

# Coal energy systems of the future – innovative way of Ukraine's energy development

*Mykola Zhykaliak*<sup>1,\*</sup>, and *Viacheslav Lukinov*<sup>2</sup>

<sup>1</sup>State Regional Geological Enterprise “Donetskgeologiya” of the State Service of Geology and Mineral Resources of Ukraine, 84511, Bahmut, O. Sybirtseva, 17, Ukraine

<sup>2</sup>Institute of Geotechnical Mechanics named by N. Poljakov of National Academy of Sciences of Ukraine, 49005, Dnipro, Simferopolska Str., 2a, Ukraine

**Abstract.** The state of implementation of the main indicators of the energy strategy of Ukraine for the period until 2035 has been analyzed and innovative prospects for the sustainable development of the national fuel and energy complex for the long term have been substantiated, taking into account the structurally unified nationwide energy supply system and the interests of future generations and the environment.

## 1 Introduction

The development in Ukraine of monopoly-oligarchic market relations in the functioning of the fuel and energy complex, the lack of real competition and clear specification of property rights in conditions of excessive irresponsible national economy management of half-shadow business structures and powerful political elites led to a significant drop in extraction of primary energy resources and a significant reduction in industrial production. Nonreplacement of compensatory growth resulting from catastrophically low volumes of target geological exploration in the depths of the effective reserves of natural gas, oil and fossil coal extracted over the past 20 years, and a low degree of use of alternative and renewable energy sources – below the minimum critical limit in the national energy balance, determined the system dependence of Ukraine’s economy from imports of natural gas, petroleum products, fossil coal and anthracite at inflated non-equilibrium prices. Therefore, the need for a balanced solution of the problem of the sustainable provision of basic industries, regional energy and social sectors by oil, gas and fossil coal resources requires an urgent, scientifically based integrated approach.

To do this it is necessary, first of all, to carry out a structural innovative restructuring of the system of extracting traditional natural gas and gas of dense rocks, as well as methane and coal production using advanced technologies that take into account specific mining and geological conditions of mine fields and deposits. In addition, innovative experimental data that have appeared in recent years predetermine the production of synthetic liquid fuel from coal and biogas, methanol from natural gas and gas mixtures through gasification, hydrogeneration and thermal dissolution of coal using hydrogen as a donor after 2025 [1, 6].

---

\*Corresponding author: [dongeo@ukr.net](mailto:dongeo@ukr.net)

The new energy idea of Ukraine, based on the existing departmental and sectoral structure, should also take into account the creation of regional and inter-sectoral innovative energy industries, subject to the provision of two major principles – respect for the interests of future generations and the preservation of the natural environment [1].

## **2 Methodology**

The methodological basis of the research is the methodology of institutional economic theory, a comprehensive analysis of the main indicators of the Energy Strategy of Ukraine for the period up to 2035 using the economic theory of sustainable development, a systematic, historical and statistical analysis of the performance indicators of the fuel and energy complex of Ukraine and the European and Ukrainian experience in reforming basic industries.

The fuel and energy complex of Ukraine is a diversified, technologically complex and geographically extensive system for the extraction of primary energy sources, production, transportation and use of fuel and energy resources, combining a powerful electric power system, heat generation and heat supply systems, coal, nuclear, gas, oil and oil refining industries.

In the structure of primary energy consumption, the gravity of natural gas consumption in Ukraine is two times higher than the gravity of its use in the global energy balance of primary energy resources. And this is in the conditions when own natural gas production provides half of the minimum gas consumption or only one third of its optimal needs for the sustainable development of the national economy [2, 3].

This is mainly due to the fact that the fuel and energy complex (FEC) of Ukraine was formed during the period of the nationwide planned economy as an integral part of the unified fuel and energy complex of the former Soviet Union, and also due to the permanent non-fulfillment of the planned program activities and the main indicators of the development of the oil and gas and coal sectors of the energy sector of the national economy over the past 25 years. As a result, the effective energy security of Ukraine with the economically balanced state regulation of the national fuel and energy complex in peacetime and during the five-year military conflict in Donbas was never formed and not implemented [4, 5].

The inherited diversified industrial complex of Ukraine with fuel and energy, metallurgical, chemical and mineral and raw specialization gave rise to complex inter-industry and intra-industry disproportions, and in the context of non-transparent ownership structure, led to a significant dependence of the national economy on imports of natural gas and petroleum products and ineffective irresponsible state regulation of national FEC by the people in power and political elites. The use of imperfect pricing mechanisms at the same time as non-transparent rent-oriented government subsidies in the absence of radical reforms, transparent market competition and a predominantly oligarchic nature of the development of the national fuel and energy complex became the main obstacles for attracting significant external financing for the introduction of advanced technologies and innovations in power generation and heat supply. In addition, the systemic crisis of ethical norms that has taken root in Ukraine since 2012 freed the semi legal economic activity in the use of fuel and energy resources from any moral restrictions, became an incentive for opportunism, rent seeking and super-profits without economically balanced calculations and taking into account socio-economic standards and norms [3].

Under current conditions, the economic aspect of the sustainable development of the national fuel and energy complex should become the leading direction of the neo-industrialization of basic industries using world experience and taking into account the institutional characteristics and national interests of Ukraine. At the same time, the

economic mechanism for managing the national fuel and energy complex provides the substantiating of the optimal structure of the fuel and energy balance of the national economy in accordance with the structure of the real recoverable value of proven reserves of natural gas, oil with condensate, coal and uranium to ensure effective energy security of the state.

### **3 Results and their discussion**

For Ukraine, energy security in difficult modern conditions is a state of protection in the nationwide interests of its citizens, society, basic industries, regions, territories and settlements from systemic threats to efficient heat supply and reliable fuel and energy supply. Therefore, the energy security of Ukraine should be an essential component of national security, and ensuring national security is one of the priorities of the state's balanced energy policy.

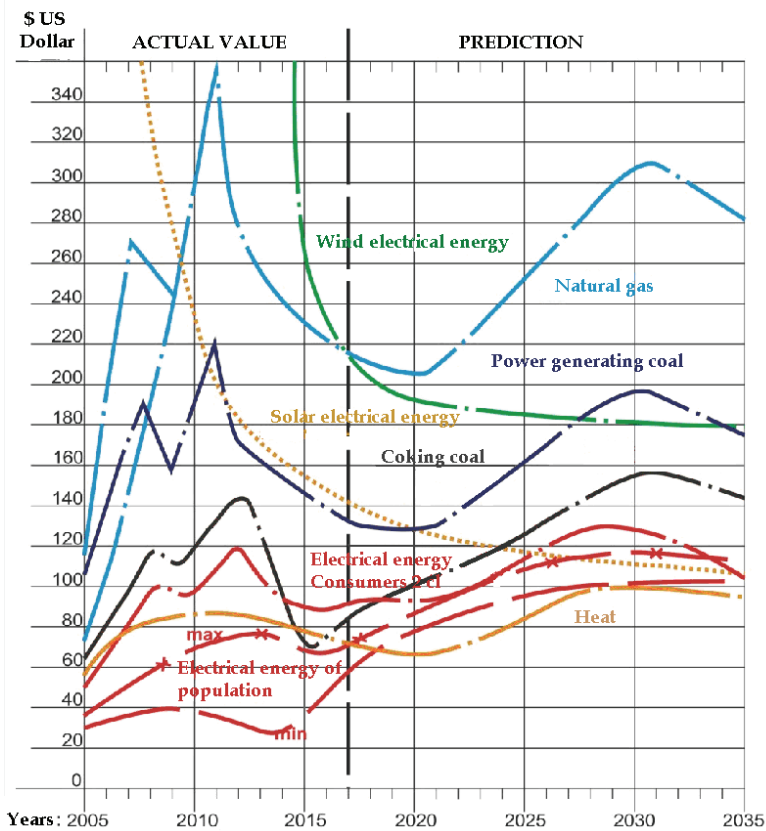
The most important principles for ensuring effective energy security of Ukraine are [3, 6]:

- guaranteed and reliable energy supply of the economy and population of the country in full volume and at balanced optimal prices in normal conditions and in the minimum required volume during crisis periods or in the event of emergencies of various kinds;
- effective control by the state and local governments over reliable energy supply for the sustainable development of basic industries, social sectors and facilities that ensure the security of the state;
- a balanced reproduction and growth of reserves of primary energy resources in accordance with the rate of consumption of exhausted fuels and the development of renewable or replacement energy sources;
- rational diversification of used types of fuel and energy and sustainable economically sparing development of national energy;
- creation of favorable economic conditions and incentives for the development of innovative areas in the energy sector, preventing energy wastefulness and increasing the energy efficiency of the national economy;
- the maximum possible use in all technological processes and innovations of competitive home equipment.

The efficiency of functioning of the national fuel and energy complex and its ability for sustainable innovative and investment development will depend primarily on the integrity of its structurally unified system, mineral and raw materials, production and economic potential [4, 5]. At the same time, the national investment policy in the energy and coal industry of Ukraine should be based on economic and environmental efficiency, optimal energy consumption and balanced prices for primary energy resources, heat and electricity (Fig. 1).

The reliable functioning of the fuel and energy complex of Ukraine in the medium and long term prospects can be ensured only on the basis of the integrated concept of sustainable development, which will generalize and balance national, regional and market-corporate interests in accordance with the forecast social and economic macro-indicators of the economic strategy of Ukraine for the period until 2035 [3, 4].

In particular, on the basis of radical technological renovation and modernization of production, taking into account Ukraine's entry into the common-European energy space and through the implementation of a balanced tax and price state policy to promote innovations in the coal and oil and gas industry, it is necessary to ensure a twofold increase in the real gross domestic product (GDP) of the country over a period of 12–15 years in prices of 2012 [3, 4].



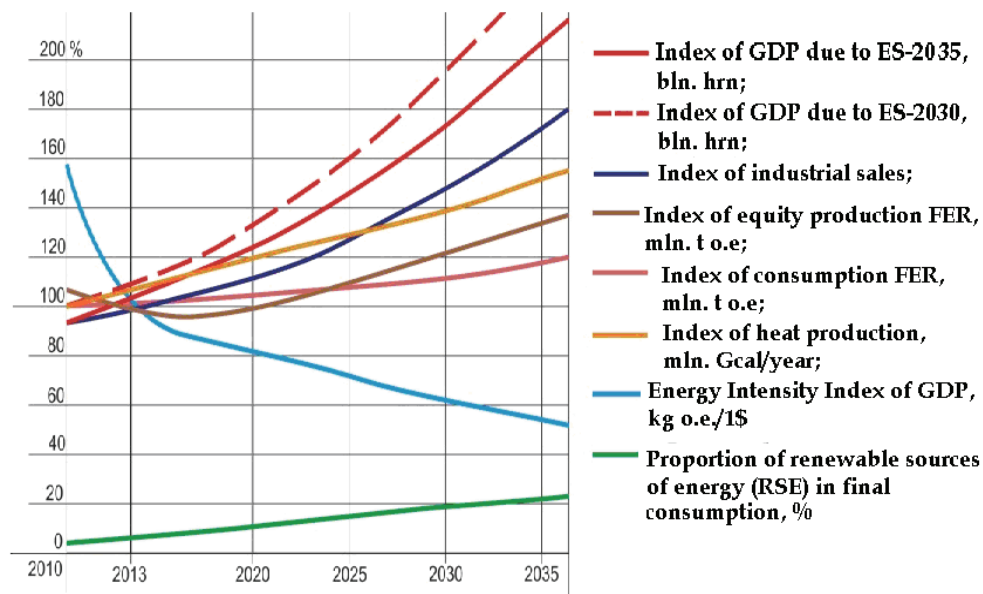
**Fig. 1.** Dynamics of average annual equilibrium prices for main types of fuel and energy.

Negative trends in reducing the role of industry in transforming the national economy into a common European economic space should also be overcome, significantly reducing the energy intensity of a country's GDP to at least the average European level and maximally utilizing the existing home mineral potential to increase its own production of hydrocarbons, uranium, coal and methane from coal reservoirs and deposits, and also significantly increase the share of renewable energy sources in the final energy consumption (Fig. 2).

World experience in energy development also indicates the expediency of transition from non-equilibrium unbalanced fuel energy to equilibrium, multicomponent and multifunctional one, which provides diversification and energy balance in the direction of low-carbon energy with a significant increase in the efficiency of using non-renewable primary energy resources [3, 6]. At the same time, state control and state regulation of the reliable functioning of the fuel and energy complex of Ukraine should ensure a transition from a strategy of permanent survival to stabilization and sustainable development.

Re-industrialization in recent years has become the leading direction of the neo-industrialization of national economies and the global economy at a new technical and technological level, using dynamically changing competitive advantages to ensure the sustainable development of intelligent industries, preserving scientific and industrial potential through the consolidation of all the resources, centralized management and improved government regulation. Despite the lack of home production of hydrocarbons and the inefficient restructuring of the coal industry, fuel and energy resources in Ukraine

ensure the livelihoods of all industries and the social sphere, contribute to the stabilization and consolidation of regions and have a decisive influence on the formation of GDP and the main financial and economic indicators of the state [2, 3, 6].



**Fig. 2.** Dynamics of indices of forecast indicators of the energy strategy for the period up to 2035 (ES-2035).

However, a high degree (60–70 %) of depletion of the initial reserves of natural gas on the main existing fields of Ukraine and the lack of at least partial real growth in the depths of technologically available profitable reserves, instead of extracted in 2013–2018 years and the uncontrollability by Ukraine of the most promising part of Azov and Black Sea shelf and the old industrial areas of Donbas have determined the manifestation of systemic risks in meeting the planned indicators of an increase in the home production of primary energy resources according to Energy Strategy for the period up to 2035 (Table 1).

The “Roadmap” for the implementation of Energy Strategy-2035 also does not provide effective stabilization and compensatory measures to prevent a permanent reduction in home production of oil and gas condensate in the existing fields and areas, structures and areas that will allow increase the balanced indicators of their home production in 2025–2035 years [4]. In addition, the formal separation of the functions of generation and supply of electricity and the establishment under the guise of energy market reforms of energy services in the form of limited liability companies (LLC) with the same final beneficial owner (controller) is not an effective regulation of the European-style energy market and, most likely, would only increase the cost of services for the supply of electricity to consumers and gain of a monopolistic and corporate management of home power generation. Therefore, only the creation of fundamentally new technologies in the field of oil and gas production and coal mining, as well as in the field of electricity generation can lead to a sharp increase in the efficiency of fuel and energy production and ensure the sustainable development of Ukraine’s energy in the long term.

Since coal is the only energy raw material, the reserves of which in Ukraine are sufficient to ensure reliable energy security of the national economy, it is necessary to ensure the formation of resource-saving, environmentally and economically efficient local coal-gas and energy complexes of new generation within the promising mine fields till

2025 year [1, 6].

**Table 1.** Dynamics of home production of primary energy resources in Ukraine for the period up to 2035.

Type of primary fuel	Years	2013	2020	2025	2030	2035
	Indicators					
Natural gas*, bln. m <sup>3</sup>	ES-2030 last revised in 2012	22.0	24.0	30.0	44.0	-
	Estimate of sustainable growth ES-2030	22.0	25.0	28.0	40.0	-
	ES -2035	21.2	24.0	28.0	34.0	42.1
	Estimate of sustainable growth ES -2035	21.5	23.0	26.0	32.0	38.0
Oil with gas condensate, mln. t	ES-2030 last revised in 2012	3.2	2.4	2.8	3.6	-
	Estimate of sustainable growth ES-2030	3.1	3.0	3.8	4.2	-
	ES -2035	3.1	3.3	3.7	4.0	4.2
	Estimate of sustainable growth ES -2035	3.1	2.8	3.0	3.5	3.8
Coal, mln. t	ES-2030 last revised in 2012	65.0	60.0	68.0	75.0	-
	Estimate of sustainable growth ES -2030	62.0	50.0	50.0	60.0	-
	ES -2035	65.0	60.0	63.0	65.0	68.0
	Estimate of sustainable growth ES -2035	62.0	55.0	60.0	65.0	70.0

\*Including gas of dense rocks and methane gas

Construction and development of modern modular coal and energy stations should be based on clean coal technologies using coal-water slurry with combined-cycle steam-gas turbines, electrochemical generators and gasifiers for generating electric power with a high (0.55–0.6) coefficient of efficiency.

Despite the fact that coal in Ukraine is the only reliable energy raw material, after 2012 the national coal industry operates according to the Pareto principle, when more than 70 % of coal mined in Ukraine is provided by 30 % of mines, and the remaining 70 mines account for less than 30 % of all Ukrainian coal mining [2]. At the same time, the long-term conjuncture on the world energy market as a whole is extremely favorable for coal due to its share in the world energy consumption (27–30 %) and in the raw material component of electricity production [4, 6, 7].

Contradictions between the crisis state of the Ukrainian coal industry and the recent innovative programs and projects will ensure, with due regard for the favorable long-term coal situation, the successful implementation of most sound initiatives aimed at achieving sustainable development of national energy from social, economic and environmental points of view. At the same time, for the conditions of the fuel and energy complex of Ukraine, the most optimal, with respect to GDP, the structure of national production of primary energy resources and energy consumption features, is the adoption as the basic formula of a non-market price of oil equivalent fuel for calculating of equilibrium balanced prices for natural gas, coal, heat and electricity and use the price of caloric and coal equivalents for natural fuels, taking into account the relevant conversion factors (Table. 2) [2, 7].

**Table 2.** Average conversion factors of natural fuel to reference fuel (caloric and coal equivalents).

Item number	Type of fuel, energy	Physical units	Reference fuel, t	
			Caloric equivalent	Coal equivalent (SKE)
1	Anthracite	1 t	0.715	1.140
2	Natural gas	1000 m <sup>3</sup>	1.149	1.350
3	Methane gas	1000 m <sup>3</sup>	0.81–1.03	0.95–1.21
4	Coke gas	1000 m <sup>3</sup>	0.575	0.676
5	Blast-furnace gas	1000 m <sup>3</sup>	0.143	0.168
6	Fossil coal	1 t	0.627	1.00
7	Bevey coal	1 t	0.258	0.325
8	Bevey coal briquettes	1 t	0.571	0.720
9	Turf pit	1 t	0.342	0.560
10	Firewood	1 m <sup>3</sup>	0.265	0.434
11	Oil with gas condensate	1 t	1.459	1.520
12	Residue of rock oil	1 t	1.365	1.422
13	Motor fuel	1 t	1.430	1.490
14	Petrol	1 t	1.490	1.550
15	Diesel fuel	1 t	1.450	1.510
16	Kerosene	1 t	1.470	1.530
17	Coke and peacoke	1 t	0.974	0.970
18	Thermal energy	1 Gkal	0.172	0.20–0.27
19	Electric Energy	1000 kW/hour	0.325*	0.123**
20	Uranium-235	1 kg	2200.0	2700.0

\*Within Ukraine

\*\*Within German

## Conclusions

It has been established that the Energy Strategy of Ukraine for the period until 2035 in the current difficult social and economic conditions must be implemented in order to increase GDP sustainably and enhance the energy security of the state in accordance with the market principles of the country's oil and gas, coal and electricity industries. The low profitability of the development of most of the explored hydrocarbon deposits and hard coal should be brought to an economically acceptable way by introducing new environmentally friendly technologies for their development and integrated innovative use of raw materials. Especially favorable opportunities for effective diversification of the sustainable development of the fuel and energy complex of Ukraine will be associated with the development of dense rock natural gas deposits and the development of the Donbass mine fields as complex methane-coal deposits.

In accordance with the Energy Strategy of Ukraine for the period until 2035, the change in the structure of the use of primary energy carriers will be implemented according to the most rational options; at the same time, the share of each of them in the total energy balance probably will not exceed 30 % and only the share of coal after 2025 will increase to 35 % due to the integrated development of coal deposits and the introduction of new innovative technologies for its processing and use. In general, coal and nuclear energy in energy consumption should be approximately equal economically, since they are mainly used and will be used in existing power plants.

The rational use of its national fuel and energy resources through the reconstruction and modernization of production, the use of new technologies and innovative achievements of

science and technology will create a reliable material and energy basis for the stabilization and sustainable functioning of the national industry, the generation of scientific and technological progress and the innovative and investment development of the national economy.

## References

1. Bulat A.F., Chemeris I.F. (2006). Nauchno-tehnicheskiye osnovy sozdaniya shakhtnykh kogeneratsionnykh kompleksov. Kyiv: Naukova dumka
2. Zhykalyak M.V., Lukinov V.V. (2016). Udoskonalennya derzhavnogo reguluyvannya stalym rozvytkom poluvno-energetychnykh resursiv Ukrainy. Mining of mineral deposits, NGU, 10(2), 97–105
3. Zhykalyak M.V., Cherevatskyi D.Yu. (2017). Sotsialno-ekonomichni aspekty energetychnoji strategiji Ukrainy na serednjo-dovgostrokovu perspektyvu. In.: IV mizhn. naukovo-praktychna konf. *Nadrokorystuvannja v Ukrainy. Perspektyvy investuvannja*, (I), 108–125
4. Energetychna strategija Ukrainy na period do 2035 roku (2017). Kyiv, 1–40
5. Onovlennja energetychnoji strategiji Ukrainy na period do 2030 roku (2012). Kyiv
6. Puchkov L.A., Vorobyev B.M., Vasyuchkov Yu.F. (2007). Ugle-energeticheskije komplekсы budushchego. *Izdatelstvo moskovskogo gornogo universiteta*. Moskva, 45–91
7. Raik M. Winkel (2007) Ekonomicheskiye i tehnikeskije aspekty razvitija gornodobyvajushzheji promyshlennosti v 10 novykh stranakh ES (EU). Gljukauf, 3. Moskva, 40–46