure 6.

Therefore, at the end of strategy period the baseline scenario provides for growth of industrial production in the 1.74 times to the level 2009, while consumption of energy resources will increase in 1.83 times, the number of industrial workers in the region – in 1.52 times, and fixed assets of industry - in 2.93 times. That is, can be considered that the further development of industry in Kharkov region will occur at the expense of retrofitting industrial base. Providing these trends will occur due to increased investment in time 10.67 - up to 24 bilion's UAH in 2020, however, these trends will be not enough for radical reduce the energy intensity of industry in Kharkiv region. Thus, at the end of strategy period the level of energy intensity of production will be reduced only by 13.5 % compared to 2009.

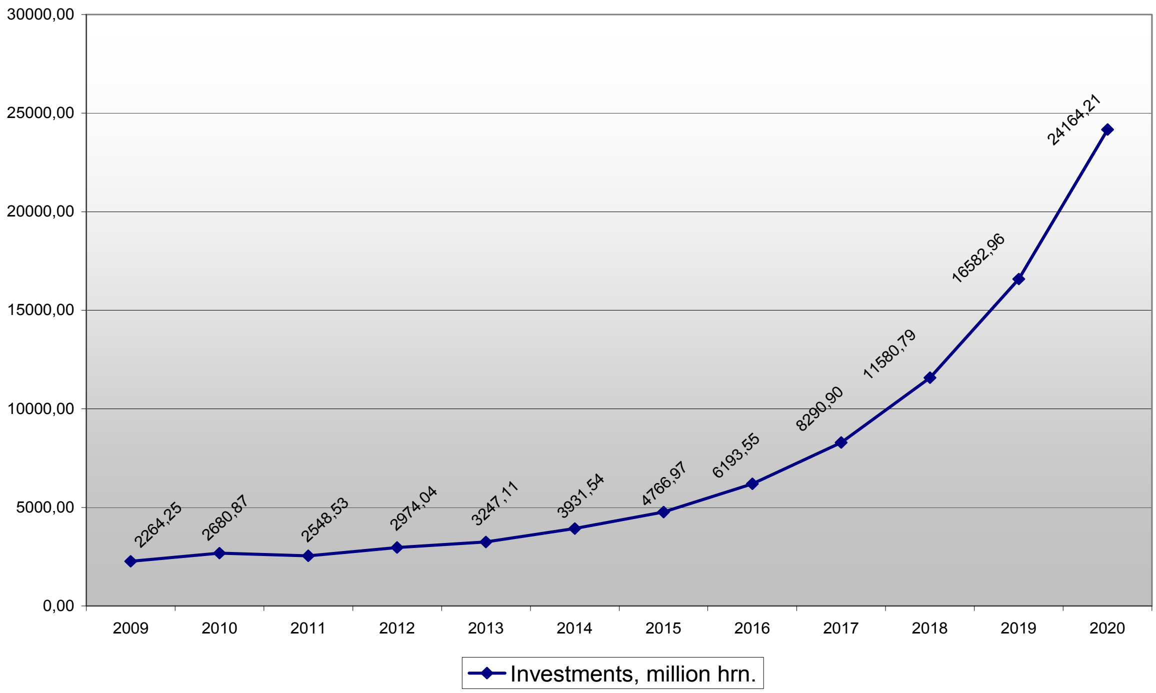
To construct groups of scenarios were defined annual rate of decline of energy intensity, as follows: for the optimistic scenario - -6.5%, for the most likely scenario - -3.75%, for the pessimistic scenario - 2%. Results of passive scenarios demonstrate the development of industry in Kharkiv region through retrofitting industrial base (Table 3).

Figure 4: Growth rates of input factors and industrial production according to the baseline scenario of passive group



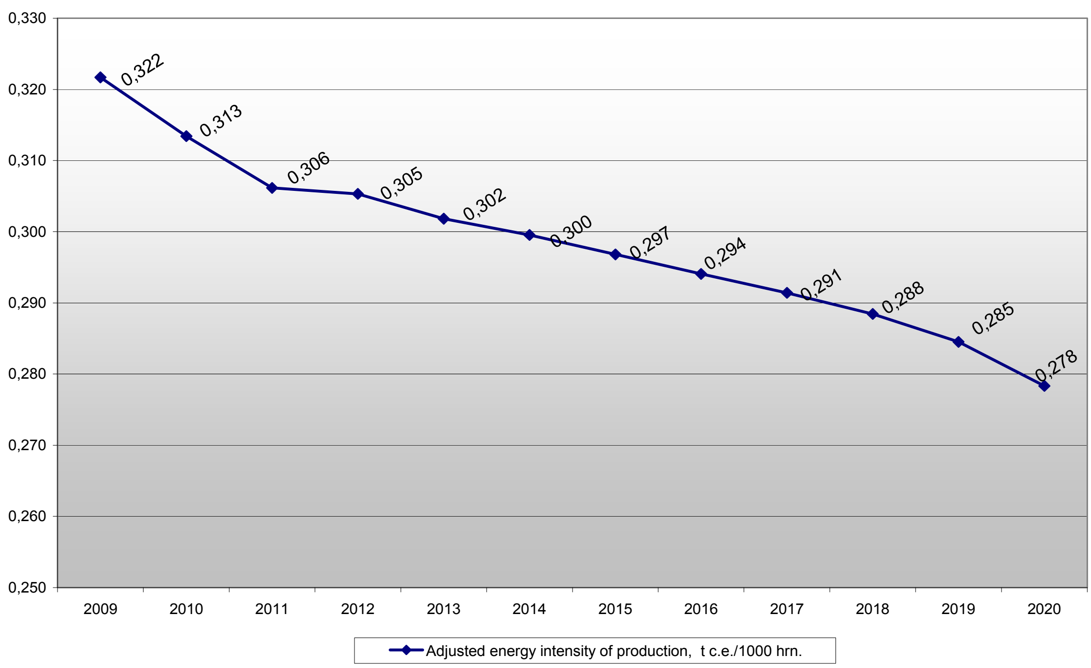
Source: Authors' calculation

Figure 5: Forecasting of investments according to the baseline scenario of passive group



Source: Authors' calculation

Figure 6: Forecasting energy intensity according to the baseline scenario of passive group



Source: Authors' calculation

Table 3: Passive scenarios group of industrial development in Kharkiv region

Indicator	*Year*		*Growth rate*
	2009	*2020*	
1	2	3	4
		Optimistic scenario	
Volume of industrial production / income, 10^6 UAH	15645,8	189534,9	12,1
Energy consumption, 10^3 UAH	4944,9	36698,59	7,4
Fixed assets, 10^6 UAH	51854,2	494509,5	9,5
Number of industrial workers, thousand people	173,4	1216,7	7,0
Investments, 10^6 UAH	3397,3	316927	93,3
Adjusted energy intensity of production, t c.e./10^3 UAH	*0,316*	*0,194*	0,6
		Most likely scenario	
Volume of industrial production / income, 10^6 UAH	15645,8	86960,2	5,6
Energy consumption, 10^3 t c.e.	4944,9	20048,6	4,1
Fixed assets, 10^6 UAH	51854,2	230264	4,4
Number of industrial workers, thousand people	173,4	566,5	3,3
Investments, 10^6 UAH	3397,3	115030	33,9
Adjusted energy intensity of production, t c.e./10^3 UAH	*0,316*	*0,231*	0,7
		Pessimistic scenario	
Volume of industrial production / income, 10^6 UAH	15645,8	45069,9	2,9
Energy consumption, 10^3 t c.e.	4944,9	12041,2	2,4
Fixed assets, 10^6 UAH	51854,2	125958	2,4
Number of industrial workers, thousand people	173,4	309,91	1,8
Investments, 10^6 UAH	3397,3	42803	12,6
Adjusted energy intensity of production, t c.e./10^3 UAH	*0,316*	*0,267*	0,8

Source: Authors' estimation

As the data in Table 3, all scenarios of industrial development in Kharkov region require substantial investments to the retrofitting of the industrial base.

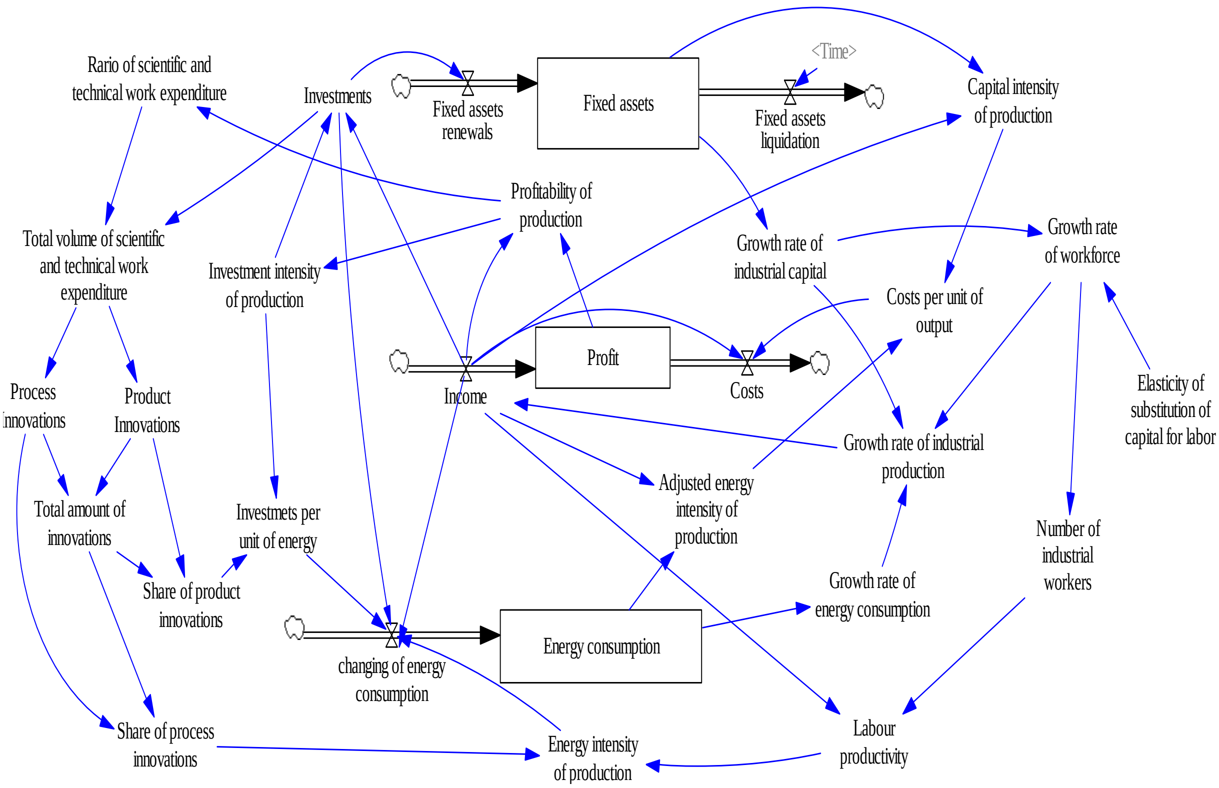
3.2 Active Scenarios Group of Energy Efficiency in the Regional Industry

Second group of energy efficiency scenarios is an active scenario of industrial development of Kharkov region. As vector of managerial impact were selected quality indicators of innovative activity in the industry of the region, as follows: the ratio of expenditure on scientific and technical work to the volume of investments (I_K), the share of product innovations in the total number of innovations (I_{PROD}), and the share of process innovations in their total number (I_{TECH}).

System-dynamic model of forecasting energy efficiency in industry of the region, taking into account managerial vector will be as follows (Figure 7).

Managerial vector of innovation activity in industry of Kharkov region is described by the equations presented in Table 4.

Figure 7: System-dynamic model of forecasting energy efficiency in industry of the region taking into account managerial vector



Source: Authors' model

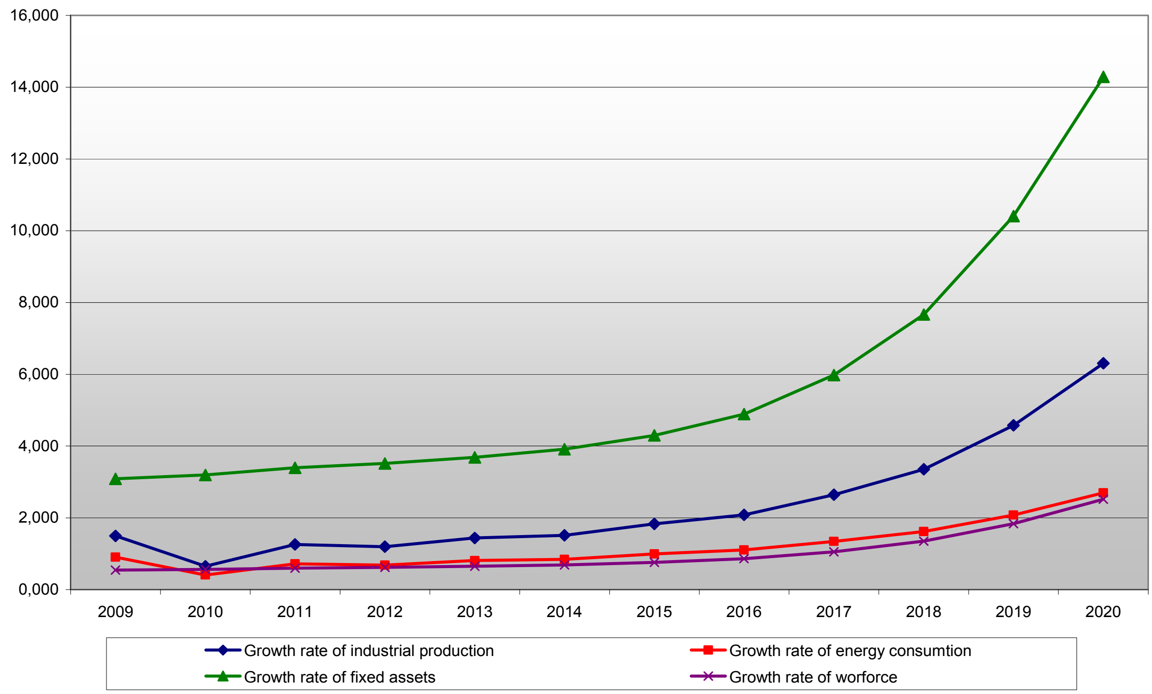
Table 4: Functional relationships between the vector of managerial impact and simulation model

Flow or variable of the simulation model	***Functional dependence***	R^2
Ratio of scientific and technical expenditure to the investments	$I_K = 0{,}424 \times e^{-5{,}283 \times P_Y}$	0,6842
Total volume of scientific and technical expenditure, 10^6 UAH	$S_C = I_K \times K$	-
Process innovations, units	$\sum I_{TECH} = 1144{,}8 \times \ln(S_C) - 5734{,}6$	0,7322
Product innovations, units	$\sum I_{PROD} = 1376 \times \ln(S_C) - 4673{,}6$	0,7908
Total amount of innovations, units	$\sum I = \sum{}^{2}{}_{PROD} + \sum I_{TECH}$	-
Share of product innovations in the total number of innovations	$I_{PROD} = \sum I_{PROD} / \sum I$	-
Share of process innovations in the total number of innovations	$I_{TECH} = \sum I_{TECH} / \sum I$	-
Energy intensity of production, t c.e./ thousand UAH	$ER_Y = 0{,}734 - 0{,}249 \times I_{TECH} - 0{,}004 \times Y_L$	0,9490
Investment per unit of energy, thousand UAH / t c.e.	$K_{ER} = 4{,}68 \times I_{PROD}^{-0{,}676} \times K_Y^{1{,}376}$	0,9872

Source: Authors' estimation

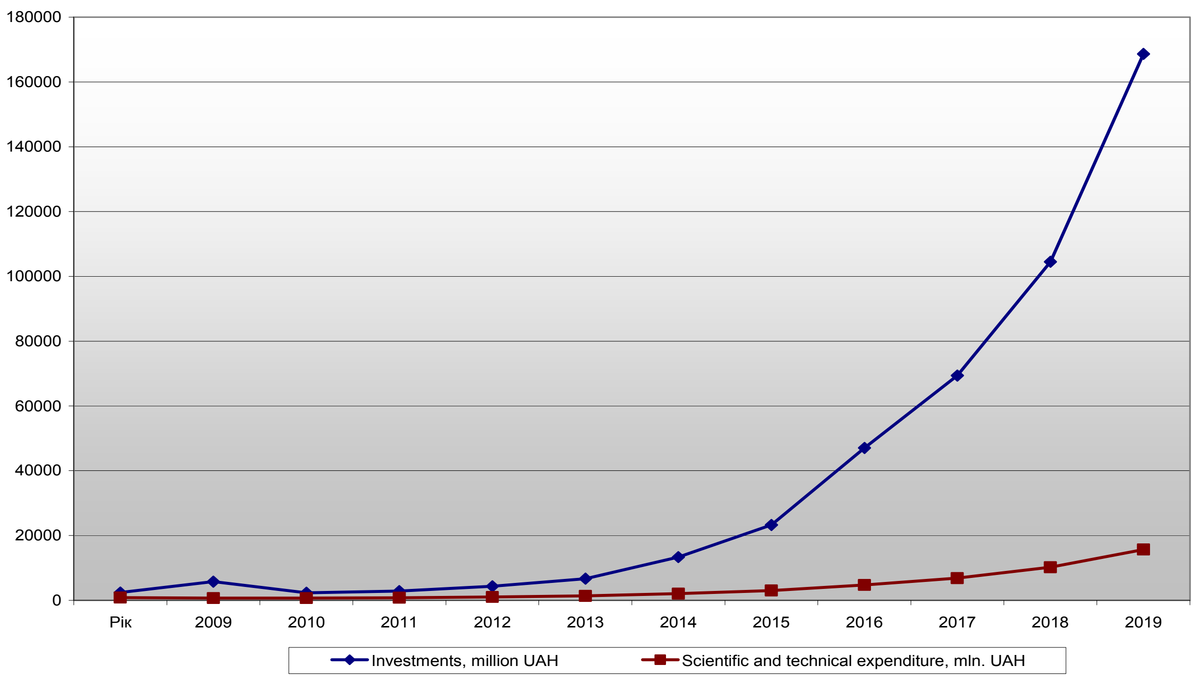
Results of constructing innovative baseline scenario are presented in Figure 8 - Figure 10.

Figure 8: Growth rates of input factors and industrial production according to the baseline scenario of active group



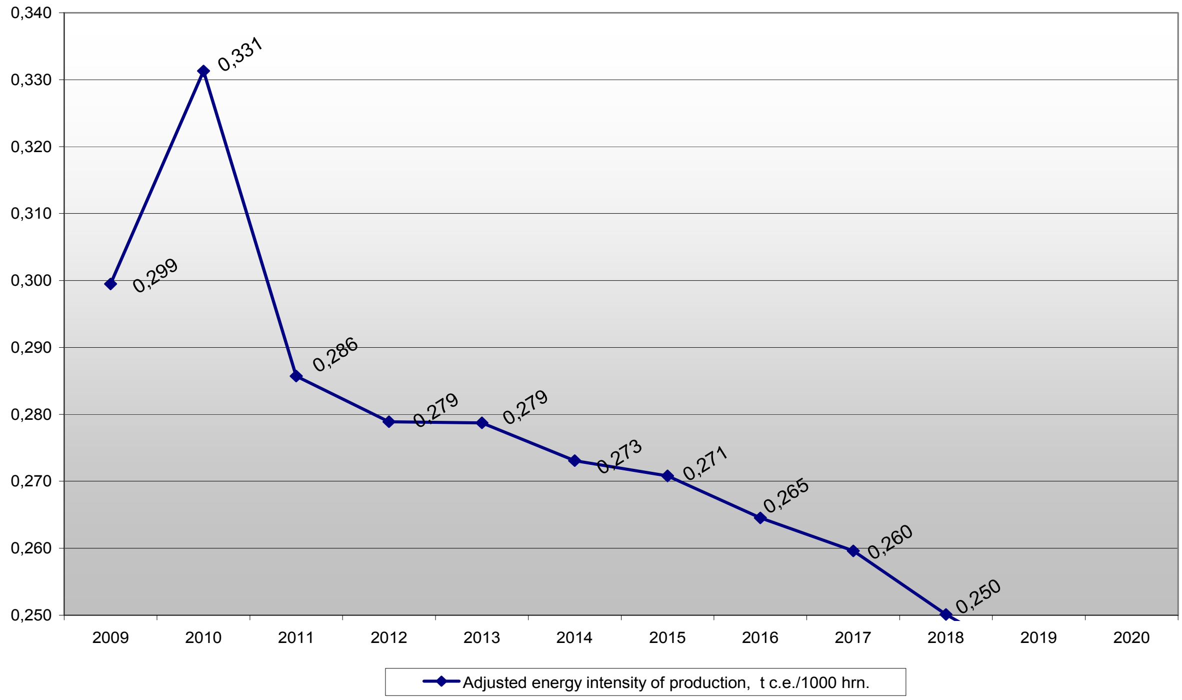
Source: Authors' calculation

Figure 9: Forecasting of investments and scientific expenditure according to the baseline scenario of active group



Source: Authors' calculation

Figure 6: Forecasting energy intensity according to the baseline scenario of active group



Source: Authors' calculation

Thus, according to the innovative baseline scenario of Kharkov region industry the volume of industrial production at the end of the strategy period (in 2020) should grow by 2.6 times, while the volume of energy consumption will grow only by 2-fold. Provision of these trends will require growth in investment up to 49 165 million UAH in 2020 (compared to 3 397 mln. UAH in 2009) and the implementation of scientific and technical work in the amount of 6190 million UAH (compared to 1765 mln. UAH in 2009). Reducing energy intensity by 10 % compared to the passive baseline scenario will require implementation innovations in the total number of 11 600 units, of which 7340 units are product innovations, and 4260 units are process innovations.

The results of active scenarios demonstrate intensive development of Kharkov region industry (Table 5).

Table 5: Active scenarios group of industrial development in Kharkov region

Indicator	*Year* 2009	*Year* 2020	*Growth rate*
Optimistic scenario			
Volume of industrial production / income, 10^6 UAH	15645,8	88864,8	5,7
Energy consumption, 10^3 UAH	4944,9	17858,6	3,6
Fixed assets, 10^6 UAH	51854,2	331094	6,4
Number of industrial workers, thousand people	173,4	814,6	4,7
Investments, 10^6 UAH	3397,3	183241	53,9
Total volume of scientific and technical expenditure, 10^6 UAH	1 765,5	16662	9,4
Adjusted energy intensity of production, t c.e./10^3 UAH	*0,316*	*0,201*	0,6

Most likely scenario			
Volume of industrial production / income, 10^6 UAH	15645,8	42643,3	2,7
Energy consumption, 10^3 UAH	4944,9	9841,3	2,0
Fixed assets, 10^6 UAH	51854,2	157908	3,0
Number of industrial workers, thousand people	173,4	388,52	2,2
Investments, 10^6 UAH	3397,3	62278	18,3
Total volume of scientific and technical expenditure, 10^6 UAH	1 765,5	6760	3,8
Adjusted energy intensity of production, t c.e./10^3 UAH	*0,316*	*0,231*	0,7
Pessimistic scenario			
Volume of industrial production / income, 10^6 UAH	15645,8	23275,1	1,5
Energy consumption, 10^3 UAH	4944,9	6060,1	1,2
Fixed assets, 10^6 UAH	51854,2	85938,8	1,7
Number of industrial workers, thousand people	173,4	211,4	1,2
Investments, 10^6 UAH	3397,3	17914	5,3
Total volume of scientific and technical expenditure, 10^6 UAH	1 765,5	2702	1,5
Adjusted energy intensity of production, t c.e./10^3 UAH	*0,316*	*0,260*	0,8

Source: Authors' estimation

Comparison of active energy efficiency scenarios with passive (Table 6) allows to assert that if innovation activity of Kharkov region industry would be rise, target values of indicators will be achieved with the less investment resources at the expense of increasing the profitability of production.

Table 6: Investment requirements under different energy efficiency scenarios Kharkov region industry (million UAH)

Scenario		*Optimistic*	*Most likely*	*Pessimistic*
2012	Passive	4055,4	3390,2	3006,6
	Active	2725,1	2373,32	2168,1
2015	Passive	19558,3	9759,8	5604,3
	Active	13397,3	5985,2	3183,6
2017	Passive	64958,1	27696,1	11799,4
	Active	49472,8	16572,4	5591,97
2020	Passive	316927	115030	42803
	Active	183241	62278	17914

Source: Authors' estimation

4. Conclusions

Consequently, the improving energy efficiency industry in Kharkov region depends on several factors: firstly, the modernization of the industrial base by replacing the physically and morally outdated equipment with the new less energy intensive, and secondly, increasing the volume of industrial activity that will provide economies of scale production, and, in third, the introduction of product and process innovations in the region industry. The decisive factor is the last one, as innovations will allow gradually moving to a new technological way, which would have a radically lower energy intensity of products.

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